Teddington Direct River Abstraction

Preliminary Environmental Information Report

Appendix 6.2 – Additional Environmental Data to Support Aquatic Ecology Assessment

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Appendix 6.2 – Additional Environmental Data to Support Aquatic Ecology Assessment

A.1 Introduction

A.1.1 This appendix summaries the baseline data in relation to water quality, hydrology and numerical modelling which supports the assessment of potential effects of the Teddington Direct River Abstraction (TDRA) Project (hereafter referred to as 'the Project') on aquatic ecology.

A.1.2 Section A.2 of this appendix provides baseline data for water temperature and flow. Section A.3 covers the hydrodynamic modelling and model outputs, while section A.4 details water quality in relation to olfaction.

A.1.3 This appendix considers data and modelling from the River Thames beyond the study area as identified in Chapter 6: Aquatic Ecology, River Thames from Molesey to Southend-on-Sea. This wider area captures the extent of the numerical modelling and available data used to determine baseline in the River Thames and allow validation of the model outputs. The river reaches included in this appendix are identified as below:

a. River Thames: River Thames and Thames Tideway extending from Molesey to Southend-on-Sea which includes the model extents for both numerical model.

b. Freshwater River Thames: River Thames within the study area extending from Teddington Weir to 2km upstream.

c. Thames Tideway: Estuarine Thames Tideway extending from Teddington Weir to Southend-on-Sea, with lower Tideway referring to reach downstream of Battersea Bridge.

d. Tidal River Thames: Thames Tideway reach from Teddington Weir to Battersea Bridge within the Environmental Impact Assessment (EIA) study area.

A.2 Baseline Water Temperature and Flow Velocity

Data collection of water temperature and flow velocity

A.2.1 Temperature of both the River Thames at Teddington and the Mogden Sewage Treatment Works (STW) final effluent have been derived from continuous sonde data. The River Thames temperature data is provided by the Environment Agency Teddington Air Quality Monitoring System (AQMS) sonde (2010 to 2017 and February to June 2019), Ricardo sonde data (2019 to December 2020) and the Thames Water Utilities Limited (TWUL) Teddington Weir sonde (2017 to 2018 and 2020 to 31 October 2023). The Mogden STW final effluent temperature (noting that this is prior to planned further tertiary treatment and then conveyance) is derived from the TWUL Mogden STW final effluent sonde (1 January 2010 to 8 Nov 2023).

A.2.2 This data has previously been used in Gate 2 assessments to show the seasonal variance in temperature difference between the Mogden final effluent and the River Thames (see Gate 2 Water Quality Assessment Report (Thames Water, 2022a)).

A.2.3 In addition to the above data sets, upstream of the River Thames at Teddington (freshwater River Thames) and downstream (Thames Tideway) temperature data have been derived to show temperature variations. There are two upstream stations that have been selected, which are Bell Weir and Mapledurham. The sites have been selected considering the continued availability of data that is adequate for characterisation of water temperature. The available temperature data from TWUL continuous sonde at Bell Weir and Mapledurham range from December 2020 to December 2023 and May 2021 to October 2022, respectively. Brentford, Cadogan and Purfleet sites have been selected downstream of the River Thames at Teddington and temperature data from continuous sondes (2010-2023) have been derived.

A.2.4 The River Thames flow at Kingston (representative for the Thames at Teddington) has been obtained from National River Flow Archive from 2010 to 2022 (CEH, n.d.). Tidal high/level information at Thames Tideway has also been obtained from the Port of London Authority (PLA) (PLA, n.d.).

Baseline water temperature

General seasonality/diurnal temperature fluctuation information - downstream of the Project’s outfall

A.2.5 Long-term measured water temperature data from the freshwater River Thames at Teddington; Brentford and Cadogan Pier in proximity of the tidal Thames; and Purfleet in the Lower Tideway were reviewed to define a temperature profile. These Tideway profiles are included here to provide wider context on water temperatures and water temperature patterns in the system (Plate A.1 and Plate A.2).

Plate A.1 Measured water temperature of the freshwater River Thames at Teddington

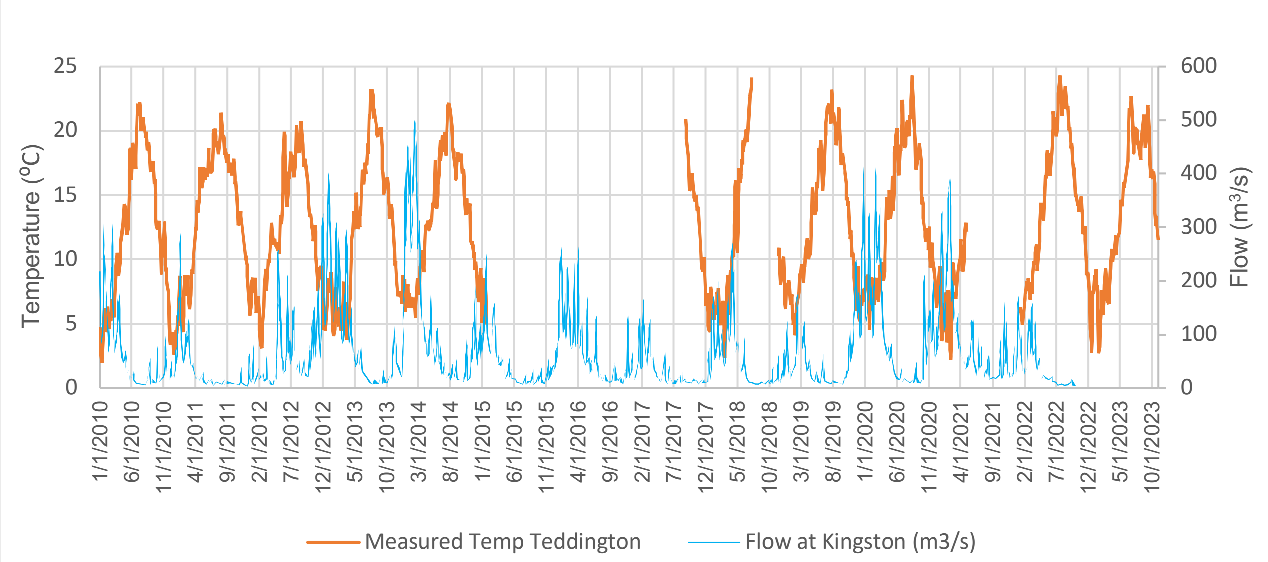
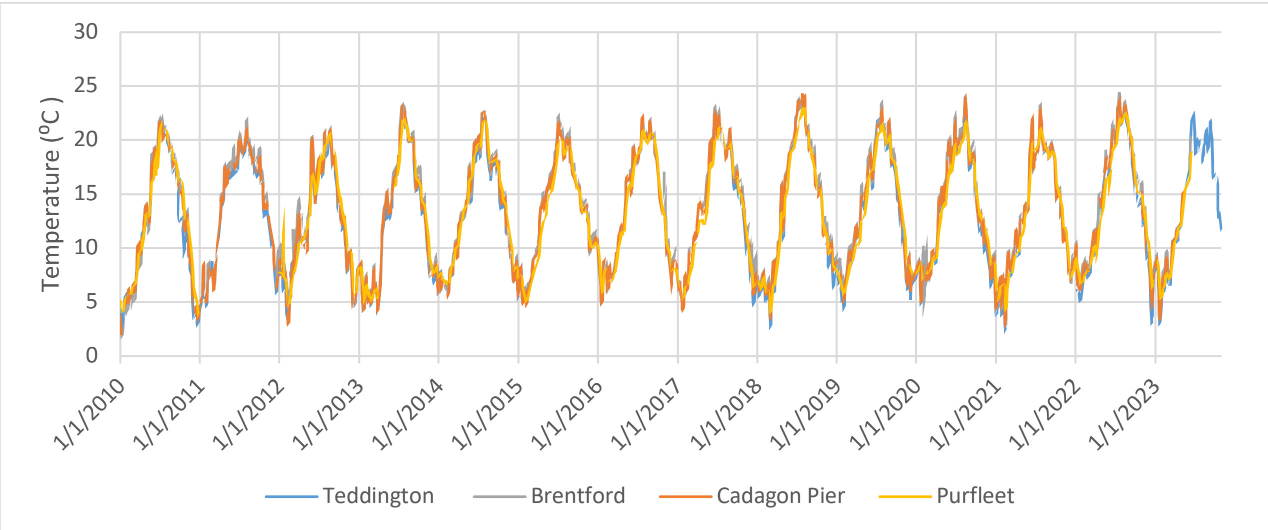


Plate A.2 Measured water temperature at selected sites in the freshwater River Thames and Thames Tideway



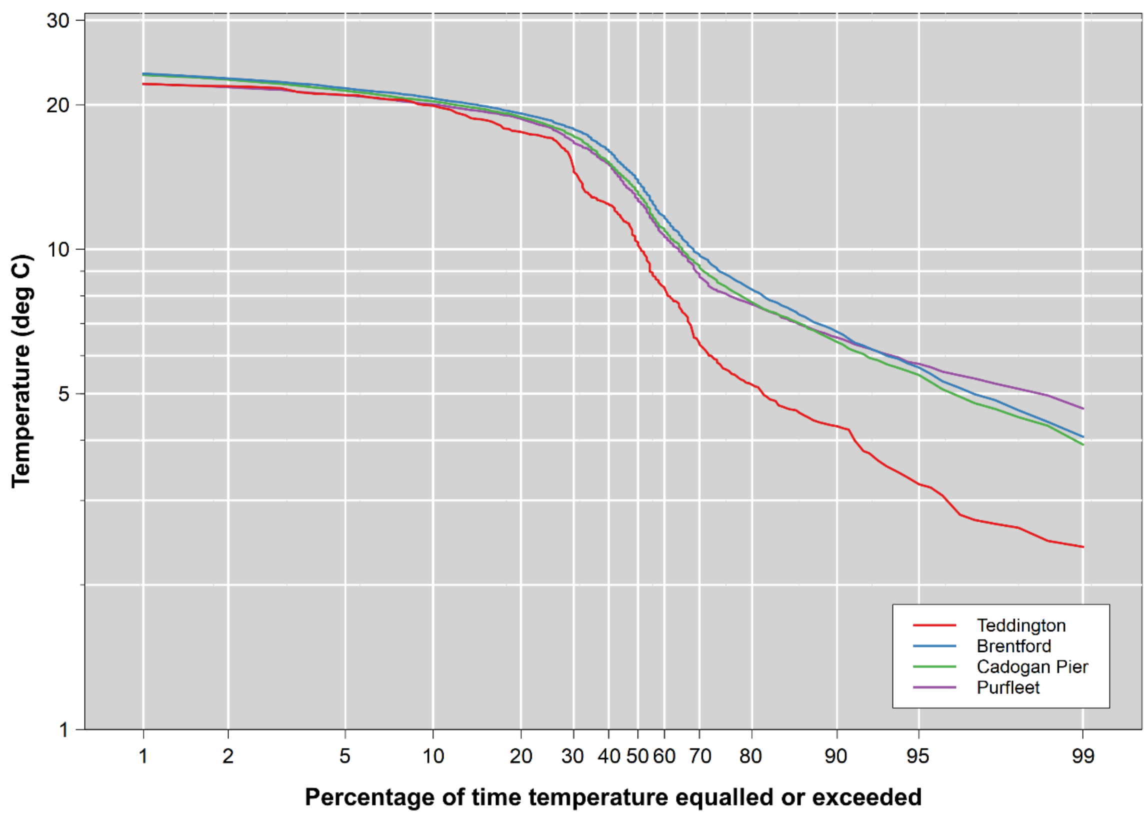
A.2.6 These profiles both show a clear seasonal trend. The profile is between an upper value of 24.3ºC in August 2020 and a lower value of 1.9ºC in January 2010. The Thames Tideway sites, and freshwater River Thames at Teddington temperature statistics are provided in Table A.1.

Table A.1 Temperatures at River Thames Tideway Sites

Site name	Max temperature (ºC)	Min temperature (ºC)	Average temperature (ºC)
Teddington	24.4	2.0	12.7
Brentford	24.5	1.5	13.7
Cadogan Pier	24.5	1.9	13.2
Purfleet	23.1	3.4	13.0

A.2.7 The Tideway profiles show higher average temperatures than the River Thames, particularly higher minimum winter temperatures (3.4ºC at Purfleet) and higher maximum summer temperatures (24.5ºC at Brentford). It is assumed that the Tideway profiles are influenced by sea temperatures and discharges, including STW discharges – at Mogden STW (notably the Brentford temperature); Beckton STW and Crossness STW (notably the Purfleet temperature).

Plate A.3 Temperature duration curves



A.2.8 The temperature duration curves for the freshwater River Thames at Teddington and Thames Tideway sites (Brentford, Cadogan Pier and Purfleet) were created and shown in Plate A.3. The curves indicate that the highest temperatures for all sites persist for only 1% of the time. For all sites, temperatures above 20ºC occur only 10% of the time. The temperatures at Teddington were lower at all times compared to Tideway stations. The temperature duration curve also shows that river temperatures as a 98th percentile at Teddington are approximately 22.2°C, and at Thames Tideway sites temperatures are approximately 22.6°C.

General seasonality/diurnal temperature fluctuation information - upstream of the Project's outfall

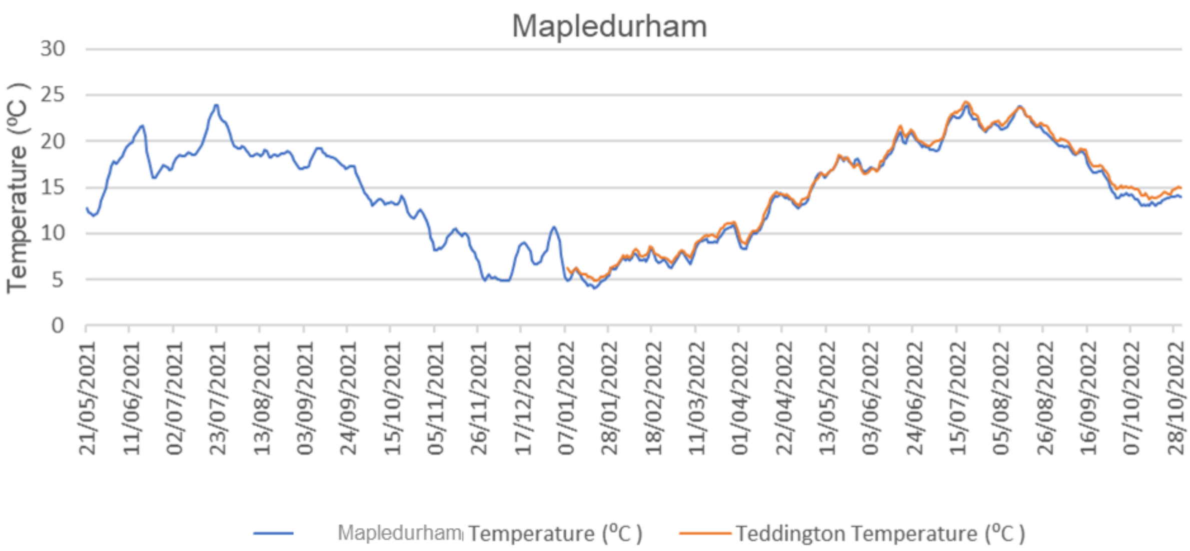
A.2.9 The long-term water temperature of the freshwater River Thames at Teddington and further upstream were reviewed to determine baseline temperature condition. The river flow has also been reviewed, and it shows that the maximum measured river flow is 503m^3/s and minimum flow is 3.57m^3/s. Flow duration statistics shows that Q95 flow is 6.87m^3/s and Q50 flow is 31.7 m^3/s.

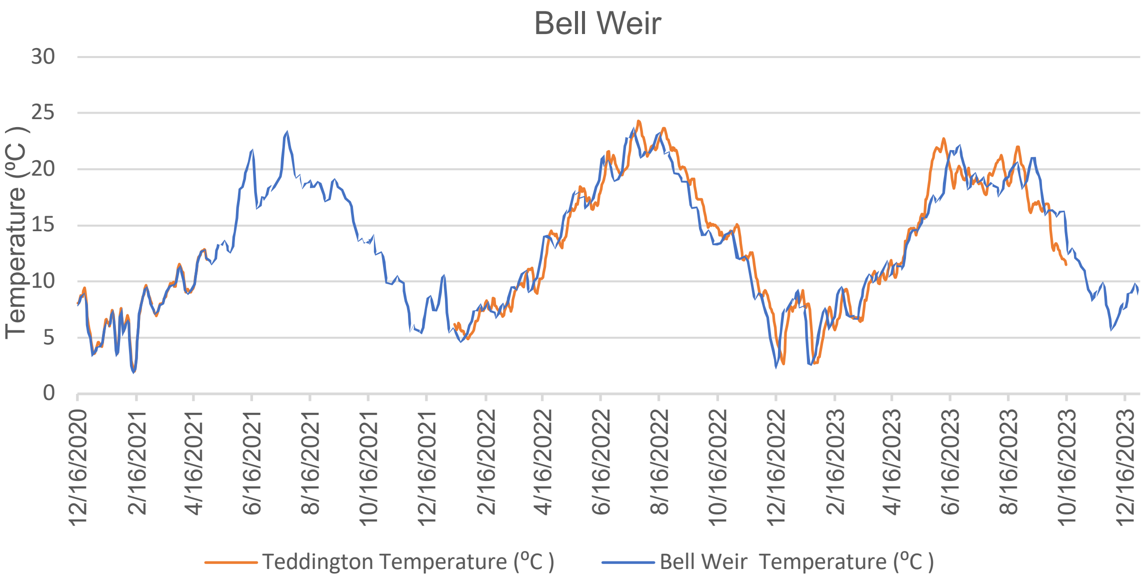
A.2.10 Two upstream sites, River Thames at Bell Weir (NG: TQ0163172116) and Mapledurham (NG:SU6695876731) were selected considering the continued availability of data that is adequate for characterisation of water temperature where temperature data has been derived from continuous sondes.

A.2.11 Plate A.4 shows that upstream temperatures at both River Thames sites, at Bell Weir and Mapledurham, follow the same pattern as in the River Thames at Teddington, with small differences. Looking at the River Thames at Bell Weir and Teddington temperatures, there is a negligible difference in the average and maximum values. However, it is noted that the minimum water temperature of the River Thames at Bell Weir is approximately 0.35^{0}C lower than at Teddington for each measured time. The difference in maximum temperatures shows that the River Thames at Teddington has a higher maximum temperature (24.3^{0}C) than River Thames at Bell Weir (23.9^{0}C). This indicates that the baseline water temperature at Teddington is warmer than the upstream water temperature.

A.2.12 When the water temperature at Teddington is compared with Mapledurham, which is located further upstream, it is observed that the maximum, mean and minimum water temperature is higher for the River Thames at Teddington, with the maximum, mean and minimum values being 0.37ºC, 0.45ºC and 0.83ºC higher, respectively, than Mapledurham. The highest difference is shown in minimum water temperature which indicates again baseline water temperature exhibits a trend of getting warmer in the downstream sections.

Plate A.4 Daily measured water temperatures upstream locations River Thames at Teddington Weir. Note: The date ranges for the data sets differ.





A.3 Hydrodynamic Modelling

A.3.1 Two hydrodynamic models have been used to support assessment:

a. TELEMAC-2D model has been developed for the freshwater reach of the River Thames between Molesey and Teddington Weir to support the assessment of the hydrodynamic baseline of the River Thames and the potential impact of operation of the Project's intake and outfall on river currents, flow velocity, water level and mixing of the discharge from the outfall into the river. The modelling focuses on an extent 270m upstream of the proposed intake and immediately downstream of Teddington Weir. This model is described further in Appendix 5.1 Surface Water and Water Quality Baseline Information.

b. TELEMAC-3D model has been developed for the reach of the Thames Estuary between Teddington Weir and Southend-on-Sea to support the assessment of the hydrodynamic and water quality baseline of the Thames Tideway and the potential impact of operation of the Project's outfall on water quality; and the potential impact of operation of the Project's tertiary treatment plant (TTP) on the discharge volume at Isleworth Ait on tidal elevation, current speed, water temperature, salinity, suspended solids and water quality hydrodynamics, mixing of the discharge from the outfall into the river. The modelling focuses on an extent 22km seawards of Teddington Weir, to Battersea Bridge. This model is described further in Appendix 5.1 Surface Water and Water Quality Baseline Information.

