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Modelling and monitoring to inform a systems approach to the management of the Humber

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Introduction

Past approaches to habitat creation and management:

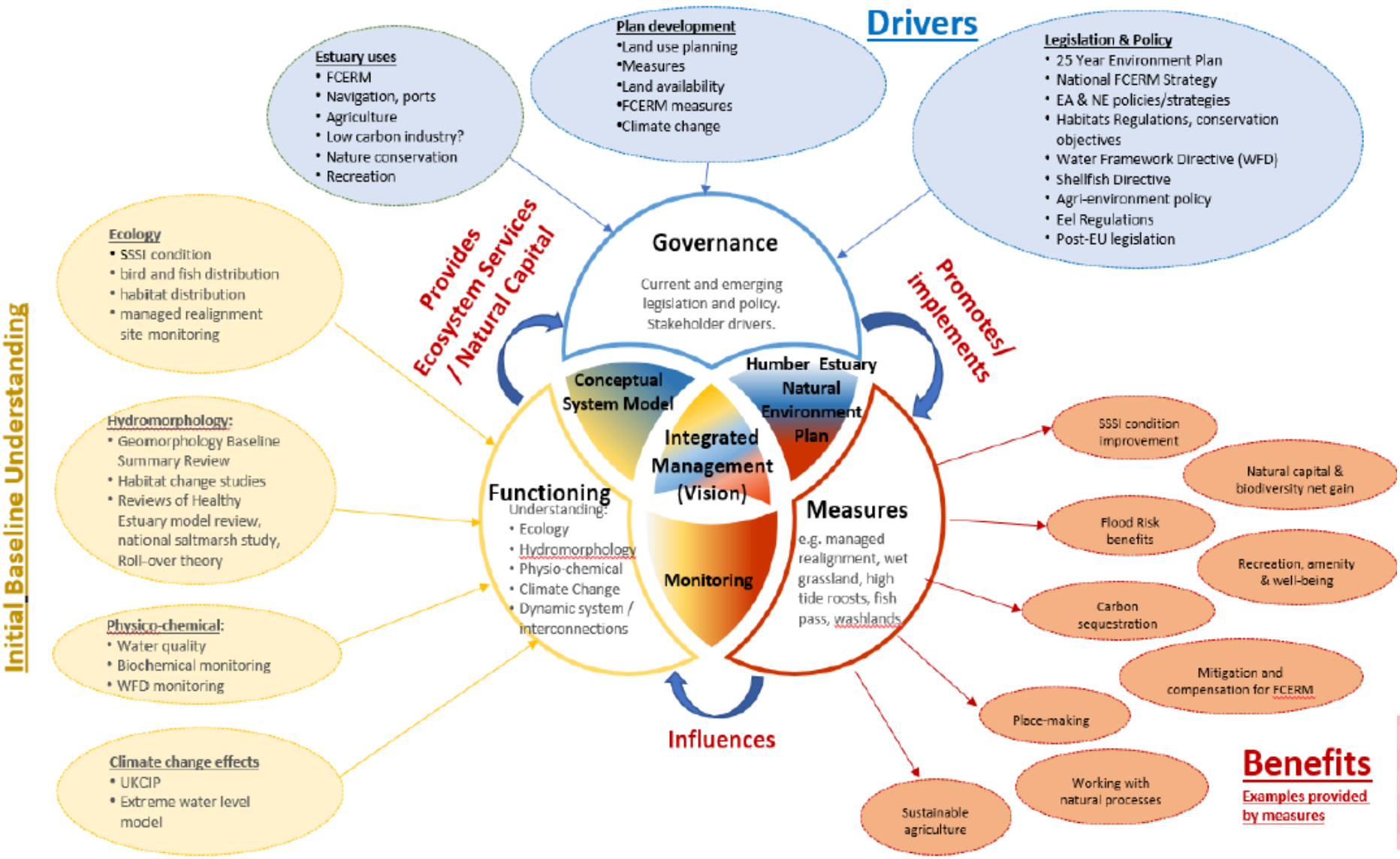
- piecemeal
- driven by discrete needs associated with individual pieces of legislation (e.g. Habitats and Water Framework Directives)

Humber 2100+ strategy team recognized need to move to systems approach that considers linkages and needs of the estuarine system as a whole

Systems approach outlined in TIDE toolbox. Comprises iterative feedback loop comprising three stages:

- Functioning, Governance and Measures

Systems approach (after TIDE)



Predicting how the estuary will respond to measures

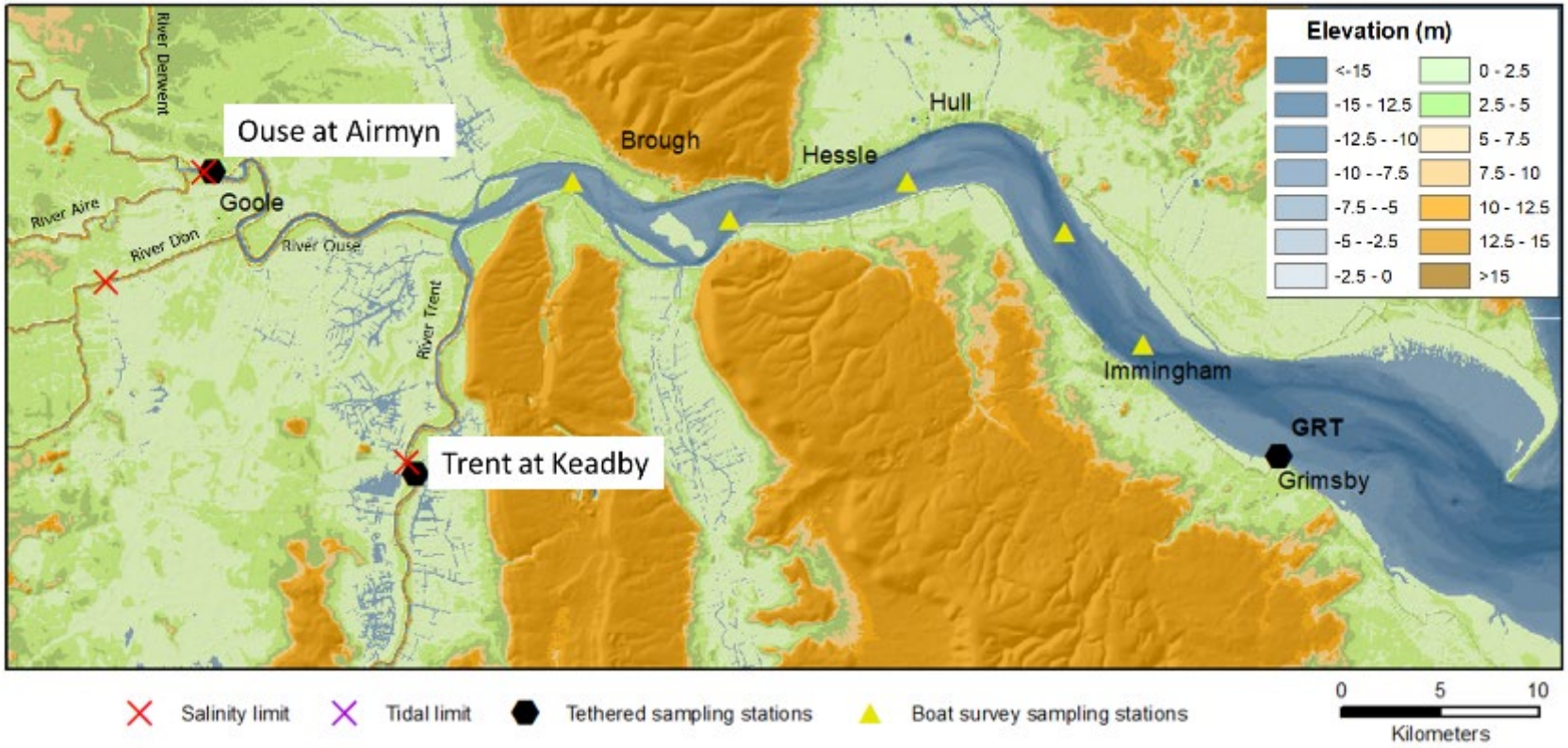
- Laboratory simulations are limited to modelling a reach or an individual location
- Field studies are dependent on flood events. Flood frequencies in the Humber are regular but not sufficient over the timeframes of IMMERSE
- Numerical tools can create ‘as realistic as possible’ predictions of flood inundation and extent at system scale
- Can simulate various measures – great for management planning
- Can account for uncertainty of future risk from climate change

Monitoring and Modelling – conflicting scales

	Monitoring	Modelling
Spatial scale	Local/ at-a-point	System
Time for data collection	Event scale	Fast (1 month overnight)
Flood scenarios	Event scale / historical observations	Unlimited combinations / return periods
Cost	Expensive	Inexpensive (computer)
Temporal scale	Event scale	Decadal to century
Management Strategies	Construction – costly/timely	Fast predictions

But need monitoring data to parameterise and validate models

Monitoring – research?



