Revised Draft Water Resources Management Plan 2024

Resource Options - Water Reuse Feasibility Report

Addendum

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Executive summary

1 This report provides a summary of changes that have been made to the water reuse options since Thames Water's 2019 Water Resources Management Plan (WRMP19) as part of the 2024 Water Resources Management Plan (WRMP24) development.

2 This report acts as an addendum to Thames Water WRMP19 Resource Options Water Reuse feasibility report, October 2018, Rev 03.

3 No new reuse options have been identified at WRMP24.

4 London Water Recycling SRO has been identified by Ofwat which includes development of the WRMP19 options at Beckton, Mogden and Mogden South Sewer reuse options through the Gate process (for further information refer to the London Water Recycling Gate 2 report[1]). Teddington DRA is also included as part of the London Water Recycling SRO, this option is included in the Direct Reuse Abstraction (DRA) feasibility addendum. Deephams Reuse has also been further developed in discussion with the Environment Agency (EA).

5 At WRMP24 backchecking of the WRMP19 screening decisions has been undertaken, where appropriate options have been further developed.

6 The updated WRMP24 feasibility assessment presents the WRMP19 options and the further developed WRMP24 options. The findings for the Stage 1 assessments were unchanged from the WRMP19 feasibility assessments. Stage 2 assessment for Deephams Reuse was updated at WRMP24 to reflect discussions with the Environment Agency, the option passed screening when implemented after 2060.

7 The following options are the confirmed list of feasible water reuse options for WRMP24:

- Beckton Reuse (up to 300 Ml/d)
- Crossness Reuse (up to 300 Ml/d)
- Mogden Reuse (up to 150 Ml/d)
- Mogden South Sewer (up to 25 Ml/d)
- Deephams Reuse post 2060 (46.5 Ml/d)

8 This report summarises the changes to the reuse options up to the end of feasibility screening. However, it should be noted that at WRMP24 Crossness Reuse option and Reuse Mogden South Sewer were rejected at further screening and are not included on the Constrained List of options for WRMP24. The rejection reasoning can be found in WRMP24 Appendix Q Scheme Rejection Register.

9 Information on option development and further screening can be found in WRMP24 Section 7 - Appraisal of Resource Options.

10 Note on terminology: At WRMP19 the terminology 'Reuse' was used, this has been maintained in the addendum for consistency with the WRMP19 feasibility report, however the terminology at WRMP24 has moved on to be 'Recycling'. The other WRMP documents refer to options as recycling options. Reuse and Recycling can be considered interchangeably in the WRMP documents.

[1] https://www.thameswater.co.uk/about-us/regulation/strategic-water-resource-solutions/water-recycling-reuse-schemes-in-london

Introduction

11 Thames Water is developing options for the 2024 Water Resources Management Plan (WRMP24). These options build on options developed as part of Thames Water's 2019 Water Resources Management Plan (WRMP19). This report provides a summary of changes that have been made to the water reuse options since WRMP19 and as part of WRMP24 development.

12 This report acts as an addendum to **Thames Water WRMP19 Resource Options Water Reuse Feasibility Report, October 2018, Rev 03.** This report should be read alongside the WRMP19 feasibility report. Information in this report supersedes information provided in the WRMP19 feasibility report.

13 Changes to the WRMP19 Water Reuse Options have been detailed in Section 0. A backchecking exercise has been completed to assess if any changes are required to WRMP19 as a result of identification of the new options or developments since WRMP19. Backchecking entails a review of options previously dismissed to see if they require reappraisal in the light of knowledge accumulated since they were previously rejected. Backchecking also provides the opportunity to take into account any changes of circumstance that might affect how an option is considered. This might include a change in the planning and environmental status of a site, changes in national and local planning policy and the emergence of viable technical solutions that were unavailable at the time the original assessment was undertaken.

14 The WRMP24 screening, option development and backchecking methodology is detailed in Section 7 - Appraisal of Resource Options.

15 This report summarises changes to the water reuse options up to the end of feasibility screening.

Structure of this report

16 Table 1 summarises the structure of this report.

Section Name	Description
Executive summary	Summary of addendum report
Introduction	This section
Updates since WRMP19	Summary of the changes made to the options list since WRMP19, including changes to WRMP19 options, new WRMP24 options and changes to Deployable Output (DO).
Updated feasibility assessment	Provides a summary of the current feasibility assessment for all options including options identified at both WRMP19 and WRMP24.
Option verification and conclusion	Validation of risk and uncertainty for all options and the confirmation of the feasible list of options.
Appendix A: Reference information	A list of useful links and references
Appendix B: Option references	Table of the options WRMP19 and WRMP24 IDs
Appendix C: Environment Agency Comments	Summary of the comments received from the Environment Agency at WRMP24 in relation to options discussed in this report.

Section Name	Description
Appendix D: Middle Thames Tideway – Cumulative effects of re-use, desalination and DRA WRMP19 Options	WRMP19 assessment of the impacts of options (water reuse, desalination and direct river abstraction) that decrease the freshwater inputs to the Thames Tideway and the cumulative limit on the total additional capacity of these options.

Table 1: Structure of this report

Note on terminology: At WRMP19 the terminology 'Reuse' was used, this has been maintained in the addendum for consistency with the WRMP19 feasibility report, however the terminology at WRMP24 has moved on to be 'Recycling'. The other WRMP documents refer to options as recycling options. Reuse and Recycling can be considered interchangeably in the WRMP documents.

Updates since WRMP19

Option Identification

17 To ensure Thames Water is aligned with the WRSE approach, the following updates have been made to option identification for WRMP24:

- The WRMP19 rejection register has been revisited to ensure that the rejection reasoning remains robust for all rejected options.
- Rejected options have been reviewed to identify any options which should be revisited due to potential for regional benefits, particularly in light of changes in requirements to plan for 1:500 drought resilience (previously 1:200 at WRMP19) and the need to plan for a long-term environmental destination that achieves and maintains a sustainable level of abstraction by 2050 (Section 2.2).
- A review has been undertaken to identify new options to be considered in addition to the existing WRMP19 options, this did not identify any new reuse options.

Feasibility Screening Criteria

18 The following tables detail the criteria used for feasibility screening, which is further detailed in the WRMP19 Water Reuse Feasibility Report. This is a 3 stage process.

- Stage 1 – Option identification and assessment of absolute and other key constraints
- Stage 2 - Assessment of site performance and compilation of short list
- Stage 3 - Further detailed assessment

Stage 1 has two phases:

- Option identification – Stages Approach to option sections shown below.
- Assessment of the options identified against absolute and other key constraints to the development of a new Water Reuse plant - the criteria for which is detailed in Table 2. This is a pass / fail assessment for each criterion.

19 At stages 2 and 3 the assessed performance of each option is reviewed against a red / amber / green classification system, as

- Red – issue or constraint can be overcome, but will be very challenging
- Amber – issue or constraint can be overcome
- Green – no constraint posed

20 Additionally, Stage 3 allows for costing of each option to provide a comparison across all water resource options. The Stage 2 criteria are shown in Table 3 and the Stage 3 criteria are shown in Table 4.

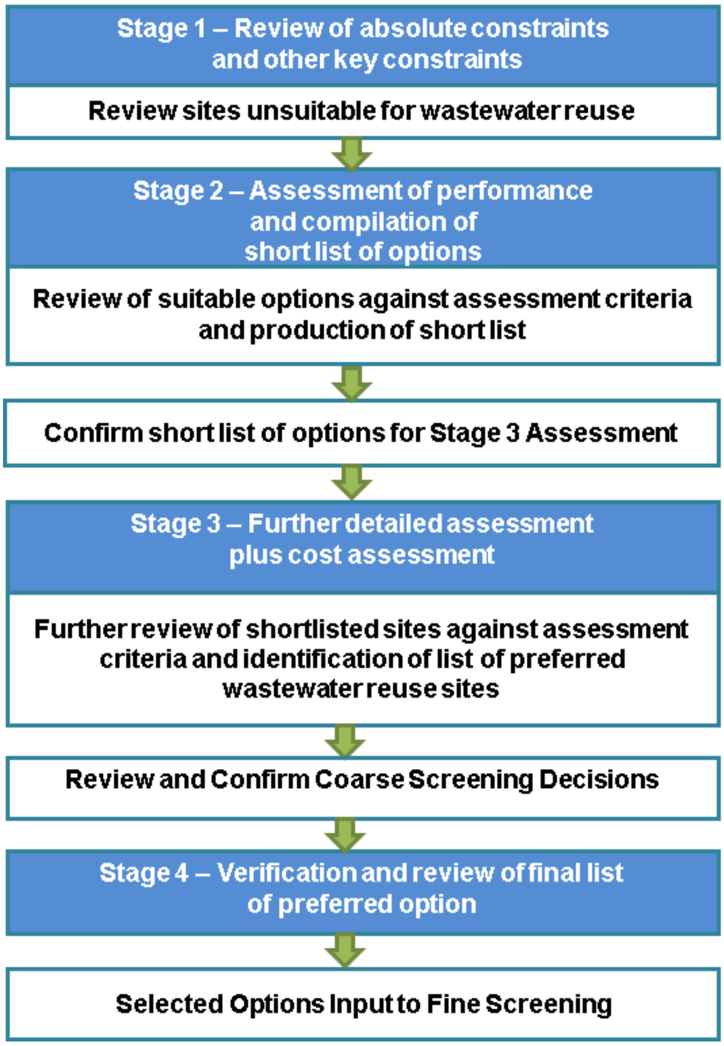

Figure 1: Staged approach to option selection

Criteria	Meaning of pass or fail
Planning, socio-economic & environmental criteria	
Potential impact on downstream abstractors	If a treatment works site's effluent discharges into a stretch of the river where its reuse would impact on downstream abstractors or where effluent discharge provides a local water resource benefit on downstream flows, it fails
National / International nature conservation sites	If the site has international designations it fails.
Areas of major built development[1]	If a significant areas of built development were required to be demolished it fails
National / International heritage sites	If the site has international designations, it fails.
Engineering criteria	
Only options which could provide a reuse water resource available to the London WRZ[2]	If an option is unable to provide reuse water as a raw water resource usable within the London WRZ, it fails. Thames Valley options have a consumptive use and would therefore reduce water availability to downstream abstractors, therefore Thames Valley options are not considered.
Compatible with Thames Water's water reuse considerations (Table 2.2 and 2.3).	Options should be IPR. Effluent discharge should be into the tidal range of the river Thames or discharges into the River Thames' tributaries will have no detrimental environmental impact, otherwise it fails.

Table 2: Criteria for Stage 1

Criterion Title	Stage 2 Criteria	Basis for assessment		
		Green	Amber	Red
Property/legal criteria				
Ownership of site & tenancies	Is there sufficient TW space required to build the facilities?	Existing TW land is available and sufficient unconstrained.	Some TW land is available, additional land may also be acquired for treatment sites and/or pipelaying required in private land under Statutory Notice.	No TW land available. Private land will need be acquired. Pipelaying required in land that cannot be served with Statutory Notice.
	Is there sufficient space to accommodate future growth and permit changes?	Space is available both for now and the future.	Space is available but is constrained both for now and the future.	No extra space for growth / there is not enough space for the maximum Scheme Capacity.
Estimated land acquisition cost	Are land acquisition costs likely to be reasonable?	Land acquisition costs likely to be relatively low. Agricultural land and isolated properties only affected.	Land acquisition costs likely to be moderate. Local or regional business or other facilities affected in addition to agricultural land.	Land acquisition costs likely to be relatively high. National businesses or land required for statutory agency's business affected in addition to agricultural land
Planning, socio-economic & environmental criteria				
Land use & land use quality	Can brownfield land be reused? Will existing non- agricultural high value land – uses be affected?	Site will reuse all brownfield land which appears to have low value.	Site contains some brownfield land to be reused and is currently occupied by existing business / commercial use.	Site contains is entirely greenfield or occupied by high value business.
Flood plain encroachment	Percentage of the site covered by floodplain	Less than 25% of the site is within Flood Zones 2 or 3 or the site is solely located within Flood Zone 1.	Between 25-50% of the site located within Flood Zones 2 or 3 or if 50% of the site benefits from existing flood protection measures.	Over 50% of the site located within Flood Zones 2 or 3 and the site does not benefit from existing flood protection measures.
Landscape character and sensitivity	Are any landscape designations affected?	No designations likely to be affected or effect likely to be positive. Site unlikely to affect a national landscape designation and not covered by a local landscape designation.	Designation of regional or local importance likely to be affected. The site lies within a locally designated landscape (e.g. Area of Great Landscape Value, Area of High Landscape Value, Strategic Landscape Area).	Designation of national importance likely to be affected. Site lies wholly or partly within or is likely to impact the setting of a national landscape designation (National Park or AONB).
Views and visual amenity	Are any visually sensitive viewpoints affected?	Important / recognised viewpoints unlikely to be affected. Site lies at a distance greater than 5km from any recognised viewpoint.	Locally visible / locally important views likely to be affected. Site lies at a distance of between 3km and	Highly visible / Panoramic views likely to be affected. Site lies at a distance less than 3km from any recognised viewpoints

Criterion Title	Stage 2 Criteria	Basis for assessment		
		Green	Amber	Red
			5km from any recognised viewpoint.	
Nature conservation and biodiversity	Are any designated species and/or areas of nature conservation/biodiversity importance affected?	No international / national or regional designations likely to be adversely affected, or effect likely to be positive. Site does not contain sites of nature conservation importance.	Designation of regional or local importance likely to be adversely affected. Site includes or lies within a regionally designated site (County Wildlife Site, or Local Nature Reserve).	Designation of national importance or Ancient Woodland likely to be adversely affected.
Archaeology and the historic environment	Are any heritage assets affected?	Heritage interest low or unknown. Site has heritage assets of low sensitivity or no records present.	Designation of regional or local importance likely to be adversely affected. No statutory designated sites present but site contains non designated heritage assets of high or moderate sensitivity.	Nationally Designated Heritage Assets likely to be affected. Site includes an international / national heritage asset (World Heritage Site, Scheduled Monument, Listed Building of a type not considered to be an absolute constraint at Stage 1), Registered Historic Park or Garden, Listed battlefield site.
Non-traffic impact of construction on local residents.	Will construction activities (excluding traffic impacts) affect local residents within a 350m radius of the site?	Less than 100 residential properties likely to be affected by on-site construction activities	Between 100-299 residential properties likely to be affected by on-site construction activities	More than 300 residential properties likely to be affected by on-site construction activities
Impact of construction on traffic	Will construction traffic affect local roads / built up areas?	Route largely not through built up areas and/or likely to have limited impacts on local traffic.	Route partly through built up areas and/or likely to have moderate impacts on local traffic.	Route predominantly through built up areas and/or likely to have substantial impacts on local traffic.
Impact on recreation	Are recreational sites or rights of way affected?	No recreational resource / right of way disrupted or affected. Sites with no formal recreational activities.	Recreational resource / right of way of local importance disrupted or affected. The site is likely to affect public rights of way.	Recreational resource / right of way of national or regional importance disrupted or affected. The site is likely to affect major recreational activities.
Water resources & water quality	Are there likely impacts on water resources and water quality, including Water Framework Directive targets?	Minor adverse impacts likely; no risk to Water Framework Directive objectives	Moderate adverse impacts likely; low risk to Water Framework Directive objectives	Major adverse impacts likely; high risk to Water Framework Directive objectives
Engineering criteria				
Network reinforcement requirements	Are significant reinforcement requirements likely to be needed to distribute water	No change to existing infrastructure	Limited modifications to existing network infrastructure	Significant network reinforcement required.
Length of conveyance routes	Total length of transfer pipeline	The length of the transfer is less than 10km from the potential abstraction to the treated water delivery point	The length of the transfer is between 10-20km from the potential abstraction to the treated water delivery point	The length of the transfer is more than 20km from the potential abstraction to the treated water delivery point

Criterion Title	Stage 2 Criteria	Basis for assessment		
		Green	Amber	Red
Pumping Head	Is the pumping head significant?	The pumping head is <50m	The pumping head is between 50m-99m	The pumping head is in excess of 100m
Water source and availability	Uncertainty around deployable output.	Scheme capacity deployable output guaranteed in all scenarios	Scheme capacity deployable output is affected by one or two issues that are expected to be resolved	Scheme capacity deployable output is affected by more than two issues or one issue that is unlikely to be resolved
Access during construction and operation	Are the means of access suitable, both for construction and operation?	Existing access arrangements are available and suitable for both construction and operation	Existing access will be suitable for operations, temporary modifications will be needed for construction activities	Existing access will require significant modification to make it suitable for both construction and operation
Connectivity to the waste system	Connectivity to wider infrastructure system.	The site is located adjacent to the wider infrastructure (waste stream)	The site is located less than 5km of the wider infrastructure (waste stream)	The site is located more than 5km from the wider waste stream infrastructure.
Construction complexity	Adverse ground conditions and major crossings.	No major crossings required or contaminated land risks identified	10 major crossings required or contaminated land risks identified	15 major crossings required or significant contaminated land risks identified.
Operational Complexity	Option requires operational capabilities that are outside TW standard operating practices or outside TW supply area	No issues/ Typical O&M procedures.	Operation of average complexity, with relatively complex processes/ operations and requirement for relatively substantial O&M procedures.	Operation of high complexity, with complex processes/ operations and requirement for major O&M procedures at regular intervals.

Table 3 Criteria for Stage 2 and basis for assessment of site performance

Criterion Title	Stage 3 Criteria	Basis for assessment		
		Green	Amber	Red
Property & legal criteria				
Ownership of site & tenancies	Assessment of ownership and tenancy constraints to any development	Land involved is under a single freehold title	Land involved has between 1 and 5 titles	More than 5 land titles involved
Planning, socio-economic & environmental criteria				
Planning policy and history	Review of Local Plan, planning policy designations and planning regulations.	The site is not allocated for significant development and there are no significant planning permissions or applications, there are no policy constraints or the site benefits from positive policy support for reservoir development	The site has some policy constraints not considered significant and no significant planning permissions or applications. May include some existing planning permissions but not considered significant. The site has significant permissions or applications but also benefits from positive policy support for reservoir development	The site or immediate area is allocated for significant development or has significant policy constraints. Extant planning permission or planning application has been submitted for significant development.
Land use & land use quality	Extent of land take and land quality, greenfield vs brownfield mix	Construction is entirely within brownfield sites	Short term effects during construction phase only on greenfield sites	Permeant effects on greenfield sites as a result of reservoir development
Flood plain encroachment (loss of floodplain / need for compensation storage)	Are there likely effects on the floodplain?	No constraint posed	Issue or constraint can be overcome	Issue or constraint can be overcome, but will be very challenging
Landscape character and sensitivity	Extent to which likely effects on landscape/townscape character & designations may be mitigated	No mitigation required	Mitigation may be employed to reduce impacts to an acceptable level	Adverse effects cannot be mitigated or constraints overcome resulting in adverse effects post mitigation
Views and visual amenity	Extent to which likely effects on visually sensitive receptors may be mitigated	No mitigation required	Mitigation may be employed to reduce impacts to an acceptable level	Adverse effects cannot be mitigated or constraints overcome resulting in adverse effects post mitigation
Employment and local economy	Extent of construction and operational effects on employment & local economy	No loss of employment	Loss of land anticipated to provide a low density of	Loss of land anticipated to provide a high density of

Criterion Title	Stage 3 Criteria	Basis for assessment: Green	Amber	Red
			employment opportunities (for example, fields that appear to be used for agricultural purposes)	employment opportunities (for example, a business park)
Nature conservation and biodiversity	Are there likely effects on sites / habitats	No constraint posed	Issue or constraint can be overcome	Issue or constraint can be overcome, but will be very challenging
Opportunity for biodiversity improvement	Extent of any opportunities for biodiversity enhancement	Site has potential improvement opportunities for both watercourse and woodlands.	Site has potential improvement opportunities for either a watercourse or woodlands.	No potential for biodiversity improvement opportunity.
Archaeology and the historic environment	Are there likely effects on heritage assets, including overall setting	No constraint posed	Issue or constraint can be overcome	Issue or constraint can be overcome, but will be very challenging
Non-traffic impact of construction on local residents	Potential to mitigate non-traffic construction impacts on local properties.	No constraint posed	Issue or constraint can be overcome	Issue or constraint can be overcome, but will be very challenging
Impact on recreation	Are there likely effects on recreational activities	No constraint posed	Issue or constraint can be overcome	Issue or constraint can be overcome, but will be very challenging
Water resources & water quality	Are there likely impacts on water resources and water quality, including Water Framework Directive targets?	No constraint posed	Issue or constraint can be overcome	Issue or constraint can be overcome, but will be very challenging
Engineering criteria				
Length of conveyance routes	Length of conveyance route(s) and scale (pipe diameter or equivalent)	Very limited need to transfer water in new conveyance (e.g. abstraction and treatment on the same site), discharge conveyance <1km.	Moderately long (<20km) or large diameter water transfer conveyance, making use of existing infrastructure where possible.	Long water transfer conveyance (>20km) which is comprised of entirely new infrastructure and / or large diameter (>1.5m) and / or significant tunnelling
Normalised cost	£/m3	< £1.00/m^3	£1.00/m^3 to £1.50/m^3	> £1.50/m^3
Water Source and Availability	Constraints on water source utilisation / availability	Availability of water is well understood and not dependent on other constraints	Availability of water is well understood but dependent on other constraints	Significant constraints on the water availability
Water treatability / process complexity	Water treatment risks and complexity of required water treatment	Sufficient water quality data is available. No concerns highlighted with respect to water quality,	Water quality data is available although may have some limitations in terms of duration / frequency / parameters.	Limited water quality data is available in terms of duration / frequency / parameters.

Criterion Title	Stage 3 Criteria	Basis for assessment: Green	Basis for assessment: Amber	Basis for assessment: Red
		standard treatment process to be employed	Some concerns with water quality although relatively simple to treat.	Significant concerns regarding water quality, risks remain about ability to treat.
Power Supply	Is sufficient power available to power the site?	Existing power supply to the site is adequate	Existing power supply is not adequate, power supply can be brought into the site relatively simply	New power supply required which would be very difficult to achieve.
Construction Complexity	More detailed review of construction requirements	Construction complexity is anticipated to have no significant impacts on construction programme and cost.	Construction complexity is anticipated to have minor impacts on construction programme and cost.	Construction complexity is anticipated to have major impacts on construction programme and cost.

