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Predicted performance of the HPC LVSE intake heads compared with the HPB intake

Predicted impingement performance of the HPC LVSE intake heads compared with the HPB intake

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David Haverson

Version and Quality Control

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Executive summary

The Hinkley Point C (HPC) cooling water system will be fitted with four low velocity side entry (LVSE) intake heads mounted on the seabed approximately 3 km offshore. The intake heads will be capped structures with the intake surfaces orthogonal to the direction of the tidal flows. These state-of-the-art intakes are specifically designed to reduce the cross-sectional area available to intercept any fish being transported in the tidal flows. The reduction in cross-sectional area combined with their low intake velocity is predicted to reduce the number of fish abstracted per cumec (cubic metre per second) of seawater compared with Hinkley Point B (HPB).

The results of preliminary assessment of the HPC LVSE intake performance are described in BEEMS Technical Report TR456. These results indicated that the predicted ratio of the HPC to HPB intake intercept areas was 0.646 which implied that HPC would abstract 64.6% of the fish and crustacea per cumec that HPB currently abstracts.

It has been suggested that the intercept area calculation in TR456 is overly simplistic and, in particular, ignores effects at slack water when the intakes would have a larger cross-sectional area, and an alternative methodology to calculate the cross-sectional area of the LVSE intakes has been produced (Environment Agency, 2019). This methodology takes account of slack water effects and tidal spread and asymmetry on the LVSE head performance. The Environment Agency (2019) methodology has been adopted in this paper.

The Environment Agency methodology uses hydrodynamic data (current speeds and directions) from a validated GETM 3D hydrodynamic model of Bridgwater Bay (BEEMS Technical Report TR267). This model is forced by European Centre for Medium-Range Weather Forecasts meteorological data, but the temporal and spatial resolution of those data means that the model is not able to fully reproduce the high frequency variability caused by local meteorology. This lack of high frequency components would reduce the spread of the estimated tidal directions compared to the real world.

The predicted performance of the proposed Sizewell C (SZC) LVSE intakes has been described in BEEMS Scientific Position Paper SPP099. To evaluate the effect of model limitations on the predicted performance of the proposed SZC LVSE intakes, the Sizewell GETM model outputs used to derive the intake intercept areas were replaced by Acoustic Doppler Current Profiler (ADCP) measurement data from the locations of the proposed SZC intakes. As expected the spread in measured tidal direction was larger with ADCP measurements than from the model. Part of this will have been due to measurement noise, but the majority is considered to be due to the instrument's ability to capture high frequency events. The equivalent ADCP dataset is not available for HPC but in order to ensure that the predicted performance of the HPC LVSE intakes reflects real world variation in tidal directions, the intercept area ratios calculated using Hinkley Point model data were scaled by the same factors determined at Sizewell from the use of modelled and ADCP input data.

This paper describes how the Environment Agency methodology has been applied and the parameterisation of the modelling. The Hinkley Point C project will use the results of this paper (SPP105) to update the results in TR456. A spreadsheet is available separately that details the calculations (Appendix A).

The results of modelling the SZC LVSE intakes in the ANSYS computational fluid dynamics (CFD) software are also presented. (The modelled SZC LVSE intakes used the same dimensions as those planned for HPC and the results are, therefore, considered representative of HPC).

Conclusions

1.LVSE intake velocities

CFD modelling of the proposed LVSE intakes at Sizewell C which have the same dimensions as those planned for HPC shows that:

i. The hydrodynamic influence of the LVSE intakes is only felt over a short distance from the structure with intake velocities falling to 0.1 m s^{-1} within approximately 1.5 to 2.5 m from the intake surfaces and to 0.05 m s^{-1} at a range of approximately 3m from the intake surfaces over the full tidal cycle;

ii. The range from the intake surface for the inward velocity to fall to the Environment Agency's required figure of 0.3 m s^{-1} is 0.0 to 0.68 m dependent upon the tidal current speed (faster tidal velocities have the effect of increasing the intake velocity). Over the tidal cycle the median distance from the intake where the inward velocity criterion of 0.3 m s^{-1} is met is 0.38 m (based upon the distribution of tidal currents at the SZC intakes).

2. Ratio of HPC to HPB intake intercept areas

Using the methodology proposed by Environment Agency (2019) to calculate the intercept area of the HPC LVSE intakes using model data, the ratio of the intercept cross-sectional areas of the proposed four HPC LVSE intakes compared with the HPB intake is 0.48 as a best estimate at a slack tide threshold of 0.2 m s^{-1}.

Calculations on the SZC LVSE intakes showed that if the model data is replaced by ADCP measurements, the calculated intercept area ratio increases by a factor of 1.5. An ADCP dataset is not available at the location of the HPC intakes and so the SZC factor has been used to scale up the model predictions to what would be expected if field measurement data were available. The revised results show that the ratio of the intercept cross-sectional areas of the proposed four HPC LVSE intakes compared with the HPB intake is 0.726 as a best estimate at a slack tide threshold of 0.2 m s^{-1} with confidence limits of 0.776 and 0.799

This means that HPC fitted with LVSE intakes is expected to abstract 72.6% of the fish and crustacea per cumec that HPB does. This ratio is appropriate to impingement assessments rather than entrainment assessments; the notable exception being for glass eels that are entrained because of their long, thin morphology.

