# Teddington Direct River Abstraction

Preliminary Environmental Information Report

Appendix 6.3 – Supporting Information for Burnell Avenue Site Operational Phase Impact Assessment

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# Appendix 6.3 – Supporting Information for Burnell Site Operational Phase Impact Assessment

A.1.1 The design and location of the near-bank in-river outfall and bankside outfall are provided in Chapter 2: Project Description. Detailed design of the Project outfall is not available at this stage. Therefore, the modelling of the two outfall options is based on parameterised design and construction, as well as good operational practice.

A.1.2 The outputs from the hydrodynamic modelling relevant to the assessment of impacts on ecological receptors are detailed in Appendix 6.2. The sections below support the assessment of the impacts of the operation of the Project based on the current outfall design scenarios. They are supported by the interpretation of the hydrodynamic modelling outputs.

## Temperature

A.1.3 Thermal modelling outlined in Appendix 6.2 showed that the extent of the thermal plume produced from the outfall would be concentrated immediately downstream of the outfall, with the highest temperature increases seen within 7-10m of the outfall for the bankside design and within 15m of the bank for the near bankside in-river option. When river temperatures are higher, the difference in temperature between the recycled water and the river temperatures would be, on average, 3.3°C for both outfall designs. When river temperatures are lower, the maximum difference in temperature between the recycled water and the river water would be, on average, 6.1°C for both outfall designs.

A.1.4 Once mixed, the modelled outputs for the A82 moderate-low flow scenario show a small increase in mixed river temperature when the scheme is operational (6 August to 12 November) with an average increase of 0.4°C above baseline. The minimum modelled temperature increase is 0.1°C, and the maximum temperature increase is 0.8°C. The modelled outputs for the M96 very-low flow scenario show an increase in temperature when the scheme is operational (11 July to 18 December and brief operation for 5 dates in January) with an average increase of 0.7°C above baseline. The minimum modelled temperature increase is 0.1°C, and the maximum temperature increase is 1.5°C.

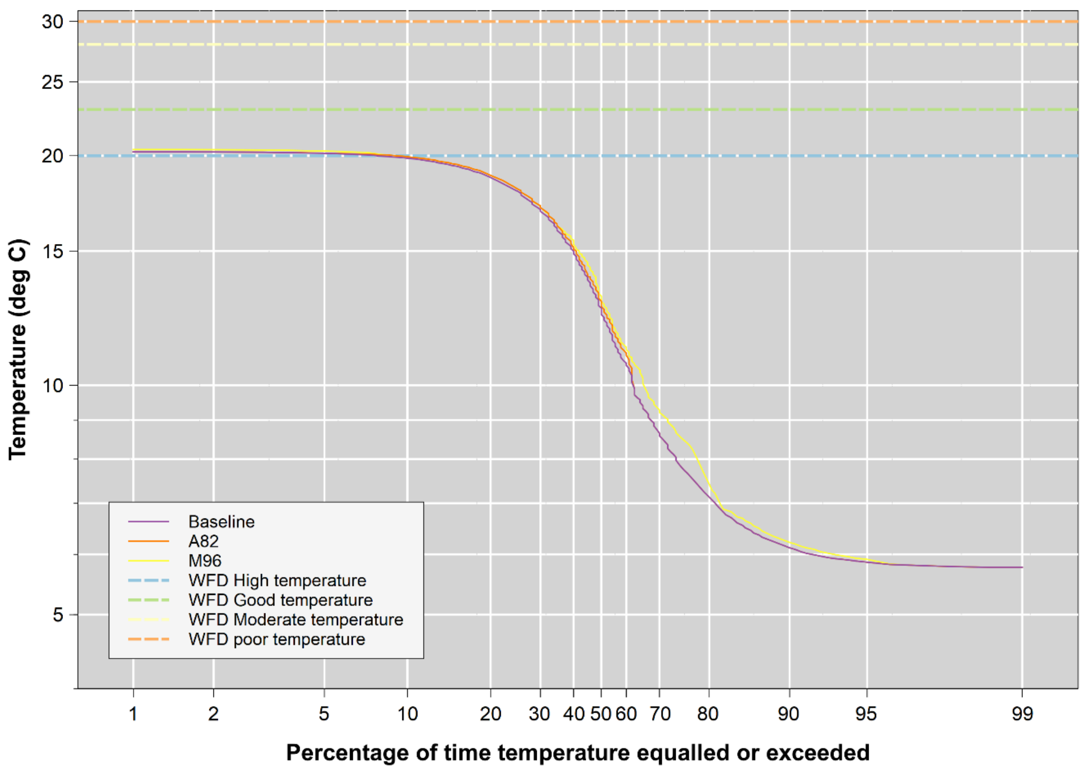
A.1.5 Under all scenarios, the thermal plume would only occupy up to 0.2% of the channel for the bankside option and 3.4% for the near bankside in-river option, which would be concentrated on the right-hand bank. An overall increase in mixed river temperatures of 1-2°C would affect up to 70m in length of the channel downstream of the outfall.

A.1.6 It is anticipated that the scheme will be operational once every two years, and within this time, the scheme will run intermittently between July and November. It may also run in June, December and January, but this is less likely. The scheme is likely to run when river temperatures are higher during the summer, and the increase in mixed water temperatures is lowest <1°C in most scenarios. The increases in river temperatures are likely to be within the natural fluctuations for the Thames.

A.1.7 Temperature predictions based on the exceptionally hot and dry summer of 2022 and the warm, dry spring of 2011 showed that the scheme would cause river temperatures to increase to a maximum of 24.3°C. This is within the natural temperature profile range recorded for the Thames (between 1.9-24.3°C). Under extreme scenarios, the predicted discharge temperature for the recycled water is 21.5°C, which is 2.8°C cooler than the ambient river temperature.

A.1.8 Temperature duration curves have been created to compare the baseline against the A82 and M96 scenarios with indications of WFD status bands (Plate A.1). The temperature duration curve shows that baseline and modelled river temperatures as a 98%ile at Teddington are just above 20°C, which indicates Good status. The baseline and modelled temperature just above 20 ºC occur only approximately 10 percent of the time, with the remaining temperatures staying below 20 ºC, which indicates a High status. Therefore, no deterioration in WFD temperature status is expected. The proposed outfall is located in the Thames (Egham to Teddington) water body, which is 31.52 km long. The EA defined the temperature status at Thames (Egham to Teddington) water body in RBMP3 (2019) as Moderate, without continuous monitoring data.

Plate A.1 Temperature duration curves comparing baseline and A82 and M96 scenarios.



## Velocity

A.1.9 Modelling in Appendix 6.2 showed that the outfall discharge would be 75Ml/d moving at 0.3m/s for both designs, and the intake will abstract up to 75Ml/d at 0.1m/s. Under lower flow conditions, the flow velocities at the point of discharge will increase by 0.05-0.075m/s for approximately 100m downstream for the bankside option. Across the channel, velocities peak around 0.05-0.3m/s and extend out approximately 10m. Under higher flow scenarios, the baseline flow is between 0.025 and 0.05m/s. Flows from the outfall are between 0.05-0.075m/s along the right-hand bank and 0.025-0.05m/s along the left-hand bank. Higher velocities around and downstream of the outfall are not present in a higher flow scenario. For the near bankside in-river option, there would be an increase in flow velocity of between 0.005-0.1 m/s over 20m across the vertical channel profile.

## Water quality

A.1.10 Many of the protected/notable aquatic species in the UK, including the Thames, are threatened by water pollution. The scheme will reduce the final effluent discharge from Mogden STW and the discharge from the outfall at Burnell will be highly treated. This means that the operation of the scheme is unlikely to impact water quality.

A.1.11 Changes in water quality due to the operation of the outfall at Burnell have the potential to impact the spread of INNS. Water quality analysis is outlined in the Water Resources and Flood Risk Appendix.

A.1.12 Effects on water quality from both outfall options are currently under review but expected to be slight as will be discharged under a discharge permit which will include water quality requirements. It is expected there will be negligible change outside of the immediate mixing zone (the discharge would be fully mixed before Teddington Weir). Potential slight changes to water quality within the mixing zone could include an increase in phosphorus and ammonia and reduction in dissolved oxygen during the operation of the Project. Further information will be available at ES.

## Macrophytes and Macroalgae

### Freshwater Thames

#### *Temperature*

A.1.13 Hypothetically, changes in temperature can have the potential to influence macrophyte and algal growth patterns, with varying impacts depending on the season, magnitude of temperature change, and species-specific tolerances. Temperature increases during spring/ summer months can lead to increased growth of macrophytes, or conversly can impact macrophyte success through shading/overgrowth from algae affecting photosynthesis and gaseous exchange. Very high water temperatures can exceed species' lethal limits. Increases in temperature can also lead to increased macroalgae growth and algal blooms. Temperature increases in the autumn/ winter months can extend the growing period for macrophytes and macroalgae.

A.1.14 It is possible that permanent increases in temperatures of 1-2°C may increase filamentous algal growth or the likelihood of algal blooms along this area of the Thames, particularly under drought conditions where flows are lower, and temperatures are naturally higher. The biomass of filamentous green algae-like species has been shown to increase significantly in temperatures above 15.7°C and can maintain its biomass between 10.7-13.0°C[1]. Temperature is an important factor in filamentous green algae growth. *Cladophora* sp. has optimum temperatures between 28-31°C. It is possible that growth of algae could impact the fitness of other plant species through inhibiting photosynthesis and gaseous exchange, and also impact other fauna using macrophytes as habitat. Increases in summer temperatures, particularly under drought conditions, could exacerbate increased algal growth (both filamentous and epiphytic) caused by baseline higher temperatures and lower flows.

A.1.15 However, projected increases in water temperature due to the scheme are predicted to be small and localised. From the modelled scenarios, it is unlikely that an overall increase in temperatures outside of the mixing zone of up to 1-2°C downstream of the outfall during operation will have a negative impact on the macrophyte community. The highest temperature increases are likely to be seen over the winter months when plants have died back and are dormant. The majority of species recorded along this section of the River Thames are characteristic of slower-flowing rivers with a higher tolerance for warmer temperatures and nutrients. Slight increases in temperature may increase plant growth downstream of the outfall, which may increase habitat availability for other groups such as macroinvertebrates and fish. However, other factors such as disturbance from boat traffic and the artificial nature of the channel and banks likely limit the potential growth of macrophytes in this reach of the Thames.

A.1.16 As the duration of the scheme is intermittent and not permanent, it is not likely to cause a long-term impact on the plant community or permanently increase filamentous algal growth within the reach. The effect of any macrophyte and algal growth due to temperature increases would be reversible, as baseline conditions would return when the scheme is not operational. As the scheme is most likely to be operational during warmer months, it is unlikely that the scheme will artificially prolong algal growth into winter months.

A.1.17 A worst case modelling scenario for temperature (very low flows of 400Ml/d and with maximum temperature differential between recycled water and river water) demonstrated that this maximum temperature change would be present only within the immediate vicinity of the discharge and would dissipate rapidly moving downstream of the discharge location (within a few meters). Examining the worst case, even the maximum temperatures predicted immediately by the

[1] Guo et al. (2022) Environmental factors associated with the filamentous green algae *Cladophora* blooms: a mesocosm experiment in a shallow eutrophic lake. Journal of Environmental Management 313.

outfall are not likely to exceed the lethal tolerance of the macrophyte species recorded in this area of the Thames. Further detail on numerical modelling is provided in Appendix 6.2. Spiked water milfoil (*M. spicatum)* has been recorded as having optimum temperatures between 30-35°C[2]. For hornwort (*C. demersum*), optimum temperatures of 30°C have been recorded[3] , and Nuttall's waterweed has been recorded as growing at 39°C[4]. Although published research on optimum temperatures and lethal limits is not available for all the species recorded in this area of the Thames, it is assumed that the majority of species will have similar temperature tolerance to other species growing in this area of the Thames.

A.1.18 Long-term exposure to temperatures above the optimum can result in poor photosynthetic rates[5] in macrophytes. It is also possible that higher long-term temperatures may decrease genetic diversity in species which can clone vegetatively (such as hornwort *C. demersum*)[6]. However, under scenarios where ambient river temperatures are highest, the temperature of the discharge will be lower than the ambient river temperature. Given the short-term increase anticipated from the scheme and the very localised nature of the impact, as well as the connectivity to other macrophyte populations within the River Thames, the long-term impact of this is considered negligible.

A.1.19 Three protected species were identified under the baseline conditions for this reach of the River Thames. These were *Potamogeton friesii* (flat-stalked pondweed), *Limosella aquatica* (mudwort) and *Persicaria minor* (small water-pepper). The macrophyte survey conducted in August 2024 around the proposed outfall did not identify any of these species as being present between the outfall location and Teddington Weir. Flat-stalked pondweed was identified during the survey, but this was upstream of the proposed outfall location near Trowlock Island. It is unlikely any changes in temperatures will impact these species.

## Velocity/flow changes

A.1.20 Hypothetically, increases in velocity have the potential to impact the macrophyte and macroalgae community through the movement of sediments and increased flow, washing plants' roots out. It could also impact macrophytes by driving a change in community composition downstream of the outfall, with species tolerant of higher velocities replacing those currently present downstream of the outfall.