Table 4: Criteria for Stage 3 and basis for assessment of site performance

Feasibility Screening

Feasibility Screening Updates

21 The overall changes to options and approach since WRMP19 are described in WRMP Section 7 Appraisal of Resource Options. Specific changes applicable to Water Reuse Options are detailed in Table 5 and Table 6. These tables should be read alongside the WRMP19 feasibility report.

WRMP19 Option Reference and name	WRSE Option Reference and name	Changes to the Option	WRMP19 Feasibility Screening Outcome	WRMP24 Feasibility Screening Outcome
London				
Deephams Reuse (46.5Ml/d) - RES-RU-DPH Option requires conveyance either through pipeline to River Lee diversion upstream of KGV intake (CON_RU-DPH-KGV) or through connection to Lockwood to KGV tunnel (CON-RU-DPH-TLTEX)	Deephams Reuse – 46.5 Ml/d, to TLT TWU_KGV_HI-REU_RE1_ALL_deephams reuse 46.5b / Deephams Reuse – 46.5 Ml/d, direct to KGV TWU_KGV_HI-REU_RE1_ALL_deephams reuse 46.5	The Environment Agency's representation on Thames Water's revised draft WRMP19 included "Recommendation 2 - Ensure that the Deephams option is feasible and does not pose a risk to the environment". That recommendation outlined, at R2.2, concerns over environmental impacts on downstream habitats from reduced flows from Deephams Sewage Treatment Works (STW); and at R2.3, in the estuarine Thames Tideway. At WRMP19 the Environment Agency required Thames Water to demonstrate that there are no WFD compliance risks with the option, in order for it to progress to detailed design by 2022/23 within AMP7. Further work has been undertaken by Thames Water since publication of WRMP19[2] with extensive collaborative working with the Environment Agency. Following completion of the further studies by Thames Water, review[3] of the findings with the Environment Agency has established that a Deephams STW Reuse option is incompatible with the environmental ambition flow targets that the Environment Agency is seeking to deliver for the Lower River Lee through WRSE and the Environment Agency's Environmental Destination work[4]. The option has been included on the Constrained List for implementation after 2060 as it could be considered following delivery of measures under the EA's Environmental Destination work.	Passed Stage 3 and Fine Screening – on Feasible List	The option passed screening and is included on the Feasible List of options for implementation after 2060.
Beckton Reuse (50Ml/d) - RES-RU-BEC-50	TWU_KGV_HI-REU_reuse beckton 50 Beckton Effluent Reuse – 50 Ml/d Treatment	**This is the 50Ml/d phase treatment component of Beckton Reuse** No critical changes. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of options as part of the Beckton Reuse option

[2] As reported in: Thames Water (2021) Deephams STW Reuse Option Assessment – Phase 3 WFD Compliance Assessment. Report prepared by Ricardo in associated with Atkins Ltd. Draft issued 15 April 2021
[3] 30 April 2021: Project meeting between Thames Water, Environment Agency, Ricardo, and Atkins Ltd
15 July 2021: Project meeting between Thames Water, Environment Agency, Ricardo, and Atkins Ltd
22 September: Regular strategic meeting between Environment Agency and Thames Water
13 October 2021: Project meeting between Thames Water, Environment Agency, Ricardo, and Atkins Ltd
[4] A summary of the position on water environment effects of the Deephams STW Reuse option , Appendix E.

WRMP19 Option Reference and name	WRSE Option Reference and name	Changes to the Option	WRMP19 Feasibility Screening Outcome	WRMP24 Feasibility Screening Outcome
Beckton Reuse (100Ml/d) - RES-RU-BEC-100	Beckton Effluent Reuse – 100 Ml/d Treatment TWU_KGV_HI-REU_reuse beckton 100	**This is the 100Ml/d phase treatment component of Beckton Reuse** No critical changes. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of options as part of the Beckton Reuse option
Beckton Reuse (150Ml/d) - RES-RU-BEC-150	Beckton Effluent Reuse – 150 Ml/d Treatment TWU_KGV_HI-REU_reuse beckton 150	**This is the 150Ml/d phase treatment component of Beckton Reuse** No critical changes. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of options as part of the Beckton Reuse option
CON-RU-BEC-LCK-300 Beckton to Lockwood Conveyance	TWU_KGV_HI-TFR_beckton to lockwood Beckton to Lockwood Tunnel Conveyance	**This is the conveyance component of Beckton Reuse** No critical changes. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of options as part of the Beckton Reuse option
CON-RWS-LCK-KGV-800 Raw Water System - Lockwood PS to KGV Reservoir Intake	TWU_KGV_HI-TFR_lockwood ps-kgv res TLT extension from Lockwood PS to King George V Reservoir intake	**This is the conveyance component of Beckton Reuse** No critical changes. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of options as part of the Beckton Reuse option
n/a	TWU_KGV_HI-TFR_KGV_ALL_beckton tokgv100	**This is an alternative conveyance option for Beckton Reuse** New option for WRMP24 WRMP24 has developed a pipeline conveyance option for up to 100 Ml/d as an alternative to Beckton to Lockwood Tunnel Conveyance and TLT extension from Lockwood PS to King George V Reservoir intake tunnels. This has been back checked against WRMP19 feasibility assessment criteria and screened out on the grounds of cost, engineering constraints and environmental impacts. Note: Letter has been sent to RAPID[5] setting out reasons for screening out this option and RAPID have provided the reply[6].	n/a	Rejected
RES-RU-MOG-50	TWU_WLJ_HI-REU_reuse mogden 50	**This is the 50Ml/d phase treatment component of Mogden Reuse** No critical changes.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of

[5] https://www.ofwat.gov.uk/wp-content/uploads/2022/05/Thames-Water-letter-to-RAPID-Beckton-pipeline-route-rejection-version2.1.pdf
[6] https://www.ofwat.gov.uk/wp-content/uploads/2022/05/Letter-from-Paul-Hickey-to-Rob-Bromley-20-May_2022.pdf

WRMP19 Option Reference and name	WRSE Option Reference and name	Changes to the Option	WRMP19 Feasibility Screening Outcome	WRMP24 Feasibility Screening Outcome
Reuse: Mogden 50 Ml/d	Mogden Effluent Reuse – Reuse Treatment Plant - 50Ml/d	Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.		options as part of the Mogden Reuse option
RES-RU-MOG-100 Reuse: Mogden 100 Ml/d	TWU_WLJ_HI-REU_reuse mogden 100 Mogden Effluent Reuse – Reuse Treatment Plant - 100Ml/d	**This is the 100Ml/d phase treatment component of Mogden Reuse** No critical changes. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of options as part of the Beckton Reuse option
RES-RU-MOG-200 Reuse: Mogden 200 Ml/d	TWU_WLJ_HI-REU_reuse mogden 200 Mogden Effluent Reuse – Reuse Treatment Plant - 200Ml/d	**This is the 200Ml/d phase treatment component of Mogden Reuse** The results show a significant risk from a 200 Ml/d scheme breaching EA thermal plume characteristics where the extent of the 2 oc temperature change from a discharge extends greater than a 25% cross sectional area of the river. The constraint therefore on maximum scheme size for Mogden is driven by the potential environmental impacts rather than the available final effluent and therefore for future scheme investigations the maximum capacity of a Mogden water recycling scheme would be capped at 150 Ml/d, Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Rejected at validation
CON-RU-MOG-WAL-200 Mogden to Walton 200 MLD [7]	TWU_WLJ_HI-TFR_reuse mogden/Walton Mogden to Walton 200 Ml/d - Conveyance for Mogden Effluent Reuse Treatment	**This is the conveyance component of Mogden Reuse** Further work has identified that the maximum capacity for the option is 150Ml/d. The design of the conveyance has been revised to reflect the reduced option capacity. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Passed – included on Feasible List of options as part of the Beckton Reuse option

[7] Further modelling has shown that a maximum capacity of 200 Ml/d has a high risk of breaching Environment Agency guidance where the extent of the 2 ^{o}c temperature change from a discharge extends greater than a 25% cross sectional area of the river, this option will therefore has a maximum of 150 Ml/d in the Gate 2 Report. s

WRMP19 Option Reference and name	WRSE Option Reference and name	Changes to the Option	WRMP19 Feasibility Screening Outcome	WRMP24 Feasibility Screening Outcome
RES-RU-MSS-25; CON-RU-MSS-WAL-25 Reuse: Mogden South Sewer 25Ml/d	TWU_WLJ_HI-REU_RE1_ALL_reuse mogden south sewer Mogden South Sewer – Reuse Treatment Plant - 25Ml/d output and associated conveyance	**This is both treatment and conveyance for Mogden South Sewer** Dry Weather Flow[1] (DWF) monitoring data was gathered during the London Effluent Reuse SRO Gate 2 stage, which showed DWF values of 33 to 36Ml/d. This is substantially below a DWF of 60 Ml/d required to support a 50Ml/d Mogden South Sewer scheme. As a result, only a smaller deployable output c.25Ml/d is possible. Further information can be found in the London Reuse Gate 2, published on Thames Water website. Refer to Mogden South Sewer Conceptional Design Report: Microsoft Word - Annex A3 J698-MS-DOC-230001-0B Mogden South Sewer Conceptual Design Report (thameswater.co.uk)	n/a	Passed – on Feasible List of options.
RES-RU-MSS-50; CON-RU-MSS-WAL-50 Reuse: Mogden South Sewer 50Ml/d	TWU_WLJ_HI-REU_RE1_ALL_reuse mogden s sewer Mogden South Sewer – Reuse Treatment Plant - 50Ml/d output and associated conveyance	**This is both treatment and conveyance for Mogden South Sewer** Dry Weather Flow[8] (DWF) monitoring data was gathered during the London Effluent Reuse SRO Gate 2 stage, which showed DWF values of 33 to 36Ml/d. This is substantially below a DWF of 60 Ml/d required to support a 50Ml/d Mogden South Sewer scheme. As a result, only a smaller deployable output c.25Ml/d is possible; this option is rejected after the additional wastewater benefits of the option are reviewed. Refer to London Effluent Reuse Gate 2 submission for development of the engineering design and environmental assessment since WRMP19.	Passed Stage 3 – on Feasible List	Rejected

Table 5: Option changes since WRMP19

[8] Dry weather flow is the flow in the sewer in a dry period with no rainfall

		WRMP19 DO (Ml/d)		WRMP24 DO (Ml/d)			Difference (Ml/d)		Impact on Feasibility Assessment Scoring (all options Passed Stage 3 at WRMP19)
WRMP19 Option Name	WRMP24 Option Name	Average	Peak	1 in 2 average	1 in 500 average	1 in 500 peak	Average	Peak	
Deephams Reuse (46.5Ml/d) - RES-RU-DPH	TWU_KGV_HI-REU_RE1_ALL_deephams reuse 46.5	45	45	42	42	42	-3	-3	No Impact
	WU_KGV_HI-REU_RE1_ALL_deephams reuse 46.5b /			42	42	42	-3	-3	No Impact
Beckton Reuse 50: RES-RU-BEC-50	TWU_KGV_HI-REU_reuse beckton 50	49	49	46	46	46	-3	-3	No impact
Beckton Reuse 100: RES-RU-BEC-100	TWU_KGV_HI-REU_reuse beckton 100	95	95	89	89	89	-6	-6	No impact
Beckton Reuse 150: RES-RU-BEC-150	TWU_KGV_HI-REU_reuse beckton 150	138	138	130	130	130	-8	-8	No impact
Beckton Reuse 200: RES-RU-BEC-200	TWU_KGV_HI-REU_reuse beckton 200	183	183	172	172	172	-11	-11	No impact
Beckton Reuse 300: RES-RU-BEC-300	TWU_KGV_HI-REU_reuse beckton 300	268	268	252	252	252	-16	-16	No impact
Beckton Reuse 380: RES-RU-BEC-380 [9]	TWU_KGV_HI-REU_reuse beckton 380	336	336	316	316	316	-20	-20	No impact
Mogden 50: RES-RU-MOG-50	TWU_WLJ_HI-REU_reuse mogden 50	49	49	46	46	46	-3	-3	No impact
Mogden 100 RES-RU-MOG-100	TWU_WLJ_HI-REU_reuse mogden 100	94	94	88	88	88	-6	-6	No impact
Mogden 150: new to WRMP24	TWU_WLJ_HI-REU_reuse mogden 150	137	137	130	130	130	-7	-7	No impact
Mogden South Sewer: RES-RU-MSS-50 CON-RU-MSS-WAL-50	TWU_WLJ_HI-REU_reuse mogden s sewer	49	49	46	46	46	-3	-3	Water Source and Availability changed from Amber to Red Gate 2 assessment led to changes:

[9] A WRMP19 review of cumulative effects of Thames Water WRMP19 options on the receptor environment in the Middle Thames Tideway identified that if there is more than a 15-20% decrease (275-366 Ml/d) in freshwater inputs to the Middle Tideway normal salinity patterns could be substantially affected. The London Effluent Reuse SRO has therefore considered options up to 300 Ml/d, however at WRMP19 a maximum capacity of 380 Ml/d was assessed as feasible for Beckton Reuse. The 380 Ml/d option remains on the Feasible List while further work is ongoing to review the cumulative impact of options on the Middle Tideway salinity. The Middle Thames Tideway – Cumulative effects of re-use, desalination and DRA WRMP19 Options is provided in Appendix D.

		WRMP19 DO (Ml/d)		WRMP24 DO (Ml/d)			Difference (Ml/d)		Impact on Feasibility Assessment Scoring (all options Passed Stage 3 at WRMP19)
WRMP19 Option Name	WRMP24 Option Name	Average	Peak	1 in 2 average	1 in 500 average	1 in 500 peak	Average	Peak	
									Amber to Red for “Water Source and Availability”, “AIC (Normalised Costs)” & “Planning Policy Designations”. Green to Amber for “Operational Complexity”
DO = Deployable Output									

Table 6 Option DO changes since WRMP19

Non-SRO option updates

Deephams Reuse

22 The final WRMP19 set out a programme of further research to ensure the option is compliant with the Water Framework Directive (WFD) Regulations before being progressed, (paragraph 11.244 of Section 11 Preferred Plan to confirm the WFD assessment).

23 Following completion of the investigations, review of the findings with the Environment Agency has established that a Deephams Sewage Treatment Works (STW) Reuse option has potential environmental risk. As such, after detailed discussion of the findings with the Environment Agency, Thames Water has withdrawn the option as the preferred WRMP19 option and also as a feasible option from future WRMPs in the medium-term period until 2060. The option has been included on the Feasible List with an earliest completion date of 2060.

Passed – on Feasible List with the constraint that the scheme cannot be delivered before 2060.

Strategic resource options

24 The following section summarises updates to the SRO Reuse options compared to WRMP19, as noted in Thames Water WRMP19 Resource Options Water Reuse Feasibility Report, October 2018, Rev 03. For full details of the engineering design development and environmental assessment since WRMP19 refer to London Effluent Reuse Gate 2 submission, published on Thames Water website (Water recycling (reuse) schemes in London | Thames Water).

25 This section details the outcome of changes to the designs on the feasibility assessments.

Beckton Reuse

26 The design of the Beckton Reuse option has been further developed for WRMP24, as part of London Effluent Reuse SRO, considering phased development in phases of 50, 100 and 150 Ml/d up to the cumulative limit of 300 Ml/d[10]. The design of these options has not materially changed since WRMP19.

27 At WRMP19 the 50 Ml/d Beckton Reuse option was rejected at Fine Screening however it has been included as a phase capacity for WRMP24 to allow flexibility of phased development in investment modelling.

28 The following conveyance elements are required as part of the Beckton Reuse option; they would be constructed with the initial phase and have sufficient capacity for all subsequent phases:

- Beckton to Lockwood tunnel - there are no material changes to the design since WRMP19.

[10] A WRMP19 review of cumulative effects of Thames Water WRMP19 options on the receptor environment in the Middle Thames Tideway identified that if there is more than a 15-20% decrease (275-366 Ml/d) in freshwater inputs to the Middle Tideway normal salinity patterns could be substantially affected. The London Effluent Reuse SRO has therefore considered options up to 300 Ml/d, however at WRMP19 a maximum capacity of 380 Ml/d was assessed as feasible for Beckton Reuse. The 380 Ml/d option remains on the Feasible List while further work is ongoing to review the cumulative impact of options on the Middle Tideway salinity.

An alternative pipeline conveyance for up to 100 Ml/d has been considered and screened out on the grounds of cost, engineering constraints and environmental impacts[11,12].

- Thames Lee Tunnel extension – Lockwood Pumping station to King George V reservoir intake - there are no material changes to the design since WRMP19. The tunnel has been designed with a capacity of around 800 Ml/d which is sufficient for 300 Ml/d from the Beckton Reuse and also to transfer the maximum flow from the existing Thames Lee Tunnel. Pumping capacity of 300 Ml/d has been included within the Beckton Reuse option.

Passed – on Feasible List with a maximum capacity of 380 Ml/d.

Mogden Reuse

29 Mogden Reuse was rejected at WRMP19 Fine Screening.

30 The option has been included in WRMP24 and is being further developed through the RAPID Gated Process within the London Effluent Reuse SRO. As part of this further development, modelling of the outfall location has been undertaken to understand the impacts of the discharge on temperature, water quality and aquatic ecology.

31 The design of the Mogden Reuse option has developed phases of 50 and 100 Ml/d for combination up to a maximum capacity of 150 Ml/d. The routes and design of the conveyance elements have also been updated (London Effluent Reuse Gate 2 submission, published on Thames Water website (Water recycling (reuse) schemes in London | Thames Water.

32 The following conveyance elements are required as part of the Mogden Reuse option; they would be constructed with the initial phase and have sufficient capacity for all subsequent phases

- Mogden to Walton 150 Ml/d

Passed – on Feasible List with a maximum capacity of 150 Ml/d

Mogden South Sewer

33 Flow monitoring has been carried out to assess the amount of flow in the sewer available for abstraction and treatment to provide an additional water resource. The results show a dry weather flow (DWF) ranging between 33 to 36 Ml/d which is substantially below a DWF of 60 Ml/d required to support a 50Ml/d option. As a result, only a smaller deployable output c.25Ml/d is possible.

34 In advance of the flow monitoring results, the design was developed for a 50 Ml/d option; however the requirements for a smaller option would be similar, although the capacity of the engineering components would be scaled back.

Passed – on Feasible List with a maximum capacity of 25 Ml/d.

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[11] Letter from SRO to RAPID https://www.ofwat.gov.uk/wp-content/uploads/2022/05/Thames-Water-letter-to-RAPID-Beckton-pipeline-route-rejection-version2.1.pdf

[12] RAPID response https://www.ofwat.gov.uk/wp-content/uploads/2022/05/Letter-from-Paul-Hickey-to-Rob-Bromley-20-May_2022.pdf

Cumulative limits

35 WRMP19 investigations identified that the decrease in freshwater inputs to the Tideway, arising from water reuse, desalination and DRA options, should be limited to no more than 275-366 Ml/d in order to mitigate impacts on potentially sensitive ecological receptors.

36 A cumulative limit on the total additional capacity of water reuse and desalination options, that decrease in freshwater inputs to the Tideway, of 366 Ml/d has therefore been included in the WRSE regional modelling. Beckton Reuse, Mogden Reuse, Crossness Reuse and Deephams Reuse capacity are included within this cumulative limit.

37 Further investigation at WRMP24 is ongoing and any updates will be included in the Final WRMP24.

Updated Feasibility Assessment

Feasibility Assessment Approach

38 This section of the report outlines the updates made in WRMP24 to the WRMP19 feasibility assessment. This should be read alongside the WRMP19 Water Reuse Feasibility Report. Where options have been rejected through the screening process the rejection reason is recorded in WRMP24 Appendix Q Scheme Rejection Register.

39 A three-stage feasibility screening approach was employed at WRMP24 and this approach is unchanged from WRMP19, details of the approach can be found in the WRMP19 Water Reuse Feasibility Report.

40 The WRMP19 Water Reuse Feasibility Report Stage 1 identified 14 water reuse option locations for further assessment. Of these 14 locations, five are considered feasible following the Stage 2 and Stage 3 assessment:

- Beckton STW
- Crossness STW
- Deephams STW
- Mogden STW
- Mogden South Sewer

41 At WRMP19, fine screening was undertaken for all options which passed the feasibility screening. The WRMP19 fine screening took account of the estimated volume of predicted water resources deficit of Thames Water and, where applicable, neighbouring companies. However, the predicted water resources need for the region at WRMP24[13] is significantly higher than at WRMP19, owing to:

- increased sustainability reductions
- a change to planning for water supply resilience for a 1 in 500 year drought from 1 in 200 at WRMP19[14]

42 Furthermore, potential new transfers identified by WRSE would allow new resource options in the Thames Water supply area to supply more of the WRSE region than was considered at WRMP19. For these reasons, the potential resource need is not being used as a consideration in the screening process at WRMP24. This is to avoid rejecting options based on Thames Water's need where there could be a regional benefit. At WRMP24 the fine screening stage has therefore been replaced by use of the WRSE investment model to compare options against cost, environmental, and resilience criteria (further detail is provided in Section 7 of the Thames Water WRMP24 documentation).

43 As a result of the above review one reuse option that was rejected at WRMP19 has been reassessed and included on the WRMP24 Feasible List, which is:

- Mogden Reuse

[13] https://wrse.uk.engagementhq.com/the-challenge
[14] A 1 in 500-year event explained: This does not refer to an event that will occur every 500 years, it is better considered an event where there is a 1 in 500 chance of the event occurring in a given year, or a 0.2% chance. The probability of it happening in one year remains the same in each of the following years.

44 Appendix 0 provides a list of the WRMP19 and WRSE option identification numbers (IDs). These can be used to cross reference options to WRSE lists and WRMP19 documentation.

Stage 1 Assessment Results

45 At WRMP19 all 350 Thames Water owned wastewater catchments were reviewed at Stage 1 to identify appropriate sites for final effluent reuse from STW and where suitable abstraction of raw sewage from wastewater catchments.

46 The Stage 1 assessment used the key constraints (as defined in WRMP19 Water Reuse Feasibility Report, Section 3.2), to focus on STW catchments, where:

- current treated effluent discharges are into a stretch of river where reuse of the water would not impact on downstream abstractors,
- discharges which would otherwise be lost in the tidal reach of the River Thames (Thames Tideway), and
- where catchments can supply the London WRZ.