Input data for model time series representation

A.3.2 Environmental assessment scenarios have been developed through engagement with the Environment Agency to represent the pattern and regularity of Project operation. The approach uses the 19,200-year stochastic flow series developed for the River Thames catchment for the Water Resources South East (WRSE) group. The stochastic flow series represent contemporary climate conditions and provide information on the return frequency, or regularity, of both the likely river flow conditions and London Water Recycling Strategic Resource Option operation. The stochastic years have been made available as 48-year continuous periods, and one of those has been selected as having representative flow characteristics to inform the environmental assessments. The selected 48-year series include a suitable range of regular low and moderate low flow periods. It does not include extreme low flows that are considered to be less regular than once every 50 years.

A.3.3 Within these patterns, a 1:5 return frequency year with moderate-low flows (model reference A82) and a 1:20 return frequency year with very low flow years (model reference M96) in the River Thames at Teddington have been selected for the detailed assessment, including modelling. The flow scenarios were approved for use by the Environment Agency. The details of the Project's projected operation pattern and modelled flow can be found in the Gate 2 Water Quality Assessment Report (Thames Water, 2022a).

A.3.4 An assessment of the water temperature impacts arising from the Project's discharge into the freshwater River Thames has been undertaken for the 75Ml/d. The temperature data was modelled using a deterministic spreadsheet model to represent the impact of the recycled water on the in-channel water temperature downstream of the outfall after the discharged water has been fully mixed with the in-channel water. To estimate a daily representation of the river temperature at Teddington, a 6th order polynomial using the daily measurements from the above-described sonde data for the River Thames at Teddington and Mogden STW was used, achieving R^2 values of 90% and 84% respectively (see Plate A.6). 'New data' indicates more recent data (2022-2023) included in addition to that used data in the Gate 2 assessment which included data from 2010 to 2021.

Plate A.5 Daily measured water temperatures and modelled reference conditions for River Thames at Teddington Weir (2010-2023)

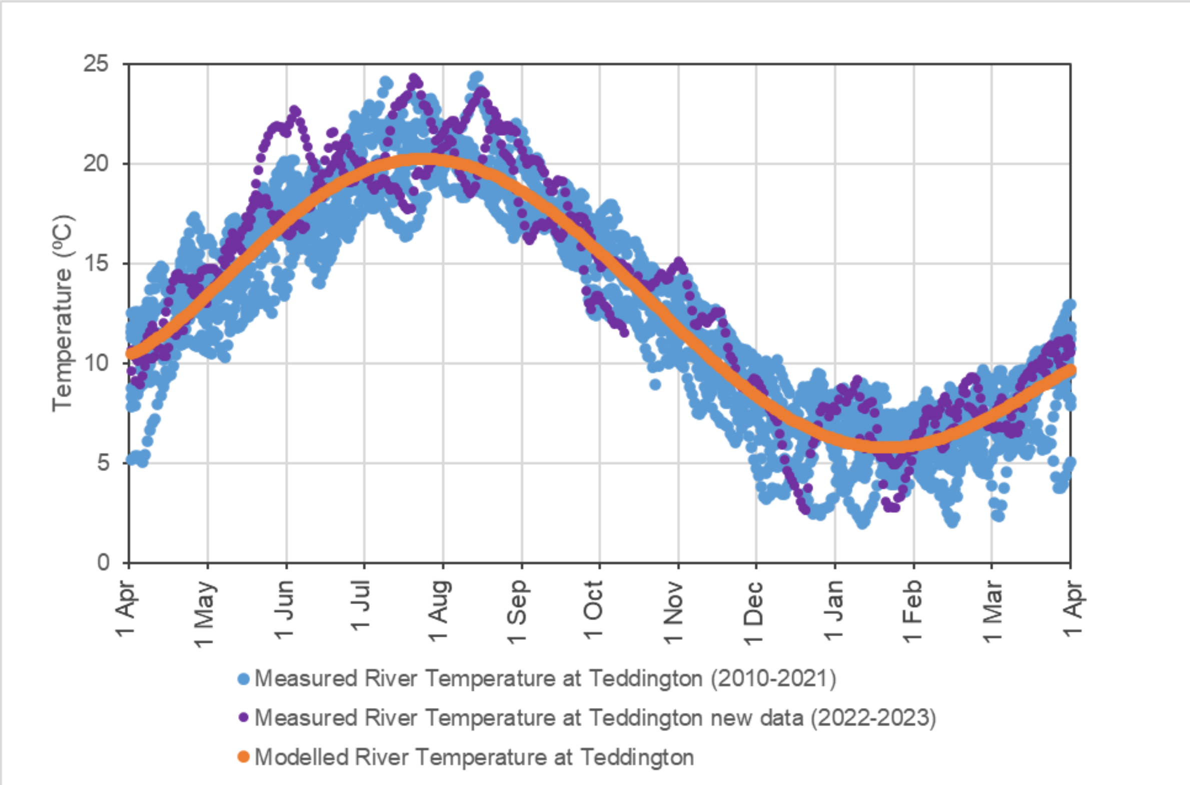
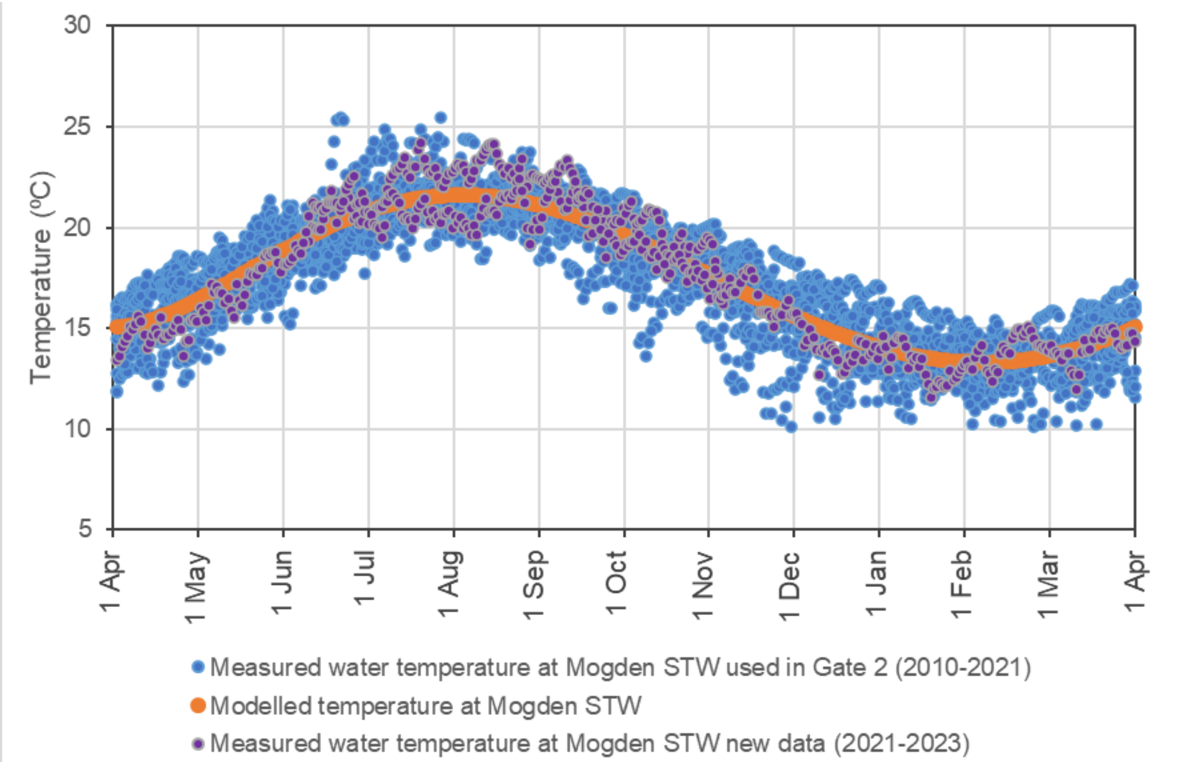


Plate A.6 Daily measured water temperatures and modelled reference conditions for Mogden STW (2010-2023)



Numerical modelling of the outfall

A.3.5 The outfall design options which have been modelled by HR Wallingford are outlined in Chapter 2: Project Description. The bankside outfall structure is intended to be buried in the riverbank and angled at 45 degrees to the river flow and modelled at an outfall velocity of 0.3m/s. The near bankside in-river outfall would comprise one or more pipes extending approximately 15m from the river bank with discharge also modelled for an outfall velocity of 0.3m/s. Modelled changes in velocities are considered in terms of their in-river velocity plume against relevant sustainable fish swimming speeds and fish burst speeds of the fish species likely to be present at the outfall location.

A.3.6 For context, it is noted that in the section of the River Thames that is ponded upstream of Teddington Weir, river velocities are homogenous across the river channel, noting slower boundary layers at the channel bed and margins. For the channel cross section wetted area at the intake:

a. A river flow of 700Ml/d, the normal river flow at time of operation of the Project in the period to 31 October. This flow has an average velocity of 0.035m/s, in the model output band of 0.025-0.05m/s. A river flow of 600Ml/d is the normal river flow at time of operation on the Project in the period from 1 November. This has not been specifically modelled as it is less common than summer and autumn operation.

b. A river flow of 400Ml/d, representing extremely low river flow conditions at time of operation of the Project in the winter period (November onwards). This flow has an average velocity of 0.020m/s, in the model output band of 0.01-0.025m/s.

c. A river flow of 300Ml/d, representing extremely low river flow conditions at time of operation of the Project in the summer and autumn period to 31 October. This flow has an average velocity of 0.015m/s, in the model output band of 0.01-0.025m/s.

A.3.7 An average river velocity of 0.05m/s would be associated with a river flow of 980Ml/d – which is the gauged long term (1883-2022) flow statistic of Q86.5 at the River Thames at Kingston river flow gauge – 86.5% of time flow velocities at the proposed location of the Project intake would be greater than 0.05m/s.

A.3.8 Criteria are listed in Table A.2 for the Project’s outfall; with criteria definitions in Table A.3. Of the aspects of hydraulic modelling reviewed, those which are considered of key importance to describing potential fisheries effects are indicated in the tables by a tick “✓”. A dash “-“ indicates where the aspects of hydraulic modelling reviewed provide supporting contextual information.

Table A.2 Outfall potential fisheries effect criteria and review of hydraulic model output

Potential fisheries effect associated with changes in river hydraulics	Aspect of hydraulic modelling reviewed									
	Outfall plume (general characterisation)							Outfall plume zone greater than 0.05 metres per second		
	Length of modelled plume (metres)	Total modelled length of left bank change (m)	Maximum modelled change of left bank (m)	Width of modelled plume (m)	Modelled plume width as percentage of channel width (%)	Modelled maximum dominant change in outfall flow velocity from baseline (m/s)	Modelled maximum local change in outfall flow velocity from baseline (m/s)	Modelled maximum length of zone along river (m)	Modelled maximum width of zone across river (m)	Modelled maximum depth of zone in river (m)
Ability of fish to readily swim away from the outfall (sustainable swimming speed)	✓	-	-	-	-	-	-	-	-	-
Change in marginal flow velocities that support elver migration	-	-	-	-	-	-	-	✓	✓	✓

Table A.3 Definitions of measurements used in the hydraulic model review

Aspect describing outfall effects	Definition of measurement
Length of modelled plume (metres)	The length of the plume at its longest axis in a downstream direction
Total modelled length of left bank change (metres/second)	The maximum length of flow velocity change on the left bank at its longest axis in a downstream direction
Maximum modelled change of left bank (metres)	The greatest change in flow identified at the left bank
Width of modelled plume (metres)	The width of the plume at its longest axis perpendicular to the downstream direction

Aspect describing outfall effects	Definition of measurement
Modelled plume width as percentage of channel width (%)	The percentage of the width of the plume with respect to the maximum channel width next to the outfall (~69m)
Modelled maximum dominant change in outfall flow velocity from baseline (metres per second)	The greatest change in flow velocity around the intake which covers the largest surface area of the model run when compared to the baseline
Max local change in outfall flow velocity from baseline (m/s)	The greatest change in flow velocity around the intake from the baseline run at the outfall (not necessarily the largest surface area)
Modelled maximum length of ≥0.05m/s zone along river (metres)	The length of the plume area of >=0.05m/s absolute velocity at its longest axis in a downstream direction on the depth-averaged plan view
Modelled maximum width of ≥0.05m/s zone across river (metres)	The width of the plume area of >=0.05m/s absolute velocity at its longest axis in a horizontal direction in cross-section on section C4 adjacent to the outfall
Modelled maximum depth of ≥0.05m/s zone in river (metres)	The depth of the plume area of >=0.05m/s absolute velocity at its longest axis in a vertical direction below the surface in cross-section on section C4 adjacent to the outfall

Freshwater River Thames modelling outputs

Numerical model water temperature change

A.3.9 Time series temperature plots showing modelled river temperature at Teddington, Mogden STW final effluent temperature and the temperature of the river once the recycled water has fully mixed (i.e. at the edge of a mixing zone) into the receiving water are presented in Plate A.7 for the representative A82 scenario (1:5 year return frequency) and Plate A.8 for the representative M96 scenario (1:20 year return frequency).

Plate A.7 Modelled temperatures in the Thames for the A82 moderate-low flow scenario

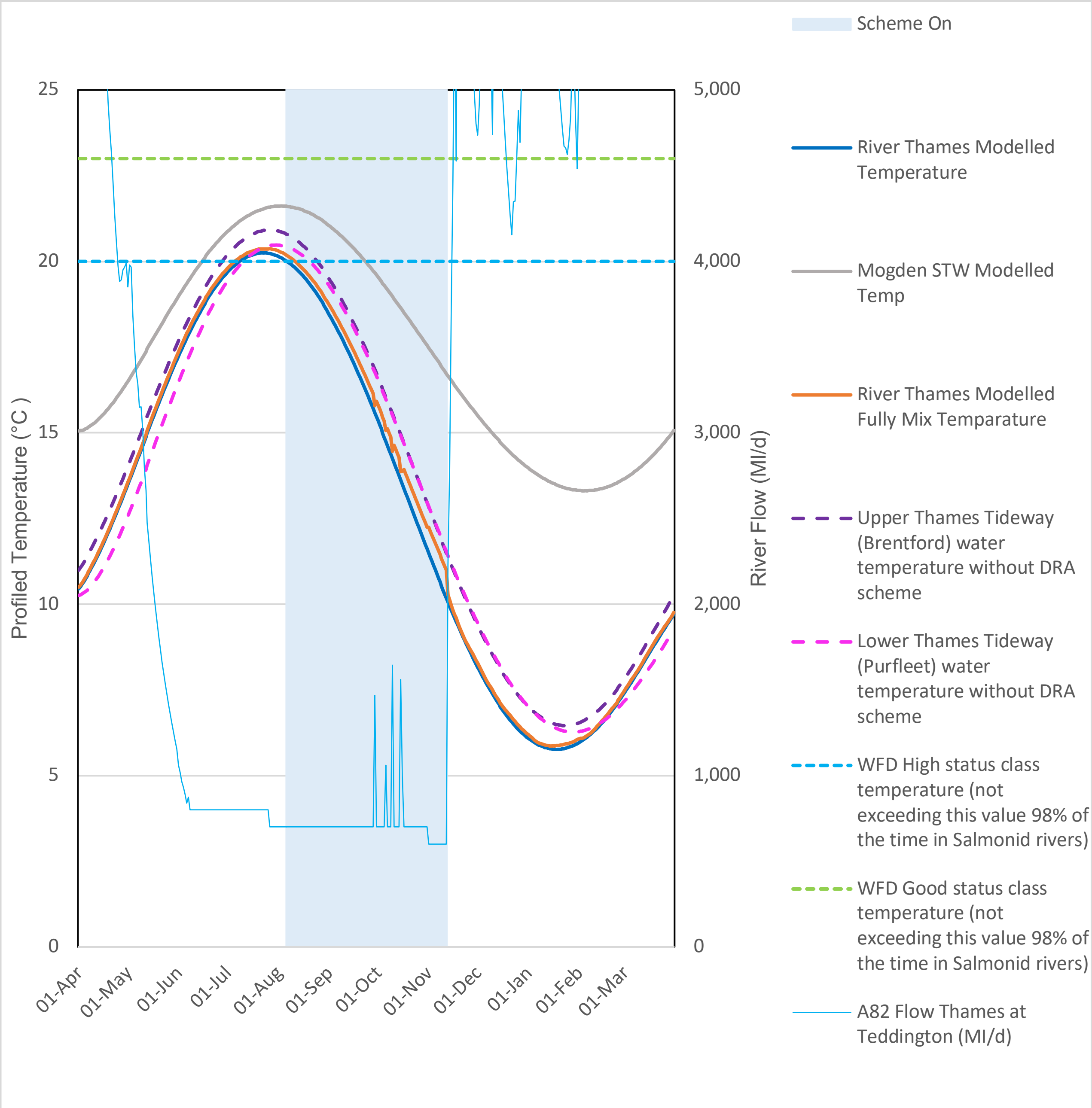
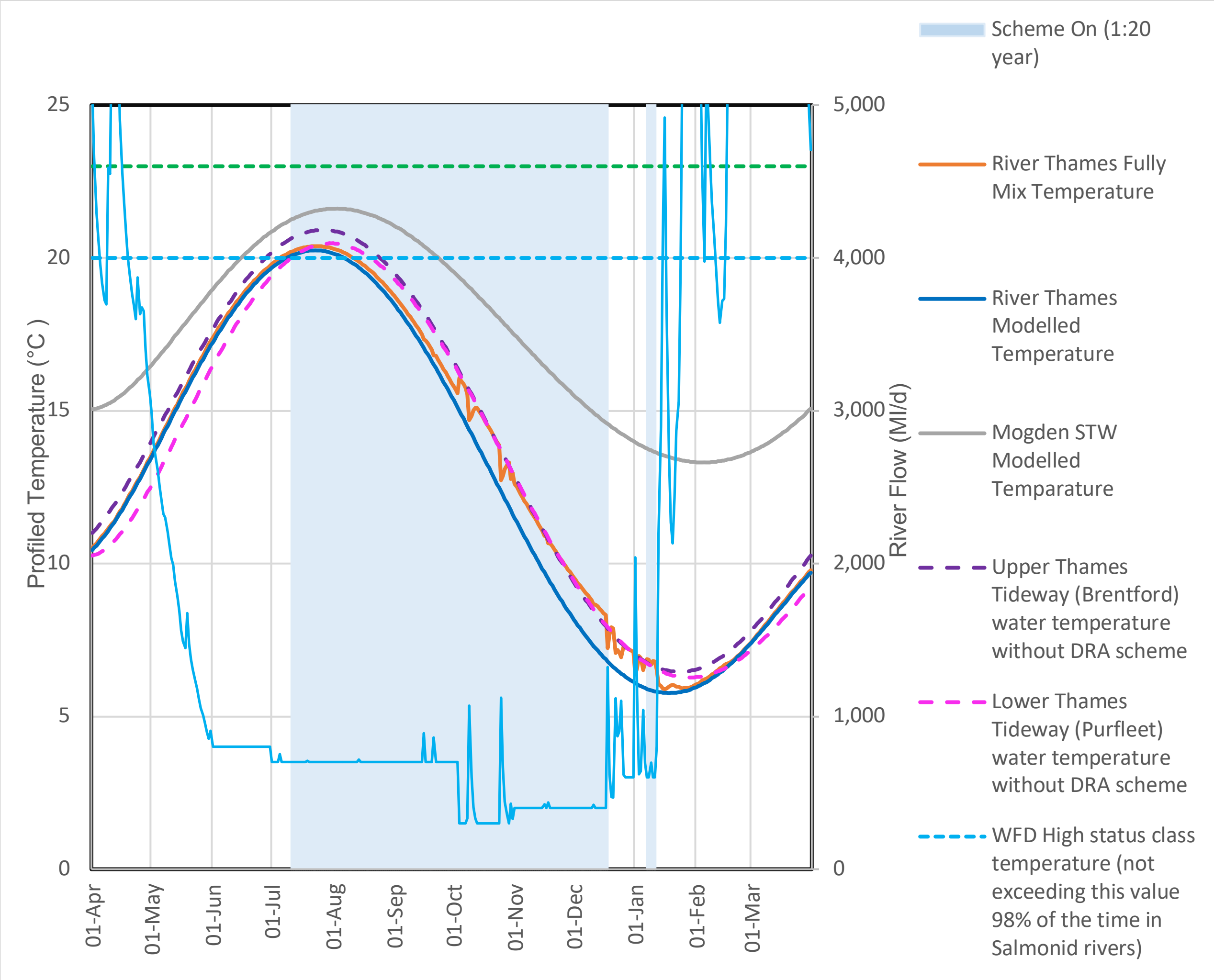


Plate A.8 Modelled temperatures in the Thames for the M96 very-low flow scenario



A.3.10 The modelled outputs for the A82 moderate-low flow scenario shows a slight increase in mixed river temperature when the Project is operational (6 August to 12 November) with the average increase of 0.4°C above baseline. The maximum modelled temperature increase is 0.8°C and the minimum temperature increase is 0.1°C.

