To be read with the Metrotidal Lower Thames Orbital Presentation: January 2019

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INTRODUCTION AND EXECUTIVE SUMMARY

The Metrotidal Lower Thames Orbital is a system of integrated infrastructure including the next generation of London's flood defences that provides substantial growth across the Lower Thames Estuary into Essex, Kent and London without an associated increase in carbon audit. The new flood defences through to the 22nd century provide a more robust system for lower cost and environmental impact and for longer duration than the TE2100 proposals. The green-growth is achieved through the generation of renewable, zero-carbon energy for over 100,000 new homes, along with improved rail connectivity and efficient data storage.

The Metrotidal Lower Thames Orbital integrates the following infrastructure to provide the improved flood defences, reduce the planning and construction costs, reduce the environmental impacts, increase the agglomeration benefits and generate the green-growth: -

1. flood defences for London and the Thames Estuary
2. renewable energy generation; solar, wind, tidal
3. twin-track rail orbital
4. cycle superhighway and promenade
5. London Estuary Express services
6. efficient data storage and distribution
7. rail freight and utility connections across the Lower Thames Estuary
8. cruise liner terminal, Thames Clipper berth and Southend Marina
9. harbour for the Thames Cockle Fleet
10. sustainable residential and commercial development

GENERAL ARRANGEMENTS: THROTTLE, TUNNEL AND ORBITAL

The integrated infrastructure consists of a tideway throttle and impoundments across Sea Reach that in the event of a storm surge reduce the maximum water level upstream by up to a meter, thereby providing London and all areas downstream to the sea with flood defences through the 21st century, while leaving the tideway open for navigation to all existing wharves and docks. The system then becomes a full barrier in the 22nd century with the flood datum raised as required to meet rising sea levels.

The tunnel formed within the impoundments links the eastern limbs of Crossrail to complete a twin-track rail orbital of the Lower Thames Estuary. The new rail orbital, with cycle superhighway and promenade, including wayleaves for data storage, distribution and utilities, improves the connectivity for over a million households thereby generating substantial agglomeration benefits across the Lower Thames Estuary into Kent and Essex. The link under the estuary is completed by two immersed-tube tunnel sections under the open-channel of the throttle that connect the north and south impoundments to form Sea Reach Station. The new station serves a Cruise Liner Terminal, Thames Clipper Berth, Southend Marina and harbour for the Thames Cockle Fleet. Renewable energy generated from a floating solar-array sheltered by the flood defence system and from wind turbines on the moles and impoundments more than offsets the demands of the flood defence system, tunnel M+E systems, data storage and new housing developments. As sea levels rise there is scope for adding tidal power generation from a flood storage system.

The new infrastructure orbital makes use of existing railway lines and is implemented without significant disturbance to areas north and south of the estuary where the impoundments come ashore. The form and finishes of the impoundments and moles are designed to minimise the visual impacts. Construction undertaken in the tideway makes use of concrete batching and casting facilities nearby on the Isle of Grain. Spoil from the excavations is reused locally for embankments and flood bunds so that the embodied energy of construction and environmental impacts are kept to a minimum.

1 LONDON'S FLOOD DEFENCES

The throttle and impoundments form a flood defence system that protects flood risk areas upstream from a storm surge. The existing 300m wide shipping channel in Sea Reach, dredged to a depth of 14.5m is channelled through a 300m wide open throttle constructed to a uniform depth of 16m between north and south moles. Each mole is 180m wide to accommodate sector surge-tide gates, like those of the Maeslantkering at Rotterdam (360m wide) and the St. Petersburg Flood Protection Barrier (200m wide). The gates are fitted when required by rising sea levels. A 60m wide, 10m deep channel is provided each side of the north and south moles to reduce the peak tidal flows and the range reduction upstream during normal tides. The channels also provide separate navigation for small ships. 3No. 40m wide open channels, one 2m deep flanked each side by one 1m deep are provided through the northeast impoundment to maintain the tideway and navigation through Ray Gut and provide a shallow channel for fish migration. The two small ship channels are fitted with two tidal gates similar in scale and operation to those of the Thames Barrier and the three shallow Ray Gut channels are fitted with simple lifting barriers when required by rising sea levels.