1. How do sediment and nutrient fluxes vary temporally in the Humber estuary?
2. What is the position, extent and composition of the TMZ and how does it vary temporally?
3. What will be the effects of projected sea-level rise and hydroclimate variability on the position, extent and composition of the TMZ?

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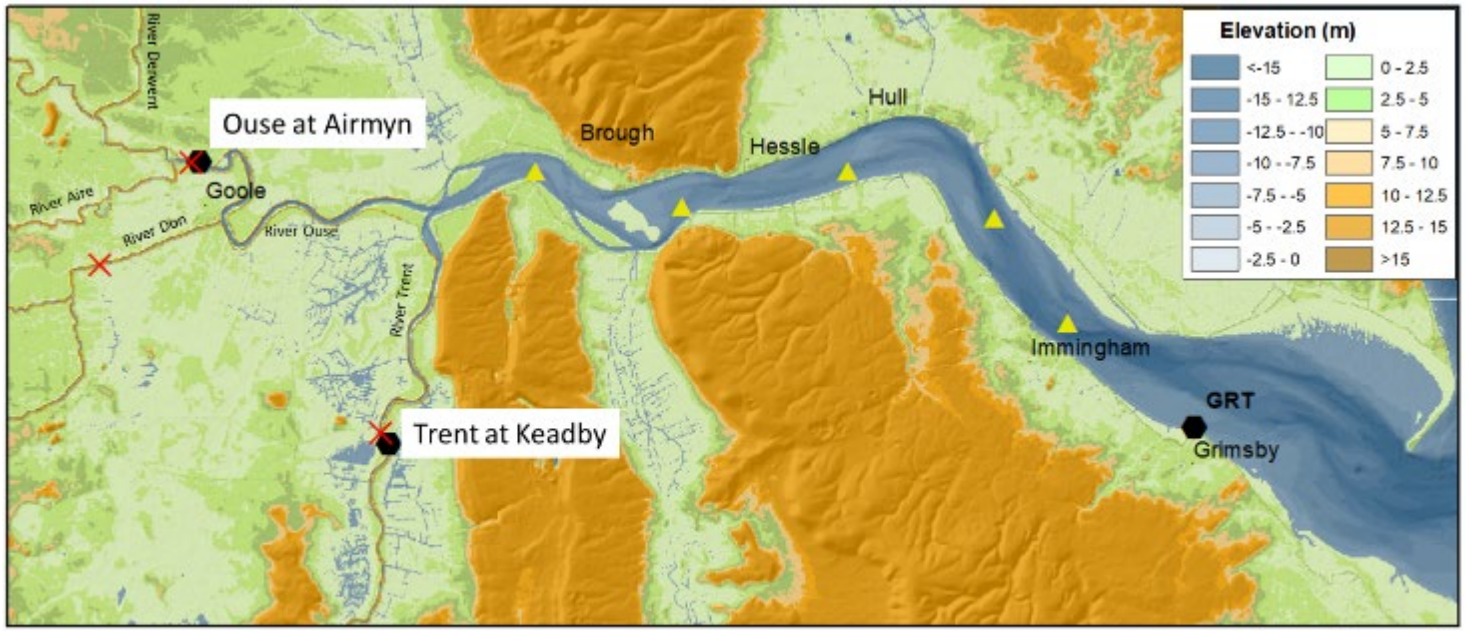

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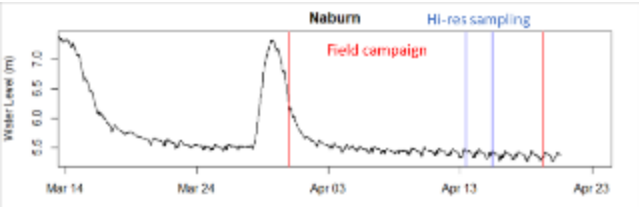
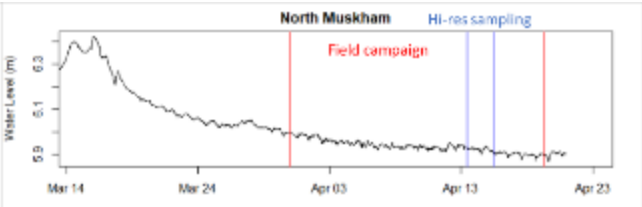
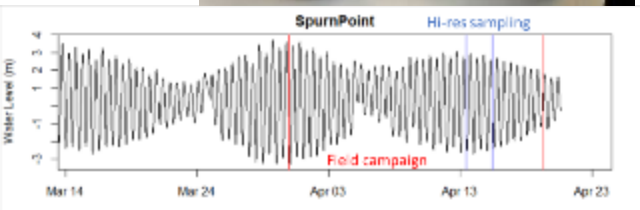
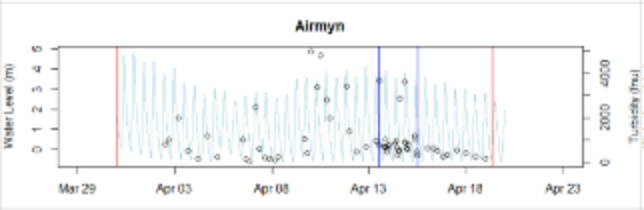
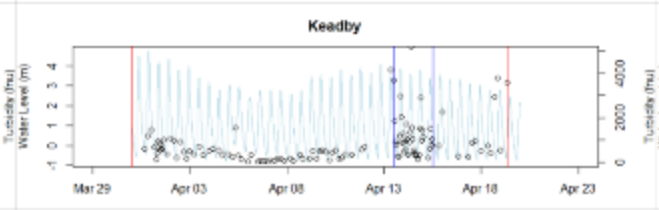
Temporal turbidity variations