A.3.11 The modelled outputs for the M96 very-low flow scenario shows an increase in temperature when the Project is operational with the average increase of 0.7°C above baseline. The maximum modelled temperature increase is 1.45°C and the minimum temperature increase is 0.12°C.

A.3.12 Table A.4 shows the predicted temperature at the Project outfall after mixing of the River Thames based on return frequencies and the likelihood of operation river flows (300Ml/d, 400Ml/d, 600Ml/d, and 700Ml/d). The predicted temperature after mixing shows that it would reach a maximum of 20°C when operating at 700Ml/d river flow occurring both 1 in 20 years and 1 in 5 years return frequency. It would also reach a maximum of 20°C when operating at 300Ml/d river flow.

Table A.4 River Thames temperatures after mixing for the 75Ml/d Project and operating river flows (showing values for 15th date of each month)

			River Thames temperature after mixing 75Ml/d Project when operating at river flows (pre abstraction) of 300-700 (Ml/d)			
Temp °C	**Discharge***	**River**	**700**	**600**	**400**	**300**
Apr	17	11	12			13
May	18	15	15			16
Jun	20	18	18			18
Jul	21	20	20			20
Aug	22	19	20			20
Sep	21	17	18			18
Oct	20	14	14			15
Nov	18	9		10	11	11
Dec	16	6		7	8	9
Jan	14	6		7	7	8
Feb	14	6		7	8	8
Mar	15	8	9			10

Highest modelled return frequency
Based on likelihood of operation at the listed river flow
1:5
1:20
1:50
less than 1:100
Not a river flow during Project operation in this month

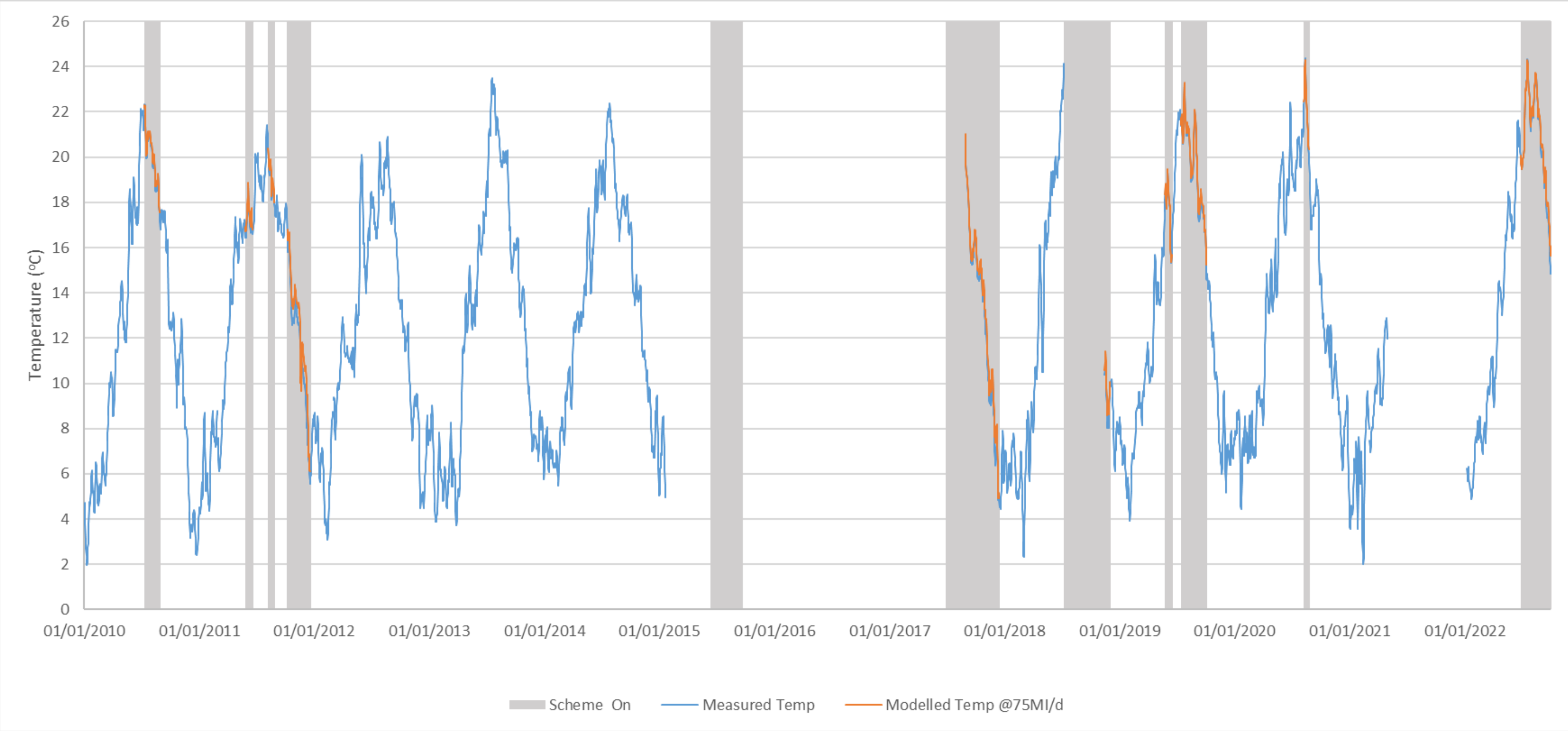
**Note: Mogden STW final effluent measured water temperature used as a proxy for discharge temperature*

Mass balance calculation based on measured temperature

A.3.13 This assessment was undertaken to understand the potential impacts of the Project on river temperature, especially at times when past events have occurred. In this way, the effect of the Project on the river water temperatures in the worst-case scenario has been calculated by considering the warmest and driest years experienced in the past.

A.3.14 The retrospective temperature change predictions have been derived using long-term (2010-2023) measured temperature data of the River Thames at Teddington and Mogden STW for the 75Ml/d Project size. To do this, measured river flows and Project operation frequency have been used (Plate A.9). The grey area indicates periods where the Project is operational. It is also limited to the latest available river flow data (30 September 2022) obtained from National River Flow Archive.

Plate A.9 Retrospective temperature change predictions



A.3.15 From the 2010-2023 data, the years 2011 and 2022 have been selected to represent the exceptionally hot and dry summer of 2022 and the exceptionally warm and dry spring of 2011. It is also noted that the highest river temperatures were recorded in 2022.

A.3.16 No significant change in river temperature at Teddington is shown by the mass balance calculation in 2011 and 2022 (App Table 3.4). It is noted that the statistics in App Table 3.4 only consider days when the Project would have been operational, and the assessment was also be limited to the latest available river flow data (30 September 2022) obtained from the National River Flow Archive (CEH, n.d.).

Table A.5 Temperature changes at River Thames at Teddington in 2011 and 2022 (Note: The below statistics show the comparison of river temperature at Teddington with and without the Project on the days when the Project would have been operational if available - which includes the autumn and early winter period in 2011 but not in 2022)

Years	River temperature at Teddington without Project (baseline)			River temperature at Teddington with Project		
	Max temperature °C	Min temperature °C	Average temperature °C	Max temperature °C	Min temperature °C	Average temperature °C
2011	20.30	5.66	14.12	20.39	6.13	14.58
2022	24.31	14.83	20.77	24.30	15.63	20.94

A.3.17 Table A.5 indicates that changes in maximum temperature are limited to <0.09°C in 2011 (exceptionally warm dry spring) and 0.01°C in 2022 (exceptionally hot dry summer). There is a slight increase in average temperature both in 2011 (0.46°C) and in 2022 (0.17°C). The increase in minimum temperature is limited to 0.47°C in 2011 and 0.8°C in 2022. This demonstrates that the greatest changes (under two recent (and different type of) extreme conditions) would occur to the minimum temperatures. It is also seen that there is a slight increase in maximum temperature in 2011 and a slight decrease in maximum temperatures in 2022.

Physical environment modelling (modelled data)

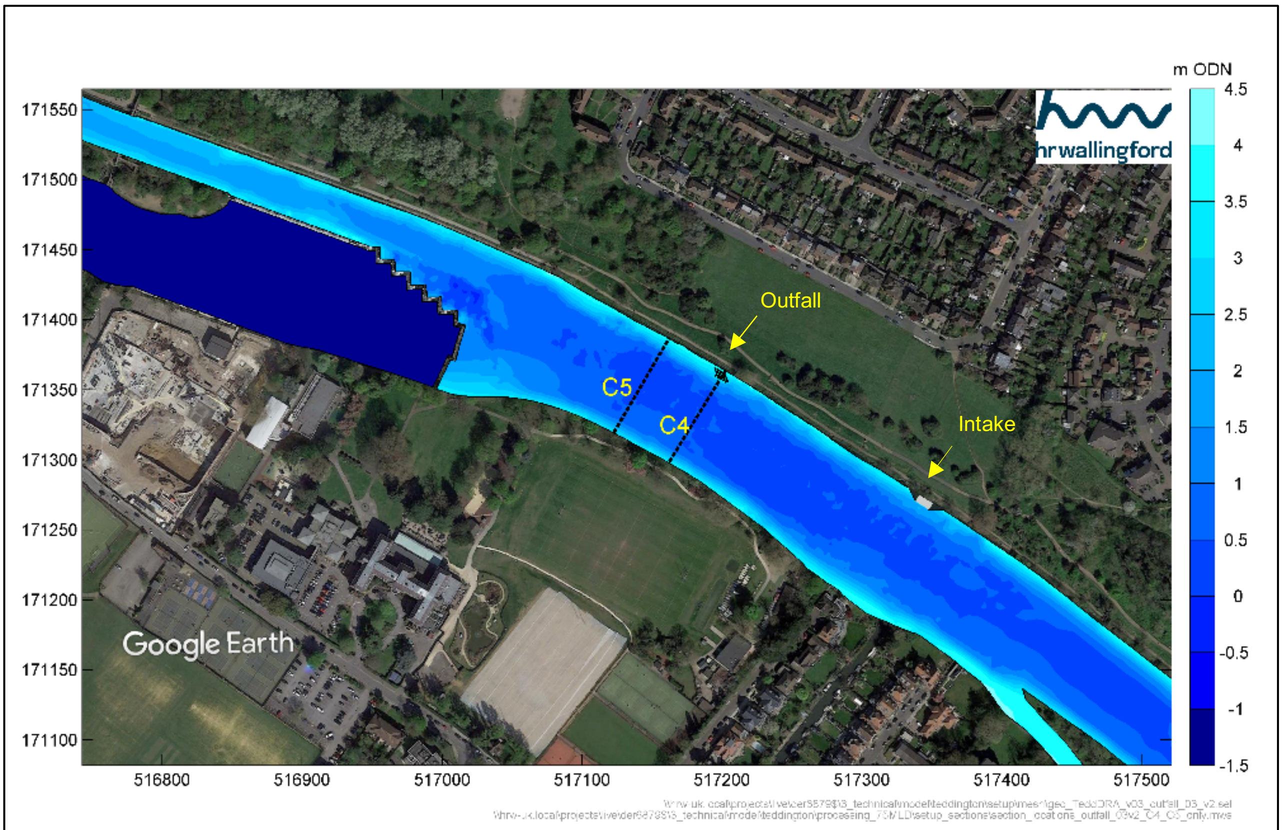
A.3.18 A plume was defined in British Energy Estuarine & Marine Studies (BEEMS) (BEEMS, 2010), Scientific Advisory Report Series No:7, which is an active mixing zone in the outfall where the properties in the receiving water body are altered by the discharge from the recycled water outfall. It is normally recognised as a zone where temperature and/or levels of other contaminants are higher than the ambient water.

A.3.19 The extent of temperature effects has been modelled by HR Wallingford for the 75Ml/d discharge scenarios under ‘normal’ low flow conditions (700Ml/d) and more ‘extreme’ low flow conditions (400Ml/d and 300Ml/d) using the Telemac-3D model which is used to assess the effects of mixing of the discharge into the river. The recycled water is fully mixed prior to Teddington Weir (~180m downstream of the discharge). This is a stable system model which uses fixed input values for scenario representation. The model extends the study area around the Project’s intake, outfall and Teddington Weir from around Kingston Railway Bridge at the upstream boundary to the downstream side of Teddington Weir at the downstream boundary. Analysis of modelled Mogden STW final effluent temperature under different flow conditions verses modelled river temperature under different flow conditions indicates that the greatest temperature change occurs when the river temperatures are lowest (i.e. winter months), with smaller degrees of change seen at higher temperatures (i.e. summer and autumn months).

A.3.20 The effects on the hydrodynamics of the River Thames around the location of the Project’s outfall have been simulated using a TELEMAC-3D model. The model extends from around Kingston Railway Bridge at the upstream boundary to the downstream side of Teddington Weir at the downstream boundary. The modelling uses the scenarios for 700Ml/d river flow (Scenario 1), 400Ml/d river flow (Scenario 2) and 300Ml/d river flow (Scenario 3), with an outfall discharge of 75Ml/d moving at 0.3m/s and the intake abstracting 75Ml/d at 0.1m/s. The modelling details and baseline model flow velocity predictions can be found in section 5.3 in Gate 2 Aquatic Physical Environment Assessment Report (Thames Water, 2022b). The model results are replicated below.

A.3.21 Thermal plume and hydrodynamic modelling was conducted with two indicative outfall configurations representing preliminary design. Firstly, via a bankside outfall, located at the bankside, with an exit velocity of 0.3m/s. Secondly, via a near bankside in-river outfall consisting of five 1m diameter pipes elevated on a concrete mattress by 2.6m ODN. Simulations also include the addition of a new intake operating with an intake velocity of 0.1m/s upstream of the outfall (Intake, Plate A.11). The obstruction to flow caused by both the concrete mattress and the pipes within the near bankside in-river outfall configuration are represented within the model by raising the bathymetry by 2.6m ODN and 3.6m ODN respectively. Outputs are also presented as vertical cross-sections of both velocity and temperature, located at the centre of the outfall (C4. Plate 3.6).

Plate A.10 75Ml/d Project discharge under 700Ml/d river flow (outfall velocity of 0.3 m/s and intake velocity of 0.1 m/s)

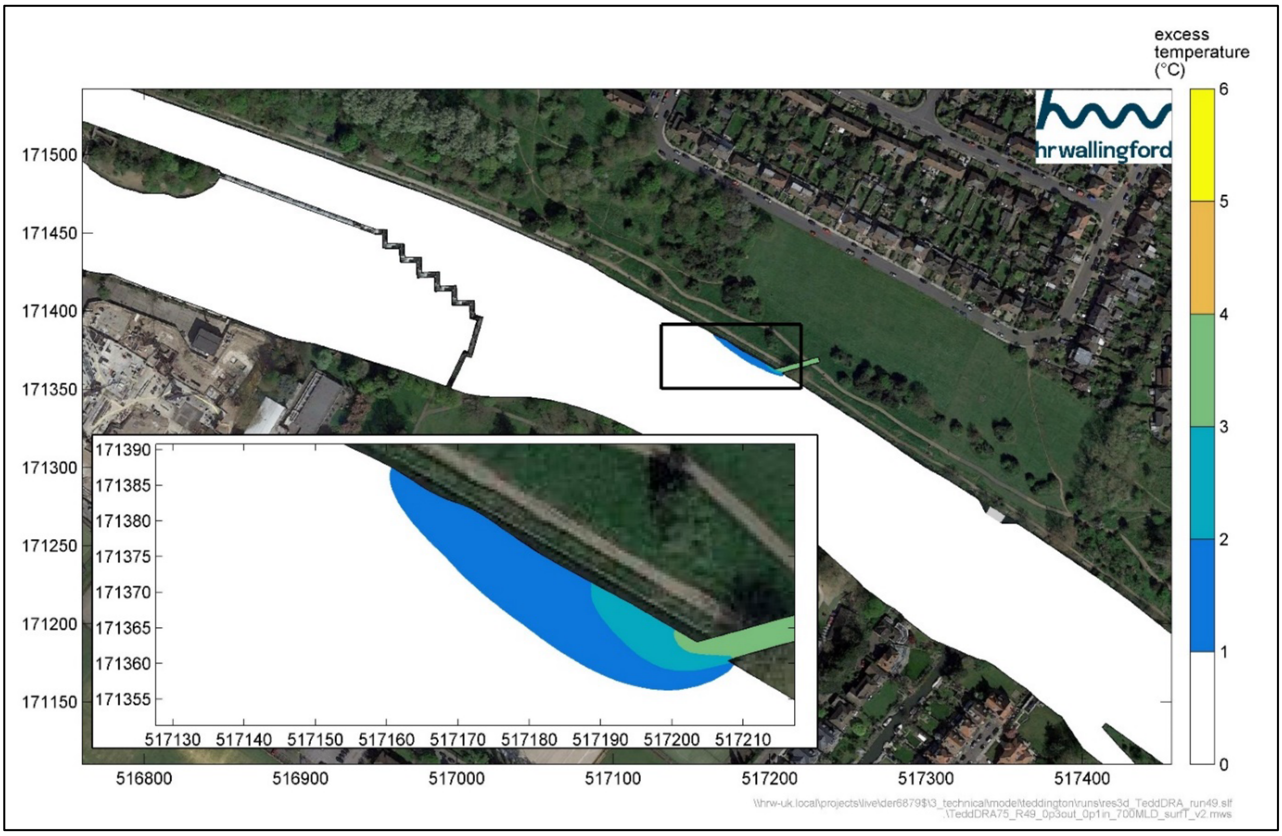


Bankside outfall thermal plume modelling

Scenario 1: 700Ml/d river flow

A.3.22 Under typical river flow conditions that the Project would operate under (58% of the Project operation would be at 700-799Ml/d), the mean river temperature is 16.9°C. The mean temperature difference between the recycled water and the river temperature during these times is 3.3°C, and therefore this is the model input value used immediately adjacent to the outfall structure. The modelled recycled water plume under these 'normal' low flow conditions is presented in plan-view in Plate A.11 and cross-section (at discharge) location in Plate A.12.

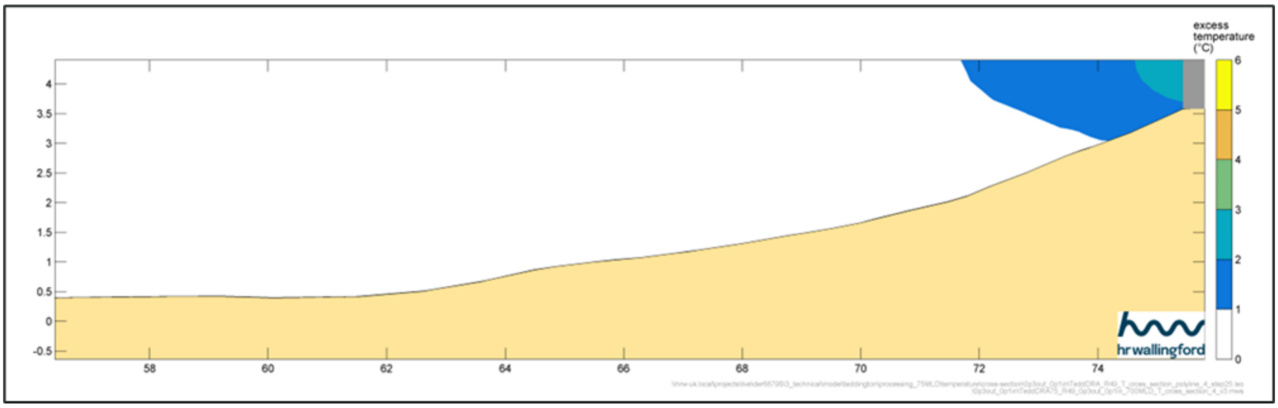
Plate A.11 75Ml/d Project bankside discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s.)



A.3.23 Plate A.11 shows that under the maximum temperature difference between the river and discharge recycled water (in measured data) during periods of 700Ml/d river flow, the discharge recycled water is fully mixed prior to Teddington Weir (~200m downstream of the discharge). The thermal plume is confined to within 7-8 metres of the discharge bank, reducing to <1ºC change ~50m downstream. At the surface 699m^2 of the plan area exceeds a 1°C increase in temperature, with 224m^2 of this area exceeding 2°C. The approximate surface area from the cross section C4 at the outfall to the downstream extent of the Teddington Weir is ~15,000m^2 and therefore the area exceeding 2°C is approximately 1.5% surface area of this.

