Safe*Coast

Phase 1 Environmental Modelling Report

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Summary

Safe*Coast is a project commissioned under the EU's Eurostars programme. The project aims to deliver the design of an innovative combined tidal power and active flood protection approach.

HR Wallingford is supporting the project, by providing environmental modelling to assist with the development of a case study for the Thames Estuary, UK.

This report describes preliminary option development and environmental modelling conducted for a tidal pool in the Thames Estuary. In conjunction with the wider project team, a preferred conceptual tidal pool has been identified that could deliver:

- a reduction in extreme tidal surge levels in the order of 0.6m – 0.7m. This is an appreciable reduction in the context of flood levels for an extreme event;
- with 24 turbines the maximum power output is presently almost 300GWh/year, with ebb only generation and use of highly efficient pumping to raise high water prior to generation.

Being conceptual in nature, these benefits could be increased with further study, including use of refined sluice operation and pumping to enhance the flood storage potential and tidal power output.

It is also apparent that the combined capacity of the turbines could be refined, to ensure that the pool is completely filled and emptied through the tidal cycle. This could significantly increase the total energy yield. The energy performance of combined ebb-flood generation may also be enhanced with refinements of the pool arrangement, pumping (and pumping efficiency), and sluice operation. It is therefore recommended that further optimisation of these parameters be undertaken.

As well as positive effects, there are potential adverse environmental effects of a scheme of this nature in this location. These would need to be addressed for this scheme (or a variant of it), to be successfully promoted.

Future scheme development will entail comparison of the scheme's environmental benefits (generation of renewable energy, flood protection of freshwater habitats, etc.) with the potential impacts identified, including any proposed mitigation or compensation plan.

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1. Introduction

1.1. The Safe*Coast Project

Safe*Coast is a project commissioned under the EU's Eurostars programme. The project aims to deliver the design of an innovative combined tidal power and active flood protection approach.

The overall project will deliver:

- The proof of concept for a reversible tidal turbine, located within a concrete caisson;
- A new installation method for concrete caissons that uses floatable elements to carry and assemble the final structure;
- A new floatable caisson foundation design, that is adjustable to different water depths and seabed conditions;
- Development of a 'case study' example project configuration that is optimised for flood protection and tidal generation.

HR Wallingford is supporting the last of these objectives, by providing environmental modelling to assist with the development of a detailed show-case study for the Thames Estuary, UK. The case study site is shown in Figure 1.1.

The overall project lead is TideTec AS.

The development of the proposed case study for the Thames Estuary is led by Metrotidal Ltd.

1.2. Scope of environmental modelling

The objective of the environmental modelling by HR Wallingford is to provide, initially, an optimised configuration for a demonstration project in the Thames Estuary, that delivers tidal energy and flood protection. This is Phase 1 of the project.

This configuration will then be passed to Safe*Coast project partners for further engineering development and costing. The initial configuration has been based on tidal turbine performance data held by HR Wallingford that are considered to be representative of the type of turbine and turbine size in operation at La Rance in France.

Phase 2 of the environmental modelling project will comprise revisiting the performance of the proposed demonstration project, using confirmed performance data for the reversible turbine developed by TideTec as part of the project.

1.3. This report

This is our phase 1 report. It provides a summary of the option development and testing that has been undertaken to investigate the flood protection and tidal power available. It provides a recommended configuration for the conceptual scheme, to be taken forward to the next phase of development.

1.4. Inputs by others

Option development has included input from Metrotidal Ltd, who have proposed a wide range of option configurations and also made extensive comments on their modes of operation, for the benefits of flood alleviation and energy production.

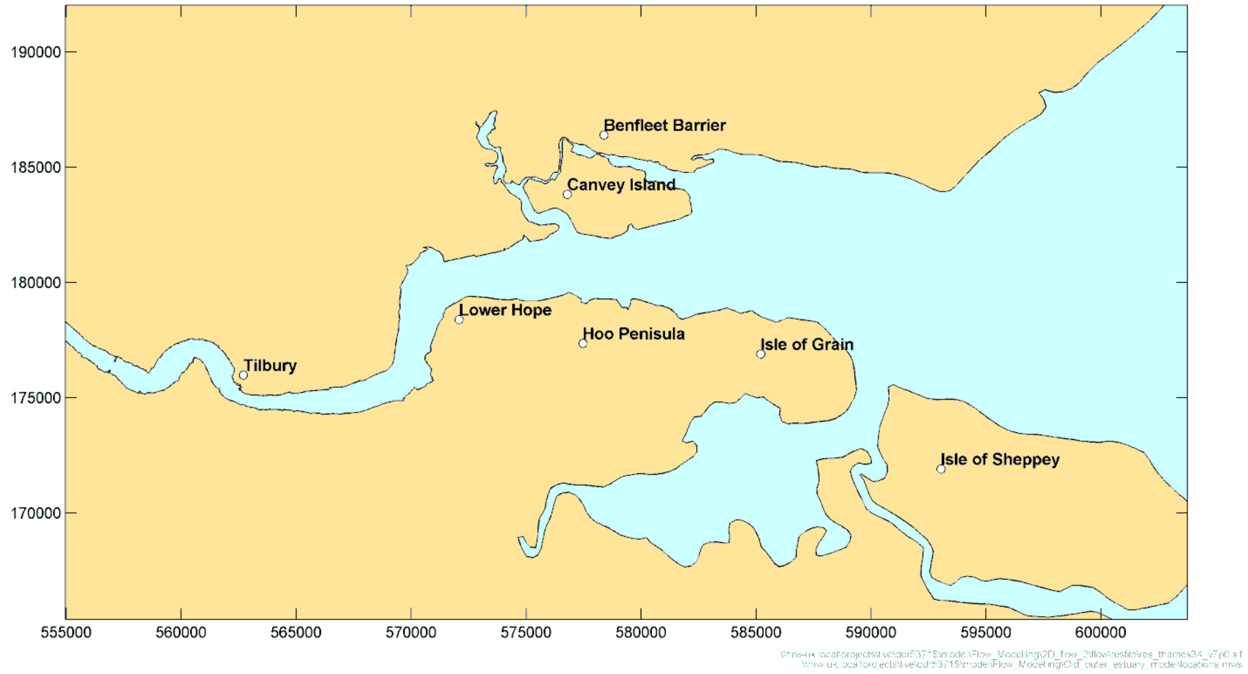

Figure 1.1: Location map of case study site

2. Approach

2.1. Overview

The following activities have been undertaken to identify and test the preferred conceptual scheme:

- Discussion with the project team of the relevant principles of Estuary river dynamics that have a bearing on tidal power/ flood management concept;
- Review of the flood defence parameters for the Thames Estuary 1:1000 year storm levels, surge tide characteristics, flood risk mitigation etc.;
- Initial development of options for Thames Estuary impoundment shapes, with input from Metrotidal Ltd;
- Estimation of resulting pool capacities;
- Modelling of likely estuary process effects, principally water levels;
- Investigation of flood storage characteristics (including surrounding freshwater marshes);
- Discussion with project team members and subsequent refinement of modelling studies;
- Identification of preferred conceptual scheme;

- Estimation of likely power outputs for the preferred scheme, based on conventional turbine technology;
- Summary of potential environmental impacts and issues for the case study site.

A combination of 0-D and 2D modelling approaches has been used to understand tidal surge benefit and energy yield. These models are described in more detail below.

Whilst many possible variations of scheme have been considered, for the purposes of reporting we have condensed these into three initial configurations and a preferred scheme.

2.2. Water level model

HR Wallingford has a 2D flow model for the entire Thames estuary to its very outer limits. This model was set up by HR Wallingford under a joint venture between the Environment Agency and the Port of London Authority as an aid to their regulatory responsibilities (Environment Agency, 2006). This existing model provides the facility to assess the effects of new infrastructure on the estuary's tidal currents and water levels. The model makes use of the state of the art TELEMAC-2D finite element flow model (http://www.opentelemac.org/). The model has a fully unstructured mesh of triangles to represent the geometry of the bed and coastline.

The model was initially established and successively validated against a wide set of tidal level, current and total discharge data throughout the estuary in 2001. The model was subsequently validated against an estuary-wide survey undertaken in late 2004 as part of the Environment Agency's TE2100 studies. The TE2100 work also validated the model in the outer estuary against water level and current data including a series of surge tide test cases. A further bathymetric update and validation exercise was undertaken in 2009.

This model has been frequently used to assess the effects of large scale interventions on the estuary environment, for clients such as Thames Water, Transport for London, the Environment Agency and port developers. The model has been used to simulate a wide variety of tidal and typical and extreme surge conditions as part of TE2100.

2.3. Tidal power model

An HR Wallingford 0D model has been used to predict the power generated by each pool option. The 0D model computes the time series of water level inside each pool, based upon the expected water level outside of the pool and the operation of sluices and turbines. It depends on being able to compute the discharge of water through open sluices and operating turbines as a function of the difference of the water level inside and out, based on an operating cycle that specifies when the sluices or turbines will be brought into or out of operation. The power generated by turbine operation is another output of the 0D model. Depending only on time variation, the model mathematically (but not physically) has no space dimension so it is referred to as zero dimensional or 0D. The model is similar to that used for investigating options to generated tidal power in the Mersey Estuary (EdF, 2011) and the wider Irish Sea area (Burrows et al., 2009).

The model is suitable for rapidly quantifying the energy that is expected to be generated for periods of a year or longer. As it is assumed (for example) that there is no variation of water level through the pool and the water level outside is equal to that predicted. Once a preferred scheme and set of operational rules are established it is usual for this computation to be followed by modelling in two dimensions which can take account of items that are represented in a simplified way in the 0D model.

Previous experience at another site of using the 0D model to identify suitable parameter combinations to study in greater depth and detail using a full 2D flow model indicated that the 0D model can give power output results differing by less than about 5% from the fuller model.

Phase 2 of the tidal power study, in addition to implementing the TideTec turbine in the equivalent 0D model, will include using the same 2D water level model as the flood modelling to show the implications of the turbine operations on flows in the nearby regions of the Thames Estuary. This will be done for both the generic (La Rance type) and TideTec turbine.

3. Flood storage

3.1. Baseline conditions

3.1.1. Introduction

It was agreed with the wider project team that the initial focus in option development should be the benefit each option delivers in terms of flood defence. This benefit was quantified as the reduction in water levels against a 'baseline' extreme event.

The focus of the flood management study has therefore been the 1:1000 year water level / tidal surge event as used for the UK Environment Agency Thames Estuary Flood Management Programme (TE2100). The maximum water level used is approximately 5.5 m OD(N) at Southend. Figure 3.1 shows the total water flow entering the Thames Estuary at four representative locations; Shoeburyness, Canvey Island, Gravesend and the Thames Barrier. The locations of the plotted results are given in Figure 3.2. These results are for existing conditions i.e. without any flood management activity including closure of the existing Thames Barrier.

The Thames Barrier is operated according to a rule based on a combination of the predicted freshwater flow entering the Thames at Teddington with the predicted peak water level at Southend. This rule would mean that the barrier would always be operated for a predicted high water level of 3.85 m OD(N) at Southend or mean daily river flow of more than 630 m^3/s. In reality the barrier is operated in a precautionary way such that it is usually closed for water levels between 0.2-0.4 m below the rule for a given freshwater flow.

The mean daily river flow of the River Thames of 65 m^3/s is insignificant with regards to flood risk management in the main tidal reaches of the Thames.

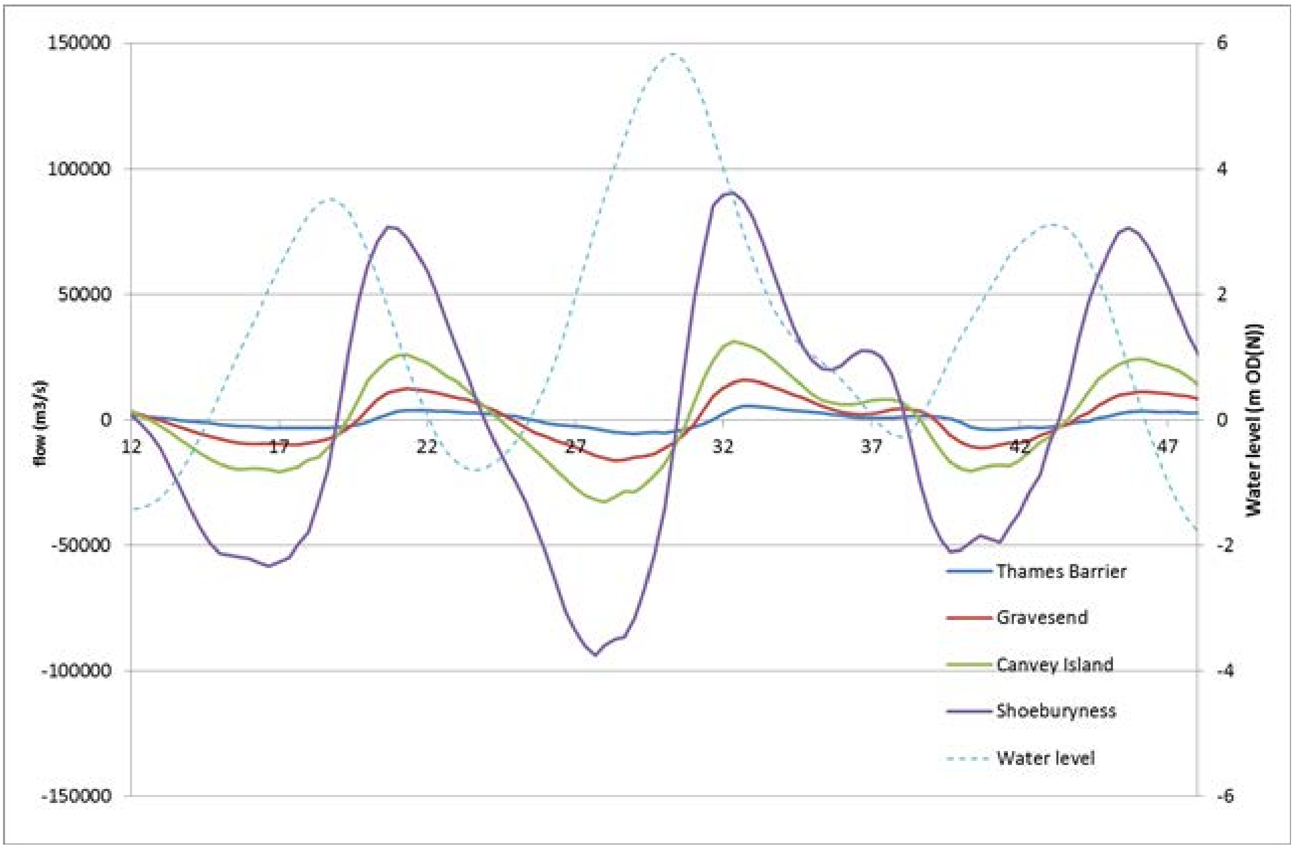

Figure 3.1: Total water flow during 5.5 m high water at Southend

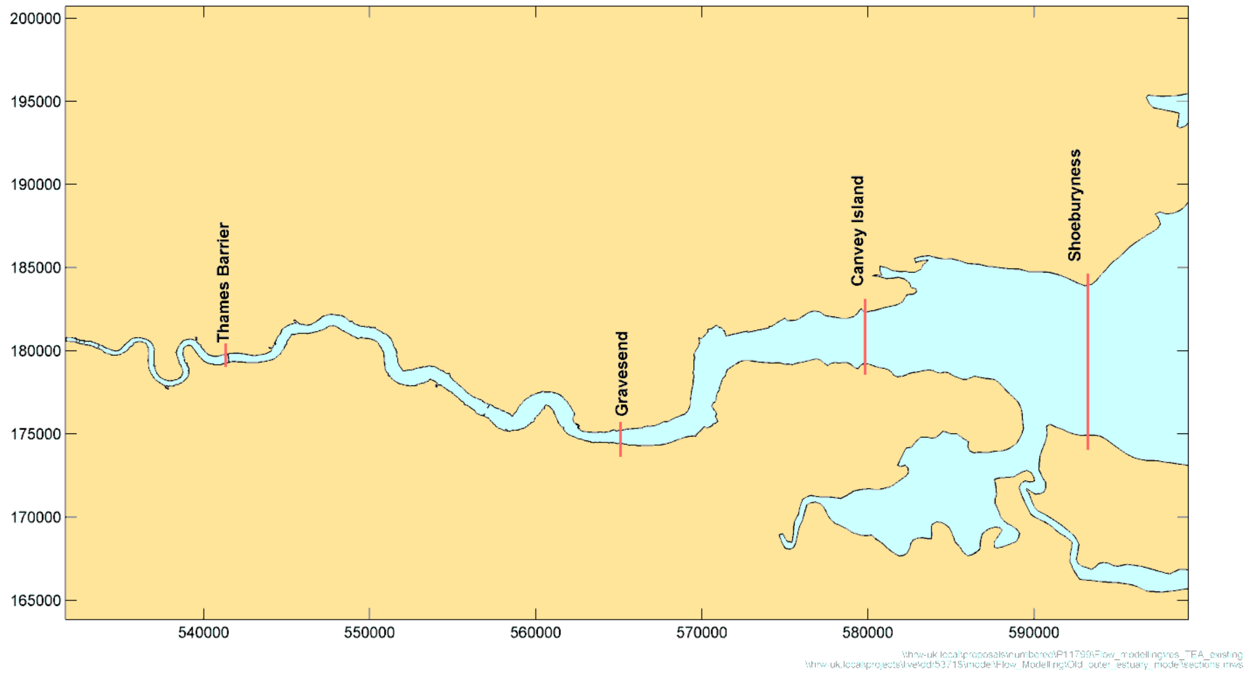

Figure 3.2: Locations of plotted discharges

3.1.2. Description of baseline flood event

There is a rapid change in volume of water entering the estuary during the surge, as shown above. In total 1,300 Mm^3 flows past Shoeburyness during the flood tide phase up to the peak water level. At Canvey Island this volume falls to 450 Mm^3, by Gravesend the total incoming volume halves to 226 Mm^3 and further reduces to 75 Mm^3 at the site of the Thames Barrier. These figures indicate two issues; the scale of flood storage required and the rapid reduction in water volume landwards of Shoeburyness. The implication for flood management is that the further upstream the flood storage is located the smaller the volume required to reduce the water level. At the same time the cross-section of the estuary, in general, reduces upstream, so the location of the flood storage pool is chosen from the balance of these two opposing factors.