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[2] Grace and Wetzel (1978) The production biology of Eurasian watermilfoil (*Myriophyllum spicatum* L.): a review. Journal of Aquatic Plant Management .
[3] Alnomani et al. (2007) Effect of temperature degrees on growth of hornwort plant *Ceratophyllum demersum* L.Karbala International Journal of Modern Science 5 (2), 404-406
[4] Ma et al., (2009) Responses to *Elodea nuttallii* and *Ceratophyllum demersum* to high temperatures. Fresenius environmental bulletin 18 (9), 1588-1596
[5] Santamaria and van Vierssen (1997) Photosynthetic temperature responses of fresh- and brackish-water macrophytes: a review. Aquatic Botany 58, 135-150.
[6] Li et al. (2024) Temperature is a cryptic factor shaping the geographical pattern of genetic variation in *Ceratophyllum demersum* across a subtropical freshwater lake. Plant diversity 46 (5) 630-639

A.1.21 Through surveys conducted in August 2024, it was recorded that the dominant in-channel macrophyte recorded downstream of the discharge point was spiked water-milfoil. Other species dominant around this area of the Thames include unbranched bur-reed (*Sparganium emersum*) and yellow waterlily (*Nuphar lutea*). The projected increases in flow directly downstream of the outfall are not likely to negatively impact these species as they can naturally tolerate velocities higher than those recorded at Teddington. Spiked water-milfoil (*M. spicatum*) and unbranched bur-reed (*S. emersum*) can survive velocities of 0.4-0.5m/s[7]. Therefore, the magnitude of impact on these species is considered to be low.

A.1.22 It is anticipated that the scheme would be operational once every two years, and within this time, the scheme would run intermittently between July and November. The intermittent nature of the operation of the scheme will lessen the impact on the macrophyte community as many of the species present can tolerate higher flows.

A.1.23 The increase in flows around the outfall is also not likely to cause any physical alterations to the channel through scour of the banks or channel, changes in flow direction, movement of sediments, siltation or washing plants away. Slightly elevated flows around the outfall may counteract any impacts from increases in temperature, which may increase algal growth. Therefore, impacts on the macrophyte community through changes in velocity are considered negligible.

A.1.24 Three protected/notable species were identified under the baseline conditions. The macrophyte survey conducted in August 2024 around the proposed outfall did not identify any of these species as being present between the outfall location and Teddington Weir. It is not likely that any local changes in velocity downstream of the outfall will impact these three protected species.

## Water quality

A.1.25 Hypothetically, changes in water quality due to the operation of both outfall designs at Burnell have the potential to impact macrophytes and macroalgae. Water quality analysis is outlined in the Water Resources and Flood Risk Appendix.

A.1.26 Effects on water quality from both outfall options are currently under review but expected to be slight as will be discharged under a discharge permit which will include water quality requirements. It is expected there will be negligible change outside of the immediate mixing zone (the discharge would be fully mixed before Teddington Weir). Potential slight changes to water quality within the mixing zone could include an increase in phosphorus and ammonia and reduction in dissolved oxygen during the operation of the Project. Further information will be available to inform the assessment at ES as water quality review informed data from the pilot plant becomes available.

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[7] O'Hare M.T., Hutchinson K.A. and Clarke R.T. (2007) The drag and reconfiguration experience by five macrophytes from a lowland river. Aquatic Botany 86 3) 253-259

A.1.27 Hypothetically, increases in phosphorus can cause macrophytes to grow larger and cover more area. It can also cause the mortality of nutrient-sensitive species and change the community so more nutrient-tolerant species become dominant. Increases in ammonia can increase algal growth and inhibit photosynthesis in macrophytes.

A.1.28 Based on the baseline data collected, the macrophyte community along the Thames is dominated by nutrient-tolerant species. RMNI EQR scores indicate that the community is already impacted by and adapted to nutrient enrichment. Further increases in phosphorus may further skew the plant community toward nutrient-tolerant species. Increases in phosphorus and ammonia may also cause an increase in filamentous algal growth, particularly during the summer months. The slight increase in phosphorus under drought conditions when the scheme is likely to operate may contribute to already high baseline algae levels.

A.1.29 Plant species such as Hornwort (*Ceratophyllum demersum*) and spiked water-milfoil (*Myriophyllum spicatum*) which were recorded around the Burnell Avenue outfall, can tolerate ammonia concentrations of 10mg/l[8].

A.1.30 The scheme is anticipated to operate once every two years, and within this time, it would run intermittently between July and November. Therefore, any increases in phosphorus due to the operation of the outfall are not likely to cause any change in the macrophyte community composition due to the duration of the project being temporary, and any effects may be reversed when the scheme is not running.

A.1.31 Any decreases in suspended sediment due to the discharge will likely benefit the macrophyte community by increasing available light and potentially reducing sedimentation. This could lead to an increase in macrophyte cover and growth. It is possible that decreases in suspended sediments, particularly during drought conditions in warmer months, may increase the growth of filamentous algae.

A.1.32 The scheme will run intermittently, and any increases in ammonia would be temporary and likely only to have negligible impacts on the macrophyte community.

A.1.33 Decreases in dissolved oxygen can impact macrophytes by impacting the growth of individuals, and it can also cause mortality to sensitive species which require high dissolved oxygen. Potential decreases in dissolved oxygen is unlikely to have any negative impacts on the macrophyte community along the Thames in the study area. The species present along this reach are tolerant of lower dissolved oxygen and flows.

A.1.34 The protected species identified under baseline conditions are not likely to be impacted by any temporary or localised changes in water quality as they have not been identified as being present directly downstream of the outfall location.

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[8] Goa J., Ren P., Zhou Q. and Zhang J. (2019) Comparartive studies of the response of sensitive and tolerant submerged macrophytes to high ammonium concentration stress. Aquatic Toxicology 211 57-65.

The outfall at Burnell may have a minor impact on water quality downstream, with the largest impacts expected within the first 7-10m downstream. As these impacts are predicted to be minor and would be intermittent, it is likely that even if these protected species were present directly downstream, the impact would only be negligible.

### Estuarine Thames

A.1.35 Assessments in Chapter 5 show that there is a negligible impact on the tidal Thames from the Burnell outfall options. Any changes to the Thames Tideway are likely to come from changes to the discharge at Mogden STW linked to the scheme. These changes are assessed in Appendix 6.2. Modelling showed that there would be no change in velocity, water levels and water quality downstream of Teddington Weir and that there would be no net change in pass forward flow over Teddington Weir.

A.1.36 Baseline data collected suggest that the Tidal Thames along Richmond Pound is still mostly freshwater-influenced. The filamentous algae *Vaucheria* sp. was the only species recorded in the channel along Isleworth Ait. This algae is very tolerant and hardy and is unlikely to be impacted by small changes in temperature, velocity and water quality. As the physical environment changes are considered negligible, it is considered that there will be no impact on the macrophyte and macroalgae community through changes in velocity, tidal exposure, temperatures, and water quality.

A.1.37 Temperature modelling shows a 1°C increase under certain low-flow scenarios. It is unlikely that a 1°C increase downstream of Teddington Weir will have an impact on the macrophyte and macroalgae community downstream of the weir.

A.1.38 It is not likely that the protected/notable species identified under baseline conditions will be present downstream of Teddington Weir as these are freshwater species and will be sensitive to any saline influences in the estuarine Thames. However, the presence/ absence of these has not been confirmed from baseline monitoring. The impacts to the upper Thames from the Burnell site are considered negligible, and therefore, if these species were present within the upper Thames, they are not likely to be impacted by the scheme.

## Macroinvertebrates

### Freshwater Thames

#### *Temperature*

A.1.39 Temperature increases have the potential to affect the survival and behaviour of freshwater macroinvertebrates. Changes in temperature may impact the community composition of macroinvertebrates, which may have knock-on effects on the fauna that feeds on them. Indirect impacts could occur through increases in temperature, which may cause changes in macrophyte, algae and phytoplankton communities, which macroinvertebrates rely on.

A.1.40 The macroinvertebrate community along the freshwater reach of the River Thames appears to be a lowland community which is adapted to slow to moderate flows and is tolerant of nutrients and moderate sedimentation. The community was predominantly made up of molluscs and crustaceans, which are fairly tolerant to fluctuations in temperatures. The taxa with the potential to be sensitive to changes in temperature included crawling water beetles (Haliplidae), riffle beetles (Elmidae), long-horned caddisfly (Leptoceridae), small square-gilled mayfly (Caenidae) and burrowing mayfly (Ephemeridae).

A.1.41 It is unlikely that an overall 1-2°C increase in temperatures downstream of the outfall will have a negative impact on the local macroinvertebrate community. The highest temperature increases may be seen over the winter months when individuals have either died or are dormant. Increases in temperatures over winter may impact macroinvertebrates by prompting earlier emergence; however, photoperiod is believed also to be an important factor. Artificially induced emergence may affect species' ability to complete their life cycles if they are reliant on seasonal factors such as the emergence of a particular plant. Increases in temperature may also reduce body size in individuals and increase the rate of development[9].

A.1.42 The increases in river temperatures are likely to be within the natural fluctuations for the Thames. They are, therefore, not likely to cause a significant impact on macroinvertebrate life cycles or behaviour. Temperature predictions based on the exceptionally hot and dry summer of 2022 and the warm, dry spring of 2011 showed that the scheme would cause river temperatures to increase to a maximum of 24.3°C. This is within the natural temperature profile range recorded for the Thames (between 1.9-24.3°C).

A.1.43 A worst case modelling scenario for temperature (very low flows of 400Ml/d and with maximum temperature differential between recycled water and river water) demonstrated that maximum temperature change would be present only within the immediate vicinity of the discharge and would dissipate rapidly (within a few meters) downstream of the discharge location. For this worst case, the increased temperature may cause mortality to localised macroinvertebrates currently using the habitat in the immediate proximity of the outfall location. The highest temperatures dissipate within the proximity of the pipework for the near bankside in-river option. For the bankside option, the highest temperatures dissipate within 4m downstream of the outfall.

A.1.44 When approaching their thermal limits, organisms show signs of stress, resulting in changes in behaviour, reduction in body size and reduced food intake. Some species may drift (voluntarily leave the substrate they occupy in response to environmental stress) due to temperature increases. This could have knock-on impacts on other fauna[10].

[9] Bonacina L., Fasano F., Mezzanotte V. and Fornaroli R. (2022) Effects of Water Temperatures of Freshwater Macroinvertebrates: a Systematic Review. Biological Reviews 98 (1) 191-221.
[10] Bonacina L., Fasano F., Mezzanotte V. and Fornaroli R. (2022) Effects of Water Temperatures of Freshwater Macroinvertebrates: a Systematic Review. Biological Reviews 98 (1) 191-221.

A.1.45 The majority of the taxon recorded along the freshwater Thames has relatively high thermal limits and is not likely to be impacted by the thermal plume produced by the outfall. Increases in mixed water temperatures in summer are also unlikely to impact these taxa due to their relatively high tolerance to temperature. Sphaeriidae have a lethal temperature limit of 32°C[11] , and for *Lumnaeidae,* the lethal limits are cited as 30°C[12]. The optimum growth for *Planorbidae* was 19-20.5°C, and temperatures of 25°C can affect survival/ fitness[13]. Out of the taxa, which have the potential to be more sensitive to temperature changes, *Caenidae* has a critical thermal maximum of 36.7-38.5[14]. *Haliplidae* beetles' behaviour has been observed to change at 25°C. Adult air-breathing species will surface more regularly at higher water temperatures, which may affect survival[15]. *Elmidae* riffle beetles have been observed to successfully undertake their life cycles at 22-25°C, and there is no evidence to suggest that an increase in water temperature would affect this family[16]. Reductions in dissolved oxygen that occur as a result of increases in water temperature have also been demonstrated to impact the survival and behaviour of many of these taxa to the same magnitude as temperature.

A.1.46 As the duration of the scheme is intermittent and not permanent, it is not likely to cause a long-term impact on the macroinvertebrate community, and any behavioural changes due to temperature increases are likely to be temporary. The effects of any temperature increases are reversible, as baseline conditions would return when the scheme is not operational. As the scheme is most likely to be operational during warmer months, it is unlikely that the scheme will artificially induce the early emergence of macroinvertebrates in the winter months.

A.1.47 Changes in temperatures could negatively impact many of the protected species listed in Table A.2.28 if they were present within the thermal plume of the outfall during the operation of the scheme. Research on the impacts of temperature increases on designated species is limited. It can be assumed that some of the designated species listed are likely to be more sensitive to temperature, velocity and water quality changes. However, there are likely to be other local environmental factors affecting the distribution of these species to a much greater extent than the operation of the scheme.