47 Six STW catchments passed the Stage 1 assessment (as shown in Table 7).

48 No new sites have been identified at WRMP24 and the Stage 1 assessment remains unchanged. Full methodology for Phase 1 assessment is detailed in Section 4 of the WRMP19 Feasibility Report, with the full list of assessed sites detailed in Appendix A of the report.

Option / STW catchments	No potential impact on downstream abstractors	No national or international nature conservation designation	No national or international heritage designation	Will the site provide water to London?	Compatible with Thames Water's reuse policy	Result
Beckton	✓	✓	✓	✓	✓	PASS
Mogden	✓	✓	✓	✓	✓	PASS
Crossness	✓	✓	✓	✓	✓	PASS
Deephams	✓	✓	✓	✓	✓	PASS
Long Reach	✓	✓	✓	✓	✓	PASS
Riverside	✓	✓	✓	✓	✓	PASS

Table 7: Sites which passed stage 1 assessment

Key changes to WRMP19 decisions

49 There are no changes from the WRMP19 assessment at the Stage 1 Assessment.

Stage 2 assessment results

50 The WRMP19 Feasibility Report identified options within the STW catchments at Stage 2 based on:

- The "reliable" source yield from the location within the catchment (generally the STW final effluent or a sewer mining location) and a corresponding expected option capacity taking into account the treatment losses.
- The treatment technology
- The location of the option discharge into a raw water body
- The location of land available for treatment

51 The Stage 2 assessment of the WRMP19 and WRMP24 options that passed Stage 1 is presented in Table 9 providing the red, amber, green assessment of the criteria described in the WRMP19 Water Reuse Feasibility Report.

52 Sixteen options passed the Stage 2 assessment at WRMP19. Further details are included in the WRMP19 Water Reuse Report.

53 Where changes have been made to WRMP19 RAG status they are identified in Table 8. The RAG assessment of SRO options below has not been reviewed at WRMP24, namely:

- Beckton Reuse
- Mogden Reuse

54 The RAG assessment for SRO option Mogden South Sewer has been revisited as part of backchecking (Section 4).

Option	Criteria	WRMP19	WRMP24	Reason for change
Deephams Reuse	Impacts on water resources & quality			Summary of current position (Appendix E) has identified that the flow reduction associated with this option is contrary to the environmental ambition for waterbodies downstream of the option. The option is likely to cause major adverse impacts including a high risk to Water Framework Directive objectives

Table 8 Changes to WRMP19 RAG status – Stage 2 assessment

Criteria	Beckton STW (Beckton STW) 300 +	Beckton STW (Beckton STW) 100-299	Beckton STW (Beckton STW) <100	Beckton mining - Abbey Mills (Luxborough Lane) 300	Beckton mining - Abbey Mills (Luxborough Lane) 100-299	Beckton mining - Abbey Mills (Luxborough Lane) <100	Beckton mining - Abbey Mills (Lower Hall) 300	Beckton mining Abbey Mills (Lower Hall) 100-299	Beckton mining - Abbey Mills (Lower Hall) <100	Crossness STW (Crossness Southern Marshes) 100 - 199	Crossness STW (Crossness Southern Marshes) <100	Crossness mining - Greenwich (Lower Hall) 100 -150	Crossness mining - Greenwich (Lower Hall) < 100	Crossness mining - Greenwich (Hogsmill) 100 -150	Crossness mining - Greenwich (Hogsmill) <100	Crossness mining – Millbrook (Hogsmill) 100 – 150	Crossness mining -Millbrook (Hogsmill) <100	Crossness mining –Wandle Valley PS (Hogsmill) <50	Mogden STW (Mogden STW) - 212	Mogden STW 100 - 200	Mogden STW <100	Mogden South Sewer 50	Deephams STW post 2060 (Deephams STW) 25- 46.5	Long Reach STW (within and adjacent to STW site) 50-90Ml/d	Riverside STW (within STW site) 38Ml/d
Property & legal																									
Sufficient TW owned land																									
Space for future growth & changes																									
Land acquisition costs																									
Planning & environmental																									
Land use & quality																									
Floodplain encroachment																									
Landscape designations																									
Visually sensitive viewpoints																									
Nature conservation and biodiversity																									
Archaeology and heritage assets																									
Non-traffic impacts on construction																									
Impacts of construction on traffic																									
Impacts on recreational sites or PRoW																									
Impacts on water resources & quality																									
Engineering																									
Network reinforcements																									
Length of conveyance																									
Pumping head																									
Water resource & availability																									
Suitable access for construction / operation																									
Connectivity for waste streams																									
Construction complexity																									
Operational complexity																									
Option taken through to Stage 3	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No

Table 9: Stage 2 assessment of all options

Notes:

a) Title includes the catchment / STW source and in brackets the location of the reuse treatment.

b) Where a criterion relates to two or more sites, the least favourable basis of assessment is shown (i.e. if one site is amber and another site red, then red will be shown).

c) Land and Legal criteria relate to pump station / treatment site location

d) The RAG assessment for SRO options had not been reviewed at WRM24

.

55 Nine options were rejected at Stage 2; the reasons for the option rejection are included in the WRMP24 Appendix Q - Scheme Rejection Register.

56 There are no changes to the WRMP19 Stage 2 feasibility assessment outcomes and the following options were therefore taken forward to Stage 3:

- Beckton Catchment - Beckton STW to site within treatment works boundary 380, 300, 200, 150, 100, 50 Ml/d
- Beckton mining - Abbey Mills to Lower Hall 300, 200, 150, 100, 50 Ml/d
- Crossness Catchment – Crossness STW to site within STW boundary 190,150,100, 50Ml/d
- Crossness Catchment – Millbrook Road SPS to site at Hogsmill STW 100, 50 Ml/d
- Crossness Catchment – Wandle Valley SPS to site at Hogsmill STW 17 Ml/d
- Mogden Catchment – Mogden STW to Site within Mogden STW 212 Ml/d
- Mogden Catchment – Mogden STW to site near Kempton 200,150,100, 50 Ml/d
- Mogden Catchment – Mogden South Sewer to site near Kempton 50 Ml/d
- Deephams Catchment – Deephams STW to site within the STW boundary 46.5 Ml/d.

Key changes to WRMP19 RAG assessment

Deephams STW (Deephams)

57 The "Impacts on water resources & quality" criteria have been reassessed from Amber to Red. However the option has still progressed to Stage 3 on the assumption that it could be implemented post 2060.

58 Further information regarding the investigations into the options is included in the WRMP19 Water Reuse Feasibility report and London Effluent Reuse SRO Gate 2 documents.

Stage 3 assessment results

59 Assessment against Stage 3 criteria of options has been undertaken for all options that passed Stage 2.

60 The Stage 3 assessment of the WRMP19 and WRMP24 options that passed Stage 2 is presented in Table 10 providing the red, amber, green assessment of the criteria described in WRMP19 Water Reuse Feasibility report. Four options passed the Stage 3 assessment. Further details are included in the WRMP19 Water Reuse Feasibility report and SRO Gate documents.

61 Where changes have been made to WRMP19 RAG status this is indicated in Table 10.

Option	Criteria	WRMP19	WRMP24	Reason for change
Deephams Reuse	Nature conservation and biodiversity	Amber	Red	Summary of the current position (Appendix E) between the EA and Thames Water has identified that the option has potential environmental risk, this criteria has therefore been updated from Amber to Red.
	Water resources & water quality	Amber	Red	Summary of the current position (Appendix E) has identified that the flow reduction associated with this option is contrary to the environmental ambition for waterbodies downstream of the option.

Table 10 Changes to WRMP19 RAG status – stage 3 assessment

Criteria	Beckton STW (Beckton) 300 +	Beckton STW (Beckton) 100-299	Beckton STW (Beckton) <100	Beckton SM - AM (LH) 300	Beckton SM -AM (LH) 100-299	Beckton SM – AM (LH) <100	Crossness STW (Southern Marshes) 100-299	Crossness STW (Southern Marshes) <100	Crossness SM – Millbrook (HM) 100 – 150	Crossness SM -Millbrook (HM) < 100	Crossness SM –Wandle Valley PS (HM) < 50	Mogden STW (Mogden) 212	Mogden STW (HF) 100 - 200	Mogden STW (HF) <100	Mogden South Sewer (HF) 50*	Deephams STW post 2060 (Deephams) 46.5
Property & legal																
Assessment of ownership and tenancy	Green	Green	Green	Green	Green	Green	Green	Green	Amber	Amber	Green	Amber	Green	Green	Green	Green
Planning, socio-economic & environmental																
Planning policy designations.	Amber	Amber	Amber	Red	Red	Red	Amber	Amber	Amber	Amber	Amber	Red	Amber	Amber	Amber	Green
Land take and land quality	Green	Green	Green	Green	Green	Green	Amber	Amber	Green	Green	Green	Amber	Amber	Amber	Amber	Green
Floodplain encroachment	Green	Green	Green	Amber	Amber	Amber	Green	Green	Amber	Amber	Red	Green	Green	Green	Green	Green
Landscape character sensitivity	Green	Green	Green	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Green
Visual sensitivity	Green	Green	Green	Amber	Amber	Amber	Amber	Amber	Red	Red	Amber	Red	Amber	Amber	Amber	Amber
Employment & local economy	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Amber	Amber	Amber	Green
Nature conservation & biodiversity	Red	Red	Amber	Amber	Amber	Amber	Red	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Red
Opportunity for biodiversity enhancement	Amber	Amber	Amber	Red	Red	Red	Amber	Amber	Red	Red	Amber	Red	Amber	Amber	Amber	Red
Heritage assets	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Green	Amber	Amber	Amber	Amber
Non-traffic construction impacts	Green	Green	Green	Amber	Amber	Amber	Green	Green	Red	Red	Red	Red	Green	Green	Green	Green
Impact on recreation	Amber	Amber	Amber	Amber	Amber	Amber	Red	Amber	Amber	Amber	Amber	Amber	Red	Amber	Amber	Green
Water resources & water quality	Amber	Amber	Amber	Green	Green	Green	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Red
Engineering																
Length of conveyance	Red	Red	Red	Amber	Amber	Amber	Red	Red	Red	Red	Amber	Red	Red	Red	Amber	Green
Normalised Cost / AIC	Green	Green	Amber	Green	Green	Green	Green	Amber	Green	Green	Green	Green	Green	Amber	Green	Green
Water source & availability	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber
Water treatment risks and complexity	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber	Amber
Power supply	Amber	Amber	Amber	Red	Red	Red	Amber	Amber	Amber	Amber	Amber	Amber	Red	Red	Red	Amber
Construction Complexity	Amber	Amber	Amber	Amber	Amber	Amber	Red	Red	Amber	Amber	Amber	Red	Amber	Amber	Amber	Amber
The option included in the feasible list	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes

Table 11: Stage 3 assessment

Location Abbreviations: STW sewage treatment works, SM sewer mining, LH lower Hall, HM Hogsmill sewage treatment works.
* required to support a 50Ml/d Mogden South Sewer scheme. As a result only a smaller deployable output c.25Ml/d is possible; the 50Ml/d option is rejected after the additional wastewater benefits of the option are reviewed
The RAG assessment for SRO options had not been reviewed at WRM24.

62 There are no changes to the WRMP19 Stage 3 feasibility assessment outcomes; nine options passed the Stage 3 assessment and seven failed the Stage 3 assessment.

63 Further information regarding the investigations into the options is included in the WRMP19 Water Reuse Feasibility report and SRO Gate documents.

64 The following list of options passed Stage 3 feasibility assessment and were taken forward for further consideration:

- Beckton Catchment - Beckton STW to site within STW boundary up to 380 Ml/d[15]
- Crossness Catchment – Crossness STW to the Southern Marshes site up to 190 Ml/d
- Mogden Catchment – Mogden STW to site near Kempton WTW up to 200 Ml/d
- Mogden Catchment – Mogden South Sewer to site near Kempton up to 50 Ml/d[16]
- Deephams Catchment – Deephams STW to site within the STW boundary 46.5 Ml/d (post 2060)

[15] A WRMP19 review of cumulative effects of Thames Water WRMP19 options on the receptor environment in the Middle Thames Tideway identified that if there is more than a 15-20% decrease (275-366 Ml/d) in freshwater inputs to the Middle Tideway normal salinity patterns could be substantially affected. The London Effluent Reuse SRO has therefore considered options up to 300 Ml/d, however at WRMP19 a maximum capacity of 380 Ml/d was assessed as feasible for Beckton Reuse. The 380 Ml/d option remains on the Feasible List while further work is ongoing to review the cumulative impact of options on the Middle Tideway salinity.

[16] Dry Weather Flow (DWF) monitoring data was gathered during the London Effluent Reuse SRO Gate 2 stage, which showed DWF values of 33 to 36Ml/d. This is substantially below a DWF of 60 Ml/d required to support a 50Ml/d Mogden South Sewer scheme. As a result only a smaller deployable output c.25Ml/d is possible; the 50Ml/d option is rejected after the additional wastewater benefits of the option are reviewed.

Option Verification and Conclusion

65 The validation discussion of risk and uncertainty in Section 7 of the WRMP19 Water Reuse Feasibility report remains unchanged. Where options have been rejected through the screening process the rejection reason is recorded in Appendix Q rejection register.

Validation

66 Following further development through the SRO Gated process Mogden STW 200 Ml/d was backchecked against the screening criteria and was rejected at validation. Environmental investigations show a significant risk from a 200 Ml/d scheme breaching EA thermal plume characteristics where the extent of the 2°c temperature change from a discharge extends greater than a 25% cross sectional area of the river.

67 The constraint on maximum scheme size for Mogden Reuse is therefore driven by the potential environmental impacts rather than the available final effluent. For future scheme investigations the maximum capacity of a Mogden water recycling scheme is therefore capped at 150 Ml/d and the 200 Ml/d option is rejected. For more information see the London Recycling SRO Gate 2 submission.

Confirmation of feasible list of options:

68 The following list of options are the confirmed list of feasible reuse options for WRMP24:

- Beckton Catchment - Beckton STW to site within STW boundary up to 380 Ml/d[17]
- Crossness Catchment – Crossness STW to the Southern Marshes site up to 190 Ml/d
- Mogden Catchment – Mogden STW to site near Kempton WTW up to 150 Ml/d[18]
- Mogden Catchment – Mogden South Sewer to site near Kempton up to 25 Ml/d
- Deephams Catchment – Deephams STW to site within the STW boundary 46.5 Ml/d (post 2060)

69 This report summarises changes to the reuse options up to the end of feasibility screening. However, it should be noted that at WRMP24 Crossness Reuse, and Mogden South Sewer 50 Ml/d were rejected at further screening and are not included on the Constrained List of options for WRMP24. The rejection reasoning can be found in WRMP24 Appendix Q Scheme Rejection Register and details of the Further Screening Process can be found in WRMP24 Section 7 – Appraisal of Resource options.

70 Following the backchecking of the WRMP19 feasibility assessment for WRMP24, flow monitoring undertaken by the London Effluent Reuse SRO showed that the Dry Weather Flow (DWF) in the Mogden South Sewer is substantially below a DWF of 60 Ml/d required to support a 50Ml/d Mogden South Sewer option. As a result, only a smaller deployable

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[17] A WRMP19 review of cumulative effects of Thames Water WRMP19 options on the receptor environment in the Middle Thames Tideway identified that if there is more than a 15-20% decrease (275-366 Ml/d) in freshwater inputs to the Middle Tideway normal salinity patterns could be substantially affected. The London Effluent Reuse SRO has therefore considered options up to 300 Ml/d, however at WRMP19 a maximum capacity of 380 Ml/d was assessed as feasible for Beckton Reuse. The 380 Ml/d option remains on the Feasible List while further work is ongoing to review the cumulative impact of options on the Middle Tideway salinity.

[18] Further modelling has shown that a maximum capacity of 200 Ml/d has a high risk of breaching Environment Agency guidance where the extent of the 2 oc temperature change from a discharge extends greater than a 25% cross sectional area of the river, this option therefore has a maximum of 150 Ml/d in the Gate 2 Report

output c.25Ml/d is possible. The RAG assessment of this option has been backchecked and the changes made to WRMP19 RAG status are indicated in Table 12 and Table 13.

Option	Criteria	WRMP19	WRMP24	Reason for change
Mogden South Sewer	Operational Complexity	Green	Amber	Further review by the SRO has concluded that the operation is of average complexity, but with relatively complex processes/ operations and requirement for relatively substantial O&M procedures. The Stage 2 assessment of Operational Complexity has therefore been changed to Amber.

Table 12 Changes to WRMP19 RAG status – Stage 2 assessment

Option	Criteria	WRMP19	WRMP24	Reason for change
Mogden South Sewer	Water Source and Availability	Amber	Red	The source flow monitoring results show only c33 Ml/d DWF available blackwater source compared to a required abstraction volume of c60 Ml/d assessed at Gate 1. The source flow is therefore insufficient for a 50 Ml/d option. Stage 3 assessment of Water Source and Availability has therefore been changed to Red as there are significant constraints on the water availability.
	Normalised cost	Amber	Red	AIC £/m^3 assessment for Gate 1 gave Normalised Costs between £1.17 and £1.49 per m^3 which under the basis for assessment is an Amber status; "£1.00/m^3 to £1.50/m^3 ". The Gate 2 assessment demonstrates likelihood of increased costs Stage 3 assessment of Normalised cost has therefore been changed to Red (>£1.50/m^3)
	Planning, socio-economic and environmental	Amber	Red	Gate 2 assessment has shown that there are a number of emerging issues around loss of woodland, proximity to the SPA and green belt status which makes the site element of the scheme (i.e. the potential site for STW/AWRP) more difficult to develop than assessed at WRMP19. Stage 3 assessment of Planning, socio-economic and environmental has therefore been changed to Red.

Table 13 Changes to WRMP19 RAG status – stage 3 assessment

71 Mogden South Sewer has been retained as a WRMP24 option while the additional wastewater benefits of the option are reviewed.

72 Information on option development and investment modelling can be found in WRMP24 Section 7 - Appraisal of Resource Options.

Appendix A Reference information

The draft WRMP24 and Technical Appendices can be found on the Thames Water website at:

Please contact consultation@thames-wrmp.co.uk for access to WRMP19 reports

Water resources | Regulation | About us | Thames Water

Please contact consultation@thames-wrmp.co.uk for access to WRMP19 reports

SRO documents referenced in report can be found on the Thames Water website at:

Regional water resources | Regulation | About us | Thames Water

Appendix B Option references

	WRMP 19 ID	WRSE ID
Beckton Effluent Reuse – 150 Ml/d Treatment	RES-DES-BEC-150;	TWU_KGV_HI-REU_reuse beckton 150
Beckton Effluent Reuse – 100 Ml/d Treatment	RES-RU-BEC-100	TWU_KGV_HI-REU_reuse beckton 100
Beckton Effluent Reuse – 50 Ml/d Treatment	RES-RU-BEC-50	TWU_KGV_HI-REU_reuse beckton 50
Beckton Effluent Reuse – TLT extension from Lockwood PS to King George V Reservoir intake	CON-RU-BEC-LCK-300	TWU_KGV_HI-TFR_beckton to lockwood
Beckton Effluent Reuse – Beckton to Lockwood Tunnel Conveyance	CON-RWS-LCK-KGV-800	TWU_KGV_HI-TFR_lockwood ps-kgv res
Beckton mining - Abbey Mills (Luxborough Lane) 300	See note	TWU_LON_HI-REU_ALL_ALL_abbeymillspslux300
Beckton mining - Abbey Mills (Luxborough Lane) 100-299	See note	TWU_LON_HI-REU_ALL_ALL_abbeymillspslux200 TWU_LON_HI-REU_ALL_ALL_abbeymillspslux150 TWU_LON_HI-REU_ALL_ALL_abbeymillspslux100
Beckton mining - Abbey Mills (Luxborough Lane) <100	See note	TWU_LON_HI-REU_ALL_ALL_abbeymills pslux50
Beckton mining - Abbey Mills (Lower Hall) 300	See note	TWU_LON_HI-REU_ALL_ALL_abbeymillspslh300
Beckton mining Abbey Mills (Lower Hall) 100-299	See note	TWU_LON_HI-REU_ALL_ALL_abbeymillspslh200 TWU_LON_HI-REU_ALL_ALL_abbeymillspslh150 TWU_LON_HI-REU_ALL_ALL_abbeymillspslh100
Beckton mining - Abbey Mills (Lower Hall) <100	See note	TWU_LON_HI-REU_ALL_ALL_abbeymillspslh50
Crossness STW (Crossness Southern Marshes) 100 - 199	See note	TWU_LON_HI-DES_RE1_ALL_crossness(erith) 300 TWU_LON_HI-DES_RE1_ALL_crossness(erith) 150
Crossness STW (Crossness Southern Marshes) <100	See note	
Crossness mining - Greenwich (Lower Hall) 100 -150	See note	TWU_LON_HI-REU_ALL_ALL_greenwichpslh150 TWU_LON_HI-REU_ALL_ALL_greenwichpslh100 TWU_LON_HI-REU_ALL_ALL_greenwichpslh50
Crossness mining - Greenwich (Lower Hall) < 100	See note	
Crossness mining - Greenwich (Hogsmill) 100 -150	See note	TWU_LON_HI-REU_ALL_ALL_greenwichpshogs150 TWU_LON_HI-REU_ALL_ALL_greenwichpshogs100
Crossness mining - Greenwich (Hogsmill) <100	See note	TWU_LON_HI-REU_ALL_ALL_greenwichpshogs50
Crossness mining – Millbrook (Hogsmill) 100 – 150	See note	TWU_LON_HI-REU_ALL_ALL_millbrookpshogs100
Crossness mining -Millbrook (Hogsmill) <100	See note	TWU_LON_HI-REU_ALL_ALL_millbrookpshogs50
Crossness mining –Wandle Valley PS (Hogsmill) <50	See note	TWU_LON_HI-REU_RE1_ALL_wandlepshogs17
Mogden Effluent Reuse (Mogden STW) - 212	See note	TWU_LON_HI-REU_RE1_ALL_mogdeneffru-stw
Mogden Effluent Reuse – Reuse Treatment Plant - 100Ml/d	RES-RU-MOG-100	TWU_WLJ_HI-REU_reuse mogden 100