This ratio is 12% than that provisionally estimated in BEEMS Technical Report TR456 but confidence in the result is much greater because it:

a. has now been calculated fully in line with the methodology in Environment Agency (2019);
b. it has been subject to an extended sensitivity analysis
c. benefits from much more realistic modelling of the HPB intake head; in particular how its intercept area varies during the tidal cycle

3. Alignment of the LVSE intakes at Hinkley Point.

The HPC LVSE intakes will be aligned in the field by the use of ADCP survey data. Such surveys can determine the tidal axis to a directional accuracy in the range ±1 to ± 2 degrees dependent upon whether the instrument is individually calibrated or the manufacturer's worst case calibration is used. This measurement accuracy, together with a realistic estimate of the accuracy that the heads can be placed on the seabed (± 1 degree) has been built into the sensitivity analyses presented in this report.

1 Background

EDF Energy is constructing a new coastal nuclear power station (Hinkley Point C, HPC), adjacent to the operational Hinkley Point B (HPB) and decommissioned Hinkley Point A (HPA) sites in Somerset. The station will be of a once-through design, abstracting large volumes of seawater for cooling the condenser steam. EDF Energy is required to evaluate the effects that the abstraction of seawater may have on the marine environment. The Centre for Environment, Fisheries and Aquaculture science (Cefas) has been contracted by EDF Energy to provide the marine evidence base and assessments of the predicted effects of HPC via a comprehensive set of studies known collectively as the BEEMS programme for HPC.

HPC will abstract approximately 132 cumecs ($m^3 s^{-1}$) compared with approximately 33.7 cumecs for the existing HPB. HPC's cooling water system incorporates a wide range of design measures to reduce losses of fish and crustacea per cumec abstracted compared with HPB:

a. Low Velocity Side Entry (LVSE) intake heads designed to reduce abstraction of all fish species;
b. Capped intakes that are known to reduce abstraction of pelagic fish that cannot easily avoid vertical currents;
c. Intakes that will be situated in much deeper water than HPB that would mean that fish swimming near to the surface would be largely invulnerable to abstraction. For energetic reasons many fish use tidal stream transport to migrate in surface waters and these fish would be at much lower risk of abstraction than at HPB;
d. Intake surfaces mounted 1.5m off the sea bed to reduce abstraction of benthic species; and
e. an advanced Fish Recovery and Return system (FRR), designed from the outset to reduce fish mortality for a wider range of species than earlier, rudimentary systems such as that fitted to Sizewell B, particularly for conservation species such as eel and lamprey.

All of these measures are expected to reduce losses of fish and crustacea but this paper focusses on the predicted performance of the HPC LVSE intakes compared to the existing intake head at HPB in reducing the losses of biota per cumec abstracted. LVSE intakes have the key advantages over other potential abstraction mitigation measures that they are expected to minimise the abstraction of biota in the first place, they are predicted to work for all fish species and they are entirely passive and therefore not prone to failure due to electrical or mechanical breakdowns.

HPC's LVSE intakes are the first examples of this technology to be constructed worldwide as far as EDF Energy is aware. These very large and highly engineered intake structures are designed to minimise impingement by:

a. limiting the exposure of the intake surfaces to the tidal stream and in so-doing reduce the risk of impingement for fish swimming with the tidal stream. i.e. they reduce the cross-sectional intercept area of the intake presented to the prevailing tidal directions by mounting the head orthogonally to the tidal flow;
b. reducing intake velocities into the head to a target velocity of 0.3 $m s^{-1}$ over as much of the length of the intake surface as practical during all tidal states in order to maximise the possibility of most fish avoiding abstraction; and
c. reducing vertical velocities which fish are ill equipped to resist by means of velocity caps on the intakes.

The HPB intake designs were designed to have low intake velocities at slack water which would give fish a chance of avoiding abstraction. However, once the tide starts to flow, fish are carried into the intake at velocities of up to 1 $m s^{-1}$ which is beyond the ability of nearly all fish found at Hinkley Point to avoid. Environment Agency guidance (Environment Agency 2005; 2010) states that "for most power plant intake purposes a design fish-escape velocity (i.e. intake velocity) of 0.3 $m s^{-1}$ will be suitable and meet best requirements".

2 Description of the HPB and the planned HPC intake heads.

The HPB and HPC intake structures are described in BEEMS Technical Report TR456 and the key points are briefly summarised here.