The current Thames Estuary 2100 (TE100) proposals consider a Long Reach Barrier with locks close to Dartford Crossing. These protect 61.8sq.km of metropolitan flood risk land upstream to the existing Thames Barrier. The Metrotidal Lower Thames Orbital would protect 172.5sq.km of flood risk land upstream to the existing Thames Barrier, while leaving the tideway open for navigation through the 21st century. The throttle effect of the open channels without tidal gates provides enough range reduction upstream to reduce the flood risk for a period of up to 40 years from the date of construction. The period is determined by hydrographic analysis of the flood defence system and the rate at which sea levels rise due to climate change.

The tideways of Ray Gut and the Leigh Channel are separated by the intertidal bank of the Chapmans Sands and Marsh End Sand that extends east from Canvey Point to the northeast

impoundment. The cross-sectional areas of the three main throttle system open channels (300 x 16 + 2 x 60 x 10 = 6,000sq.m) and of the three Ray Gut open channels (40 x 2 + 2 x 40 = 160sq.m) are adjusted so that their separate basins fill at similar rates and the flood tides cover Marsh End Sand and Chapman Sands as they do today. As sea levels rise the fitting of tidal gates to the Ray Gut channels and the raising of a shallow ridge across Chapman Sands and Marsh End Sand from Canvey Point to the impoundment provides a modest reduction in peak flow rates and tidal range upstream for a modest amount of work and minimum environmental impact. The shallow ridge is raised to the intertidal height of Clock Bank beside Canvey Point so that the system is still covered at high tide. With the Ray Gut gates and the existing Benfleet Barrier closed at low tide ahead of a surge tide the volume of the intertidal flood storage north of Chapman Sands and Marsh End Sand is reserved until the flood tide filling the Thames basin begins to spill over the shallow ridge. The area of Ray Gut, Hadleigh Ray and the subsidiary creeks upstream to the Benfleet Barrier is 9.9sq.km so for every meter of the shallow ridge raised across Chapman Sands and Marsh End Sands the flood storage capacity increases by 9.9 million cubic meters. The volume of flood storage held in reserve helps to reduce peak flow rates through the main throttle channels into the Thames basin during the early phase of the incoming surge tide and when the flood storage comes into use during the later phase of the surge tide the volume helps to reduce the peak range upstream thereby postponing the fitting of tidal gates to the side channels of the main system. The scale of the peak flow and range reduction benefits and the period for postponing the fitting of gates are determined by hydrographic analysis. The management and control of peak flow rates during a surge and normal tides is also resolved through hydrographic analysis, with a target of reducing the peak flow rates to within 2.5 m per sec so that they have minimal impact on navigation.

Later in the 21st century, as sea levels rise, the fitting of tidal gates to the two 60m side channels requires mechanical engineering equivalent to only two of the existing Thames Barrier gates on Woolwich Reach. The substantial reduction in flood risk through the 21st century enables the Government's Flood Re agreement to be renegotiated to reduce flood-risk insurance premia and release a large area of land for safe redevelopment. If sea levels begin

to rise more rapidly in the 22nd century the 180m wide north and south moles can then be fitted with sector-gates of similar scale to those already built for the Maeslantkering system at Rotterdam and for the St. Petersburg Flood Protection Barrier to extend the flood protection into the 22nd century. The flood datum of the relatively short and fully accessible flood barrier between the high ground of Southend and the Hoo Peninsula protects the whole of the Thames basin and can be raised at modest cost to address rising sea levels through the 22nd century. In this way the cost of the flood defence system can be phased, with the passive, economical open-throttle system providing protection through most of the 21st century, supplemented by the flood storage system then the fitting of tidal gates later in the century and by raising the flood barrier datum at modest cost later in the 22nd century, if required by rising sea levels.