	WRMP 19 ID	WRSE ID
		TWU_WLJ_HI-REU_RE2_ALL_reuse mogden 100 p2
Mogden Effluent Reuse – Reuse Treatment Plant - 50Ml/d	RES-RU-MOG-50	TWU_WLJ_HI-REU_RE1_CNO_reuse mogden 50 TWU_WLJ_HI-REU_RE2_ALL_reuse mogden 50 p2
Mogden to Walton 200 Ml/d - Conveyance for Mogden Effluent Reuse Treatment	CON-RU-MOG-WAL-200	TWU_WLJ_HI-TFR_reuse mogden/Walton
Mogden South Sewer – Reuse Treatment Plant - 50Ml/d output	RES-RU-MSS-50;	TWU_WLJ_HI-REU_RE1_ALL_reuse mogden s sewer
Mogden South Sewer – Reuse Treatment Plant – 25Ml/d output		
Mogden South Sewer associated conveyance	CON-RU-MSS-WAL-50	
Deephams STW post 2060 (Deephams STW) 46.5 Ml/d	RES-RU-DPH and either CON_RU-DPH-KGV; or CON-RU-DPH-TLTEX	TWU_KGV_HI-REU_RE1_ALL_deephams reuse 46.5
Deephams STW post 2060 (Deephams STW) 25 Ml/d	See note	TWU_LON_HI-REU_RE1_ALL_deephams reuse 25
Long Reach STW (within and adjacent to STW site) 50-90Ml/d	See note	TWU_LON_HI-REU_RE1_ALL_lrstweffluentreuse80 TWU_LON_HI-REU_RE1_ALL_lrstweffluentreuse50
Riverside STW (within STW site) 38Ml/d	See note	TWU_LON_HI-REU_RE1_ALL_riversideeff.reuse38

Table 14: Option WRMP19 and WRSE IDs

NOTE: Note - Options rejected prior to constrained list were not all assigned a WRMP19 ID

Appendix C Environment Agency Comments

Source	Option description	Environment Agency comments	Date of response	Outcome of option screening
Summary of position (Appendix E) between Environment Agency and Thames Water on water environment effects of the Deephams STW Reuse option Mar 2022 v0.5	Deephams Reuse	Environmental ambition scenarios for the South East to redress these deficits. The flow reduction associated with a Deephams STW Reuse Option is therefore contrary to the environmental ambition for these waterbodies as laid out by the Environment Agency Waterbody Assessment Tool (2021) and adopted by WRSE, if the scheme were implemented before 2060, after which schemes such as Beckton Reuse will be able to provide compensatory flows. No further work on the environmental risks of a Deephams STW Reuse option before this point, or work to identify bespoke mitigation of the risks, will satisfactorily resolve the risk in the absence of a compensatory scheme.	March 2022	As the option is not viable prior to 2060, it has been appraised for a post 2060 introduction

Table 15: Environment Agency Engagement

Appendix D Middle Thames Tideway – Cumulative effects of re-use, desalination and DRA WRMP19 Options

Middle Thames Tideway – Cumulative effects of re-use, desalination and DRA WRMP19 options

Report for Thames Water Utilities Limited

ED 10474 | Final 1.0 | Date 26/06/2017

Customer:

Thames Water Utilities Limited

Customer reference:

ED10474

Confidentiality, copyright & reproduction:

Contact:

Trevor Wade
Ricardo Energy & Environment
Enterprise House, Manchester Science Park,
Manchester. M15 6SE. United Kingdom

t: +44 (0) 161 227 9777
e: trevor.wade@ricardo.com

Ricardo-AEA Ltd is certificated to ISO9001 and ISO14001

Author:

Trevor Wade, Jon Hawes, Peter Mulder

Approved By:

Dr Kieran Conlan

Date:

26 June 2017

Ricardo Energy & Environment reference:

Ref: ED10474- Final 1.0

Executive summary

A desktop review has been undertaken to assess the potential cumulative effects of Thames Water WRMP options proposed for the Middle Tideway. This includes consideration of Beckton Sewage Treatment Works (STW) reuse and desalination plants; Crossness STW desalination plant; Teddington direct river abstraction (DRA); Lower Lee DRA; and Deephams STW reuse. The key objective of review is to establish the potential cumulative impacts of potential WRMP19 options on the receptor environment in the Middle Thames Tideway, with an emphasis on the ecological receptor communities.

The possible effects on the Middle Thames Tideway may include the following:

- Immediate, local salinity effects.
- Longer term spatial effect on salinity in the wider Thames Tideway.
- Local changes in tidal level.

This review, which considers the five schemes acting together, has concluded the following:

1. Brine discharges would be diluted with STW effluent and the potential for local salinity impacts on the Middle Tideway for individual options is minor to negligible as local salinity levels are not expected to exceed background levels. Any resulting effects are local and will not have a significant effect on the local ecology.

2. Cumulatively, the Middle Tideway options may result in a potential <u>moderate</u> exacerbation of normal patterns of salinity ingress, changing local salinities within the Middle Tideway. The magnitude of change is difficult to predict but initial view if that options which decrease freshwater inputs to the Middle Tideway by greater than 15-20% (275-366) Ml/d could substantially affect the normal salinity patterns. Potentially sensitive ecological receptors in the estuarine habitats of the Middle Tideway include no (current) national or international designated habitats and at least ten different protected species. Of these, it is anticipated that at highest <u>moderate, probably reversible impacts</u> would occur on brown/sea trout, bullhead, European smelt (a fish) and the swollen spire snail. In addition, a <u>moderate, probable reversible impact</u> is anticipated as a result of disruption of communities through displacement of individual species within the community mosaic due to individual species salinity preferences. In both instances, reversibility is considered to occur over the short to medium term, depending on the mobility and life cycle of individual species and how often the schemes are switched on.

3. It is noted that the implementation of some of the schemes could be decades away. The future ecological baseline of the Thames Tideway is difficult to forecast, with climate and other changes (e.g. implementation of the Tideway Tunnel) known to influence the future qualities of associated watercourses. A Marine Conservation Zone (MCZ) is proposed for the Thames Tideway for European smelt, European eel and Tentacled lagoon worm, which could result in a minor impact in the future. Furthermore, recovery of the Thames Estuary may have allowed more sensitive species to re-establish and a moderate impact could result in the future. Finally, climate change (sea level rise, drier summers and potentially lower summer freshwater inputs) may result in more routine and stronger saline ingress in the summer period and resilient communities would have to adapt to this regardless of the implementation of future water resource schemes.

4. Uncertainties in the assessment include a requirement to improve confidence in the exact predicted change in local salinities through development of a tideway model; and the absence of primary research evidence for salinity tolerances of some sensitive species (e.g. Swollen spire snail). Provision of such evidence is unlikely to result in a significant improvement in prediction of the expected results.

5. The effect of any changes in water level from abstraction is considered likely to be offset by tidal inflow, resulting in no material impact on associated intertidal habitats.

When considered as part of the WRMP Feasibility Studies, should these cumulative effects be deemed sufficiently significant in isolation we would recommend more detailed analysis to substantiate this initial review before any of the schemes are promoted for implementation.

Table of contents

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1 Introduction

1.1 Background

Ricardo Energy & Environment ('Ricardo')[1] has been commissioned by Thames Water Utilities Limited (Thames Water) to assess the potential cumulative impact of Thames Water's WRMP19 options on the receptor environment in the Middle Thames Tideway.

The potential WRMP19 options along with existing baseline considerations have been shown in **Figure 1.1** and **Table A** in **Appendix A**:

- Beckton Sewage Treatment Works (STW) re-use scheme – 300 Ml/day[2] net reduction in STW final effluent flows;
- Beckton Desalination plant[3] – 187 Ml/day abstraction for 3 hours twice a day at ebb tide, with 26.5 Ml/day of process brine returned via Beckton STW final effluent and the remainder 10.3 Ml/day waste stream returned to the Beckton STW. The plant potable supply output is 150 Ml/day;
- Crossness desalination plant – 373.6Ml/day abstraction for 3 hours twice a day at ebb tide, with 53Ml/day of process brine returned via Crossness STW final effluent and the remainder 20.6 Ml/day waste stream returned to the Crossness STW; River Thames at Teddington Direct River Abstraction (DRA) – continuous 300 Ml/day abstraction upstream of Teddington Weir[4]; and
- Either Deephams STW re-use scheme – 46.5Ml/day net reduction in in STW final effluent flow; or freshwater Lower River Lee DRA – average 35Ml/day abstraction (in a severe drought scenario with the Hoddeston Transfer operating [12.5 Ml/day]) abstraction sized for 150 Ml/day peak instantaneous abstraction upstream of Three Mills Lock[5][6].

The possible effects on the Middle Thames Tideway may include the following:

1. Immediate, local salinity effects.
2. Longer term spatial effect on salinity in the wider Thames Tideway.
3. Local changes in tidal level.

It should be noted that the evidence presented here is based on limited data, and no modelling of the dynamic tidal salinity regime has been undertaken. It is based on mass balance calculations of water movement between discharge and abstraction locations and the Tideway, with estimates taken from assumed water movement within the vicinity of the locations and the broader estuary.

[1] As part of a share purchase agreement, Ricardo acquired Cascade Consulting (Environment & Planning) Limited in 2015.
[2] 1 Megalitres per day (Ml/day) = 1,000m^3 per day = 1,000,000 litres per day.
[3] Beckton reuse and desalination options unlikely to be undertaken together due to lack of land available at/near Beckton STW and the cost of two separate treated / water tunnels to or via Coppermills Water Treatment Works (WTW).
[4] Teddington Weir is the freshwater/tidal limit of the River Thames.
[5] Since its construction in 2008, Three Mills Lock is the tidal limit of the River Lee.
[6] WARMS2 modelling of the Lower Lee option indicates a lower Deployable Output for the Lower Lee option than Deephams. Therefore, the baseline consideration includes Deephams re-use option.

1.2 Scope of the report

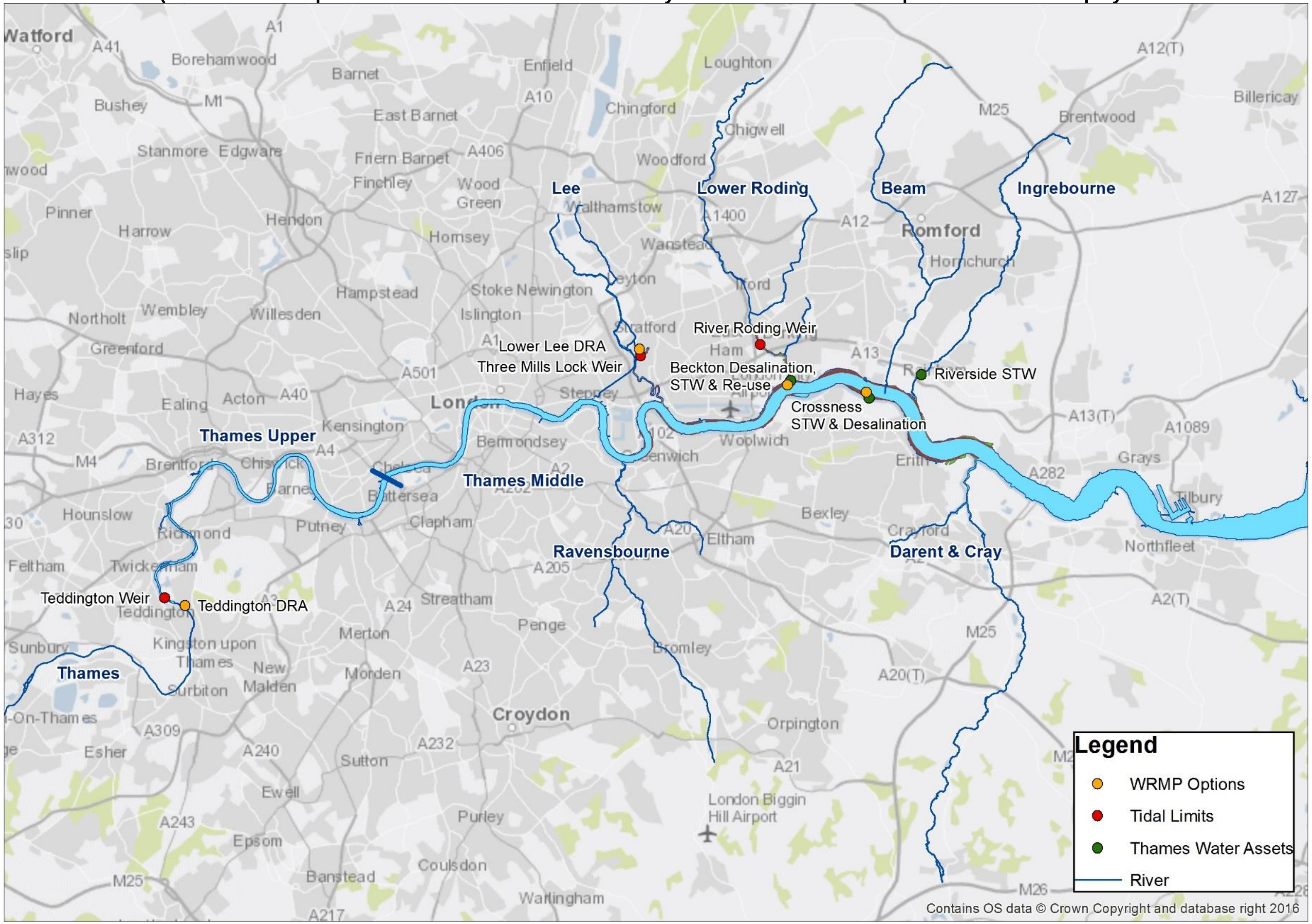
The key objective of this technical briefing note is to establish the potential cumulative impacts of potential WRMP19 options on the receptor environment in the Middle Thames Tideway, with an emphasis on the ecological receptor communities.

Section 2 of the report sets out the data used and environmental baseline for the Middle and Upper Thames Estuary.

Section 3 sets out the impact assessment.

Section 4 provides conclusions and an analysis of any uncertainties.

Figure 1.1 Key features in the Upper and Middle Thames Estuary
(note lowermost part of WFD Middle Thames waterbody down to Stanford-Le-Hope has not been displayed.



2 Current baseline

2.1 Data sources used

The following data sources were made available by the Environment Agency under data request NR45213 or accessed from publicly available sources or held by Ricardo have been used in this assessment, with monitoring locations shown in **Figure 2.1** (water quality), **Figure 2.2** (ecology) and **Figure 2.3** (intertidal habitats).

Salinity data

- Environment Agency (EA) Water Quality Archive (WIMS), accessed from: environment.data.gov.uk/water-quality
  A total of 21 water quality sites holding chlorine and salinity data were shortlisted.
  EA continuous monitoring of conductivity at their network of AQMS stations in the Upper Tideway are also available and can be converted to salinity data. However, the furthest seawards of these sites is Cadogan Pier (Chelsea) and these data do not allow interpretation of salinity effects in the Middle Tideway and are not presented here.

Fish species data

- EA National Fish Monitoring Programme (NFMP): Transitional and Coastal Waters (TraC) Fish Counts for all species for all Estuaries and all Years (2006-2016), accessed from: https://data.gov.uk/dataset/trac-fish-counts-for-all-species-for-all-estuaries-and-all-years

Benthic macroinvertebrate data

- EA Thames WFD Benthic Survey (2007), survey code TMTWD0307B.
- EA Thames Upper and Thames Middle macroinvertebrate species data for period 2000-2017, which included a total of 79 samples taken from 22 sites and processed over a 500µm sieve. The dataset includes primary (multi-annual) and secondary (single sample) sites.

Designated sites and habitats

- Shapefiles from: Map and Geographic Information Centre (MAGIC) map, accessed from: magic.defra.gov.uk.

Saltmarsh

- EA saltmarsh surveys for Thames Tideway at 27 locations between 2007 and 2012.

Flow

- National Rivers Flow Archive (NRFA) data for River Thames at Kingston (site ID 39001), accessed from: http://nrfa.ceh.ac.uk/data/station/meanflow/39001

Other data sources used include:

- EA Catchment Data Explorer, last updated 17 February 2016, accessed from: http://environment.data.gov.uk/catchment-planning/
- Thames Water (2013). Lower Thames Operating Agreement NEP Investigation. Report prepared by Cascade Consulting.
- Thames Water (2017). Thames Tideway Drought Plan EAR. Report prepared by Cascade Consulting. *Draft*.
- Environment Agency (1997). The Water Quality of the Tidal Thames.