2.1 HPB Intakes

The HPB and decommissioned HPA intakes both share a single, shared massive concrete headworks that consists of a cylindrical caisson structure of approximately 39 m diameter and 24 m height. Apart from at the base of the structure, the caisson is open to seawater flow from all directions. The caisson is located approximately 640 m offshore and has provision for 6 intake tunnels which could be connected to onshore pump houses and screening plant. A dry tunnel is also provided which allows pedestrian access to the interior of the caisson. Onshore, at HPB and previously at HPA, the intake tunnels rise into open forebays from which water to cool the condensers flows via four large drum screens.

At the intake caisson, the power station water intake tunnels rise through the base of the structure which is divided into 6 equal sectors with no interconnections between the sectors; 2 sectors were used previously for HPA, 3 were reserved for a future HPC (this option was discounted in the mid-1990s due to the age of the structure) and one is used for HPB.

The HPB sector faces approximately south east. Each sector has 2 intake surfaces; a vertical face that rises from just above the seabed to a height of 5.8 m with a surface area 118.4 m^2 and a horizontal surface extending approximately 5.3 m towards the centre of the caisson with a surface area of 93.5 m^2 (Source EDF Energy). Water entering the intakes is screened through 250 mm pitch bar screens. The vertical screen could originally be lifted but the bars screening the horizontal surface are fixed.

At and above low water neaps both the HPB vertical and horizontal intake surfaces are submerged and the cooling water flow is abstracted through a total surface area of approximately 212 m^2. At low water on springs the seawater level can drop below the horizontal screen (at which point the intake surface area is 118.4 m^2) and the intake surface area falls to a minimum of approximately 77 m^2 at lowest slack water on springs).

2.2 HPC intakes

The planned HPC intakes will be low velocity side entry (LVSE) structures. A total of four LVSE heads will be installed with two heads fitted on each of the two intake tunnels. The intake heads will be located approximately 3 km offshore.

Each head will have two intake faces of 2m in height with the bottom of the intake surfaces being at 1.5 m off the sea bed in order to reduce the abstraction of benthic organisms.

The LVSE head dimensions are as follows:

- Each intake surface is 35.5 m long and 2m high with the middle of the intake face 2.5 m off the sea bed.
- Area per intake face = 71 m^2, 2 faces/head=142 m^2 per head. With 4 heads the total surface area = 568 m^2.
- When the tide is flowing only 4 intake faces are exposed to the tide i.e. intake exposed surface area = 284 m^2.

2.3 Hydrodynamic considerations

2.3.1 Intake head performance

At slack water, both the HPB and HPC intakes will abstract from all intake faces equally. Fish will not be transported to the heads by the tidal current and therefore only fish local to the heads or which swim into the abstraction zone (a zone parallel and close to the intake surfaces) will be abstracted. At slack water the intake velocities of the HPC intakes will be approximately 0.23 m s^{-1} whereas the intake velocity of the HPB intake will vary with tidal level between 0.16 m s^{-1} at high water slack to a range of between 0.28 to 0.44 m s^{-1} at low water slack.

In theory, with the HPC intakes orthogonal to the tidal flow, the current will flow past the HPC intake surfaces and only fish that are in an abstraction risk zone will be likely to be abstracted. In practice, the size of this abstraction zone (i.e. the distance from the intake surface) will depend on the effects of turbulence when the tidal current interacts with the intake head. To this end, the HPC intakes have been designed to linearise flow velocities along the head and to reduce the formation of initial eddies by the use of shaped nose cones at each end of the intake. The intake velocity of the HPC intakes will not increase with the tidal flow if the intakes are perfectly aligned to the tidal flow. In practice there is a spread around the modal directions of the tidal flow and there is also some tidal asymmetry, i.e. the tidal flow directions are not exactly 180 degrees apart, and so one side of the HPC intakes will be exposed to the tide for part of each tidal cycle. This will increase the abstraction cross-sectional area of the intakes and serve to increase intake velocities.

In BEEMS Technical Report TR456, an initial rule of thumb assumption was made that the abstraction risk zone extended approximately 2 m from the head based upon physical modelling studies on the HPC LVSE heads (HRW, 2013). This would give an abstraction cross-sectional area (the intake intercept area) of 2 m × 2 m height per intake face, 8 m^2 per head or a total of 32 m^2 for the four intakes designed for HPC. It has been suggested that this assumption is overly simplistic and, in particular, ignores effects at slack water when the intakes would have a larger cross-sectional area, and an alternative methodology to calculate the cross-sectional area of the LVSE intakes has been produced (Environment Agency, 2019). This methodology takes account of slack water effects and tidal spread and asymmetry on the LVSE head performance. We have adopted the Environment Agency (2019) methodology in this paper.

The intercept area of the HPB intake was calculated from the relative geometry of the intake to the tidal current directions over a 1-day tidal cycle in TR456. The following changes to the HPB intercept area calculation have been adopted in this paper:

a. the HPB projected area calculation in TR456 contained an error that was identified by consultees - the calculation has been corrected in this paper;

b. the TR456 method did not include the effects of slack water when the head abstracts equally on all submerged intake surfaces – the calculation now includes this effect in common with the LVSE calculation; and

c. in common with the HPC LVSE calculation, the HPB intercept area has now been calculated over a 30 day tidal cycle.

