Future Coastal Flooding Risk in the Severn Estuary Due to Sea Level Rise

by

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Why the Severn Estuary?

- In England and Wales estimated that 5m people and 2m properties currently at risk from flooding
- Many of these properties located in coastal flood-plains along Severn Estuary where tides are amplified as they propagate up the estuary
- Storm surges also pose major threat to flooding along Severn Estuary - with world renown Severn Bore also occurring during peak spring tides
- Sea level rise and severer storms also expected to exacerbate flood risk due to wave amplification

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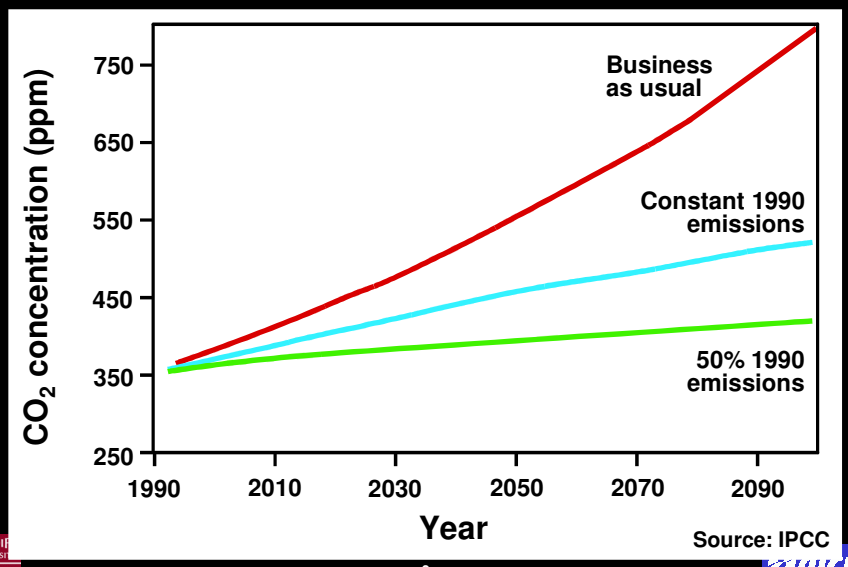
Predicted Future CO_2 Levels



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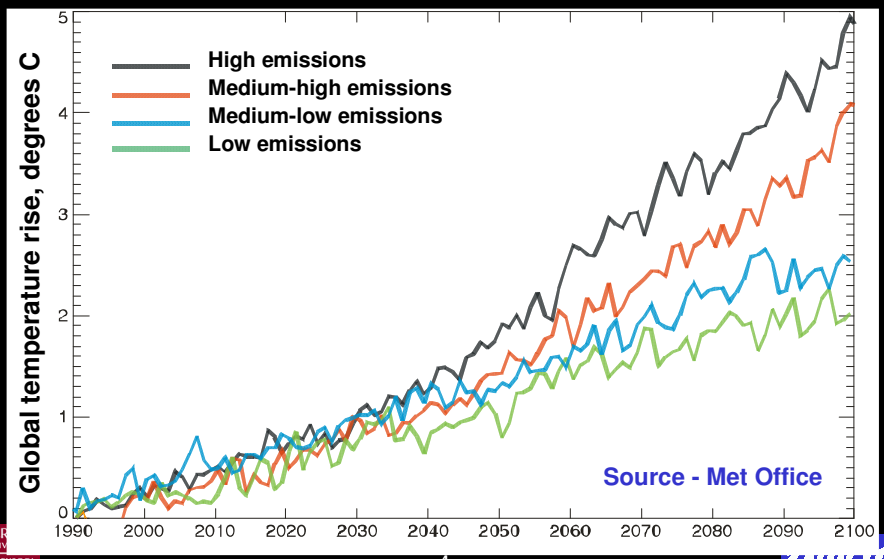
Predicted Mean Temperature Rise



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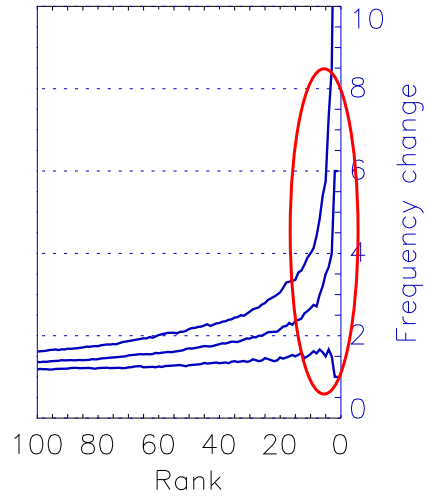
Predicted Mean Rainfall Changes



For South West UK

Present day wet events with a 5 yr return period are predicted to occur between 1.5 & 8.5 times more often

Source - Met Office

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Boscastle - Picturesque Village in U.K.