2 RENEWABLE ENERGY GENERATION

The integrated infrastructure includes enough renewable energy generation to more than offset the demands of the system and 100,000 new homes. The sheltered sub-tidal area of the estuary within the impoundment accommodates 400 hectares of floating solar arrays with an annual output assessed from the solar farm on the Hoo Peninsula at Malmaynes Hall Farm 6km southwest from the throttle, and the projected annual output of the 360-hectare Cleve Hill Solar Park near Faversham in North Kent, 24km southeast from the throttle. The floating solar arrays are sheltered by the northeast impoundment and protected by a perimeter boom. The solar power generated is enough to offset the energy for the flood defence system, the tunnel M+E systems, the data storage and distribution and the demand for up to 100,000 new homes. Additional renewable energy is generated by wind turbines mounted on the moles and impoundments where they can be readily accessed for servicing. As sea levels rise there is scope for adding tidal power generation from the flood storage system.

3 LOWER THAMES RAIL ORBITAL

The cost of a twin-track rail orbital under the Lower Thames Estuary is substantially reduced by integrating the orbital construction with the impoundments and throttle of the flood defence system across Sea Reach. The twin tracks approach from the south on an embankment over the Stoke Marshes before they descend in an open-cutting to enter the portal of a cut-and-cover tunnel formed within the southwest impoundment over the Yantlet Flats. The tunnel descends within the impoundment to reach the south mole and throttle where two 180m lengths of immersed-tube tunnel, similar in scale to those of the Øresund Link, complete the connection under the main open tideway of Sea Reach to the north mole and northeast impoundment. Here the tunnel rises to run within the northeast impoundment across the Leigh Small Ships Anchorage, Leigh Channel and then passes under Ray Gut before rising within the impoundment to reach the shore at Southend. As a result, the 7.3km overall length of the Sea Reach Tunnel is formed from 6,940m of cut-and-cover construction integrated within the flood defence system leaving only 360m of immersed-tube construction under the open tideway. The immersed-tube tunnel accommodates a 2-platform Sea Reach Station with separate sections for fast through lines, a cycle superhighway and a promenade. Lifts and ramps within the moles each side connect the cycle superhighway and pedestrian thoroughfares on the impoundments with those under the tideway.

Where the northeast impoundment meets the sea wall at Southend the new flood barrier datum, cycle superhighway and promenade continue east along the sea wall to Marine Parade, which is already at an appropriate height and from where they provide emergency and maintenance vehicular access for the impoundment and throttle. A bridge carries the promenade and cycle superhighway across Ray Gut, with the central span formed by a lift bridge for navigation. The cut-and-cover rail tunnel on shore continues northwards beneath the Adventure Island funfair and the Western Esplanade to enter a 1,220m bored Southend Tunnel under Pier Hill and the High Street. This includes a 250m Southend Central underground station, between the junction of Alexandra Street and Heygate Avenue and the C2C railway bridge. The bored Southend Tunnel then rises to a portal on the west side of

Southend Victoria Station behind the Central Museum, from where the new tracks rise in a 900m open cutting to merge with the existing tracks to Shenfield just before the East Street bridge by Prittlewell Station.

From the south portal of Sea Reach Tunnel beside the Hoo shore, the twin-tracks of the rail orbital rise in a 300m open cutting protected by flood bunds to reach 5m chart datum level along the western field boundary of the Allhallows and Stoke Marshes and merge with the Isle of Grain Line. A new low-level Allhallows Station protected by flood bunds is provided to the northeast of Binney Road, which passes over the line. The new line continues at low level protected by flood bunds to pass beneath the A228 Grain Road and a redirected Burrows Lane by Middle Stoke.

From the Middle Stoke merge to Hoo Junction the 14.2km single-track Isle of Grain Line is dualled on the northside where for most of the way there is enough railway land to accommodate the additional track. West of Sharnal Street the existing bridges are already built to allow for twin-tracking. For the 5.5km from Allhallows Station to a new Kingsnorth Station on Stoke Road beside the former Beluncle Halt, the new and re-laid tracks are protected and screened by embankments raised on each side to 11m chart flood datum level. Spoil from construction of the Sea Reach and Southend Tunnels is used to extend the northwest embankment 60m inland from the new low-level twin tracks and form the site for the revisited Stoke Harbour Masterplan. At Cliffe, where the former station site has been redeveloped, a new station is provided on the west side of Station Road. At Hoo Junction, where the sidings and signalling are upgraded for the Crossrail extension to Gravesend, another new station is provided just west of the merge with the North Kent Line, bringing the total length of the Isle of Grain Line dualling works to 14.6km.