Figure 2.1 Water quality monitoring sites

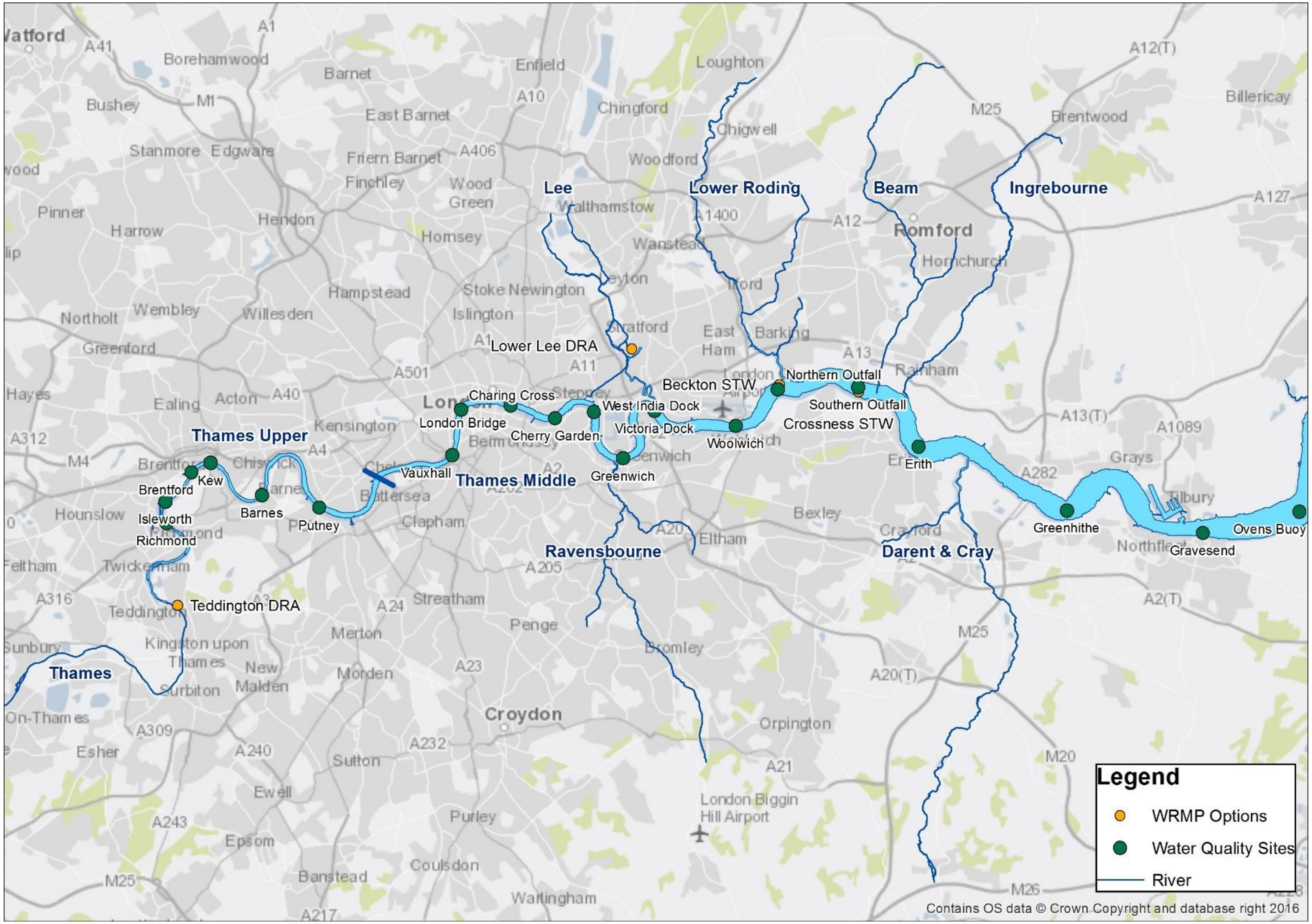


Figure 2.2 Ecological monitoring sites

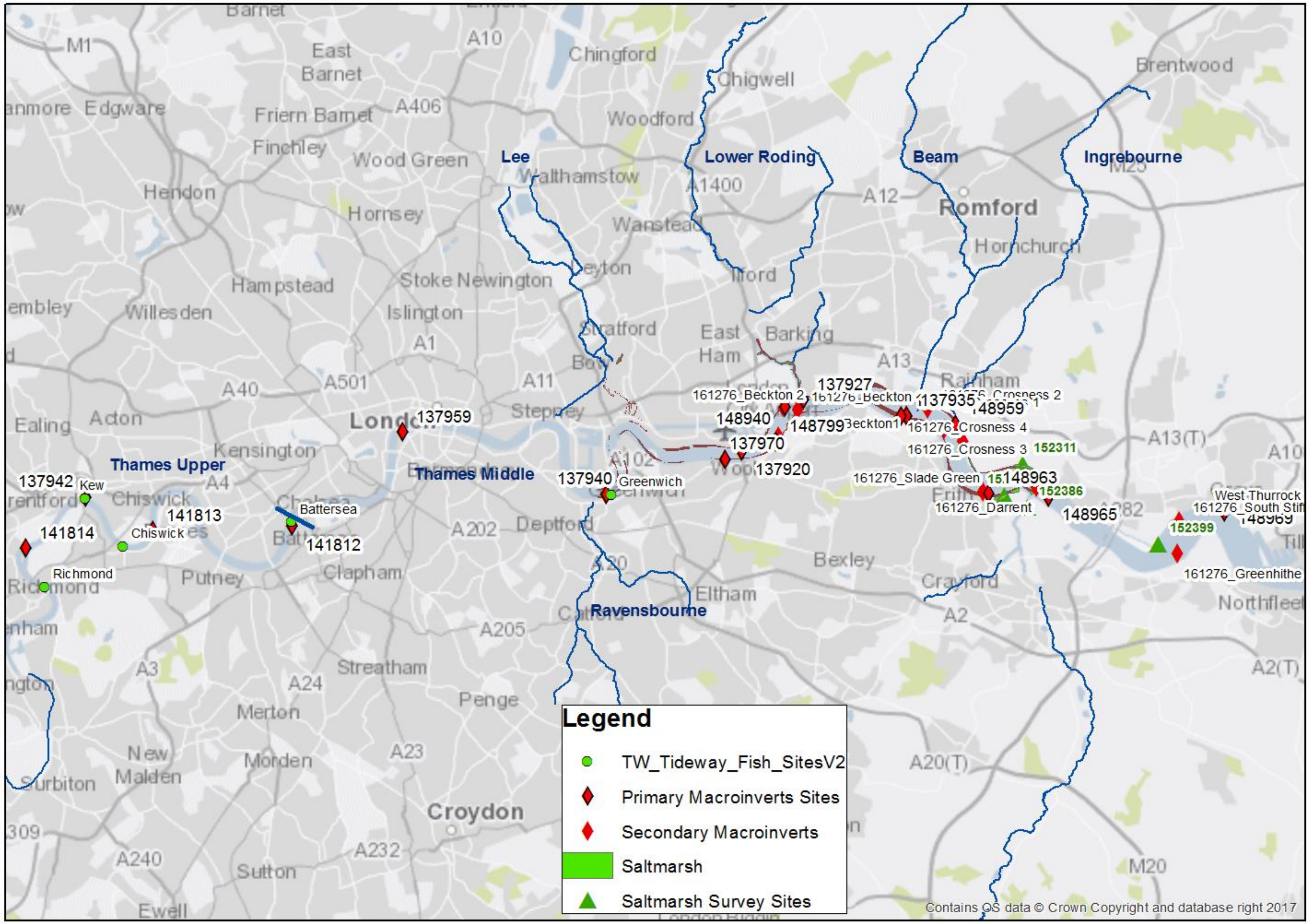
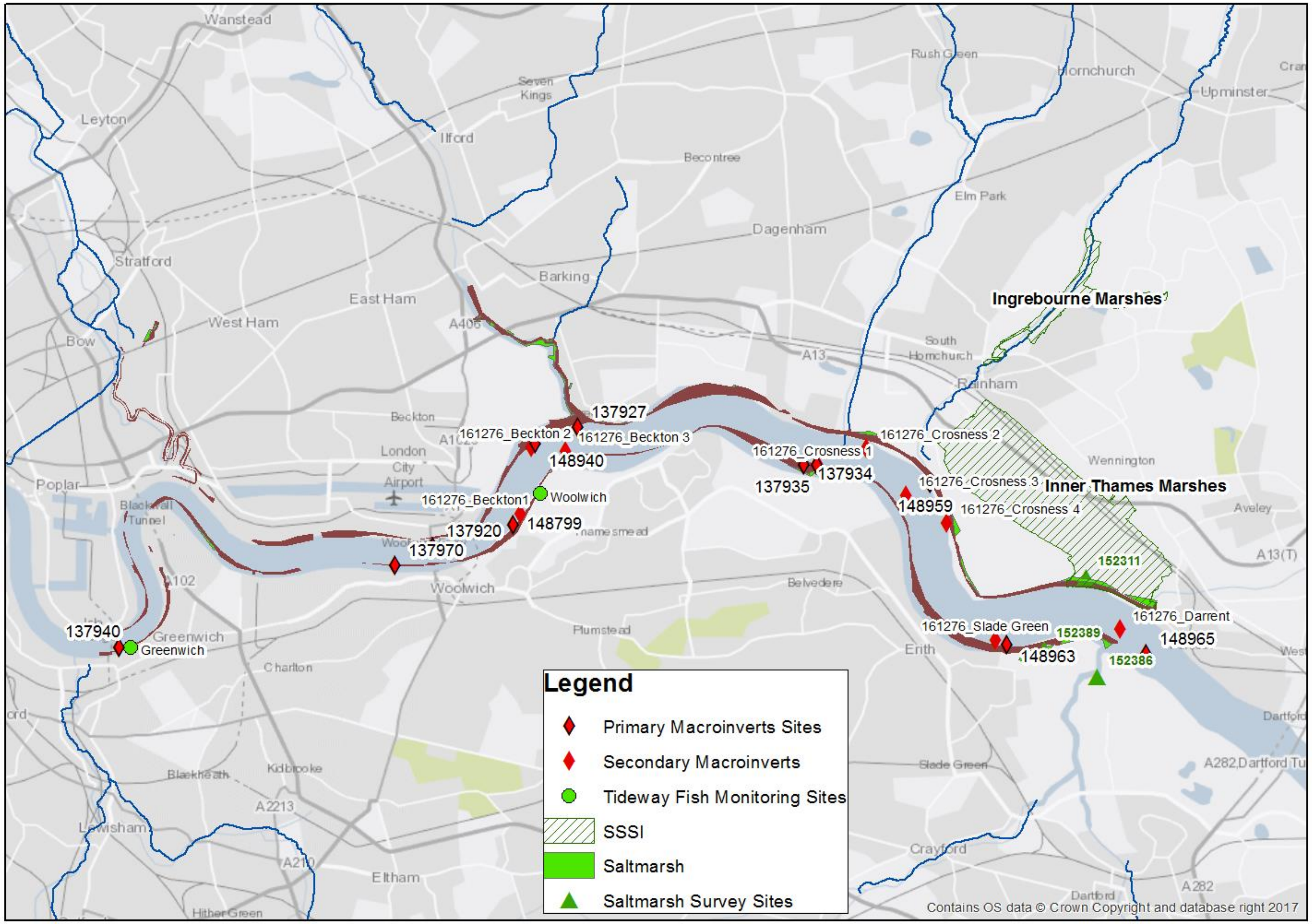


Figure 2.3 Intertidal habitats in Middle Thames around Beckton STW and Crossness STW



2.2 Baseline hydrology

As set out in **Figure 1.1** and **Table A** (**Appendix A)**, there are a number of waterbodies which require consideration in terms of hydrology.

2.2.1 Flows over Teddington Weir

Gauged low flow (Q95) at Teddington Weir (1883-2015) is 650 Ml/day[7].

Immediately below Teddington Weir the Thames is tidal. However, within the 5.6km reach between Teddington Weir and Richmond, levels are controlled at low tide by the Richmond Sluice, which is a half-tide sluice with a lock. On the outgoing (ebb) tide the sluice is closed by Port of London Authority to maintain a level of at least 1.72 metres above ordnance datum (mAOD) for navigation. Water levels downstream of Richmond Sluice remain tidally influenced. Once incoming (flood) tide levels at Richmond have risen above 1.72mAOD the sluices are raised, allowing tidal flow into the reach up to Teddington Weir.

For periods of 6-7 hours from mid-ebb tide through low tide to mid-flood tide the level is artificially maintained. Low tidal levels are not normally observed upstream of Richmond Sluice. The normally observed tidal amplitude upstream of Richmond Sluice is half that which would be expected if it was not there.

Seawards of Richmond Sluice a full tidal level regime is present.

2.2.2 Tributaries

There are a number of moderate sized tributaries in the Middle Thames waterbody, including:

- River Lee, which has a gauged Q95 flow of 285 Ml/day (with a large proportion derived from Deephams STW at low flow).
- River Roding, which has a gauged Q95 flow of 17 Ml/day
- River Beam, which has a gauged Q95 flow of 6 Ml/day
- River Ingrebourne, which has a gauged Q95 flow of 8 Ml/day
- Rivers Darent & Cray, which have a combined gauged Q95 flow of 19 Ml/day

2.2.3 Existing discharges

Excluding any discharges into freshwater rivers, final treated effluent is currently discharged into the Middle Thames from the following STW sources at the following dry weather flow values estimated by Thames Water for 2016:

- Beckton STW – 1,111 Ml/day
- Crossness STW – 494 Ml/day
- Riverside STW – 92 Ml/day

2.2.4 Existing abstractions

Excluding any abstractions from freshwater rivers, the Thames Gateway Water Treatment Plant (WTP) was first opened in 2010 and has a licence to abstract up to 200 Ml/day.

[7] Q95 (the 5 percentile flow) is the flow which was equalled or exceeded for 95% of the flow record. The Q95 flow is an important ‘low flow’ parameter particularly relevance in the assessment of river abstraction and water quality conditions.

It has been assumed that abstraction is on the ebb tide for 3 hours before seasonal cut-offs in place between 1 April and 31 August (when abstraction needs to cease 1 hour before low tide). When operated, process brine is discharged back to the Thames Tideway via the Beckton STW final effluent as a continuous release.

2.3 Water quality (salinity)

Salinity in the Thames Tideway is influenced by freshwater flow as well as tidal stage.

Spot sampling salinity data[8] across the Thames Tideway were analysed at low flow conditions, high flow conditions and all/average flow conditions (see **Figures 2.4a-c** below). In addition, local salinity conditions at the Upper Tideway (using Richmond EA site, just downstream of Teddington Weir), at Lower Lee (using Victoria Dock EA site), Beckton STW (using Northern Outfall EA site) and Crossness (using Southern Outfall EA site) have been set out against River Thames flows at Kingston (see **Figure 2.5a-2.5d**). In the absence of flow data for all tributaries and also all major inputs, River Thames flows are considered an absolute influence, but also as an indicator for flow conditions elsewhere in the catchment – as lower flows at Teddington are likely to coincide with lower flows elsewhere in the catchment, including at major tributaries STWs; and similarly higher flows at Teddington are likely to represent higher flows elsewhere in the catchment.

It is also noted that the salinity data are based on monthly spot samples taken by the EA over a 10-year period and that these have not been taken consistently at a certain tidal stage. The values reported in **Figure 2.4a** and **Table 2.2** represent averages of the measured data at each location for a specified flow condition. The flow and ebb of different salinity waters is a normal estuarine process, where the incoming tide brings in higher salinity water, which moves seaward during the outgoing tide. Without co-interpreting with tidal data, it was not possible at this point to describe salinity as a function of tidal stage (high water, low water, spring tide, neap tide).

Baseline data indicate the following:

- Under all flow conditions, salinity at Teddington Weir is low, ranging between 0.3 and 0.4 ‰ (full marine water is approximately 35 to 36 ‰).
- The salinity range at the Tidal Lee confluence (11.4 km from London Bridge) is between 0.3 and 5.7‰.
- The salinity range at Beckton (18km from London Bridge) is 0.9 and 9.3‰.
- The salinity range at Crossness (22km from London Bridge) is 0.6 to 11.6‰.
- Lower flows at Kingston coincide clearly with elevated salinity measurements at the River Lee confluence, Beckton STW and Crossness STW. The pattern of elevated salinity during periods of low flows includes both higher overall salinities (assumed at high tide) and an absence of lower salinities (assumed at low tide) although the limitations of the dataset should be noted.
- Although Figure 3.4 does not show this as clearly as Figure 3.1 in Environment Agency (1997) (see **Figure B**, **Appendix B**), near Beckton and Crossness, there is a plateau in salinity instead of a continual increase as a likely result of anthropogenic influences, notably a number of STW freshwater additions.

[8] Unless specified otherwise, all salinity values in this report are expressed as parts per thousand (ppt) or ‰

Although the data could not discern these patterns, it is our understanding from Environment Agency (1997) that:

- The tidal excursion in the middle reaches of the Thames averages 13km to 14km but the net daily seaward movement of a discrete body of water in summer is only 1 to 2km.
- At slack water, there is little difference between the salinity at the surface and near the bed.
- During the run of the tide, there is a difference between the salinity mid-channel and that near the banks.

Figure 2.4a Salinity across the Thames Tideway (using EA data 2005-2015) High and low refer to flows in the River Thames

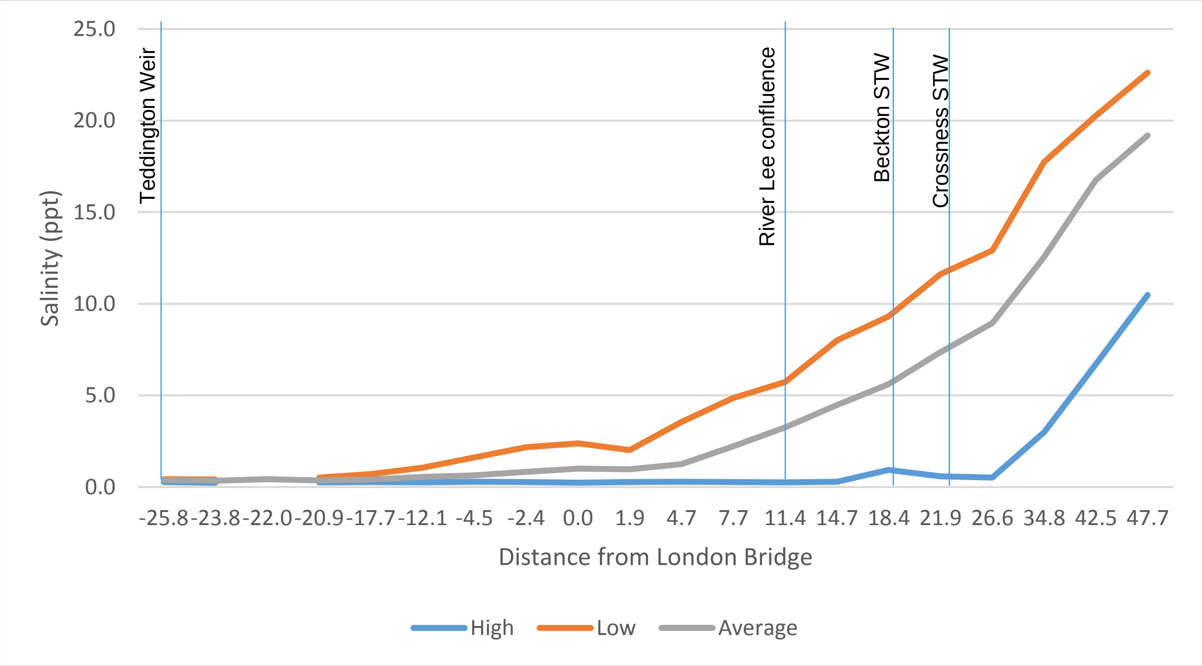


Figure 2.4b Salinity gradient across Thames Tideway at low flows (using EA spot sampling data)

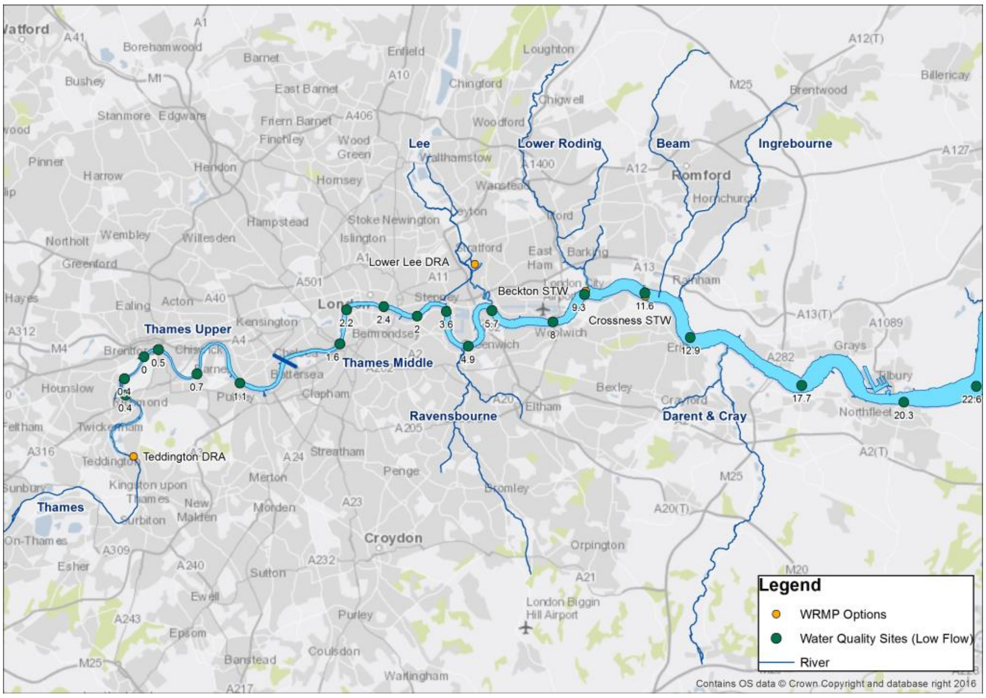


Figure 2.4c Salinity gradient across Thames Tideway at high flows (using EA spot sampling data)

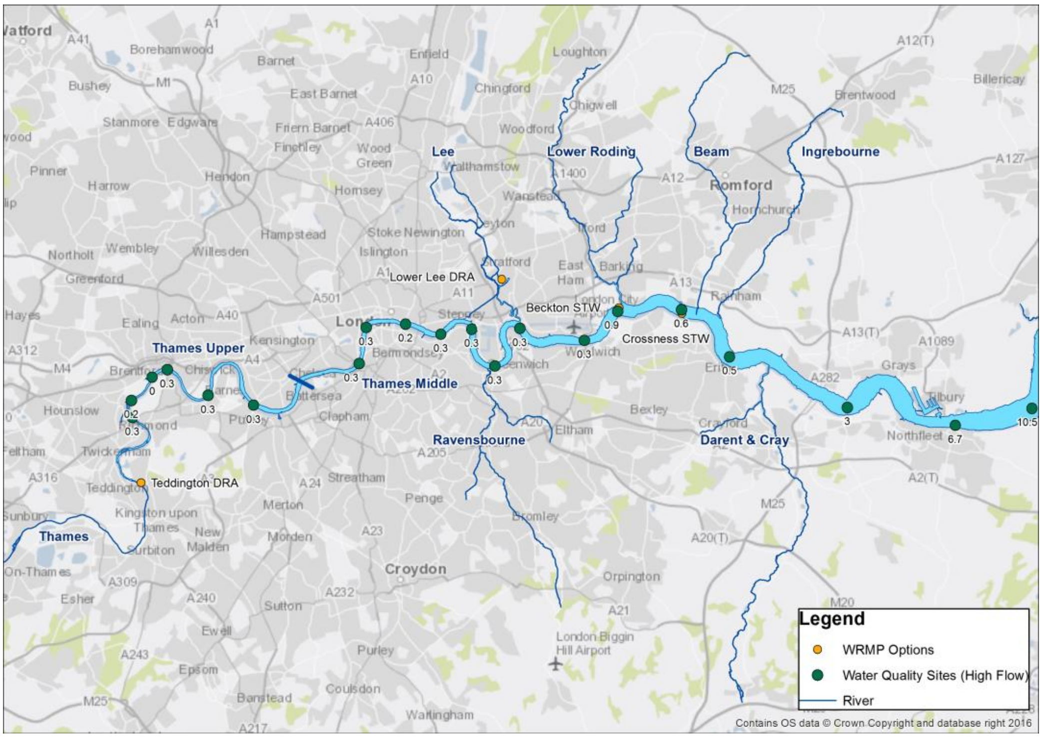


Table 2.2 Salinity across the Thames Tideway (‰) from spot sampling data

WRMP option location	Corresponding EA monitoring site	Average salinity (1)	Minimum recorded (1)	Maximum recorded (1)	Average high flow salinity (2)	Average low flow salinity (3)
Teddington	Richmond	0.4	0.2	1.3	0.3	0.4
River Lee	Victoria Dock	3.3	0.04	10.5	5.7	0.3
Beckton STW	Northern Outfall	5.6	0.2	14.7	0.9	9.3
Crossness STW	Southern Outfall	7.4	0.4	16.4	0.6	11.6

Note:
(1) all years and tidal stages, all flow conditions, 2006-2016
(2) all years and tidal stages, high flow conditions, 2006-2016
(3) all years and tidal stages, low flow conditions (Q95), 2006-2016

Figure 2.5a Freshwater flow at Teddington (blue) compared to salinity just downstream of Teddington Weir (Richmond) (amber), red line indicates Q95 flow value for Kingston

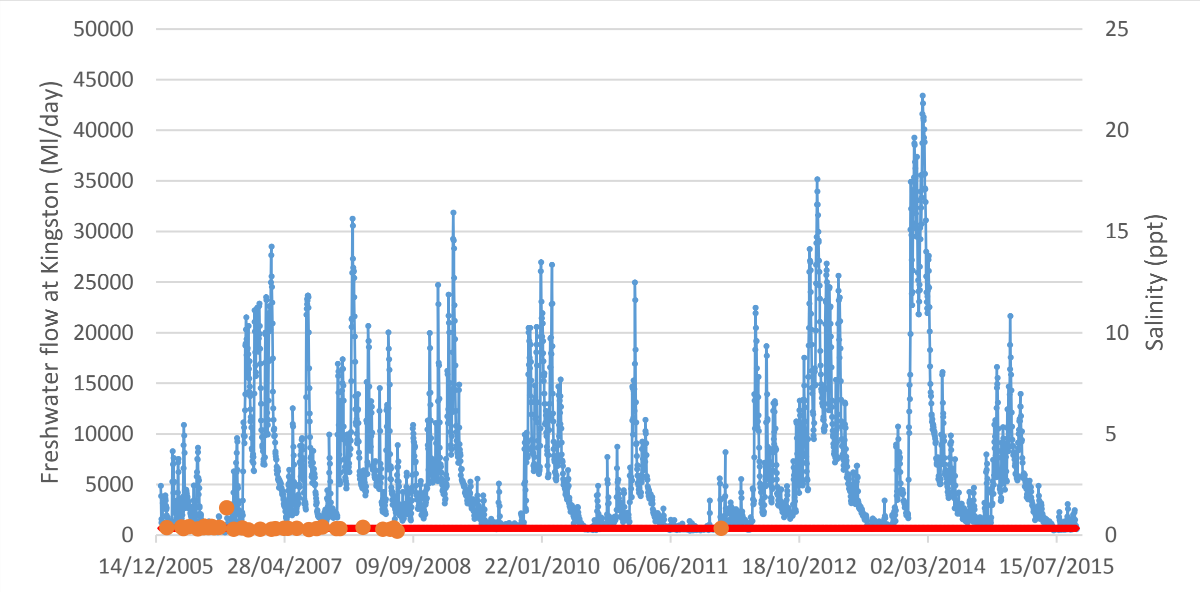


Figure 2.5b Freshwater flow at Teddington (blue) compared to salinity at River Lee (Victoria Dock) (amber), red line indicates Q95 flow value for Kingston