A.1.48 In terms of notable species, increases in water temperatures may particularly threaten depressed river mussel. However, this species was not recorded in

[11] Murray A.R. (1975) The Ecology of Saskatchewan Sphaeriidae (Mollusca; Bivalvia): An Evaluation of Some Components of Their Environment. University of Saskatchewan Thesis, Saskatchewan.
[12] Harris, R. E., & Charleston, W. A. G. (1977). Some temperature responses of Lymnaea tomentosa and L. columella (Mollusca: Gastropoda) and their eggs. New Zealand Journal of Zoology, 4(1), 45–49.
[13] K. Costil, Influence Of Temperature On Survival And Growth Of Two Freshwater Planorbid Species, Planorbarius Corneus (L.) And Planorbis Planorbis (L.), Journal Of Molluscan Studies 60 (3) 223–235
[14] Puckett R.T. and Jerry L.C. (2004) Physiological Tolerance Ranges of Larval *Caenis latipennis* (Ephemeroptera: Caenidea) in Response to Fluctuations in Dissolved Oxygen Concentration, pH and Temperature. Texas Journal of Science 56 (2): 123-130.
[15] Banks Tb>, Kincaid R.M. and Boersma K.S. (2018) Temperatures and Dissolved Oxygen Determine Submersion Time in Aquatic Beetle *Pltodytes callosus* (Coleoptera: Haliplidae). Journal of Insect Behaviour https://doi.org/10.1007/s10905-018-9689-6
[16] Elliott J.M. (2008) The ecology of riffle beetles (Coleoptera: Elmidae). Freshwater Biological Association.

any of the macroinvertebrate sampling or the targeted depressed river mussel surveys conducted as part of the baseline and are not likely to be present within the study area.

A.1.49 Swollen river mussel (*Unio tumidus)* was recorded around the Burnell site. At 30 (±0.5)°C, swollen river mussel have been observed to reach critical temperature, and metabolic rates increase, which results in the exhaustion of energy resources[17]. Other factors like water quality, water oxygenation and artificial channel modifications may limit the distribution of this species. River orb mussel (*Sphaerium rivicola*) is highly sensitive to water pollution as this pressure tends to decrease the dissolved oxygen concentration. Sensitivity to eutrophication seems to increase with increasing water temperatures[18]. Given the anticipated duration of the scheme, its localised effects, and the low likelihood of protected macroinvertebrates being present within the affected area, the impact on temperature increases for notable macroinvertebrate species in the Thames is likely to be minor.

## Velocity/flow

A.1.50 Increases in velocity have the potential to impact the macroinvertebrate community through the movement of sediments and habitat disturbance, particularly movements of larger substrate. Any disturbance to macrophytes and phytoplankton could have knock-on effects on macroinvertebrates, which require certain plants to complete their life cycles. Increases in velocity may displace macroinvertebrates from suitable habitats or cause mortality.

A.1.51 The macroinvertebrates recorded in the baseline section were indicative of a community of a large lowland river with a preference for slower flows. A high proportion of the macroinvertebrates recorded were molluscs, worms and crustaceans. There were also a number of taxa recorded which have a preference for higher flows and highly oxygenated water. These were crawling water beetles (*Haliplidae*), riffle beetles (*Elmidae*), long-horned caddisfly (*Leptoceridae*), small square-gilled mayfly (*Caenidae*) and burrowing mayfly (*Ephemeridae*). LIFE scores based on baseline monitoring were indicative of a community adapted to moderate to slow-flowing water. LIFE EQRs indicated that low flows along the Thames may currently impact the community. The presence of Teddington Weir likely has an impact on the macroinvertebrate community by artificially altering river flows. Increases in flow may be of some benefit to the macroinvertebrate community. However, the temporary nature of the increases is likely to have a negligible impact.

A.1.52 Sudden increases in flow have been shown not to affect the overall abundance and number of the following macroinvertebrates: *Crangonyx pseudogracilis* (freshwater shrimp), *Ostracoda* sp. (seed shrimp), *Sphaeriidae* (pea clam),

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[17] Romanenko O.V., Krot Y.G., Krasyuk Y.M., Konovets I.M. (2023) Peculiarities of Unio tumidus and Unio pictorum (Unionidae) Adaptive Reactions to the Water Temperature Increase in the Macrocosm. Hydrobiological Journal 59 (3) 39-50

[18] Van Damme, D. 2011. Sphaerium rivicola. The IUCN Red List of Threatened Species 2011: e.T155853A4855157. http://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T155853A4855157.en Accessed on 18 December 2024

*Chironomidae* (non-biting midge) and *Caenis* sp. (mayfly). Flow increases up to 4-7.6cm/s can change the behaviour of individuals of the recorded species and cause drift but would not cause an overall decline in species. Species are likely to move from an area before velocities reach high enough levels to move sediments[19]. A current velocity above 0.12 m/s−1 would wash away *Bithynia tentaculata* (faucet snail) and *Physella acuta* (bladder snail). However, *Ancylus fluviatilis* (river limpet) has been found to be unaffected by velocities up to 0.23 $m/s^{-1}$[20].

A.1.53 Velocities from the outfall are estimated to be a maximum of 0.3m/s directly at the point of discharge. The species outlined above, which have been recorded along the Thames and other species of similar tolerance limits, may be disturbed by the operation of the outfall. However, 0.3m/s is a prediction under more extreme scenarios, and the velocity is predicted to begin dissipating after 10m to less than 0.05m/s, meaning the majority of the channel would see much smaller increases in velocity. As the scheme is predicted to run intermittently, the duration of impact will likely be temporary. Any disturbance would be reversible when the scheme is not running, as the scheme is not predicted to cause any movement of sediments or scouring to the channel bed or bankside.

A.1.54 Protected/notable macroinvertebrate species identified from baseline conditions may be more sensitive to changes in velocity, as some of these species have specific habitat requirements or are adapted to large, slow-flowing lowland rivers. However, published research on the impacts of velocity increases on the protected species recorded within the baseline section is not widely available. The riffle beetle *Macronychus quadrituberculatus*, dark-winged soldier fly (*Oxycera analis*), the mayfly (*Ephemera lineata*) and swollen river mussel have all been recorded around the Burnell site. It is likely, given the ranges of these species, that the species listed can tolerate higher velocities than the baseline velocity for around Burnell.

A.1.55 Many of the species recorded are adapted to large lowland rivers (striped mayfly) and are not likely to be negatively impacted by temporary velocity increases of 0.3m/s.

## Water quality

A.1.56 Effects on water quality from both outfall options are currently under review but expected to be slight as will be discharged under a discharge permit which will include water quality requirements. It is expected there will be negligible change outside of the immediate mixing zone (the discharge would be fully mixed before Teddington Weir). Potential slight changes to water quality within the mixing zone could include an increase in phosphorus and ammonia and reduction in dissolved oxygen during the operation of the Project. Further information will be available at ES when data from the pilot plant is available.

[19] Imbert J.B and Perry J.A. (200) Drift and benthic invertebrate responses to stepwise and abrupt increases in non-scouring flow. Hydrobiologia 436: 191-208
[20] Schossow M., Arndt H. and Becker G. (2016) Response of gastropod grazers to food conditions, current velocity and substratum roughness. Limnologica 58: 49-58

A.1.57 Increases in phosphorus and ammonia may cause the mortality of nutrient-sensitive species and change the community composition towards more nutrient-tolerant species. Baseline macroinvertebrate data from the Thames was indicative of a community of nutrient-tolerant species. WHPT ASPT scores were low and indicative of a skew toward nutrient-tolerant species. ASPT EQRs were indicative of a macroinvertebrate community impacted by high nutrient levels. Further increases in phosphorus may further skew the macroinvertebrate community toward nutrient-tolerant species.

A.1.58 Many of the baseline taxon recorded have a high tolerance to nutrient enrichment. Small increases in phosphorus and ammonia during the operation of Burnell are not likely to exceed the tolerance thresholds of the macroinvertebrate species recorded along the Thames.

A.1.59 The scheme is anticipated to operate once every two years, and within this time, it will run intermittently between July and November. Any increases in phosphorus due to the operation of the outfall are not likely to cause any change in the macroinvertebrate community composition due to the scheme operation being temporary in duration, and any effects may be reversed when the scheme is not operational.

A.1.60 The proportion of Sediment-sensitive Invertebrates (PSI) scores from the baseline data suggested that the macroinvertebrate community is mostly associated with sedimented channel beds. PSI EQR scores indicated that the macroinvertebrate community along the Thames may be impacted by sedimentation. Any decrease in suspended sediment from due to the discharge will likely benefit the macroinvertebrate community by reducing sedimentation, meaning more sensitive species may be able to survive.

A.1.61 Decreases in dissolved oxygen can affect macroinvertebrates by altering the growth rate of individuals, and it may also cause mortality to sensitive species that require high dissolved oxygen. Any potential decrease in dissolved oxygen from the discharge is likely to be small and is unlikely to have any negative impacts on the macroinvertebrate community along the Thames. The species present along this reach are tolerant of lower dissolved oxygen and lower flows.

### Estuarine Thames

A.1.62 Assessments in Chapter 5 show that there would be a negligible impact on the physical environment of the tidal Thames from the Burnell outfall. Any changes to the Thames Tideway are likely to come from changes to the discharge at Mogden STW linked to the scheme. These changes are assessed in Appendix 6.2. Modelling showed that there would be no change in velocity, water levels and water quality downstream of Teddington Weir and that there would be no net change in pass forward flow over Teddington Weir.

A.1.63 Baseline data collected indicate that the Tidal Thames along Richmond Pound remains predominately influenced by freshwater. Samples from this section of the Thames were dominated by freshwater invertebrates, though species with a preference for more saline conditions were more prevalent compared to sites upstream of Teddington. This includes species such as Gammarus zaddachi.

A.1.64 As the physical environment changes are considered negligible, it is considered that there will be no impact on the macroinvertebrate community through changes in velocity, tidal exposure, temperatures, and water quality.

A.1.65 Temperature modelling shows a 1°C increase under certain low-flow scenarios. It is unlikely that a 1°C increase downstream of Teddington Weir will have an impact on the macroinvertebrate community downstream of the weir.

## Fish

### Freshwater Thames

#### *Temperature*

A.1.66 Changes to the temperature regime of the freshwater Thames as a result of the operational phase of the project could impact fish.

## Thermal Preferenda

A.1.67 The scheme operation could lead to temperature changes within the River Thames that exceed the temperature preferenda of species present and could have sub-lethal or lethal effects in extreme circumstances.

A.1.68 The maximum modelled temperature increases to ambient river temperature for the A82 and M96 scenarios are 0.8°C and 1.5°C, respectively. These both fall within the High WFD standard category (See Appendix 5.3 for more details) for an increase or decrease in the ambient river temperature, therefore not causing a deterioration in WFD status. As a result, this is not predicted to cause a deterioration in the fisheries community. Under these scenarios, the predicted temperature of the River Thames after mixing would reach a maximum of 20°C, which remains below the upper lethal limit for the most sensitive species (approximately >23°C) identified in the freshwater Thames (see Appendix 6.1). Although the maximum recorded temperature within the River Thames is 24.3°C, under this extreme scenario, the predicted discharge temperature for the recycled water is 21.5°C, which is 2.8°C cooler than the ambient river temperature. Therefore, beyond a certain temperature threshold, the scheme is not expected to push the river temperature beyond the critical thermal maximum for the most temperature-sensitive species and may even help alleviate heat stress.

A.1.69 The magnitude of the impact of temperature on the preferred temperature range for fish of both the bankside and near bankside in-river outfall in the River Thames is predicted to be negligible, given the small incremental change to mixed river temperatures. It is noted these changes are localised to a small extent of approximately 200m of the Freshwater River Thames above Teddington Weir and do not put any species identified within their upper lethal limit for temperature, which factored with the intermittent frequency and duration of operation the scheme is considered unlikely to affect the fish assemblage of the River Thames. The maximum temperature change to mixed river temperature is predicted to be 1.45°C above the ambient river temperature under the M96 scenario, which is a very low flow year with a return frequency of 1:20. Therefore, this scenario is only predicted to occur twice every 50 years and is still compliant with WFD High standard for an increase or decrease to the ambient river temperature. Furthermore, under maximum temperature extremes, it is noted that recycled water is predicted to discharge at a lower temperature than ambient river temperature and will not push the river temperature beyond the critical thermal maximum for fish. It is anticipated that any effects on the fish populations of the River Thames will be reversible in the short term due to the intermittent operation and localised area of effect through further mitigation. Therefore, the impact of temperature on the exceedance of thermal preferenda of fish in the River Thames is considered to be Minor for both bankside and near bankside in-river outfall. However, it is noted that the near bankside in-river outfall reduces impacts on the marginal habitat, consequently further limiting any impacts of changes in temperature on the exceedance of thermal preferenda of juvenile coarse fish or migrating elvers.

## Thermal Barrier

A.1.70 The difference in temperature between the outfall discharge and ambient river temperatures may cause a temperature change downstream of the outfall, which could act as a thermal barrier to upstream salmonid migration, therefore reducing salmonid migration success. Although the outfall is at a fixed point near Teddington Weir, reduced migration success could affect salmonid recruitment throughout the Thames catchment upstream of Teddington Weir.

A.1.71 The thermal plume modelling was completed in Gate 2 after conferring with the Environment Agency (Appendix 6.2). The following guidance was identified for the assessment of thermal plumes. These documents do not directly offer suggestions for freshwater and strategic resource option projects; therefore, they have been considered as a guide only.

a. A study carried out by Turnpenny and Liney (2006)[21] recommended a limit for thermal plumes of 25% of the channel cross-sectional area exceedance of the mixing zone (95%ile).

b. This same limit is indicated in an Environment Agency`s report called “Cooling Water Options for New Generation of Nuclear Power Stations in the UK (SC070015/SR3)”.

c. Subsequently, it is also recommended in the British Energy Estuarine & Marine Studies (BEEMS), The Scientific Advisory Report No:8[22].

