ABP Lowestoft

Lake Lothing Third Crossing

Overview of CTV Characteristics

February 2019





Innovative Thinking - Sustainable Solutions

Page intentionally left blank

Lake Lothing Third Crossing

Overview of CTV Characteristics

February 2019

Document Information

Document History and Authorisation		
Title	Lake Lothing Third Crossing	
	Overview of CTV Characteristics	
Commissioned by	ABP Lowestoft	
Issue date	February 2019	
Document ref	R.3006	
Project no	R/4566/02	
Date	**Version**	**Revision Details**
21/02/2019	1	Issued for Client Use

Prepared	Approved	Authorised
A J Brooks	M J Smedley	N J Kitson
[redacted]	[redacted]	[redacted]

Suggested Citation

ABPmer, (2019). Lake Lothing Third Crossing, Overview of CTV Characteristics, ABPmer Report No. R.3006.
A report produced by ABPmer for ABP Lowestoft, February 2019.

Contributing Authors

Anthony Brooks, Monty Smedley, Adam Fitzpatrick, Nick Kitson.

ABPmer
Quayside Suite, Medina Chambers, Town Quay, Southampton, Hampshire SO14 2AQ
T: +44 (0) 2380 711844 W: http://www.abpmer.co.uk/

About ABPmer

ABPmer has 65 years port related research and consultancy experience, and appreciates that the successful design and operation of ports, harbours and wharfs is dependent on understanding both the marine environment and port operational requirements. ABPmer provides an independent port consultancy service, using the combined expertise of its diverse team to deliver services across a range of disciplines including: marine engineering, port design, safety, management, compliance audits, marine scientific services (biology, oceanography, geomorphology, hydrography) and data management. By integrating our capabilities, we deliver a tailor-made service to our clients. ABPmer employs 50 staff, located in offices in Southampton. All our work is undertaken in accordance with our Quality Management System certified to ISO 9001:2015 for the delivery of Environmental Consultancy and Research Services.

Authors

Anthony Brooks (PhD, MIMarEST, CSci, CMarSci, CEnv) is a marine physical processes and offshore wind specialist with expertise in offshore, coastal and estuarine environments. He provides technical input to a wide variety of projects, including offshore wind, tidal power and port developments, and has been providing Masterplanning support for ABP since 2017. During this time, Tony has co-authored the Lowestoft masterplan, providing an understanding of ports, trades and long-term drivers of change. Tony is also a marine climate change specialist, providing support and technical input to investigations considering potential climate change impacts. Tony has more than a 10 years' experience, is a Chartered Marine Scientist and a Chartered Environmentalist. Tony has co-authored this report.

Monty Smedley (BSc) is a Principal Maritime Consultant with over 20 years' experience working as a consultant on port and navigation studies. He leads on ABPmer's navigation and marine risk studies, and is a Lead Auditor for Port Marine Safety Code compliance projects. Monty has managed a wide range of marine risk management studies including implementation of an ABP Group wide risk assessment and accident/incident reporting system, Stena Line Ports compliance audits, developing navigational guidelines, pilotage manuals and developing a reporting system for marine accident/incident. Monty is a graduate of Southampton Institute who studied at Warsash Maritime Academy, with a degree in Maritime Studies. In addition, Monty is also an experienced Sea Kayak Coach and a recreational yachtsman with a practical understanding of the water sports industry. Monty has co-authored this report.

Adam Fitzpatrick (BSc, MNI) is a Senior Maritime Consultant; an experienced mariner with operational knowledge of a range of ship and boat handling aspects. Adam was previously the Chief Officer for a towage company with responsibility for safety of operations, passage planning, maintaining a navigational watch and ensuring compliance with state and international regulations. Adam was also previously a deck officer for Carnival UK; during this period, he was responsible for passage planning, emergency response, ship operation, navigation and ship stability. Adam also completed training with the Royal Navy as an officer based at Britannia Royal Naval College, Dartmouth; including sea time on the aircraft carrier HMS Ark Royal. Adam has co-authored this report.

Nick Kitson (IEng, MIET) is Head of Operations at ABPmer and has over thirty years' experience in modelling port, coastal and riverine processes and hydraulic structures and the collection and analysis of field data. Having managed projects on wave overtopping, sea defence stability, the hydraulic efficiency of marine structures and forces on floating bodies Nick has also managed and participated in ABPmer's contributions to a number of European research projects considering port environmental issues. Nick is responsible for the development and maintenance of the Company's Quality Management programme, which is certified to ISO 9001:2015 and which includes the development of quality and risk management control techniques for use in ABPmer's project delivery. Nick is qualified in mechanical engineering, is currently a member of the Institution of Engineering Technology and has served as a member of the BSI technical committee for standards in marine renewable energy. Nick is the Project Director and final signatory for this report.

Contents

Tables

Figures

1 Background

The Lake Lothing Third Crossing (LLTC) Bridge has been proposed by Suffolk County Council (SCC) as a way of alleviating transport problems in Lowestoft. The Promoter's preferred option is a bascule bridge across the Inner Harbour, with a water level to bridge underside clearance of 12 m above Highest Astronomical Tide (HAT) at the mid-section of the bridge. With the bridge in place, ABP anticipates potentially adverse implications for port operations. Specifically, that future, wind energy customers will be unwilling to take port berths to the west of the proposed LLTC Bridge, particularly for Crew Transfer Vessels (CTVs) that are typically involved in time-critical wind farm operations associated with developments off the coast of East Anglia (Figure 1).

However, a new bridge only has the potential to be detrimental to CTV movements if bridge openings are required to allow CTVs to pass through, thereby adding time (and cost) to each journey. Accordingly, an understanding of CTV air draught requirements (including margins of safety) is an important component of ABP's future business strategy.