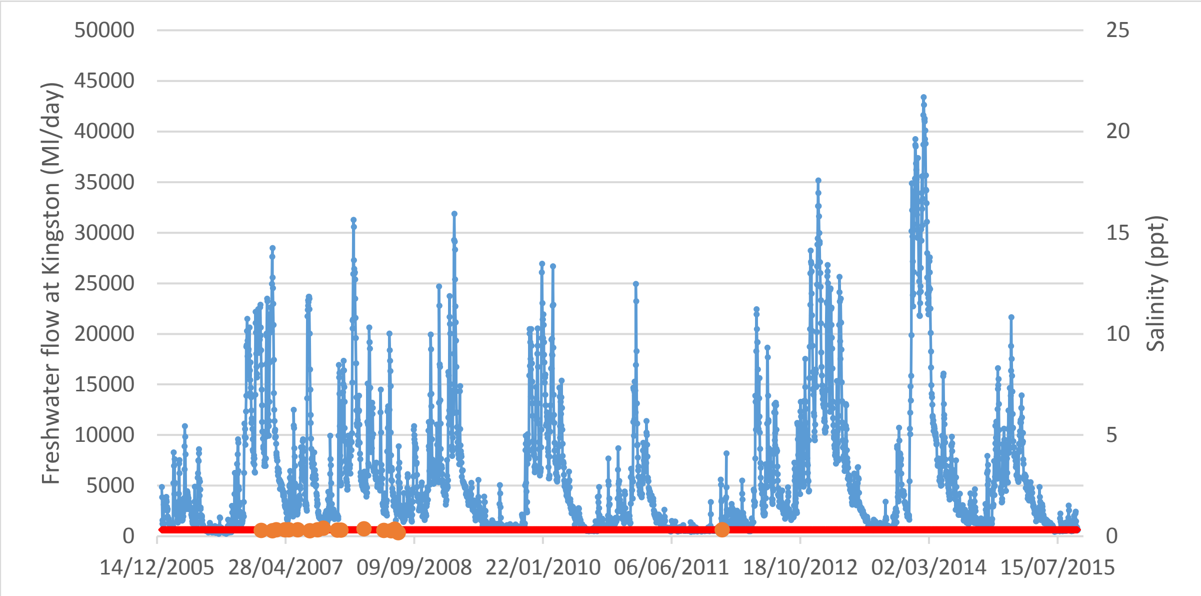


Figure 2.5c Freshwater flow at Teddington (blue) compared to salinity near Beckton STW (Northern Outfall) (amber), red line indicates Q95 flow value for Kingston

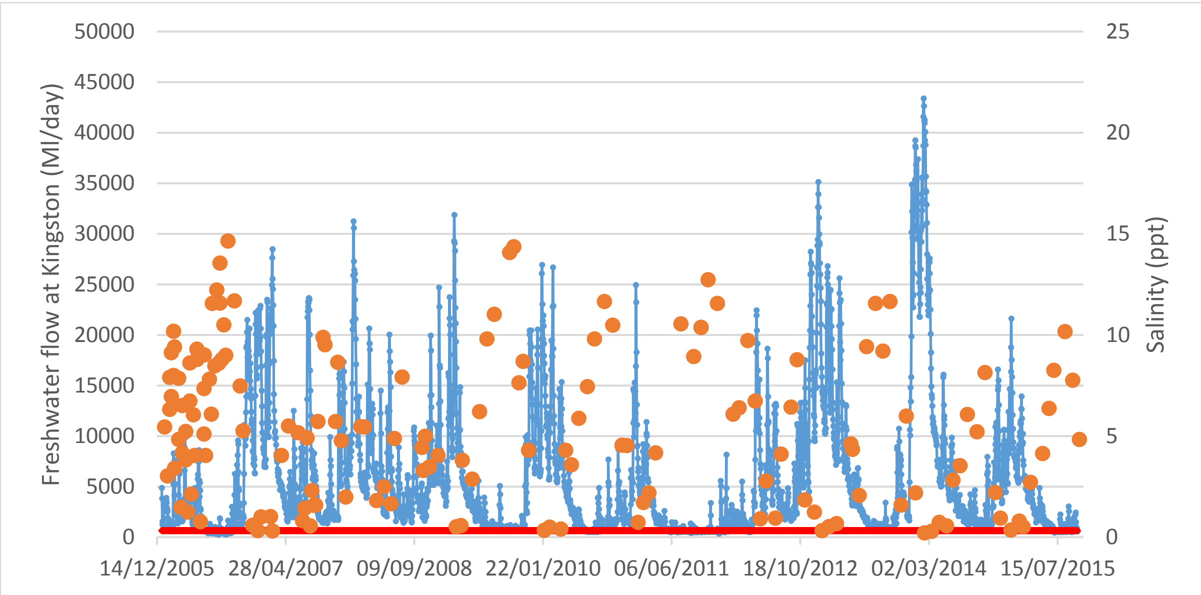
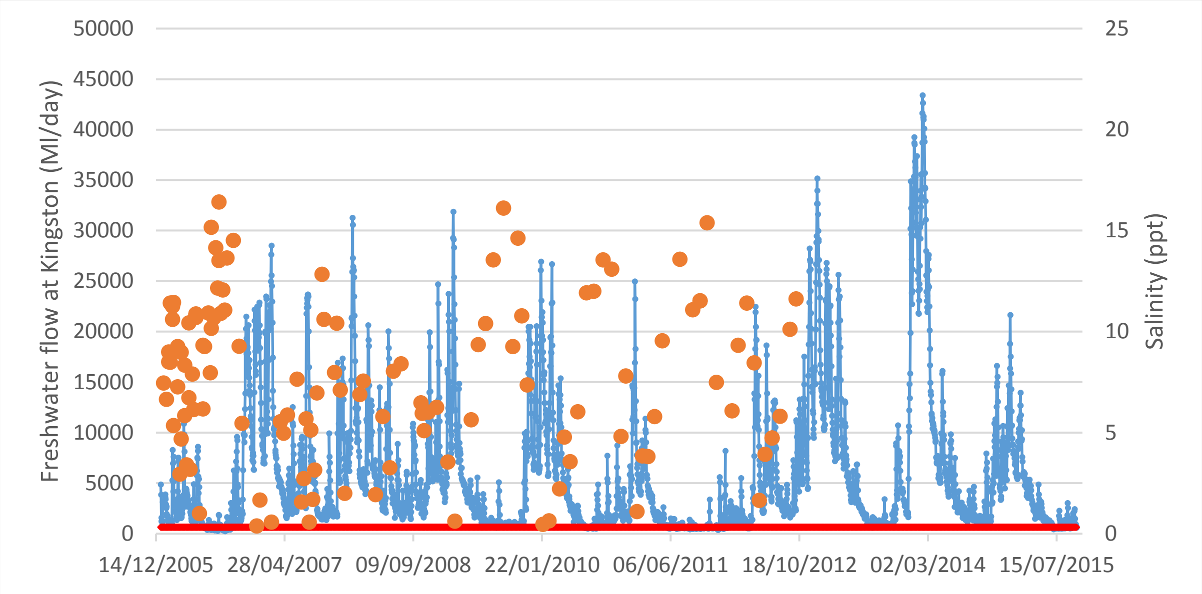


Figure 2.5d Freshwater flow at Teddington compared to salinity near Crossness STW (Southern Outfall), red line indicates Q95 flow value for Kingston


Freshwater flow at Kingston (Ml/day)
Salinity (ppt)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
25
20
15
10
5
0
14/12/2005
28/04/2007
09/09/2008
22/01/2010
06/06/2011
18/10/2012
02/03/2014
15/07/2015

2.4 Designated sites and habitats

The Thames Tideway has not received any statutory designation (e.g. Special Area of Conservation (SAC), Special Protection Area (SPA), Site of Special Scientific Interest (SSSI), etc.). It has a local designation as a Site of Metropolitan Importance for Nature Conservation (SMINC) and is proposed as a Marine Conservation Zone (pMCZ). The cover of potentially sensitive intertidal habitats such as mudflats and saltmarsh is generally low within the Upper and Middle Tideway.

2.4.1 Thames Estuary Proposed Marine Conservation Zone (pMCZ)

A proposal for a Thames Estuary Marine Conservation Zone is currently being considered[9]. The proposed site extends along the greater part of the tidal River Thames from Richmond to the estuary mouth at Southend-on-Sea, and is designed to protect different species and habitats along distinct stretches of the river. As a whole, the site is considered to be an important spawning and nursery ground for various fish species, particularly European Smelt (*Osmerus eperlanus*) and European Eel (*Anguilla anguilla*). There are known Smelt spawning habitats present above the proposed Crossness Desalinisation plant site. A geographically restricted but important population of Tentacled Lagoon Worm (*Alkmaria romijni*) occurs at Greenhithe (downstream of both Beckton and Crossness STW). The proposed MCZ partially overlaps the Benfleet and Southend Marshes Ramsar site, the South Thames Estuary & Marshes Site of Special Scientific Interest (SSSI) and the Thames Estuary & Marshes Special Protected Area (SPA). The site will also completely contain the Holehaven Creek SSSI.

2.4.2 Thames Tideway SMINC

The tidal Thames and its tributaries comprise a Site of Metropolitan Importance for Nature Conservation (SMINC)[10], site reference M031. The Thames and its tidal tributaries provide the following valuable habitats; mud-flats, shingle beach, islands, river-channel and inter-tidal macroalgae - which are not to be found elsewhere in London. The SMINC has been designated for fish, wintering birds, marine invertebrates and as a green corridor.

2.4.3 Intertidal mudflats

Data obtained from the European Marine Observation Data Network, alongside the WFD Sensitive Habitat layers (valuable on the Magic Map Application[11]) indicates that the intertidal habitat of the Middle Thames Tideway waterbody consists mostly of littoral mudflats (LS.LMu). The extent of this habitat in the Middle Tideway is displayed in **Figure 2.3** and has been estimated to be approximately 3,153,123m^2 in the area two kilometres upstream and two kilometres downstream of Beckton STW and Crossness STW.

Littoral mud habitats consist of two main biotope complexes which include polychaete/bivalve–dominated mid estuarine mud shores (LS.LMu.MEst) and polychaete/oligochaete–dominated upper estuarine mud shores (LS.LMu.UEst). These two biotope complexes are split by position in the estuary, specifically regarding the salinity regime. Mid-estuarine shores of fine sediment are mostly in the silt and clay fraction (particle size less than 0.063 mm in diameter), although sandy mud may contain up to 40% sand (mostly very fine and fine sand). Most mid

[9] DEFRA (2013). Marine Conservation Zones: Consultation on proposals for designation in 2013 Annex A.3 – Balanced Seas sites requiring further consideration. (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/82726/mcz-annex-a3-121213.pdf)
[10] London Borough of Tower Hamlets (2016). SINC Citations April 2016. Accessed October 2016 from http://www.towerhamlets.gov.uk/Documents/Environmental-protection/SINCcitationsApril2016.pdf
[11] http://magic.defra.gov.uk/MagicMap.aspx

estuarine muddy shores are subject to some freshwater influence, though at some locations more marine conditions may prevail. Mid estuarine muds support rich communities characterised by polychaetes, bivalves and oligochaetes.

Intertidal mudflats are considered a NERC Act 2006 Section 41 Priority Habitat, however, due to extensive modification, the habitats in the Middle Thames Tideway do not meet the description of intertidal mudflats as described by the UK Biodiversity Action Plan (BAP) group.

2.4.4 Saltmarsh

Data obtained from the European Marine Observation Data Network, alongside the WFD Sensitive Habitat layers (valuable on the Magic Map Application[12]) indicates that the intertidal habitat of the Middle Thames comprises a small extent of Saltmarsh habitat (LS. LMp. Sm). The extent of this habitat in the Middle Thames Tideway is displayed in **Figure 2.3** and has been estimated to be approximately 311,334m^2 in the area two kilometres upstream and two kilometres downstream of Beckton STW and Crossness STW.

Data from four monitoring sites in the Middle Tideway have been reviewed for macrophyte species. These four sites are located downstream of the Crossness STW discharge (see **Figure 2.3**), with three sites (15286, 15289 and 152311) located in the immediate vicinity of the confluence of the River Darent and the Thames (Dartford Creek). The fourth site (152399) is located downstream of this confluence at West Thurrock. The species composition of the four sites differs slightly.

Site 152311 (north bank, in front of Inner Thames Marshes SSSI) was dominated by *Plantago maritima, Triglochin maritima* and *Aster tripolium*.

Site 152389 (south bank, just upstream of River Darent) was heavily dominated by *Bolboschoenus maritimus, Elytrigia atherica* and *Phragmites australis*.

Site 152386 (south bank, on River Darent) appeared to have a higher species diversity, with less dominance by the species *Triglochin maritima* and *Puccinellia maritima*.

The farthest downstream site (**Site 152399**, north bank just d/s of Dartford Tunnel at Thurrock) further differed from the upstream sites, with a community comprised of mainly the following species: *Atriplex portulacoides*, *Triglochin maritima* and *Puccinellia maritima*.

The full species list, including percentage cover, from the most recent (201) survey of these sites is found in Appendix D.

Concentration of this habitat is centred on the Middle Thames Tideway, extending as far upstream as North Greenwich Pier. The greatest density of this habitat is understood to be located within the tidal creeks of the Middle Thames Tideway, such as Barking Creek (River Roding) and the Dartford Creek (River Darent).

The character of the saltmarsh communities is affected by height up the shore, resulting in a zonation pattern related to the degree or frequency of immersion in seawater. The saltmarshes associated with the Thames Tideway are mostly governed by marine and tidal processes, and the development of saltmarsh vegetation is dependent on the presence of intertidal mudflats. Sediment grain size is of particular importance to saltmarsh communities and as such, can be sensitive to changes in sediment transport and nutrient availability.

[12] http://magic.defra.gov.uk/MagicMap.aspx

Areas with high structural and plant diversity, particularly where freshwater seepages provide a transition from fresh to brackish conditions, are particularly important for invertebrates and these upper parts of the saltmarsh can be sensitive to salinity changes.

Saltmarsh plants themselves live inhabit an environment hostile to terrestrial plants and are tolerant of fluctuating salinity, especially at the lower shore[13]. Consequently, these habitats have a **Very Low** sensitivity to salinity changes.

2.5 Estuarine ecology

This section considers fish, benthic macroinvertebrates recorded in the Upper and Middle Thames Tideway.

As part of the designated and notable species analysis, all species lists were compared against NERC Act 2006 Section 41 species lists, as derived from the November 2016 Conservation Designation Spreadsheet, as published by the Joint Nature Conservation Committee (JNCC)[14].

Additional analysis was undertaken for fish and selected macroinvertebrate species. For fish, although most species are 'brackish' or 'estuarine' and generally well adapted to changes in salinity, there is evidence of individual species having preferences to certain salinity conditions, e.g. very low or low salinity species. As several fish species use the Thames Tideway as a breeding ground, this is particularly relevant for some juvenile life stages. The additional analysis for macroinvertebrate species focused on the salinity sensitivity of the most abundant taxa to determine potential changes in community composition.

2.5.1 Fish

Both the Upper Thames and Middle Thames TraC WFD waterbodies have been identified as being of good ecological potential for fish in RMBP2.

Table 2.3 lists the average abundance of each species recorded in the different reaches of the Upper and Middle Thames Tideway between 2011 and 2015, for both Spring (S) and Autumn (A) surveys. These data have been provided by the Environment Agency as part of a data request. **Figure 2.2** shows the location of the four Upper (Richmond, Kew, Chiswick and Battersea) and three Middle Thames Tideway Fish monitoring sites (Greenwich, Woolwich and West Thurrock). The Greenwich monitoring site is located 3.4 kilometres upstream of the confluence with the tidal River Lee and approximately 10 kilometres upstream of Beckton sewage treatment works (STW). The Woolwich monitoring location is situated approximately 1.8 km upstream of the Beckton STW. West Thurrock is situated considerably downstream of the other two fish monitoring sites, approximately 8.3 kilometres downstream of the Dartford Creek (Crossness STW and River Darent confluence).

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[13] Tyler-Walters, H. (2001). Saltmarsh (pioneer). In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/25

[14] Accessed May 2016 from: http://jncc.defra.gov.uk/page-3418

Table 2.3 Showing fish species and average abundance recorded in the Thames during bi-annual surveys at nine sites from the Upper and Middle Tideway between 2011 and 2015 (see Table 2.4 below for explanation of guilds). Species highlighted in **bold** rely on the estuarine environment of the tideway for either spawning or nursery habitat. Shading signifies separate guilds

						Upper Thames Tideway				Middle Thames Tideway		
Species		Guild	Sensitivity – juvenile	Sensitivity-Spawning	Season caught	Richmond	Kew	Chiswick	Battersea	Greenwich	West Thurrock	Woolwich
3-spined stickleback	***Gasterosteus aculeatus***	DA	**Yes**	**Yes**	A	2	3	2	2	2	1	1
					S	1	1	-	4	1	-	-
Brown / sea trout[15]	***Salmo trutta***		**Yes**	**No**	A	1	-	-	-	-	-	-
					S	1	-	1	-	-	-	-
European eel	***Anguilla***		**Yes**	**NA**	A	1	1	2	1	3	1	1
					S	1	8	1	1	2	-	-
European Smelt	***Osmerus eperlanus***		**Yes**	**Yes**	A	-	-	2	5	3	1	44
					S	1	2	31	3	2	1	-
Common goby	***Pomatoschistus microps***	ER	**NA**	**Yes**	A	5	-	-	6	2	29	9
					S	-	-	-	-		2	
Flounder	***Platichthys flesus***		**Yes**	**No**	A	3	8	9	10	7	7	128
					S	20	22	16	79	4	2	-
Hooknose / Pogge	*Agonus cataphractus*		NA	NA	A	-	-	-	-	1	1	2
					S	-	-	-	-	-	1	-
Sand goby	***Pomatoschistus minutus***		**Yes**	**No**	A	-	1	2	-	2	4	156
					S	-	-	-	-	-	-	-
Bleak	*Alburnus*	FW	**NA**	NA	A	-	20	2	-	-	-	-
					S	1	1	3	1	-	-	-
Bullhead	*Cottus gobio*		**NA**	Yes	A	2	3	-	-	-	-	-
					S	1	2	1	-	-	-	-
Chub	*Leuciscus cephalus*		NA	NA	A	-	-	-	-	-	-	-
					S	5	1	-	1	1	-	-
Common bream	*Abramis brama*		NA	NA	A	2	4	2	31	13	1	-
					S	2	2	1	2	3	-	-
Dace	***Leuciscus***		**NA**	**NA**	A	333	20	14	3	1	-	-
					S	111	33	12	4	1	-	-
Gudgeon	*Gobio*		NA	NA	A	11	1	-	-	-	-	-
					S	-	-	-	-	-	-	-

[15] Sea trout is the common name usually applied to anadromous (or sea-run) forms of brown trout.

						Upper Thames Tideway				Middle Thames Tideway		
Species		Guild	Sensitivity – juvenile	Sensitivity- Spawning	Season caught	Richmond	Kew	Chiswick	Battersea	Greenwich	West Thurrock	Woolwich
Minnow	*Phoxinus phoxinus*		NA	NA	A	-	-	-	-	-	-	-
					S	3	-	-	-	-	-	-
Mirror carp	*Cyprinus carpio*		NA	NA	A	-	-	-	-	-	-	-
					S	1	-	-	-	-	-	-
Perch	***Perca fluviatilis***		**Yes**	**Yes**	A	2	4	-	-	1	-	2
					S	2	3	1	1	2	-	-
Pike	*Esox lucius*		NA	NA	A	-	-	-	-	-	-	-
					S	-	-	-	-	1	-	-
Roach	***Rutilus rutilus***		**NA**	**Yes**	A	42	6	1	19	1	-	-
					S	3	24	1	2	1	-	-
Roach x common bream hybrid	*Rutilus rutilus x Abramis brama*		NA	NA	A	-	-	-	10	1	-	-
					S	-	-	-	-	-	-	-
Rudd	*Scardinius erythrophthalmus*		NA	NA	A	1	-	-	-	-	-	-
					S	-	-	-	1	-	-	-
Zander	*Sander lucioperca*		NA	NA	A	-	-	-	1	1	-	-
					S	-	-	-	-	-	-	-
Butterfish	*Pholis gunnellus*		NA	NA	A	-	-	-	-	-	1	-
					S	-	-	-	-	-	-	-
Dab	*Limanda limanda*		NA	NA	A	-	-	-	-	-	-	1
					S	-	-	-	-	-	1	-
Golden goby	*Gobius auratus*		NA	NA	A	-	-	-	-	1	-	-
					S	-	-	-	-	-	-	-
Grey mullet sp.	*Mugilidae*		NA	NA	A	-	-	-	-	-	1	-
					S	-	-	-	-	-	-	-
Painted goby	*Pomatoschistus pictus*	MA	NA	NA	S	-	-	-	-	-	-	5
					A	-	-	-	-	-	-	-
Plaice	***Pleuronectes platessa***		**Yes**	**No**	A	-	-	-	-	-	1	-
					S	-	-	-	-	-	2	-
Pouting / Bib	***Trisopterus luscus***		**Yes**	**NA**	A	-	-	-	-	-	-	2
					S	-	-	-	-	-	-	-
Red mullet	*Mullus surmuletus*		NA	NA	A	-	-	-	-	-	-	6
					S	-	-	-	-	-	-	-
Short-snouted sea horse	***Hippocampus hippocampus***		**Yes**	**NA**	A	-	-	-	-	1	-	-
					S	-	-	-	-	-	-	-

Species		Guild	Sensitivity – juvenile	Sensitivity-Spawning	Season caught	Upper Thames Tideway: Richmond	Upper Thames Tideway: Kew	Upper Thames Tideway: Chiswick	Upper Thames Tideway: Battersea	Middle Thames Tideway: Greenwich	Middle Thames Tideway: West Thurrock	Middle Thames Tideway: Woolwich
Thornback ray / Roker	*Raja clavata*		NA	NA	A	-	-	-	-	-	-	2
					S	-	-	-	-	-	-	-
Transparent goby	*Aphia minuta*		NA	NA	A	-	-	-	-	-	5	-
					S	-	-	-	-	-	-	-
Tub gurnard	*Trigla lucerna*		NA	NA	A	-	-	-	-	-	-	1
					S	-	-	-	-	-	-	-
Cod	***Gadus morhua***		No	No	A	2	-	-	-	-	-	-
					S	-	-	-	-			
Whiting	***Merlangius merlangius***		**Yes**	**No**	A	-	-	-	-	-	-	11
					S	-	-	-	-	-	-	-
Sand smelt	*Atherina presbyter*	MJ	?	?	A	1	2	-	2	6	3	-
					S	-	-	-	-	-	-	-
Sea bass	***Dicentrarchus labrax***	MJ	**Yes**	**No**	A	6	44	11	2	10	11	1
					S	-	1	1	2	5	17	-
5-bearded rockling	*Ciliata mustela*	MS	?	?	A	-	-	-	-	-	5	-
					S	-	-	-	-	-	-	-
Dover sole	***Solea solea***	MS	**Yes**	**Yes**	A	-	-	-	-	1	2	132
					S	-	-	-	-	-	5	-
Herring	***Clupea harengus***	MS	**Yes**	**No**	A	-	-	-	-	5	1	7
					S	-	-	-	-	2	19	-
Sprat	***Sprattus sprattus***	MS	**Yes**	**No**	A	-	-	2	-	18	9	8
					S	-	-	-	-	-	7	-
Thin lipped grey mullet	***Liza ramada***	MS	**Yes**	**No**	A	-	-	1	-	-	3	-
					S	-	-	-	-	-	2	-

Those species highlighted in bold in **Table 2.3** (species which rely on the estuarine environment of the tideway for either spawning or nursery habitat) have been further assessed for sensitivity to changes in salinity, using data from available literature. These sensitivities have been categorised in **Table 2.3** as; Sensitivity – Juvenile (referring to the species use of estuarine waters as nursery habitat) and Sensitivity –Spawning (referring to the use of the estuarine environment for spawning). The use of estuarine waters for both these purposes is governed by environmental cues, such as temperature, light and salinity. As such, a change in the salinity regime/ mixing characterises of an estuary could result in local changes in usage by these species.