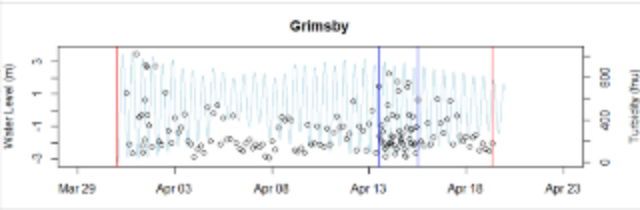


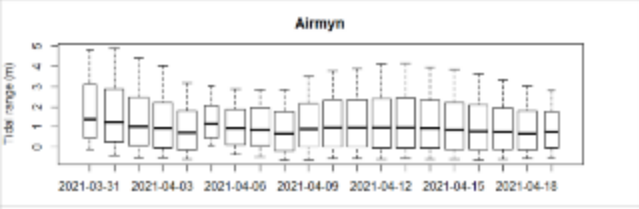


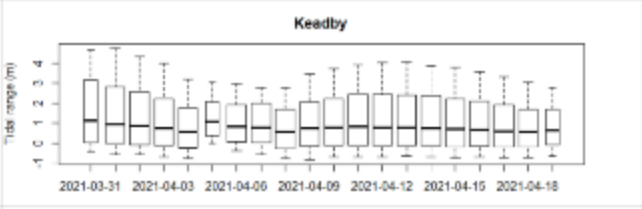


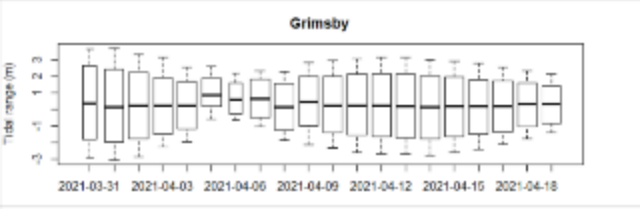


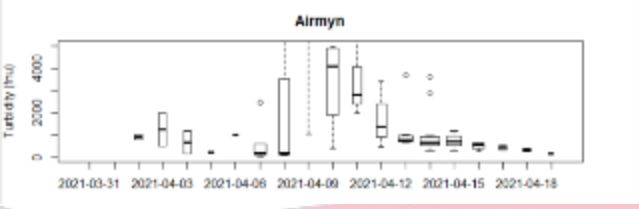


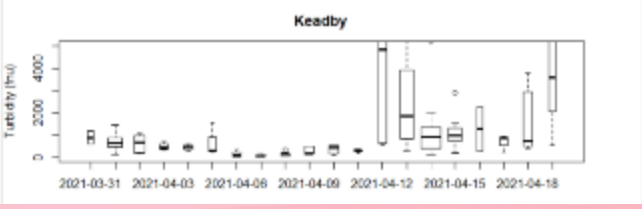


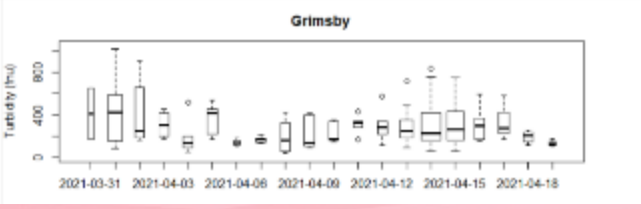








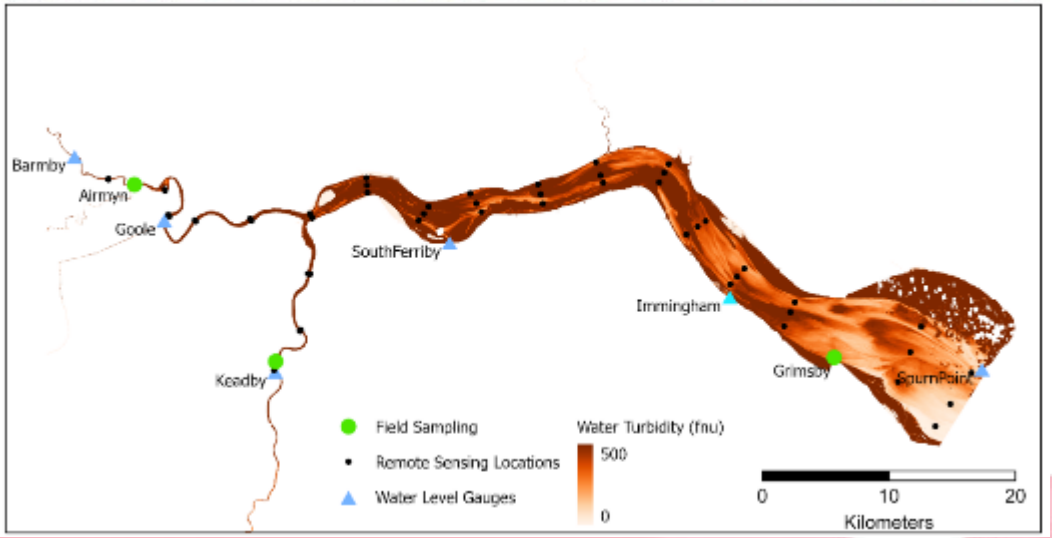




Spatial turbidity variations

- Sentinel 2A image of the Humber
- Atmospherically corrected using Acolite
- Masked to extract water areas
- Clouds and cloud shadows detected using FMASK and removed

- Turbidity estimated using the method of Dogliotti et al. (2015; doi: 10.1016/j.rse.2014.09.020)
- Validation points extracted at transects every 5 km. 3 Points on each transect



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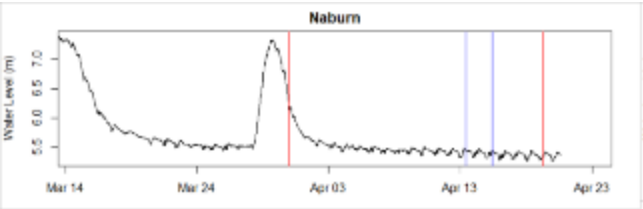
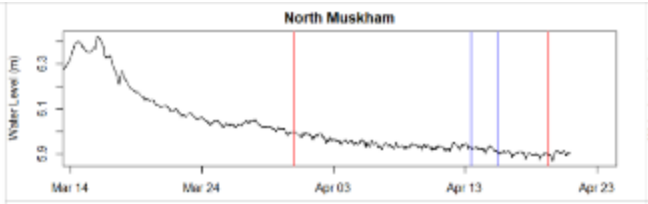
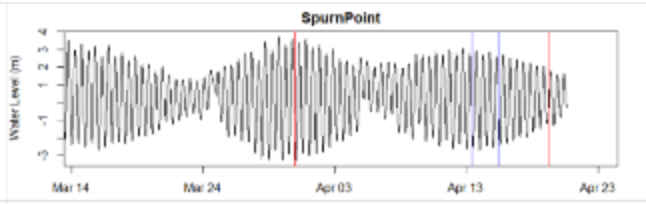
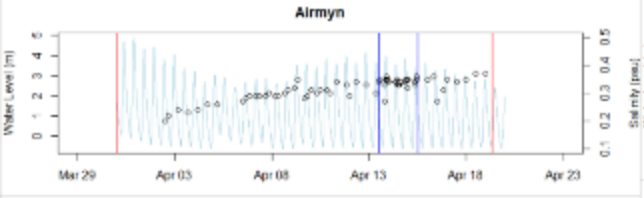
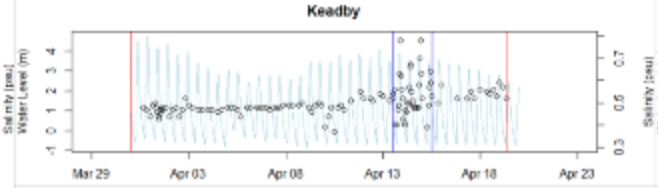
Temporal salinity variations