A.1.72 The thermal plume modelling predicts that the plume area of the 75Ml/d option is at a maximum of 1.2% of the channel cross-section for the bankside outfall

[21] Turnpenny, A. & Liney, K. (2006). Review and development of temperature standards for marine and freshwater environments. Jacobs Report for SNIFFER and UKTAG.
[22] BEEMS, (2011). ‘Thermal Standards for cooling water from new build power stations’ *BEEMS*, No.008, pp. 1-147

and 7.7% cross-sectional area for the near bankside in-river outfall. Therefore, both options conform to the above guidance.

A.1.73 Several environmental factors, including temperature, trigger migration for both Atlantic salmon and sea trout. Whilst temperature has been found to influence salmonid migration, research on the migration of resident brown trout and sea trout has demonstrated that the timings of diadromous spawning migration undertaken by sea trout were observed to correlate more to photoperiods than temperature[23]. Salmonid upstream migration has been researched to be inhibited once temperatures exceed 21.5°C [24,25]. However, below this temperature, oxygen levels are suggested to be a more important factor affecting migration[26].

A.1.74 The average temperature increases for the A82 and M96 scenarios are noted to be 0.4°C and 0.7°C, respectively, with a maximum modelled temperature increase to ambient river temperature of 1.45°C down to Teddington Weir (approximately 200m). The maximum modelled temperature increase during the peak salmonid migration months of July to August is 0.27°C under both the A82 and M96 scenarios. It is known that salmonids will cross small temperature changes similar to and in excess of these throughout their upstream migration, for example, at watercourse confluences where a natural change in temperature may occur. It has been noted that in laboratory and field observations, salmonids have often willingly crossed temperature changes of several degrees Celsius. Where evidence suggests possible effects of thermal barriers, it has been confounded by other issues, such as changes in dissolved oxygen[27,28,29]. Additionally, the small variations in temperature in the Freshwater Thames between the outfall and Teddington Weir are lower than observed temperatures in the Thames Tideway below Teddington Weir at all times, apart from some brief minor increases above the Tideway temperature under the M96 scenario (1 in the 20-year scenario). Therefore, during the majority of scheme operation salmonids will migrate up the Tideway through higher temperatures than they will experience in the Freshwater Thames.

A.1.75 The modelling of the thermal plume shows that under the low flow (300 Ml/d) scenario, the mixing zone for the bankside outfall is confined to within ten metres of the discharge and reduces to <1ºC change ~70m downstream of the outfall and the area of the >2°C contour covers 0.1% of the cross-sectional area

[23] García-Vega, A., Fuentes-Pérez, J.F., Leunda Urretabizkaia, P.M., Ganuza, J.A., and Sanz-Ronda, F.J. (2022). Upstream migration of anadromous and potamodromous brown trout: patterns and triggers in a 25-year overview. *Hydrobiologia*. 849, pp. 197-213.
[24] BEEMS, (2011). 'Thermal Standards for cooling water from new build power stations' *BEEMS*, No.008, pp. 1-147
[25] Webb, B. & Walsh, A.J. (2004). Changing UK river temperatures and their impact on fish populations, Hydrology: Science & Practice for the 21st Century. 2, pp. 177-191.
[26] Rosten, C., Horsfield, R., Anderson, K. & Turnpenny, A.W.H., 2010. Influences of Environmental Variables and Stocking on Atlantic Salmon Upstream Migrations in the River Thames, UK. In: (P. Kemp, ed.) *Salmonid Fisheries: Freshwater Habitat Management*. Chichester: Blackwell Publishing Ltd, pp. 296–306.
[27] BEEMS, (2011). 'Thermal Standards for cooling water from new build power stations' *BEEMS*, No.008, pp. 1-147
[28] Turnpenny, A., Coughlan, J. & Liney, K. (2006). Review of Temperature and Dissolved Oxygen Effects on Fish in Transitional Waters. Jacobs Report for the Environment Agency.
[29] Rosten, C., Horsfield, R., Anderson, K. & Turnpenny, A.W.H., 2010. Influences of Environmental Variables and Stocking on Atlantic Salmon Upstream Migrations in the River Thames, UK. In: (P. Kemp, ed.) *Salmonid Fisheries: Freshwater Habitat Management*. Chichester: Blackwell Publishing Ltd, pp. 296–306.

of the channel. Under the near bankside in-river outfall, the mixing zone is confined to within 20m of the bank and reduces to <1°C change ~60m downstream and the area of the >2°C contour covers 0.2% of the cross-sectional area of the channel. This leaves the vast majority of the 80m-wide river channel seeing less than a 1°C temperature change under both outfall options. This shows that the mixing zone does not stretch across the entire width, is held close to the water surface area, and does not form a barrier across the watercourse. The predicted thermal changes fall well within the regulatory criteria on all counts. Additionally, the outfall is located on the opposite bank to the current fish pass; therefore, salmonids will not be migrating directly into the plume.

A.1.76 The magnitude of the impact of temperature on salmonid migration through the formation of a thermal barrier for both the bankside and near bankside in-river outfall has been categorised as negligible. This is due to the small incremental change to mixed river temperatures and confinement of the thermal plume to the righthand riverbank for both options on a river with a width of approximately 80m. Temperature fluctuations resulting from the TDRA scheme would fall within the natural range of variations fish experience during migration. Given the intermittent frequency and limited duration of operation, these fluctuations are unlikely to affect salmonid migration in the River Thames. It is also noted that the Project is compliant with WFD High standards for increases or decreases to the ambient river temperature and that the extent of the thermal plume complies with identified guidance. It is anticipated that any effects on salmonid migration within the River Thames will be reversible in the short term due to the intermittent operation and localised area of effect through further mitigation. Therefore, impacts on salmonid migration due to the formation of a thermal barrier in the River Thames are considered to be Minor for both the bankside and near bankside in-river outfall. Neither option is expected to create thermal barriers that would impact salmonid migration.

## Thermal Attraction

### European eel

A.1.77 The difference in temperature between the outfall discharge and ambient river temperatures may disrupt the upstream migration of European eels. They may be thermally attracted to the warmer discharge of the outfall, which could reduce migration success within the Thames Catchment. Migration of elvers is triggered by several environmental factors, including temperature, with elvers reported to migrate upstream through the estuary at temperatures of 9-18°C[30].

A.1.78 Elver migration is typically known to take place between April and September every year [31,32] and the previously discussed eel trap data collected by ZSL

[30] BEEMS, (2011). 'Thermal Standards for cooling water from new build power stations' *BEEMS*, No.008, pp. 1-147
[31] Boardman, R.M., Pinder, A.C., Piper, A.T, Gutmann Roberts C, Wright RM and & Britton JR (2024) Environmental influences on the phenology of immigrating juvenile eels over weirs at the tidal limit of regulated rivers Hydrobiologia 851 4439-4458
[32] Naismith, I.A., and Knights, B. (1988). Migrations of elvers and juvenile European eels, Anguilla anguilla L., in the River Thames. J. Fish. Biol. 33 (Supplement A), 161-175.

shows peak migration from the Thames tideway to the freshwater Thames takes place between July, August and September. Therefore, the scheme operation and peak elver migration period will overlap. Predicted average ambient river temperatures and recycled water temperatures from April to September can be seen in Table A.1. These predictions have been derived using long-term (2010-2023) measured temperature data from the River Thames at Purfleet, Teddington and Mogden STW.

Table A.1 Average temperatures for the ambient River Thames and recycled water within the identified peak upstream migration period for juvenile European eel elvers (April – September).

| Month | Average ambient river temperature at Purfleet (°C) | Average ambient river temperature at Teddington (°C) | Average recycled water temperature (°C) using STW final effluent temperature as conservative proxy | Temperature difference between ambient river and recycled water (°C) as proxy for difference at point of discharge | Average fully mixed river temperatures (°C) outside of discharge plume | Average increase to ambient river temperature (°C) outside of discharge plume at Teddington |
|---|---|---|---|---|---|---|
| April | 11.3 | 11.8 | 15.6 | 3.8 | -* | -* |
| May | 14.5 | 15.3 | 17.7 | 2.4 | -* | -* |
| June | 17.8 | 18.6 | 20.0 | 1.4 | -* | -* |
| July | 20.1 | 20.1 | 21.3 | 1.3 | 20.2 | 0.1 |
| August | 20.1 | 19.5 | 21.4 | 1.9 | 19.7 | 0.2 |
| September | 18.2 | 17.1 | 20.4 | 3.3 | 17.4 | 0.3 |
| April | 11.3 | 11.8 | 15.6 | 3.8 | -* | -* |

**Month not modelled under the A82 or M96 scenario; therefore, fully mixed river temperatures are not available.*

A.1.79 Table A.1 and Table A.2 show that the average river temperatures of the estuarine Thames at Purfleet in April are 11.3°C. April, the start of the upstream eel migration, aligns with literature that reports that eel migration in the Thames estuary is triggered when temperature fluctuations are between 10°C and 15°C for juvenile eel[33]. It is also shown that temperatures across from Teddington to Purfleet are not uniform and that fluctuations are expected across the course of a river.

A.1.80 Table A.1 shows that the discharge temperature difference (between the average monthly ambient temperature of the River Thames at Teddington and the recycled water) ranges from 3.8°C to 1.3°C. Within the identified peak migration months of July, August and September, the monthly average

[33] Naismith, I.A., and Knights, B. (1988). Migrations of elvers and juvenile European eels, *Anguilla anguilla* L. in the River Thames. J. Fish. Biol. 33 (Supplement A.), pp. 161-175.

temperature difference between the ambient temperature of the River Thames and the recycled water ranges from 1.3°C to 3.3°C. This results in an average temperature increase in the ambient river temperature of up to 0.3°C in peak migration months of July to September. These temperature increases are considered to have limited attraction potential and are within the realms of natural temperature fluctuations elvers may experience on their upstream migration. Particularly in June, July and August, which includes peak migration months, where the temperature difference between the ambient river temperature and recycled water is <2°aC, resulting in a low magnitude of impact. Slightly larger monthly average temperature differences between ambient river temperature and recycled water temperature can be seen in April and May, at 3.8°C and 2.3°C, respectively.

A.1.81 The frequency of project operation during the eel upstream migration period must be considered. As shown in Table A.3, project operations in April and May are predicted to occur at a frequency of less than 1:100 years. In June, operation is predicted to occur on a 1:50-year frequency and in July, a 1:20-year frequency. Scheme operation is most likely to coincide with the eel migration months of August and September, which is predicted to occur at a 1:5-year frequency. The largest overlap with eel migration and scheme operation is predicted to occur in August rather than September, based on the number of eels and migration peaks, as shown in Appendix 6.1 a higher number of eels were caught in August than in September, showing the largest overlap with eel migration is predicted to occur in August. The temperature difference between the ambient river temperature and recycled water in August is predicted to be low and, on average, <2°C.

Table A.2 Predicted frequency of Teddington DRA operation during the eel migration period shown alongside the average temperature difference between ambient river temperature and recycled water temperatures.

| Month | Predicted operational frequency | Average Temperature difference between ambient river and recycled water (°C) as proxy for difference at point of discharge |
|---|---|---|
| April | <1:100 Years | 4.6°C |
| May | <1:100 Years | 2.3°C |
| June | 1:50 Years | 1.4°C |
| July | 1:20 Years | 1.3°C |
| August | 1:5 Years | 1.9°C |
| September | 1:5 Years | 3.3°C |

A.1.82 Research states that 30°C is the highest temperature eels will tolerate for a prolonged period. At this temperature, eels showed avoidance behaviour and attempted to escape the tanks they were held in, but at 28°C, eels still demonstrated good aerobic scope[34]. This research suggests eels would be inclined to avoid the outfall if temperatures were to locally increase up toward 30°C (this is unlikely according to the modelling) and that their ability to swim away from a thermal plume of this temperature would be unaffected if individuals were to attempt to migrate through the thermal plume. The paper above showed that aerobic scope in eels increased with increasing temperature. Assuming migrating eels are instinctively trying to preserve energy in order to migrate upstream successfully, it is likely in summer (higher) water temperatures that are already within their optimal range, they would be inclined to avoid localised warmer waters that would cause an increase in their metabolic rate suggesting they would not attempt to migrate up the outfall.

A.1.83 Other studies have shown that European eel respond negatively to a temperature increase of more than 3°C above an acclimation temperature of 12°C[35]. This suggests elvers would likely avoid attempting to enter the outfall due to the steeper temperature gradient within the mixing zone. Another study suggests that pigmented elvers showed no reaction to increases in >12°C above an acclimation temperature of 9.5°C when presented with a sharply defined interface[36]. A lack of reaction suggests that elvers may not show an attraction to the temperature increases from the outfall and continue migrating upstream.