Of the species listed in **Table 2.4**, the following are all recorded as using estuaries as nursery habitat for juveniles; three-spined stickleback[16] (*Gasterosteus aculeatus*), European eel[17] (*Anguilla anguilla*), smelt[18] (*Osmerus eperlanus*), flounder[19] (*Platichthys flesus);* sand goby (*Pomatoschistus minutus);* perch[20] (*Perca fluviatilis);* plaice[21] *(Pleuronectes platessa);* whiting[22] (*Merlangius merlangus*)*;* sea bass[23] *(Dicentrarchus labrax); Dover sole[24] (Solea solea),* herring[25] *(Clupea harengus);* sprat[25] *(Sprattus sprattus);* thin lipped grey mullet *(Liza ramada),* pouting/bib[26] (*Trisopterus luscus*) and the short snouted seahorse[26] (*Hippocampus* hippocampus). Although not recorded in the data presented in **Table 2.3**, Cod (*Gadus morhua*) are also known to use the Lower Thames Tideway as nursery grounds[26].

For some catadromous species, spawning in the full salinity of coastal waters (such as flounder) and the ability of juveniles to reach the correct (low salinity) estuarine nursery grounds is dependent on selective tidal transport, and it is suggested that salinity is an abiotic parameter which may govern larval / juvenile transport[27]. As such, upstream migration of the saline intrusion distance and increased salinity of lower estuary waters may impact on juvenile migration through removal or alteration of environmental cues. The data presented in **Table 2.3** indicates that the Middle Tideway is of particular nursery importance to juvenile Dover sole.

Of the species listed in **Table 2.4**, the following are all recorded as using estuaries as spawning grounds; three-spined stickleback[28]; Common goby (*Pomatoschistus microps* in the upper tideway); sand goby; roach (*Rutilus rutilus),* dace (*Leuciscus leuciscus*); smelt[18]; perch[29]; flounder[26]; *Dover sole* and whiting[26] .

Changes to salinity may impact on breeding success and fish growth[26]. For example, salinity tolerance of eggs has been shown to vary with temperature in *G. aculeatus*, and has been determined to be between 3.3 parts per thousand (‰) and 16 ‰ at 10ºC[16]. Perch are known to spawn in estuarine environments with an approximate salinity of ~9.6 ‰ [29], as such, spatial change in the salinity of the mid-tideway may result in an upstream shift of spawning location. For catadromous and anadromous species, estuarine salinity (governed in part, in natural

[16] Wootton R.J. (1976). The Biology of Sticklebacks. Academic Press, London, 387 pp.
[17] Crean, S. R., Dick, J. T. A., Evans, D. W., Rosell, R. S. and Elwood, R. W. (2005). Survival of juvenile European eels (*Anguilla anguilla*), transferred among salinities, and developmental shifts in their salinity preference. Journal of Zoology, 266: 11–14.
[18] Maitland, P. S. & Nature, E. (2003). The status of smelt *Osmerus eperlanus* in England. English Nat. Res. Reports 516, 83
[19] Gibson, R. N. (1997). Behaviour and the distribution of flatfishes. J. Sea Res. 37, 241–256
[20] Kottelat, M. & Freyhof, J. (1972). Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, Berlin. 646 pp.
[21] Ellis, J. R., Milligan, S. P., Readdy, L., Taylor, N. & Brown, M. J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep. 147, 56pp
[22] Henderson, P.A. and Holmes, R.H.A. (1989). Whiting migration in the Bristol Channel: A predator-prey relationship. Journal of Fish Biology, 34: 409–416.
[23] http://www.fao.org/fishery/culturedspecies/Dicentrarchus_labrax/en
[24] Claridge, P.N. & Potter, I.C. (1987). Size composition and seasonal changes in abundance of juvenile sole, *Solea solea*, in the Severn Estuary and Inner Bristol Channel. Journal of the Marine Biological Association of the United Kingdom, 67: 561–569.
[25] Power, M., Attrill, M. J. & Thomas, R. M. (2000). Temporal abundance patterns and growth of juvenile herring and sprat from the Thames estuary 1977–1992. Journal of Fish Biology, 56: 1408–1426.
[26] ZSL (2017). Fish, T. T. & Process, P. Guidance Document Conservation of Tidal Thames Fish through the Planning Process. 1–20 (2016).
[27] Gibson, R. N. (1997). Behaviour and the distribution of flatfishes. J. Sea Res. 37, 241–256.
[28] Wootton R.J. (1976). The Biology of Sticklebacks. Academic Press, London, 387pp.
[29] Skovrind, M., Christensen, E. A. F., Carl, H., Jacobsen, L. & Møller, P. R. (2013). Marine spawning sites of perch Perca fluviatilis revealed by oviduct-inserted acoustic transmitters. *Aquat. Biol.* **19,** 201–206,

systems, by discharge and magnitude of tidal mixing) is understood to be one of several environmental cues associated with migration (upstream or downstream) for spawning[30].

From all of the species recorded, European smelt, European eel, Brown trout, Dover sole, plaice, herring, and whiting and European bullhead are all NERC Section 41 species. The very high number of (juvenile) Dover sole caught at the Woolwich site in the autumn surveys is of note, alongside high numbers of European smelt and flounder. Comparatively few Whiting and Herring were caught, with Whiting being only encountered at Woolwich. European eel were observed most often at the Greenwich Monitoring site. Very low numbers of brown trout have been caught in the period assessed (2011-2015). The distribution of catch of European bullhead shows no records downstream of the Chiswick sampling site.

European eel (*Anguilla anguilla*) is a catadromous species which migrates from freshwater to spawn in the open ocean (and as such, spawning sites are not dependent on estuaries). This species has several juvenile stages, and reaches UK estuaries such as the Thames tideway as a glass eel, which have preferences for fully saline (35 ‰) waters. The species then develops a tolerance for salinity fluctuation as individuals mature in estuarine environments. However, as these individuals mature to fully pigmented elvers (after approximately 9 weeks), this tolerance is lost and increased mortality ensues if exposed to fully saline waters. A large increase in salinity within an estuary during the elver stage could be detrimental to eel recruitment. The European eel has also been classified as “Critically Endangered” on the International Union for Conservation of Nature (IUCN) Red List.

European smelt (*Osmerus eperlanus*) is found in coastal waters, however it is mainly distributed in estuaries. The species is anadromous and migrates into large clean rivers at spawning time. Estuaries are considered of great importance to Smelt, as both feeding grounds and a nursery habitat for juveniles[31]. This species spawns in tributaries of lakes or along shallow shores of lakes and rivers on sand, gravel, stones and plant material, preferably in fast-flowing water[32]. Monitoring of this species in the Thames tideway has been extensive, and indications are that the stock spawns in a location in the Upper Tideway, above Battersea Park[31,26]. As such, the species is considered sensitive to spatial variations in estuarine salinity, which may shift the spawning location.

Dover sole (*Solea solea*) is known to spawn in the eastern channel[21], and there are records of the species spawning within the Lower and mid Thames tideway[26]. The high number of juveniles using the mid tideway as nursery grounds also indicate potential sensitivity of this species to salinity variations. Viability of Dover sole eggs, in the context of estuarine salinity fluctuation, is considered high- with evidence for a salinity range of between 20 ‰ and 40 ‰, although higher salinities interfere with the hatching process and lower salinities slow development[33].

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[30] Audet, C., Fitzgerald, G. J. and Guderley, H. (1986). Environmental control of salinity preferences in four sympatric species of sticklebacks: Gasterosteus aculeatus, Gasterosteus wheatlandi, Pungitius pungitius and Apeltes quadracus. Journal of Fish Biology, 28: 725–739.

[31] Maitland, P. S. & Nature, E. (2003). The status of smelt *Osmerus eperlanus* in England. English Nat. Res. Reports 516, 83

[32] Rochard, E. & Elie, P. (1994). La macrofaune aquatique de l'estuaire de la Gironde. Contribution au livre blanc de l'Agence de l'Eau Adour Garonne. p. 1-56. In J.-L. Mauvais and J.-F. Guillaud (eds.) État des connaissances sur l'estuaire de la Gironde. Agence de l'Eau Adour-Garonne, Éditions Bergeret, Bordeaux, France. 115 p

[33] Fonds, M. (1979). Laboratory Observations on the Influence of Temperature and Salinity on Development of the Eggs and Growth of the Larvae of Solea solea. Mar. Ecol. Prog. Ser. 1, 91–99.

Herring (*Clupea harengus*) is known to spawn in the outer Thames Estuary[21], and use the tideway as nursery grounds[24,26]. Spawning has been recorded in this species between 5 ‰ and 35 ‰ and the salinity tolerance of the juvenile is understood to be wider than that of the adult[34].

European plaice (*Pleuronectes platessa*) are understood to utilise the Thames Tideway as nursery habitat for juveniles. Juvenile plaice are strongly habitat specific during early life stages, displaying preference for soft sediments in very shallow waters. The surface-water salinity in shallow (0–1 metres) acceptable nursery grounds is required to fluctuate between 14 and 24 practical salinity unit (‰), however, extremes of 0 ‰ (heavy land runoff) and 30 ‰ (up-welling) occur occasionally[35]

Whiting (*Merlangius merlangus*) is a marine species that utilises estuarine habitats and other coastal waters as nursery grounds[36]. This species is believed to spawn in the outer Thames estuary[26]. As a euryhaline, estuarine opportunist, the larval stages of this species are understood to enter the estuarine environment in month immediately post spawning (i.e. June and July) and have been shown to emigrate from estuarine environments in winter months, or earlier in conjunction with heavy river discharge[37] . This shows a preference for higher salinity conditions within the estuarine environment.

Of the freshwater species identified **within Table 2.3,** the highest abundances are observed in the catch of Dace from Richmond (333 average during autumn surveys). Overall, higher numbers of flounder are encountered in the Upper Tideway sites than in the Middle Tideway (apart from at the Woolwich Site in Autumn). **Table 2.3** indicates that the highest abundances of estuarine fish species appear to be caught at the Woolwich monitoring site during the Autumn survey. The highest diversity of species within the DA, FW and ER guild types (i.e. predominately freshwater and estuarine species) appears to be at the Greenwich monitoring location. Diversity of marine species with no estuarine requirement (MA guild) was distributed evenly across the three sites.

In terms of commercial and recreational angling fish, the warm shallow waters, backwaters, creeks and the foreshore of the Thames tideway provides a nursery area for sea bass and flounder (which can tolerate very low salinities – as demonstrated by the data shown in **Table 2.3** – showing higher average numbers of Sea Bass observed in the lower salinity Upper Tideway monitoring sites). The Middle Tideway provided nursery habitat for Dover sole, which spawns in a sole nursery near Woolwich.

[34] Holliday, F. G. T. & Blaxter, J. H. S. (1960). The effects of salinity on the developing eggs and larvae of the herring. *J. mar. biol. Ass. U.K.* **39,** 591–603

[35] Wennhage, H., Pihl, L. & Stål, J. (2007). Distribution and quality of plaice (*Pleuronectes platessa*) nursery grounds on the Swedish west coast. J. Sea Res. 57, 218–229.

[36] Potter, I.C., Gardner, D.C. And Claridge, P.N. (1988). Age composition, growth, movements, meristics and parasites of the whiting, *Merlangius merlangus*, in the Severn Estuary and Bristol Channel. Journal of the Marine Biological Association of the United Kingdom, 68: 295–313.

[37] Wennhage, H., Pihl, L. & Stål, J. (2007). Distribution and quality of plaice (*Pleuronectes platessa*) nursery grounds on the Swedish west coast. J. Sea Res. 57, 218–229.

Table 2.4 Ecological Guilds of Estuarine Species (from UKTAG 2012[38], based on Elliot & Hemingway, 2002[39])

Ecological Guild	Abbreviation	Use of Estuary
Adventitious freshwater species	FW	Freshwater species with no estuarine requirement
Estuarine Residents	ER	Spend whole life in estuary
Adventitious marine species	MA	Marine species with no estuarine requirement
Marine seasonal	MS	Marine species with seasonal migrations to the estuary as adults
Marine juvenile	MJ	Marine species using the estuary as a nursery area
Diadromous species	DA	Species that use estuaries during migrations between marine and freshwater habitats

2.5.2 Benthic macroinvertebrates

Both WFD water bodies of the Thames Tideway of relevance to these options (Thames Upper and Thames Middle, see **Figure 1.1**) are considered transitional water bodies. The tool which has been developed to assess marine benthic macroinvertebrate quality in transitional waters, the Infaunal Quality Index (IQI), is only considered accurate in those water of an average salinity great that 18 ‰. Waters of less than this salinity are classified in the Marine Nature Conservation Review[40] (MNCR) as "Low Salinity" waters. Part of the Thames Middle waterbody, i.e. the section located downstream of the Dartford Bridge, is generally considered a waterbody of "Variable Salinity" (18-30 ‰), and as such the IQI tool is considered accurate for those waters. The Thames Upper and part of the Thames Middle waterbody, i.e. the section upstream of the Dartford Bridge, are located in the "Low Salinity" zone.

The macroinvertebrate baseline described in this section focusses on those monitoring sites located in the "Low salinity" zone. However, full IQI values have not been calculated for the data made available, however the component indices, namely the AZTI Marine Biotic Index (AMBI score and subsequent biotic coefficient) and the Simpsons Diversity Index have been calculated and used to assess community structure and the sensitivity of the macrobenthic assemblage to pressures.

The lack of WFD classification of the benthic invertebrate element in the Thames Upper waterbody could be attributed to the lack in suitable assessment tools. For the Thames Middle, conclusions from WFD investigations made available by the EA under the data request suggest that a low confidence was attributed to the first WFD classification in 2009. More recent classification indicates that the element is not failing and considered to the at good status, but to be on the good/moderate border, which may mean that "a return to moderate in future is possible due to natural variation"

A great deal of benthic monitoring has been undertaken within the Thames Tideway (Middle and Upper included). This section uses the most recent data from selected sites in the upper and middle tideway to provide a snapshot of the community structure and characterising

[38] UKTAG (2012). Practitioners Guide to the Transitional Fish Classification Index. Version 07 301112.
[39] Elliott, M. & Hemingway, K. L. (2002). Fishes in Estuaries. Blackwell Science, Oxford.
[40] Hiscock, K. (ed.) (1996). Marine Nature Conservation Review: rationale and methods. Peterborough: Joint Nature Conservation Committee. [Coasts and seas of the United Kingdom. MNCR series.]
TEOS-10 Thermodynamic Equation of Seawater 2010

macroinvertebrate species within the areas of the tideway which may be impacted by cumulative effects of the options described.

2.5.2.1 Thames Upper Tideway macroinvertebrates

Benthic macroinvertebrate data from the Upper Thames Tideway has been made available (from the Environment Agency's Biosys database) from four sites; Kew St, Isleworth, Barnes and Battersea (which straddles the border of Upper and Middle Tideway waterbodies) – see Appendix C (**Table C.1**) for locations and site ID. The data represent benthic invertebrate samples, acquired form 3-minute kick sample surveys in winter, spring, summer and autumn - analysed through a sieve of 500µm mesh size. Data has only been made available for the period 2007 – 2012.

The benthic invertebrate community at all four upper tideway sites is outlined by **Table D.2** in Appendix D. From this table, showing total cumulative abundance of the 20 most common species at each site from 2007 until 2012 (including all four annual monitoring surveys). **Table D.2** shows community at each site to be dominated by oligochaete worms, the gammarid crustacean *Gammarus zaddachi* and the New Zealand Mudsnail (*Potamopyrgus antipodarum*).

The benthic invertebrate community at Barnes is dominated principally by those taxa described above, with a total of over 24,493 individuals identified as Oligochaetes recorded over the 2007-2012 period. *G. zaddachi* and *P. antipodarum* were the next most abundant species (15,662 and 2215 individuals respectively). These were followed by *Radix balthica, Helobdella stagnalis* and *Chironomidae*

At Kew St, species composition was dominated by worms from the families Enchytraeidae and Naididae (previously Tubificidae) including Nais sp., *Nais elinguis*, *Tubifex*, *Limnodrilus* sp., Psammoryctides barbatus. High abundance of individuals from the families Gammaridae and Chironomidae was also observed as well as high abundances of the New Zealand Mudsnail (*Potamopyrgus antipodarum*). The freshwater gastropod *Bithynia leachii* is also present at this site (one occurrence in June 2007) notable for its inclusion on the Global Red List (Lower Risk, least concern. The Banded Demoiselle dragonfly, *Calopteryx splendens,* has been recorded at this site (single occurrence in December 2010) and is notable for its inclusion on the Global Red List (Lower Risk, least concern) and on the Odonata Red Data List for Great Britain (2008).

The Isleworth site was dominated by oligochaetes and *G. zaddachi*, followed *by P. antipodarum. Asellus aquaticus*, Chironomidae and *Radix balthica* were the next most commonly occurring taxa. The freshwater gastropod *Bithynia leachii* is also present at this site (one occurrence in December 2007) notable for its inclusion on the Global Red List (Lower Risk, least concern)

The benthic community at the most downstream of the Upper Tideway monitoring sites that of Battersea, was also dominated by Oligochaeta, *G. zaddachi,* and *P. antipodarum*. However, unlike the preceding sites, the next most common species were found to be the estuarine decapod crustaceans *Crangon* and *Palaemon longirostris*. Overall, fewer species were recorded from this site, alongside a lower abundance of G. zaddachi. This structure indicates the start of a more middle estuarine dominated community, with greater salinity tolerance.

2.5.2.2 Thames Middle Tideway macroinvertebrates

Benthic macroinvertebrate species and abundance data were made available by the Environment Agency. These data are sourced from a number of monitoring programmes, such as the Thames Benthic programme (which includes a large number of sites, sampled twice a year from 2000 – 2008) and the WFD classification sampling programmes. The first WFD programme in the Middle Thames was undertaken in 2007 (with samples taken across the entire estuary at approximately 40 sites), with a second round undertaken in 2008/2009 and the most recent round in 2012. More recently, more samples were taken from the southernmost part of the Middle Thames waterbody in 2012, 2015 and 2016. These results were, however, omitted considering their distance downstream of Beckton and Crossness STW, using Dartford Bridge as a cut-off point (18‰).

Data from 21 no. of these sites (taken from the monitoring programmes described above) has been reviewed in order to establish a baseline sensitivity of the macrobenthic communities of the Thames Middle waterbody. Fourteen (14 No.) of the sites have multi-annual datasets and are thus considered the primary monitoring sites. A further seven (7 No.) have data from 2012 only and are considered secondary, highlighted in Bold in **Table 2.5**. The five (5 No.) most common species from each site have been displayed (see Error! Reference source not found. **.5)**, taken from the most recent survey data available at each site. This allows for a high level overview of the community structure of each site. The sites are distributed from which are distributed from South Bank (Station Code 137959 – 20.6 Km U/S Beckton STW), to station Code 148969_2007 (West Thurrock ~14.8 Km d/s Crossness STW.