A.3.24 Plate A.12 cross-section shows that the discharge's 2°C temperature contour is limited to 1m closest to the bankside outfall on the right bank, with a >1°C contour limited to 4m from the outfall. The 2°C contour covers 0.2% of the cross-sectional area of the channel, leaving the vast majority of the channel seeing less than a 1°C temperature change.

Plate A.12 75Ml/d Project bankside discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s) cross section at the outfall

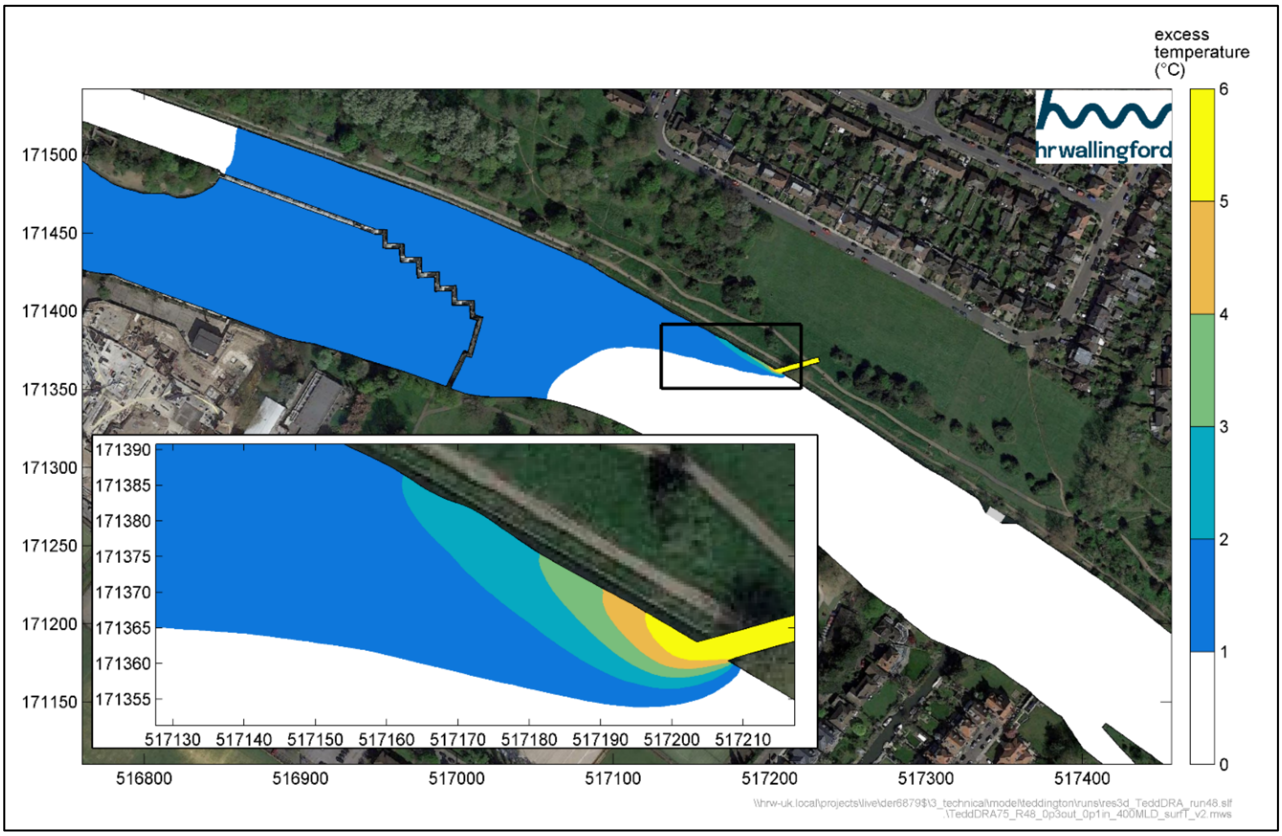


Scenario 2: 400Ml/d river flow

A.3.25 During the lowest river temperatures, the Project would operate at times that would correspond with very low river flows (400Ml/d). The mean temperature difference between the recycled water and the river temperature (8.9^{o}C) during these times is 6.1^{o}C, and therefore this is the model input value used immediately adjacent to the outfall structure in this scenario. Although this increase in temperature is localised and dissipates rapidly, this scenario was selected to demonstrate a likely worst case for temperature when the highest temperature difference occurred during a period of very low flows.

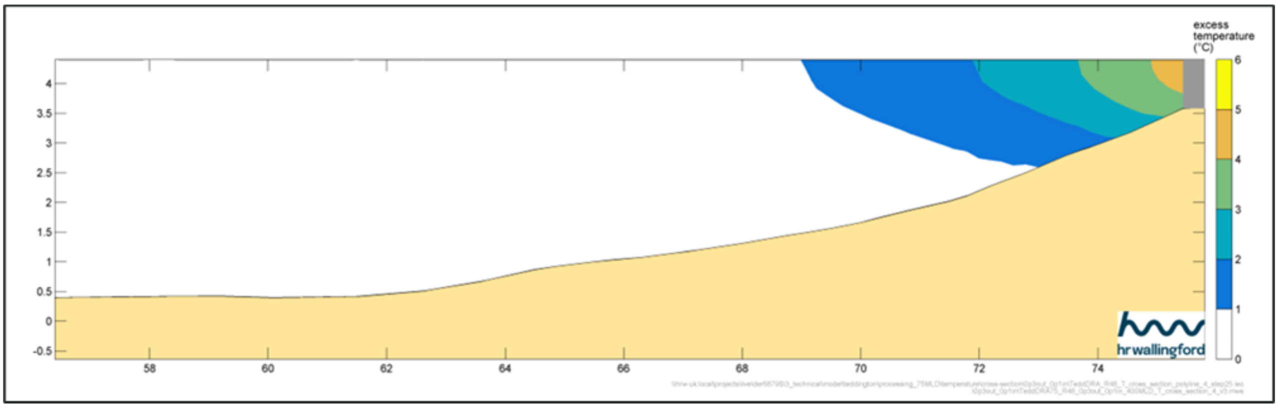
A.3.26 Under the 400Ml/d scenario, Plate A.13 shows the channel seeing a 1-2°C temperature change with a 2-6°C temperature contour confined to within 10m of the discharge bank, reducing to between 1-2°C change ~50m downstream. It is estimated that the Project under 400Ml/d flow would operate at 9% of time within a water resource year (1 April to 31 March). The discharged recycled water is modelled as fully mixed into the river water prior to Teddington Weir (~180m downstream of the discharge), exhibiting an increase temperature of 1-2°C across the entire channel. At the surface 10,789m^2 of the plan area exceeds a 1°C increase in temperature, with ~408m^2 of this area exceeding 2°C. The approximate surface area from the cross section C4 at the outfall to downstream extent of the Teddington Weir is ~15,000m^2 and therefore the area exceeding 2°C is approximately 2.7% of this.

Plate A.13 75Ml/d Project bankside discharge under 400Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.27 Plate A.14 C4 cross-section shows that the discharges 2-6°C temperature contour is limited to 4m closest to the discharge outfall on the right bank with end of pipe temperatures dissipating within a very short distance of the outfall and with a >1°C contour limited to 7m from the outfall. The >3°C contour covers 0.5% of the cross-sectional area of the channel, >2°C contour covers 1.2% and with 3.1% of the area exceeding >1°C. The vast majority of the channel at the outfall sees less than a 1°C temperature change.

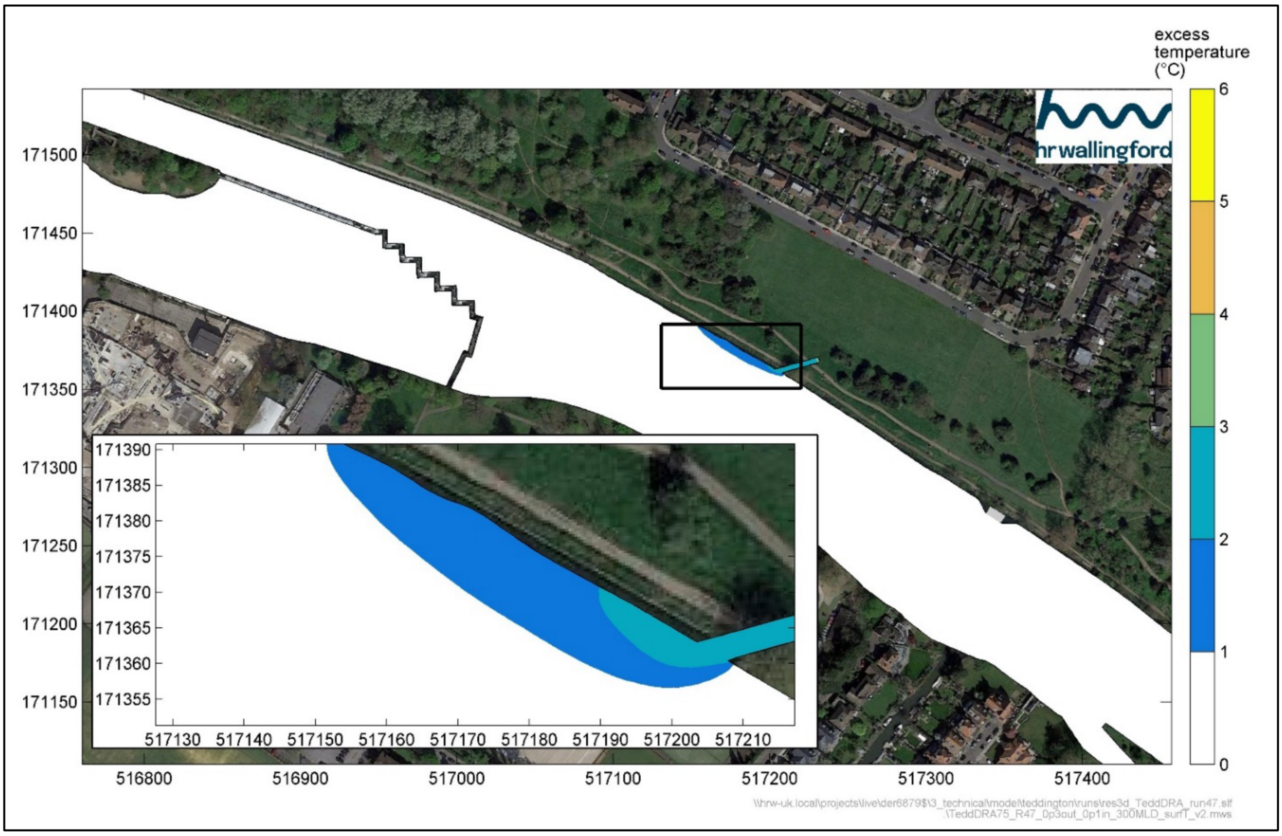
Plate A.14 75Ml/d Project bankside discharge under 400Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s.) cross section at outfall



Scenario 3: 300Ml/d river flow

A.3.28 At the lowest flow scenario (300Ml/d), the Project would discharge at River Thames temperatures of 13.0°C (mean), when recycled water temperatures would be 3.0°C warmer and therefore this is the model input value used immediately adjacent to the outfall structure in this scenario, as shown in Plate A.16 cross-section at discharge.

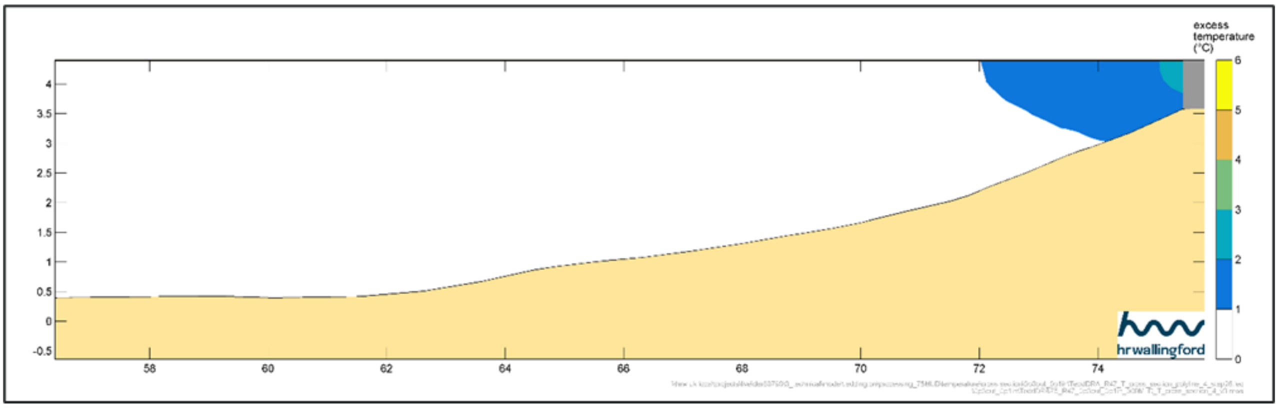
Plate A.15 75Ml/d bankside discharge under 300 Ml/d river flow (outfall velocity of 0.3 m/s and intake velocity of 0.1 m/s.)



A.3.29 The model outputs show that under all extreme flow and temperature differential, the recycled water is fully mixed prior to Teddington Weir (~180m downstream of the discharge). Under 300Ml/d flows (Plate A.15) the thermal plume is greater than a 2°C change confined to within 10m of the discharge and reduces to <1ºC change ~70m downstream. At the surface approximately 780m^2 of the plan area exceeds a 1°C increase in temperature, with 174m^2 of this area exceeding 2°C. The approximate surface area from the cross section C4 at the outfall to downstream extent of the Teddington Weir is ~15,000m^2 and therefore the area exceeding 2°C is approximately 1.2% of this.

A.3.30 Plate A.16 shows that the cross-sectional area of the 2°C contour covers 0.1% of the cross-sectional area of the channel, leaving the vast majority of the channel seeing less than a 1°C temperature change. It is noted that the Project under 300Ml/d flow would operate only 17% of time within a water resource year (1 April to 31 March).

Plate A.16 75Ml/d Project bankside discharge under 300Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s) cross section at outfall

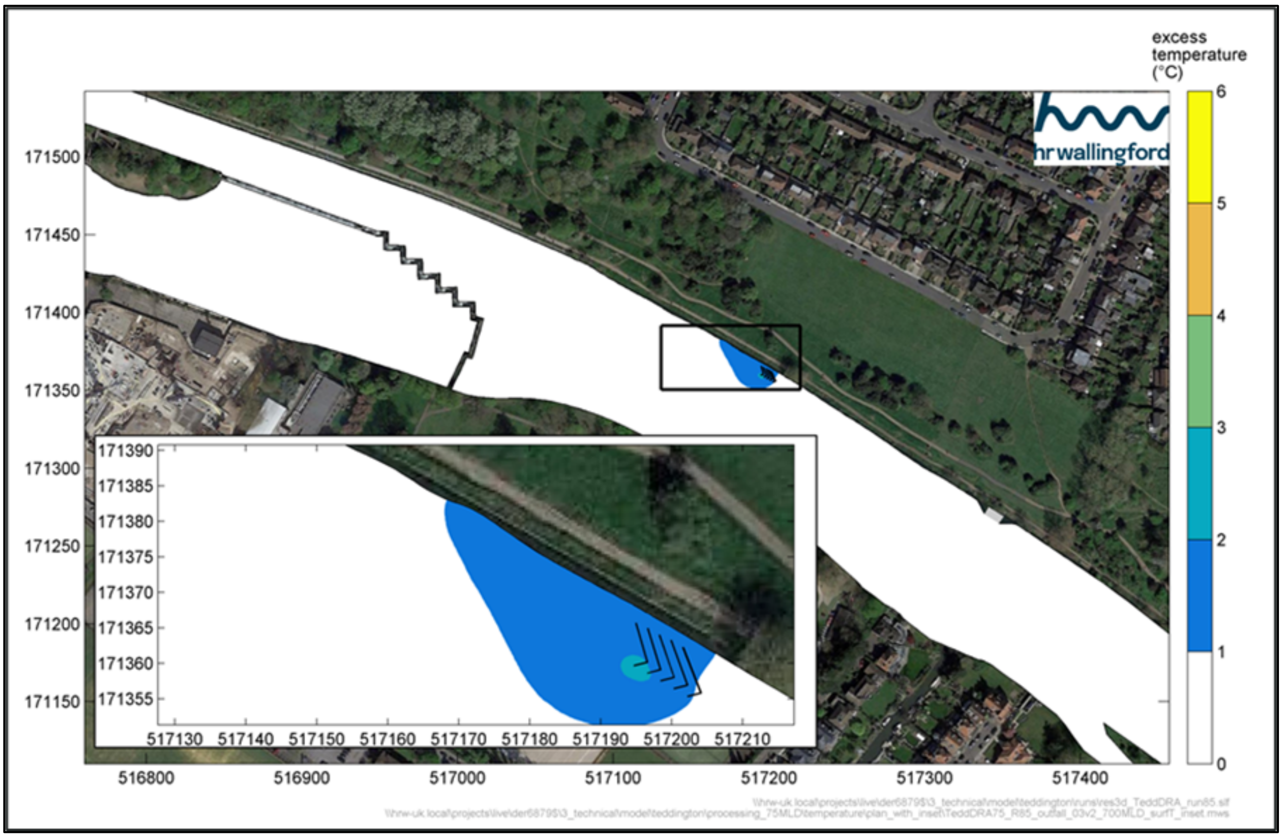


Near bankside in-river outfall thermal plume modelling

Scenario 1: 700Ml/d river flow

A.3.31 Under typical river flow conditions that the Project would operate under (58% of the Project operation would be at 700-799Ml/d), the mean river temperature is 16.9°C. The mean temperature difference between the recycled water and the river temperature during these times is 3.3°C, and therefore this is the model input value used immediately adjacent to the outfall structure in this scenario. The modelled recycled water plume under these 'normal' low flow conditions is presented in plan-view in Plate A.17 and cross-section (at discharge) location in Plate A.18.

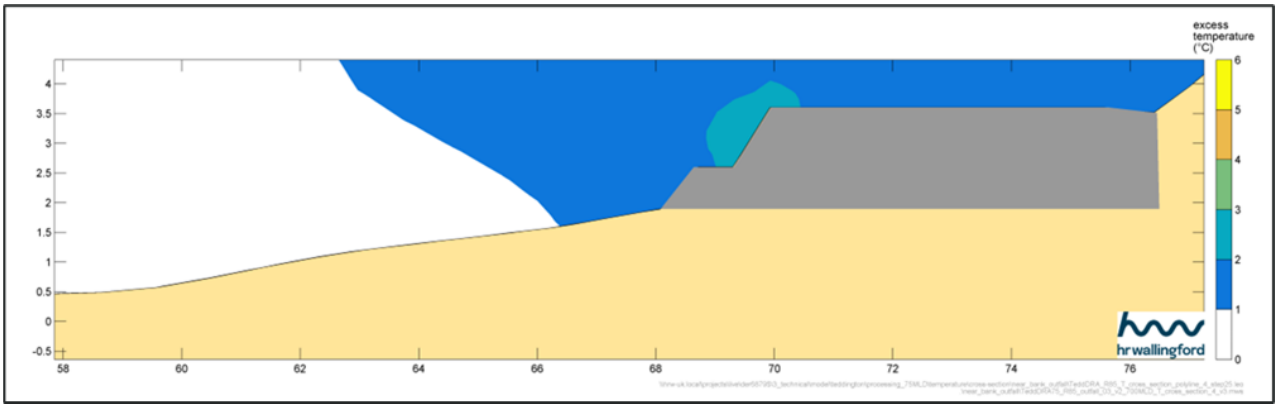
Plate A.17 75Ml/d Project near bankside in-river discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.32 Plate A.17 shows that under maximum temperature difference between the river and discharge recycled water (in measured data) during periods of 700Ml/d river flow, the discharge recycled water is fully mixed prior to Teddington Weir (~180m downstream of the discharge). The thermal plume is confined to within 15m of the discharge bank, reducing to <1ºC change ~40m downstream. At the surface 560m^2 of the plan area exceeds a 1°C increase in temperature, with 11m^2 of this area exceeding 2°C. The approximate surface area from the cross section C4 at the outfall to downstream extent of the Teddington Weir is ~15,000m^2 and therefore the area exceeding 2°C is approximately 0.07% of this.