A.1.84 During periods when the scheme operates concurrently with upstream eel migration, temperature differences between the river and recycled water remain relatively low—less than 2°C in peak migration months (July and August) and less than 3.5°C in September. These differences fall within the natural temperature fluctuations that eels encounter throughout their migration. While there is limited evidence to confirm or refute the formal attraction of eels to warmer water, it is noted that upstream migration occurs during warmer months, when river temperatures may already be within the optimal range for eels. As a result, any thermal attraction to the minor temperature increases around the outfall is likely to be minimal and, in some cases, may even lead to avoidance behaviour. The duration and frequency of the scheme's operation relative to the eel migration period is low. Based on historical data from a six-year period (2013–2018), the scheme is estimated to overlap with only 20% of the European eel elver upstream migration window (April to September). The predicted frequency of operation varies by month:

a. April and May: Less than once in 100 years

b. June: Once in 50 years

[34] Claësson, D., Wang, T. and Malte, H. (2016). Maximal oxygen consumption increases with temperature in the European eel (Anguilla anguilla) through increased heart rate and arteriovenous extraction. Conservation Physiology, 4(1),

[35] Tongiorgi, P., Tosi, L. and Balsamo, M. 1986. Thermal preferences in upstream migrating glass-eels of Anguilla anguilla (L.). Journal
of Fish Biology, 28(4): 501–510.

[36] Handeland, S. O., Wilkinson, E., Sveinsbø, b., McCormick, S. D. and Stefansson, S. O. (2008). Temperature influence on the development and loss of seawater tolerance in two fast-growing strains of Atlantic salmon. Aquaculture, 233 (1-4), pp. 513-529

c. July (peak migration month): Once in 20 years

d. August and September (peak migration months): Once in 5 years

A.1.85 Additionally, when Teddington Weir overtops, the scheme will not be operational. Historical data indicate that these overtopping events align with peak European eel migration, ensuring that the scheme will not be running during the most critical migration events. Any potential effects on eel migration are expected to be short-term and reversible, given the scheme's intermittent operation and mitigation measures. As such, the anticipated attraction effects of the Teddington DRA scheme on European eel elvers are predicted to be minor for both the bankside and near bankside in-river outfall. However, it is noted that the near bankside in-river outfall is offset from the river margins, where elvers are likely to migrate, meaning that the highest degree of change is outside of their likely path, which may further reduce the likelihood of attraction to the outfall under this option.

## Coarse Fish

A.1.86 The temperature gradient at the outfall may also act as an attractant to other Lusitanian fish species, such as coarse fish, resulting in congregation at the outfall, potentially increasing the risk of disease spread, predation and exposure to pollutants.

A.1.87 Temperature increases within the mixing zone, and the ambient river temperature of the Freshwater Thames fall within the temperature preferenda identified for coarse fish in Appendix 6.1. Therefore, coarse fish may respond positively to the temperature gradient. However, the scope for attraction is considered to be limited and weak. The temperature increases are small and within the realm of natural temperature changes experienced along the river whilst also confined to a small section of the Freshwater Thames during the intermittent operation of the Project. Attraction of coarse fish may result from factors other than increase in temperature (i.e. non-phenological), e.g., changes in habitat complexity due to structure associated with outfalls, discharge water quality and nutrient availability.

A.1.88 The temperature gradient at the outfall may act as a minor attractant for some Lusitanian species of fish, resulting in congregation and possibly increased levels of predation and pathogenic transmission[25]. However, where this phenomenon has been reported in relation to power station outfalls (e.g., in the case of sea bass[37]), temperature increases have generally been much larger, typically up to 10°C. Therefore, the scope of attraction is considered limited under this scenario due to the small temperature changes modelled and the intermittent nature of project operation.

A.1.89 The magnitude of the impact of thermal attraction from both the near bankside in-river and bankside outfall options on coarse fish populations is considered to be negligible. This is due to the small incremental change to mixed river

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[37] Pickett, G.D. and Pawson, M.G. 1994. Sea bass: biology, exploitation and conservation. Chapman & Hall, London, UK.

temperatures and confinement of the thermal plume to a small area of the righthand bank under both options on a river with a width of approximately 80m. However, as the temperature does have a minor increase, some scope for attraction remains. Although temperature changes are localised to approximately a 200m stretch of the Freshwater Thames above Teddington Weir, these fall within the natural temperature variations that fish experience along the course of the river. When combined with the intermittent frequency and limited duration of operation of the scheme, these temperature changes are unlikely to have a significant effect on fish populations in the River Thames. The Project complies with WFD High standards for increases or decreases in the ambient river temperature, and the extent of the thermal plume aligns with the relevant guidance. It is anticipated that any effects on coarse fish populations within the River Thames will be reversible in the short term due to the intermittent operation and localised area of effect through further mitigation. Therefore, impacts on coarse fish due to thermal attraction to both the near bankside in-river and bankside outfall in the River Thames are considered to be minor. However, it is noted that the near bankside in-river outfall is offset from the river margins reducing impacts on the marginal habitat.

## Velocity/flow

A.1.90 Changes to the flow regime of the Freshwater Thames as a result of the operational phase of the intake and outfall could impact fish through changes in flow, causing displacement of juvenile fish, disorientation of migratory fish, attraction to the outfall, impingement or entrainment or changes to water quality including impacts on olfaction.

A.1.91 Changes in flow as a result of the outfall discharge could result in the displacement of juvenile fish or the disorientation of migrating salmonids.

### Juvenile Fish Displacement

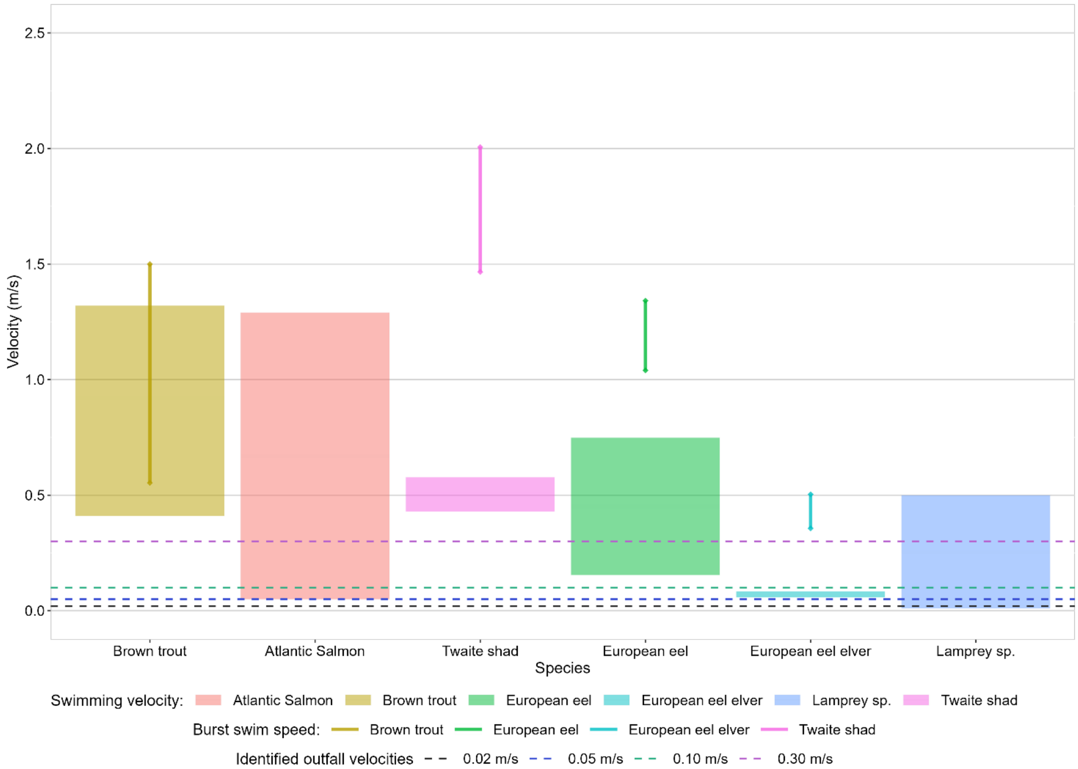
A.1.92 Disruptions to the flow regime may displace juvenile fish, negatively affecting the fish populations of the River Thames.

A.1.93 Findings of modelling of different outfall velocities within the outfall channel under alternative outfall designs are set out using a criteria assessment relevant to fish swimming speeds (species and life stages), migratory corridors and resident fish behaviours. With the EA SWIMIT V3.3 model, there are limitations associated with the length of fish that can be assessed and the ambient water temperatures within which the fish is swimming, and these limitations are considered within the assessment.

A.1.94 As a precautionary measure, only maximum sustainable swimming speeds were considered within the SWIMIT V3.3 model as a 90%ile. This identified that where data were available, fish fry, young of year fish (termed 0+), and juvenile fish were susceptible to outfall velocities between 0.05m/s and 0.3 m/s (presented in Plate A.2 and Plate A.3) in relation to sustainable swimming speeds. Thus, fish fry, 0+ and juvenile fish may not be able to hold station within the outfall location at these velocities. Modelling (Appendix 6.2) shows velocity increases across the majority of the channel are <0.05m/s. Under the bankside outfall, velocities of 0.05m/s to 0.3m/s only extend for approximately 10m from the outfall and cover a cross-sectional area up to approximately 1.5%. Under the near bank in-river outfall, velocities of 0.05m/s to 0.3m/s only extend for <10m from the outfall and cover a cross-sectional area up to approximately 3.0%. Under both options, this leaves only a small exclusion range close to the outfall where weaker swimming fish may not be able to hold station but will be able to swim under or around this velocity change. Flow within rivers is not always equal. Therefore, it is common to have areas where weaker swimming fish may not be able to hold station, and, as the exclusion zone only covers up to 3.0% for 10m, any weaker swimming fish that do enter this area will not be significantly displaced before being able to hold station again. This exclusion zone only restricts access to approximately 10m of marginal habitat. This is not considered significant due to the extensive, similar habitat available adjacent to the outfall location.

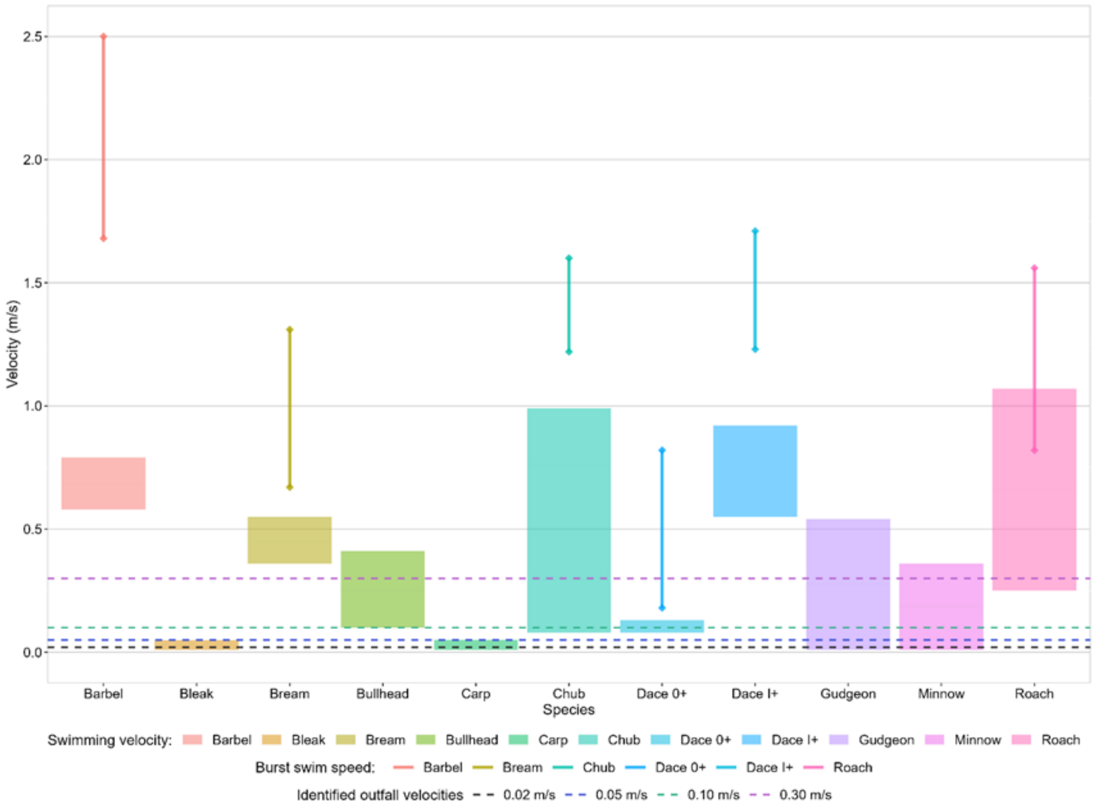
A.1.95 Fish can utilise different muscle blocks within their bodies in order to facilitate burst speeds for brief periods of a minute or less. Considering their burst speeds, fish fry, 0+, and juvenile fish can swim out or away from the outfall flows, as presented in Plate A.2 and Plate A.3. However, there are some limitations within the SWIMIT V3.3 model in relation to European eel, and, as a precautionary measure, elvers were considered in detail as part of the assessment.

## Plate A.2 Identified outfall velocities of Teddington DRA relative to the known migratory fish population endurance swimming velocity, habitat conditions and species-specific burst swimming speed capabilities[38]




[38] *Note*: Burst swimming speed and swimming velocity variance shown for fish size ranges as follows: brown trout, 50 – 200 mm; Twaite Shad, 290 – 390 mm; European eel, 80 – 780 mm; and European eel elvers 50 – 80 mm.