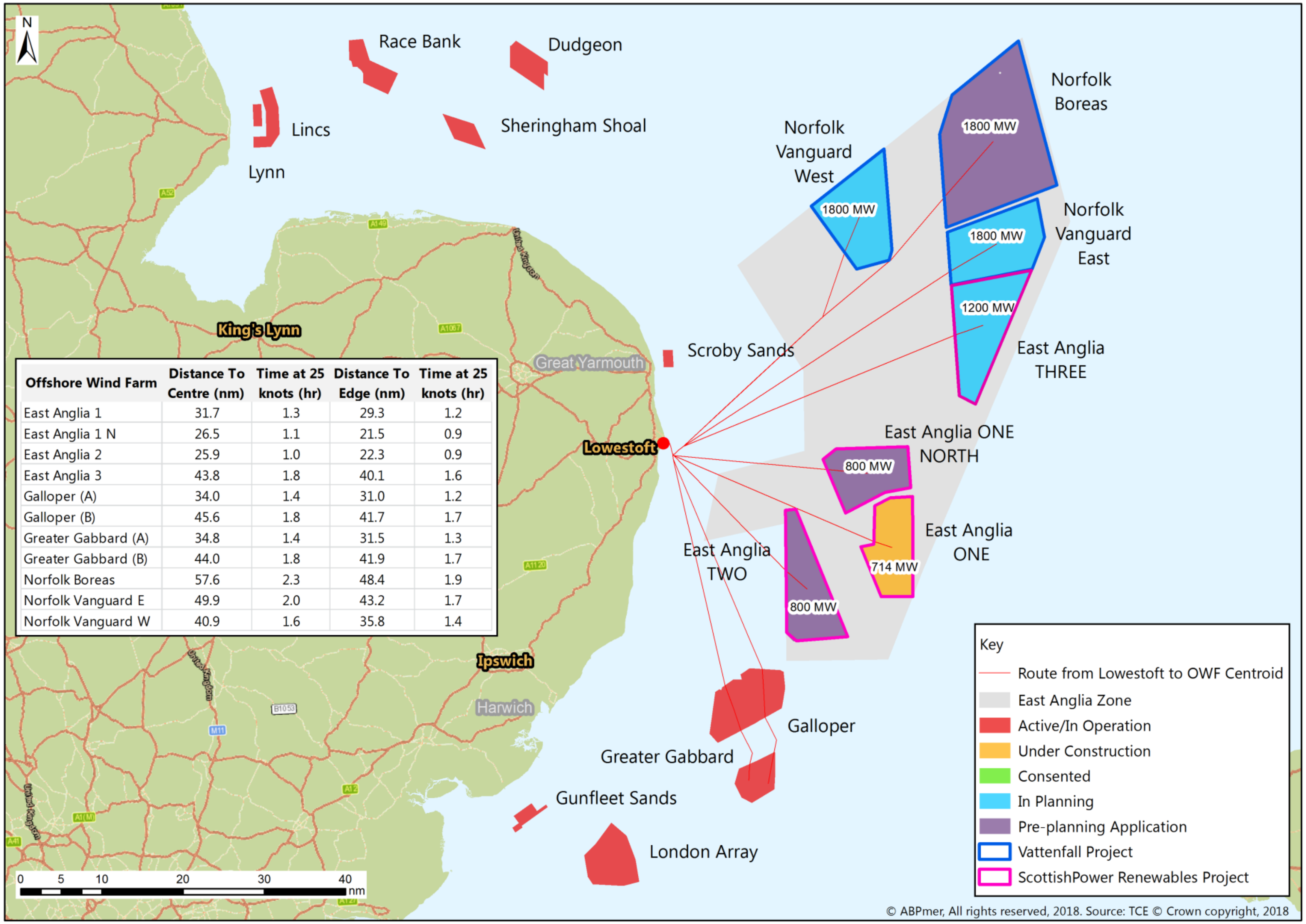
1.1 Study purpose

This study has been commissioned by ABP Lowestoft to answer the following specific questions:

- What is the air draught requirement(s) of the CTVs in use now at Lowestoft?
- What are realistic assumptions about CTV (or other future similar vessel) air draughts that could realistically work out of ABP Lowestoft over the next two or three decades (i.e. in a possible context of increasing vessel size and changing height/air draught requirements)?
- Are there other factors which may require the bridge to be lifted – for example, tidal considerations; i.e. 'could a 15 m length overall (LOA) CTV transit without a bridge lift' etc.)?

Each of these questions is addressed in subsequent Sections of this report. In considering the purpose of the study, this report is structured as follows:

Section 2	Describes the water level variation at Lowestoft;
Section 3	Introduces the concepts of Air Draught (AD) and Air Draught Clearance (ADC);
Section 4	Discusses the current ADC requirements for CTVs using Lowestoft;
Section 5	Considers factors affecting the future ADC requirements for CTVs based out of Lowestoft;
Section 6	Investigates other factors that may influence the requirements for bridge lifting; and
Section 7	Summarises the Conclusions from this study.



Offshore Wind Farm	Distance To Centre (nm)	Time at 25 knots (hr)	Distance To Edge (nm)	Time at 25 knots (hr)
East Anglia 1	31.7	1.3	29.3	1.2
East Anglia 1 N	26.5	1.1	21.5	0.9
East Anglia 2	25.9	1.0	22.3	0.9
East Anglia 3	43.8	1.8	40.1	1.6
Galloper (A)	34.0	1.4	31.0	1.2
Galloper (B)	45.6	1.8	41.7	1.7
Greater Gabbard (A)	34.8	1.4	31.5	1.3
Greater Gabbard (B)	44.0	1.8	41.9	1.7
Norfolk Boreas	57.6	2.3	48.4	1.9
Norfolk Vanguard E	49.9	2.0	43.2	1.7
Norfolk Vanguard W	40.9	1.6	35.8	1.4

Figure 1. Planned and operational wind farms off the coast of East Anglia

2 Factors Influencing Local Water Levels

With a fixed-elevation structure, such as the proposed LLTC bridge, the vertical clearance for vessels transiting beneath the crossing will be strongly influenced by the elevation of the water level within Lake Lothing.

2.1 Water Levels at Lowestoft

The Port of Lowestoft is situated on the East Anglia coastline within the Southern North Sea. At any point in time, the water level height at Lowestoft is the sum of the astronomical tidal level, and a residual (non-tidal) component, which is caused by meteorological forcing[1]. This Section summarises the characteristics of the tidal height, expressed as 'water level', and the way in which this information has been used to inform CTV operation and the subsequent assessment of the need for LLTC bridge openings.

2.2 Tidal level and phasing

Table 1 summarises a range of statistically predicted tidal levels for Lowestoft, taken from the 2018 Admiralty tide tables (UKHO, 2018). These water levels constitute the astronomically influenced element of the tide and so do not include any potential contribution from non-tidal (meteorological) influences. The tidal cycle at Lowestoft is described as semi-diurnal (meaning the tide comes in and goes out twice a day). A semi-diurnal tide is typically six hours from low water to high water (the 'flood tide') and a further six hours from high water to low water (the 'ebb tide').

Tides are created by the gravitational attraction of the moon and sun; the magnitude of the attraction depending on the relative distances, from earth, of the moon and the sun. The position of the moon is the most influential component of this process. When the sun and moon are aligned their respective gravitational forces act in combination, and the tidal range is at its greatest, termed 'spring' tides. As the sun and moon move out of alignment, the tidal range reduces to its lowest point, termed 'neap' tides. The mean spring tidal range at Lowestoft is 1.9 m and the mean neap tidal range is 1.1 m (Table 1).