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Boscastle - August 2004 (1:400 yr flood)

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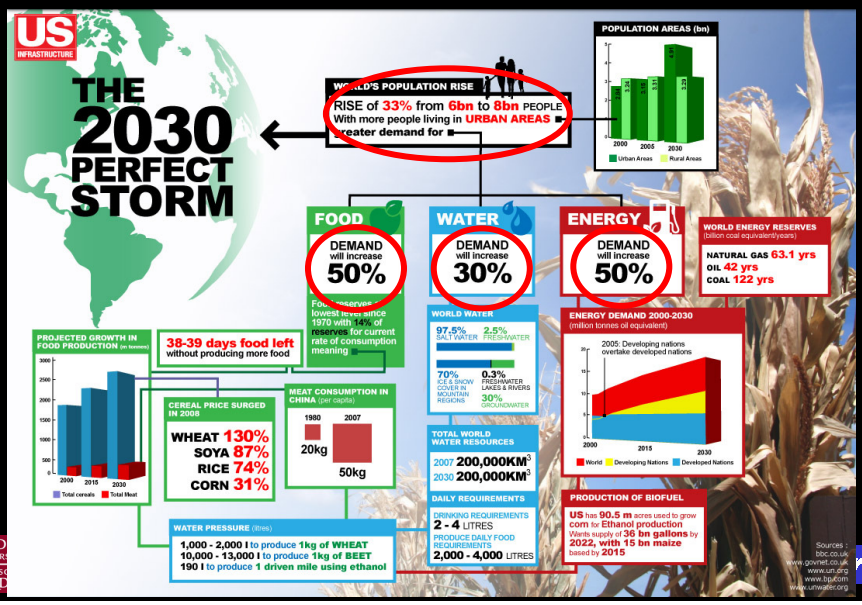
The Perfect Storm → 2030



Severn Estuary and Tidal Power

- Growing global increase in energy demand
- Decarbonisation ➢ rise in electricity demand
- EU target of 20% of energy from renewables by 2020 - 15% target for UK (≈ 35% of electricity)
- Wales' 2025 target for marine renewables energy is 14 TWh/yr - Barrage would generate over 60%
- Tidal energy ➢ advantage of being predictable
- Severn Estuary is ideal for tidal range energy

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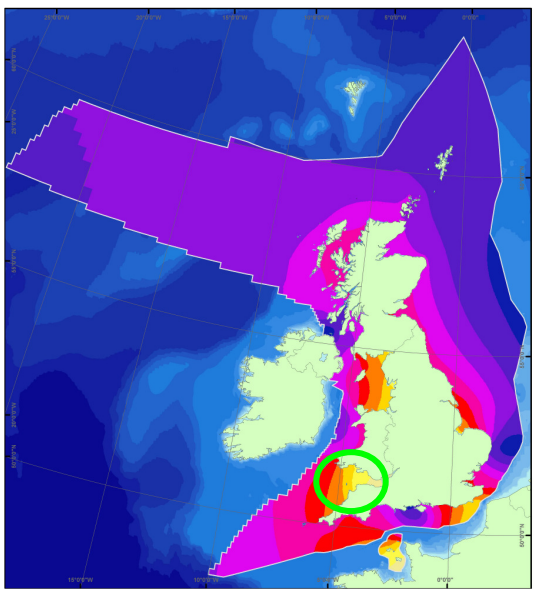
Mean Spring Tidal Range Resource



Source – DTI Atlas of Marine Renewable Energy Resources

Mean Spring Tidal Range (m)
- > 12
- 10 - 12
- 8 - 10
- 7 - 8
- 6 - 7
- 5 - 6
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- < 1
- Land
- & UK Continental Shelf
- Channel Island Territorial Sea Limit

Severn Barrage - 1849

First proposed by Thomas Fulljames - 1849

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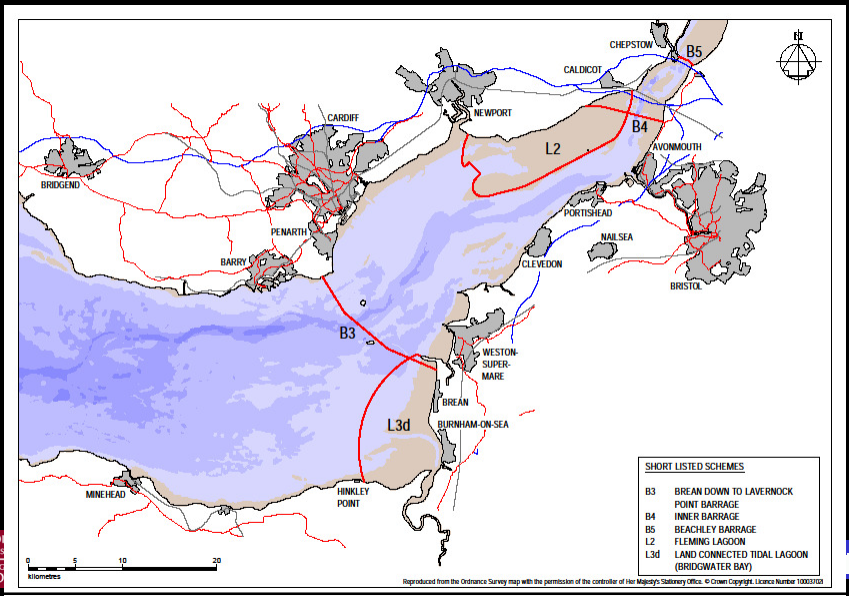
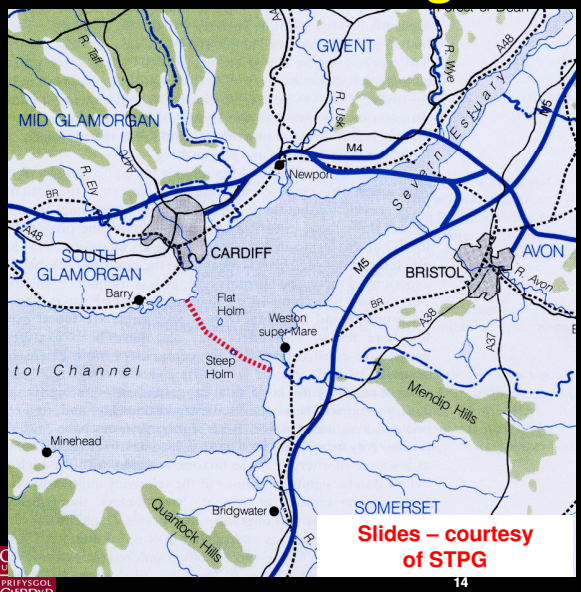
Government Short Listed Proposals