A.3.33 Plate A.18 cross-section shows that the discharge's 1°C temperature contour is limited to 14m closest to the bankside outfall on the right bank, with a >2°C contour limited to close proximity of the near bankside in-river outfall pipes. The 2°C contour covers 0.4% of the cross-sectional area of the channel, leaving the vast majority of the channel seeing less than a 1°C temperature change.

Plate A.18 75Ml/d Project near bankside in-river discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s) cross section at outfall

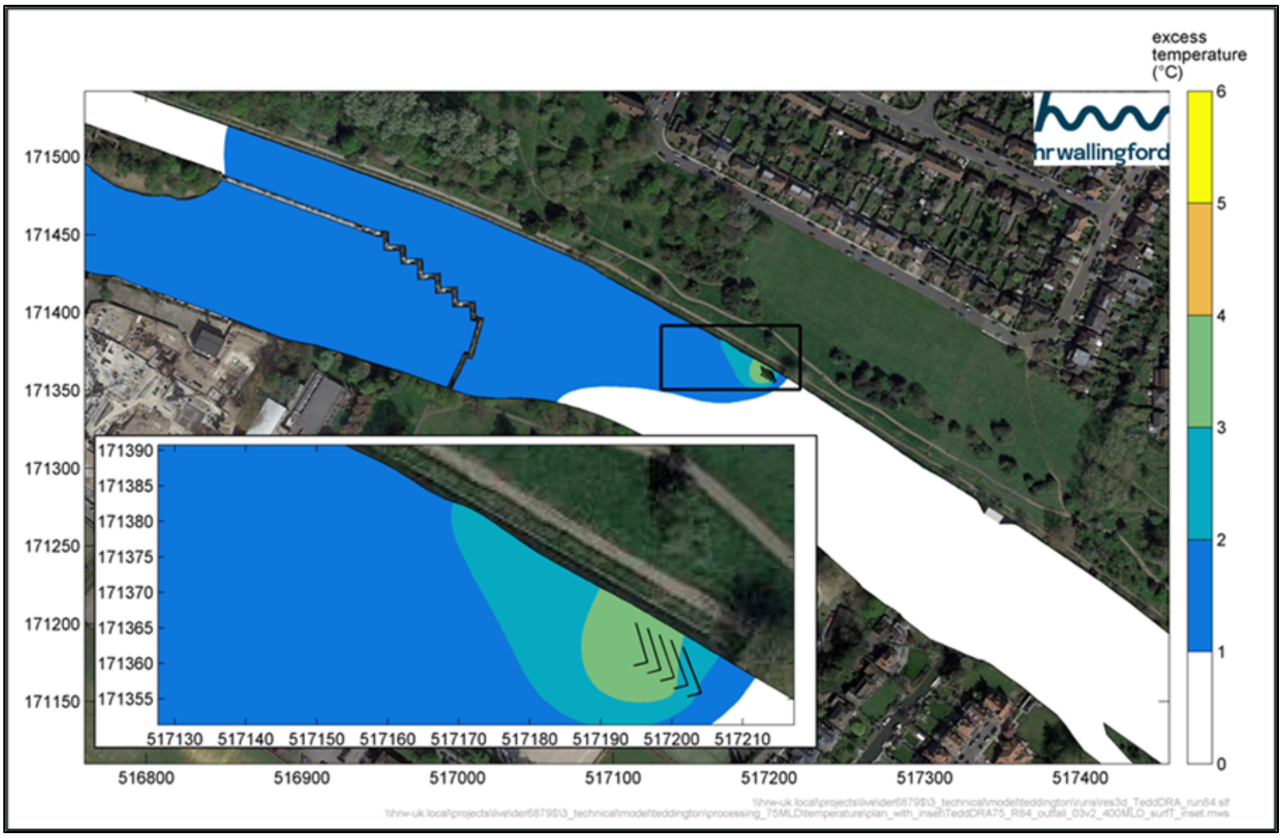


Scenario 2: 400Ml/d river flow

A.3.34 During the coldest river temperatures, the Project would operate at times that would correspond with very low river flows (400Ml/d). The mean temperature difference between the recycled water and the river temperature (8.9^{o}C) during these times is 6.1^{o}C and therefore this is the model input value used immediately adjacent to the outfall structure in this scenario.

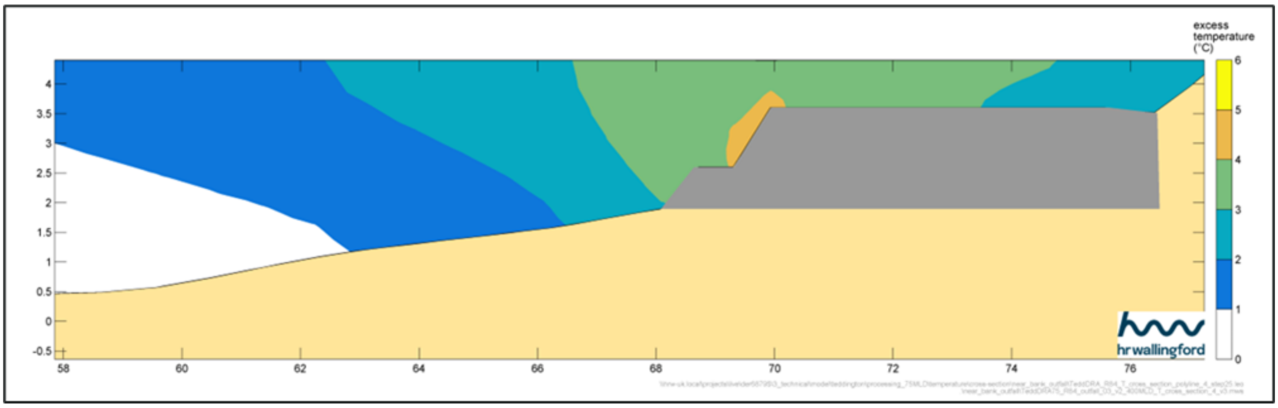
A.3.35 Under the 400Ml/d and recycled water maximum excess temperatures of +6.1°C scenario, Plate A.19 shows the channel seeing a >1°C temperature change with a 2-5°C temperature contour confined to within 20m of the discharge bank, reducing to between1-2°C change ~50m downstream. It is estimated that the Project under 400Ml/d flow would operate at 9% of time within a water resource year (1 April to 31 March). The recycled water discharge appears fully mixed prior to Teddington Weir (~180m downstream of the discharge), exhibiting an increase in temperature of 1-2°C across the entire channel. At the surface 12,669m^2 of the plan area exceeds a 1°C increase in temperature, with ~551m^2 of this area exceeding 2°C. The approximate surface area from the cross section C4 at the outfall to downstream extent of the Teddington Weir is ~15,000m^2 and therefore the area exceeding 2°C is approximately 3.7% of this surface area.

Plate A.19 75Ml/d Project near bankside in-river discharge under 400Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.36 Plate A.20 cross-section shows that the discharges 2-5°C temperature contour is limited to 15m closest to the discharge outfall on the right bank, with a >1°C contour covering 20m from the outfall. A >4°C contour occurs in close proximity to the near bankside in-river outfall pipes. The >3°C contour covers 3.4% of the cross-sectional area of the channel, >2°C contour covers 7.7% of cross sectional area and 14.8% of the area exceeds 1°C.

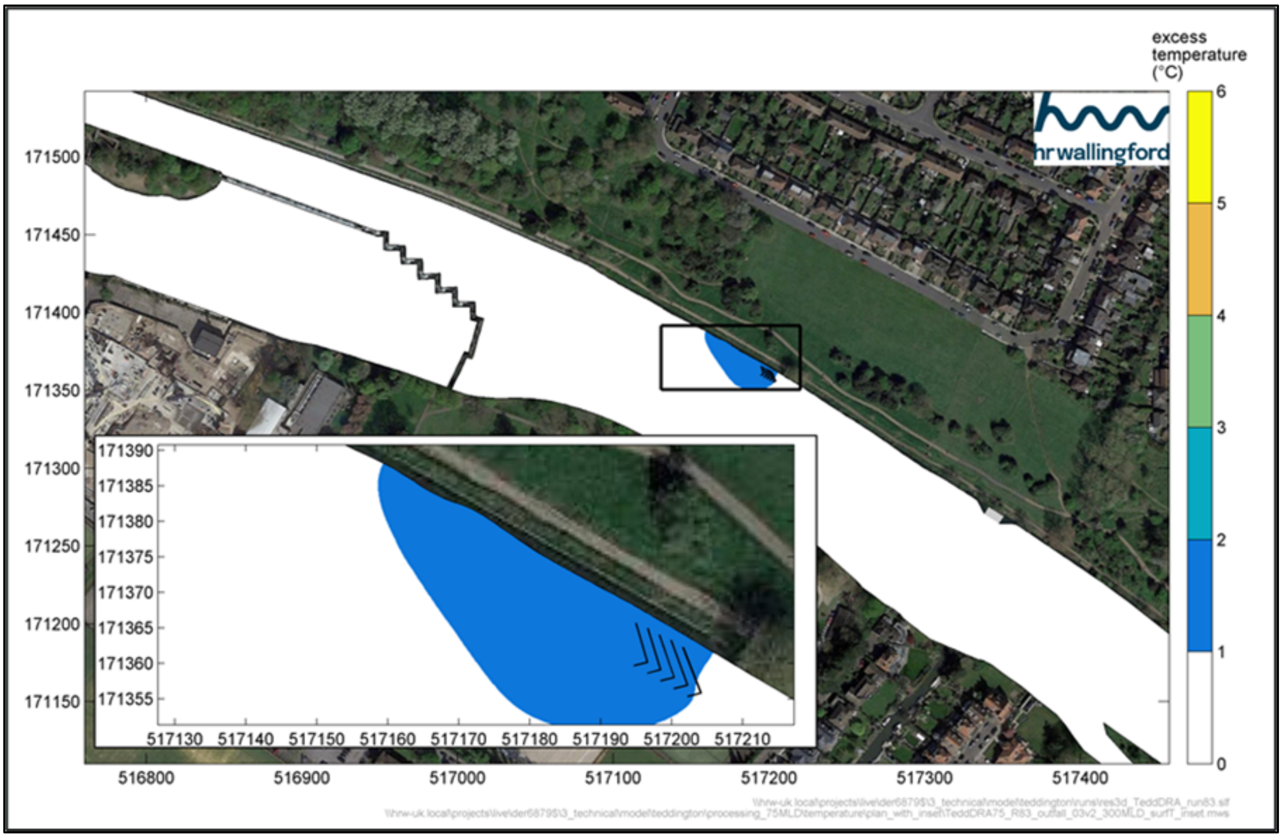
Plate A.20 75Ml/d Project near bankside in-river discharge under 400Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s) cross section at outfall



Scenario 3: 300Ml/d river flow

A.3.37 At the lowest flow scenario (300Ml/d), the Project would discharge at River Thames temperatures of 13.0°C (mean), when recycled water temperatures would be 3.0°C warmer and therefore this is the model input value used immediately adjacent to the outfall structure in this scenario, as shown in Plate A.21 plan view and Plate A.22 cross-section at discharge.

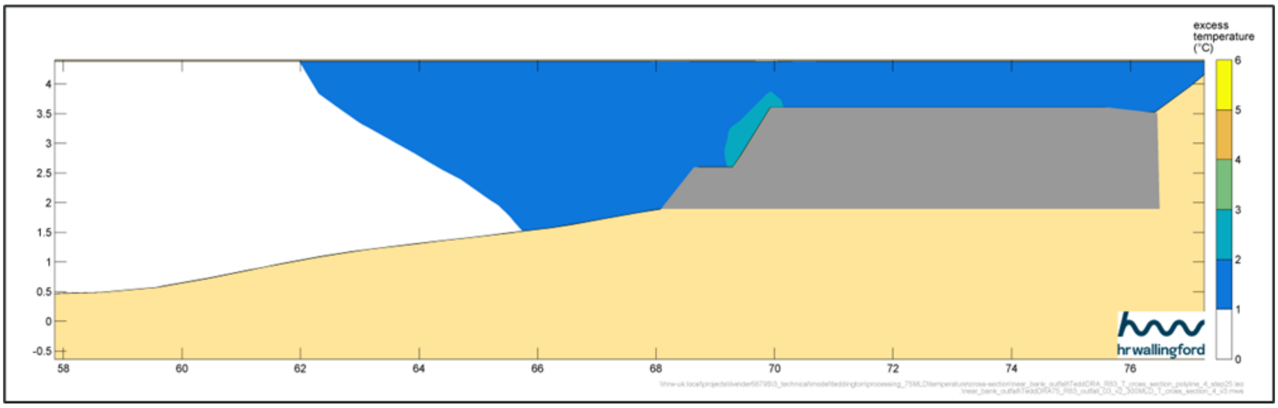
Plate A.21 75Ml/d Project near bankside in-river discharge under 300Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.38 The model outputs show that under all extreme flow and temperature differential, the recycled water is fully mixed prior to Teddington Weir (~180m downstream of the discharge). Under 300Ml/d flows (Plate A.21 the thermal plume is greater than a 1°C change confined to within 15m of the discharge and reduces to <1ºC change ~50m downstream. At the surface approximately 809m^2 of the plan area exceeds a 1°C increase in temperature and no area of > 2°C area is identified.

A.3.39 Plate A.22 shows that the cross-sectional area of the >2°C contour covers 0.2% of the cross-sectional area of the channel, leaving the vast majority of the channel seeing less than a 1°C temperature change. It is noted that the Project under 300Ml/d flow would operate only 17% of time within a water resource year (1 April to 31 March).

Plate A.22 75Ml/d Project near bankside in-river discharge under 300Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s) cross section at outfall

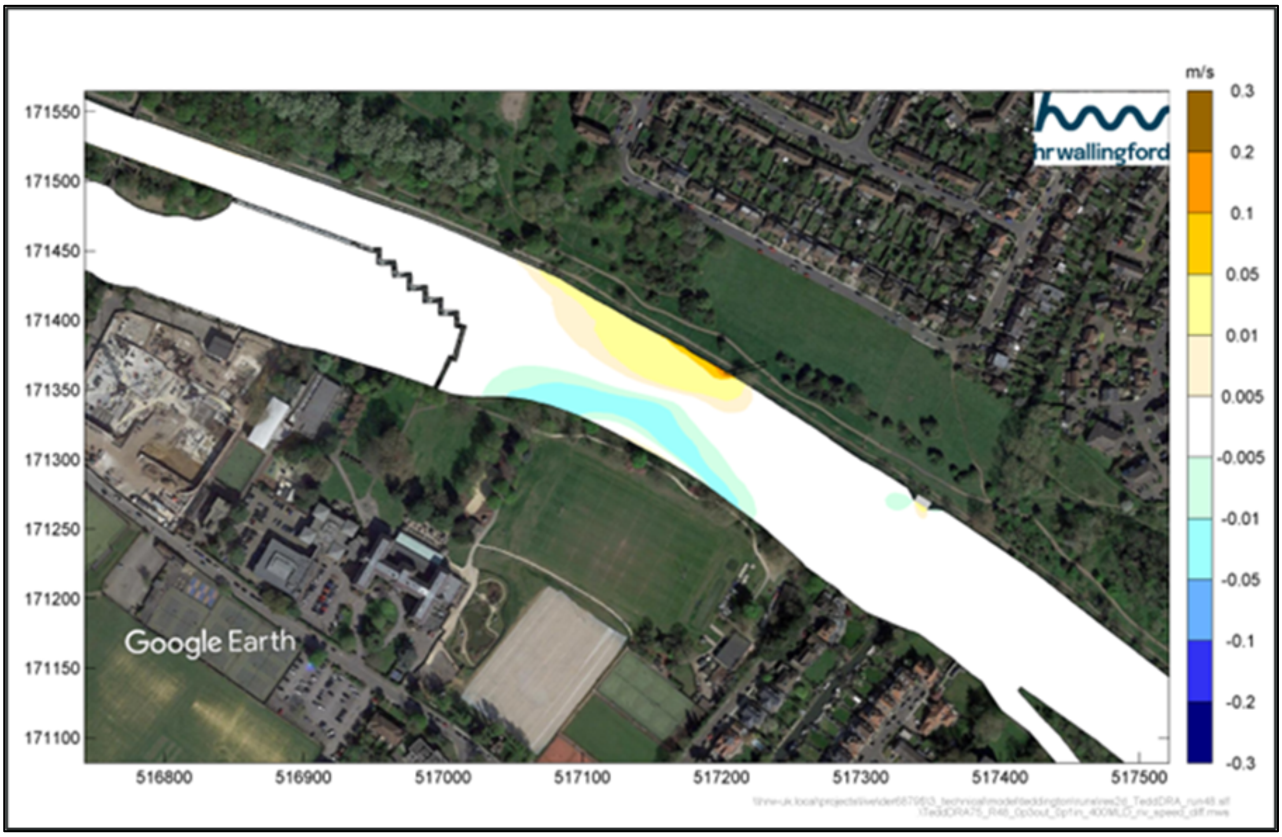


Bankside outfall hydrodynamic modelling

Scenario 1: 700Ml/d river flow

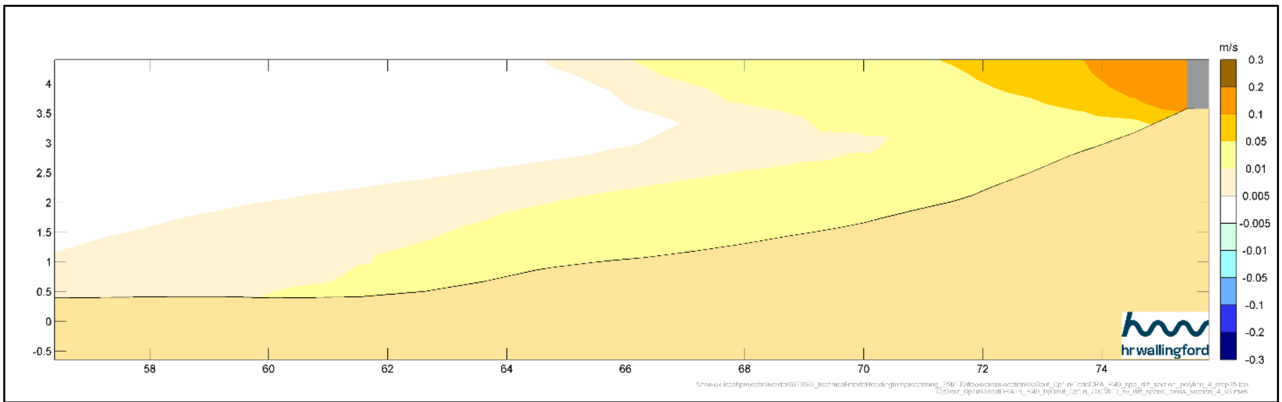
A.3.40 During periods of 700Ml/d river flow depth-averaged river flow velocities increased by 0.005-0.3m/s surrounding the bankside outfall (Plate A.23). Higher flow velocities are observed along the right bank, localised around the outfall, with reductions of 0.005-0.05m/s in velocity occurring by the left bank. Velocity gradients disappear prior to Teddington Weir (~180m downstream of the discharge). Velocity vectors remain predominantly in a downstream direction, although some slight deflection towards the outfall as upstream flow passes by remains. 2303m^2 of the plan area exceeds a velocity increase of 0.01m/s, while 2333m^2 observe a decrease in velocity of over 0.01m/s. Minor reductions in velocity (<-0.01 m/s) were observed immediately downstream of the intake abstraction.

Plate A.23 Depth-average velocity for the bankside outfall – 75Ml/d Project discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.41 Plate A.24 shows modelled changes in flow velocity for the river cross-section perpendicular to the location of the Project outfall under the 700Ml/d river flows. The difference data shows that velocities peak around the outfall (right side of the cross-section) at around 0.05-0.20m/s and extend to a maximum of ~5m out into the channel. The modelling suggests that there is an increase in flow velocity of between 0.005-0.1m/s out to around 20m across the vertical channel profile. The remainder of the channels shows either limited change in velocity or a reduction in velocity (-0.005 to 0.005m/s). 8.7% of the cross-sectional area of the channel observes an increase in velocity of >+0.01 m/s.

Plate A.24 Cross-sectional velocity difference at the bankside outfall – 75Ml/d Project discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s).