Table 1. Tidal levels at Lowestoft

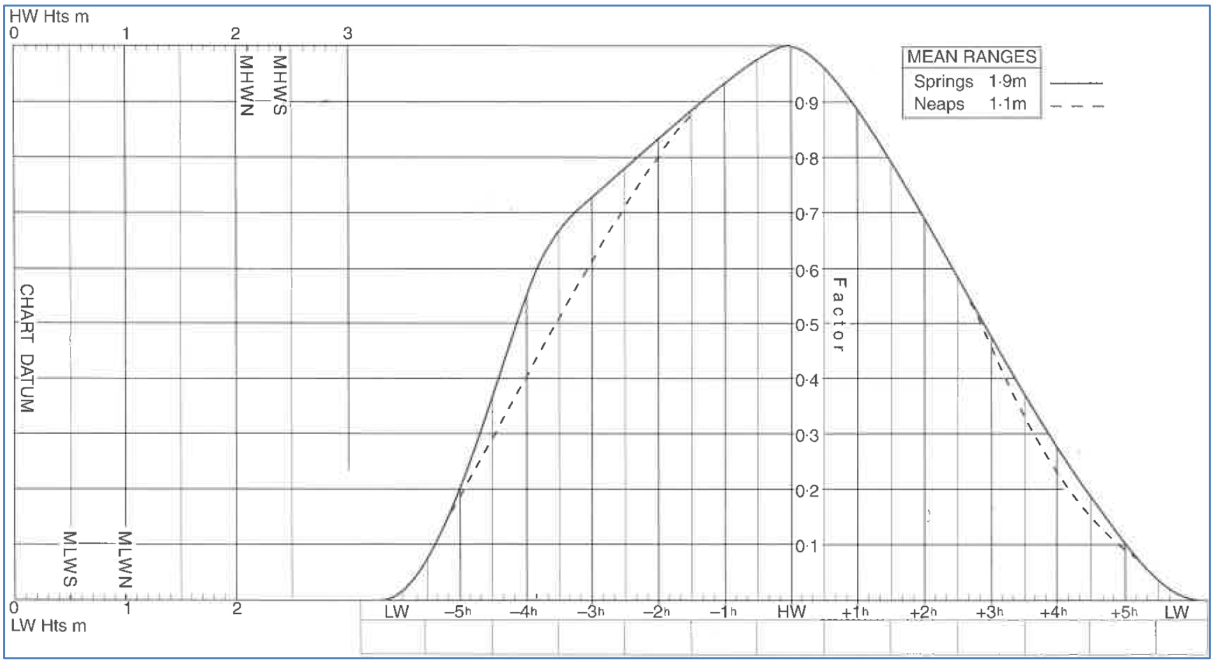
Tidal Level		Lowestoft	
		mCD	mODN
Highest Astronomical Tide	HAT	2.9	1.4
Mean High Water Springs	MHWS	2.4	0.9
Mean High Water Neaps	MHWN	2.1	0.6
Mean Sea Level	MSL	1.7	0.2
Mean Low Water Neaps	MLWN	1.0	-0.5
Mean Low Water Springs	MLWS	0.5	-1.0
Lowest Astronomical Tide	LAT	0.1	-1.4
Mean Spring Tidal Range	(MHWS–MLWS)	1.9 m	
Mean Neap Tidal Range	(MHWN-MLWN)	1.1 m	
Astronomical Tidal Range	(HAT-LAT)	2.8 m	
Note: Conversion from mCD to mODN at Lowestoft = -1.50 m.			

Source: UKHO, 2018

[1] Meteorological forcing is the combined influence of prevailing atmospheric pressure and wind speed effects.

The relatively modest tidal range at Lowestoft (of 1.9 m at mean Spring tide) is due to its geographic proximity to an amphidromic point (this is a point in the sea at which there is no tidal range). The proximity of Lowestoft to an amphidromic point also contributes to the phasing of the tide, where the tide level increases and decreases (rises and falls) relatively slowly, within the tidal range. The tidal curve for Lowestoft is presented in Figure 2, which illustrates that the tide curve is almost symmetrical (comparing the shapes of the flood and ebb tidal phases) about high water on neap tides, but asymmetric on spring tides. During a spring tide, the flood (incoming) tide rises quickly at first and then slows, and can be seen as a small bulge on the rising tide curve, see Figure 2. A consequence of this asymmetry is a longer period of higher water levels at Lowestoft during spring tides.

The relatively modest tidal range observed at Lowestoft results in longer periods of higher water levels within Lake Lothing. For example; based on the range between the highest and lowest astronomical tides (HAT and LAT), a water level of at least 1.5 m above Chart Datum (CD) can be expected to occur for up to 7.5 hours within each tidal cycle. This is approximately the period between 4.5 hours before and 3 hours after high water (see Figure 2), or around 60% of each tidal cycle.



Source: UKHO, 2018

Figure 2. Predicted tidal curve for Lowestoft

2.3 Difference between observed and predicted water levels

Observed tidal water levels generally have an additional contribution from non-tidal influences, which introduce a difference from the predicted water level. This is often termed the 'tidal residual' and can be positive or negative, thereby providing observed water levels that are higher or lower than the predicted water level. The co-timing of the tidal and residual contributions to water level is important, as a positive residual in conjunction with a high tidal level will result in a high-water level which could exceed the elevation of HAT (defined in Table 1).

To consider the relative influence of the tidal residuals within Lake Lothing, observed water levels for the period between 1964 and 2018 have been obtained from the National Tidal and Sea Level Facility (NTSLF) tide gauge at Lowestoft, and analysed. Summary statistics of the observed water levels over the 54-year period are provided in Table 2, which illustrate the combined effect of non-tidal influences on the resultant water levels within the Port.

Table 2. Water level statistics, based on observed-predicted water levels at Lowestoft, between January 1964 and March 2018

Event	Date / Time (UTC)	Predicted tidal level (mCD)	Observed water level (mCD)	Residual tide (m)
Maximum observed water level	05/12/2013 22:00	2.56	4.74	2.18
Minimum observed water level	03/11/1979 15:00	0.42	-0.92	-1.34
Maximum observed tidal residual	14/02/1989 08:00	1.18	3.69	2.51
Minimum observed tidal residua	19/12/1982 15:00	1.54	-0.40	-1.94
Average residual tide (m)	0.15			
Residual: 10th Percentile (m)	0.01			
Residual: 50th Percentile (m)	0.11			
Residual: 90th Percentile (m)	0.33			

The NTSLF water level records for Lowestoft indicate that an observed HW elevation equivalent to the MHWS tidal level (2.4 mCD) was exceeded on 13,775 tides over the full record (approximately 37% of the observed tides; and an average of 262 tides per year). Meanwhile, an observed HW elevation equivalent to the HAT level (2.9 mCD) was exceeded on 914 tides (approx. 2.5% of the tides on record; and an average of 17 tides per year). In respect of residual water levels, a residual value of at least 1 m (either positive or negative) occurred during 287 tides over the full record, which is 0.8% of the tides measured during the 54-year observation period.