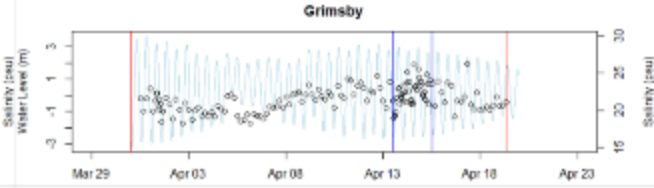


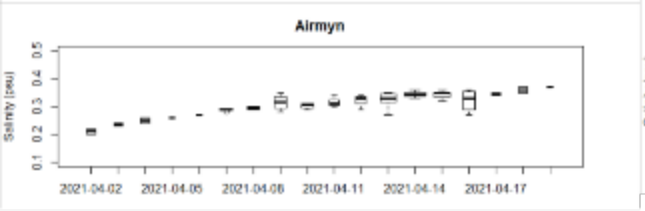


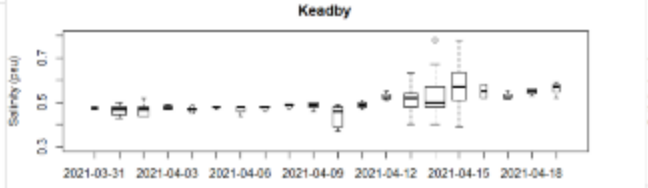


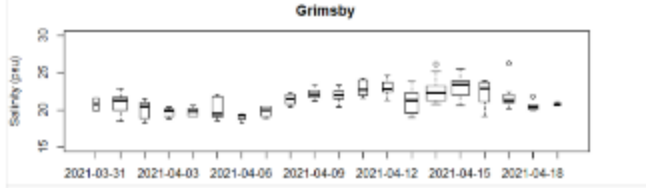


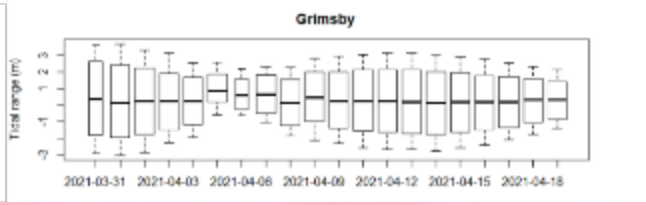












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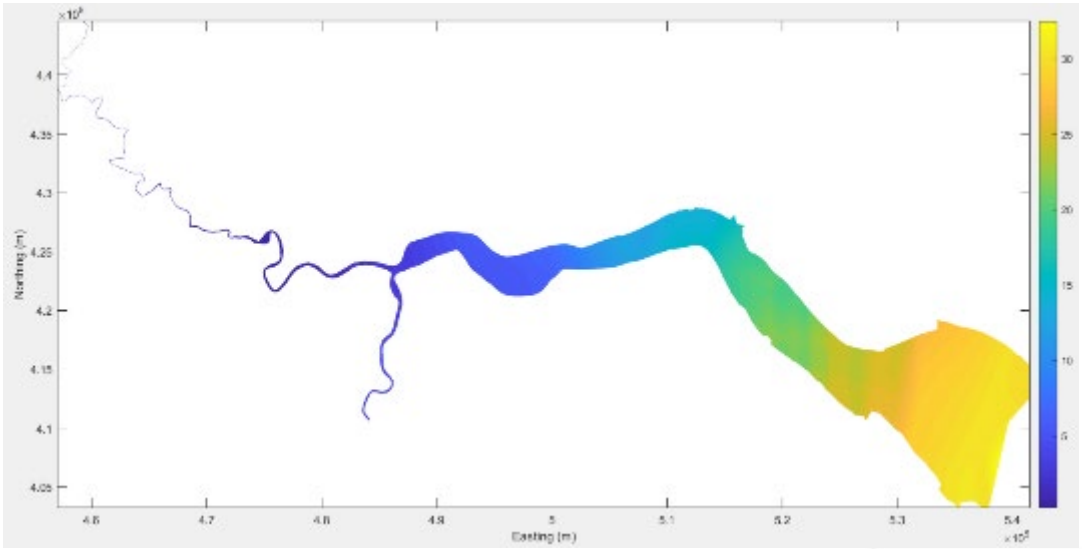
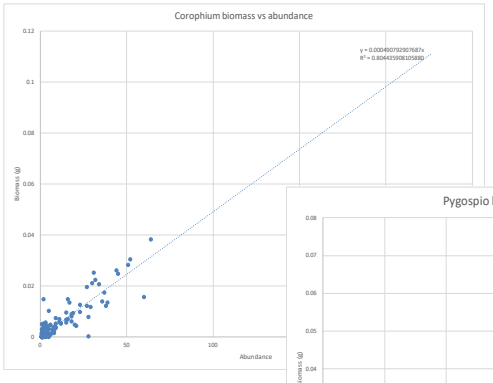
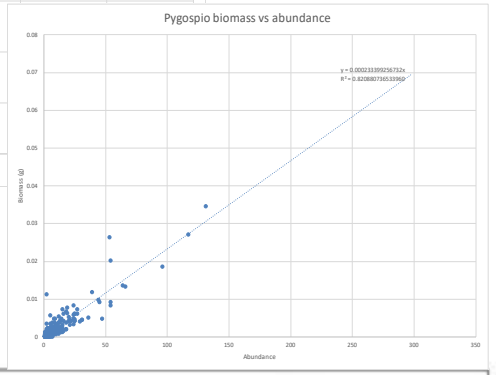
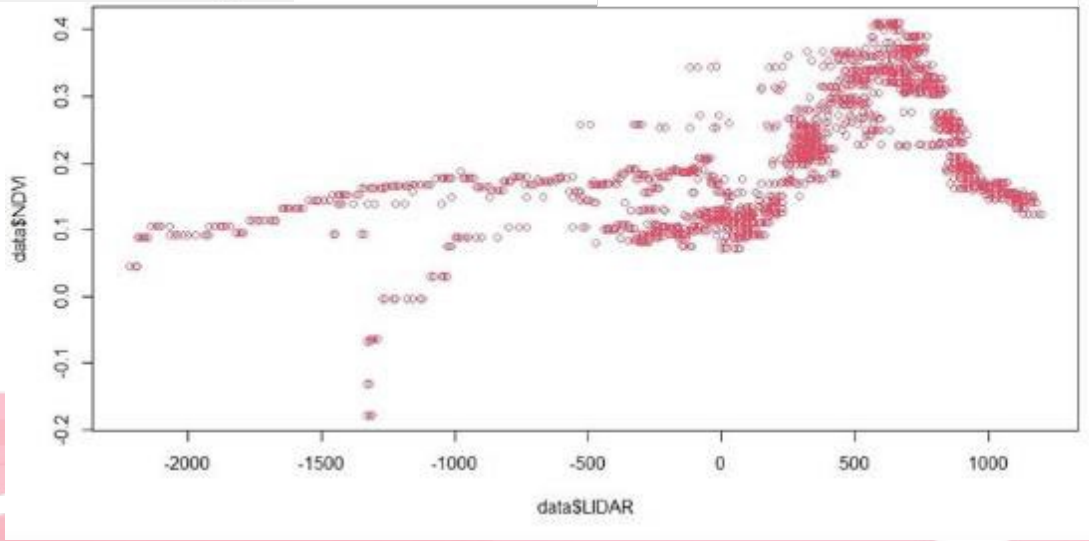
Spatial salinity variations (from EA sampling), biomass vs abundance and relationship between NDVI and LiDAR









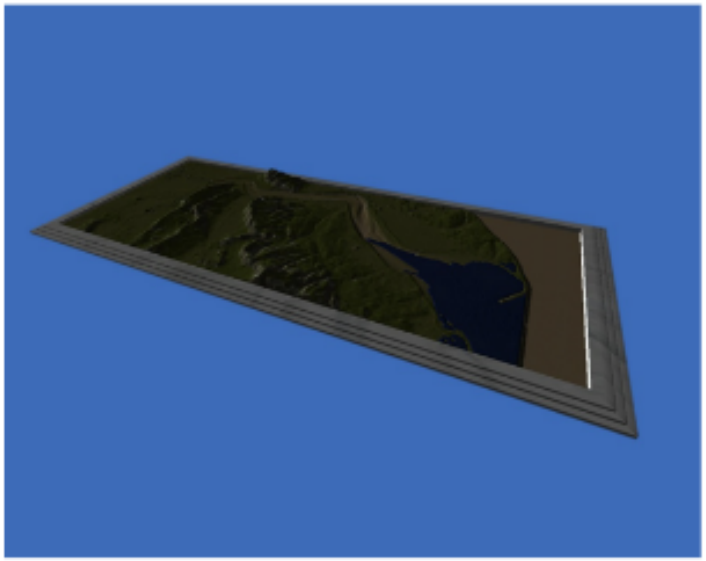
Modelling measures and scenarios

26 measures (and combinations of measures) assessed for 12 SLR- storm surge scenarios (present day, +0.5m, +1.0m, +2.0m; 1-, 200-, 1000- return periods):

- 1 degraded defence measure
- 2 dredging measures
- 12 MR/flood storage + raised defence measures
- 5 barrier + raised defence measures
- 4 compound (barrier + MR/flood storage + raised defence) measures
- 2 groyne/peninsula measures