The twin-track Sea Reach and Southend Tunnels complete an orbital service between Gravesend in Kent and Shenfield in Essex with new stations at Hoo Junction, Cliffe, Stoke, Sea Reach and an underground connection at Southend Central to the C2C Services. The orbital link can start as an independent service using the same specification of rolling stock,

signalling and sidings at Hoo Junction as the projected extension of Crossrail from Abbey Wood to Gravesend. In due course the services can be merged to provide a Crossrail Orbital of the Lower Thames Estuary from Central London accompanied by an Essex-Kent Orbital service between Shenfield and Tonbridge formed by connecting the Medway Valley Line services from Strood through the tunnel to Shenfield. The Essex-Kent Orbital extends agglomeration benefits across the South East Local Enterprise Partnership (SELEP) region. 12.3km of new line across the Lower Thames Estuary completes a 132km Crossrail orbital of the Thames Estuary Region from the eastern limbs diverging at Whitechapel. The addition of a twin-track chord at Hoo Junction to incorporate the Medway Valley Line opens the 108km outer orbital service between Tonbridge in Kent and Shenfield in Essex. The opening of a new chord at Shenfield between the Southend Victoria Line and the Great Eastern Mainline extends the Essex-Kent orbital to provide 120km services between Chelmsford and Tonbridge making use of sidings at Brook Street beside the Chelmer and Tonbridge West Yard near to the Medway.

4 CYCLE SUPERHIGHWAY AND PROMENADE

Route 1 of the Sustrans National Cycle Network follows the North Sea Coast from Dover to Edinburgh and the Shetland Islands. To cross the Thames Estuary Route 1 diverts inland through London first running west on the south bank from Rochester, Gravesend, Dartford and Woolwich to pass through the Greenwich foot tunnel from where the route then heads north up the Lee Valley before returning east through Harlow and Chelmsford to Maldon on the Blackwater Estuary.

The rail orbital under the Thames Estuary is accompanied by a cycle superhighway that completes a direct link between the Medway Towns and Southend conurbation. The new 20.7km cycle superhighway connects Route 1 at Chattenden by the Medway Towns to Route 16 on the Western Esplanade at Southend and makes use of the existing Sustrans route 179 and the recently completed traffic-free extensions to the London Medway Commercial Park

together with the traffic-free cycle superhighway accompanying the rail orbital from the Amazon warehouse at Stoke to the Western Esplanade in Southend. Routes 16 and 13 from Southend, already being developed by Sustrans, complete a connection west then north to Route 1 at Chelmsford. The new connection from Route 1 at Chattenden to the Western Esplanade at Southend enables a more direct North Sea Coastal Route to be extended from Southend to Maldon that avoids the detour inland to London and opens a connection across the estuary. Renewable energy charging points along this new cycle superhighway support convenient and reliable commuting by bike and electric scooter between the Medway Towns and Southend conurbation.

The north and south impoundments also complete a new promenade between Southend, Allhallows and Lower Stoke with fine views over the estuary.

5 LONDON ESTUARY EXPRESS SERVICES

Once the Lower Thames Orbital is merged with Crossrail services and accompanied by an all-stops Essex-Kent Orbital the Crossrail services need only stop at Wickford, Southend Airport, Southend Central and Ebbsfleet to provide a Crossrail Orbital Express for the Lower Thames Estuary. The merging of services to form the Crossrail Orbital Express allows the rail depot and terminus at Southend Victoria to be designated for redevelopment. The existing connection to HS1 at Ebbsfleet provides a high-speed Javelin service between St. Pancras International and Southend Airport, with stops at Stratford, Ebbsfleet, Southend Central resulting in an overall journey time between West London and Southend Airport of 34 minutes. The combination of the Crossrail Orbital Express, Essex-Kent Orbital and London Estuary Express services unites the conurbations of Southend in Essex and the Medway Towns in Kent to provide agglomeration benefits across the Lower Thames Estuary into Essex, Kent and London embracing an area with a larger population than Greater Manchester.