The above exceedances clearly illustrate that non-tidal contributions can have a considerable effect on water levels at the port, resulting in observed levels substantially higher than the predicted HAT elevation. The influence of these non-tidal contributions at Lowestoft is much greater, in relative significance, than for an area with a larger tidal range.

2.4 Climate change, sea level rise and storminess

It is now widely accepted that climatic change will cause a continuing increase in future mean sea level. Information on the rate and magnitude of anticipated relative sea-level change at Lowestoft during the 21st Century is available from the UK Climate Impacts Programme (UKCP09) (Lowe et al., 2009). The findings of the programme suggest that mean sea-level at Lowestoft will have risen between 0.41 and 0.58 m above 1990 levels by 2100, (based on the 50th percentile estimate of the low and high emissions scenarios[2], respectively), with the rates of change increasing during the second half of the 21st Century (Lowe et al., 2009).

In terms of storminess (which has the potential to increase the frequency and magnitude of non-tidal surge water levels), the UKCP09 report indicates there is no statistically significant increase in predicted storminess over the next century (Lowe et al., 2009). However, it is noted that there are very high levels of uncertainty associated with this prediction.

2 This range of sea-level rise projections, from UKCP09, is approximately equivalent to the 50th percentile estimates for the RCP2.6 and RCP4.5 scenarios assessed in the recently updated UK Climate Projections 2018 (UKCP18) study (Palmer, *et al*., 2018) (https://www.metoffice.gov.uk/research/collaboration/ukcp/about)

3 Air Draught and Air Draught Clearance

This Section introduces the concepts of Air Draught and Air Draught Clearance, and their relevance to the required vertical clearance for vessels passing under an overhead obstruction. To provide clearance for vessels to proceed without the need for bridge opening, a vessel's air draught must be considered.

3.1 Vessel air draught

Vessel air draught is defined as the height of the vessel, measured from the sea or water surface to the highest point of the vessel (typically the top of the mast, antenna or aerials). The sea or water surface is defined as the highest navigable water level. Air draught is variable, as it alters according to the vessel's loaded state as well as other factors such as water density. Therefore, there should always be a positive Air Draught Clearance (ADC) to provide the necessary margin of safety. Further information on ADC is presented in Section 3.2 of this Report.

The general arrangement for a CTV is shown in Figure 3; the wheel house (also termed the Coach House) is the upper-most structure, from which the vessel is navigated. This will typically have a mast with navigational equipment affixed. These masts may be collapsible, although the ease with which this can be done varies between craft. Finally, large MF/HF/VHF antenna (referred to in the industry as 'whip aerials') may also add yet further height to the vessel. Accordingly, in collating vessel information for the purposes of this study, information on both superstructure height as well as aerial height is cited, where available.

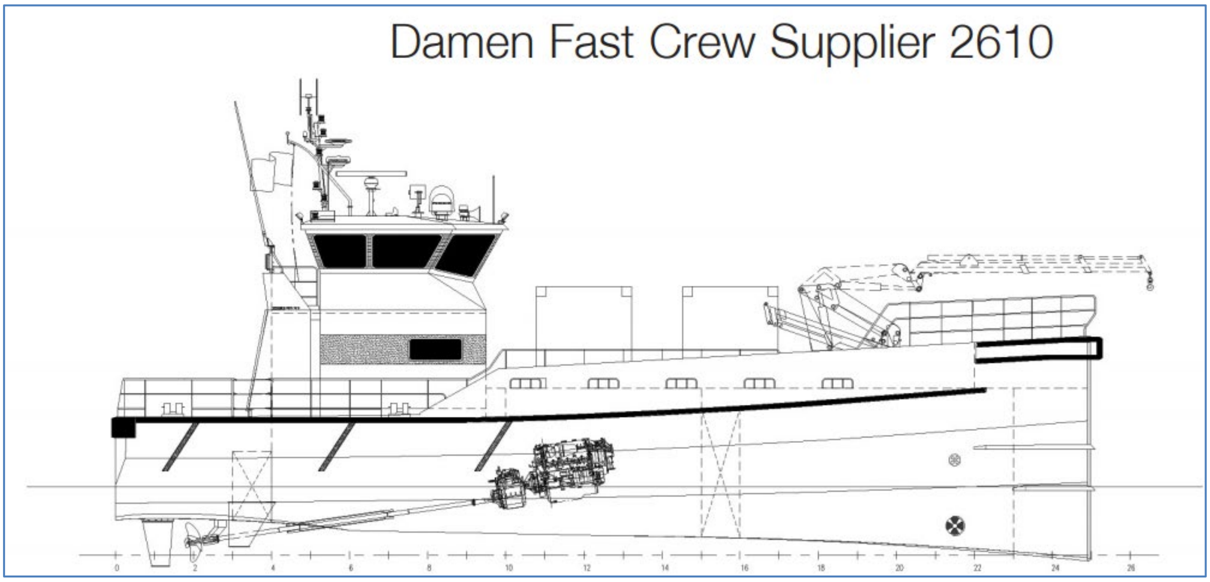


Figure 3. General arangement of a CTV: MarineCo Mariah CTV (26 m LOA) – Used in Galloper OWF and based out of Shell Quay, Lowestoft

3.2 Air draught clearance (ADC)

In a similar manner to determining under keel clearance (UKC) a safe value of air draught clearance (ADC) needs to be considered, in conjunction with the vessel's maximum air draught requirement, to determine the required vertical clearance under the bridge. Figure 4 illustrates these concepts schematically.