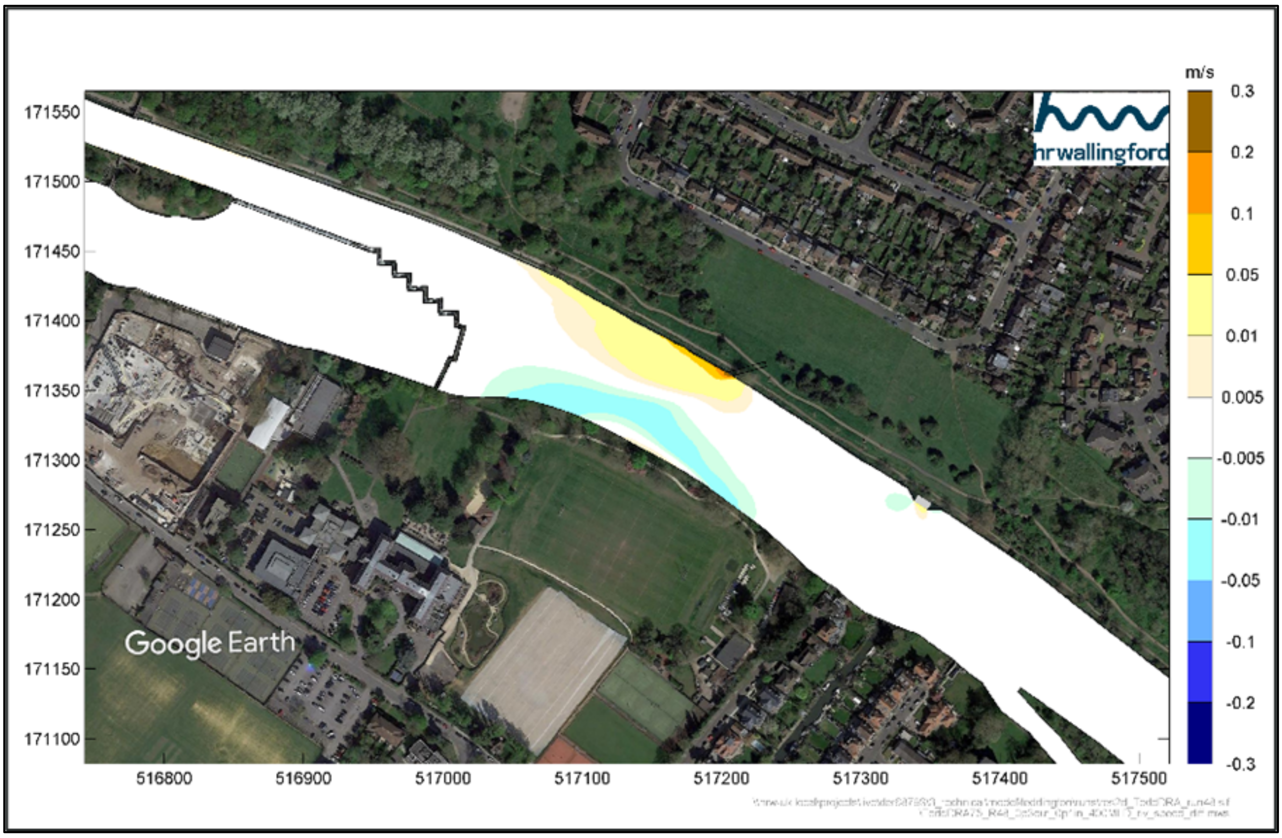


Scenario 2: 400Ml/driver flow

A.3.42 During periods of 400Ml/d river flow depth-averaged river flow velocities increase by 0.005-0.3m/s surrounding the bankside outfall (Plate A.25). Higher flow velocities are observed along the right bank, localised around the outfall, with reductions of 0.005-0.05m/s in velocity occurring along the left bank. Velocity gradients disappear prior to Teddington Weir (~180m downstream of the discharge). Velocity vectors remain predominantly in a downstream direction, although some slight deflections towards the outfall as upstream flow passes by remains.

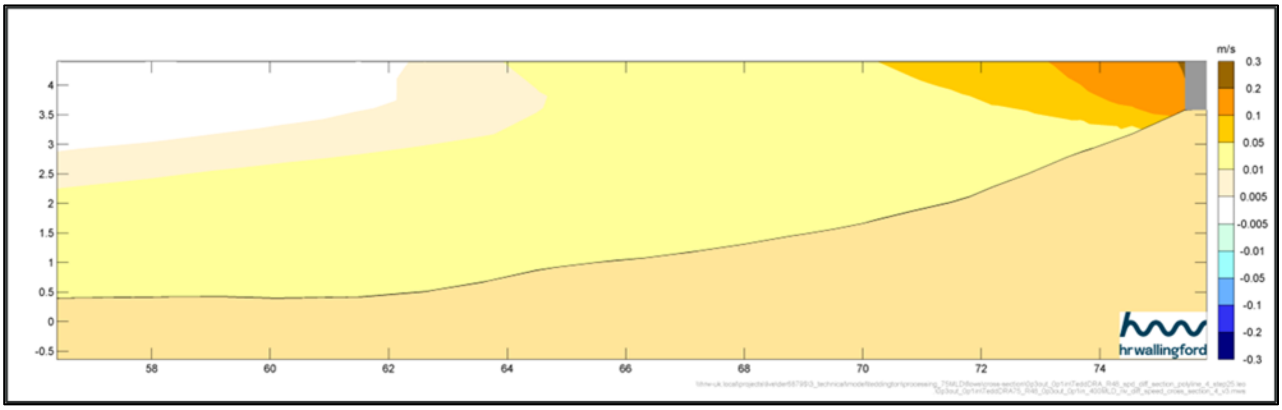
A.3.43 The modelled differences in velocity remain similar to 700Ml/d river flows, although the reduced flow velocities on the left bank appear to cover more of the channel laterally and longitudinally. This is further evidenced by 3608m^2 of the plan area exceeding a velocity increase of 0.01m/s, while 2732m^2 observe a decrease in velocity of over 0.01m/s. Minor reductions in velocity (<-0.01 m/s) are observed immediately downstream of the intake abstraction.

Plate A.25 Depth-average velocity for the bankside outfall – 75Ml/d Project discharge under 400Ml/d river flow (outfall velocity of 0.3 m/s and intake velocity of 0.1 m/s)



A.3.44 Plate A.26 shows modelled changes in flow velocity for the river cross-section perpendicular to the location of the Project's outfall under the 400Ml/d river flows. The difference data shows that velocities peak around the outfall (right side of the cross-section) at around 0.05-0.20m/s and extend to a maximum of ~6m out into the channel. The modelling suggests that there is an increase in flow velocity of between 0.005-0.1m/s out to over 20m across the vertical channel profile. The remainder of the channels shows either limited change in velocity or a reduction in velocity (-0.005 to 0.005m/s). 30.6% of the cross-sectional area of the channel observes an increase in velocity of >+0.01 m/s.

Plate A.26 Cross-sectional velocity difference at the bankside outfall – 75Ml/d Project discharge under 400Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s).

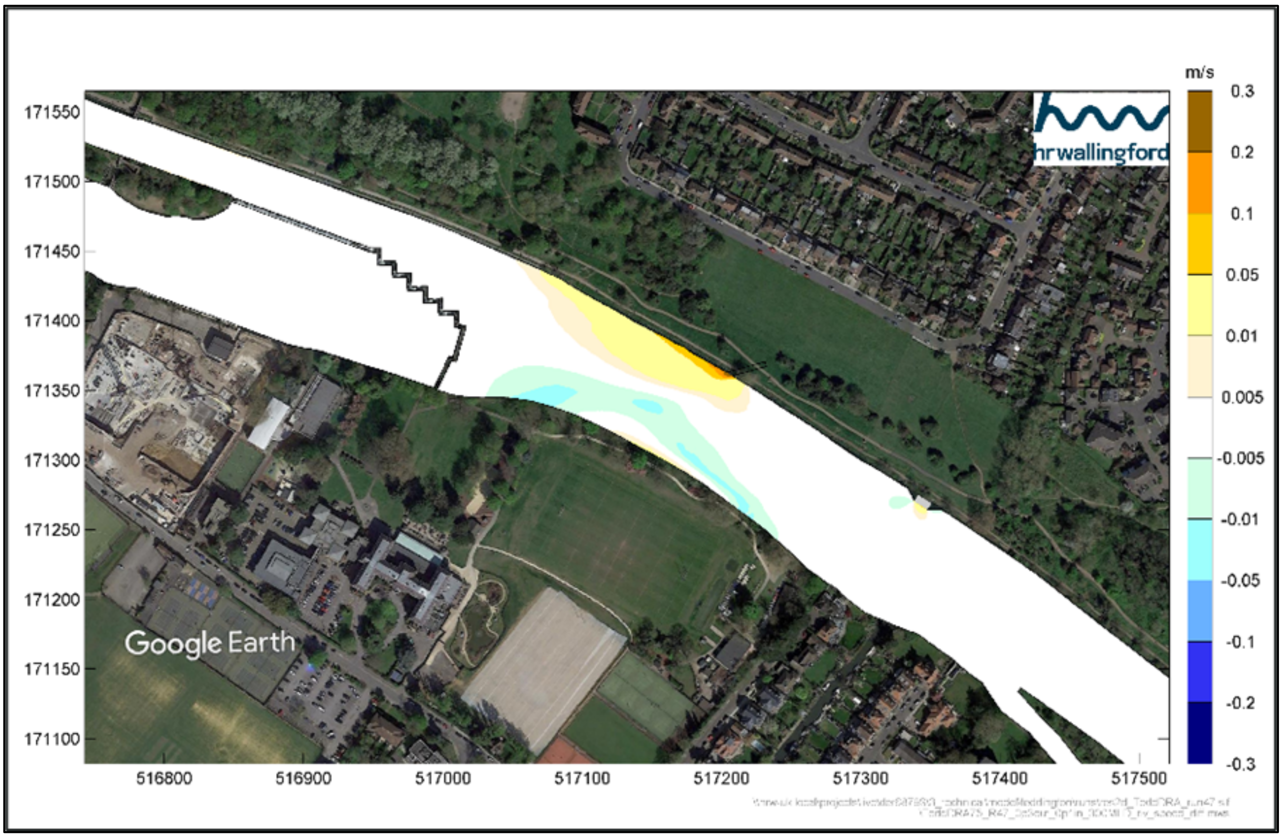


Scenario 3: 300Ml/d river flow

A.3.45 During periods of 300Ml/d river flow depth-averaged river flow velocities increased by 0.005-0.3m/s surrounding the bankside outfall (Plate A.27). Higher flow velocities are observed along the right bank, localised around the outfall, with reductions of 0.005-0.05m/s in velocity occurring by the left bank. Velocity gradients disappear prior to Teddington Weir (~180m downstream of the discharge). Velocity vectors remain predominantly in a downstream direction, although some slight deflection towards the outfall as upstream flow passes by remains.

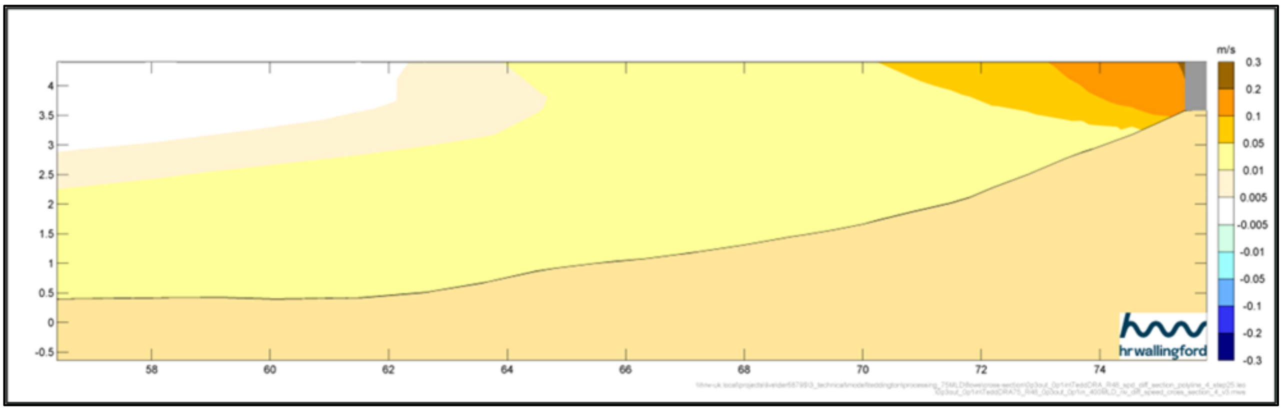
A.3.46 The modelled differences in velocity remain similar to 700Ml/d river flows, although the reduced flow velocities on the left bank appear to cover more of the channel laterally and longitudinally. This is further evidenced by 3552m^2 of the plan area exceeding a velocity increase of 0.01m/s, while 945m^2 observe a decrease in velocity of over 0.01m/s. Minor reductions in velocity (<-0.01m/s) were observed immediately downstream of the intake abstraction.

Plate A.27 Depth-average velocity for the bankside outfall – 75Ml/d Project discharge under 300Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.47 Plate A.28 shows modelled changes in flow velocity for the river cross-section perpendicular to the location of the Project's outfall under the 700Ml/d river flows. The difference data shows that velocities peak around the outfall (right side of the cross-section) at around 0.05-0.20m/s and extend to a maximum of ~6m out into the channel. The modelling suggests that there is an increase in flow velocity of between 0.005-0.1m/s out to over 20m across the cross channel profile. The remainder of the channel shows either limited change in velocity or a reduction in velocity (-0.005 to 0.005m/s). 31.2% of the cross-sectional area of the channel observes an increase in velocity of >+0.01m/s.

Plate A.28 Cross-sectional velocity difference at the bankside outfall – 75Ml/d Project discharge under 300Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s).



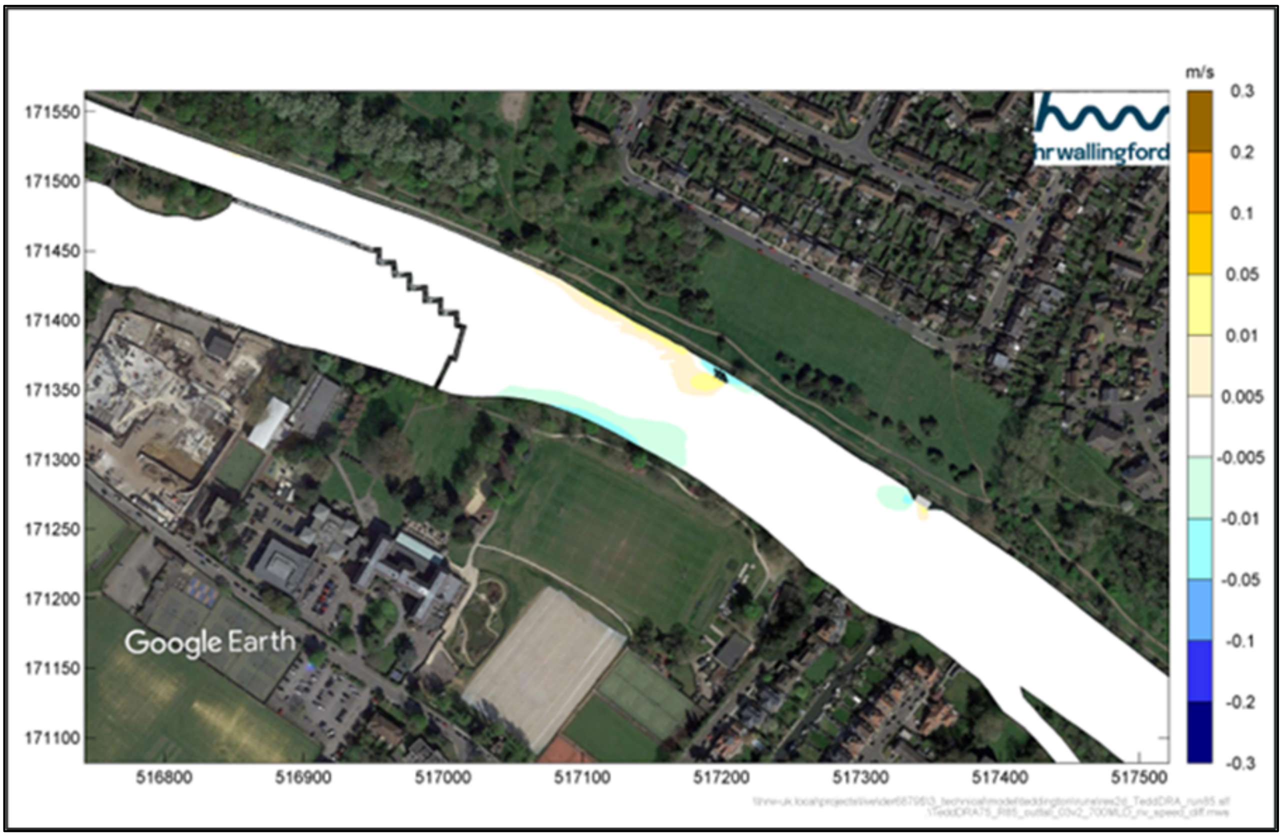
Near bankside in-river outfall hydrodynamic modelling

Scenario 1: 700Ml/d river flow

A.3.48 During periods of 700Ml/d river flow depth-averaged river flow velocities changed by -0.005 to +0.3m/s surrounding the bankside outfall (Plate A.29). Higher flow velocities are observed along the right bank, localised around the outfall, with reductions of 0.005-0.01m/s in velocity occurring by the left bank. Velocity gradients disappear prior to Teddington Weir (~180m downstream of the discharge). Velocity vectors remain predominantly in a downstream direction, although some slight deflection towards the outfall as upstream flow passes by remains.

A.3.49 Velocity differences along the right and left bank appear low in magnitude, covering little of the channel longitudinally and laterally. This is evidenced by only 626m^2 of the plan area exceeding a velocity increase of 0.01m/s, while only 556m^2 observe a decrease in velocity of over 0.01m/s.

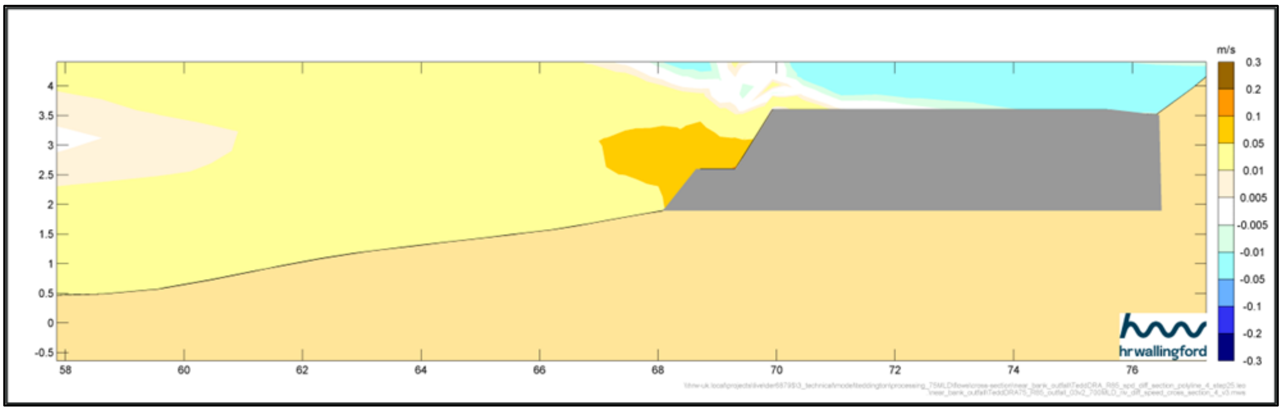
Plate A.29 Depth-average velocity for the near bankside in-river outfall – 75Ml/d Project discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.50 Plate A.30 shows modelled changes in flow velocity for the river cross-section perpendicular to the location of the Project's outfall under the 700Ml/d river flows. The difference data shows that velocities peak around the discharge location surrounding the pipes (right side of the cross-section). Above the concrete mattress and pipes a reduction in channel velocity is observed between 0-0.05m/s. The modelling suggests that there is an increase in flow velocity of between 0.005-0.1m/s out to around 20m across the vertical channel profile.

A.3.51 The remainder of the channel shows either limited change in velocity or a reduction in velocity (-0.005 to 0.005m/s).