The peak water level associated with this surge case is shown in Figure 3.3 and Table 3.1, below. The table also compares the water level for the extreme surge case with those typically experienced during a spring tide. The locations of the tide gauges shown in Table 3.1 are provided in Figure 3.2.

In reality, flood management in the tidal Thames is subject to the operation of the Thames Barrier. As a sensitivity test a baseline case with the barrier closed was also run and maximum water levels included in Table 3.1. In this case the barrier was closed throughout the simulation.

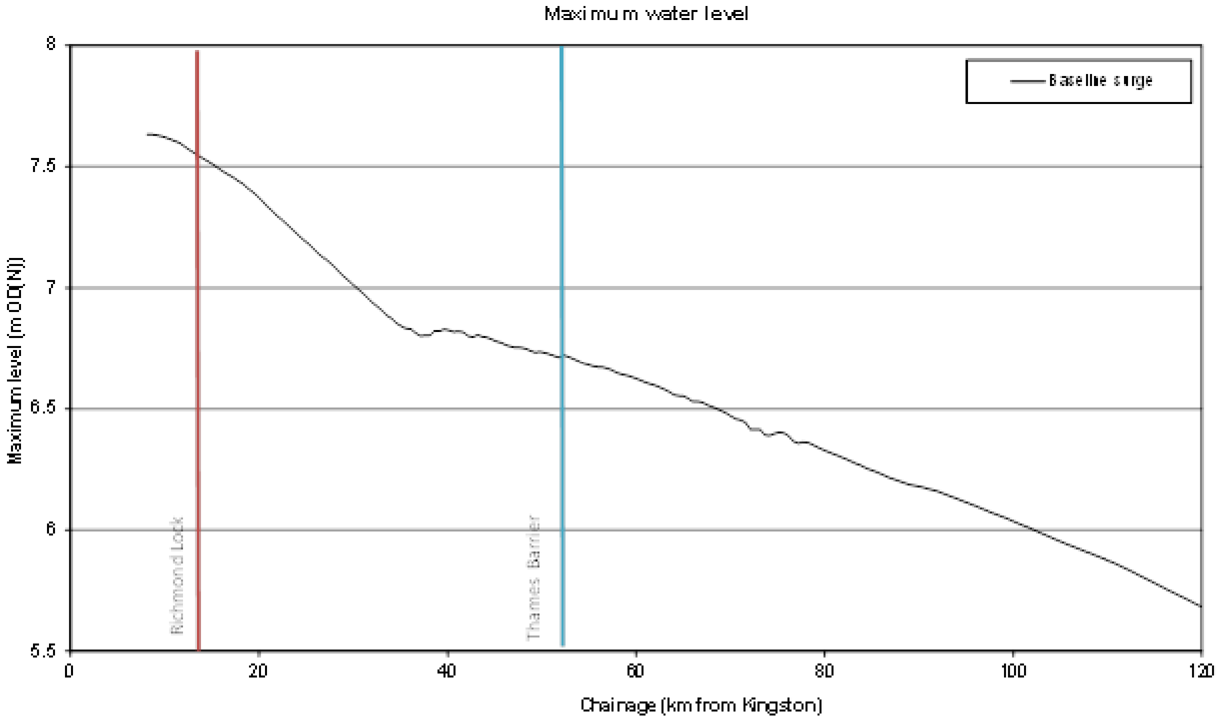

Figure 3.3: Maximum water level for 1:1000 year surge, no flood management interventions

Table 3.1: Maximum water level m OD(N)

Location	Spring tide	1:1000 year surge, no flood management interventions	1:1000 year surge, Thames Barrier closed
Richmond	4.46	7.55	n/a1
Westminster	4.11	6.84	n/a
Tower Bridge	4.19	6.82	n/a
Silvertown	4.13	6.72	6.56
Erith	3.94	6.55	6.55
Tilbury	3.73	6.36	6.40
Coryton	3.47	6.12	6.11
Southend	3.23	5.91	5.92
Herne Bay	2.77	5.45	5.46
Margate	2.38	5.02	5.03
Walton	2.26	4.87	4.87

1 Landward of Thames Barrier, maximum level is a function of the operation of the barrier.

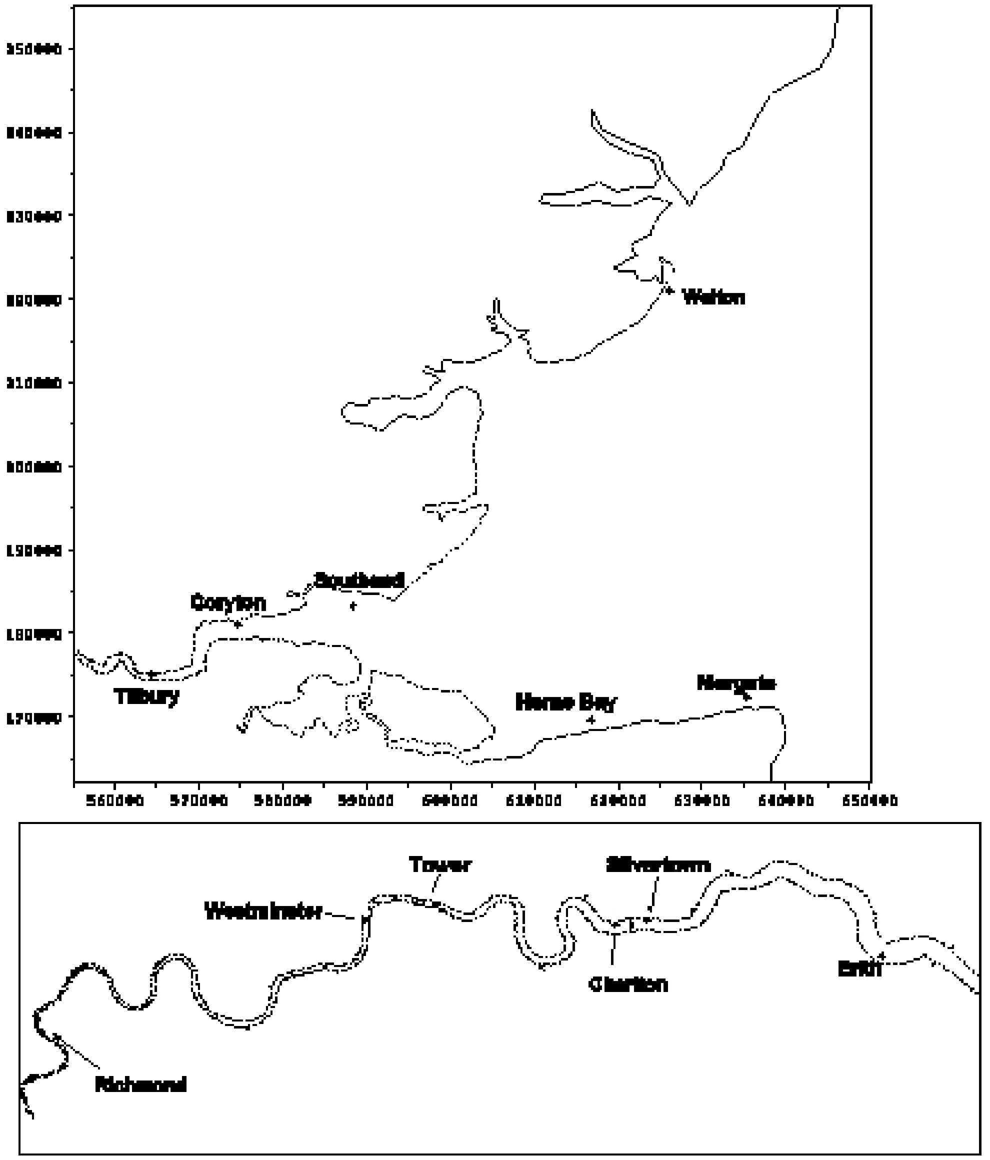

Figure 3.4: Tide gauge locations

3.2. Initial option testing

3.2.1. Option 1

Option 1, as illustrated in Figure 3.5, is intended to be the largest likely, single, flood storage pool. It includes:

- 21 km of embankment in the estuary surrounding the main tidal power / flood storage pool;
- Tidal power turbines in deep water at eastern end of pool;

- A flood storage area south of Lower Hope Point, linked to the estuary by sluices located as far landward as possible;
- A southern embankment of 11.5 km across low lying areas between the estuary and existing high ground on the Hoo Peninsula;
- An upgrade to 14 km of the flood defence wall between the flood storage area and the main pool including a set of sluices so that the whole area can be used for flood storage.

Allied to this, the test case included closure of the Benfleet barrier.

The main pool covered an area of approximately 27 km^2 with the flood able area covering an area of 21 km^2.

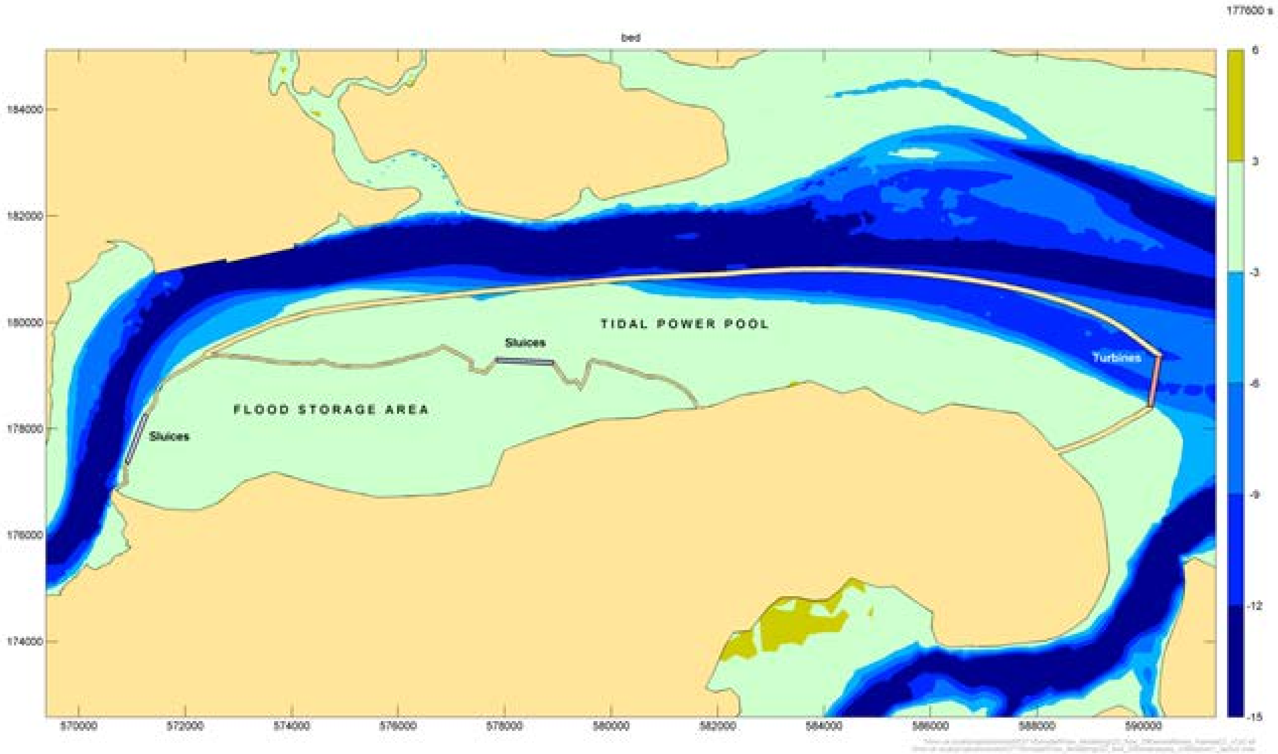

Figure 3.5: Option 1 layout

The pool was firstly tested as a simple passive blockage, before being tested for a series of options for sluice flow magnitude and timing. The discharge of water through the sluices was based on Torricelli's law which makes the flow a function of the square root of the water level difference. This can be further modified with coefficients to represent entrance and exit head losses. The sensitivity to locating the sluices in deep water was also investigated. The results are summarised below at a subset of the extracted data points. Table 3.2 shows the maximum simulated water levels with the difference from the existing case shown for each test case in Table 3.3. As some of the effects are small, the values have been quoted to 3 significant figures.

Table 3.2: Maximum water levels for Option 1

Test ID	Description	Tower Bridge	Silvertown	Coryton
2	No sluices	6.836	6.723	6.109
37	4 x 2000 m^2 culverts at landward end	6.835	6.720	6.103

Test ID	Description	Tower Bridge	Silvertown	Coryton
38	4 x 2000 m^2 culverts in deep water at centre	6.836	6.713	6.058
39	4 x 6000 m^2 culverts at landward end	6.835	6.720	6.103
40	4 x 6000 m^2 culverts in deep water at centre	6.832	6.709	6.052

Table 3.3: Change in maximum water levels for Option 1

Test ID	Description	Tower Bridge	Silvertown	Coryton
2	No sluices	0.015	0.005	-0.010
37	4 x 2000 m^2 culverts at landward end	0.014	0.002	-0.016
38	4 x 2000 m^2 culverts in deep water at centre of pool	0.015	-0.005	-0.061
39	4 x 6000 m^2 culverts at landward end	0.014	0.002	-0.016
40	4 x 6000 m^2 culverts in deep water at centre of pool	0.011	-0.009	-0.067

These results show that without any flow entering the flood storage areas the peak water levels increase at, and landwards of, Silvertown. Inclusion of flow into the flood storage area can reduce the peak water level as long as the sluices are located in the deep water in the centre of the pool. Increased flow into the pool can increase the effect of the option. The largest effect at Silvertown is less than 1 cm even for the 4 x 6,000 m^2 sluice test case, although this is a combination of the increase in water levels associated with the structure and the decrease from the sluices.

The volume of water entering the pool for test ID 40 was 170 Mm^3 with a peak flow rate of 16,000 m^3/s. The sluice opening timing was at a water level of +4 m OD(N) with an aim of modifying the very top of the tide. Runs with the sluices operating earlier had been shown to increase the peak water level.

As indicated by Figure 3.6, the water level within the pool reaches less than 5 m and some of the flood storage area is not inundated. This is factor of the maximum flow available for the sluices used and the travel time for the water to cover the available area, noting the presence of a second set of sluices linking the pool to the flood storage area.

The conclusion of the initial Option 1 testing was that flood storage alone would be unlikely to provide sufficient water level reduction. Therefore the subsequent initial options used a combined approach of flood storage volume and throttling of the incoming surge tide.