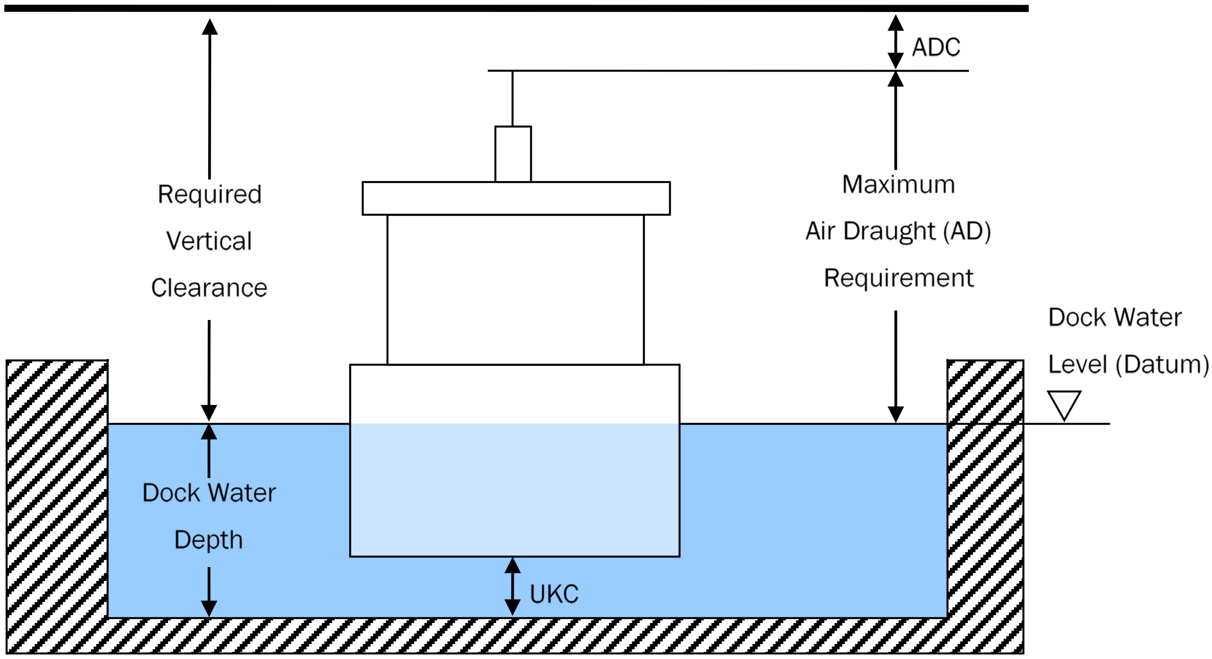


Figure 4. Conceptual Model for Air Draught (AD) and Air Draught Clearance (ADC)

Guidance and recommendations for the design of vertical and horizontal dimensions of harbour approach channels, manoeuvring and anchorage areas within harbours, can be found in the PIANC publication 'Harbour Approach Channels Design Guidelines' (PIANC, 2014)'. This publication provides information on establishing depth and width requirements for navigational channels, including overhead obstructions and appropriate air draught clearances. The publication is considered best practice and provides expert guidance and state of the art knowledge on this subject.

To derive ADC, the vessel should be considered in its lightest load (presenting the worst-case scenario). The PIANC guidance (PIANC, 2014) identifies that the clearance between the top of the vessel and the bottom of the overhead structure should be equal to, or greater than, 5% of the air draught, but not less than 2 m for 'inner channels'. For 'outer channels', where wave conditions are a significant factor, an additional allowance should be included.

At the time of writing, SCC's plans identify a proposed vertical clearance to the underside of the LLTC bridge of 12.0 m above HAT (equivalent to 14.9 m above CD). If adopted, this would provide the following air draught restrictions for vessel transit, without the need for a bridge lift:

- 11.0 m over HAT, with an ADC of 1 m; and
- 10.0 m over HAT, with an ADC of 2 m.

The use of an ADC of 2 m (or greater, for larger vessels) is typically applied when there is potential for the ships' superstructure (bridge, funnel etc.) to contact a fixed overhead obstruction.

In the case of CTVs, the upper most part of the vessel will be the mast (with navigational lights, aerials and other navigational equipment). It should be noted, that whilst these aerials and antenna may seem flexible, it is highly undesirable for them to contact an overhead structure as any damage to equipment may mean the vessel is unable to communicate effectively or navigational equipment may lose positional accuracy. This may mean the vessel cannot proceed safely to sea. In determining the ADC, it is also important to consider the likely sea surface condition (wave activity and variance of the actual tide from the predicted tide). The PIANC guidance (PIANC, 2014) recognises these uncertainties in its recommendations of ADC.

An assessment of the bridge lifting requirements for passage of CTVs at Lowestoft, is considered in the remaining Sections of this Report. The calculation of bridge lift requirements, as a function of CTV air draught, remains very sensitive to changes in air draught (particularly in the range of 11 to 13 m), as described in Section 5.

The navigational risk assessment will need to fully address ADC in forming its conclusion.

4 Air Draught Requirements of CTVs Currently in Use at Lowestoft

A number of offshore wind farm operations involving the use of CTVs are based out of Lowestoft. These CTVs are operated by marine service providers who either own or lease vessels, according to demand. As such, it is the case that a wide range of different CTVs will use the port over the course of a given year. Existing CTV operations based out of the port are briefly summarised below.

CTVs in use: Lowestoft Outer Harbour

- **East Anglia ONE** (Scottish Power Renewables): Construction coordination/ O&M base - Hamilton Dock. Support contract awarded to Turner Iceni, with operations beginning in 2018. Guaranteed provision of six berths to Scottish Power Renewables. It is understood that Turner Iceni anticipate using 23 m Length overall (LOA) CTVs, such as the Iceni Vengeance, which have an air draught of 11.6 m to the top of the Direction Finding (DF) aerial and whip aerials >11.6 m (Table 3).
- **Greater Gabbard** (SSE): O&M base - Waveney Dock/ Trawl Dock. 10-15 CTVs in regular use, with six of these associated with re-grouting work being undertaken by ENGIE Fabricom. It is understood that the variety of CTVs typically in use by GGOWL, which includes some from Windcat Workboats, are *circa* 18-25 m in length. It is also understood that none of the Windcat vessels have air draughts exceeding 12 m (Table 3).

CTVs in use: Lowestoft Inner Harbour

- **Galloper** (various partners, including RWE Innogy): Construction coordination base – Shell Quay. Support contract awarded to James Fisher Marine Services, with operations undertaken 2016-2018. Most Galloper vessels now operate from Harwich, although a small number of vessels continue to operate from Shell Quay during summer months, when vessel numbers outweigh current berth availability at Harwich. CTVs typically in use are *circa* 20–25 m in length, such as the 25.75 m MarineCo Mariah which has an air draught of 10 m (to the top of the mast, with aerials down; 15 m with whip aerials up).

CTVs in use: North Sea Region

- The vast majority of CTVs currently servicing the OWF market are in the range 15 to 25 m LOA and the majority of these have air draughts less than 12 m. Some larger CTVs (e.g. 23 m+), which are increasingly being used to service further offshore (Round 3) wind farms, have masts supporting navigational equipment which exceed 12 m air draught.

A summary of the air draught characteristics of various larger CTVs currently servicing the North Sea offshore wind market, is provided in Table 3.