Plate A.3 Identified outfall velocities of Teddington DRA relative to the known coarse fish population endurance swimming velocity, habitat conditions and species-specific burst swimming speed capabilities[39].




A.1.96 The magnitude of the impact of the outfall velocity on the displacement of juvenile fish for both the near bankside in-river and bankside outfall options has been categorised as negligible given the small severity of change to overall river velocity, with the majority of the river seeing a change of <0.05m/s. These changes are localised to a small, approximately 200m stretch of the Freshwater Thames above Teddington Weir and fall within the natural velocity variations that fish experience along the course of the river. Given the intermittent frequency and limited duration of operation of the scheme, these changes are unlikely to have a significant effect on fish populations in the River Thames. A potential exclusion zone for weaker-swimming fish was identified; however, it is limited to 10m downstream of the outfall, covering only 1.5% of the cross-sectional area for the bankside outfall and 10m downstream of the outfall, covering only 3.0% of the cross-sectional area for the near bank in-river outfall. Given its small extent, this does not represent a substantial portion of habitat and is unlikely to have a significant effect on fish populations.

A.1.97 Furthermore, the identified exclusion zone is easily avoidable and would not significantly displace any fish. Therefore, it is not considered to impact juvenile fish populations. It is anticipated that any effects on juvenile fish populations within the River Thames will be reversible in the short term due to the

[39] *Note*: Burst swimming speed variance shown for fish size ranges as follows: barbel, 60 – 240 mm; bream, 50 – 180mm; chub, 80 – 300 mm; dace 0+, 20 – 60 mm; dace 1+, 100 – 300 mm; and roach, 50 – 230 mm.

intermittent operation and localised area of effect through further mitigation. Therefore, effects on juvenile fish due to displacement by outfall velocity in the River Thames for both the bankside and near bankside in-river options are considered to be minor. However, it is noted that the near bankside in-river outfall reduces impacts on the marginal habitat by moving the identified potential exclusion zone for weak swimming fish out of the margin and into the channel, further reducing impacts for juvenile coarse fish.

### Salmonid Disorientation

A.1.98 Disruptions to the flow regime may disorientate salmonids and negatively affect migration success.

A.1.99 Velocity changes would be localised between the intake, outfall and Teddington Weir, with changes of <0.05m/s for the majority of the channel. A small change such as this would be within the range of natural flow variations and unlikely to disorientate fish. Additionally, it is important to note that migrating salmonids will have just negotiated the Thames Tideway, where flows would have been tidally influenced; therefore, the flow conditions in this area of the freshwater Thames will be relatively more stable. Overall, it is considered unlikely that these minor changes to flow conditions will disorientate fish such as adult salmonids, owing to their strong swimming ability.

A.1.100 Both outfall structure designs act as energy dissipators by receiving the water from the recycled water conveyance tunnel and slowing the speed of the water to the required flow velocities when it discharges into the river. The internal outfall weir also acts as a hard barrier to prevent fish or any backflow from the river from entering the tunnel system.

A.1.101 A key principle in the selection of the outfall site was to ensure the location is within an area of the river where sufficient mixing of water can be achieved prior to water travelling over Teddington Weir. Therefore, under all model scenarios and outfall velocities, the discharge was fully mixed into the river before it went over Teddington Weir/through the fish pass using the current outfall location presented at Gate 2.

A.1.102 The magnitude of the impact of the outfall velocity on salmonid migration for both the near bankside in-river and bankside outfall options has been categorised as negligible given the small severity of change to overall river velocity, with the majority of the river seeing a change of <0.05m/s. It is noted these changes are localised to a small area of approximately 200m of the Freshwater Thames above Teddington Weir and are within the range of velocity fluctuations that fish will experience naturally on their migration. Considering this, as well as the intermittent frequency and duration of operation of the scheme, the outfall velocity is unlikely to affect salmonid migration in the River Thames. It is anticipated that any effects on salmonid migration within the River Thames will be reversible in the short term due to the intermittent operation and localised area of effect through further mitigation. Therefore, effects on salmonid migration due to disorientation in the River Thames for both the near bankside in-river and bankside outfall options are considered to be minor. Neither option will likely affect salmonid disorientation.

## Flow Attraction

A.1.103 The increase in velocity at the outfall as a result of the discharge may disrupt the upstream migration of European eel elver as they may be attracted to the higher flows of the outfall, which could reduce the migration success of European eel within the Thames Catchment.

A.1.104 Hydrodynamic impacts were modelled under the scenarios for 300 Ml/d river flow (Scenario 1), 400 Ml/d river flow (Scenario 2) and 700 Ml/d river flow (Scenario 3), with an outfall discharge of 75 Ml/d moving at 0.3m/s and the intake abstracting 75 Ml/d.

A.1.105 All three scenarios showed that flow velocities at the point of discharge would be 0.1-0.3m/s, which dissipates quickly down to ≤0.1m/s within approximately 10m of the discharge point under both outfall options. Generally, in a small area around the outfall (~10m upstream and ~100m downstream), flow velocity would increase by around 0.01-0.05m/s.

A.1.106 Changes to flow around the outfall are considered to be small and within the range of natural flow changes that elver will experience during their migration upstream. The elevated flow velocity above ambient in the River Thames around the discharge location may still act as an attractant. However, there is limited evidence available to prove or disprove this. Any fish or backflow from the river will be prevented from entering the outfall pipe by the internal weir, which acts as a hard barrier. In addition, the discharge rate of 0.3m/s should also ensure that elvers and juvenile fish cannot enter the outfall.

A.1.107 Elver may attempt to migrate unsuccessfully up the outfall, which may cause delays in their upstream migration and result in increased energy expenditure that could lead to reduced migration success in extreme circumstances. It should be noted that there is limited evidence to prove this. The scheme is only intermittently operational, overlaps with 20% of the eel migration period across a 6-year period, and will not be operating during the overtopping of Teddington Weir, which has been identified to be a key migration event reducing any impacts.

A.1.108 Whilst it is uncertain whether velocity changes will create a formal attraction, the overall impact is predicted to be low. Elvers will be unable to enter the pipe system due to the internal weir system incorporated within its design and the current flow rate of 0.3m/s, which dissipates to <0.1m/s within 10m of discharge under both outfall options. The duration and frequency of the scheme’s operation relative to the eel migration period is low. Based on historical data from a six-year period (2013–2018), the scheme is estimated to overlap with only 20% of the European eel elver upstream migration window (April to September). The predicted frequency of operation varies by month:

a. April and May: Less than once in 100 years

b. June: Once in 50 years

c. July (peak migration month): Once in 20 years

d. August and September (peak migration months): Once in 5 years

A.1.109 Additionally, when Teddington Weir overtops, the scheme will not be operational. Historical data indicates that these overtopping events align with peak European eel migration, ensuring that the scheme will not be running during the most critical migration events. Any potential effects on eel migration are expected to be short-term and reversible, given the scheme's intermittent operation and mitigation measures. As such, the anticipated attraction effects of the Teddington DRA scheme on European eel elvers are predicted to be Minor for both the bankside and near bankside in-river outfall. However, it is noted that the near bankside in-river outfall is offset from the river margins, where elver are likely to migrate, meaning that the highest degree of change is outside of their likely path, which may further reduce the likelihood of attraction to the outfall under this option.

## Impingement and Entrainment

A.1.110 The intake may impact fish species through impingement or entrainment of juvenile fish and European eel elvers.

A.1.111 Entrainment is the unwanted passage of fish through a water intake, which is generally caused by an absent or inadequate screen surrounding the water intake. Impingement is the physical contact of a fish with such a barrier structure (screen) due to intake velocities, which are too high to allow the fish to escape. Fish entrainment and fish impingement are both referred to in this report as fish entrapment.

A.1.112 To comply with the Eels Regulations, the intake mesh size and approach velocity design will comply with Best Achievable Eel Protection using the EA guidance document LIT66008[40]. This design will be determined by intake screen's location in relation to the tidal limit and being installed parallel to the river flow. Table A.43 presents the risk of entrapment to the current fish populations in the vicinity of the Project intake and is based on the identified fish population around the intake location.

Table A.3 Entrapment risk to fish populations at the Project intake location

| Species/group | Presence | Abundance/presence based Risk |
|---|---|---|
| Dominant coarse fish species<br>Roach (*Rutilus rutilus*)<br>Gudgeon (*Gobio gobio*)<br>Bleak (*Alburnus alburnus*)<br>Dace (*Leuciscus leuciscus*) | Expected at the Project intake, mainly at the adult stage, but also larvae may drift here (noting that this stretch of river does | Medium risk – to larvae/post-larvae from entrapment, on account of potentially higher numbers (based on adult numbers in catches) compared to others present in this reach; |

[40] Environment Agency (2024). Safe passage for eels: Best Achievable Eel Protection (BAEP). LIT 66008

| Species/group | Presence | Abundance/presence based Risk |
|---|---|---|
| Chub (*Squalius cephalus*)<br>Pike (*Esox lucius*)<br>Perch *(Perca fluviatilis)* | not provide suitable larval habitat, e.g., in terms of depth) | habitat not optimal for young life stages. Project operation will be limited when vulnerable larval lifestages are most likely to be present (April – June).<br>Adults able to avoid impingement through swimming ability coupled with operation at warm temperatures (swimming ability increased further). The intake is recomended to have a clearance of at least 0.3 m above the riverbed to reduce the entrapment risk of benthic species. |
| Other coarse fish species/hybrids<br>Tench (*Tinca tinca*),<br>Barbel (*Barbus barbus*),<br>Common bream (*Abramis brama),*<br>Common carp (*Cyprinus carpio),*<br>Mirror carp (*C. carpio carpio*),<br>Grass carp (*Ctenopharyngodon idella*),<br>Zander (*Sander lucioperca*),<br>Roach x common bream hybrid (*Rutilus rutilus x Abramis brama*),<br>Ruffe (*Gymnocephalus cernua),*<br>Silver bream (*Blicca bjoerkna),*<br>3-spined stickleback (*Gasterosteus aculeatus*),<br>Rudd (*Scardinius erythrophthalmus),*<br>Bullhead (*Cottus gobio*),<br>Stone loach (*Barbatula barbatula)*<br>Minnow (*Phoxinus phoxinus*) | May sporadically be present at much lower densities at the larval to adult stage noting that this stretch of river does not provide suitable larval habitat, e.g. in terms of depth. | Low risk– to larvae/post larvae from entrapment only, on account of low numbers (based on adult numbers in catches) compared to others present in this reach; habitat not optimal for young life stages. Project operation will be limited when vulnerbale larval lifestages are most likely to be present (April – June).<br>Adults are able to avoid impingement through swimming ability coupled with operation at warm temperatures (swimming ability increased further). The intake is reccomended to have a clearance of at least 0.3 m above the riverbed to reduce the entrapment risk of benthic species. |

| Species/group | Presence | Abundance/presence based Risk |
|---|---|---|
| Flounder | 0+ and older individuals may be in the vicinity of the project intake and vulnerable to entrapment. | Low risk– Low risk of impingement as they will not be free swimming within the water column and will be on the river bed (and too large for entrainment). No 0+ individuals present on account of low densities expected to be in this reach and spawning grounds not in the vicinity. The intake is reccomended to have a clearance of at least 0.3 m above the riverbed to reduce the entrapment risk of benthic species. |
| Seabass | Very few juveniles would be in the vicinity of the intake and vulnerable to entrapment. This limited presence at the intake reach is likely owing to Teddington Weir. | Low risk – Low numbers expected to be within this reach. Spawning grounds not in the vicinity. Juvenile life stages would be too large for entrainment and would be able to avoid impingement. |
| European eel | Likely to be present at the project intake, including elver and adult life stages. Glass eel highly unlikely to be present. | Medium risk - to elvers only (entrainment and/or impingement). Swimming ability of life stages present means they would be able to exhibit avoidance behaviour.<br>Larger elvers would be too large for entrainment. Adults will be able to avoid the low velocities.<br>The intake is reccomended to have a clearance of at least 0.3 m above the riverbed to reduce the entrapment risk of benthic species. |
| Salmonids | Brown trout would be the most likely salmonid species to be present in the vicinity of the project intake, with much smaller numbers of Atlantic | Low risk – Swimming ability of species/life stages present means they would be able to exhibit avoidance. No life stage expected to be present in |

| Species/group | Presence | Abundance/presence based Risk |
|---|---|---|
| | salmon potentially present. The area encompassed by the project reach is not a suitable spawning habitat for these species, nor is it for the early life stages; therefore, older life stages (adult and smolts) are the only life stages likely to be present. | reach that is small enough for entrainment. |
| River & Brook lamprey | Juvenile and adult life stages could be present in the vicinity of the intake. The area encompassed by the project reach is considered not suitable spawning habitat for this species. | Low risk – Screen size would exclude ammocetes, and individuals would be able to avoid the low intake velocity. There may be a risk of impingement to a low number of ammocetes. |
| Sea lamprey | Individuals could be present (juvenile and adult life stages) in the vicinity of the intake. The area encompassed by the project reach is considered not suitable spawning habitat for this species. | Low risk – Low numbers expected to be present, and screen size would exclude ammocetes and adults; ammocetes may be at risk of impingement (if present). |
| Twaite shad | Individuals could be present (mainly adult life stages) in the vicinity of the intake if passage were improved over Teddington Weir. The area encompassed by the project reach is considered not suitable spawning | Low risk – No early life stages likely to be present; therefore, there is no entrainment risk. Any adults that may be present would be able to avoid impingement owing to the low intake velocities. |

| Species/group | Presence | Abundance/presence based Risk |
|---|---|---|
| | habitat for this species. | |
| Smelt | Present in the Thames upper transitional waterbody and the project site is just upstream of the tidal limit at Teddington Weir. This species' spawning habitat is approximately 20 km downstream of the project site. Taking this into account, and the absence of fish catches, adult, juvenile and larval smelt currently are not expected to be present at the intake reach owing to the presence of Teddington Weir. | Low risk – (currently) Adults would be able to avoid impingement owing to the low intake velocities. |

A.1.113 The proposed screen technology to mitigate fish entrainment and impingement at the intake is a travelling screen with a 1.75mm mesh size. The travelling screens have a permanent stainless steel side seal, which prevents the bypass of aquatic life, and a smooth mesh surface and a large filtration area with low approach velocities. These features minimise fish injury and impingement. Key features include:

a. A low through-slot velocity.

b. Active debris-handling capability through an equipped with a low pressure (≤3 bar) spray bar, covering the full screen width, for ensuring removal of any impinged larvae on the screen face, which are returned to the river.

c. The screen mesh panels are corrosion-free and biofouling-resistant.

d. There is no minimum clearance above the riverbed. However, it is recommended that clearance is at least 0.3 m above the riverbed to reduce the risk of benthic species such as European eel and bullhead becoming impinged.