2.3.2 What is the definition of slack water

As velocity increases from 0 m s^{-1}, the behaviour of the intakes will change from equal abstraction on all intake surfaces to preferentially abstracting from intake surfaces facing into the tidal current. In marine hydrodynamics, slack water is often characterised as velocities less than or equal to 0.1 m s^{-1}. Environment Agency (2019) considered the effects on the LVSE performance using a slack water definition of 0.1 to 0.3m s^{-1}. This point is examined in more detail in section 4.1.

3 LVSE Intakes – predicted intake velocities

The LVSE intakes have been modelled previously for the Sizewell project using ANSYS computational fluid dynamics (CFD) software to determine the distribution of intake velocities across the intake surfaces in tidal currents ranging from 0 m s^{-1} to 1.0 m s^{-1} (BEEMS Scientific Position Paper SPP099). The modelled SZC intake heads had the same dimensions as those planned for HPC and the results are therefore expected to be representative of the HPC intake performance. The modelling work has not, therefore, been repeated for this report but the key results have been reproduced below.

Figure 1 shows the distance from the SZC intake surface where the inward velocity (the velocity into the intake surfaces) falls to 0.3 m s^{-1} was 0.0 m to 0.68 m. Over the tidal cycle the median range to 0.3 m s^{-1} is 0.38 m.

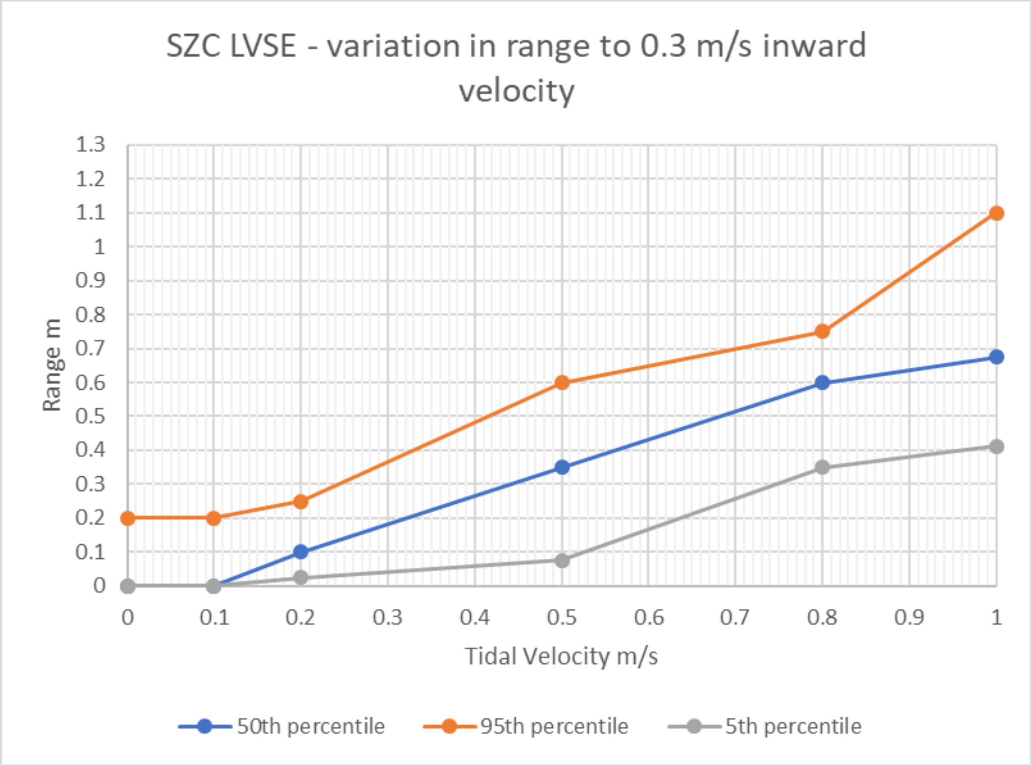

Figure 1 Modelled range to 0.3 m/s inward velocity at different tidal current speeds

The influence of the LVSE intakes is only felt over a short distance with inward velocities falling to 0.1 m s^{-1} over a range of approximately 1.5 m to 2.5 m from the intake surfaces and further to 0.05 m s^{-1} at a distance of approximately 3 m from the intake surfaces over the full tidal cycle (Figure 2).