Table 3. Summary of air draught characteristics for larger CTVs currently serving the North Sea offshore wind market

Builder/ Operator	Contact Details	Vessel Name	LOA (m)	Beam (m)	Draught (m)	Air Draught (m) [superstructure]	Air Draught (m) [aerial/mast]	Comment
Aluminium Marine Consultants (AMC) (Builder)	http://www.aluminium-boats.com	Typhoon TOW Hurricane TOW	25.0	8.2	1.45	8.0	9-10	[Supply vessels to (amongst others) Mainproze Offshore Ltd]
South Boats/ Alicat (Builder)	http://www.southboatsiow.com/vessels/ [Richard Howes/ Ben Colman]	[Typhoon class]	26.0			7.8 (top of wheel house roof)	12.5 (Top of highest aerial = 15.2 m above waterline)	[Supply vessels to (amongst others) Turbine Transfers Ltd, Seacat Services and Turner ICENI]
Strategic Marine (Builder)	http://www.strategicmarine.com/ [Hans Randklev]	Njord StratCat	26.0	9.2	1.6	*c.* 8.0 (top of wheel house roof)	12.5 (Top of mast)	[Supply vessels to (amongst others) Mainproze Offshore Ltd, SureWind Marine Ltd and EMS Maritime Offshore GmbH]
PIRIOU	http://www.piriou.com/index.php [Sylvain Montels]	[WFSV 26 P/W]	27.4	8.0	1.45	8.0 (Top of wheel house)	12.5 (Top of mast) MF/HF antenna 16.4 m	
Windcat (Builder/ Operator)	http://www.windcatworkboats.com/ [Neil Clarkson]	-	-	-	-	<12.0	<12	[All Windcat vessels have an air draught of less than 12 m]
Mainprize Offshore Ltd (Operator)	http://www.mainprizeoffshore.co.uk/ [Andrew Sellers]	MO3 built by Strategic Marine)	26.0	11.2	2.16	-	12 (>12 m with whip aerials)	In theory, aerials and masts can fold down but difficult and not really designed to do this. Mainprize have supplied designs to Manor and Carlene boat charters who have built MO3, MO4 and MO5 equivalents
		MO5	26.0	-	-	-	12 (>12 m with whip aerials)	(Very similar air draught to MO3)
Turbine Transfers (Operator)	http://www.turbinetransfers.co.uk/	Bull Bay (built by Austal)	27.0	7.85	1.6	-	13.1	Mast can be dropped down although may involve crane etc.
		Cemlyn Bay (built by South Boats)	25.0	8.0	1.2	-	11.5 (Whip aerial c.1-2 m above 11.5 m)	

Builder/ Operator	Contact Details	Vessel Name	LOA (m)	Beam (m)	Draught (m)	Air Draught (m) [superstructure]	Air Draught (m) [aerial/mast]	Comment
Vroon Offshore Services (formerly MPI) (Operator)	http://www.mpi-offshore.com/workboats-fleet/ [David Leckie]	Snowball (PIRIOU)	22.0	7.0	1.1	*c.* 6.3 (Top of wheel house roof), estimated.	c. 9.3 (Top of mast), estimated.	
Seacat Services (Operator)	http://www.seacatservices.co.uk/	Seacat Freedom (built by South Boats)	23.2	7.7	1.2	*c.* 6.8 (top of wheel house roof), estimated.	c. 11.2 (Top of mast; 14.9 m Top of whip aerial), estimated.	
SureWind Marine Ltd (Operator)	http://www.surewindmarine.com/	Sure Dynamic (built by Strategic Marine)	26.2	8.9	1.8	*c.* 8.0 (top of wheel house roof)	*c.* 12.5 (Top of mast)	[Same as Njord StratCat]
EMS Maritime Offshore GmbH (Operator)	http://www.offshoreservice.de/en/about-us/company-partners/	Windea 4 (built by Strategic Marine)	27.5	8.9	1.6	*c.* 8.0 (top of wheel house roof)	*c.* 12.5 (Top of mast)	[Same as Njord StratCat]
MarineCo	http://mcouk.com/our-fleet-summary/ [Andy Banks]	Mariah (built by Damen)	25.75	10.4	2.2	5.0 (top of coach roof)	10 (to top of mast, with aerials down) 15 m (with whip aerials up)	
Turner ICENI (Operator)	http://www.icenimarine.co.uk/ (Owen Nutt)	ICENI Conquest (built by Alicat)	21.0	7.66	1.1	7.0 (top of wheel house roof)	11	
		ICENI Vengeance (built by South Boats)	23.0	8.0	1.5	7.1 (top of wheel house roof)	11.6 (to top of DF aerial) >11.6 (with whip aerials up)	

Red = would require bridge opening at certain tidal states
Amber = may require bridge opening at certain tidal states, depending on specified safety clearance margin
Green = would not require bridge opening at any tidal state

5 Future Assumptions About CTV Air Draughts

Windfarms are being built increasingly further offshore and as these distances have increased, so too has the overall size of CTVs being used in operations. This largely reflects a requirement for greater sea-keeping characteristics in (usually rougher) offshore waters, rather than a need for greater personnel carrying capacity, since vessels of this type are currently restricted to a maximum of 12 passengers. For Round 3 projects (such as East Anglia ONE) the CTVs now in use are generally in the range 20-25 m, with some vessels on the market now approaching 30 m LOA (e.g. WINDEA 4, operated by EMS Maritime Offshore GmbH). Conversely, earlier (smaller) Round 1 projects (generally built closer to shore) more typically made use of smaller vessels (*c.* 15-20 m LOA).

There is not a straightforward relationship between vessel length and air draught, not least because coach house size may sometimes remain fixed, with only hull length/ beam increasing. However, in general terms, increases in CTV length/beam will be accompanied by an associated increase in air draught and the proportion of vessels with an air draught of up to 15 m will increase.

Although there is a range of industry opinion on the optimum dimensions of CTVs and the future rate of change in size, there has been a demonstrable trend towards larger vessels that correlates with the development of bigger offshore windfarms, which are situated increasingly further from their onshore base of operations. Any analysis of future air draught requirements must recognise this trend.

6 Other Factors Affecting Bridge Lifts

The latest generation of CTVs appearing on the market have been increasing in size and several of these craft have masts supporting navigational equipment that could necessitate bridge opening at higher tidal states. Whilst some craft are able to pivot their masts/aerials (reducing air draught) this is not necessarily straightforward and is considered to be inappropriate for daily operations. It is reasonable to assume that in future, these larger CTVs will represent a greater proportion of vessels currently serving the offshore wind market. On that basis, it will become more challenging in the future for service providers to readily source vessels that will be entirely unaffected by a bridge with a vertical clearance of 12 m; this vertical clearance having to accommodate both the air draught of the vessel and the additional air draught clearance necessary for safe passage.