Severn Barrage Proposal Site



Slides – courtesy of STPG

Some key facts:

- Cardiff to Weston
- 2nd highest spring tidal range ≈ 14 m
- Length about 16 km
- Generate ≈ 5% of U.K. electricity
- Total cost ≈ £20 bn
- Save ≈ 7.3 million tonnes carbon pa

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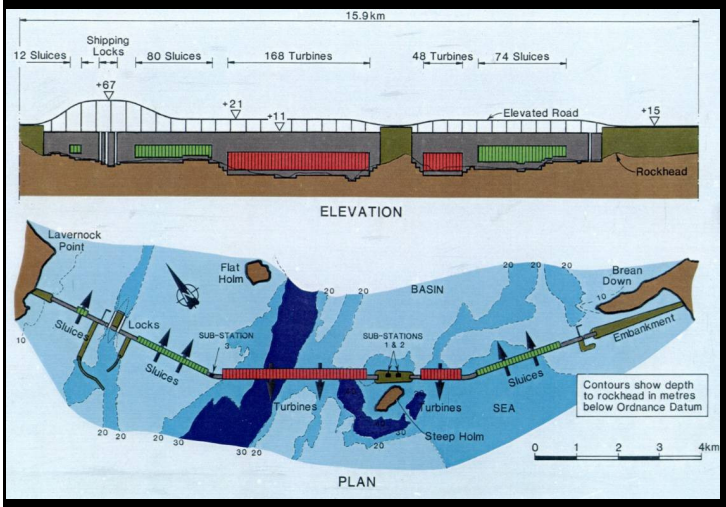
Barrage Layout (1989 Report)



Key facts:

- 216 turbines each 40 MW ≈ 17 TWh pa
- 166 sluices
- Ship locks
- Fish pass?
- Public road & railway

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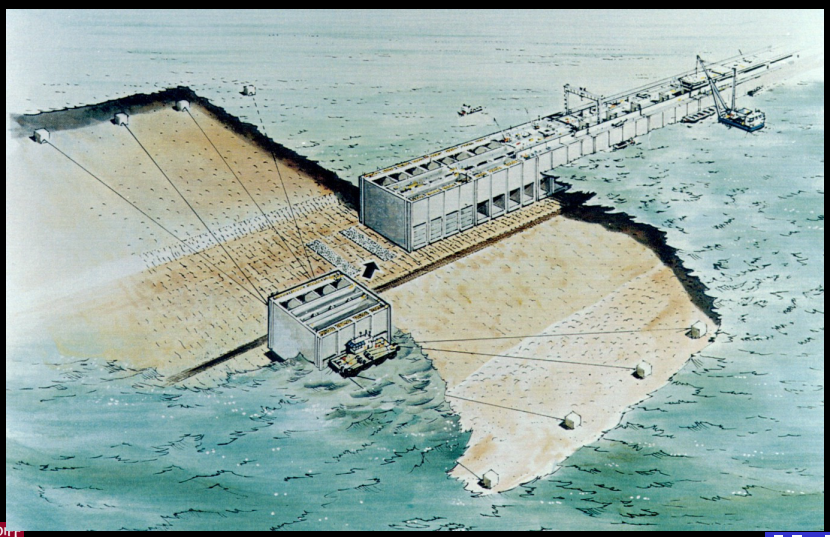
Construction: Prefabricated Caissons



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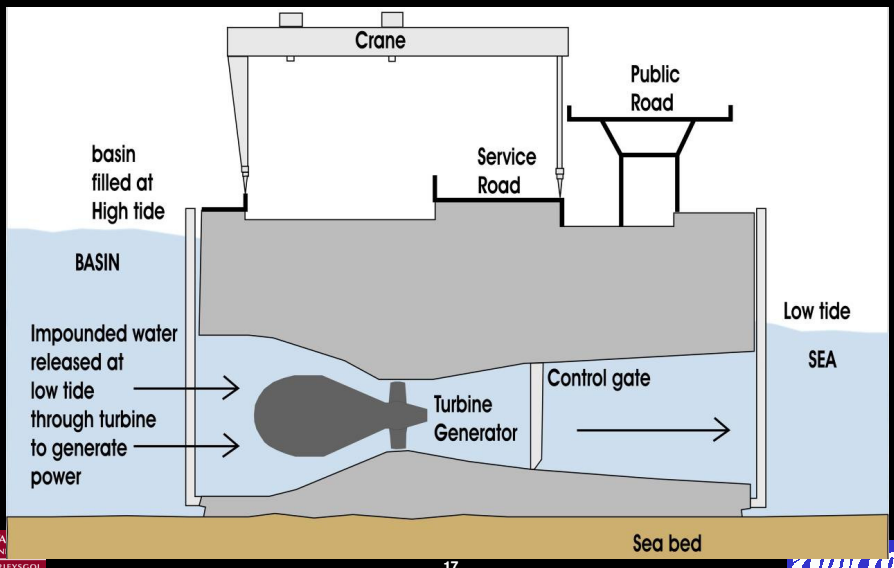
Tidal Power Generation