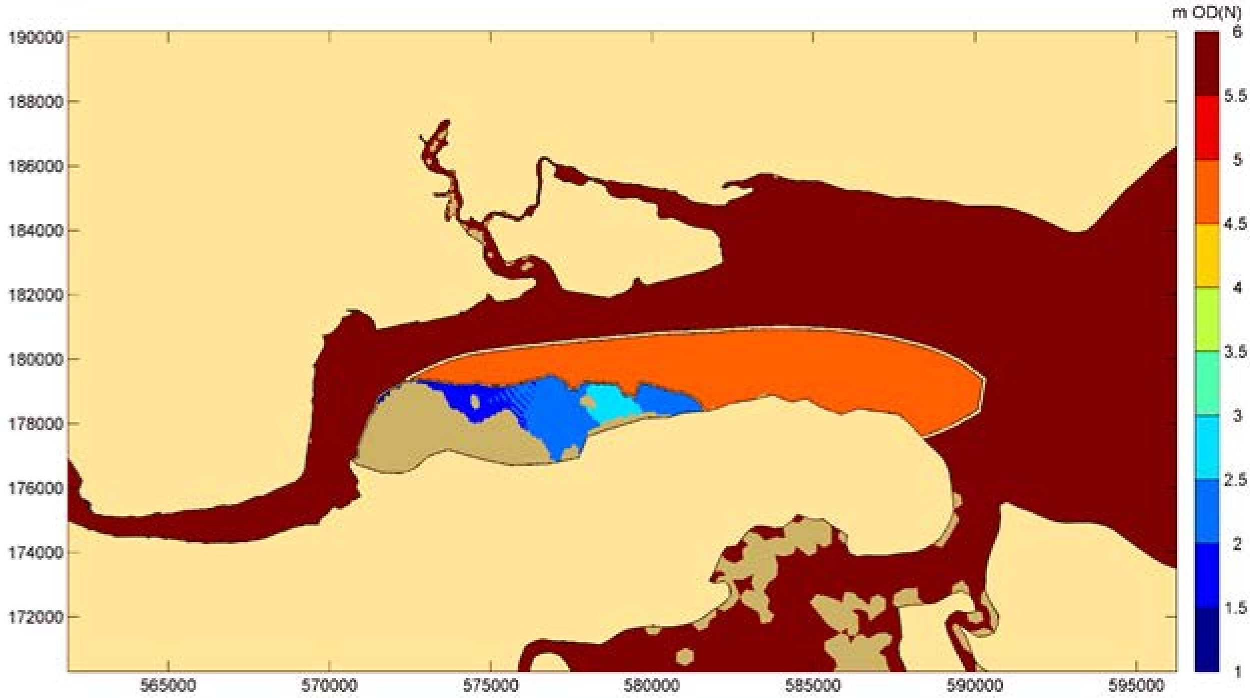

Figure 3.6: Maximum water level for Option 1 – 4 x 6,000 m^2 culverts in deep water

3.2.2. Option 2

Option 2, as illustrated in Figure 3.7, is intended to be a case including a throttle effect for the incoming surge. It includes:

- 15 km of embankment in the estuary surrounding the southern tidal power / flood storage pool (27 km^2);
- 9 km of embankment surrounding a northern flood storage pool (16 km^2);
- Tidal power turbines in deep water in the centre of the southern pool;
- A southern embankment of 2.5 km across low lying areas between the southern pool and existing high ground on the Hoo Peninsula;
- For each pool the sluices were located slightly landward of the throttle.

Allied to this, the test case included closure of the Benfleet barrier.

The combined pools covered an area of approximately 47 km^2.

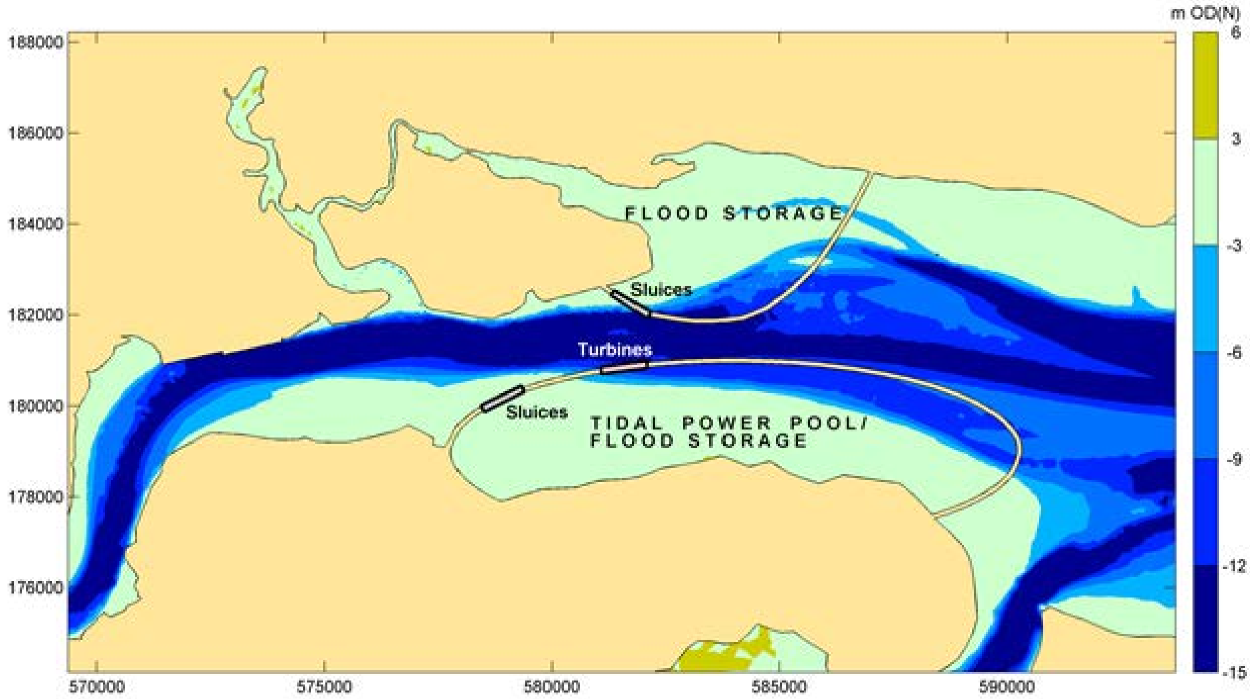

Figure 3.7: Option 2 layout

The pool was firstly tested as a simple passive blockage before being tested for a series of options for sluice flow magnitude and timing. The sensitivity to locating the sluices in deep water was also investigated. The results are summarised below at a subset of the extracted data points. Table 3.4 shows the maximum simulated water levels with the difference from the existing case shown for each test case in Table 3.5. As some of the effects are small, the values have again been quoted to 3 significant figures.

Table 3.4: Maximum water levels for Option 2

Test ID	Description	Tower Bridge	Silvertown	Coryton
4	No sluices	6.844	6.735	6.152
27	4 x 2000 m^2 sluices in deep water	6.702	6.554	5.957
28	4 x 1000 m^2 sluices in deep water	6.726	6.589	6.001
29	4 x 500 m^2 sluices in deep water	6.743	6.620	6.041
30	4 x 6000 m^2 sluices in deep water	6.710	6.561	5.957
35	4 x 2000 m^2 sluices in shallow water	6.837	6.724	6.139

Table 3.5: Change in maximum water levels for Option 2

Test ID	Description	Tower Bridge	Silvertown	Coryton
4	No sluices	0.023	0.017	0.033
27	4 x 2000 m^2 sluices in deep water	-0.119	-0.164	-0.163
28	4 x 1000 m^2 sluices in deep water	-0.095	-0.130	-0.118
29	4 x 500 m^2 sluices in deep water	-0.078	-0.098	-0.078
30	4 x 6000 m^2 sluices in deep water	-0.111	-0.157	-0.162
35	4 x 2000 m^2 sluices in shallow water	0.016	0.006	0.020

These results show that without any flow entering the flood storage areas (run ID 4) the peak water levels slightly increase at, and landwards of, Silvertown. Inclusion of flow into the flood storage area can reduce the peak water level as long as the sluices are located in the deep water in the centre of the pool.

As for Option 1, the sluice opening timing was at a water level of +4 m OD(N) with an aim of modifying the very top of the tide. Runs with the sluices operating earlier had been shown able to increase the peak water level. As shown by Figure 3.8 the water level within the south pool reaches less than 5 m but the north pool nearly fills.

The effect of the sluices increases from the 500 m^2 sluices to the 2000 m^2 sluices. However for the 6000 m^2 sluices little additional effect is shown. In addition to any flood storage effect, the sluices also provide additional impedance to the incoming flow as shown by Figure 3.9. This shows the formation of a jet of flow between the two sets of sluices. Peak currents of between 3 and 3.5 m/s are shown.

In conclusion, Option 2 demonstrated the benefit of sluices removing a portion of the incoming flow into the flood storage area and the requirement to have the sluices in deep water. The test cases also showed a potential for additional impedance of the incoming flow if the sluices are located in the throttled area.

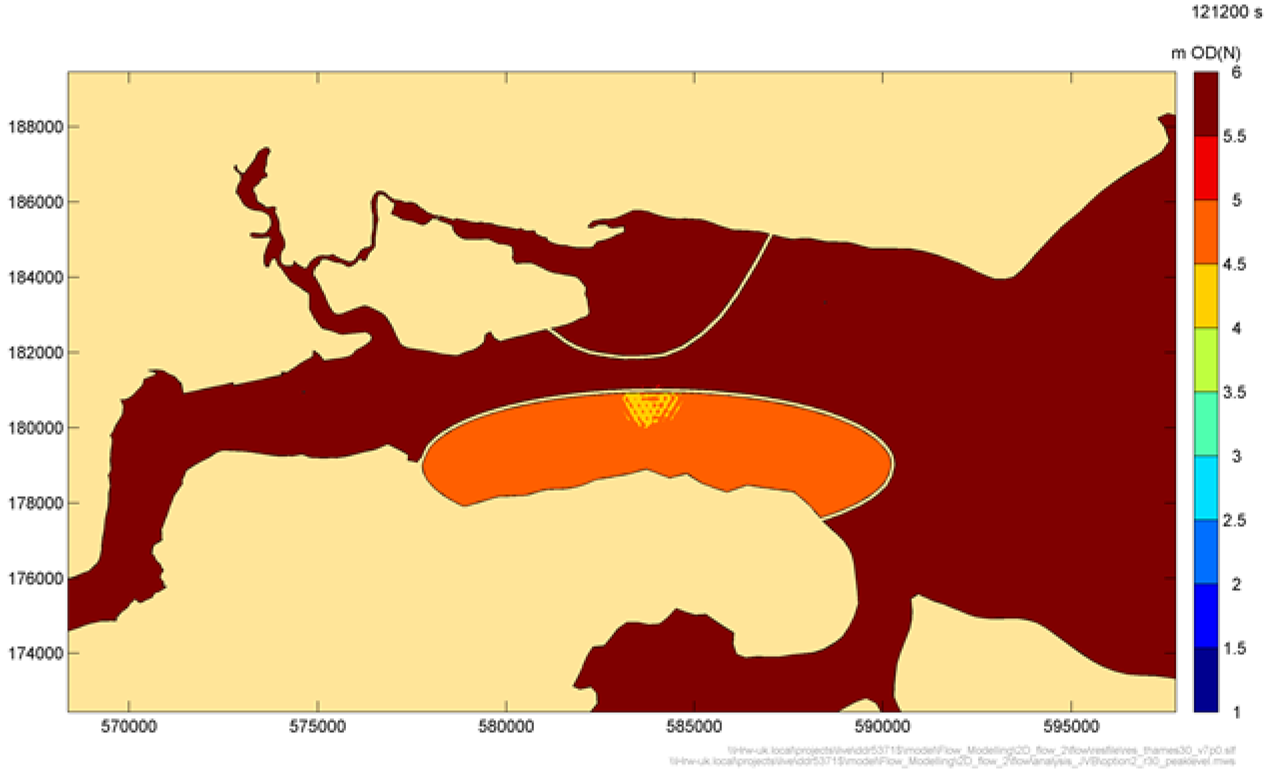

Figure 3.8: Maximum water level for Option 2 – 4 x 6,000 m^2 culverts in deep water

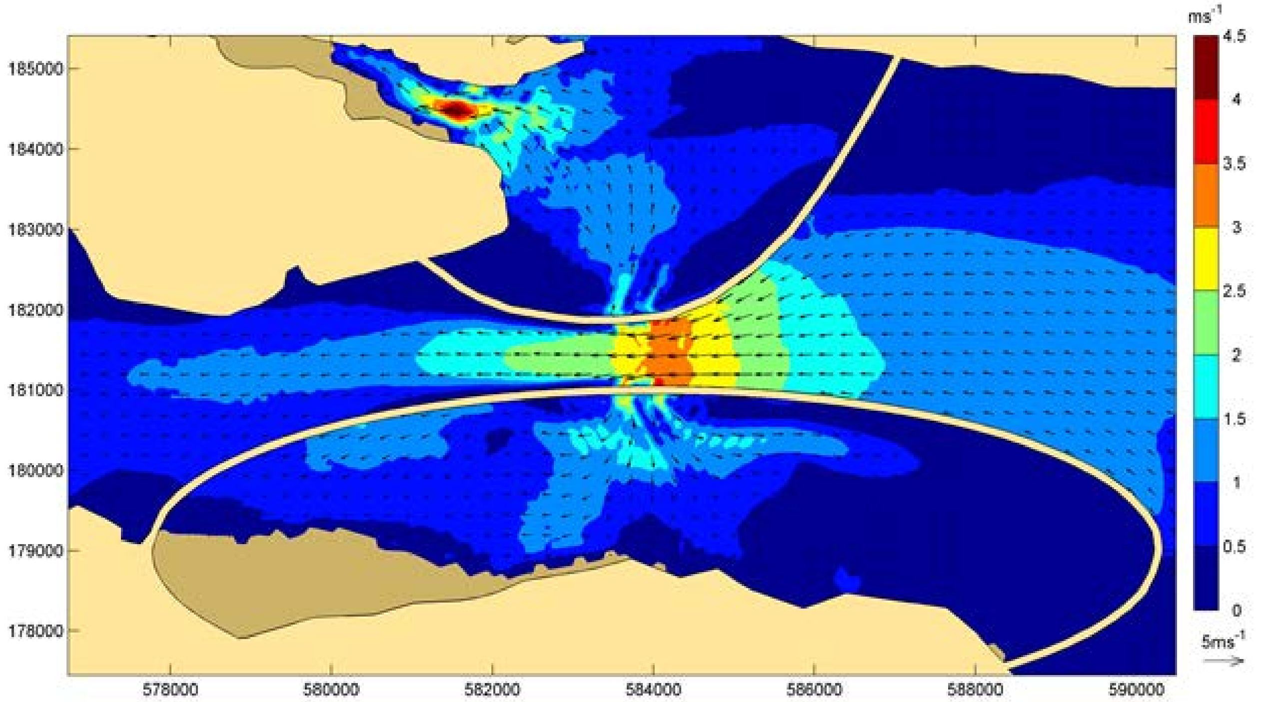

Figure 3.9: Flood tide flow for Option 2 with 4 x 6000 m^2 sluices

3.2.3. Option 3

The above tests showed that peak water levels could be increased by the structures without sluices. The flow appeared to be able to accelerate through the throttle without significant impedance because of the smooth form of the pools. Therefore a less smooth test case was undertaken to inform the development of the preferred conceptual scheme. Option 3 was the same as Option 2, except the pools were cut in half at the narrowest point of the throttle to give hydrodynamically unsympathetic corners facing the incoming flow.

For this example no sluices were included to investigate the potential benefit of the 1,000 m throttle in isolation.

In conclusion, because Option 3 lacks a smooth outline to the pools it brought benefit in creating a throttle effect in impending the incoming surge. In this case without sluices, reduction in peak water level of up to 0.07 m was achieved which contrasted with the increases in peak water level which had been the case for Options 1 and 2. The increased throttle effect had the result of high currents in the gap even for typical spring tides and therefore any preferred scheme should be able to mitigate this effect for typical spring tide conditions.