As previously stated, vessels with an air draught greater than 10 to 11 m would require a lift of the bridge at some high-water levels, depending on the necessary ADC safety margin. It is possible to calculate the amount of time the proposed LLTC bridge would need to be opened for vessels of varying air draught. To carry out this analysis, an hourly time series of total water level (tidal and residual) from the NTSLF Lowestoft tide gauge (for a 54-year record, between January 1964 and March 2018), has been used.

The analysis, summarised in Table 4, identifies the proportion of time that the proposed LLTC bridge would need to open for the passage of a CTV with a given AD. ADCs of 1 m and 2 m are presented together, for comparison. Hence, for a CTV with a 12 m air draught, and applying a 1 m ADC (safety margin), the bridge would need to open 36.4% of the time. This value increases to 85.9% of the time with an ADC of 2 m. The results of this analysis identify the sensitivity of air draught, especially around the 11 to 13 m range, through which the proportion of time requiring a bridge lift changes from 0.5% (negligible) at 11 m, through to *circa* 85% (significant) at 13 m. This is based on a 1 m ADC. Clearly, the greater the ADC, the greater the effect.

Table 4. Proportion of time (%)[3] that the proposed LLTC would require opening for CTVs with air draughts in the range 10–15 m

Vessel Air Draught (m)	Proportion of time requiring bridge opening (%)	
	1 m ADC	2 m ADC
10	<0.1	0.5
11	0.5	36.4
12	36.4	85.9
13	85.9	100.0
14	100.0	100.0
15	100.0	100.0

This statistical analysis, using long term (1964-2018) tide gauge records at Lowestoft, demonstrates that for CTVs with air draughts similar to the minimum vertical clearance of the bridge, small variations in vessel air draught have the capacity to cause pronounced changes in the number of occasions that the bridge would need to be opened to allow vessels through. This is a consequence of the modest tidal range at the port (Table 1) and the associated slow rate of water level change (see Section 2.2). The extended period over which higher water levels occur at Lowestoft (Section 2.2) means that future

[3] The % time that a bridge opening is required has been calculated using the full 54-year data set and therefore includes a bias to the median mean sea level over the period, which will have been influenced by climate change effects.

increases in vessel size will result in a disproportionate increase in the frequency of bridge opening required. This further supports ABP's assertion that port users will be dissuaded from taking berths to the west of the proposed LLTC bridge once it is in place.

6.1 Bridge opening across a tidal cycle

It is also useful to understand over how much of a tidal cycle the proposed LLTC bridge would need to be opened for a given size of CTV. As an example; based on a 12 m CTV vessel height (air draught) with an ADC of 1 m, the vessel would be able to pass under the proposed LLTC bridge at maximum tidal water levels of approximately 1.9 mCD and lower. At water levels higher than 1.9 mCD, the proposed LLTC bridge would need to be opened. Based on the tidal curve presented in Figure 2, water levels of 1.9 mCD and above can be expected to occur for around 5.5 hours per tide (i.e. between 3.5-hours before and 2-hours after HW) on the largest of tides (HAT to LAT), which equates to approximately 44% of the largest tidal range (between LAT and HAT). i.e. a bridge opening is required for nearly half of a full tidal cycle, for the example vessel.

6.2 Observed versus predicted water level

Another factor to be considered to determine the most appropriate ADC, is the amount by which the total observed water level may differ from that predicted to occur due to the tide alone; a result of non-tidal influences (Section 2.3) or from rising sea levels (Section 2.4). To provide some measure of the observed differences between the predicted tide and actual tide at Lowestoft, Table 2 presents a series of statistics to describe the residual (i.e. non-tidal water level) component of the record. A tidal residual of at least ±1 m was observed to occur 287 times during the observation period, which comprises about 0.8% of the total available record (Section 2.3). This information has subsequently been used to inform the discussion in Section 6.

6.3 Climate change, sea level rise and storminess

By 2083 (i.e. 60 years after bridge construction is complete, and following the rationale set out in the DfT (2014) guidance), mean sea level is anticipated to rise by approximately 0.45 m above present (2018) levels (based on the 95th percentile estimate of the medium emissions scenario), and ranging between 0.37 m and 0.55 m above 2018 levels[4], for the low to high emissions scenarios, respectively (UKCP09). The range estimates, based on the different scenarios, encompass the uncertainty about future reductions in greenhouse gas emissions.

Rising sea level will serve to reduce the vertical distance from the water surface to the bridge, thereby affecting air draught requirements and increasing the frequency with which bridge opening would be required to allow vessel access. Quantification of how an increase in sea level will alter the percentage of time the bridge would require opening for any given point in the future, is not straightforward. This is because the number of instances will vary both inter-and intra-annually (hence the reason a long-term water level record has been used in the analysis presented in Table 4). Moreover, the sensitivity to sea level rise will also be dependent upon CTV air draught and specified ADC. However, to provide some context, further analysis is presented in Table 5.

4 This range of sea-level rise projections, from UKCP09, is approximately equivalent to the 95th percentile estimates for the RCP2.6 and RCP4.5 scenarios assessed in the recently updated UK Climate Projections 2018 (UKCP18) study (Palmer, *et al.*, 2018) (https://www.metoffice.gov.uk/research/collaboration/ukcp/about)

The water level records for the year 2017 have been re-analysed, with the influence of predicted sea level rise included, to determine the proportion of time for which the proposed LLTC would require opening (for the same range of vessel air draughts), and allowing for either a 1 m or 2 m ADC. A single year's records have been used in order to remove the long-term residual bias of sea level rise that may be present in the full 54-year record.

Water levels for 2017 have been compared with those of a three-year period (2015 to 2017) and a five-year period (2013 to 2017), to verify that 2017 may be considered a representative year for tidal water levels in the more recent past.

The analysis of the percentage of time a bridge opening will be required (presented in Table 4, and which includes the effects of sea level rise within the 54-year data record) is repeated in Table 5 for both 2017 (present) and 2083 (accounting for future sea level rise of 0.45 m, based on the UKCP09 medium emissions scenario). The results show that for a vessel with a 12 m air draught, and allowing for a 1 m ADC, sea level rise could increase the proportion of time that the bridge will require opening by around half (from 41.3% in 2017 to 64.2% in 2083).