Work Package 3.5 - Design measures for flood risk management in the Humber

Draft – February 2022



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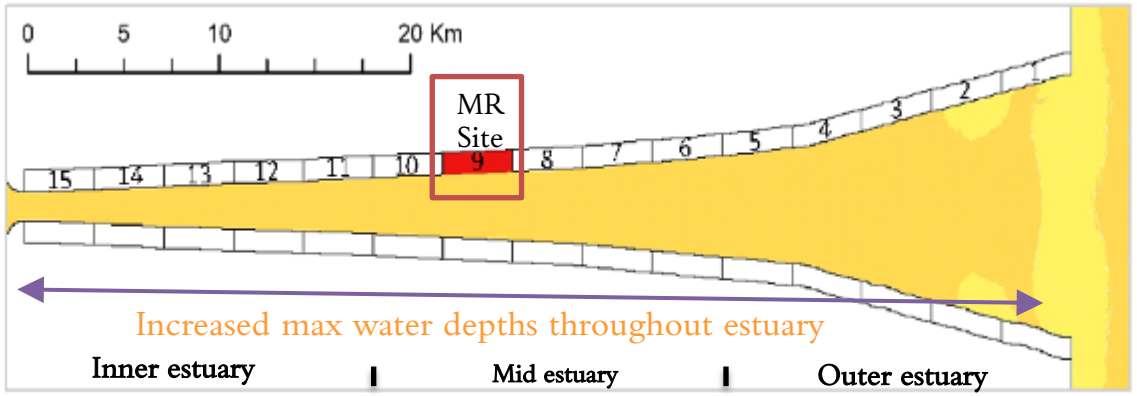
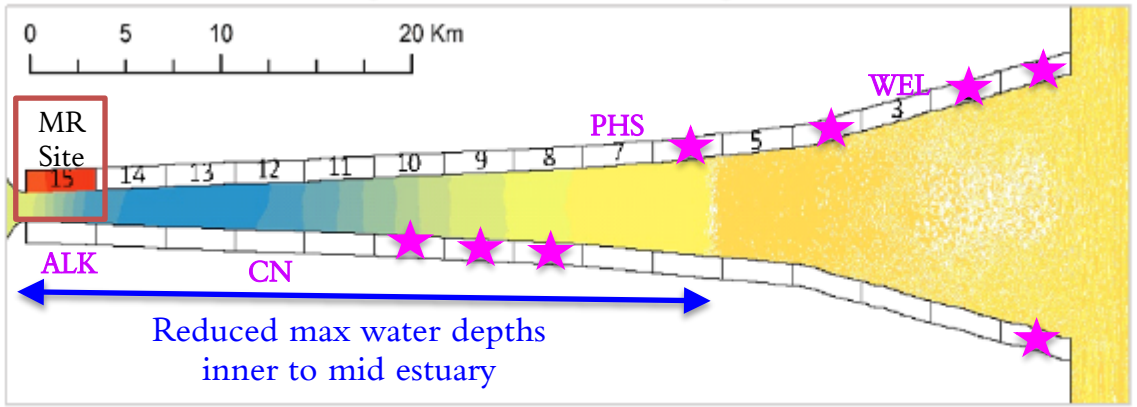
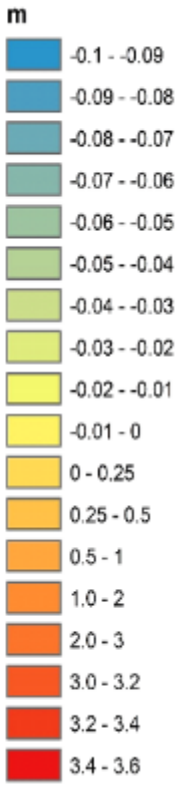
Where is the most effective place for MR in a funnel shaped estuary?







Present day sea level

C

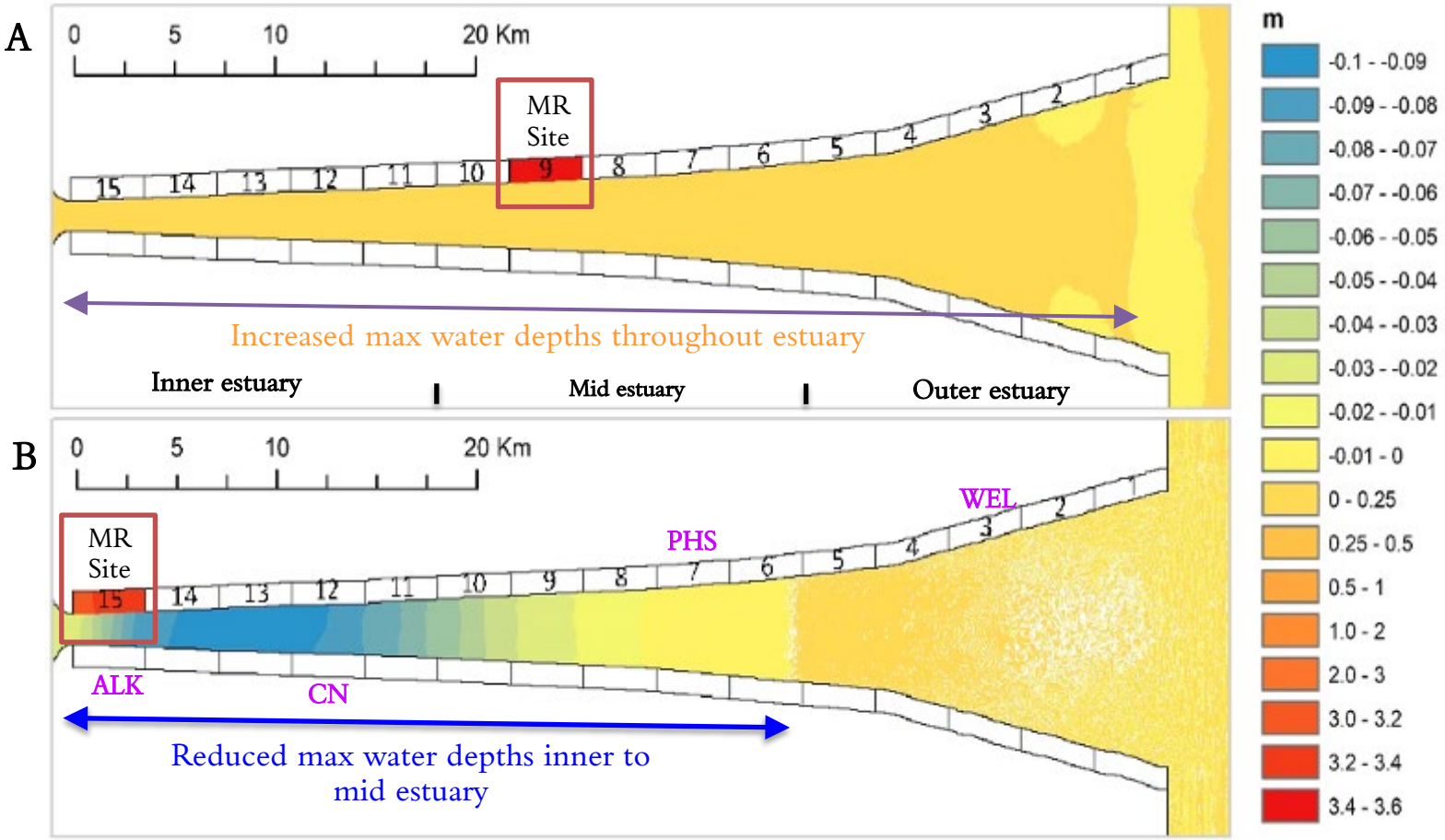
Equivalent Humber MR sites by location:
ALK = Alkborough
CN = Chowder Ness
PHS = Paull Holme Strays
WEL = Welwick

D

Equivalent EA proposed future Humber MR sites by location:
Site 1: Kilnsea / Donna Nook
Site 2: Skeffling extension
Site 4: Sunk Island
Site 6: Keyingham
Sites 8, 9, 10: Goxhill

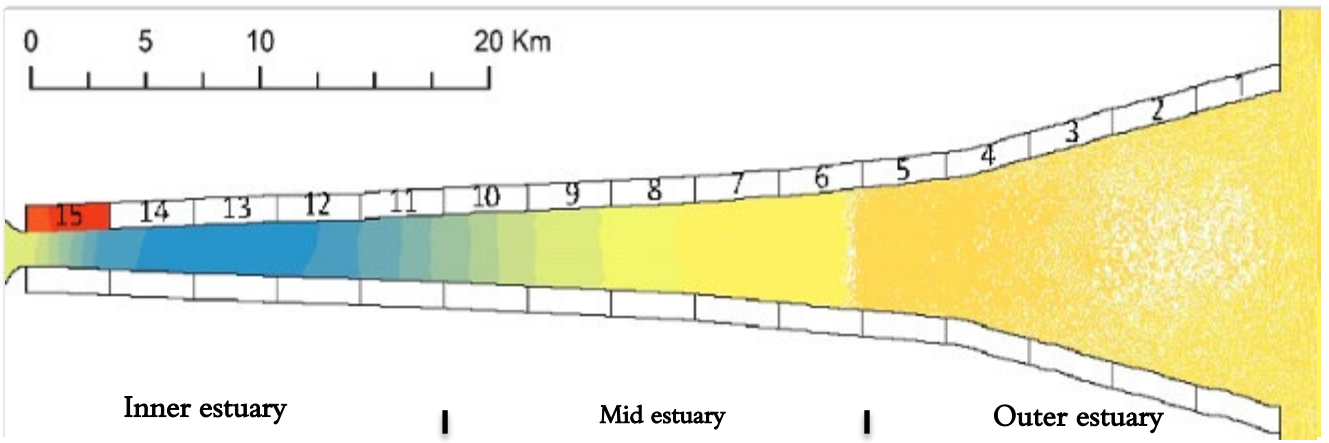
...all located in the mid to outer estuary...