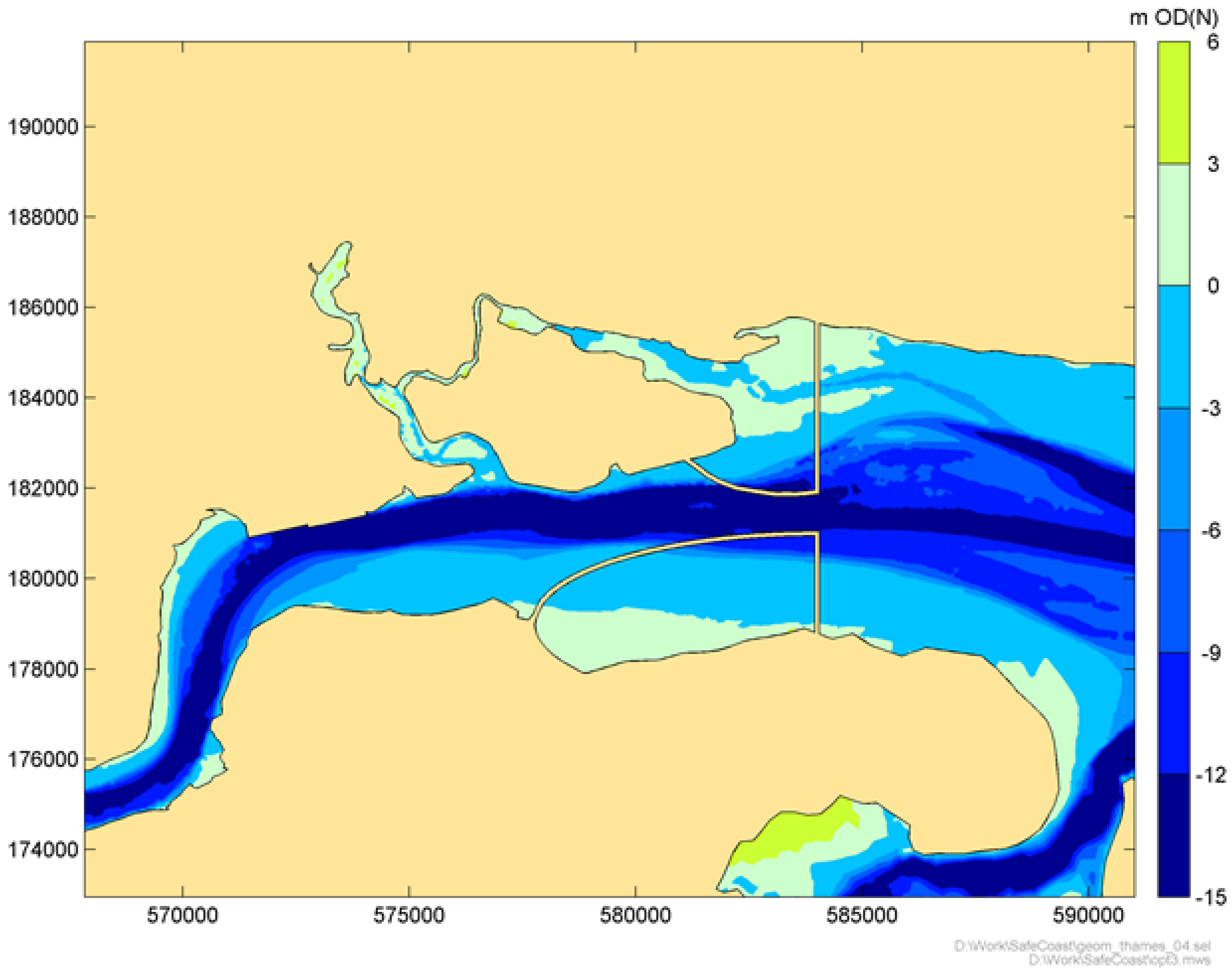

Figure 3.10: Option 3 layout

Table 3.6: Maximum water level results for Option 3, no sluices

Description	Tower Bridge	Silvertown	Coryton
Maximum level (m OD(N))	6.759	6.648	6.051
Difference from baseline (m)	-0.062	-0.070	-0.068

3.3. Preferred option

The beneficial aspects of the three option tests above were identified in the development of a preferred option for taking forward (Option 4). The key parameters were:

- Hydrodynamically unsympathetic form to the incoming flow;
- A potential to increase the throttling from the 1000 m investigated above;
- Sluices located in the throttle to increase the jetting effect.

In addition, consideration was given to the opportunity to reduce the currents in the throttle for typical conditions.

The above considerations were combined into Option 4 which includes a south pool like Option 2, but with a separate east - west wall to form the northern side of the throttle. The sluices were to be located within the throttle and the tidal power turbines to the east of the throttle. The northern wall was joined to Canvey Island by a ‘tidal gate’. This structure would be open for typical conditions reducing currents in the throttle area, but which could close to provide maximum throttling effect from the structure. With this addition, the throttle width was reduced to 600 m as typical currents would be acceptable with the tidal gate open.

As for the other options, sluices were set at a suitable height to allow filling of the pool towards the top of the surge. For the test case the sluices were set at 3.2 m OD(N) which is slightly lower than highest astronomical tide (3.5 mOD(N) at Southend). Therefore for most tides the sluices will be dry. To reduce flood risk any way of reducing the number of mechanical or electrical means of managing water levels are considered advantageous. For this sluice height, the sluices could be left open well before the arrival of the surge.

There is significant further optimisation of the sluice height, size and operation which would be pursued if the scheme were taken forward to detailed design.

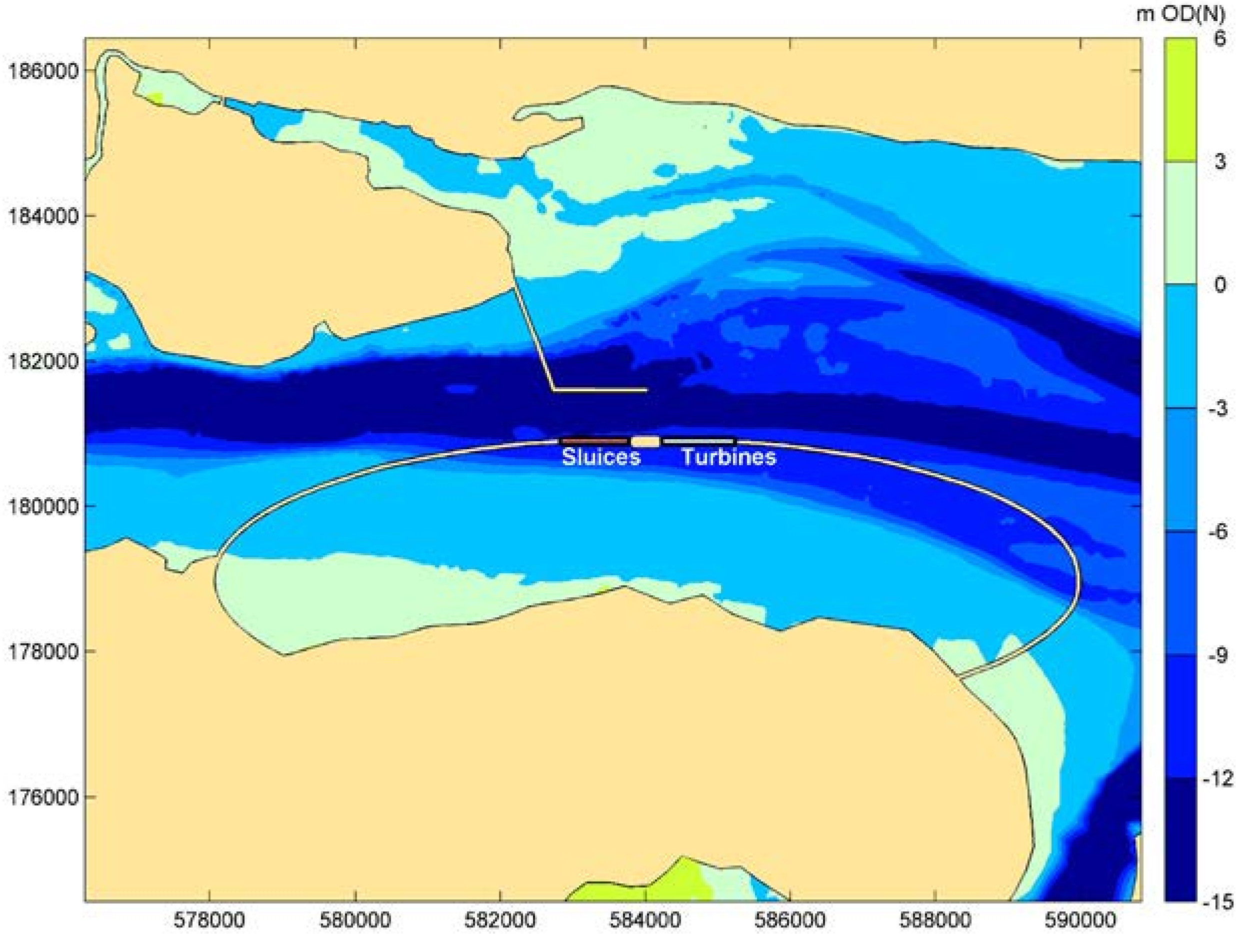

Figure 3.11: Option 4 layout

Table 3.7: Maximum water levels for Option 4

Test ID	Description	Tower Bridge	Silvertown	Coryton
31	Baseline (existing) case	6.821	6.718	6.119
48	No sluices	6.676	6.558	5.924
49	4 x 2000 m^2 sluices in deep water	6.181	6.028	5.442
50	4 x 6000 m^2 sluices in deep water	6.199	6.042	5.451

Table 3.8: Change in maximum water levels for Option 4

Test ID	Description	Tower Bridge	Silvertown	Coryton
48	No sluices	-0.145	-0.160	-0.195
49	4 x 2000 m^2 sluices in deep water	-0.640	-0.690	-0.678
50	4 x 6000 m^2 sluices in deep water	-0.622	-0.676	-0.668

The above table shows that the amount of throttle and the hydrodynamically unsympathetic form was able to reduce the peak level by approximately 15 cm throughout central London. With the sluicing in operation the effect of the structure delivers a lowering of water levels of between 60 and 70 cm. In the context of an extreme surge event, this would represent a material and useful reduction in flood levels.

Interestingly, the larger sluices do not result in an increased effect. The different sluice options fill the flood storage area at the same rate resulting in a very similar effect on maximum water levels in the estuary. The larger sluices do result in lower currents in their immediate vicinity which may be advantageous in consideration of the detailed design of the sluices, their housings and the need for scour protection on the sea bed adjacent to the sluice entrance and exit points.

Figure 3.12 shows the currents in the throttle for a passive structure and Figure 3.13 shows similar area during sluice operation. The sluices appear to enhance the deflection of the flow towards the south which reduces the effective flow cross section available to the incoming tide and so reduces peak levels markedly.

Excavation of intertidal areas and pumping could increase the beneficial effects on water levels, but have not been investigated.

Peak currents of 3-4 m/s are shown in the gap. These are high for the Thames Estuary and therefore erosion would be expected in the gap during these episodic flood defence operations, without suitable bed protection. Increased depths would increase the cross-sectional area and may therefore reduce the throttle effect of the structure in reducing peak water levels in the estuary. Scour around the various structures would also require consideration during the detailed design of such a scheme. The scheme, if taken forward, would need to prevent scour of the riverbed to protect the foundations of our structures and stabilise the cross-section area of the throttle so that it remains effective.

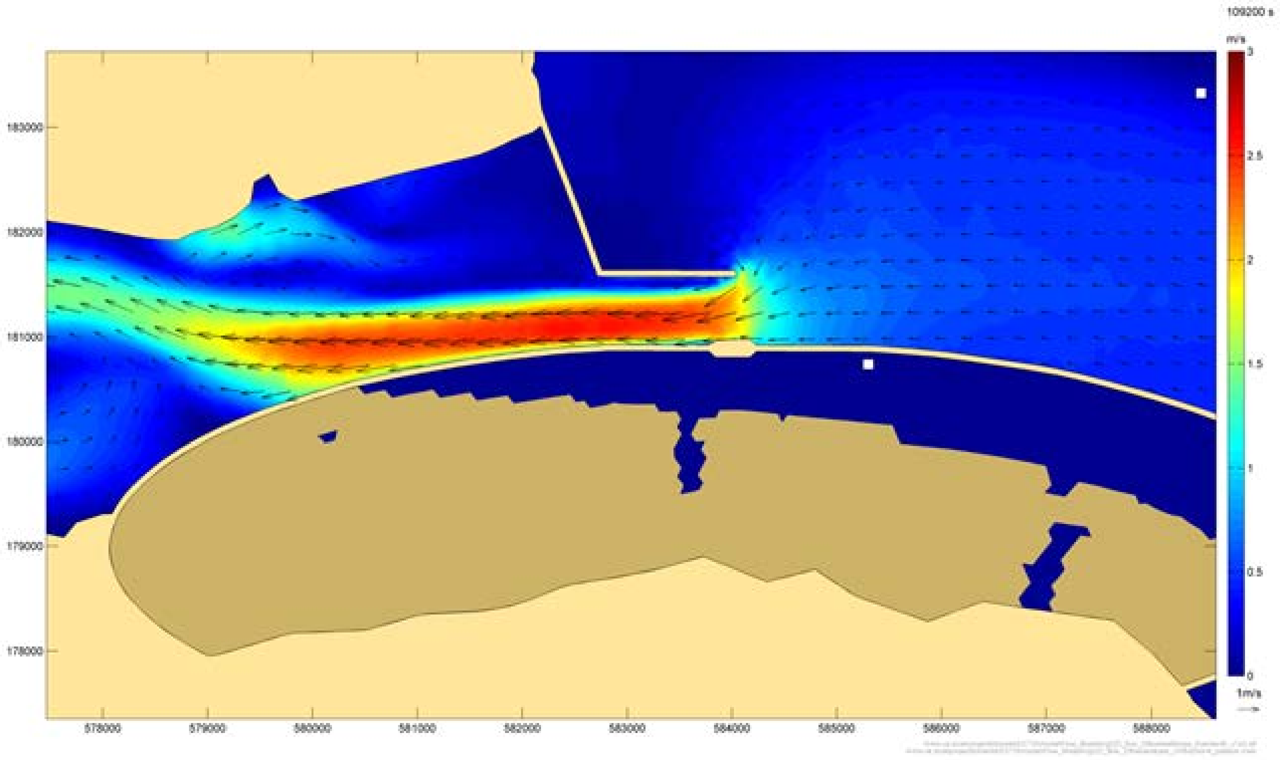

Figure 3.12: Currents during incoming surge, no sluices

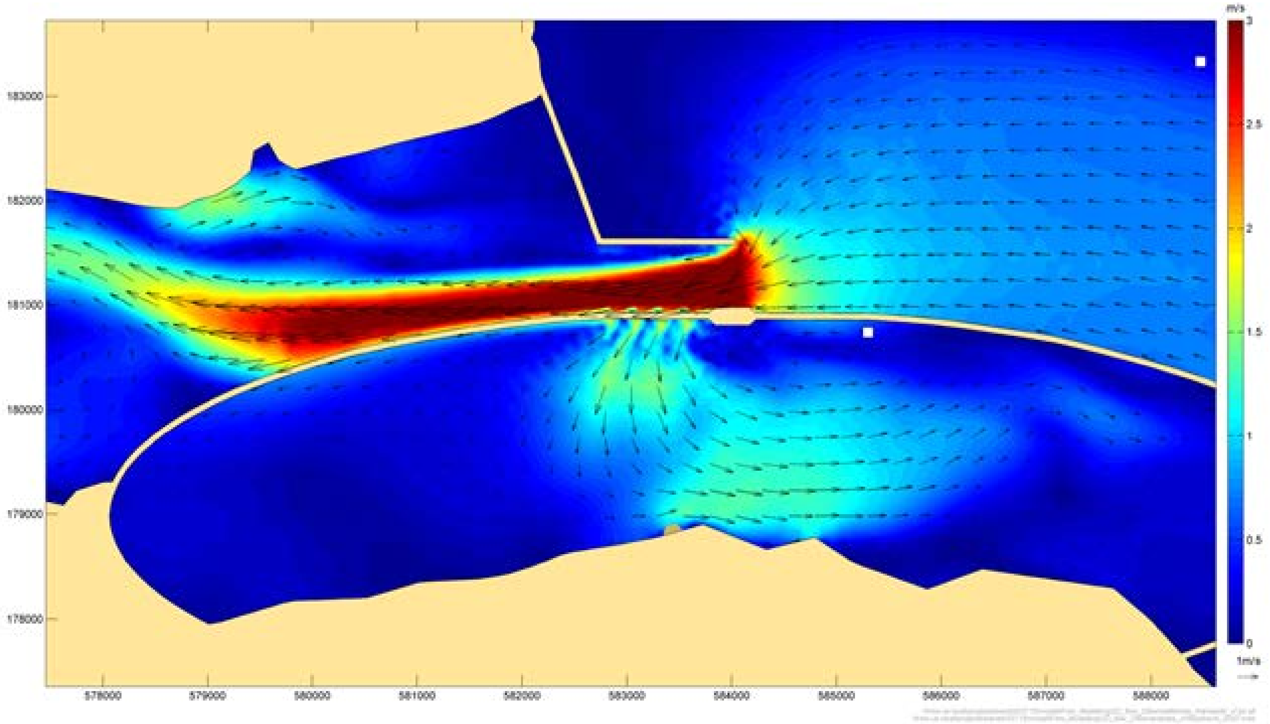

Figure 3.13: Currents during incoming surge, 4 x 2000 m^2 sluices

The time series of water level in the pool (Figure 3.14) shows the pool fills to within 0.5 m of the water level outside. This result was very similar for both sluice sizes tested.