6 EFFICIENT DATA STORAGE AND DISTRIBUTION

Where the northeast impoundment runs across the deeper waters of the Leigh Small Ships Anchorage and Leigh Channel voids within the impoundment accommodate a substantial, energy-efficient Tier 4 data storage and distribution centre of some 48,000sq.m floor area (over 500,000sq, ft): -

- the solar energy generated from the floating-array along with local wind power from the London Array provides a resilient and diverse stream of local, zero-carbon energy backed up by the National Grid
- the uniformly cool temperatures of the sea water provide efficient datacentre cooling loads throughout the year
- the wayleaves of the new rail connectivity, data storage and distribution centres extend across the Lower Thames Estuary into Essex, Kent and Central London to serve a region with over million households and associated businesses.

7 RAIL FREIGHT AND UTILITY CONNECTIONS

The new rail chord to the Great Eastern Mainline at Shenfield opens a 150km freight route along the eastern seaboard of England for night services between the ports of Felixstowe, Harwich and Thamesport that bypass congested routes into Central London.

The rail tunnel provides new utility wayleaves between Essex and Kent that improve the management, resilience and distribution of electricity, gas, mains water and communications.

8 CRUISE LINER TERMINAL, THAMES CLIPPER BERTH AND SOUTHEND MARINA

The northeast impoundment supports a deep-water, cruise liner terminal and Thames Clipper Berth close to the shipping channel and served by the new Sea Reach Station. The shorter voyage on the Lower Estuary and frequent rail services from the terminal enable more cruise lines to include London on their itineraries. The Thames Clipper Berth provides a convenient terminal for the extension of existing river services from Central London and Canary Wharf and opens an Outer Estuary service from Tilbury to Sheerness.

A stretch of the northeast impoundment close to the Sea Reach station accommodates a Southend Marina and alternative moorings for the Leigh Small Ships Anchorage.

9 HARBOUR FOR THE THAMES COCKLE FLEET

The cockle fleet currently operates from Leigh-on-Sea and their main cockle beds are in the shallows of the outer estuary off Foulness Island and the Dengie Peninsula. The silting of Leigh Creek and use of larger vessels is inhibiting the operations of the fleet, with access to Leigh-on-Sea maintained along Ray Gut. However, the northeast impoundment can also provide deep moorings for the Thames Cockle Fleet where the vessels will be served by the Sea Reach Station and be closer to their main cockle beds to the north, around the Essex Coast.

10 SUSTAINABLE RESIDENTIAL AND COMMERCIAL DEVELOPMENT

The integrated infrastructure of the Metrotidal Lower Thames Orbital, including the extension to the Sustrans network, stimulates and supports sustainable residential development for over 100,000 new homes and associated businesses across the Lower Thames Estuary into Essex and Kent by providing: -

- the additional 172.5sq.km area of land protected from surge-tide flood risk
- the reduced insurance premia for development of this land
- the improved connectivity of the rail orbital services, cycle superhighway and promenade
- the zero-carbon energy, data storage, distribution and utilities required for the new homes and businesses

The sustainable development is focused around existing and proposed railway stations including the locations of the revisited Stoke Harbour Masterplan on the Hoo Peninsula, the Ebbsfleet Garden City Masterplan, Peters Village on the Medway and other substantial residential development sites. The new rail orbitals and cycle superhighway also serve significant commercial growth zones at Southend Airport, Southend Victoria, the Isle of Grain, the London Medway Commercial Park and Hoo Junction with a combined commercial development area of 6.0 sq.km. The radically improved connectivity of the rail orbital and cycle superhighway allows the 100,000 new homes to be distributed widely across the Lower Thames Estuary with only a modest proportion developed on the Hoo Peninsula. 11.5km of pylons between the Isle of Grain and Kingsnorth are replaced by a 9km undersea cable along the Medway Estuary. The marshlands are conserved for recreational use with new housing integrated along the line of the infrastructure orbital to reduce the costs and impacts while increasing the resilience to flooding.