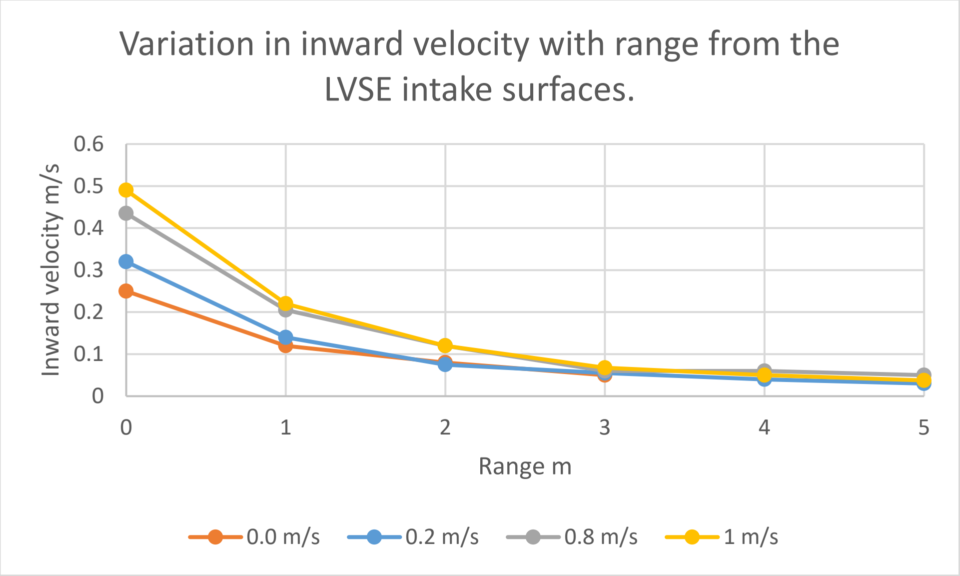

Figure 2 Variation in inward velocity with distance from the LVSE intake surfaces with tidal current speed

4 Methodology used to predict the intake head intercept cross-sectional areas.

4.1 Hinkley Point C LVSE intakes

As described in section 2.3.1, we have used the methodology described in Environment Agency (2019) to calculate the intercept cross-sectional area of the four HPC LVSE intakes. Environment Agency (2019) describes the results of 3 variants to the preferred approach with different slack water thresholds of 0.1, 0.2 and 0.3 m s^{-1}. We have adopted the same methodology as Environment Agency (2019) and with the parameterisation described below:

i. The tidal current data are from the validated GETM 3D hydrodynamic model of Bridgwater Bay at a height of 2.5m off the seabed corresponding to the centre of the HPC intake surfaces.

ii. For the Sizewell project, the LVSE heads were initially modelled using data from the validated Sizewell GETM model. Due to limitations in the frequency of meteorology data, the Sizewell GETM model (and the equivalent Hinkley Point model) is unable to fully represent high frequency events which it was expected would lead to the modelled spread in tidal directions being lower than in real life. To investigate this issue the model data was replace with ADCP data measured at the appropriate depth at the Sizewell C intake locations. The effect of the replacement dataset was to increase the calculated intercept area ratio by a factor of approximately 1.5 at a slack threshold of 0.2 m s^{-1} (SPP099). An equivalent ADCP dataset is not available at Hinkley Point and so the calculated HPC:HPB intercept area was scaled by the factors determined in SPP099 (See section 5).

iii. There are two intake locations on each of the two HPC intake tunnels for two LVSE intake heads. The results were not expected to vary on each tunnel run but for completeness we have modelled all 4 heads.

iv. The model data were for 30 days (720h) in winter or two full spring-neap tidal cycles at a one hour interval.

v. The model output was transformed into a 2 dimensional histogram with rows of direction and columns of current speed with the directions and velocities grouped into bins. From the modelling data it had previously been determined that tidal direction is tightly distributed around the modal direction at Hinkley (Figure 3) and it is, therefore, very important to use a sufficiently small directional bin size to avoid biasing the analysis results. It was found that a 1 degree bin size was satisfactory. For current speed the same bin size was used as in Environment Agency (2019) (0.1m/s).

vi. Head alignment. EDF's construction engineers have confirmed that they can readily place the heads at any desired alignment to an accuracy of at least 1 degree. Due to the slight tidal asymmetry at each location, we adjusted the head alignment at each location to achieve minimum intercept cross-sectional areas at each location.

vii. The intercept projected area of the LVSE intakes was calculated as described in Environment Agency (2019).

viii. Slack water conditions are treated differently in the Environment Agency methodology. At slack water, the area scale factor of the LVSE intakes compared with the HPB intakes was set at 1 i.e. differences in abstraction were determined by the differences in flow rates. The flow velocity at slack was set to 0.3 m s^{-1} (i.e. greater than the design specification of 0.16 to 0.28m s^{-1} (occasionally at lowest slack tides 0.44 m s^{-1}). This only produced a small overestimate in calculated intercept area.). Both parameters are as described in Environment Agency (2019).

ix. The threshold speed for considering the tide to be slack was subjected to uncertainty analysis as the calculation is sensitive to this parameter. Based upon inspection of modelling data Hinkley Point, slack water can conservatively be represented by current speeds less than or equal to 0.2 m s^{-1}.

x. The calculation of the intercept area for the HPB intakes is described in section 4.2.

xi. Spreadsheets showing the calculations are available as described in Table A1.