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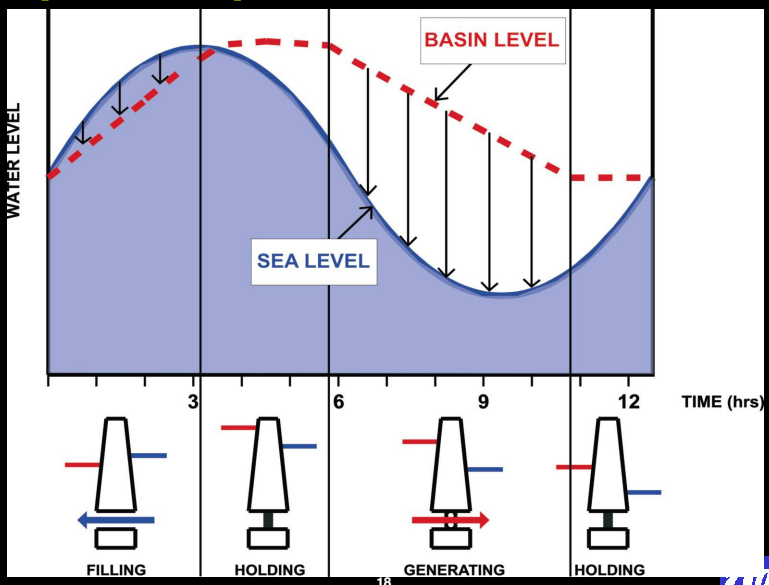
Proposed Operation - Ebb Generation



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Existing Estuarine Environment

- Tide Range - 14 m on springs, 7 m on neaps
  - High tidal currents and large inter-tidal areas
  - 30 Mt sediment suspended on springs, 4 Mt neaps
  - Little sunlight penetration through water column
  - Reduced saturation dissolved oxygen levels
- Ecology
  - Harsh estuarine regime with high currents
  - Limited aquatic life in water column / bed
  - Bird numbers per km^2 are relatively small

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Changing Natural Environment

- Climate Change
  - Temperature rise will affect ecology, birds etc
  - Sea level rise will lead to increased flood risk
- Water Quality
  - Cleaner effluent discharges with EU WFD
  - Nutrient reduction will affect aquatic life
- Legislation
  - Long term projects (>120 yr) require assessment against future - not just current - environment

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Main Effects of Barrage

- Spring tide range reduced from 14 m to 7 m
  - Significant loss of upstream inter-tidal habitats
  - Reduced currents up & downstream of barrage
  - Reduced turbidity / suspended sediment levels
  - Increased light penetration through water column - with increased water clarity
  - Increased primary productivity and changed bio-diversity of benthic fauna and flora
- Upstream tidal range of 7m is still relatively large compared to most deltas world-wide

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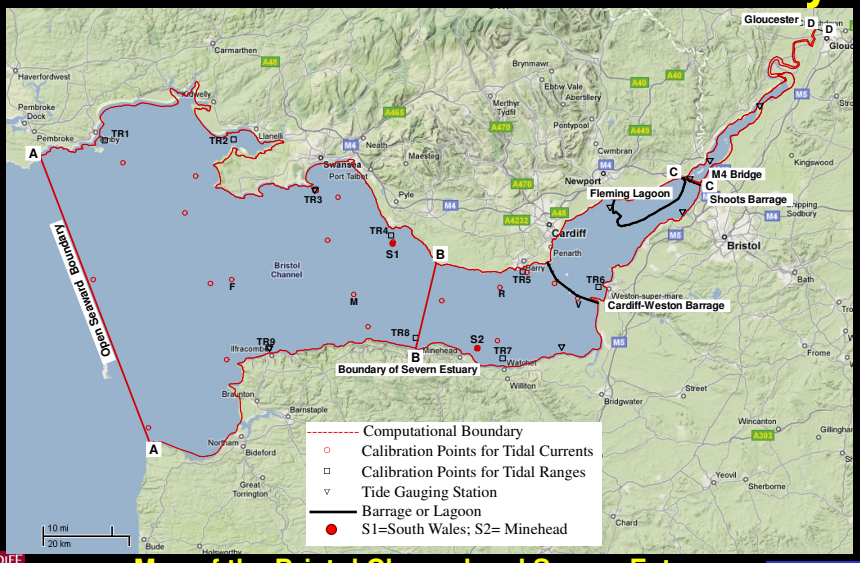
Domain and Seaward Boundary