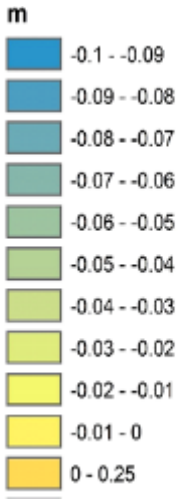
Where is the most effective place for MR in a funnel shaped estuary?

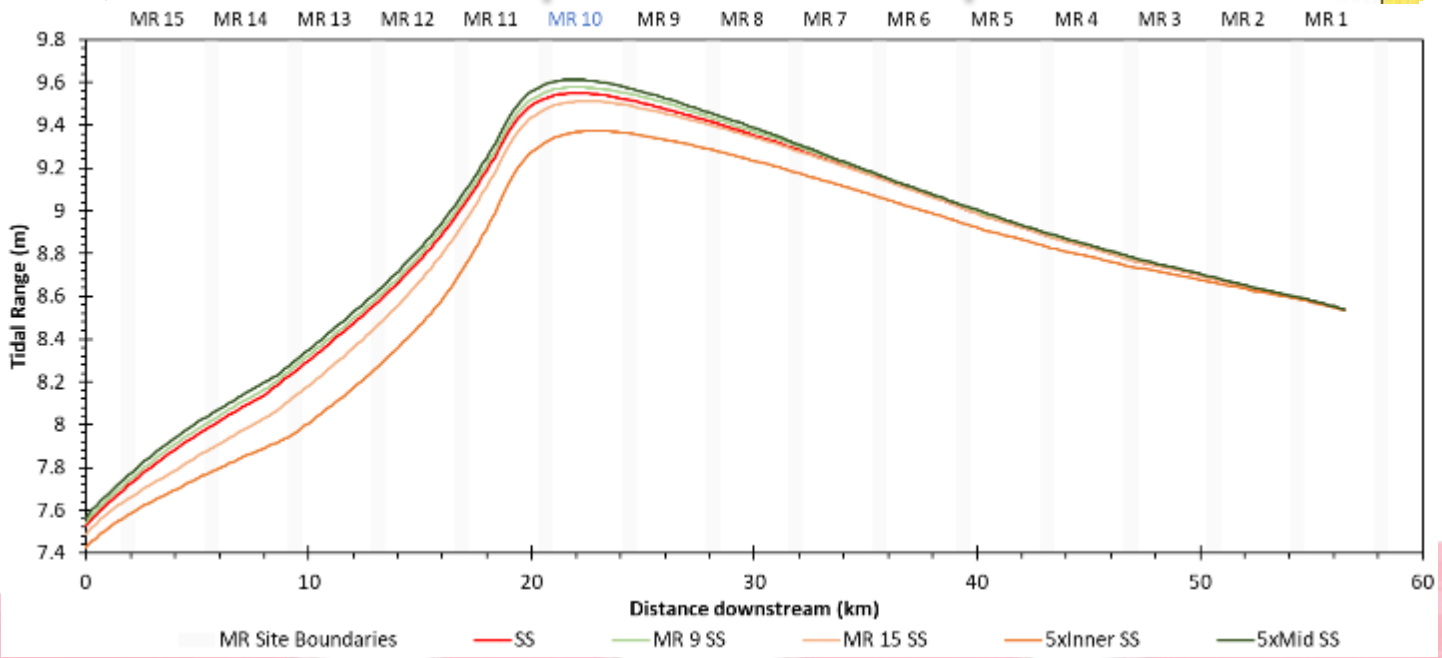


Equivalent locations of current MR and flood storage sites:
ALK = Alkborough, CN = Chowder Ness, PHS = Paull Holme Strays, WEL = Welwick

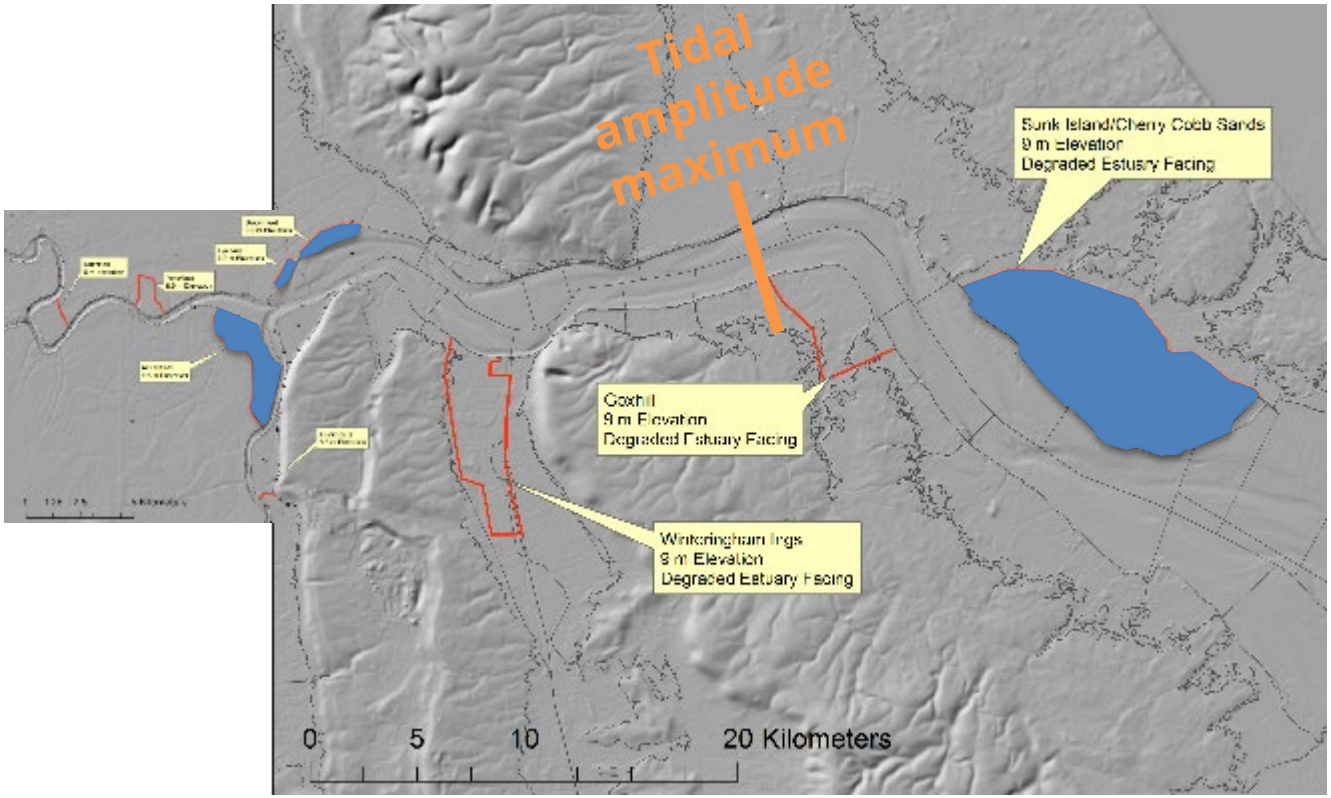
Importance of location of tidal amplitude maximum