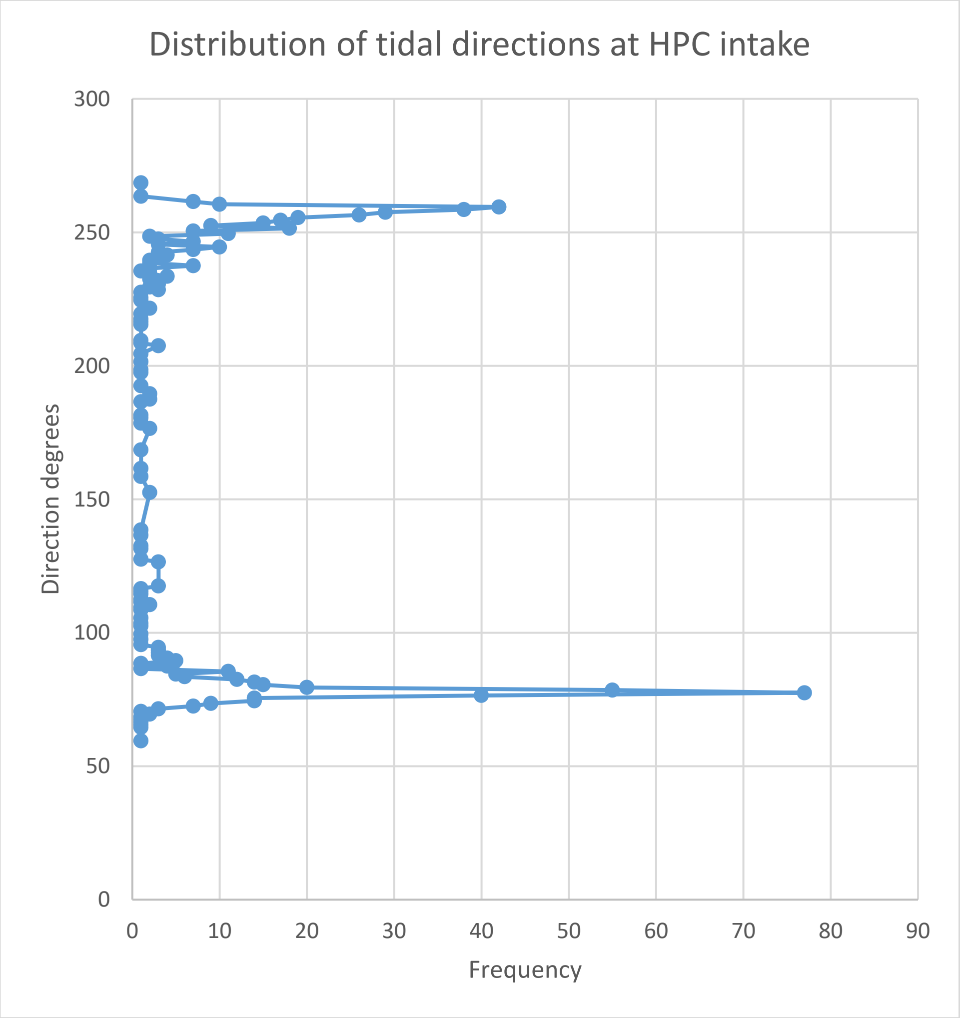

Figure 3 Modelled HPC current direction histogram at 2.5m above the seabed at the location of LVSE intake

4.2 HPB intake

As described in section 0, the combined area of the HPB intake surfaces is 212 m^2 and in accordance with Environment Agency (2019) this should be used as the HPB intercept area at slack water. However, the HPB intake area at slack water varies according to the tidal height. At high water slack it is 212m^2 but on some low tides the slack water level falls to (and very occasionally below) the horizontal screen height and so the slack area is then just the area of the vertical screen (118.4m^2). A mean slack water area has therefore been calculated using the modelled tidal elevation over the 30 day modelling period. (The few occasions when the low water slack level was below the top of the vertical screen have been ignored as sensitivity tests showed that the inclusion of these events made no material difference to the calculated HPB intercept areas).

The modelled period of slack water at HPB is a mean of approximately 0.8 hours on each tide using a threshold of 0.2m s^{-1} as a slack definition and 1.8 hours at a slack threshold of 0.3 m s^{-1}.

Figure 4 shows the modelled histogram of tidal current speed at the HPB intake from the validated Bridgwater Bay GETM model at 2.5 m above the sea bed.