The water level in the pool was initialised at the low water level for the set of tides simulated. If the initial water level in the pool was lower more volume would be available. For example if the water level were lowered to Lowest Astronomical Tide, approximately 7% more volume would be available and it is expected that the water level in the estuary could be further reduced at the peak of a surge as long as the timing is appropriate.

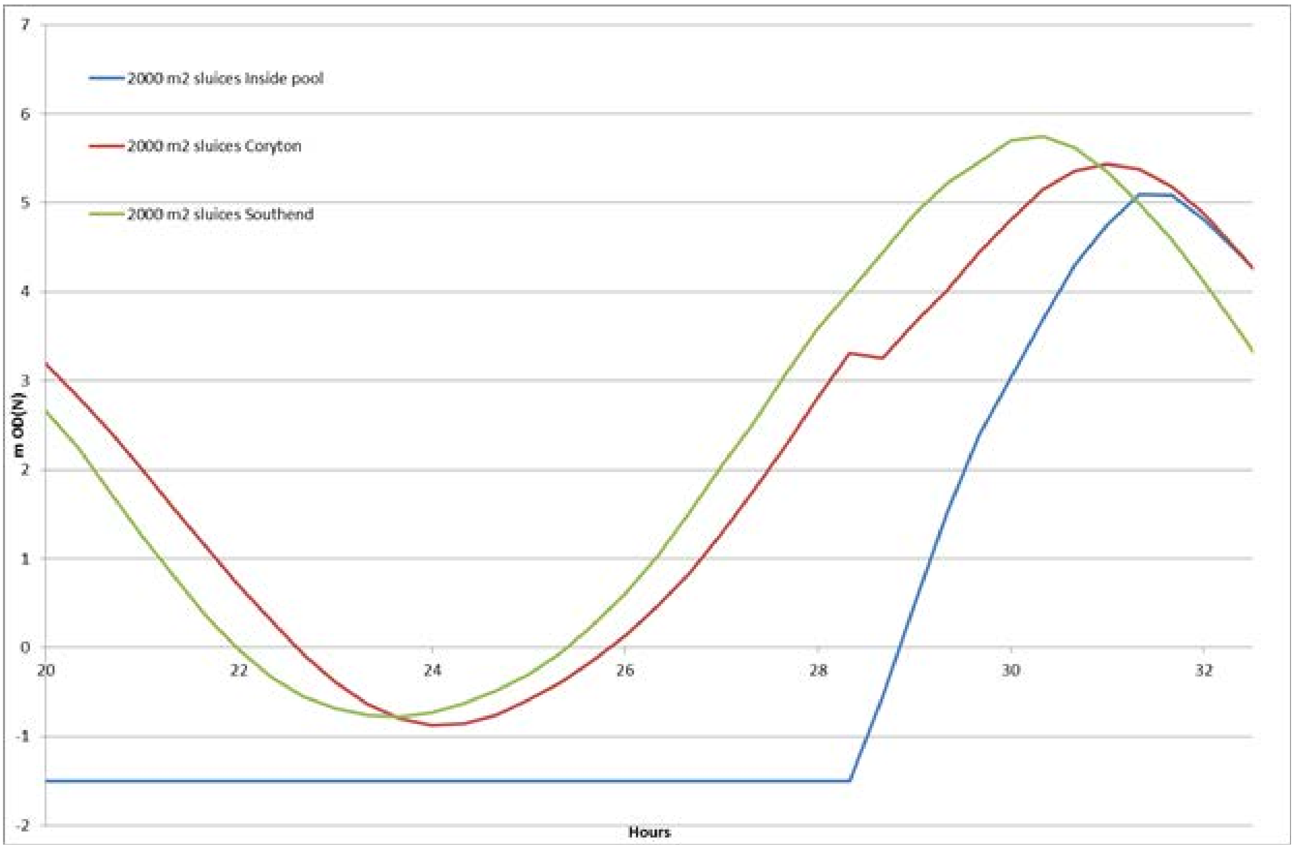

Figure 3.14: Time series of water level, Option 4, 4 x 2000 m^2 sluices

A simulation of the hydrodynamics for typical spring tide conditions was also completed. In this case the 600 m tidal gate north of the gap was fully open. Figure 3.15 and Figure 3.16 show the current magnitude and patterns at times of peak ebb and flood tide. The largest currents occur during the ebb tide which is reflected in a plot of the through tide maximum current (Figure 3.17).

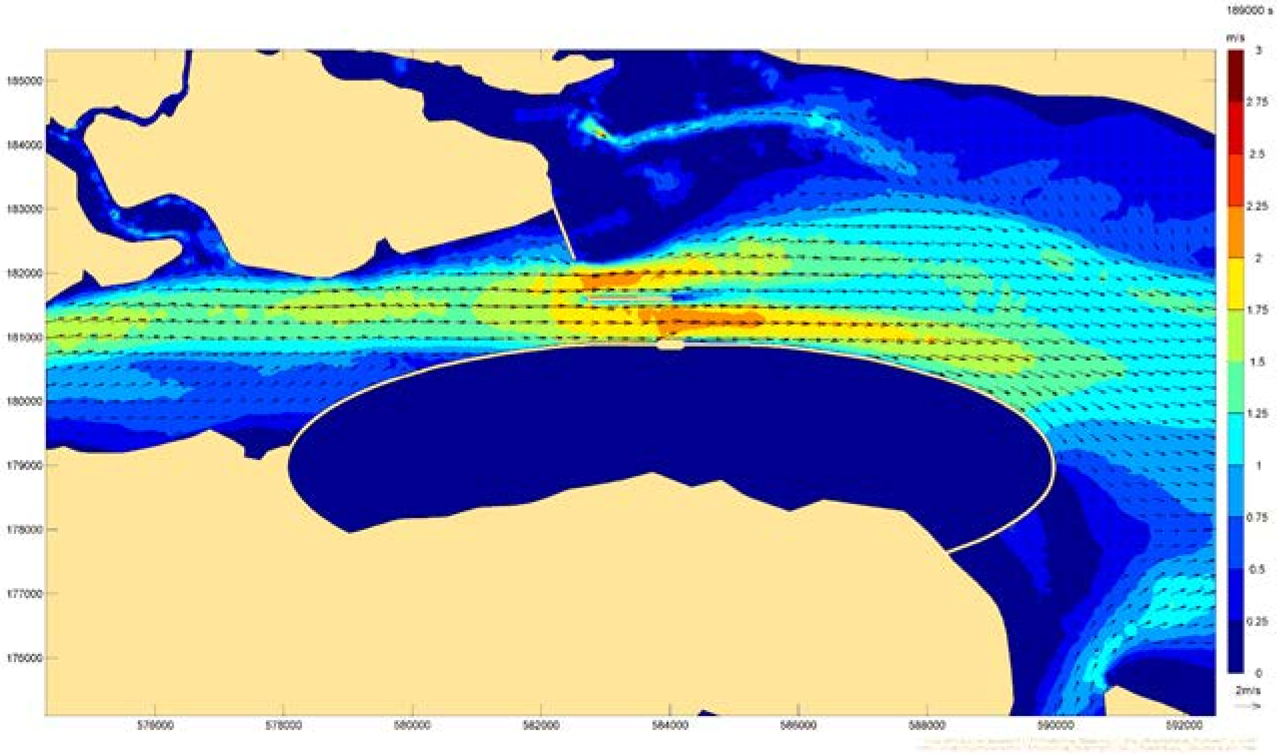

Figure 3.15: Currents at time of peak spring tide ebb, Option 4

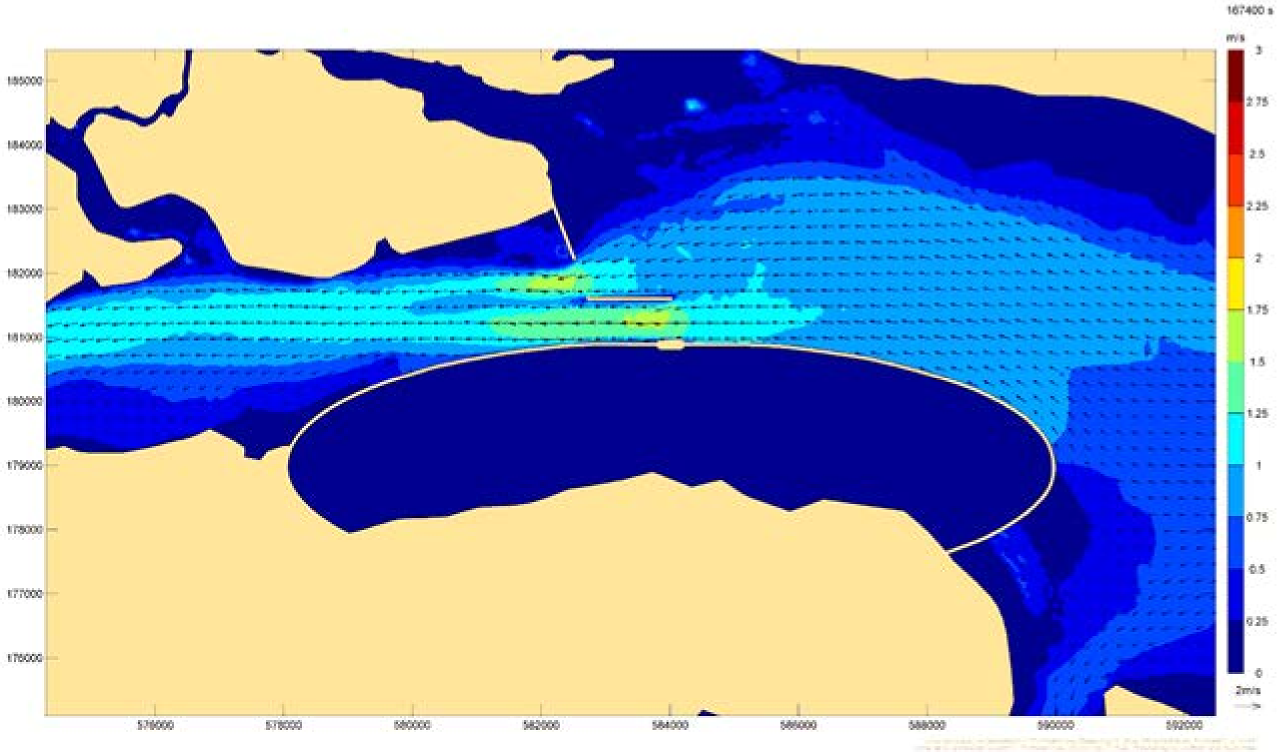

Figure 3.16: Currents at time of peak spring tide flood, Option 4

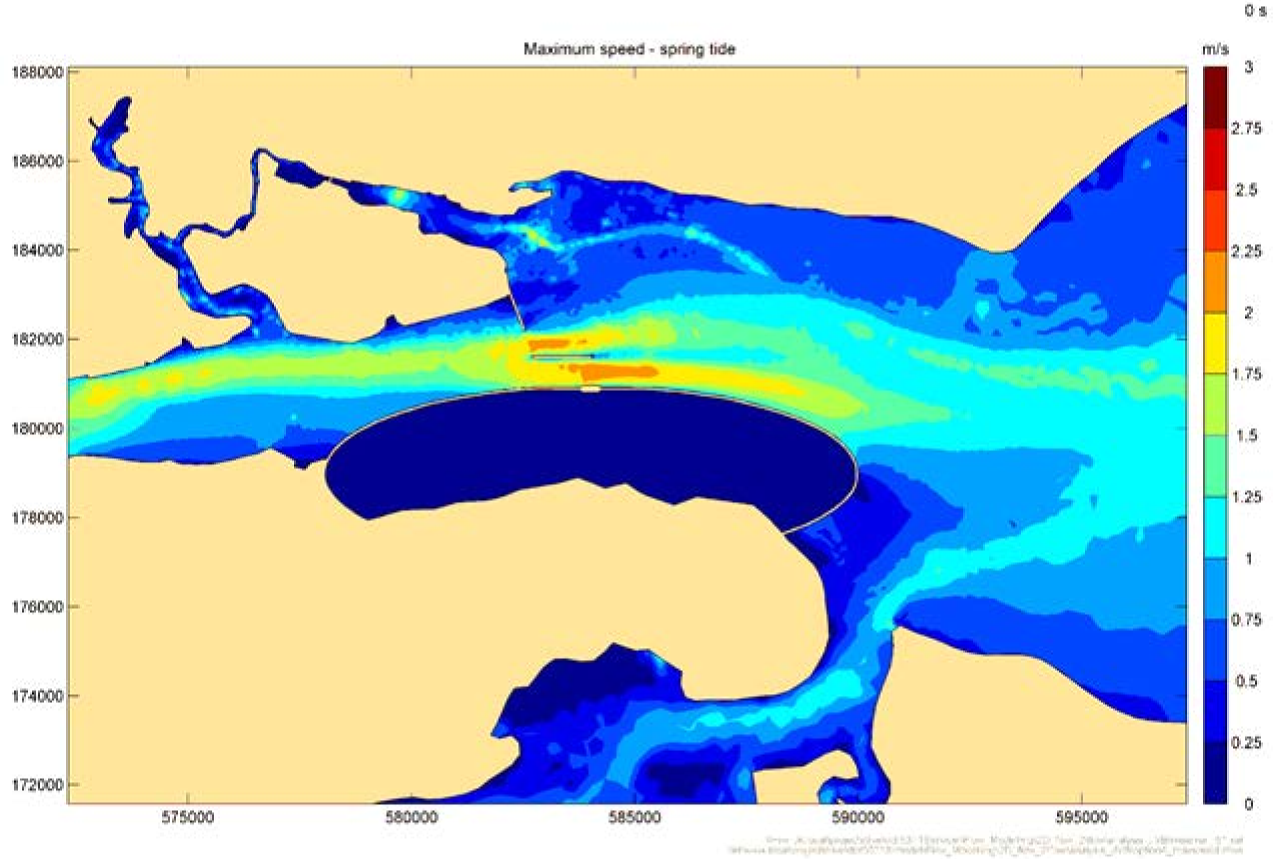

Figure 3.17: Maximum through-tide current magnitude, spring tide, Option 4

A view of the footprint of effect of the works in the surrounding hydrodynamic and sediment regimes can be judged by plotting the difference in maximum through tide current for the layout compared to baseline conditions. This parameter is plotted as Figure 3.18, below.

A minimum threshold of change of 0.2 m/s has been used to show the areas with a potential for noticeable change. The largest changes are speed increases in the gaps and speed decreases in areas which are sheltered from ebb tides by the structures. If sediment supply is available these areas of speed reduction may accrete in the long term, although other factors such as changes to wave conditions should also be considered to refine the area of likely long term sediment accumulation.

In the areas of speed increase, erosion may occur depending on the bed strength. Bed protection in the areas with the highest predicted increase in current speed is likely to be required, to avoid unwanted amounts of erosion.