A.1.114 These screens are installed worldwide, and applications in the UK conform to the Eels Regulations. They have been successfully installed and are operating at several water intake sites within the River Thames, which have been proven to reduce fish entrapment.

### *Screen performance*

A.1.115 A number of relevant case studies were assessed to evaluate the effectiveness of the 1.75mm travelling screens, including:

a. Assessment of larval fish entrainment of Hydrolox™ screens at an intake on the River Thames at Egham (approximately 26km upstream of the Project intake). The Hydrolox™ screen performed better in terms of larval fish entrainment compared to the 1mm and 2mm passive wedge wire cylinder (PWWC) screens. In addition, no impingement of larval fish or reduction of abstraction rates was observed throughout the study[41].

Further investigations of larval fish entrainment were undertaken at Chertsey[42] and Sunnymeads[43, 44] raw water intake sites.

i. At the Chertsey intake on the River Thames (approximately 22km upstream of the Project intake), a screen performance assessment was carried out in June 2014. The Hydrolox™ screen was efficient at reducing larval fish entrainment, with a total of ten individuals entrained across the four weeks and a maximum of four individuals occurring in any one week, concluding that an average of 94% of the fish population in the vicinity of the screens was excluded during this time despite the significant presence of the smaller size class range (<8mm).

ii. At the Sunnymeads intake on the River Thames (approximately 33km upstream of the Project intake), a screen performance assessment was carried out in 2015 and again in 2016. In 2015, Hydrolox™ screens excluded 28.4% of larval fish; however, the screen performance varied on a weekly basis, with the highest exclusion occurring during mid-May 2015 (75%)[43]. The repeat study during a later part of the fish spawning season in 2016 concluded the Hydrolox™ screen had an average exclusion of larval fish of 72.1% when compared to the raw water intake control[44].

A.1.116 It should be noted that in both Lower Thames studies, the greatest entrainment of fish occurred in spring (mid-May and mid-June) when lower-size classes of fish were present. This is when Project operation is predicted to be highly unlikely. The timing of the monitoring programme undertaken in 2016 closely aligns with when the Project is likely to be operational. Therefore, it could be considered that through July and August, when larval fish are larger, the Hydrolox screen could exclude approximately 72% or more of larval fish.

A.1.117 The majority of fish at risk of entrainment at the Project intake during normal operation are expected to be juvenile stages, a large proportion of which would not typically survive to adulthood in the riverine environment owing to factors such as predation and competition. To determine the potential for species population level effects due to entrainment of these predominantly juvenile life

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[41] Turnpenny, A.W.H, Bromley, R., Coyle, S. and Hawley, K. (2008). AMP4 Lower Thames Water Intakes Investigation. Report by Jacobs Engineering UK Ltd on behalf of Thames Water Utilities Ltd and Three Valleys Water. 177pp.

[42] Jacobs Engineering UK Ltd (2014). Chertsey Water Treatment Works: Screen Performance Monitoring. Official Sensitive Report to Affinity Water Ltd. Reference Number: B18627B8/REP/001. Rev 1. 38pp.

[43] Jacobs Engineering UK Ltd (2016). Sunnymeads Water Treatment Works: Screen Assessment, Impingement, Entrainment and Biofouling Study. Official Sensitive Report to Affinity Water Ltd. Reference Number: B2270400/REP/001. Rev. 2. 46pp.

[44] Jacobs Engineering UK Ltd (2016). Sunnymeads Water Treatment Works: Screen Assessment, fish entrainment study. Official Sensitive Report to Affinity Water Ltd. Reference Number: B18627B8/REP001. Rev. 1. 36pp.

history stages, losses of these fish can be expressed as equivalent adults by calculating an equivalent adult value (EAV). These EAVs are then used to convert an annual rate of loss due to entrapment of predominantly juvenile fish into an annual rate of loss of individual fish that would mature and join the spawning population.

A.1.118 In the absence of larval fish data and entrainment studies in the vicinity of the Teddington intake, EAVs in relation to larval numbers entrained cannot be calculated. However, a suitable proxy study has been identified and used to provide example EAVs that illustrate the proportional impact of entrainment on each species as sampled at Teddington. This proxy study is the aforementioned case study at Egham, which is also on the River Thames with a comparable habitat (a slow-flowing glide on an impounded reach). It included comparable species composition and was conducted on an identical screen design.

A.1.119 The entrainment study was undertaken across an approximately 12-week sampling period from April 2007 to July 2007. Following this, fish density and standing stocks were calculated using EA hydroacoustic surveys, which were applied to the estimated volume for the reach of interest to calculate the fish population of the reaches. EAVs were then calculated and applied to the results of the fish entrainment study, where entrained fish losses were quantified as a proportion of the adult standing stock. A full breakdown of the method and results can be found in the Egham report.

A.1.120 During the study, the Hydrolox travelling screen entrained an average of 56 fish fry per megalitre. This example entrainment value has been applied to the operation of the Project; however, the EAV was calculated using the proportion of species caught during juvenile seine netting at the intake location in August 2024. Due to a lack of data on the larval fish distribution at the intake location, the EAV has been calculated assuming that all fish caught were of the maximum age at which they can physically pass through the screens, as researched within the Egham study. By doing this, EAVs are a worst case (i.e., the maximum value). Where lifetable data were not available (3-spined stickleback, minnow and European eel), their EAV has been assumed to be 1:1, meaning they are calculated on an equivalence one-to-one ratio of adults: larvae. The estimates present an example of the proportions of fish which may be entrained (Table A.5).

Table A.4 Estimated EAVs calculated for the Teddington DRA intake based on an entrainment rate of 56 fish per megalitre, as identified within the Egham study.

| Species | Max length (no of days) through Hydrolox (Egham study) | Max EAV per fish (from lookup tables used in Egham study) | Number of fish caught at TDRA Intake location in August 2024 | Percentage composition of catch | Estimated number of larvae to one equivalent adult | Estimated ratio based on entrainment through Hydrolox | Estimated EAV Fish/Ml | Estimated Daily EAV for Teddington DRA Intake under 75Mld operation |
|---|---|---|---|---|---|---|---|---|
| **Perch** | 67 | 0.013 | 39 | 1.98% | 76.34 | 1.107 | 0.015 | 1.09 |
| **Dace** | 43 | 0.009 | 530 | 26.86% | 116.28 | 15.043 | 0.129 | 9.70 |
| **Roach** | 95 | 0.017 | 293 | 14.85% | 58.14 | 8.316 | 0.143 | 10.73 |
| **Bleak** | 97 | 0.028 | 1,108 | 56.16% | 36.23 | 31.449 | 0.868 | 65.10 |
| **3-spined stickleback** | - | 1 | 1 | 0.05% | 1 | 0.028 | 0.028 | 2.13 |
| **Minnow** | - | 1 | 1 | 0.05% | 1 | 0.028 | 0.028 | 2.13 |
| **European eel** | - | 1 | 1 | 0.05% | 1 | 0.028 | 0.028 | 2.13 |
| **Total** | - | - | 1,973 | 100% | - | - | 1.240 | 93.00 |

A.1.121 The calculated EAVs have been applied to project operation at the maximum intake rate of 75Ml/d. The total entrainment has been calculated assuming Project operation during sensitive times for juvenile fish. For the calculation, the identified season of April 1st to July 31st has been applied to the modelled scenarios, including the A82 scenario (1:5 year) and the M96 scenario (1:20 year). The reach of interest identified to calculate the standing stock of the River Thames relevant to the Project intake is Molesey Weir to Teddington Weir. Calculations for the reach area, depth and volume are presented within the Egham Study. However, more recent hydroacoustic data from the Environment Agency has been used with fish density estimates gathered between 2010 and 2016 (excluding 2015, no data available) being used to estimate the fish population to allow for a more up-to-date estimate of the standing stock for the reach. These details are summarised in Table A.5 below.

Table A.5 Presentation of the Reach characteristics, standing stock and EAV calculations for Hydrolox travelling screens with a mesh size of 1.75mm at Teddington DRA intake.

| | **Operation under A82 Scenario (1:5 years)** | **Operation under M96 Scenario (1:20 years)** |
|---|---|---|
| **Reach of interest** | Molesey Lock – Teddington Lock | Molesey Lock – Teddington Lock |
| **Estimated reach area** | 588,000m2 | 588,000m2 |
| **Estimated reach depth** | 2.40m | 2.40m |
| **Estimated reach volume** | 1,411,200m3 | 1,411,200m3 |
| **Fish per 1000m$^3$** | 23 | 23 |
| **Fish population estimate of reach** | 3.2 x 104 | 3.2 x 104 |
| **Density estimate (fish/m$^2$)** | 0.0552 | 0.0552 |
| **Standing fish stock of reach** | 32,458 | 32,458 |
| **EAV entrained per day under 75Ml/d** | 93 | 93 |
| **Projected EAV from April to July (inclusive)** | 0* | 1,860 |
| **Percentage loss of standing stock** | 0%* | 5.73% |

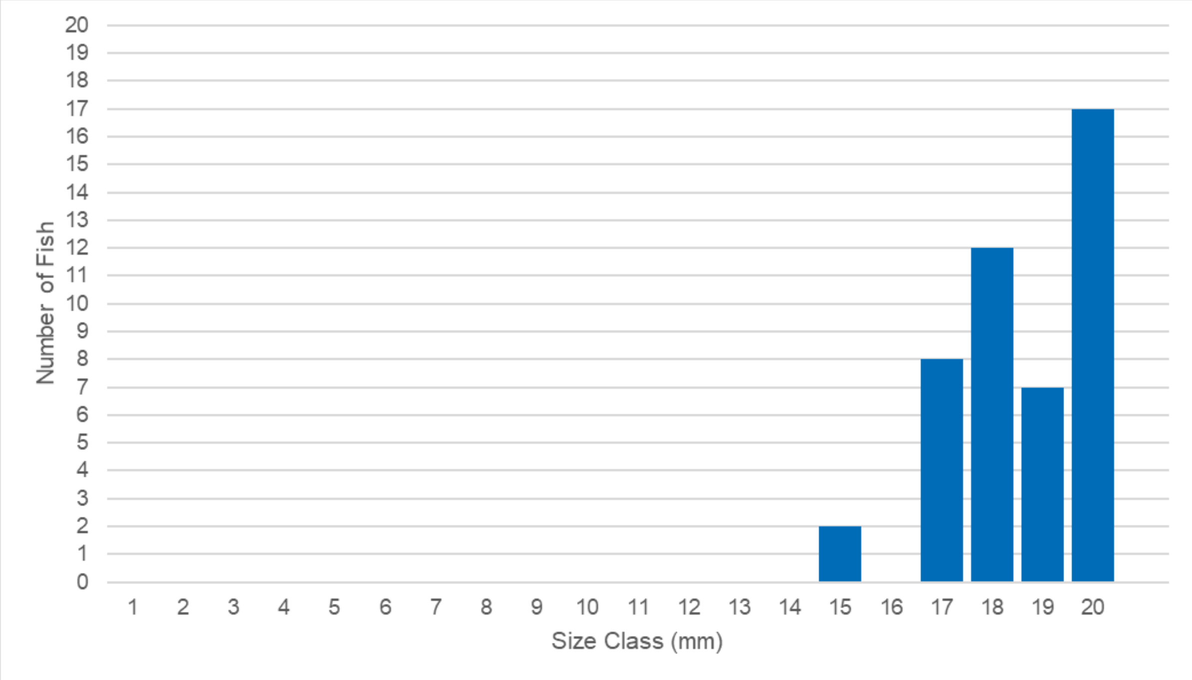
**No operation from April to July under this scenario*

A.1.122 Under the A82 scenario, there is no project operation from April to July. The Project was only modelled to ‘switch on’ from August to November; therefore, no entrainment was calculated. Some small fish may likely be present in August; however, within the Egham study, it was found that no post-larval fish over 20.1mm would pass through the 1.75mm Hydrolox mesh, and only a very small proportion of fish over 14.1mm did pass through. Therefore, the true size limit falls between these values (Table A.6). During the fish survey around the Project's intake and outfall location in August 2024, 1,973 individuals were caught. Of these individuals, only 46 measured 20mm or below, with the minimum size caught being 15mm (Plate A.4). Therefore, it can be calculated that only 2.33% of the marginal population in August may be at risk of entrainment, and by applying the percentage of fish that could pass through the screen (using a pass rate of 11% for the 14.1-16mm size class) only 0.26% can pass through the screens which will result in minimal entrainment. Therefore, under the A82 scenario, it is not considered that the Project will have a significant impact on the fish populations of the River Thames.