Table 5. Comparison of the proportion of time (%) that the proposed LLTC would require opening for CTVs with air draughts in the range 10–15 m between the present day and 2083, due to sea level rise[5]

Vessel Air Draught (m)	Proportion of time requiring bridge opening (%)			
	1 m ADC		2 m ADC	
	2017 (present)	2083 (future SLR)	2017 (present)	2083 (future SLR)
10	0.0	0.1	0.8	9.2
11	0.8	9.2	41.3	64.2
12	41.3	64.2	88.7	99.1
13	88.7	99.1	100.0	100.0
14	100.0	100.0	100.0	100.0
15	100.0	100.0	100.0	100.0

It is further considered that there will be no statistically significant increase in storminess over the next century (Lowe et al., 2009) and so there is no justification to calculate the potential contribution of storms to changes in water levels, in terms of magnitude, frequency and duration. However, there is considerable uncertainty associated with this prediction and it remains a realistic possibility that increases in storminess will occur, extending the frequency with which observed water levels exceed that predicted (based on tidal influences alone), as previously noted.

6.4 Summary

The above discussion highlights the high level of variability that can be expected around future water levels and the potential implications for bridge lifts. Notwithstanding this uncertainty, it can be concluded, with some confidence, that the results of the above analysis indicate that any increase in mean sea level (conservative or otherwise), will result in a greater frequency of requirements for bridge lifts, especially for vessels with air draughts of 11.0+ m.

5 `This analysis contrasts changes in % of opening time solely due to the effects of sea level rise between the present day and 2083.

7 Conclusions

CTVs are engaged in time-critical operations. The proposed LLTC crossing has a vertical clearance of 12.0 m above HAT, to the underside of the bridge. A 1 m ADC, allows the unimpeded transit of a vessel with an air draught of 11 m or less, except on very rare occasions (0.5% of the time throughout the 54-year period analysed) where water levels exceed HAT. Any vessel with an air draught larger than 11 m will require a bridge lift, depending on the state of tide. Similar constraints will apply to vessels larger than 10 m air draught, were a 2 m air draught clearance to be required.

With the bridge in place, ABP anticipates potentially adverse implications for port operations, with future wind energy customers being unwilling to be based to the west of the proposed LLTC Bridge. The following specific factors are summarised:

- Windfarms are being built increasingly further offshore: as distances from land increase, so too has the overall size of CTVs to reflect the requirement for greater sea-keeping capability. For Round 3 wind farm projects, CTVs now in use are generally in the range 20-25 m, with some vessels on the market now approaching 30 m LOA. In general terms, increases in CTV length/ beam will be accompanied by an increase in air draught.
- Several offshore wind farm operations are based out of Lowestoft. This analysis has identified that current customers use CTVs (for Construction Coordination/O&M) with air draughts in the 10 to 13 m range. Given the upward trend in vessel size, it is anticipated that more CTVs deployed on future offshore wind farm builds are likely to have air draughts of up to 15 m.
- The analysis of observed tidal height, versus predicted tidal level identified that the maximum difference observed in the analysed 54-year record was *circa* 2.5 m. That is to say, the actual tidal height was 2.5 m above that predicted. The median exceedance, based on a 54-year data period, is around +0.1 m. However, it should be noted that a surge tide of at least ±1 m was observed on 287 occasions during this 54-year data period. The above exceedances clearly illustrate that non-tidal contributions have a considerable effect on water levels observed at the port.
- The relatively modest tidal range at Lowestoft means that there is a slow rise and fall of the tide. This results in longer periods of higher water levels within Lake Lothing, providing for longer time windows over which the proposed LLTC bridge would impede traffic flow for CTVs of 11+ m air draught.
- A statistical analysis of the long-term (1964-2018) tide gauge records at Lowestoft demonstrates that, for CTVs which have air draughts similar to the minimum vertical clearance of the bridge, small variations in vessel air draught have the capacity to cause pronounced changes in the number of occasions that the proposed LLTC bridge would need to be opened to allow vessels through.
- For a CTV with a 12 m air draught, and applying a 1 m ADC (safety margin), the bridge would need to open 36.4% of the time. This reflects the situation at the current time, with data analysis based on water levels over the full 1964 – 2018 time period.
- Mean sea level is predicted to rise by approximately 0.45 m above present levels, by 2083 (i.e. 60 years after bridge construction is complete). An analysis of the proportion of time that the proposed bridge will then require opening, for a range of vessel air draughts, shows that it will increase by around half for vessels with a 12 m air draught, and applying a 1 m ADC (from 41.3% to 64.2%).

8 References

Department for Transport (DfT) 2014. TAG Unit A1.1: Cost-benefit Analysis. Accessed on 5 June 2018. (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/670310/TAG_Unit_A1.1_-_Cost_Benefit_Analysis_November2014.pdf).

ISO 9001:2015 Quality management systems -- Requirements. International Organization for Standardization.

Lowe, J. A., Howard, T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S. and Bradley, S., 2009. UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK.

Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts, C. and Wolf, J. 2018. UKCP18 Marine Report. November 2018.

PIANC, 2014. Harbour Approach Channels Design Guidelines, PIANC Report Number 121, Maritime Navigation Commission.

UKHO, 2018. United Kingdom Hydrographic Office – Admiralty Tide Tables, 2018.

9 Abbreviations

ABP	Associated British Ports
AD	Air Draught
ADC	Air Draught Clearance
AMC	Aluminium Marine Consultants
BSI	British Standards Institution
CD	Chart Datum
CTV	Crew Transfer Vessels
DF	Direction Finding
DfT	Department for Transport
EIA	Environmental Impact Assessment
GGOWL	Greater Gabbard Offshore Wind Limited
HAT	Highest Astronomical Tide
HF	High Frequency
HMS	Her Majesty's Ship
Hts	Height(s)
HW	High Water
ISO	International Organization for Standardization
LAT	Lowest Astronomical Tide
LLTC	Lake Lothing Third Crossing
LOA	Length Overall
MF	Medium Frequency
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
MW	Megawatt(s)
nm	Nautical Miles
NTSLF	National Tidal and Sea Level Facility
O&M	Operations and Maintenance
ODN	Ordnance Datum Newlyn
OWF	Offshore Wind Farm
PIANC	Permanent International Association of Navigation Congresses
SCC	Suffolk County Council
SLR	Sea Level Rise
SSE	SSE plc
TAG	Transport Analysis Guidance
TCE	The Crown Estate
UK	United Kingdom
UKC	Under Keel Clearance
UKCP09	UK Climate Projections (2009)
UKCP18	UK Climate Projections (2018)
UKHO	United Kingdom Hydrographic Office
VHF	Very High Frequency
Windcat	Windcat Workboats

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Contact Us

ABPmer

Quayside Suite,
Medina Chambers
Town Quay, Southampton
SO14 2AQ

T +44 (0) 23 8071 1840
F +44 (0) 23 8071 1841
E enquiries@abpmer.co.uk

www.abpmer.co.uk