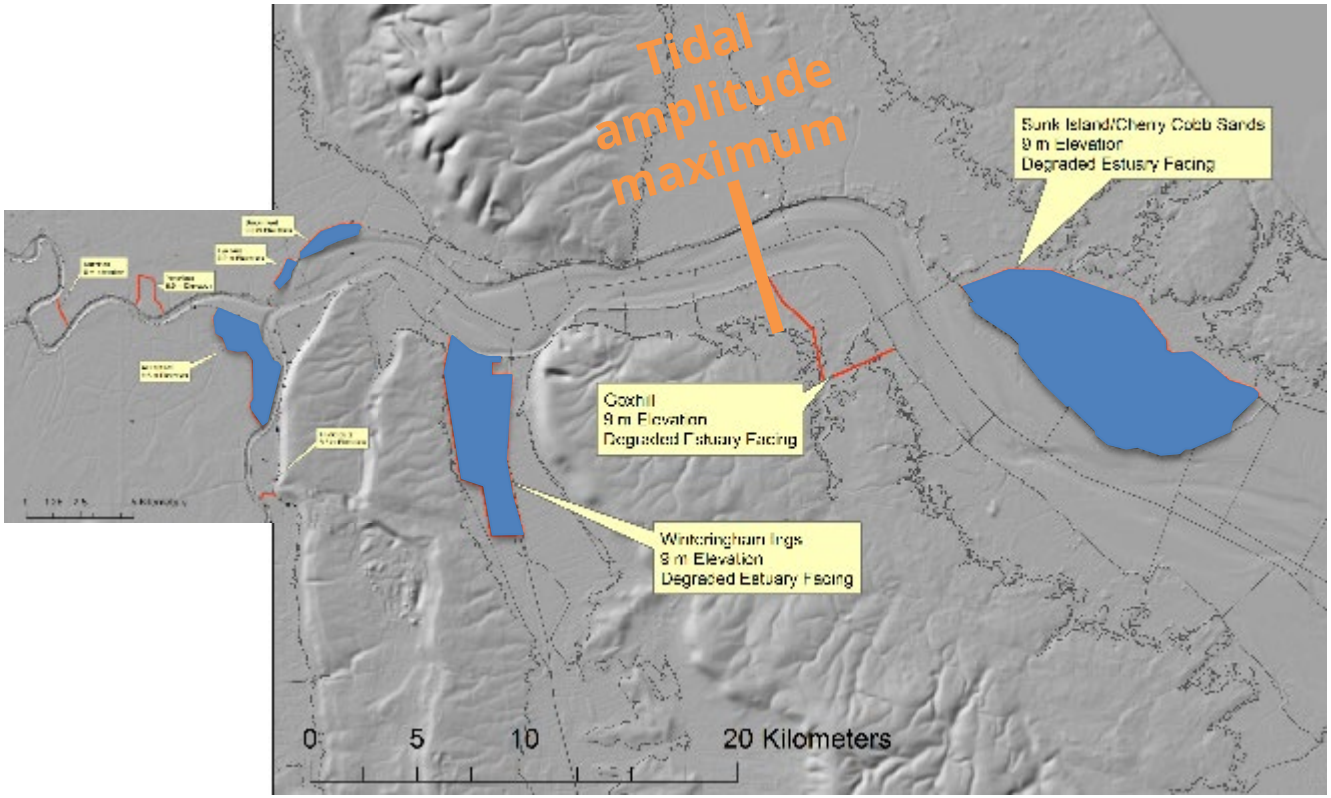
MR in the Humber – protection against 200-year return period storm surge



Potential MR at Adlingfleet, Broomfleet, Faxfleet and Sunk Island/Cherry Cobb Sands:

- Increased flood volume in comparison to baseline (1.22 $x10^6$ m^3) for present day scenario
- But, reduced flood volume with SLR scenarios (up to 250 $x10^6$ m^3 from baseline with 2 m SLR)

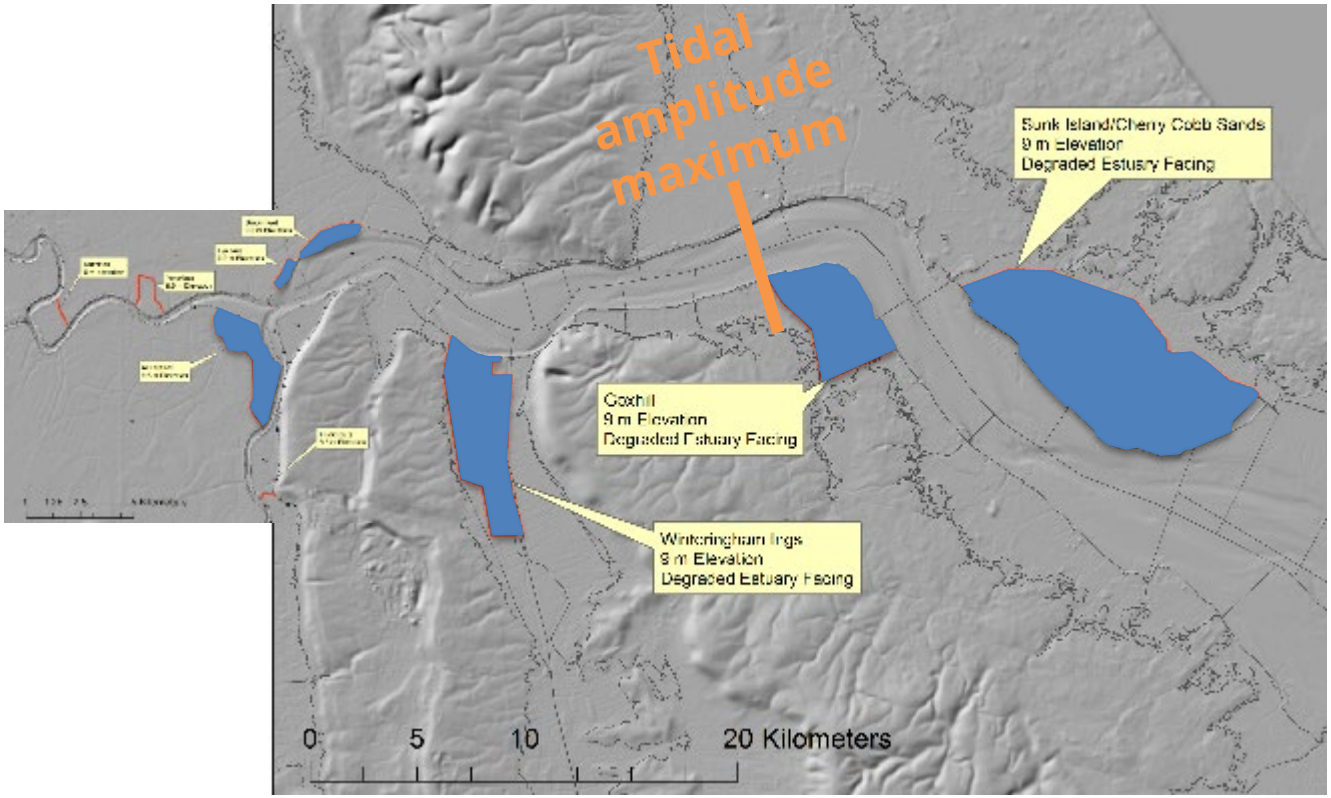
MR in the Humber – protection against 200-year return period storm surge



Potential MR at Adlingfleet, Broomfleet, Faxfleet, Sunk Island/Cherry Cobb Sands and Winteringham Ings:

- Reduced flood volume in comparison to baseline (4.15 $x10^6$ m^3) for present day scenario
- Reduced flood volume with SLR scenarios (up to 511 $x10^6$ m^3 from baseline with 2 m SLR)

MR in the Humber – protection against 200-year return period storm surge



Potential MR at Adlingfleet, Broomfleet, Faxfleet, Sunk Island/Cherry Cobb Sands, Winteringham Ings and Goxhill:

- Reduced flood volume in comparison to baseline (5.94 $x10^6$ m^3) for present day scenario
- Reduced flood volume with SLR scenarios (up to 573 $x10^6$ m^3 from baseline with 2 m SLR)