Table A.6 Presentation of the Reach characteristics, standing stock and EAV calculations for Hydrolox travelling screens with a mesh size of 1.75mm at Teddington DRA intake.

| Size class (mm) | Passed (%) | Did not pass (%) | Number of fish |
|---|---|---|---|
| <6 | 100 | 0 | - |
| 6.1 – 8 | 100 | 0 | - |
| 8.1 – 10 | 100 | 0 | 59 |
| 10.1 – 12 | 100 | 0 | 61 |
| 12.1 – 14 | 22 | 78 | 60 |
| 14.1 – 16 | 11 | 89 | 63 |
| 16.1 – 20 | 3 | 97 | 40 |
| 20.1 – 24 | 0 | 100 | 15 |
| 24.1 – 28 | 0 | 100 | 21 |
| 28.1 – 32 | 0 | 100 | 11 |
| 32.1 - 36 | 0 | 100 | 1 |

Plate A.4 Fish smaller than 20.1mm caught at the project intake and outfall location during juvenile seine netting surveys on 08 August 2024.




A.1.123 Under the M96 scenario, project operation is only predicted to occur from April to July for 20 days in July. The number of fish entrained is estimated to be equivalent to 5.73% of the standing stock of the Molesey to Teddington reach.

A.1.124 In a fish risk model developed for the Thames Tideway (Tideway Fish Risk Model- TFRM: Turnpenny *et al.*, 2004), an allowable annual mortality of ≤10% due to pollution effects was the criterion developed for sustainability. This figure was chosen on the basis that exploited fish populations commonly yield a sustainable harvest in the order of several ten per cents and, therefore, should absorb 10% above natural mortality rates without threatening population survival; on the other hand, it would not be practicable to detect reliably a figure of <10% mortality owing to statistical noise. Therefore, the 10% annual mortality figure provides a sensible rule-of-thumb for a first-level screening of significance. Based on this, the number of fish entrained under the M96 scenario is not considered to have a significant impact on the population of the River Thames.

A.1.125 Applying the Egham study results to the Project intake yields a number of assumptions. Worst-case scenarios have been used to avoid incorporating bias that may downplay the estimated proportion of adult fish lost. However, as a result, it is considered that the EAVs are likely to be lower than those predicted here. Inconsistencies between the Egham study and the Project intake have been carried over. During the Egham study, due to a lack of a spray bar during the entrainment surveys, impinged fish were carried over the top and into the intake by the travelling screen. This is considered unlikely to occur during the operation of the TDRA intake, as a spray bar will be installed to remove impinged fish and debris and reduce biofouling. This is likely to further reduce the EAV.

A.1.126 Furthermore, the areas around the Teddington intake are prone to high levels of disturbance from recreational activity and boats and offer limited opportunity for spawning. As such, the habitat associated with the Project reach is more suited to juvenile and adult fish, though isolated pockets of macrophytes are present, which may offer limited and localised spawning opportunities to certain species of coarse fish. Therefore, it is expected that fish larvae present in the intake location migrate there through downstream juvenile drift and, as a result, are generally older/larger than in the spawning reaches. Larvae may also be more likely to settle into nursery areas upstream of the Project intake due to the location being at the downstream extent of the freshwater Thames.

A.1.127 Considering their burst speeds, juvenile fish and the higher size class of fish expected to be found at the intake location all can exhibit avoidance behaviour from the intake flows (as presented in Plate A.2).

A.1.128 Following this assessment, the magnitude of the impact of entrapment of fish populations at the intake is considered to be low given the compliance with identified legislation and guidance and low predicted EAVs under the A82 and M96 scenarios. When factored with the intermittent frequency and duration of operation of the scheme and limited operation during the most vulnerable months for the early life stages of fish, it is considered unlikely the intake will significantly affect fish populations in the River Thames. It is anticipated that any effects on fish populations within the River Thames will be reversible in the short term due to the intermittent operation and localised area of effect through further mitigation. Therefore, impacts on fish due to impingement or entrainment at the outfall in the River Thames are considered to be Minor. However, should screen designs change, this assessment should be updated.

## Olfaction

A.1.129 In relation to the Project, there is the potential to influence diadromous fish species migration via:

a. The weakening of olfactory cues into the River Thames at Teddington due to changes in the proportion of river water in the pass-forward flow under very low river flow conditions.

b. The potential that olfactory inhibitors may be discharged into the lowest freshwater River Thames through the DRA outfall, mixing with the olfactory inhibitors already present in the freshwater River Thames, which then may change the zone of inhibitor accumulation around the physical barrier (Teddington Weir).

c. The potential for less discharge of olfactory inhibitors present within the Mogden STW effluent at Isleworth Ait, with a reduction in concentration and change in the zone of inhibitor accumulation in the upper Tideway.

A.1.130 A combination of all of the above coupled with environmental parameters such as river flow, temperature and dissolved oxygen may influence the olfactory cues of diadromous fish.

A.1.131 Appendix 6.2 states that although the baseline olfaction considerations required to assess the potential impact of the TDRA Project are well studied, the potential for change from the TDRA Project is dependent on results from the Pilot Plant.

A.1.132 It is noted that the scheme will not be introducing a new source of olfactory inhibitors into the Thames catchment but instead redistributing Mogden STW's final effluent, which will undergo tertiary treatment prior to discharge at Teddington. This represents both a potential reduction in the total input (following treatment) and distribution of the current discharge.

A.1.133 Whilst it is currently unclear how much the tertiary treatment process will reduce olfactory inhibitors within the recycled water, it can be assumed that inhibitors already present in the final effluent of Mogden STW will be further diluted due to a wider distribution, but this may extend the zone of inhibitor accumulation. The current location of the proposed outfall has been chosen so that the recycled water will be fully mixed prior to going over Teddington Weir, which will further aid dispersion and minimise concentrations downstream.

A.1.134 The location of the outfall is also low down within the Thames Catchment and is not upstream of any known salmonid or lamprey spawning grounds. As a result, it is not anticipated that the outfall will prevent these species from locating their natal spawning grounds. While olfaction is an important cue in the migration process, it is also one of many multimodalities used by fish to navigate during their migration.

A.1.135 Currently, the magnitude of the impact of both the near bankside in-river and bankside outfall options on olfaction is predicted to be Negligible. Considering the intermittent frequency and duration of operation of the Project, combined with the fact that the Project is not introducing a new source of olfactory inhibitors in the Thames Catchment but is redistributing Mogden STW's final effluent, which will have undergone tertiary treatment, it is unlikely to affect fish populations or migration in the River Thames. Furthermore, the outfall is also low down within the Thames Catchment and is not upstream of any known salmonid or lamprey spawning grounds. Therefore, it is not predicted to prevent these species from locating their natal spawning grounds. It is anticipated that any effects on fish populations within the River Thames will be reversible in the short term due to the intermittent operation and localised area of effect through further mitigation. Therefore, the effects on fish due to olfaction disruption for both the near bankside in-river and bankside outfall options are considered Minor. It is not predicted that either the near bankside in-river or bankside outfall options will change impacts relating to olfaction. However, following further understanding of the tertiary treatment process, this assessment should be updated at ES.

## Invasive Non-native Species (INNS)

A.1.136 Temperature increases due to the operation of the Burnell outfall have the potential to affect the survival, behaviour and growth of a range of INNS. Groups present in the freshwater Thames include aquatic invertebrates, macrophytes, riparian plants and fish.

A.1.137 The <2°C increases in ambient river temperature predicted downstream of the mixing zone may have a range of effects on the INNS currently present within the area. Increases in temperature may potentially improve the fitness of some individual INNS present, resulting in a competitive advantage over other native species.

A.1.138 Invertebrate INNS present in high numbers include Asian clams, New Zealand mud snail, demon shrimp and the polychaete *Hypania invalida*. These species have broad temperature preference ranges, and temperature increases of <2°C will likely have little negative effect on their fitness. Asian Clams have been found to have plasticity of their thermal limits, and populations have a strong potential to withstand long-term warming. The New Zealand mud snail also has a wide temperature range and can tolerate temperatures up to 34°C.

A.1.139 Macrophyte INNS present in the area include Nutall's waterweed and floating pennywort. Again, these species have broad temperature preferences and may even be more productive at higher temperatures. Nutall's waterweed will grow during temperatures greater than 6°C, so temperature increases within the river may extend the growing period, which may increase the ability of the plant to spread. So, slight increases in temperature may increase INNS plant growth downstream of the outfall.

A.1.140 As the duration of the scheme is intermittent and not permanent, the changes in temperature are not likely to cause a long-term impact on the growth of macrophyte INNS. The effects of any macrophyte growth due to temperature increases are reversible, as baseline conditions would return when the scheme is not operational. As the scheme is most likely to be operational during warmer months, it is unlikely that the scheme will artificially prolong growth into the winter months. The effects of the thermal plume are also localised to the area immediately downstream of the outfall, limiting the habitat in which INNS experience temperature increases.

A.1.141 Changes in velocity from the outfall at Burnell have the potential to impact the INNS community through the movement of sediments and increased flow, washing species out. It could also impact INNS by driving a change in community composition downstream of the outfall, with invasive species tolerant of higher velocities potentially outcompeting native species currently present downstream of the outfall.

A.1.142 Of the macroinvertebrate INNS, Asian Clams, New Zealand mud snail, Demon shrimp and *Hypania invalida* were present in high numbers. Asian Clams are generally found in lowland rivers at lower velocities. New Zealand mud snails have a preference for lower velocities but can burrow into sediment in higher flow conditions. Demon shrimp are generally associated with artificial bank structures and do not have a preference for higher flow conditions.

A.1.143 Of the macrophyte INNS present in the highest abundance, floating pennywort generally favours slowing-flowing environments and margins. Nuttall’s waterweed, although it can grow in fast-flowing conditions, is rarely abundant in rivers with high flows.

A.1.144 The increase in flows around the outfall is also not likely to cause any physical alterations to the channel through scour of the banks or channel, changes in flow direction, movement of sediments, siltation or washing plants away.

A.1.145 It is anticipated that the scheme would be operational once every two years, and within this time, the scheme would run intermittently between July and November. The intermittent nature of the operation of the scheme, along with the flow condition preferences of the most abundant INNS, suggests that the potential to cause an increase in the spread of INNS by the scheme is negligible.

A.1.146 Increases in phosphorus can cause macrophytes to grow larger and cover more area and can cause changes in the community of both macrophytes and invertebrates to more nutrient-tolerant species. It can also cause the mortality of nutrient-sensitive species and change the community so more nutrient-tolerant species become dominant.

A.1.147 INNS generally have wide tolerances to changes in nutrient conditions, with some having a preference for higher nutrient conditions. For example, Nutall’s waterweed is able to grow in eutrophic conditions and benefits from higher levels of ammonia. Asian clams, demon shrimp, and New Zealand mud snails are also all tolerant of high nutrient levels in the water. The increases in nutrients predicted from the scheme are minimal and are not expected to influence the spread of INNS within the freshwater Thames.

A.1.148 Dissolved oxygen is predicted to reduce by 0.3-1.3mg/l but would still be ≥9.3mg/l. This potential decrease in dissolved oxygen is unlikely to have any negative impacts on the INNS present along the Thames. The species present along this reach are generally tolerant of lower dissolved oxygen and flows and will be tolerant of dissolved oxygen levels of 9.3mg/l.

A.1.149 The treated effluent discharge at Burnell will be highly treated, and the small changes to water quality mentioned, combined with the localised area of the impact and the intermittent nature of the scheme, are not likely to cause significant impacts on the further spread of INNS within the freshwater Thames. The operational phase of the Burnell Site is considered to have a negligible effect on the spread of INNS.

### Estuarine Thames

A.1.150 Assessments in Chapter 5 show that there would be a negligible impact on the tidal Thames from the Burnell outfall. Any changes to the Thames Tideway are likely to come from changes to the discharge at Mogden STW linked to the scheme. These changes are assessed in Appendix 5.1. Modelling showed that there would be no change in velocity, water levels and water quality downstream of Teddington Weir and that there would be no net change in pass forward flow over Teddington Weir.

A.1.151 As the physical environment changes are considered negligible, it is considered that there will be no impact on INNS through changes in velocity, tidal exposure, temperatures, and water quality.

A.1.152 Temperature modelling shows a 1°C increase under certain low-flow scenarios. It is unlikely that a 1°C increase downstream of Teddington Weir will have an impact on the INNS community downstream of the weir.

Thames Water