Map of the Bristol Channel and Severn Estuary

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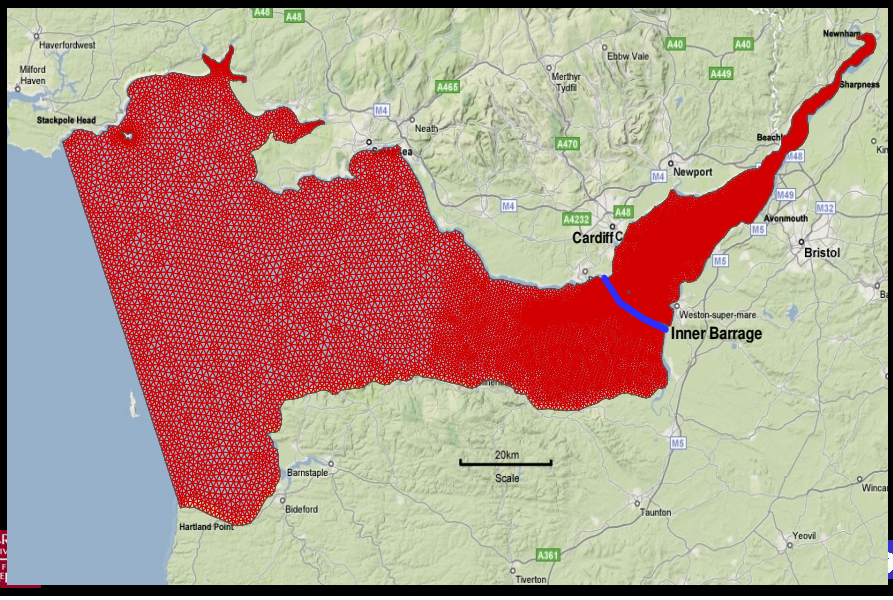
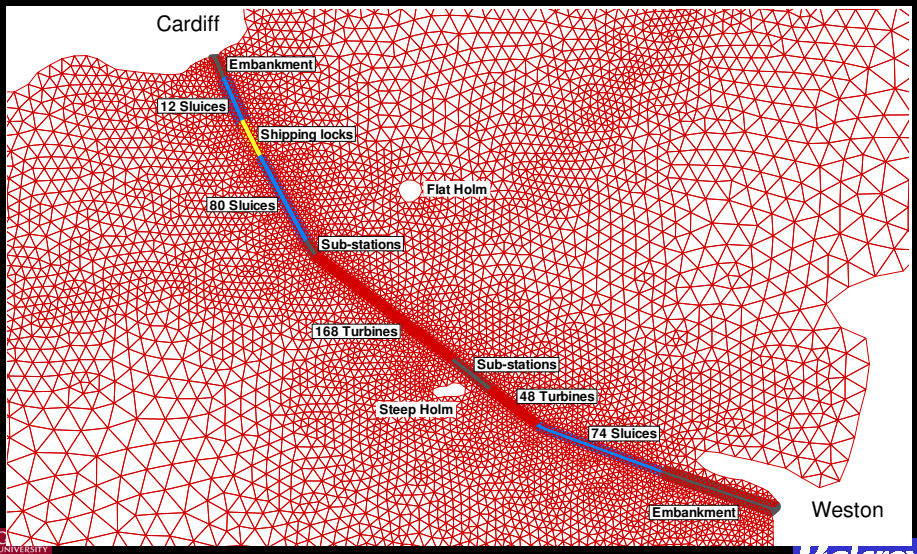
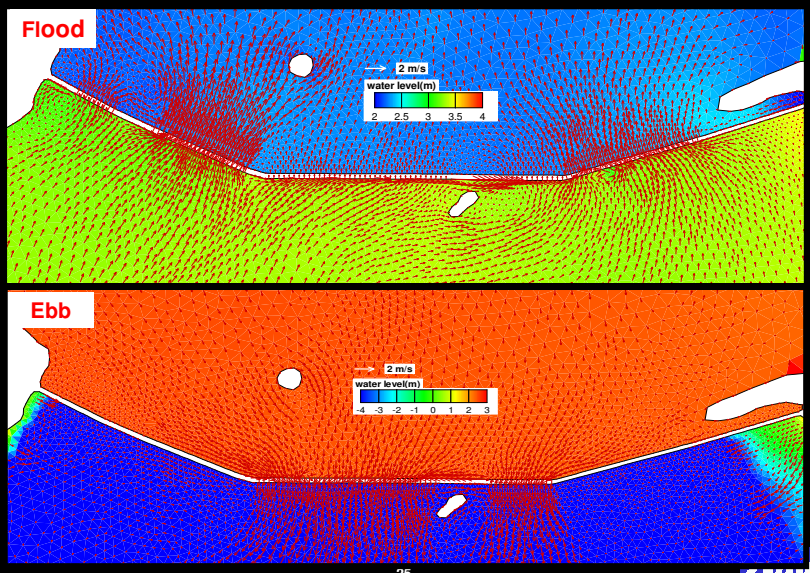
Severn Estuary - Numerical Model



Grid Refinement Around Barrage



Velocity Field Around Barrage



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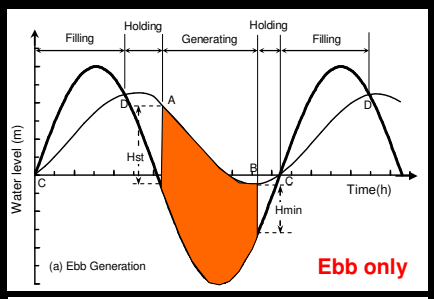
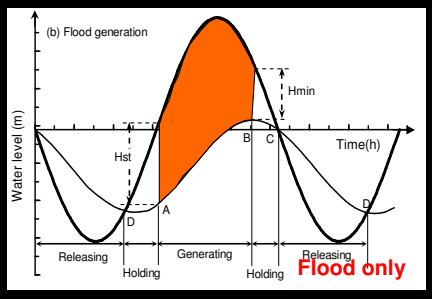
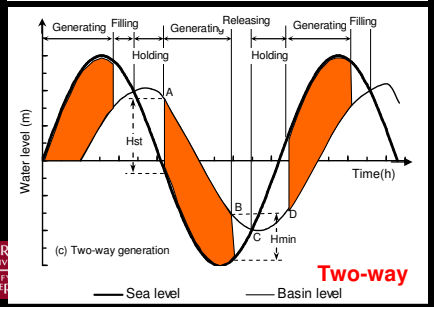
Three Modes of Operation Studied