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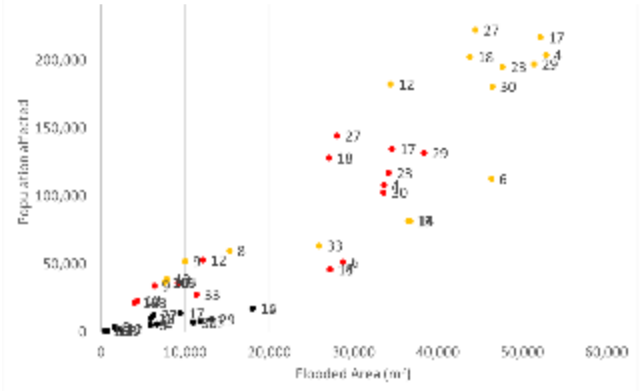
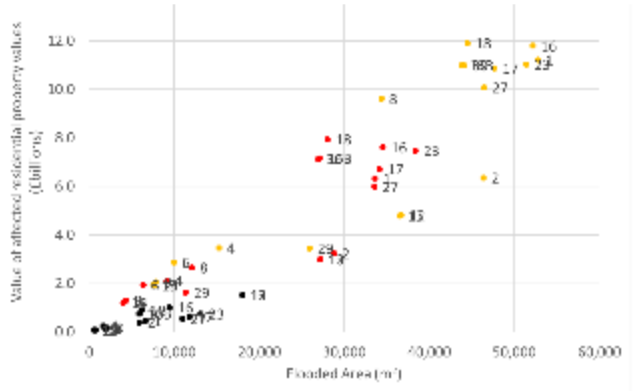
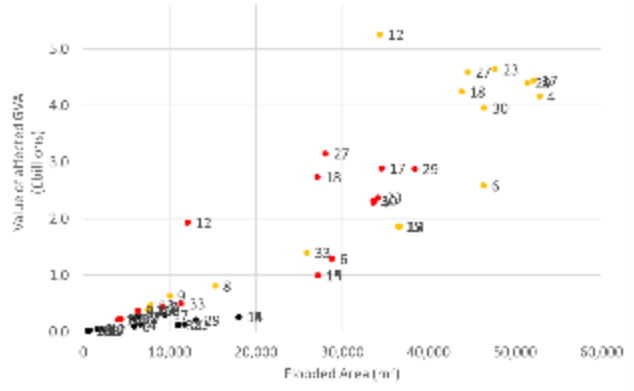
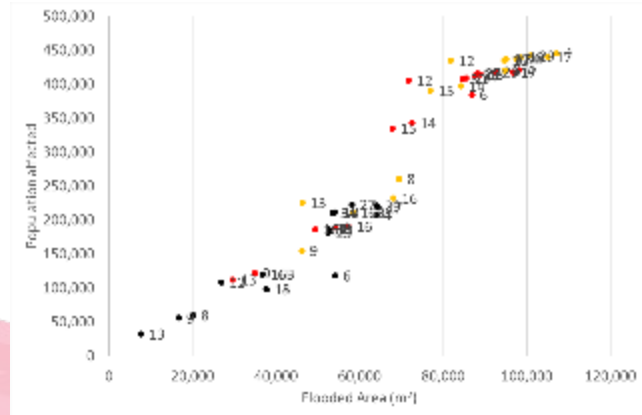
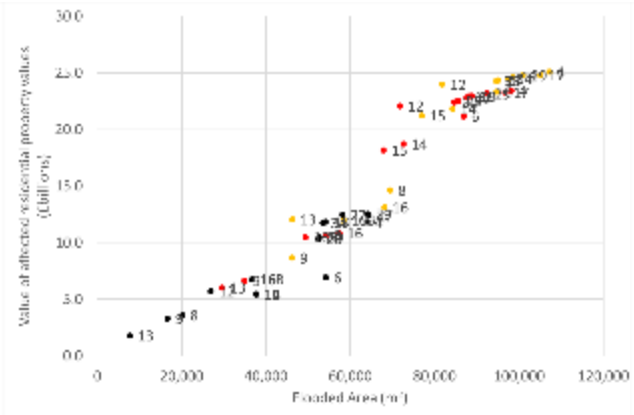
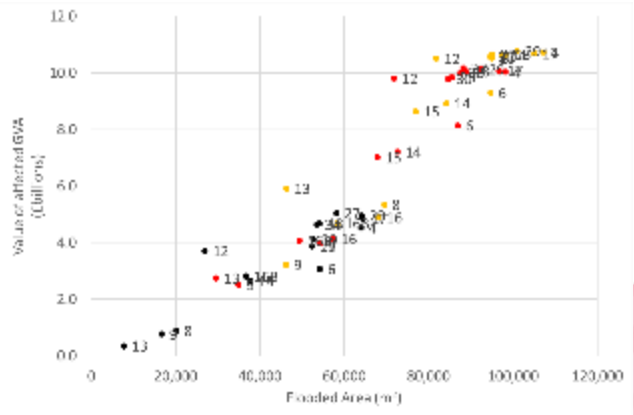
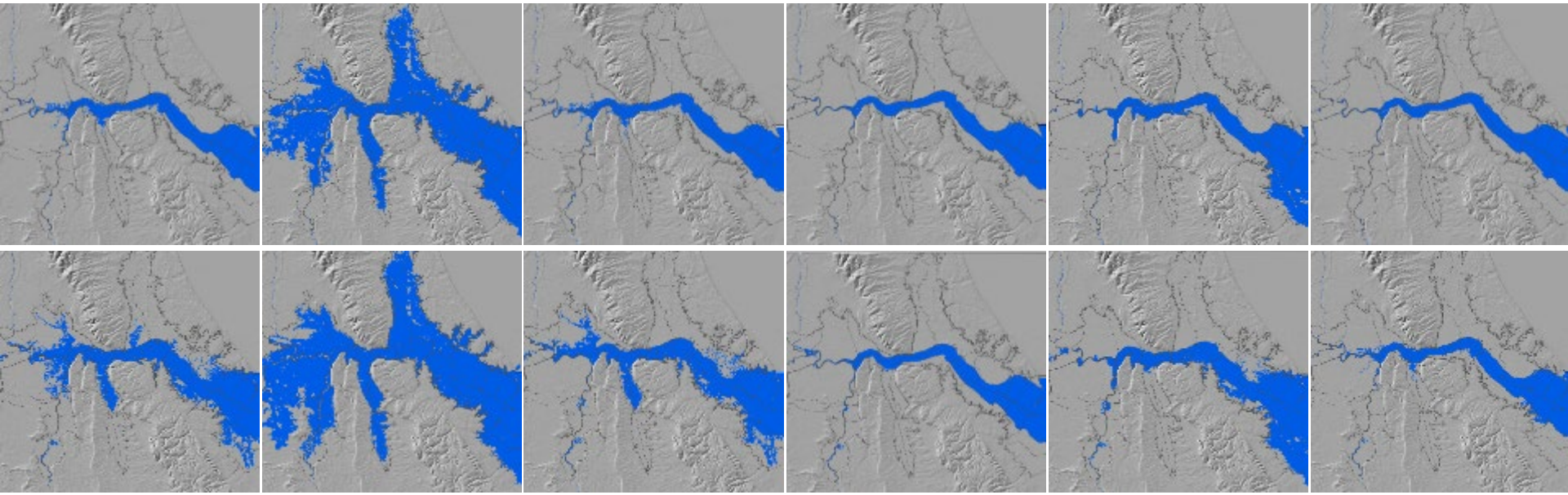
Projected human costs: +1m SLR (top), +2m SLR (bottom)

Population vs flooded area	Value of residential properties vs flooded area	GVA (lost) to economy vs flooded area
		
		

Examples: 200 year storm surge +0m SLR (top), +1m SLR (bottom)



Present day defences	Degraded defences	2 MR sites in mid- to outer-estuary, + raised defences in high priority areas	3 MR sites; 2 in mid- to outer-estuary + 1 in inner- to mid-estuary + raise all defences by 1 m	3 MR sites; 2 in mid- to outer-estuary + 1 in inner- to mid-estuary, 6 FS sites in inner estuary, 2 FS sites in outer estuary + raised defences in high priority areas	Outer estuary Barrier, seaward defences raised 1 m

Conclusions

Shift towards considering estuaries as a whole, not in piecemeal fashion- systems approach following TIDE

Numerical modelling is a crucial tool to inform decision making on optimal measures at the system scale

Managed realignment/ flood storage can be a crucial component of flood management strategies

MR most beneficial (for flood risk) landward of the tidal amplitude maximum in funnel-shaped macrotidal estuaries

But ecological diversity is greatest seaward of the tidal amplitude maximum: conflict!

Still need to maintain or enhance defences in economically sensitive areas to keep pace with climate change

Transferability

How can our work help others?

- A generic numerical modelling tool to enable the assessment of different measures and combinations of measures
- Optimal locations of managed realignment sites in the Humber in particular and funnel-shaped estuaries in general
- A generic numerical modelling tool to enable the assessment of the impacts of different management strategies on flood risk and ecological integrity