Plate A.30 Cross-sectional velocity difference at the near bankside in-river outfall – 75Ml/d Project discharge under 700Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)

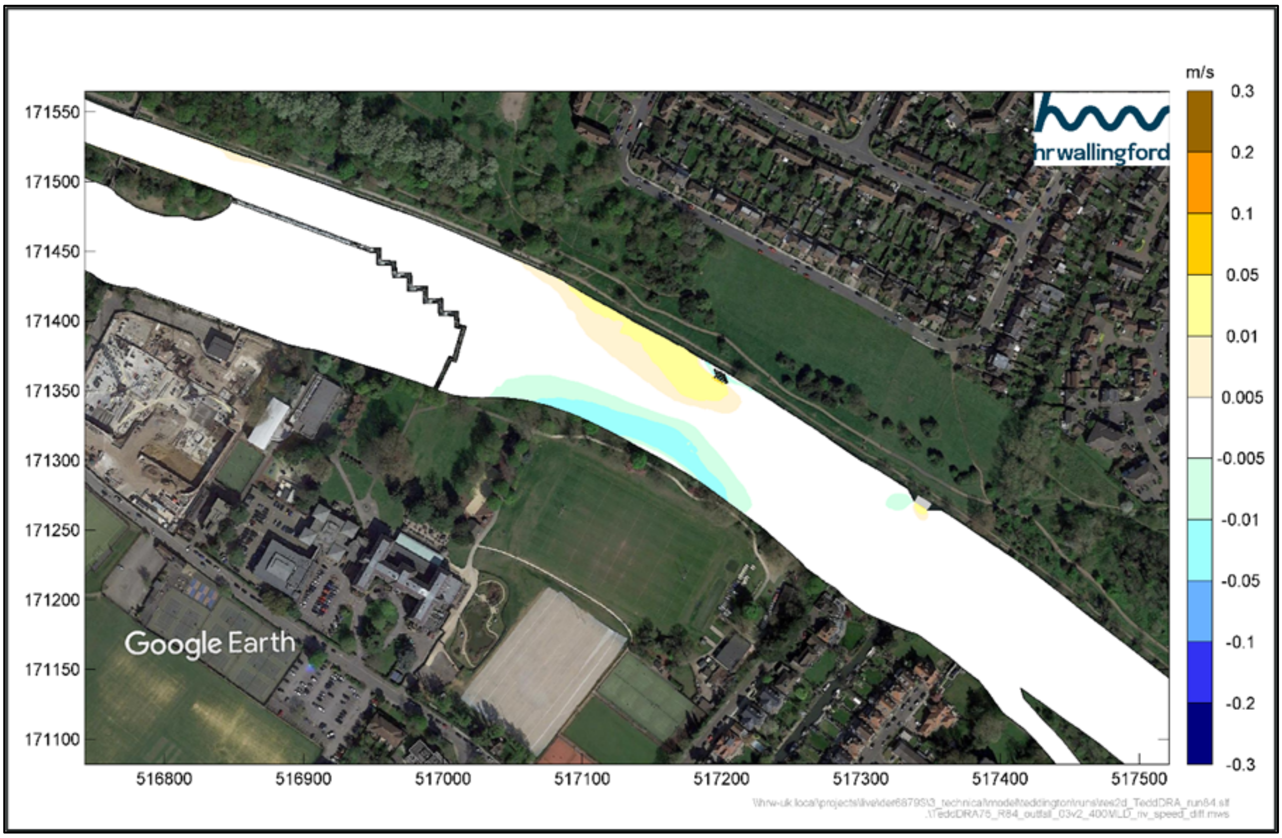


Scenario 2: 400Ml/d river flow

A.3.52 During periods of 400Ml/d river flow depth-averaged river flow, velocities increase by 0.005-0.05m/s surrounding the bankside outfall (Plate A.31). Higher flow velocities are observed along the right bank, localised around the outfall, with reductions of 0.005-0.05m/s in velocity occurring along the left bank. Velocity gradients disappear prior to Teddington Weir (~180m downstream of the discharge). Velocity vectors remain predominantly in a downstream direction, although some slight deflections towards the outfall as upstream flow passes by remain.

A.3.53 Velocity differences along the right and left bank appear low in magnitude, covering little of the channel longitudinally and laterally. This is evidenced by 2085m^2 of the plan area exceeding a velocity increase of 0.01m/s, with 2008m^2 observing a decrease in velocity of over 0.01m/s.

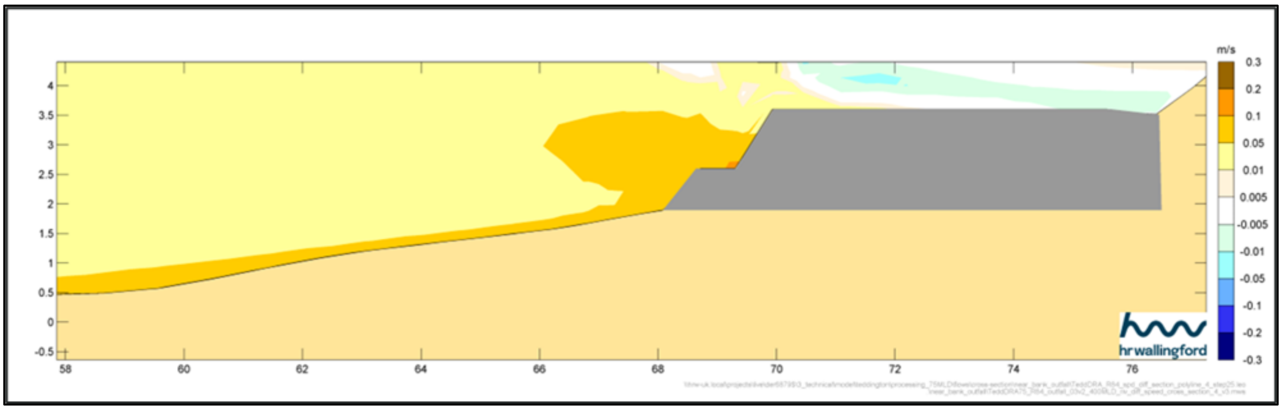
Plate A.31 Depth-average velocity for the near bankside in-river outfall – 75Ml/d Project discharge under 400Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.54 Plate A.32 shows modelled changes in flow velocity for the river cross-section perpendicular to the location of the Project's outfall under the 400Ml/d flows. The difference data shows that velocities peak around the discharge location surrounding the pipes (right side of the cross-section), and along the river bed heading out towards the middle of the channel. Above the concrete mattress and pipes a reduction in channel velocity is observed between 0-0.1m/s. The modelling suggests that there is an increase in flow velocity of between 0.005-0.05m/s out to over 20m across the vertical channel profile.

A.3.55 The remainder of the channel shows either limited change in velocity or a reduction in velocity (-0.005 to 0.005m/s).

Plate A.32 Cross-sectional velocity difference at the near bankside in-river outfall – 75Ml/d Project discharge under 400Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s).

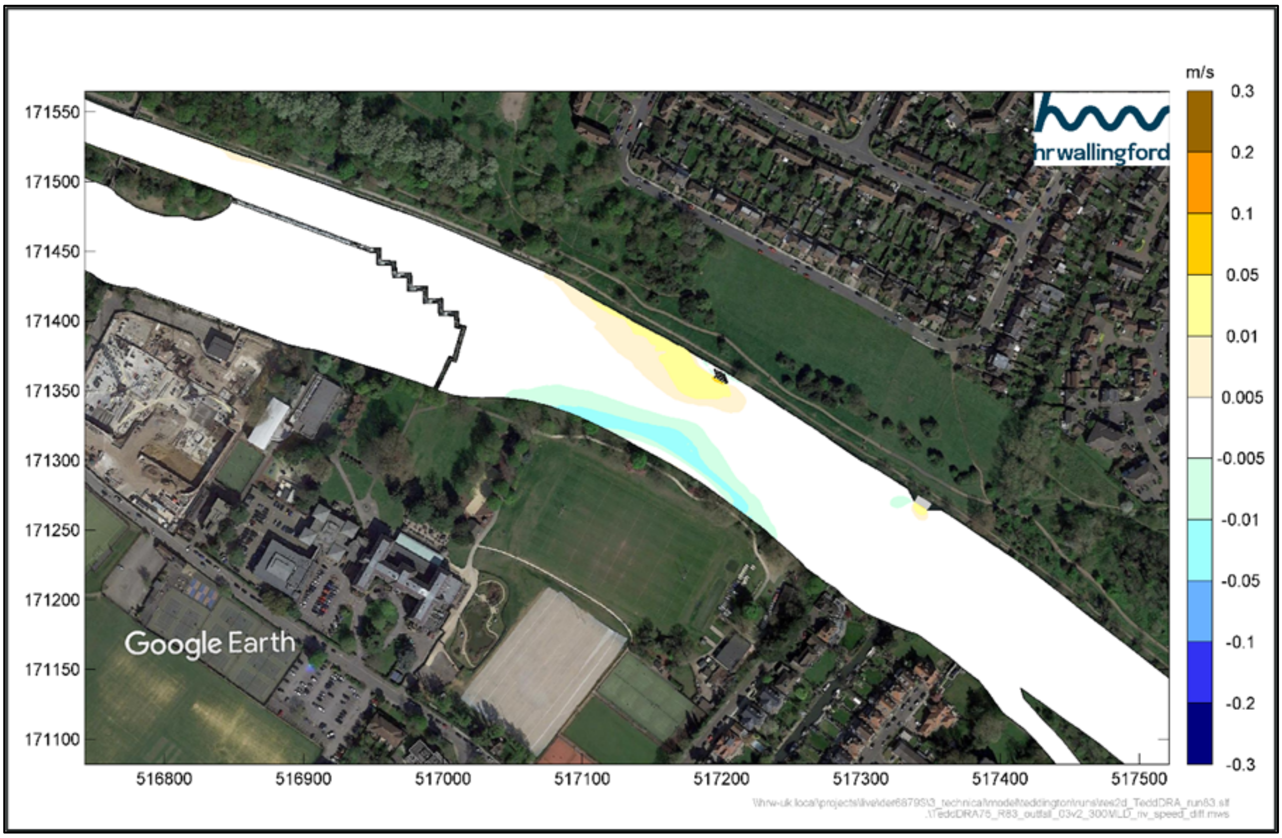


Scenario 3: 300Ml/d river flow

A.3.56 During periods of 300Ml/d river flow depth-averaged river flow velocities change by 0-0.005m/s surrounding the bankside outfall (Plate A.33). Higher flow velocities are observed along the right bank, localised around the outfall, with reductions of 0.005-0.01m/s in velocity occurring by the left bank. Velocity gradients disappear prior to Teddington Weir (~180m downstream of the discharge). Velocity vectors remain predominantly in a downstream direction, although some slight deflections towards the outfall as upstream flow passes by remain.

A.3.57 Velocity differences along the right and left bank appear low in magnitude, covering little of the channel longitudinally and laterally. This is evidenced by 1552m^2 of the plan area exceeding a velocity increase of 0.01m/s, while only 1382m^2 observe a decrease in velocity of over 0.01m/s.

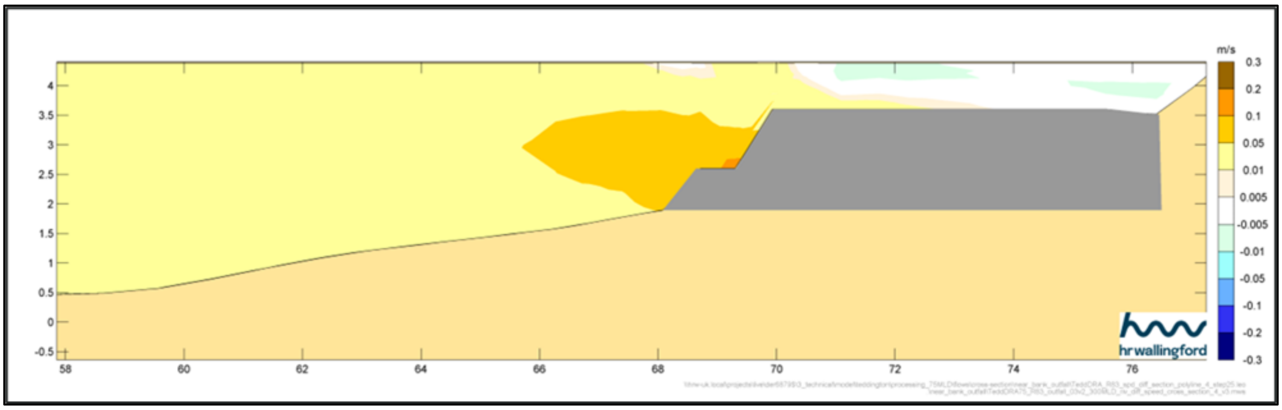
Plate A.33 Depth-average velocity for the near bankside in-river outfall – 75Ml/d Project discharge under 300Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s)



A.3.58 Plate A.34 shows modelled changes in flow velocity for the river cross-section perpendicular to the location of the Project's outfall under the 300Ml/d river flows. The difference data shows that velocities peak around the discharge location surrounding the pipes (right side of the cross-section). Above the concrete mattress and pipes a reduction in channel velocity is observed between 0-0.01m/s. The modelling suggests that there is an increase in flow velocity of between 0.005-0.1m/s out to over 20m across the vertical channel profile.

A.3.59 The remainder of the channel shows either limited change in velocity or a reduction in velocity (-0.005 to 0.005m/s).

Plate A.34 Cross-sectional velocity difference at the near bankside in-river outfall – 75Ml/d Project discharge under 300Ml/d river flow (outfall velocity of 0.3m/s and intake velocity of 0.1m/s).



Thames Tideway

Temperature modelling

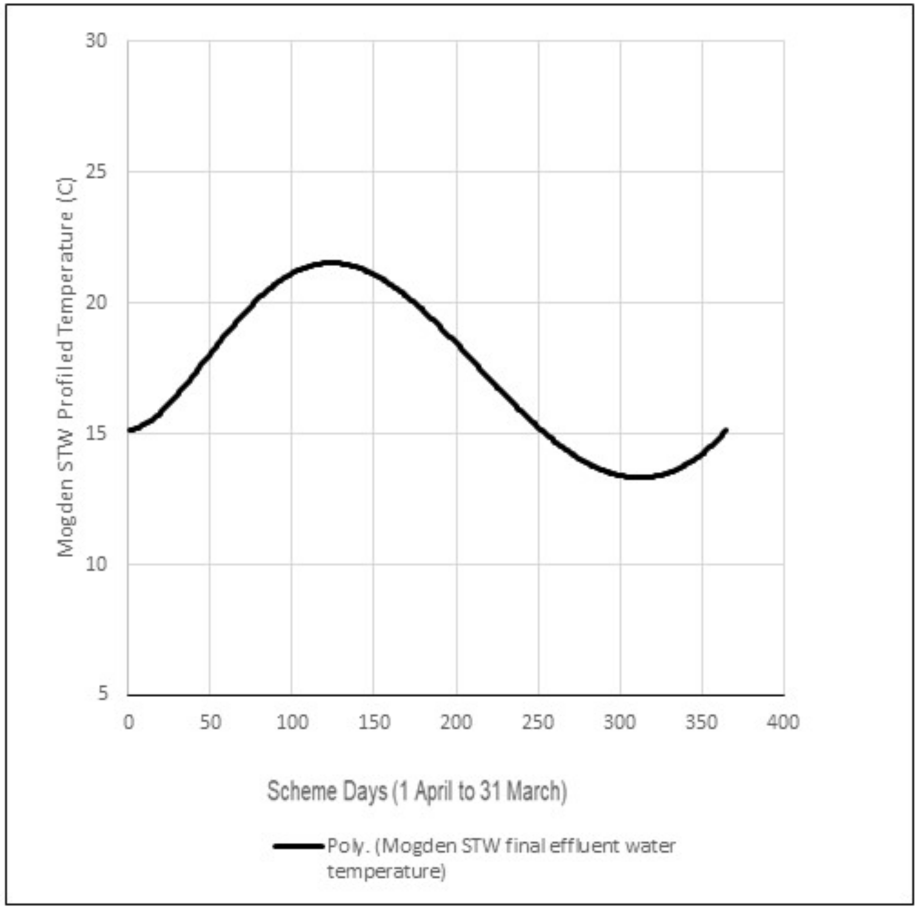
A.3.60 Long-term Environment Agency water temperature data from the Thames Tideway were reviewed (Plate A.35). The Tideway profiles show higher average temperatures than the freshwater River Thames, particularly higher minimum winter temperatures (3.44ºC at Purfleet) and higher maximum summer temperatures (24.49ºC at Brentford).

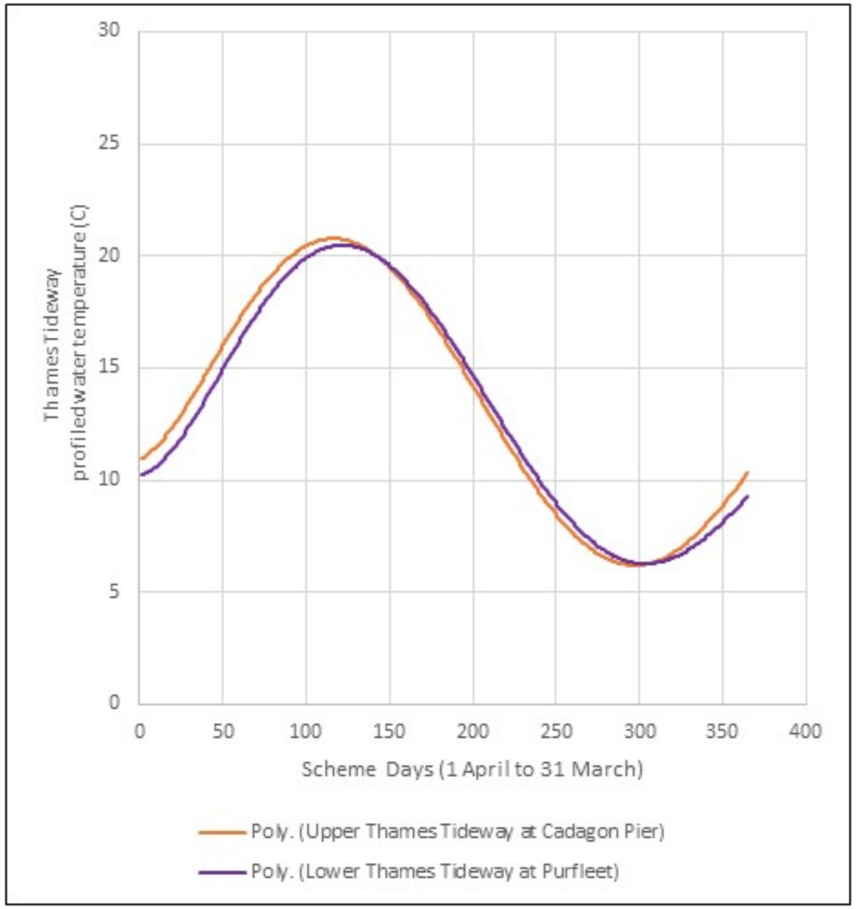
A.3.61 A curve has been fitted to the daily average temperature data for Mogden STW final effluent, Cadogan Pier in the tidal Thames and at Purfleet in the lower Tideway and is shown in Plate A.35.

A.3.62 These profiles both show a clear seasonal trend. The Mogden STW final effluent profile is between an upper value of 21.9ºC and a lower value of 13.06ºC. It is noted that the Tideway profiles are developed from the measured baseline and are without the Project. The Tideway profile at Cadogan Pier shows higher spring and summer water temperatures than the Lower Tideway profile at Purfleet.

A.3.63 The long-term measured water temperature data set indicates that the average water temperature at Teddington is 1.04ºC colder than the average water temperatures in the tidal Thames at Brentford and 0.54ºC colder than Cadogan Pier. This shows that there is an increasing water temperature profile at the baseline condition from freshwater River Thames at Teddington to tidal Thames at Cadogan Pier.