Model predictions resulted in peak power output for:-

- ➔ **Starting Head = 4.0 m**
- ➔ **Minimum Head = 2.0 m**

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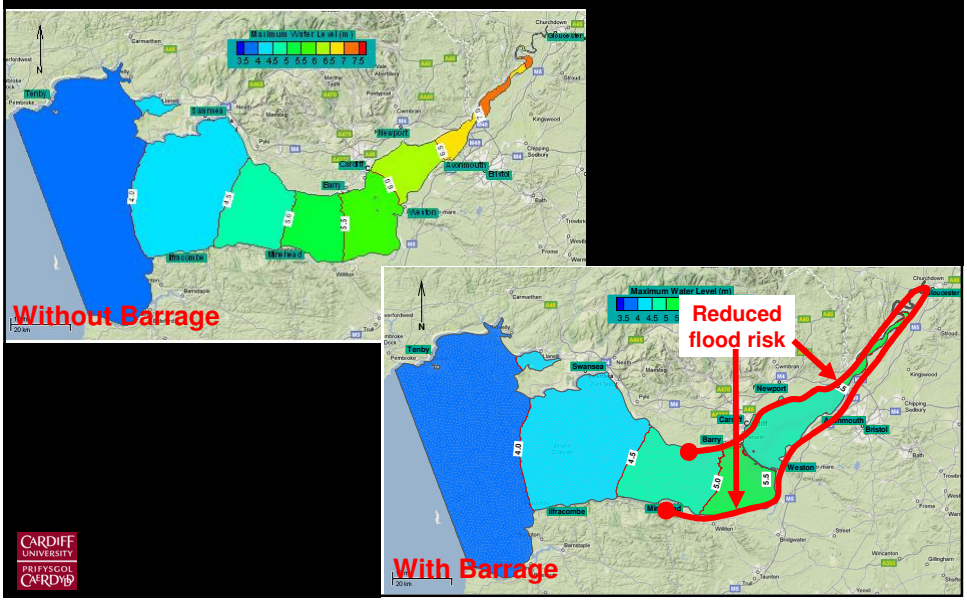
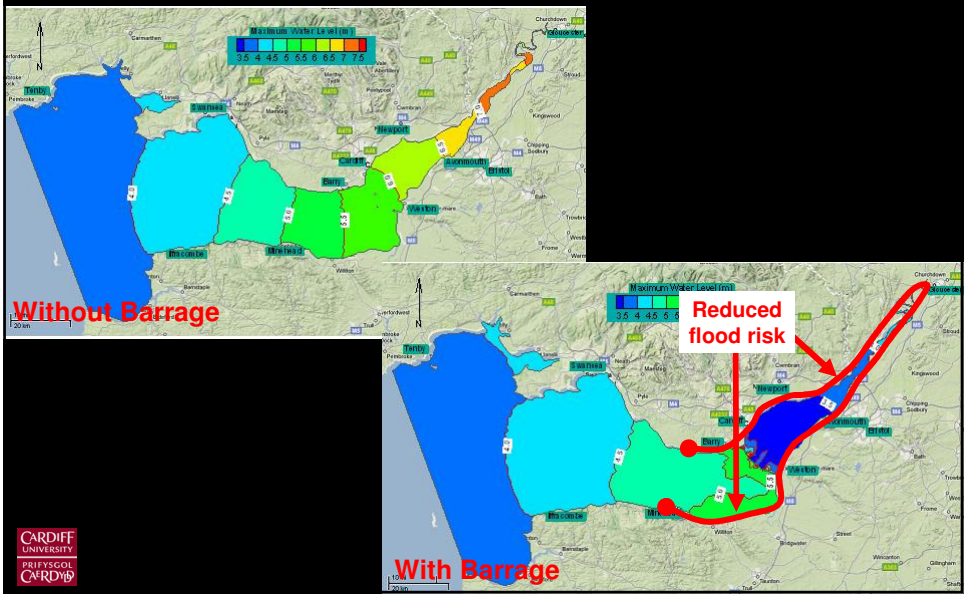
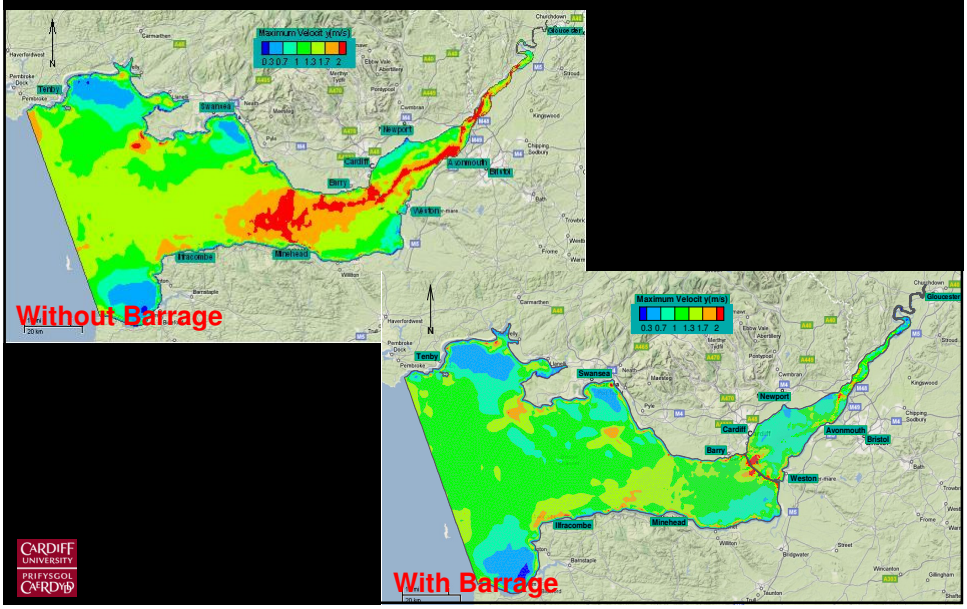
Maximum Water Levels - Ebb Only