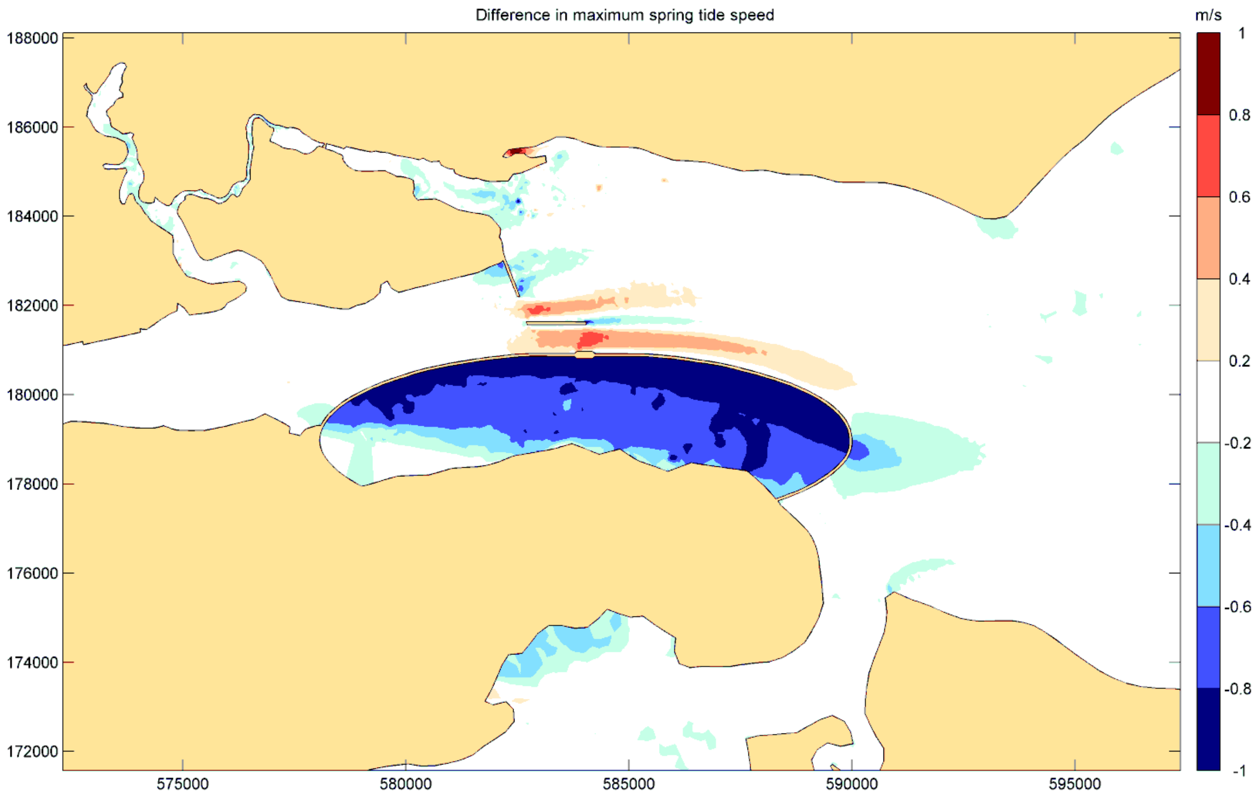

Figure 3.18: Change to maximum through-tide current magnitude, spring tide, Option 4

3.4. Discussion

Modelling the situation for Option 4 has shown it to be advantageous for flood management, however it should be noted that the layout modelled is not yet a fully optimized solution and therefore should be regarded as a preliminary 'proof of concept' layout. The modelling has demonstrated the important ingredients to flood water level reduction from this type of structure.

More improvements in the performance of Option 4 could be generated by further investigation and sensitivity testing, e.g. for anticipated sea level rise and morphological change to the Thames Estuary system.

Further throttling could be advantageous, however navigational issues and the increased cost of extending the length of the tidal gate on the north side of the structure must at some point limit the allowable reduction in channel width.

4. Tidal power

4.1. Introduction

With the pool extent and location chosen to provide maximum benefit for flood management, the potential for tidal power to be generated by the pool was investigated.

There are many parameters available to tune the power output from the preferred scheme – type and number of turbines, minimum water level difference to generate, and use of sluices and/or pumping. To investigate these parameters a 0D model has been used into which a series of combinations of operating rules can be added. The use of the 0D model also allowed calculation of power output for a long period, for a whole range of tide ranges. See section 2.3 above for a brief description of the 0D model.

For the preferred case, a year of predicted tides at the nearby Sheerness tide gauge was used. Whilst the tide gauge at Sheerness is part of the national tide gauge network and therefore provides an excellent set of tidal harmonics from which to predict the tide, it is a little seaward of the proposed turbine locations with a small reduction in typical tide range (4% less tide range for mean spring tide). Predicted power outputs for the pool are therefore slightly under predicted.

The variation in geometry within the pool was modelled by extracting the change in surface area for 0.1 m increments of water height. In this way the volume of water entering or leaving the pool and the water level within the pool could be related.

4.2. Choice of turbines

The starting point for the initial choice of turbines was linked to the available water depth at the site. Figure 4.1 shows a section of the bathymetry along the line of the proposed impounding bund and the proposed sites of the sluices (used for tidal power and flood management) and the turbines. At the site of the turbines a minimum depth of approximately -10 m OD(N) is shown. The anticipation would be that the turbines will be submerged at all stages of the tide. Figure 4.1 also shows the level of Lowest Astronomical Tide (-2.9 mOD(N)). Therefore about 7 m of water depth remains for the turbines themselves and any associated housing or other structures.

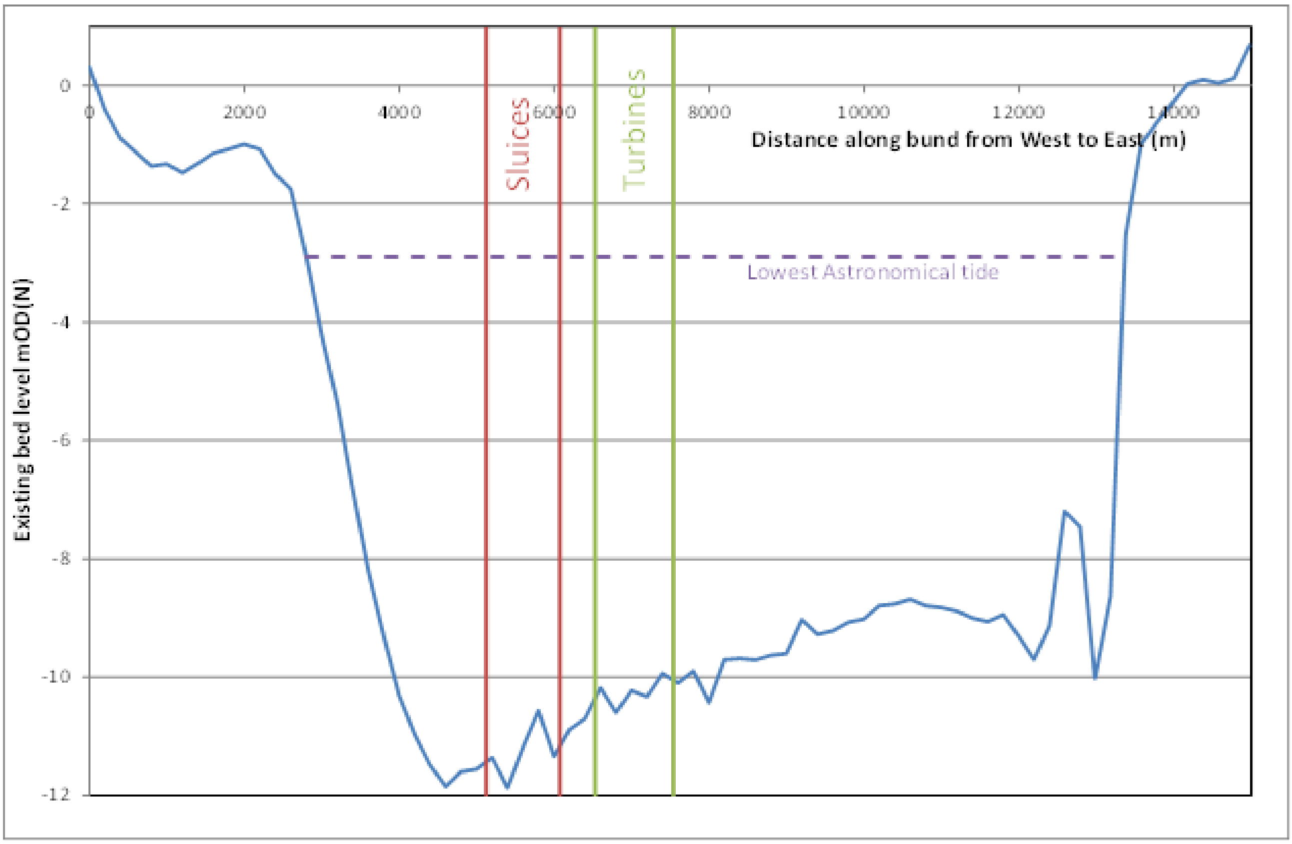

Figure 4.1: Existing bed level along bund line

The initial phase of the Safe*Coast project was aimed to use available knowledge of existing turbine technologies to provide a baseline against which any turbine developed under the project could be compared. It was proposed that the initial testing should be based on turbines similar to those employed at the La Rance tidal Barrage in France which are closest to the size of the turbines applicable in the proposed case with a diameter of 5.35 m (Table 4.1).

Table 4.1: Turbine characteristics summary at La Rance tidal power barrage

Parameter	Value
Diameter	5.35 m
Weight	470 T
Rated head	5.65 m
Discharge at rated head	275 m^3/s
Output	10 MW

Source: De Laleu presentation to BHA annual conference 2009

With 24 turbines the average power output at La Rance is about 60 MW (540 GWhr/year).

The implementation of the turbines in the model, based on what is known of the La Rance turbines, used discharge and power relationships for a single turbine in generating mode as shown in Figure 4.2. This has been done bearing in mind a requirement to compare the performance of turbines developed under the

Safe*Coast project against that of the presently operational La Rance tidal power station. It is anticipated that smaller turbines will be proposed and tested at the next phase of the present study.

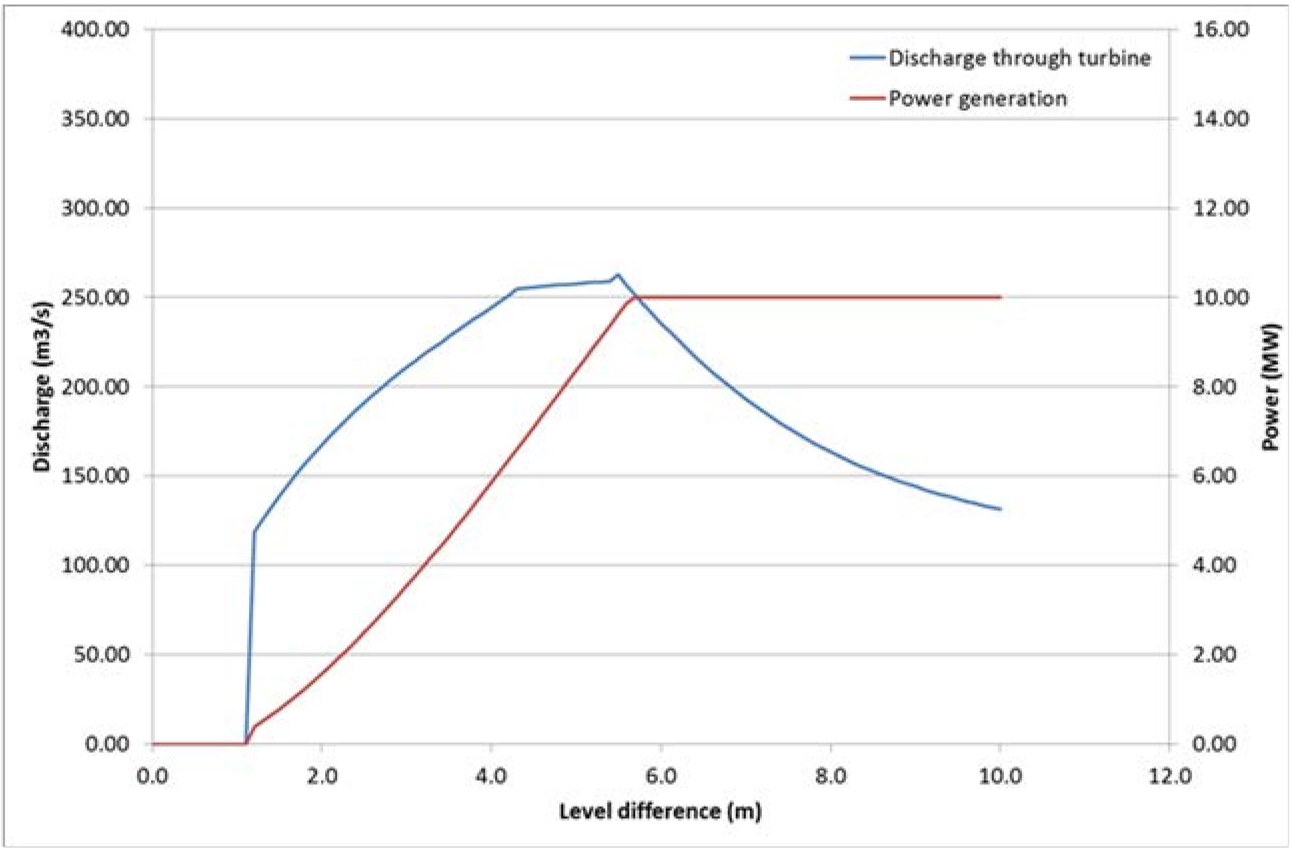

Figure 4.2: Assumed relationships of discharge and power to head difference for turbines implemented

4.3. Sensitivity tests

To explore the behaviour of the proposed pool a series of sensitivity tests were performed, to move the proposals towards an optimum. It should be remembered that a final optimised approach would be subject to extensive testing and experiment during the detailed design studies of the pool with further amendments made during the early years of operation as has been the case at La Rance.

The model results are output for total power provided in a year (GWhr/year), the average power generation for each test (MW) and the power generated per turbine (GWhr/year). These factors hide considerable variation in the time of generation and the maximum power output. Therefore sample time histories of power generation and water level are also provided where this additional information is useful in understanding the results.

4.3.1. Number of turbines

A set of tests were done with only the total number of turbines varied. The results are provided in Table 4.2 below. The optimum power would be achieved with the most turbines generating their maximum power (in this case 10MW) for the longest time. However the total number of turbines will increase the capital cost of the development so repeatedly increasing the number of turbines is not desirable. Little change in the total power output is shown between the runs with 40 and 48 turbines, therefore more than this may not be worthwhile.

Table 4.2: Sensitivity tests for number of turbines

Starting head for generation (m)	Number of turbines	Number of sluices	Total power (GWhr/year)	Average power (MW)	Power per turbine (GWhr/year)
2.4 m - 3.6 m	24	6	205.5	23.4	8.6
2.8 m - 4.0 m	40	6	230.3	26.3	5.8
3.0 m - 4.2 m	48	6	234.8	26.8	4.9

4.3.2. Starting head for generation

The above tests employed a table of starting heads for generation giving starting heads for 24 turbines between 2.4 m and 3.6 m depending on the preceding high water level. The values of 2.4 m and 3.6 m used correspond to small and large tides respectively. This table was established by carrying out runs with a variety of starting heads and choosing the best power production from them. Different values for starting head were used with different numbers of turbines. The sensitivity of these results to a constant starting head was also included as shown in Table 4.3 below.

Table 4.3: Sensitivity tests for the starting head for generation

Starting head for generation (m)	Number of turbines	Number of sluices	Total power (GWhr/year)	Average power (MW)	Power per turbine (GWhr/year)
2.4 m - 3.6 m	24	6	205.5	23.4	8.6
3.15 m	24	6	202.1	23.1	8.4

The modelling showed a low sensitivity to starting head for a given number of turbines. In reality with the tide range in the Thames Estuary being smaller than at other tidal power locations, less variation may be available to optimise this parameter.

The maximum head that occurs during power generation has been extracted from the power model and is summarised in Table 4.4 below.

Table 4.4: Maximum head during power generation

<table>
<tr><th>Run</th><th colspan="2">Maximum head during generation phase (m)</th></tr>
<tr><td>24 turbines - ebb only generation</td><td colspan="2">4.03</td></tr>
<tr><td>48 turbines - ebb only generation</td><td colspan="2">3.47</td></tr>
<tr><td>24 turbines flood and ebb generation</td><td>2.96 flood tide</td><td>2.99 ebb tide</td></tr>
<tr><td>24 turbines ebb only generation with pumping</td><td colspan="2">4.71</td></tr>
</table>

4.3.3. Ebb and flood tide generation

All the above test cases were for ebb only generation. The Tide Tec turbine is anticipated to be used with generation in both ebb and flood phases of the tide therefore a sensitivity test case with two directions of flow was included. Table 4.5 shows the power results; Figure 4.3 shows the water level in the pool under both test cases as well as the time history of power output.