Plate A.35 Profiled water temperature at Mogden STW (final effluent) and Thames Tideway (Cadogan Pier, Purfleet)



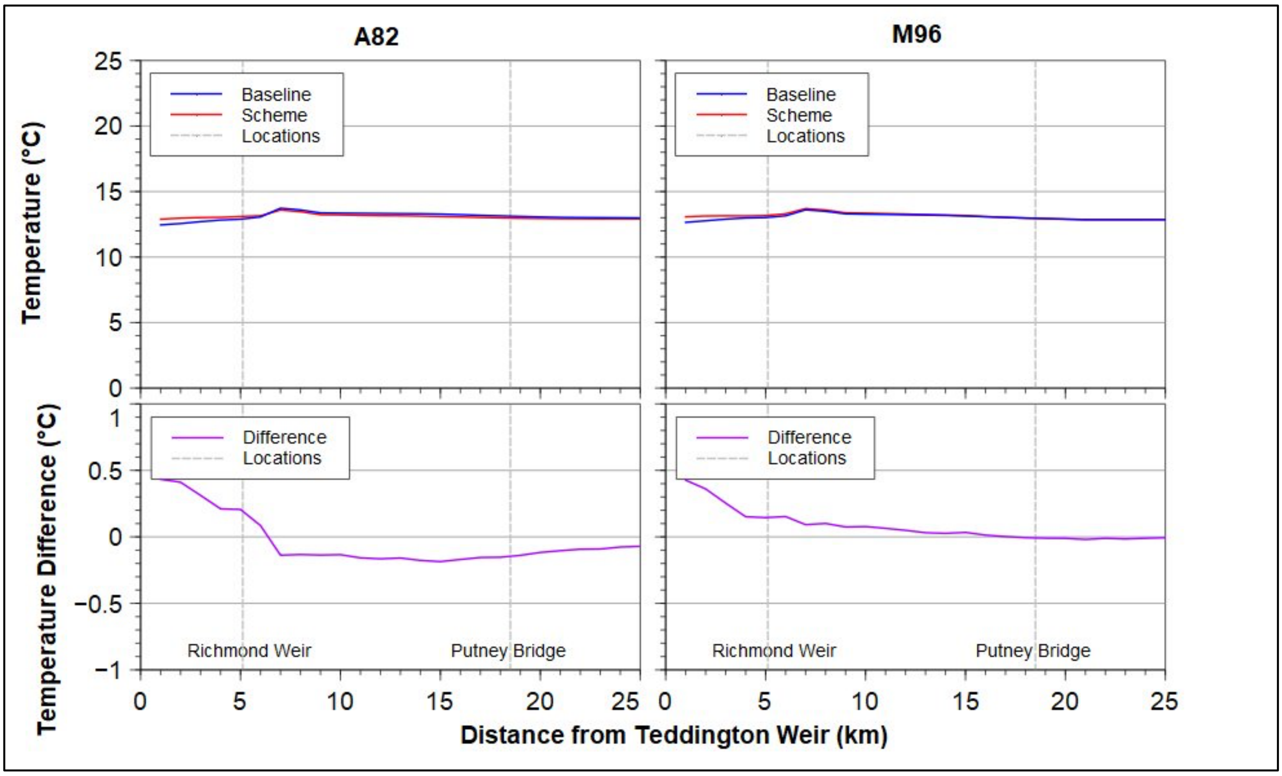


A.3.64 Plate A.36 shows the modelled median (50th percentile) temperature changes in the 25km reach during the Project operation (75Ml/d) for the A82 and M96 flows under the whole tidal cycle.

A.3.65 The water temperature data show median water temperature of ~13°C within Richmond Pound, increasing to ~14°C outside of the Pound around the Mogden STW discharge and declining to ~13°C for the remainder of the reach. The data show there is no significant difference between A82 and M96 for the whole tidal cycle.

A.3.66 The greatest impact on water temperature occurs directly downstream of Teddington Weir. 1km downstream of the weir, during A82 flows, water temperature in the tidal Thames are ~0.5°C greater than during baseline conditions. This temperature increase is reduced heading downstream until approximately 6.5km, where temperatures begin to decrease compared to baseline conditions to a minimum of ~0.2°C lower, reaching 7km downstream. Here the temperature difference slowly reduces back to baseline conditions as it flows towards the end of the reach (25km). Similar trends in temperature differences are observed during M96 flows upstream of Richmond Weir, with higher temperatures observed during baseline conditions that decrease to baseline conditions until 4km downstream. Following this, these temperatures steady out at ~0.2°C greater than the baseline, before slowly returning to baseline conditions between 6-15km.

Plate A.36 Median water temperature change in the tidal Thames under a 75Ml/d Project operation



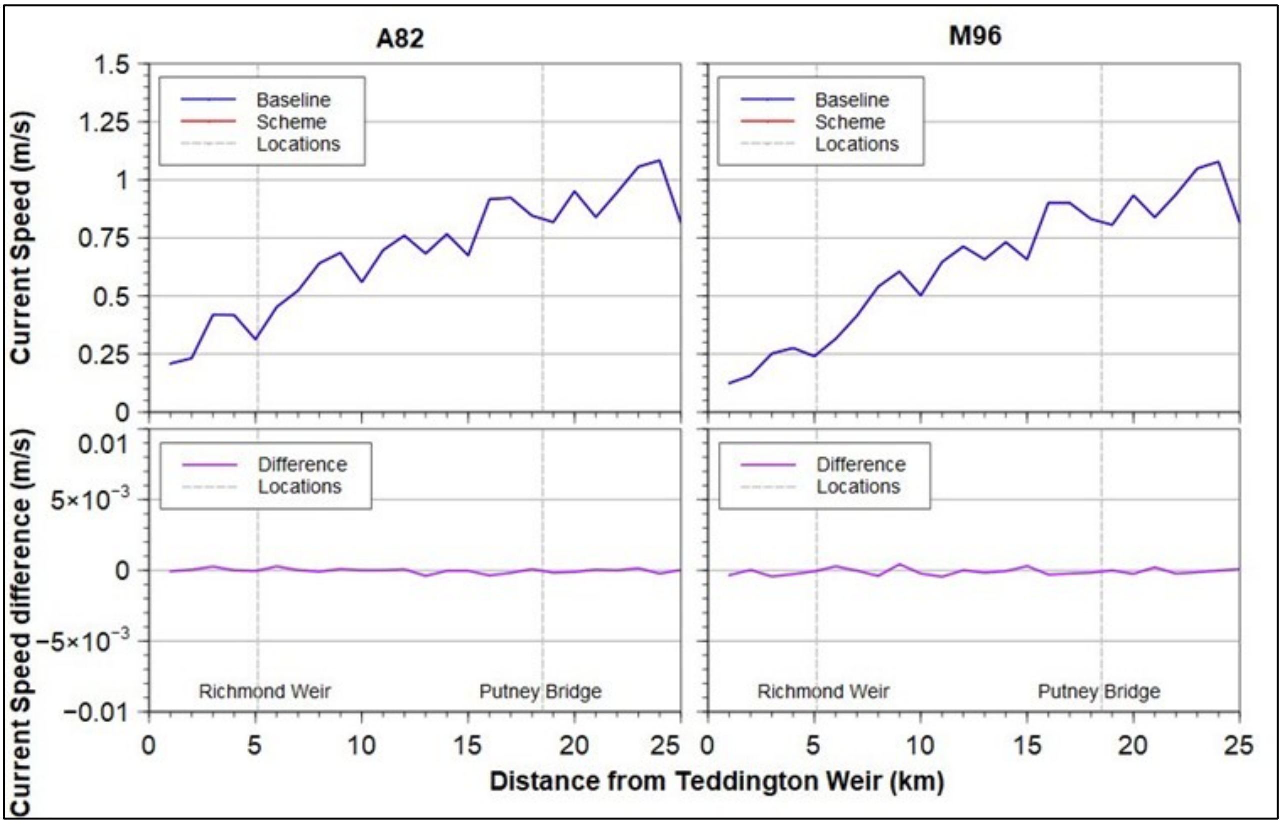
Velocity change

A.3.67 Plate A.37 shows the modelled median (50th percentile) velocity changes in the 25km reach during the Project operation (75Ml/d) for the A82 and M96 flows under the whole tidal cycle.

A.3.68 The median (50th percentile) velocity across the whole tidal cycles for A82 and M96 ranges from ~0.15m/s at 0km increasing gradually along the reach to a peak of around 1.2m/s at 24km downstream and then declining to ~0.75m/s at 25km at the end of the reach. Between Teddington Weir and 15km downstream, median current speeds are elevated by ~0.1m/s.

A.3.69 The operation of the Project has negligible impact on velocity in the tidal Thames. Velocity differences fluctuate between -0.001 and 0.001m/s for both A82 and M96 flows across the entirety of the reach, with no noticeable trends. There are no significant differences between observations for the A82 and M96 models.

Plate A.37 Median velocity change in the tidal Thames under a 75 Ml/d Project operation



Summary of the Tideway model scenario temperature outcomes

a. Measured water river temperature in the Thames Tideway shows that there is a raised water temperature profile at the baseline condition from the River Thames at Teddington to the tidal Thames at Cadogan Pier.

b. Temperature profiles have been derived from long term measured data, which show water temperatures at Purfleet higher in winter and lower in summer than temperatures at Cadogan Pier.

c. The modelled output shows that during the Project operation, the reduction in Mogden STW final effluent discharged at Isleworth Ait would lead to a reduction in Tideway temperature of less than one degree under the A82 flow scenario and a reduction in temperature of approximately 1°C under M96 flow scenario.

A.4 Water Quality - Olfaction

Factors that influence fish migration

A.4.1 Migratory fish species have complex life cycles often with multiple stages including freshwater and seaward migrations along with juvenile imprinting phases. Migratory species such as salmonids (Atlantic salmon/sea trout), lamprey and European eel use a range of cues including olfaction (smell), water temperature, dissolved oxygen, river flow, tidal state, and lunar phase to trigger and navigate migrations.

A.4.2 In addition to impacts on the physical continuity of migratory pathways, the presence of chemical inhibitors (which disrupt fish olfaction), and changes in water quality, physical habitat modifications and changes in flow have also been shown to impact the success of migratory species by limiting their ability to access watercourses as a result of their influence on migratory cues, natal stream imprinting, habitat availability and navigation.

A.4.3 Within both Atlantic salmon and sea trout populations, their movement between rivers and the sea often involves periods where they rest and/or acclimatise to the ambient water conditions (Hubley *et al.*, 2008). This is because both returning adults and smolts on their seaward migration experience challenging physiological transformations when moving between saline and freshwater environs (Thorstad *et al.,* 2012). These stages within the salmonid migration may involve temporarily utilising weir pools, river confluences/tributaries and/or areas of cooler water (High *et al.*, 2006).

Migration within the Thames

A.4.4 Many fish species migrate between the coastal environment, the Thames Estuary and, within Thames, the freshwater river and river tributaries (Colclough *et al.*, 2002). It should be noted that not all species undertake diadromous migrations between freshwater and the marine environs as they rely upon the ebb and flow of the tide in order to access feeding, nursery and even spawning areas (Elliott and Hemingway, 2002). Elliott *et al.* (2007) describes the functionality of freshwater, estuarine and marine fish species and how and (more importantly) why fish move between freshwater and marine systems (Elliott *et al.*, 2007). A well-defined diadromous fish group or 'guild' has been developed, which is widely used across Europe by regulators and scientists as diadromous fish are considered to be 'disturbance-sensitive taxa' in relation to the EU Water Framework Directive (Lepage *et al.*, 2016). Coates *et al.* (2007) list the diadromous species present within the Thames and this species list was derived from Environment Agency fisheries data. The species of diadromous fish relevant to London Effluent Reuse SRO are:

a. Atlantic salmon

b. Sea trout

c. European eel, and

d. European smelt (*Osmerus eperlanus*)

A.4.5 Shads and in particular Twaite shad have not been included within this review as there has been no known spawning within the Thames since the end of the 19th century (Wheeler, 1979). Sea lamprey again have not been included within this review due to the lack of evidence to support their spawning within the Thames (Colclough, n.d.). River lamprey have also not been considered as they have not been recorded within the project area (EA, 2025).

A.4.6 It should be noted that the term diadromous only describes the movement of a species between freshwater and marine; within this, anadromous relates to fish migrating up rivers from the sea to spawn and catadromous relates to fish migrating down rivers to the sea to spawn.

Olfactory cues and disruption

A.4.7 In relation to the Project, while the Project is operational, up to 75Ml/d would be discharged at the outfall into the freshwater River Thames and subsequently there would be 75Ml/d less discharge from Mogden STW at Isleworth Ait during that period, therefore there is the potential to influence diadromous fish species migration via:

a. The weakening of olfactory cues into the freshwater 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 Project's 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 reduction in concentration and change in the zone of inhibitor accumulation in the tidal Thames.

A.4.8 The following sections identify the role of olfaction during diadromous migration and the key determinands which are important.

A.4.9 A number of potential fish olfaction disruption chemicals have been identified through a literature review during Gate 2 (Thames Water, 2022a) and summarised below; in the majority of cases, these inhibitors are likely to impact all fish species through impacts upon migration which may affect recruitment. Potential fish olfaction disruption chemicals identified in this review are listed in Table A.6.

Table A.6 Chemicals identified from literature review with potential for disruption of fish olfaction

Metal	Pesticide	Surfactant	Endocrine Disruptor	
Copper	Carbamate pesticides	Alkylbenzene-sulfonates	17a-ethinyloestradiol (EE2)	Norgestrel
Mercury	Organophosphate pesticides	Diamines	17ß-oestradiol (E2)	Raloxifene
Aluminium	Phenylurea pesticides	Quaternary Ammonium Salts	19-norethindrone	Trenbolone
Cadmium	Pyrethroid pesticides	Imidazolinium salts	4-nonylphenol	Triclosan
Zinc	-	-	Bisphenol A	Vinclozolin metabolite M2
Chromium	-	-	Bisphenol F	-
Cobalt	-	-	Bisphenol S	-
Iron	-	-	Chlorophene	-
Nickel	-	-	Fenitrothion	-
Selenium	-	-	Flutamide	-
Silver	-	-	Ibuprofen	-

A.4.10 In addition to the potential fish olfaction disruption chemicals listed above, changes to pH have been shown to impact the olfactory response of diadromous fish and is likely to affect all fish species.

Review of olfactory potential effects

A.4.11 Migratory fish will enter the River Thames from the Thames Estuary after a period of acclimatisation. Once the fish have entered the freshwater River Thames at Teddington they travel upstream further into the Thames Catchment towards Surbiton.

A.4.12 During operation, while the Project is discharging to the freshwater River Thames, there is potential for the recycled water to have an impact on the fish olfaction disruption chemicals concentrations within the water courses.

A.4.13 To assess the risk of potential fish olfaction disruption within the freshwater River Thames a review of the relative concentration of potential fish olfaction disruption chemicals along the sampling locations was completed. The samples taken during the Pan-SRO monitoring programme give an indication of the potential fish olfaction disruption chemicals encountered by migratory fish under baseline conditions and give an indication of the water quality as the fish travel upstream.

A.4.14 Table A.7 details the determinands that measured positive in samples and where the highest concentrations were observed within the river samples. The determinands that did not measure a positive sample were screened out (indicated by the grey shading in the table) as they were not appropriate for characterisation, this however does not exclude them as a potential risk, only that there is not enough information to assess further at this time.

A.4.15 There also a general trend that the highest concentrations of potential fish olfaction disruption chemicals are found at the Surbiton and Teddington sites which are the furthest downstream sites and are therefore most influenced by additional inputs along the river. Further analysis on olfaction risk will be undertaken and presented at ES.

Table A.7 Teddington olfaction risk characterisation. Data collected between 26/01/2021 and 16/07/2024

Group	Determinand		TWUL Walton Intake			TWUL Hampton Intake			River Thames at Surbiton Intake			River Thames at Teddington Weir			Thames at Kew			Thames at Kingston		
		Units	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD
Metals	Aluminium dissolved	µg/l	14.71	24	12	16.24	46	19				26.07	46	23	15.88	32	11	21.64	33	14
	Aluminium total	µg/l	106.75	24	24	106.11	46	46				120.35	46	45	188.03	32	31	144.55	33	33
	Cadmium dissolved	µg/l	0.025	24	5	0.021	46	4	0.020	24	3	0.02	47	6	0.02	46	5	0.03	22	1
	Cadmium total	µg/l	0.038	24	15	0.026	46	24	0.028	24	13	0.03	46	29	0.04	45	36	0.03	22	8
	Chromium (III) dissolved	µg/l	6.15	24	6	1.79	46	8	1.32	24	4	1.03	46	5	1.04	45	8	1.00	33	2
	Chromium (VI) dissolved	µg/l	5.84	24	2	3.10	46	24	5.86	24	3	3.21	47	22	3.24	45	23	1.58	33	22
	Chromium dissolved	µg/l	6.00	24	13	1.42	46	26	1.07	24	15	0.63	46	28	0.71	45	32	0.42	33	13
	Chromium total	µg/l	7.29	24	22	2.04	46	42	1.81	24	23	0.84	46	41	1.66	45	41	0.77	33	26
	Cobalt dissolved	µg/l	0.28	24	24	0.27	46	45				0.29	45	43	0.32	32	31	0.41	33	32
	Cobalt total	µg/l	0.47	24	24	0.37	46	46				0.41	45	44	0.60	32	32	0.53	33	33
	Copper dissolved	µg/l	2.28	24	24	2.21	46	46	2.33	24	24	2.25	46	46	2.45	45	45	1.99	22	19
	Copper total	µg/l	3.27	24	24	3.31	46	46	3.29	24	24	3.44	46	46	5.15	45	45	3.23	22	19
	Iron dissolved	µg/l	39.33	24	24	39.94	46	46	42.48	24	23	63.42	46	45	43.53	45	45	48.00	22	19
	Iron total	µg/l	345.58	24	24	301.28	46	46	285.88	24	24	452.22	46	46	454.22	45	45	302.27	22	19
	Mercury dissolved	µg/l	0.0077	24	17	0.0040	46	30	0.02	24	17	0.0052	46	34	0.32	45	30	0.004	22	12
	Mercury total	µg/l	0.012	24	22	0.0065	46	42	0.034	24	24	0.0082	46	44	0.81	45	42	0.005	22	16
	Nickel dissolved	µg/l	1.96	24	23	1.94	46	44	2.27	24	23	2.08	46	45	2.18	45	44	1.82	22	19
	Nickel total	µg/l	3.10	24	23	2.31	46	46	6.03	24	24	2.53	46	46	2.66	45	44	2.07	22	19
	Selenium dissolved	µg/l	0.50	24	23	0.45	46	44				0.44	46	45	0.47	32	32	0.43	33	32
	Selenium total	µg/l	0.70	24	23	0.52	46	46				0.52	46	46	0.62	32	32	0.55	33	33
	Silver dissolved	µg/l	0.50	24	23							0.59	45	0	0.13	22	0	0.14	22	1
	Silver total	µg/l	0.70	24	23							0.59	45	1	0.14	22	1	0.15	22	1

Group	Determinand		TWUL Walton Intake			TWUL Hampton Intake			River Thames at Surbiton Intake			River Thames at Teddington Weir			Thames at Kew			Thames at Kingston		
		Units	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD	Mean	No. samples	No. >LOD
	Zinc dissolved	µg/l	8.20	24	22	6.22	46	45	5.59	24	24	7.78	46	46	8.09	45	45	4.50	22	19
	Zinc total	µg/l	20.40	24	24	16.83	46	46	16.44	24	24	15.70	46	46	21.38	45	45	12.33	22	19
Carbamate pesticides	Mancozeb	µg/l	0.58	24	12							0.49	45	23	0.70	1	1			
Organophosphate pesticides	Diazinon	µg/l	0.01	24	0	0.01	46	0	0.01	24	24	0.01	46	0	0.01	45	0	0.01	22	0
	Fenitrothion	µg/l	0.01	24	0	0.01	22	0				0.01	46	0	0.01	33	0	0.01	33	0
Phenylurea pesticides	Isoproturon	µg/l	0.002	24	1	0.002	46	0	0.002	24	0	0.002	46	1	0.002	45	3	0.002	22	2
	Linuron	µg/l	0.02	24	3	0.017	46	3	0.025	24	3	0.02	46	3	0.01	45	2	0.01	22	0
Pyrethoid pesticides	Cypermethrin	µg/l	0.00094	24	6	0.00045	46	17	0.00011	24	9	0.001	46	20	0.0006	45	37	0.0002	22	7
	Permethrin	µg/l	0.0011	24	3	0.001	24	2	0.0011	24	3	0.001	46	3	0.001	45	11	0.001	22	2
Endocrine disrupting chemicals	17a-ethinyloestradiol (EE2)	µg/l				0.00003	22	1				0.00003	21	1	0.00003	22	0	0.00003	22	2
	17ß-oestradiol (E2)	µg/l				0.0003	22	1				0.0003	21	2	0.0007	22	17	0.0004	22	3
	4-nonylphenol	µg/l	0.041	24	2	0.044	46	9	0.041	24	7	0.05	46	16	0.07	45	37	0.07	22	16
	Bis(4-hydroxyphenyl) propane (bisphenol A)	µg/l				0.01	22	2				0.01	21	4	0.03	22	9	0.01	22	5
	Bisphenol S	µg/l										0.02	20	6	0.02	21	7	0.02	22	4
	Ibuprofen	µg/l										0.02	20	20	0.05	21	21	0.02	22	14
	Triclosan	µg/l	0.01	24	0	0.01	46	0	0.01	24	1	0.01	46	1	0.01	45	0	0.01	22	0
Alkylbenzene-sulfonates	Sum C10-C14 alkylbenzene sulfonic acids	µg/l	0.1	11	5	0.1	46	0				0.11	31	6	0.10	32	5	0.10	33	6

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