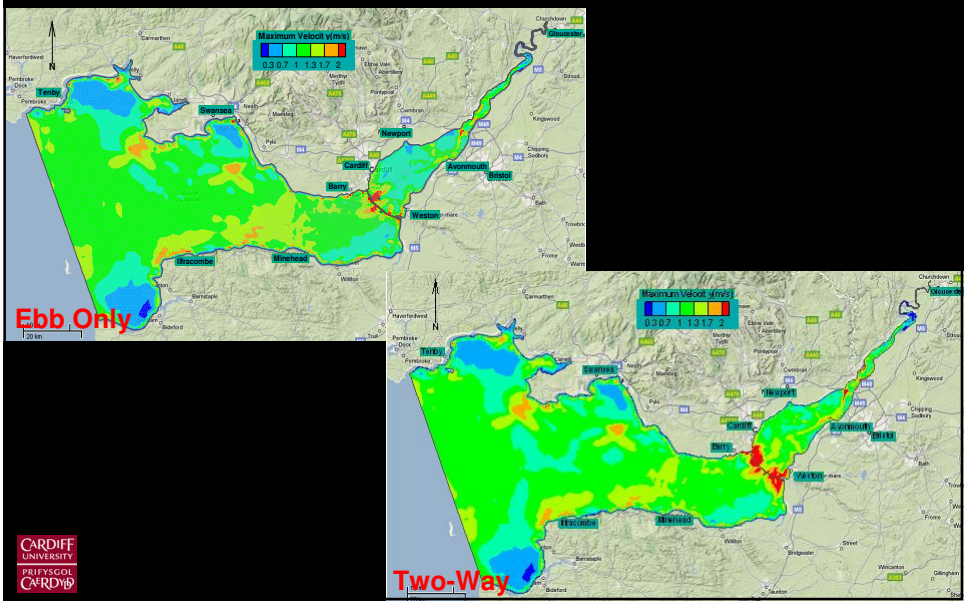
Maximum Water Levels - Two-Way



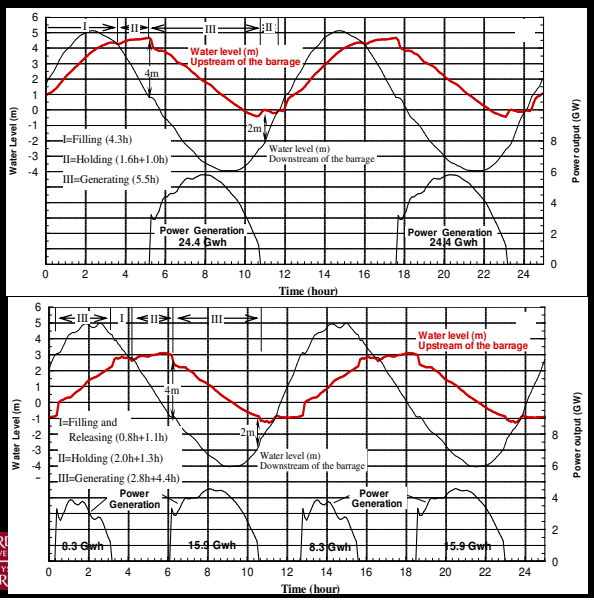
Maximum Tidal Currents - Ebb Only



Maximum Currents - Ebb and Two-Way



Water levels and Power Output



Ebb Only

- 48.8 GWh/24.8h
- 5.2 m mean tide
- High tide 4.6 m

Two-Way

- 48.4 GWh/24.8h
- 4.4 m mean tide
- High tide 3.2 m

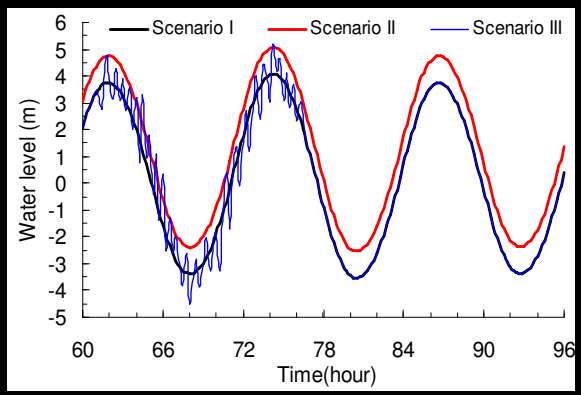
Climate Change Impact Predictions

- Three open boundary scenarios considered:

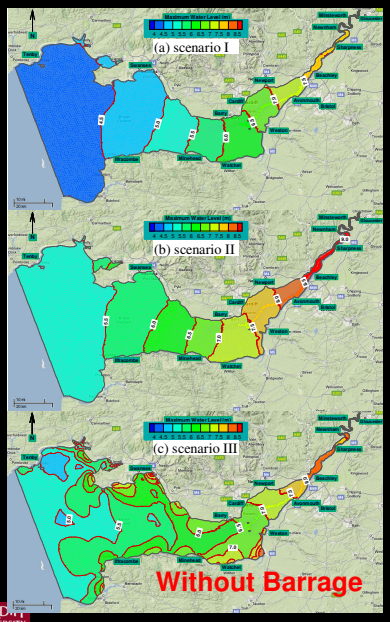
I. **POL 2004 time series of tides**

II. **Scenario I + 1m sea level rise**

III. **Scenario I + 1m surge height**



Simulations for Scenarios Without Barrage



Without Barrage

- Under scenario I, maximum water levels occurred in reach between Beachley and Newnham, ranging from 7.5-8.0 m
- Under scenario II, maximum water levels were predicted to increase by about 1.0 m along entire estuary
- Under scenario III, distribution of maximum water levels was fairly uneven in estuary downstream of proposed barrage site