Table 4.5: Sensitivity tests for ebb only or ebb and flood generation

Generation mode	Number of turbines	Number of sluices	Total power (GWhr/year)	Average power (MW)	Power per turbine (GWhr/year)
Ebb only	24	6	202.1	23.1	8.4
Flood/Ebb	24	6	193.8	22.1	8.1

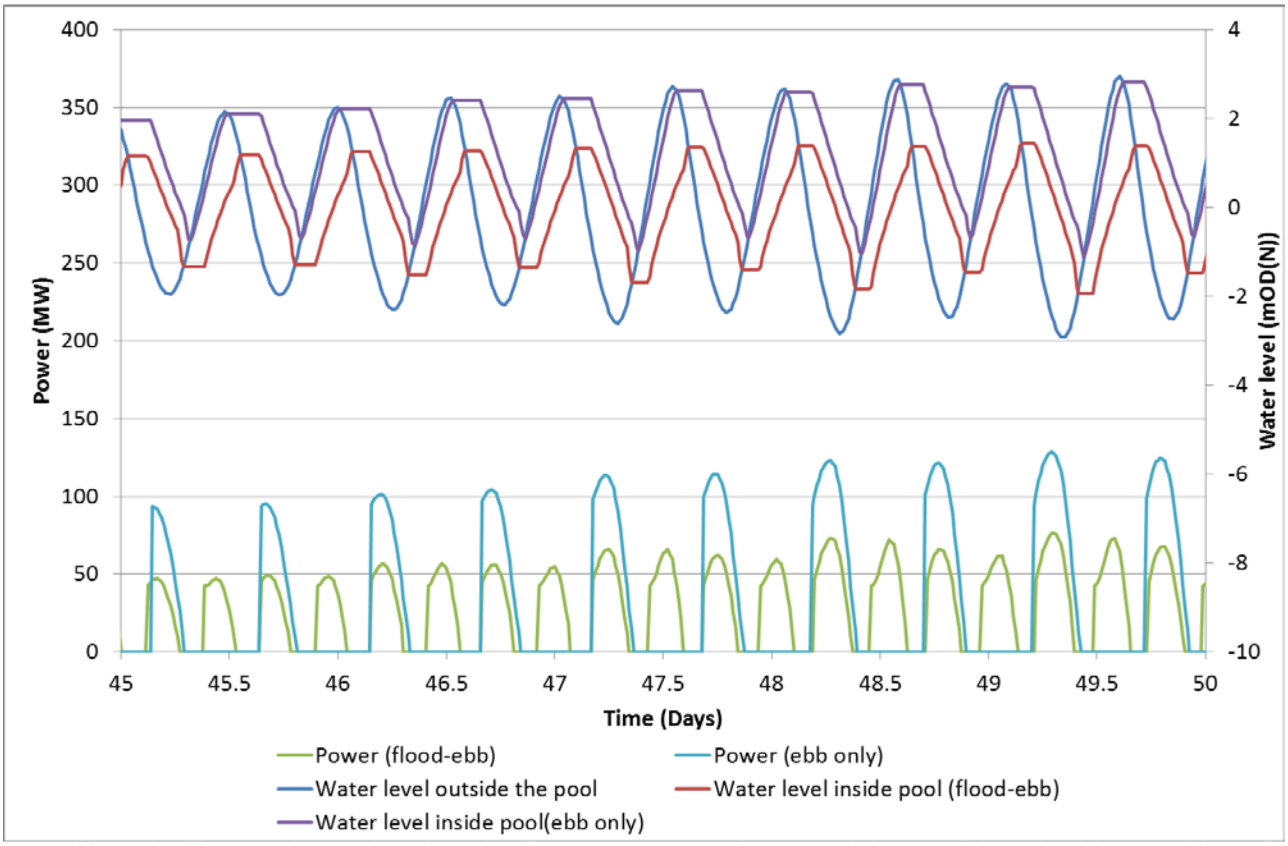

Figure 4.3: Water level and power for ebb only and flood-ebb generation

The starting head for ebb only generation was again 3.15 m, for the ebb and flood case the starting head was taken as 2.1 m because the head difference is generally lower for this type of operation. With 24 turbines it is found that there is not a clear benefit to generating on both flood and ebb. However, at present the difference in power output is marginal. By fine-tuning the number of turbines, and sluice operation, it should be possible to convert more energy in combined flood-ebb generation mode.

4.3.4. Pumping

To further increase the power output, the possibility of pumping was examined. The bathymetry at the site contains a significant amount of intertidal flats. Without lowering these bed levels by dredging, not much additional water volume (and therefore power) could be achieved by pumping water levels lower at low water, therefore a case with pumps used to increase the water level at high tide was investigated.

For the pumping scenario with 24 turbines, pumps running at a power of 7 W per square metre of pool were used to raise high water inside the pool until the water level outside fell to mean sea level. This pump power level is taken from MacKay, 2007. It corresponds to a pumping rate of 210MW which is slightly less than the total rated turbine power of 240MW. The pumping was carried out with an efficiency of 85%. This resulted in a period of higher power generation during the ebb tide. The predicted power output also needed to subtract the amount of power used in the pumping. This led to the results in Table 4.6 below and illustrated in Figure 4.4.

Table 4.6: Sensitivity tests for the effect of pumping

	Number of turbines	Number of sluices	Total power (GWhr/year)	Average power (MW)	Power per turbine (GWhr/year)
Ebb only with no pumping	24	6	202.1	23.1	8.4
Ebb only with pumping	24	6	298.8	34.1	12.5

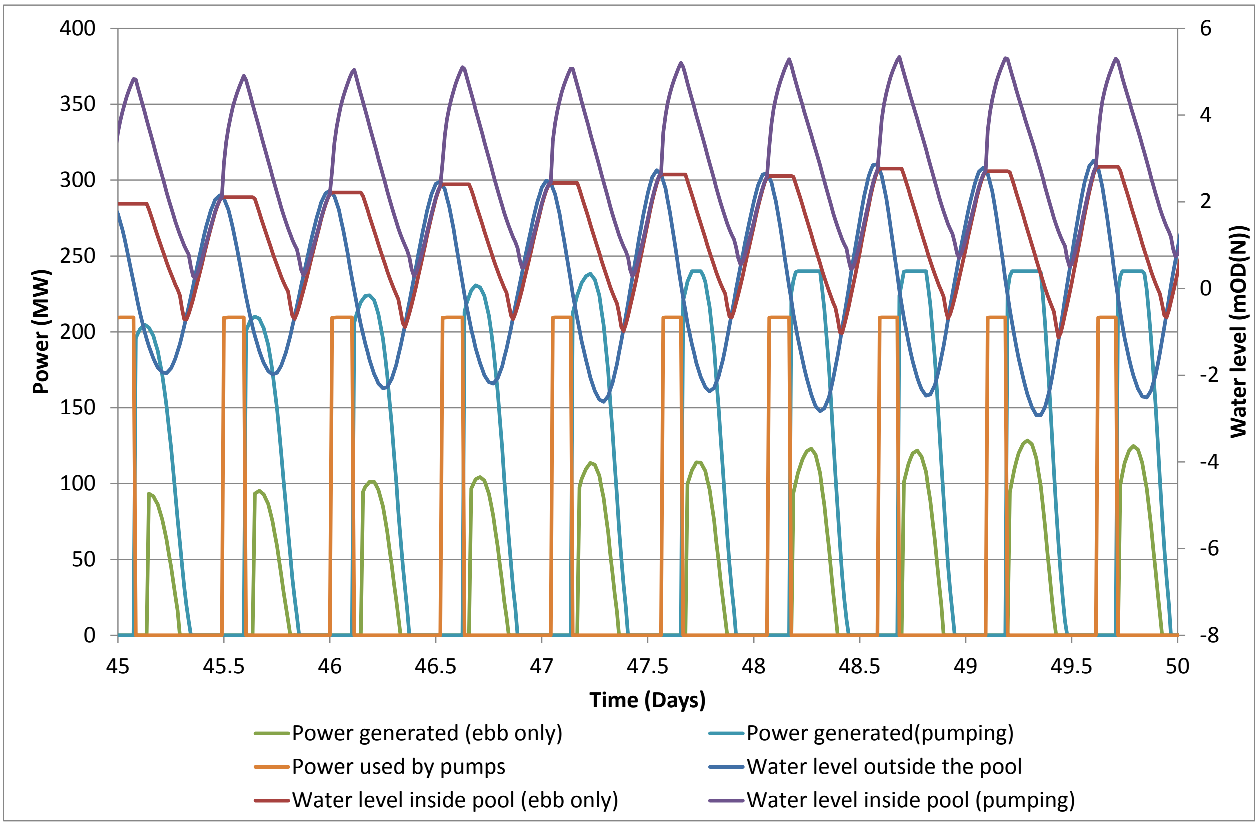

Figure 4.4: Water level and power for flood-ebb generation with and without pumping

In the case of 24 turbines with pumping there was a substantial increase in the net total power output. The introduction of a twin pool arrangement may further increase the net power available from pumping as described in MacKay (2007).

A further test was carried out to demonstrate the importance of pumping efficiency. The model was re-run with the following table of pumping discharge for the La Rance turbines (Table 4.7). The pumping efficiency represented in this table is as low as 23% compared to the 85% used in the testing above. With the lower discharges given by the reduced pumping efficiency it was found that there could be no benefit in additional power output from pumping.

The conclusion of this test was that if pumping is to be pursued, maximizing the efficiency of the pumping operation is a key parameter in governing the total power produced by the pool.

Table 4.7: Performance of turbines La Rance, pumping from sea to basin (from Swane, 2007)

Head (m)	1	2	3	6
Power per turbine (MW)	10	10	10	10
Dischrage (m^3/s)	225	195	170	105

Source: Swane, H. 2007

4.3.5. Influence of additional turbines on sensitivity tests

The reasoning for the number of turbines chosen for the testing (24) was described in Section 4.3.1. However the analysis suggests that a scheme with 24 turbines is of insufficient capacity to completely fill and empty the proposed size of pool through the tidal cycle. This lack of capacity also had the consequence of reducing the potential for improvement of power output by generation during the flood and ebb tidal phases or the use of pumping. Therefore, for comparison, additional sensitivity results are presented for 48 turbines in Table 4.8 below.

Table 4.8: Sensitivity tests for 48 turbines

Generation mode	Number of turbines	Number of sluices	Total power (GWhr/year)	Average power (MW)	Power per turbine (GWhr/year)
Ebb only	48	6	234.8	26.8	4.9
Flood/Ebb with no pumping	48	6	273.8	31.2	5.7
Flood/Ebb with pumping	48	6	338.6	38.6	7.1

It can be seen that with more turbines, there is a total energy yield benefit from flood /ebb generation, and also from pumping. Pumping was again only used to raise the water level and enhance the ebb generation. The pumping rate as before was 210MW so not using all the turbines at their full rated turbine power. Pumping using a twin pool arrangement may also allow the overall footprint of the scheme to be reduced, for a given power output. Against these benefits should be set the additional cost from extra turbines. It is therefore recommended that further optimisation of turbine numbers, taking into account these other factors, would be beneficial.

4.4. Discussion

Sensitivity tests have been presented relating to the number of turbines, the starting head chosen for generation (an important aspect of the operating cycle chosen), the use of ebb only or combined ebb and flood generation and the possible inclusion of pumping.

It has been found that 24 turbines are able to yield only about 12% less energy than 48, so 24 turbines have been used for the remaining test cases. Adjusting the starting head formulation between a value of 3.15 m and using a formulation dependent on tidal range, made only a small difference in the energy produced with the largest being from use of a table of starting heads. This was used in the assessment of the number of turbines.

It was found that including both ebb and flood generation did not increase the power produced for the case of 24 turbines. This could be explored further as it may be possible to increase the power output from ebb-flood generation. Also in the case of 24 turbines it was found that pumping the water level higher before generating would potentially have a benefit when the power consumed in the pumping process is taken into account, provided turbines with a high pumping efficiency can be used.

Many factors both intrinsic to the development and more widely will influence the final decision about the turbine size, number of turbines, turbine location and operating cycle (ebb only/flood and ebb, starting head, pumping). For this reason the sensitivity tests described above have been carried out to provide indications of the effects of these choices on output and scheme functioning. Further work in the context of this project will use actual figures for turbine designs and allow more definitive results to be provided.

Another possible consideration is the use of a twin pool system with pumping between the pools instead of the single pool considered here. Such a scheme can give greater power output (net of the power used for pumping) as well as the possibility of much longer periods of net energy generation. If required this can be assessed in further work, as far as it is expected that the engineering can ensure security in the case of significantly higher or lower water levels than exist under the natural environment.

It is therefore recommended that further optimisation, taking into account these factors, would be beneficial before a final concept scheme is determined.

5. Environmental review

5.1. Background

The conceptual tidal pool is situated adjacent to the Hoo Peninsula and Isle of Grain, Kent, in the Thames Estuary with training wall extending south from Canvey Island, Essex, and a training wall mid-estuary (see Figure 3.11).

This area of the Thames Estuary has various statutory and proposed environmental designations, including international designations of Special Protected Area (SPA), Special Area of Conservation (SAC), Ramsar wetland of international importance, and national designation as a Marine Conservation Zone (MCZ). The entire area is not designated, but forms a patchwork of interlocking designations. These designations are shown on the Department of Environment, Food and Rural Affairs (Defra) Geographic Information System website, MAGIC, as shown from the screen capture in Figure 5.1. Thames Estuary & Marshes SPA and Ramsar and South Thames Estuary & Marshes Site of Special Scientific Interest (SSSI) are the main designated sites coinciding with the area of the conceptual pool.

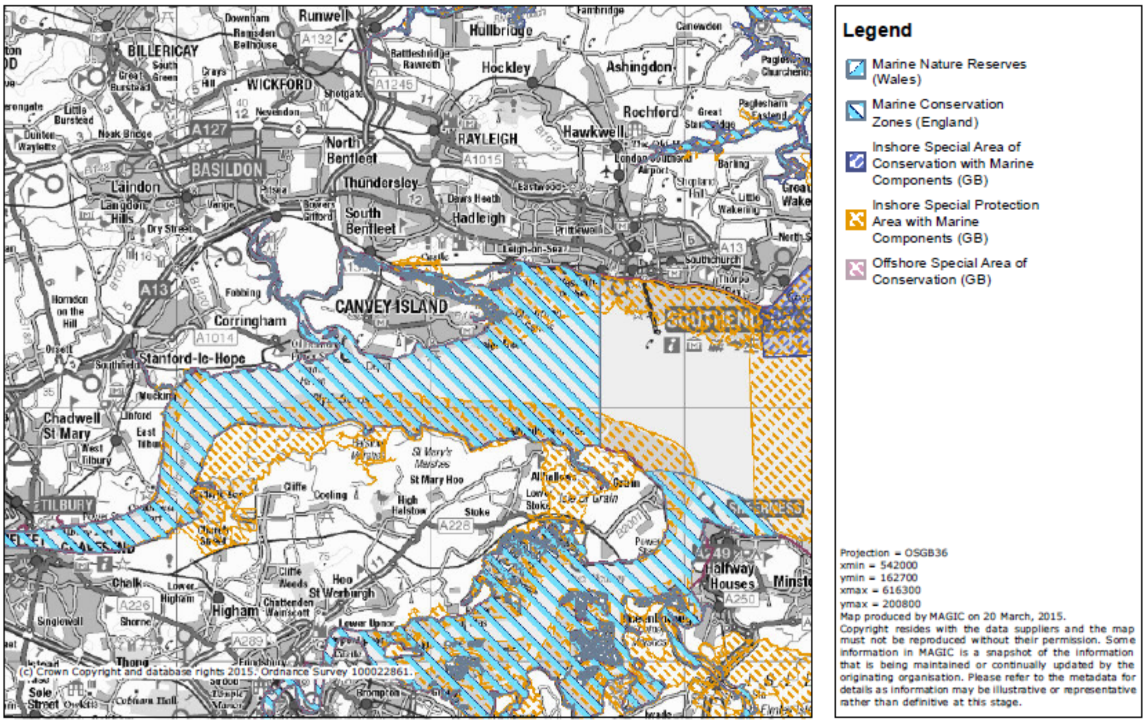

Figure 5.1: MAGIC map display of environmental designations

Source: Department of Environment, Food and Rural Affairs

5.2. Environmental impacts

5.2.1. Physical changes

Tidal exposure of the area enclosed by the pool will be altered, partly through a phase shift of the tide heights as shown in Figure 4.3, but also in terms of the area which is inundated. There will also be a reduction in tidal height and hence area of intertidal that is routinely exposed. The remaining intertidal will also be exposed for shorter durations.