11 THE REVISITED STOKE HARBOUR MASTERPLAN

The Stoke Harbour Masterplan by Shelter won a Wolfson Economics Prize in 2014. The masterplan envisaged a polycentric New Garden City with a population of 150,000 on the Hoo Peninsula seeded by Stoke Harbour, a self-sufficient new town of 35,000-48,000 people on the shore of the Medway Estuary. The Metrotidal Lower Thames Orbital provides the transport, renewable energy generation and data infrastructure for the polycentric development to be distributed over a much wider area around existing foci across the Lower Thames Estuary. Within this wider network the Hoo Peninsula provides a more modest contribution of housing around the new stations at Hoo Junction, Cliffe, Kingsnorth and Allhallows. Greater emphasis is then placed on conserving the existing Hoo Peninsula historic landscapes for recreational use by the growing population of the Lower Thames Estuary region, with access provided by the rail orbital and cycle superhighway.

Since 2014 development has proceeded at pace on the London Medway Commercial Park with the opening of new distribution centres including the substantial Amazon depot, creating new employment that adds to the case for a modest band of residential development along the shore of the Medway Estuary. Here the Metrotidal Lower Thames Orbital runs at low level protected by flood bunds, the existing pylons and overhead cables are replaced by an undersea cable and 60m wide strips of land are raised to 11m flood datum on the northwest side of the orbital using spoil from the tunnel construction to create 4No. residential development sites overlooking the estuary with a combined length of 3km. Their overall area of 18 hectares developed to 250 habitable rooms per hectare provides accommodation for up to 6,000 people in four phases of construction. The integration of housing along the orbital forms a linear settlement between the new stations at Kingsnorth and Allhallows in which all the homes have direct access to the new stations, renewable power generation, data networks and the cycle superhighway.

12 CORE METROTIDAL SCHEME AND SUBSEQUENT COMPONENTS

The core Metrotidal scheme integrates the first phase for the next generation of London's flood defences with the new twin-track rail orbital providing independent services between Gravesend and Shenfield via Southend Central. The subsequent upgrades to the flood defence system and the integration of the rail orbital with Crossrail and other services follow as independent phases as and when required, along with the additional components of the integration. Accordingly, the preliminary estimated budget of the integrated infrastructure is assessed in two parts, for the core scheme and for the subsequent components.

Core Scheme: -

Flood defence

- Passive open-throttle channels and moles in the tideway
- Southwest and Northeast impoundments
- Ray Gut passive open channels
- 9m flood bund from Lower Stoke to the southwest impoundment
- 9m flood bund around Adventure Island to Marine Parade

Rail Orbital

- Dualling of the Isle of Grain Line from Hoo Junction to Lower Stoke without stations
- Sea Reach Tunnel and approaches without stations
- Southend Tunnel and approaches with Southend Central underground station
- Signalling for rail services between Gravesend and Shenfield
- Closure and sale of Southend Victoria Station for redevelopment

Land Take

- Dualling of the Isle of Grain Line occurs within existing Network Rail sites
- Corridor required from Lower Stoke to the sea wall at Allhallows
- Sea Reach Tunnel site across the tideway owned by the Crown Estate
- Southend Tunnel site under the north bank owned by Southend BC
- Southend Victoria owned by Network Rail
- The route crosses and passes under fewer than 30No. freeholds

Subsequent Components: -

Flood defence

- Extension of riverbed scour resistance, as required by rising sea levels
- Chapman Sands intertidal flood storage to reduce tidal ranges and peak flow rates
- Tidal gates to close Ray Gut when required by rising sea levels
- Tidal gates to close the two 60m channels when required by rising sea levels
- Sector gates to close the main channel when required by rising sea levels
- Raising of the flood barrier datum as required by rising sea levels in the 22nd century

Renewable energy generation

- 4.0sq.km floating solar array with grid connection
- Wind turbines mounted on the moles and impoundments
- Tidal power from the flood storage

Cycle Superhighway and Promenade

- Completing the Sustrans Route 1 between Rochester, Chelmsford and Maldon

Rail Orbital

- New stations along the line including Sea Reach Station
- Merging services with Crossrail
- HS1 high-speed services extension
- Essex-Kent orbital services
- Freight services

Data Storage and Distribution

Utilities

Southend Marina

Relocation of the Cockle Fleet

Ferry Services

Removal of pylons

Revisited Stoke Harbour Masterplan

Sustainable Residential development

Sustainable Commercial development

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