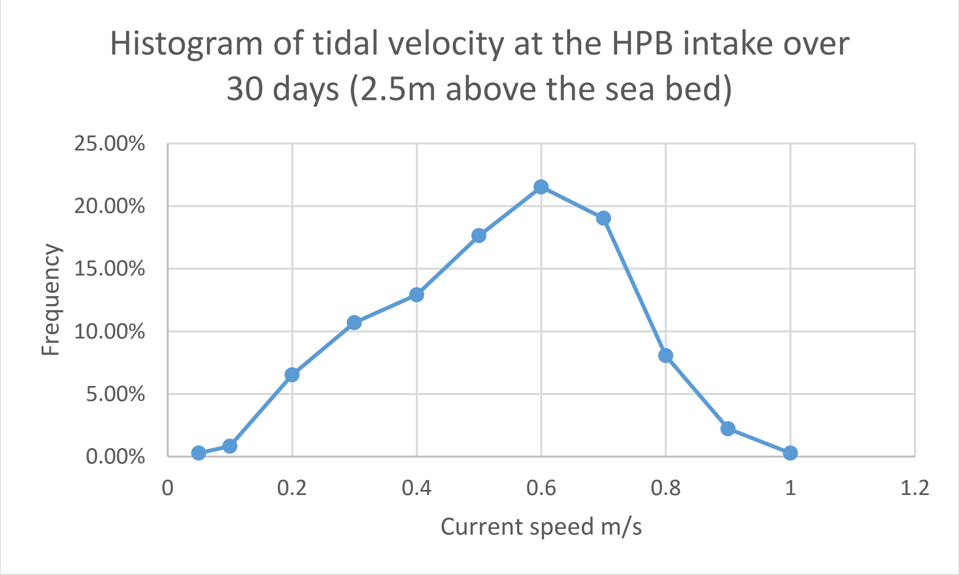

Figure 4 Tidal speed histogram at the HPB intake.

5 Results

The following results are from the provided supplementary spreadsheets (Appendix A).

The calculated intercept areas of the HPC intakes using modelling data from the GETM model are shown in Table 1

Table 1 Calculated intercept area of the 4 HPC LVSE intakes (assuming that the intakes were all one location)

Slack threshold m s^{-1}	**HPC 1 east**	**HPC 1 west**	**HPC 2 east**	**HPC 2 west**	**Mean Area m^2**
0.1	24.35	24.65	25.18	25.51	**24.9**
0.2	29.40	30.73	31.83	31.89	**31.0**
0.3	43.09	42.65	45.29	43.73	**43.7**

Table 2 shows the calculated intercept area of the HPB intakes.

Table 2 Calculated intercept area of the HPB intakes over a 30 day tidal cycle

Slack threshold m/s	**Area m2**
0.1	**64.22**
0.2	64.22
0.3	90.68

Notes

1. The calculated intercept area at a threshold of 0.1 m s^{-1} has been set at the same value as for a threshold of 0.2 m s^{-1}. In reality the value at 0.1 m s^{-1} will be smaller than shown but this will not materially alter the conclusions of the study.
2. The intercept area at 0.3 m s^{-1} includes the effect of the modelled slack water period being approximately 1.8 hours

Table 3 shows the ratio of the HPC to HPB intercept area at each of the slack water thresholds.

Table 3 Calculated HPC/HPB intercept area ratio using model data

Slack threshold m/s	HPC 1 east	HPC 1 west	HPC 2 east	HPC 2 west	Mean intercept area ratio
0.1	0.379	0.434	0.392	0.397	**0.401**
0.2	0.458	0.478	0.496	0.497	**0.482**
0.3	0.509	0.470	0.499	0.482	**0.490**

Studies at Sizewell showed that when the modelled current speeds and directions were replaced by Acoustic Doppler Current Profiler (ADCP) measurements the spread of tidal directions increased. This had the effect of increasing the calculated ratio of SZC to SZB intercept ratio by 1.508 for a slack threshold of 0.2 m s^{-1} and 1.421 for a slack threshold of 0.3 m s^{-1} (SPP099). The equivalent ADCP data are not available for Hinkley Point and so we have applied the Sizewell factors to the Hinkley Point results (Table 4).

Table 4 Calculated mean HPC:HPB intercept area ratio assuming use of ADCP data

Slack threshold m s^{-1}	Mean ratio of intercept areas
0.1	0.603
0.2	**0.726**
0.3	0.697

5.1 Sensitivity analyses

The LVSE intakes will be aligned in the field by the use of ADCP survey data. Such surveys can determine the tidal axis to a directional accuracy in the range ±1 to ± 2 degrees dependent upon whether the instrument is individually calibrated or the manufacturer's worst case calibration is used.

EDF Energy’s construction contractors have confirmed that the intake heads can be placed on the seabed to an accuracy of ± 1 degree.

For sensitivity tests it has been assumed that the ADCP will not be individually calibrated and that the instrument will produce normally distributed errors with one standard deviation of 1 degree. Head placement errors will also be normally distributed with one standard deviation of 0.5 degrees. Simulating the combined error from the two independent error sources over 10,000 trials gives 5 and 95 percentile errors of ± 1.85 degrees.