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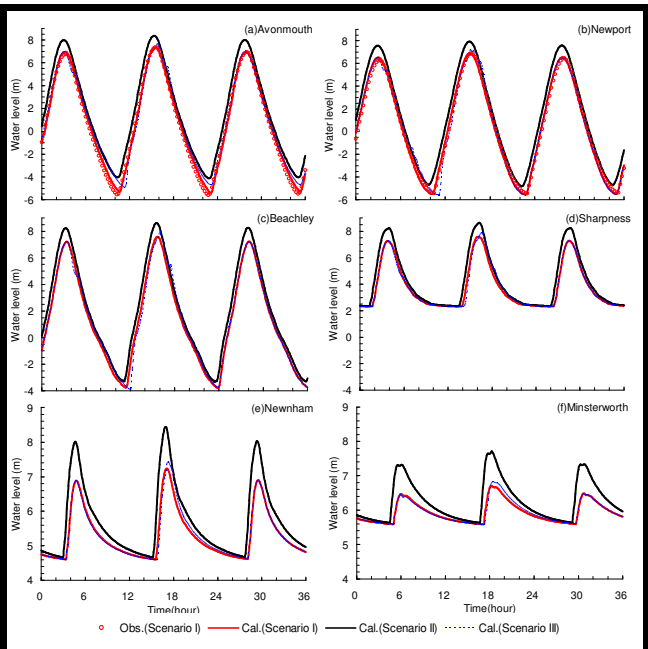

Predicted tides at different sites without barrage

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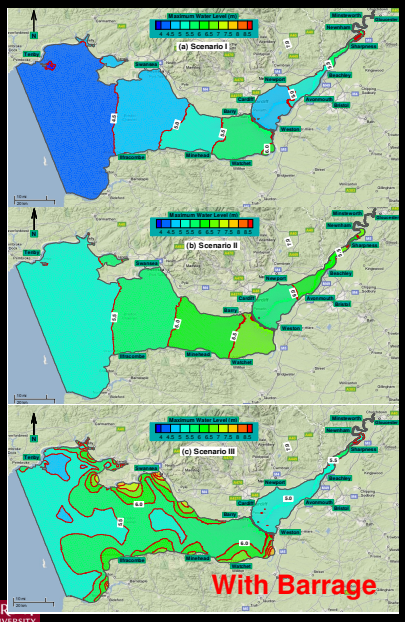
Simulations for Scenarios With Barrage



With Barrage

- Under scenario I, maximum water levels were predicted to decrease by about 0.5 m in the area downstream of barrage and decrease by 1.4-2.0 m in area upstream of barrage
- Under scenario II, construction of barrage would effectively reduce maximum water levels by 1.0 m in middle and inner estuary reaches
- Under scenario III, distribution of maximum water levels upstream of barrage would not be influenced by sea level surge due to construction of barrage

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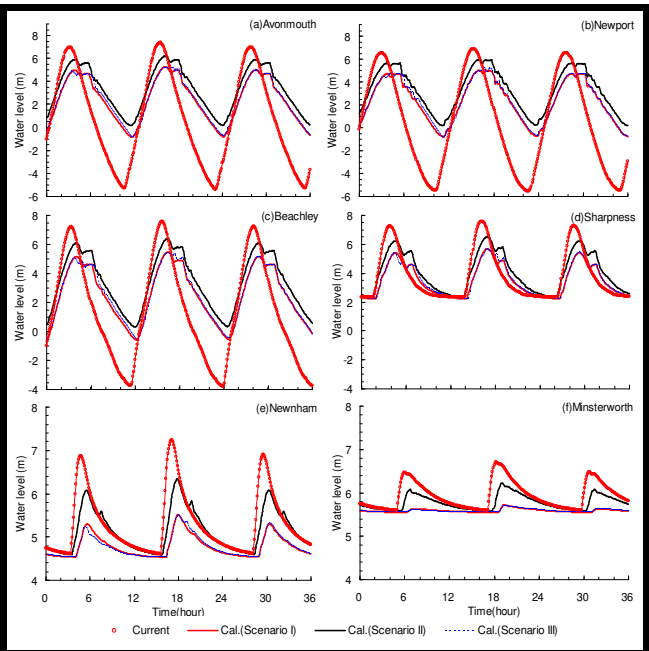

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Predicted tides at different sites with barrage

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Summarising

- Severn Barrage would have a lasting impact on a unique UK macro-tidal estuary:
  - Provide 5% of UK's electricity from renewables
  - Reduce intertidal habitats by around 14,000 ha
  - Reduce peak water levels – up and downstream
  - Flood generation leads to lower power generation
  - Ebb only and two-way generate ➢ similar power
  - Two-way generation gives little rise in mean basin level and groundwater level - reducing flood risk
  - Sea level rise and surge effects reduced by barrage

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Summarising (Continued)

- Variation in maximum water levels at Avonmouth for different boundary scenarios taken as indication of potential magnitude of sea level rise in region
- Without barrage sea level rise at Avonmouth could reach about 1.0 m by 2100 for scenario II, which would lead to annualised monetary losses of about £6.5M (≈ €8M) in this coastal floodplain
- With barrage peak water levels at Avonmouth for all scenarios would be less than without barrage
- Coastal flood risk upstream of barrage could be reduced significantly with different barrage modes of operation and particularly two-way generation

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