In addition to these changes, tidal current speed will also alter as illustrated by Figure 3.18. As a result of these changes, sediment deposition and erosion patterns will be altered, with increased deposition where currents are decreased and increased erosion where currents are increased.

It is likely that the affected area of the middle of the estuary, which is already a deeper channel, will deepen further and that this deepening will be along a considerable length (around 5 km) of the Thames. There are liable to be different effects from slower currents further up the estuary, however, the modelling has not considered this upper area. Whilst this middle area is deepening, it is likely that the areas to the east of the Canvey conceptual training wall and east of the conceptual pool enclosure will accrete sediments. Depending on the levels that they attain, these areas will either increase in intertidal mudflat/sandflat or potentially eventually develop salt marsh.

Yantlet Creek is a winding watercourse which cuts off the northern part of the Isle of Grain from the rest of the Hoo Peninsula to the west. The position of the conceptual pool will mean that the Yantlet Creek complex will no longer be connected to the natural tidal system at the main northern creek inlet. It is likely that through time the creek complex will fill with sediments due to the currents being slowed through the complex and cease to be intertidal habitat, allowing the island to become part of the peninsula.

It is also possible that sediments within the pool area will gradually accrete with time, decreasing its flood storage capacity.

The extended ‘stand’ at high water may lead to increased erosion of the foreshore and steepening of the intertidal profile, leading to losses of intertidal area.

Within the conceptual pool, it is likely that there will be a tendency for the sediments to gradually accrue more silts and clays, as the lower currents will allow these to settle out. It is possible that this would lead to shallowing throughout the pool area over time. As with the areas to the east of the Canvey conceptual training wall and to the east of the conceptual pool enclosure, the conceptual pool may potentially eventually develop salt marsh in some of the accreting areas.

Water and sediment quality are unlikely to be seriously adversely affected by the conceptual pool. The risk of increased frequency and magnitude of algal bloom events within the conceptual pool would however need to be considered. This would be attributable to the reduced water exchange (reduced tide range) and higher temperatures within the pool. Blooms within the pool area would lead to local drops in dissolved oxygen, following the mortality of the algal cells or potential toxicity if the algae are of certain types. This type of effect would be significantly mitigated if the pumping option for tidal power generation were used, as this would maintain (or increase the water volume exchanged between the pool and the estuary.

5.2.2. Biological environment

Coastal vegetation

The saltmarshes and grazing marsh complexes support a wide range of characteristic vegetation, with species regarded as nationally scarce being recorded. The citation for the South Thames Estuary and Marsh SSSI lists:

- *Inula crithmoides* Golden samphire
- *Puccinellia fasciculata*
- *Carex divisa* Divided sedge
- *Chenopodium botrydes* Small goosefoot
- *Rumex maritimus* Golden dock
- *Bupleurum tenuissimum* Slender hare’s ear
- *Trifolium squamosum* Sea clover
- *Hordeum marinum* Sea barley
- *Zostera angustifolia* Eelgrass
- *Zostera noltii* Eelgrass
- *Crambe maritime* Sea kale.

The distribution and abundance of these species could be altered by changes to the marshes following the reduction of tidal incursion into, or the silting up of the creek systems which feed the marshes.

To balance any effect on marsh within the pool there are also freshwater conservation sites around the estuary that could benefit from a reduced risk of inundation by seawater during extreme events as demonstrated by the flood management operation of the scheme. An understanding of the balance of adverse impacts and benefits would be undertaken during the EIA of the scheme if it were pursued.

5.2.3. Marine macrobenthos

Alterations to the tidal exposure and water depths are likely to alter the nature of the macrobenthos distributions, as organisms tend to be adapted to these, in addition to particular sediment types. Loss of intertidal areas by raising low water will lead to a loss of benthic habitat.

5.2.4. Marine fish

There are a variety of ways that the conceptual pool may impact on fish populations within the estuary. It is likely that some will pass through the tidal turbines and this provides four categories of potential sources of injury to fish (APEM, 2010):

- Mechanical, including strike, abrasion and grinding
- Pressure
- Shear and turbulence
- Cavitation.

Mechanical injuries include bruising, lacerations, skeletal fractures, scrapes, internal haemorrhaging and eye damage. Direct pressure injuries concentrate on gas filled cavities in the fish, in particular the swim bladder, although indirectly there may also be rapid pressure changes in the blood which can impair internal organs or cause haemorrhages in the eyes, pectoral girdle and anterior region of the spine. Shear and turbulence may also cause mechanical type injuries, such as bruising, lacerations and eye damage. Cavitation can cause haemorrhaging and eye damage. There is considerable research into mitigating fish effects of turbines and it would be anticipated that the present scheme would take advantage of the knowledge generated by the installation of other pools, for example at Swansea, to minimise adverse fish impacts.

The decreased entrance to the estuary from the conceptual pool and training wall will act as impedance to any fish which migrates as part of its life cycle. It will particularly affect fish with slower swimming speeds, or those that prefer to move within the shallow zones, as the reduced area of estuary available for fish passage will be deeper and the currents faster. Fish known to have Thames populations and also migrate include:

- *Salmo salar* Atlantic salmon
- *Anguilla anguilla* European eel
- *Solea solea* Sole
- *Alosa fallax* Twaite shad
- *Alosa alosa* Allis shad
- *Osmersus eperlanus* Smelt
- *Salmo trutta* Sea trout
- *Lampetra fluviatilis* River lamprey
- *Platichthys flesus* European flounder.

This partial barrier to fish migration is liable to be a severe potential impact and has the potential to be a showstopper, in the absence of robust mitigation and compensation measures. The detailed design of the proposed scheme will need to reduce these impacts, for example, by creating low current areas around the bunded flood storage area or temporary gaps in the structure towards Canvey Island.

Harbour seals are also likely to use the funnelling effect to increase their predation on all fish passing through this area (see paragraph 5.2.6), which may disadvantage the fish populations.

Loss of the Yantlet Creek complex would reduce habitat suitable for juvenile nursery fish as well as small species and others which use such habitat for shelter.

5.2.5. Birds

As previously mentioned, the area of the conceptual pool is partly situated within the Thames Estuary Ramsar and SPA, the South Thames Estuary and Marshes SSSI and adjacent to the Medway Estuary and Marshes Ramsar and SPA. All of these designations reflect the rich diversity of birds which rely on the area for roosting, feeding, overwintering, loafing or nesting. The 1993 citation for the SPA gives that "The site qualifies under Article 4.2 as a wetland of international importance by virtue of regularly supporting over 20,000 waterfowl, with and average peak count of 53,900 birds recorded in the five winter period 1986/87 to 1990/91."

The qualifying bird species are:

- *Branta bernicla bernicla*; Dark-bellied brent goose (Non-breeding)
- *Tadorna tadorna*; Common shelduck (Non-breeding)
- *Anas acuta*; Northern pintail (Non-breeding)
- *Recurvirostra avosetta*; Pied avocet (Breeding)
- *Recurvirostra avosetta*; Pied avocet (Non-breeding)
- *Charadrius hiaticula*; Ringed plover (Non-breeding)
- *Pluvialis squatarola*; Grey plover (Non-breeding)
- *Calidris canutus*; Red knot (Non-breeding)
- *Calidris alpina alpina*; Dunlin (Non-breeding)
- *Tringa totanus*; Common redshank (Non-breeding)
- *Sterna albifrons*; Little tern (Breeding).

Conservation objectives for the SPA are to:

Ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring:

- the extent and distribution of the habitats of the qualifying features
- the structure and function of the habitats of the qualifying features
- the supporting processes on which the habitats of the qualifying features rely
- the population of each of the qualifying features, and
- the distribution of the qualifying features within the site.

In addition to these SPA species, the South Thames Estuary and Marshes SSSI citation mentions:

- *Anser albifrons albifrons* White-fronted goose
- *Tadorna tadorna* Shelduck
- *Anas strepera* Gadwall
- *Anas crecca* Teal
- *Anas clypeata* Shoveler

- *Anas querquedula* Garganey (Breeding)
- *Pluvialis squatarola* Grey plover
- *Numenius arquata* Curlew
- *Limosa limosa* Black-tailed godwit
- *Panurus biarmicus* Bearded tit (Breeding)
- *Circus cyaneus* Hen harrier
- *Asio flammeus* Short-eared owl
- *Philmachus pugnax* Ruff
- *Sterna hirundo* Common tern
- *Pluvialis apricaria* Golden plover.

The mosaic habitats that the birds rely upon and are cited would be permanently altered by the conceptual pool. This will include permanent inundation, shorter duration of exposure, and altered sediment composition. This is likely to be considered a major potential impact and a potential showstopper, in the absence of robust mitigation and compensation measures.

It is likely that the presence of the pool will provide some other impact to the waterbird populations, although this may vary from species to species and be a mix of beneficial and adverse effects. For example, changes to the tidal exposure could reduce or improve foraging opportunities for waders. The waters of the conceptual pool will have a reduced wave climate to the open estuary and could offer improved loafing opportunities. However, any changes to the macrobenthos within the conceptual pool could also adversely impact foraging opportunities in some species, whilst advantaging others. The breeding birds and those more terrestrially focussed are unlikely to be impacted by the conceptual pool.

5.2.6. Marine mammals

The Thames Estuary is believed to have a population of harbour seals (*Phoca vitulina*) which represents approximately 10% of those found in England (Barker et al, 2014). The mudflats, sandflats and outer estuary intertidal sand banks, act as important haul out areas for seals to rest, breed and moult. A recent survey of seals, carried out by the Zoological Society of London (ZSL) Thames Harbour Seal Conservation Project (Barker et al, 2013) showed observations of seal groups in the area of the conceptual pool and training walls (see Figure 5.2).

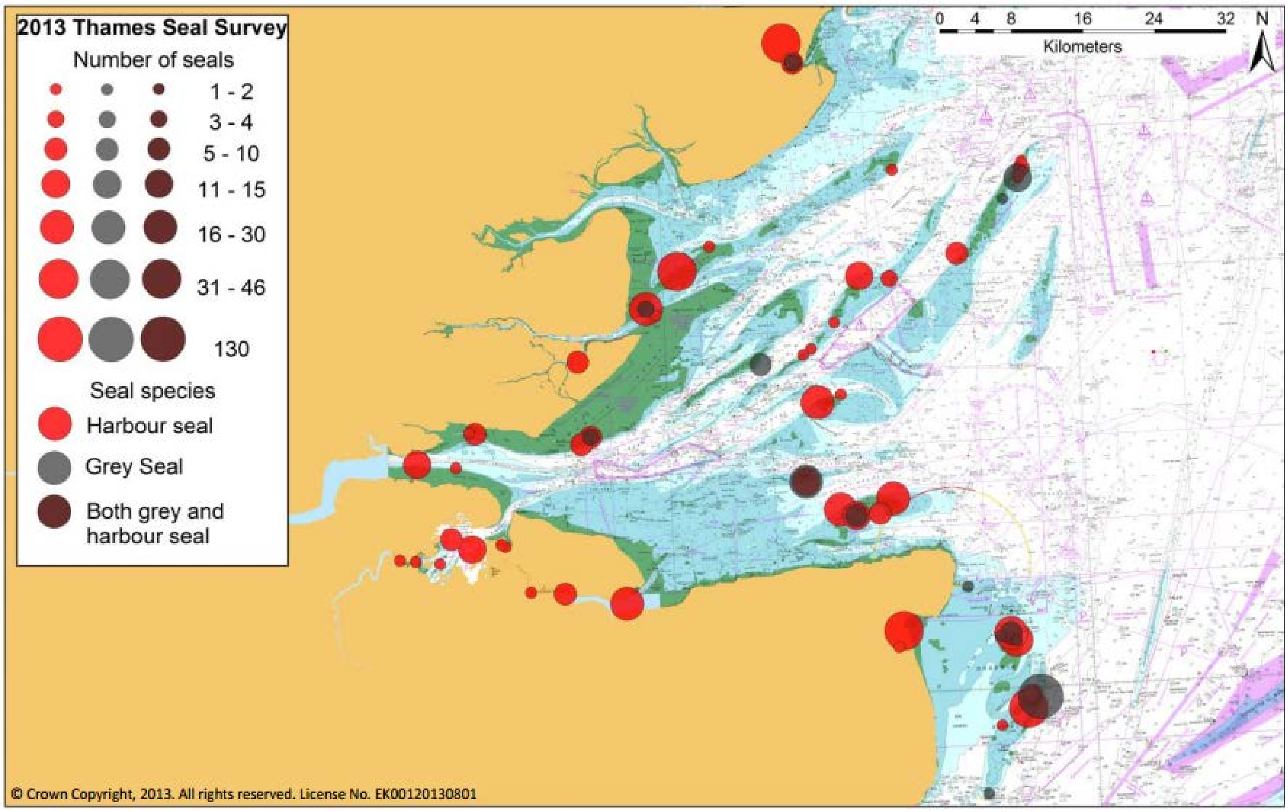

Figure 5.2: Location of harbour seal, grey seal and mixed seal groups encountered during the ZSL 2013 harbour seal survey

Source: Thames Harbour Seal Conservation Project, Zoological Society of London

A tagging programme was undertaken of 10 seals and the tracking indicated that the seals used the area of the conceptual pool and training walls for swimming and probably foraging. The north bank intertidal mud and sand flats were preferred as haul out sites.

The increased currents in the part of the estuary affected by the conceptual pool and training walls are unlikely to provide any effect on the seals' transit capabilities. It may be that they learn to use this constricted area for more successful predation on fish which are channelled through this area.

5.2.7. Human environment

Navigation

The conceptual pool and associated training walls will considerably reduce the estuary width available to ship passage, and also modify slightly the tidal heights outside the pool. Increased currents through the area may provide a navigational challenge, although there are other areas of the estuary where existing conditions are equivalent. These impacts have been reduced by the inclusion of the northern tidal gate in the design and further development of this approach may further reduce any navigational impacts of the works. The improved low water depth at this point may facilitate passage of vessels with deep draught.

5.2.8. Fisheries

There are fleets of small inshore commercial boats on either side of the Estuary, some working out of Leigh-on-Sea, Canvey Island or Benfleet in Essex and others working out of Queenborough, Whitstable and Margate. If there are impacts to sole, as expected by restricting their migration, these boats will lose a significant part of their current targeted catch.

5.2.9. Visual amenity

The walls of the conceptual pool are expected to be high (up to 8m above OD(N)) and as they will be within an area which is currently predominantly low lying marshes and fields, they will be visible from considerable distance. Whether the change to visual impact is regarded as adverse or beneficial will largely be down to public perception, but the constructions are likely to be visible from many of the dense population areas on the Essex coast which make up the Southend-on-Sea conurbation. Visual impacts can be addressed in part by design to make the structure as far as possible similar to the flood walls present in the area or if that is not possible to make the structures sympathetic to the surrounding landscape.

5.2.10. Leisure/recreation

The Allhallows caravan site small shingle beach frontage will be enclosed by the conceptual pool, which may be perceived as a reduction in the amenity value of this small holiday village. There may be some potential for creating footpaths or alternative viewing areas in more detailed design to offset this.

Recreational navigation such as small sailing craft may be adversely affected by the constricted estuary and the increased tidal speeds within the constriction. As with other identified impacts this issue would be addressed as part of the scheme's EIA and the balance of potential impacts and benefits addressed.

5.2.11. Cultural and archaeological

English Heritage carried out a Hoo Peninsula Historic Landscape Project beginning October 2009 and reported in 2013 (Carpenter et al 2013). There are several features of historical interest situated on the coastline which would be enclosed by the conceptual pool. Slough Fort is a small Victorian gun emplacement, situated in the Allhallows caravan site and currently used as a riding school stable. The Grain Island Firing Point (or Yantlet Battery) is sited immediately to the east of Yantlet Creek on an area of land known as Grain Marsh. It was constructed in the period between the First and Second World Wars and used as a firing point up until the 1950s. Beside the mouth and on the east side of Yantlet Creek is a monument known as the London Stone, marking the limits of the jurisdiction of the City of London. It is an 8 m tall column, which is thought to possibly date back to the medieval period, although the inscription is now illegible. An inscription on the plinth dates to the late 19th century, when the stone was re-erected.

There are also various WW2 aircraft crash sites within the intertidal area.

These interest sites will not be directly affected by the conceptual pool, but may lose context with their environment surrounding landscape. A full assessment of the historical cultural and archaeological impacts of the works would be included in the EIA, should the scheme be taken forward. The EIA will also include assessment of mitigation or management of any identified impacts.

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