Table 5 shows the calculated intercept area for the 4 HPC intakes for up to ±3 degrees misalignment around the optimum head alignment directions. The cells in green provide the mean, upper and lower confidence limits.

Table 5 Calculated mean HPC intercept areas (m^2) and HPC:HPB intercept area ratios for different amounts of head misalignment with a realistic slack velocity threshold of 0.2 m s^{-1}. Green cells provide the mean, 5 and 95 percentile confidence values.

	-3°	-2°	-1.85°	0°	+1.85°	+2°	+3°
HPC mean intercept area m^2	35.59	33.12	33.08	31.0	34.07	34.23	37.59
Mean intercept area ratio	0.835	0.777	0.776	0.726	0.799	0.803	0.882

The calculations have also been repeated for completeness at an assumed slack water threshold of 0.3 m s^{-1} (Table 6). As stated in Section 4.1, this threshold is considered unrealistically high based upon model data at Hinkley Point. The cells in orange provide the mean, upper and lower confidence limits.

Table 6 Calculated HPC intercept areas (m^2) and HPC:HPB intercept area ratios with an unrealistic slack velocity threshold of 0.3 m s^{-1}

	-3°	-2°	-1.85°	0°	+1.85°	+2°	+3°
HPC mean intercept area m2	48.84	46.4	46.13	44.5	46.66	47.05	50.36
Mean ratio	0.765	0.727	0.723	0.697	0.731	0.737	0.789

6 Conclusions

6.1 LVSE intake velocities

Computational Fluid Dynamic (CFD) modelling of the proposed Sizewell C LVSE intake heads, which are the same dimensions as the HPC LVSE intakes shows that:

i. The hydrodynamic influence of the LVSE intakes is only felt over a short distance with inward velocities falling to 0.1 m s^{-1} over a distance of approximately 1.5 to 2.5 m from the intake surfaces and to 0.05 m s^{-1} at a distance of approximately 3m from the intake surfaces over virtually the full tidal cycle;

ii. The range from the intake surface for the inward velocity to fall to the Environment Agency (2005, 2010) criterion of 0.3 m s^{-1} is 0.0 to 0.68 m dependent upon the tidal current speed. Over the tidal cycle the median distance to an inward velocity of 0.3 m s^{-1} is 0.38 m based upon the distribution of tidal currents at the SZC intakes.

6.2 Ratio of HPC to HPB intake intercept areas

Using the methodology proposed by Environment Agency (2019) to calculate the intercept area of the HPC LVSE intakes using model data, the ratio of the intercept cross-sectional areas of the proposed four HPC LVSE intakes compared with the HPB intake is 0.48 as a best estimate at a slack tide threshold of 0.2 m s^{-1}.

Calculations on the SZC LVSE intakes showed that if the model data is replaced by ADCP measurements, the calculated intercept area ratio increases by a factor of 1.5. An ADCP dataset is not available at the location of the HPC intakes and so the SZC factor has been used to scale up the model predictions to what would be expected if field measurement were available. The revised results show that the ratio of the intercept cross-sectional areas of the proposed four HPC LVSE intakes compared with the HPB intake is 0.726 as a best estimate at a slack tide threshold of 0.2 m s^{-1} with confidence limits of 0.776 and 0.799

This means that HPC fitted with LVSE intakes is expected to abstract 72.6% of the fish and crustacea per cumec that HPB does. This ratio is appropriate to impingement assessments rather than entrainment assessments; the notable exception being for glass eels that are entrained because of their long, thin morphology.

This ratio is 12% larger than that provisionally estimated in BEEMS Technical Report TR456 but confidence in the result is much greater because it:

a. has now been calculated fully in line with the methodology in Environment Agency (2019);
b. it has been subject to an extended sensitivity analysis ; and
c. benefits from much more realistic modelling of the HPB intake head; in particular how its intercept area varies during the tidal cycle

6.3 Alignment of the LVSE intakes at HPC

The HPC LVSE intakes will be aligned in the field by the use of ADCP survey data. Such surveys can determine the tidal axis to a directional accuracy in the range ±1 to ± 2 degrees dependent upon whether the instrument is individually calibrated or the manufacturer's worst case calibration is used. This measurement accuracy, together with a realistic estimate of the accuracy that the heads can be placed on the seabed (± 1 degree) has been built into the sensitivity analyses presented in this report.

References

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HRW (2013) Numerical & Physical Modelling of the Hinkley Point C Intake & Outfall Structures. Task 1 – Physical Modelling of Flows at Intake Heads (TN-10). HR Wallingford Ltd. May 2013.

Appendix A

Table A1 Spreadsheets showing detailed calculations provided in support of this Scientific Position Paper

Filename	Contents
HP intake velocities 2-5m from the bed v5.xlsx	Intercept area calculations for HPC intakes
HPB_intake velocities 2-5m from the bed v2.xlsx	Intercept area calculations for HPB intake
LVSE Supplementary calculations 5May2020.xlsx	SZC LVSE intake velocities