Table 2.5 Most common taxa from Thames Middle monitoring sites (most recent data from each site)

Sample code_year	S	AMBI Co-efficient	Simpson Diversity	Most common taxa (% of sample)	2nd Most common taxa (% of sample)	3rd Most common taxa (% of sample)	4th Most common taxa (% of sample)	5th Most common taxa (% of sample)
137959_2007	3	0.50	0.64	*Potamopyrgus antipodarum (55.6%)*	*Tubificoides benedii (33.3%)*	*Limnodrilus sp. (11.1%)*	-	-
137940_2007	12	0.75	0.79	*Gammaridae (34.2%)*	*Gammarus zaddachi (27.6%)*	*Potamopyrgus antipodarum (10.5%)*	*Boccardiella ligerica (10.5%)*	*Apocorophium lacustre (3.9%)*
142047_2007	3	0.14	0.10	*Limnodrilus (95%)*	*Baltidrilus costata (2.5%)*	COLLEMBOLA *(2.5%)*	-	-
137920_2012	9	0.81	0.67	*Corophium volutator (41.9%)*	*Boccardiella ligerica (38.2%)*	*Streblospio (9.8%)*	*Marenzelleria (5.7%)*	*Enchytraeidae (3.1%)*
137970_2007	1	0.14	0.00	*Limnodrilus (100%)*	-	-	-	-
148799_2007	4	0.49	0.90	*Streblospio shrubsolii (40%)*	*Tubificoides pseudogaster (20%)*	NEMERTEA *(20%)*	*Corophium volutator (20%)*	-
161276_2012_ Beckton 1	3	0.14	0.51	*Tubificoides heterochaetus (70%)*	COPEPODA *(20%)*	*Baltidrilus costata (10%)*	-	-
148940_2007	12	0.39	0.74	*Streblospio shrubsolii (43.2%)*	*Tubificoides pseudogaster (22.9%)*	*Baltidrilus costata (12.7%)*	*Hediste diversicolor (5.9%)*	*Enchytraeidae (4.2%)*
161276_2012_ Beckton 2	15	0.55	0.45	*Corophium volutator (71.7%)*	*Cochliopidae (16.9%)*	*Streblospio (3.6%)*	*Hediste diversicolor (2.6%)*	*Enchytraeidae (2.3%)*
137927_2007	3	0.14	0.38	*Baltidrilus* costata (78.6%)	Tubificoides heterochaetus (14.3%)	OLIGOCHAETA (7.1%)	-	-
137934_2008	8	0.28	0.62	*Baltidrilus costata (53.1%)*	NEMATODA *(30.3%)*	*Paranais litoralis (7.6%)*	*Limnodrilus (5.7%)*	*Enchytraeidae (1.9%)*
137935_2008	11	0.15	0.53	*Tubificoides heterochaetus (49.5%)*	*Limnodrilus (48%)*	*Streblospio shrubsolii (0.7%)*	*Tharyx "species A" (0.2%)*	OLIGOCHAETA *(0.2%)*
161276_2012_ Crossness 1	12	0.18	0.59	*Tubificoides heterochaetus (52.5%)*	*Paranais litoralis (36.1%)*	*Streblospio (3%)*	*Marenzelleria (2%)*	*Baltidrilus costata (1.8%)*

Sample code_year	S	AMBI Co-efficient	Simpson Diversity	Most common taxa (% of sample)	2nd Most common taxa (% of sample)	3rd Most common taxa (% of sample)	4th Most common taxa (% of sample)	5th Most common taxa (% of sample)
148959_2007	8	0.38	0.89	*Baltidrilus costata (28.6%)*	COPEPODA *(21.4%)*	*Tubificoides heterochaetus (14.3%)*	*Tubificoides pseudogaster (7.1%)*	*Streblospio shrubsolii (7.1%)*
161276_2012_ Crossness 3	4	0.58	0.20	NEMERTEA *(89.7%)*	*Streblospio (3.4%)*	*Hediste diversicolor (3.4%)*	*Conopeum reticulum (3.4%)*	-
148963_2007	10	0.54	0.73	*Streblospio shrubsolii (43.1%)*	*Boccardiella ligerica (27.7%)*	*Corophium volutator (9.2%)*	*Hediste diversicolor (6.2%)*	*Tubificoides pseudogaster (3.1%)*
161276_2012_ Slade Green	7	0.17	0.14	*Tubificoides heterochaetus (92.8%)*	*Streblospio (5.6%)*	*Tubificoides benedii (0.3%)*	*Hediste diversicolor (0.3%)*	*Corophium volutator (0.3%)*
148965_2007	12	0.35	0.64	*Streblospio shrubsolii (43%)*	*Tubificoides heterochaetus (41%)*	*Tubificoides pseudogaster (5.2%)*	*Tubificoides benedii (2.3%)*	COPEPODA *(2.2%)*
161276_2012_ Darrent	3	0.86	0.15	COPEPODA *(92.1%)*	*Gammaridae (5.3%)*	NEMERTEA *(2.6%)*	-	-
161276_2012_ South Stifford	13	0.43	0.66	*Streblospio (52.1%)*	*Tubificoides benedii (19.7%)*	*Tharyx "species A" (16.9%)*	*Tubificoides pseudogaster (1.4%)*	*Polydora cornuta (1.4%)*
148969_2007	13	0.50	0.46	*Streblospio shrubsolii (71.9%)*	*Tubificoides benedii (10.4%)*	*Corophium volutator (8.3%)*	*Tharyx "species A" (3%)*	*Tubificoides heterochaetus (2%)*

Table 2.5 shows a notable increase in species characteristic of upper estuarine habitats with downstream progress, specifically the dominance at stations 148963 and 148965 of the Polychaete species *Streblospio shrubsolii*. There is also characteristic estuarine succession of oligochaete species distribution present within the data. This pattern shows changes in dominance with progression downstream, from *Tubifex tubifex* and/or *Limnodrilus hoffmeisteri* dominated biotopes in the oligohaline upper estuary, to *Baltidrilus costata* dominated in the mesohaline upper / mid estuary, followed by a greater proportion of species such as *Tubificoides benedeni*. This pattern has been shown to be relevant in the Thames Tideway[41] and is evident from **Table 2.5**.

Oligochaete dominated biotopes are recorded from a range of salinity regimes from full salinity to variable salinity (such as **SS.SMu.SMuVS.CapTubi**) to low salinity (**SS.SMu.SMuVS.LhofTtub**) habitats. The biotope most often associated with the species *Limnodrilus hoffmeisteri* (the genus *Limnodrilus* is strongly associated with the sites in the upper section of the Middle Tideway) is described by Connor *et* al.[42] as **SS.SMu.SMuVS.LhofTtub**. The species characterizing these biotopes are likely to vary, and studies[42] have identified how species change over a hypothetical salinity gradient with marine stenohaline species present at full salinities replaced by more euryhaline oligochaete species including *Tubificoides benedii* and *Tubificoides pseudogaster,* as seen in the data set displayed in **Table 2.5**.

Four species of gammarid shrimps were recorded at relatively high abundance in the Thames Tideway[43]: *Gammarus pulex* is associated with freshwater habitats (little to no salinity); *Gammarus zaddachi* lives in the upper and mid estuary, often reaching to the limits of tidal influence and *Gammarus salinus* can be found in the higher salinity of the mid and outer zones. *Gammarus duebeni* has an exceptionally wide-ranging tolerance and as such, can live in a wide range of environments that differ in terms of salinity[44]. Error! Not a valid bookmark self-reference.**5** shows that in the case of the most recent survey data available from all sites, the only identified gammarid species to be encountered in significant abundance was *Gammarus zaddachi*. As such, this species is likely to be the most abundant shrimp species in the Middle Thames Tideway and has been cited in the Thames Tideway Habitat Action Plan[45]. This common species is not identified as endangered nor has it received any conservation designations, but is important in the ecological functioning of estuarine habitats where it is present in high densities as it provides an important food resource for fish and birds[46]. *Gammarus zaddachi* prefers areas of very low salinity, found most commonly just below the low water mark but also intertidally. It also colonises cobbles and gravel banks, which provide refugia when the habitats are exposed by the ebbing tide. *Gammarus zaddachi* has been attributed an AMBI score of III, suggesting it is tolerant to excess organic matter enrichment. They occur under normal conditions, but are stimulated by organic enrichment and slight unbalance situations.

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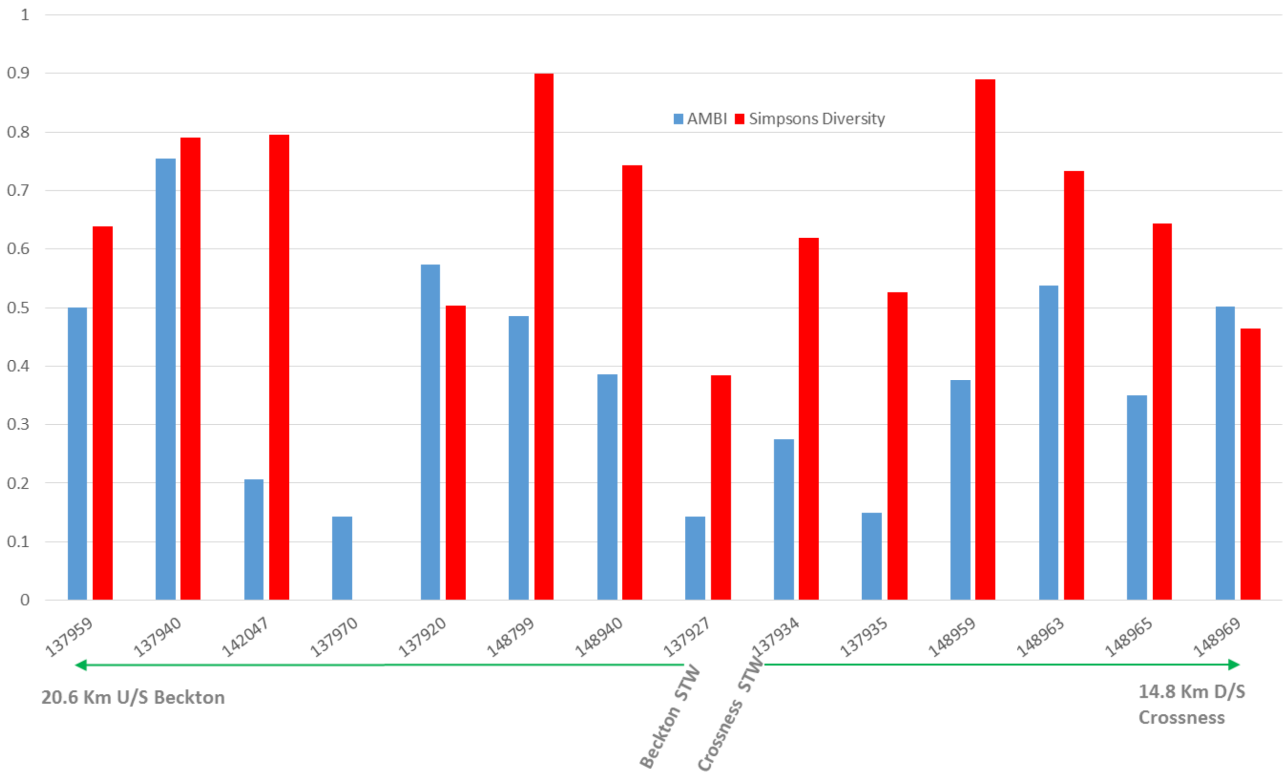
[41] Hunter, J., & Arthur, D.R. (1978). Some aspects of the ecology of *Peloscolex benedeni* Udekem (Oligochaeta: Tubificidae) in the Thames estuary. Estuarine and Coastal Marine Science, 6, 197-208.
[42] Giere, O. & Pfannkuche, O. (1982). Biology and ecology of marine Oligochaeta, a review. Oceanography and Marine Biology, 20, 173-30
[43] Environment Agency (n.d.). Invertebrate Animals of the Tidal Thames. Publication 006239.
[44] Sutcliffe, D. (2000) Subspecies, morphs and clines in the amphipod *Gammarus duebeni* from fresh and saline waters. *Freshwater Forum* **13** p60–75.
[45] Thames Estuary Partnership. Tidal Thames Habitat Action Plan. Accessed through www.thamesweb.com on 14 February 2012
[46] Elliott, M. and Hemmingway, K. L. (eds.) (2002). Fishes in Estuaries. Blackwell Science, Oxford.

The entire abundance datasets for each site were analysed to provide a snapshot of the AMBI and Simpsons Diversity Index scores for all sites, across the length of the Mid Tideway, for the most recent available data. These scores, although not quantitative due to the use of single replicate data, are shown below (**Figure 2.66**).

Figure 2.6 Showing AMBI scores and Simpson's diversity for each site, for a single replicate / year. The data are shown against distance downstream or upstream of the two large STWs



As **Figure 2.66** shows, there is degree of variation in both AMBI and Simpsons Diversity with progression downstream. The normalised AMBI biotic co-efficient varies from 0.5 and 0.75 at the two furthest upstream sites (137959 and 137940- considered "slightly polluted"), dropping immediately to <0.2 at sites 124047 and 137970 ("Heavily Polluted" and Greenwich and Woolwich). However, the variation in this metric is shown by the result from site 137920 (increasing to 0.57 – "Slightly Polluted") at a site which is ~670 m d/s of the 137970.

Both metrics show some degree of tracking of each other. For the single year and replicate data presented, one can clearly see the reduced AMBI biotic coefficient values, indicative of greater impact on and on the macroinvertebrate assemblage, at sites 137927, 137934 and 137935 (immediately downstream of Beckton and Crossness STW). The Simpsons Diversity indices calculated for these sites are correspondingly low, indicative of community dominance by few, (usually R-selected) species. In the case of each of these three potentially impacted sites, this is demonstrated by the dominance of the Oligochaete species *Baltidrilus costata*, alongside resurgence in contribution of *Limnodrillus* sp, possibly representative of the discussed plateau of fresher water in this area as a result of the water treatment infrastructure discharges.

Table 2.6 Sensitivity to salinity of most abundant taxa from Thames Middle Monitoring sites

Most Common Species (All Sites)	Sensitivity to salinity	Reference
Limnodrilus hoffmeisteri	Medium	Budd, G.C. (2003). *Limnodrilus hoffmeisteri,* an oligochaete. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1859
Nais sp.	Minor	Worsfold, T. (2003). Introduction to Oligochaetes. NMBAQC Benthic Invertebr. Taxon. Work.
Boccardiella ligerica	Minor	Jensen, K. R. (2010). NOBANIS - Marine invasive species in Nordic waters - Fact Sheet *Telmatogeton japonicus*. Identif. key to Mar. invasive species Nord. Waters 1–3.
Corophium volutator	Minor	Neal, K.J. & Avant, P. (2006). *Corophium volutator* A mud shrimp. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1661
Gammaridae	NA	Family taxon, multiple sensitivities
Marenzelleria viridis	Minor	http://www.marinespecies.org/polychaeta/aphia.php?p=taxdetails&id=131135
Limnodrilus	Medium	Worsfold, T. (2003). Introduction to Oligochaetes. NMBAQC Benthic Invertebr Taxon. Work.
Potamopyrgus antipodarum	Minor	http://animaldiversity.org/accounts/Potamopyrgus_antipodarum/
Lekanesphaera rugicauda	Medium	Hosie, A.M. (2009). *Lekanesphaera rugicauda,* a sea slater. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/221
HARPACTICOIDA	Minor	Marine taxon
Asellus aquaticus	High	Freshwater species, sensitivity assumed to be high.
Oligochaeta	NA	Multiple species with varying tolerances. Worsfold, T. (2003). Introduction to Oligochaetes. NMBAQC Benthic Invertebr. Taxon. Work.
Psychodidae	Uncertain -	No data available.

Most Common Species (All Sites)	Sensitivity to salinity	Reference
Baltidilus costata	Minor	Worsfold, T. (2003). Introduction to Oligochaetes. NMBAQC Benthic Invertebr. Taxon. Work.
Microprotopus maculatus	Minor	http://species-identification.org/species.php?species_group=crustacea&menuentry=soorten&id=355&tab=beschrijving
Tubificoides pseudogaster	Minor	Giere, O. & Pfannkuche, O. (1982). Biology and ecology of marine Oligochaeta, a review. Oceanography and Marine Biology, 20, 173-30.
Tubificoides heterochaetus	Medium	Worsfold, T. (2003). Introduction to Oligochaetes. NMBAQC Benthic Invertebr. Taxon. Work.
Tubificoides benedii	Minor	http://eunis.eea.europa.eu/habitats/5494. Budd, G.C. (2005). *Tubificoides benedii* A sludge-worm. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1862
Cochliopidae	Uncertain	No data available.
Nephtys sp.	Minor	Budd, G.C. & Hughes, J.R. (2005). *Nephtys hombergii* A catworm. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1710
Hydrobia ulvae	Minor	Ashley, M. (2016). Hediste diversicolor, Macoma balthica and Eteone longa in littoral muddy sand. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/1127
Streblospio shrubsolii	Minor	Attrill, M.J. ed., (1998). A rehabilitated estuarine ecosystem: The environment and ecology of the Thames estuary. Berlin: Springer Science & Business Media
Streblospio sp.	Minor	Attrill, M.J. ed., (1998). A rehabilitated estuarine ecosystem: The environment and ecology of the Thames estuary. Berlin: Springer Science & Business Media
Capitella sp.	Minor	Tillin, H.M. (2016). *Capitella capitata* in enriched sublittoral muddy sediments. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/106
Tharyx spp.	Uncertain	No data available.

Most Common Species (All Sites)	Sensitivity to salinity	Reference
Polydora cornuta	Minor	Ashley, M. (2016). *Hediste diversicolor*, *Macoma balthica* and *Eteone longa* in littoral muddy sand. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/1127
Melita palmata	Minor	Marchini, A., Caronni, S. & Occhipinti-Ambrogi, A. (2008). Size variations of the amphipod crustacean *Melita palmata* in two Adriatic lagoons: Goro and Lesina. Transitional Waters Bull. 2, 1–12
Corophiidae	Uncertain	Family taxon, multiple sensitivities
Apocorophium lacustre	Minor	Described as salt tolerant in: Wolf, B., Kiel, E., Hagge, A., Krieg, H.-J. & Feld, C.K. (2009). Using the salinity preferences of benthic macroinvertebrates to classify running waters in brackish marshes in Germany. Ecological Indicators 9:837-847
Conopeum reticulum	Minor	Tyler-Walters, H. & Ballerstedt, S. (2005). *Conopeum reticulum,* an encrusting bryozoan. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/
Paranais litoralis	Medium	Worsfold, T. (2003). Introduction to Oligochaetes. NMBAQC Benthic Invertebr Taxon. Work.

Table 2.6 Shows sensitivities to salinity increase, derived from the MarLIN sensitivity assessments or available scientific literature, of the most common species recorded from the selected sites in the Middle Thames. Where specific MarLIN sensitivity values are available, these have been used. More commonly, these values were not available and the sensitivity value for the biotope, which is characterised by the species in question, is used. Where scientific literature have been consulted, no sensitivity has been accorded the species in question – as such the salinity range associated with the species has been recorded. If this range is within the "Low Salinity" bracket, the species has been accorded a precautionary **Medium** sensitivity such as in the case of the Oligochaete *T. heterochaetus*. If the species is associated with Full or Variable salinity values, the species has been accorded the **Minor** sensitivity category. The term NA has been used where the taxa described is of genus level or higher, making specific sensitivity analysis impossible, as different species within a genus or family may have differing tolerances to environmental parameters. Where insufficient data are available to classify, the entry has been accorded the "Uncertain" value.

Table 2.7 displays a high level community sensitivity assessment, based upon the described sensitives of the three most abundant species at each site (from a single replicate of the most recent data available). The Simpsons Diversity value and the number of specie recorded at that site are shown for reference. Where insufficient data, or the NA term is shown, the highest sensitivity value of the other taxa is used as the overall community classification.

Table 2.7 Overall sensitivity of the benthic communities (based on the 3 most abundant taxa) to salinity increase within the primary monitoring sites of the Mid Tideway

Site (most recent Sample – 1 replicate)	Number of Species	Simpson Diversity	Sensitivity of 3 most dominant Species	Overall Sensitivity of Community
137959_2007	3	0.64	Med x Minor x Minor	Medium
137940_2007	12	0.79	Minor x Minor x Minor	Minor
142047_2007	3	0.10	Med x Minor x Med	Medium
137970_2007	1	0.00	Med	Medium
137920_2012	9	0.67	Minor x Minor x Minor	Minor
148799_2007	4	0.90	Minor x Minor x NA	Minor
148940_2007	12	0.74	Minor x Minor x Minor	Minor
137927_2008	7	0.65	Minor x Med x Uncertain	Medium
137934_2008	8	0.62	Minor x NA x Med	Medium
137935_2008	11	0.53	Med x Med x Minor	Medium
148959_2007	8	0.89	Minor x NA x Med	Medium
148963_2007	10	0.73	Minor x Minor x Minor	Minor
148965_2007	12	0.64	Minor x Med x Minor	Medium
148969_2007	13	0.46	Minor x Minor x Minor	Minor

From **Table 2.7,** one can see the majority of the community sensitivities at the primary sites are accorded the **Medium** category (8/14). This is considered a precautionary value, as the majority of the sites which have been accorded **Medium** sensitivity have records of the Oligochaete *Tubificoides heterochaetus* - known to have a low salinity preference and to be very common in the Thames Estuary[47]. The exact salinity tolerance (‰) values of this species are uncertain, as such the confidence in assessment must be low.

There are two biotopes (classified by the MNCR) which are considered likely to be present in the Middle Thames Tideway, the MarLIN Sensitivity Assessment of these biotopes is considered applicable as a secondary means of deriving macrobenthic community sensitivity to salinity increase. These two biotopes are **SS.SMu.SMuVS.CapTubi** and **SS.SMu.SMuVS.LhofTtub,** and are described in greater detail above. However, it must be stressed that this is an estimation based on the data shown in **Table 2.5** and as such, actual biotope classification is beyond the scope of this report.

The biotope **SS.SMu.SMuVS.CapTubiis** considered to have **high resistance** to change between full salinity and variable or reduced, although some mortality may occur before species acclimation[48]. The second of the two likely biotopes is present within the upper section of the Mid Tideway, **SS.SMu.SMuVS.LhofTtub** (possibly associated with sites 137959,142047 and 137970), is found in low salinity habitats (<18 ‰). The key functional

[47] Worsfold, T. (2003). Introduction to Oligochaetes. NMBAQC Benthic Invertebr Taxon. Work.
[48] Tillin, H.M. (2016). *Capitella capitata* and *Tubificoides* spp. in reduced salinity infralittoral muddy sediment. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/32

species, *L. hoffmeisteri* and *T. tubifex*, are essentially freshwater species, able to tolerate very low interstitial salinities and therefore able to penetrate from freshwater ecosystems into upper estuaries, which although tidal, are dominated by freshwater conditions[49]. As this biotope is restricted to low salinities an increase in salinity at the pressure benchmark would lead to loss of the characterizing species *L. hoffmeisteri, T. tubifex,* resulting in a **Medium** MarLIN sensitivity value.

[49] Tillin, H.M. & Budd, G., (2002). *Limnodrilus hoffmeisteri*, *Tubifex tubifex* and *Gammarus* spp. in low salinity infralittoral muddy sediment. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/35

2.5.3 Notable species

The below NERC Act 2006 Section 41 designated species have been further assessed as being potentially sensitive to salinity changes.

2.5.3.1 Trembling Sea Mat (*Victorella pavida)*

V. pavida is a colonial bryozoan that may form either diffuse branching chains or develop into dense clumps. During the peak of the growth season (summer), colonies have the appearance and texture of velvet. Individuals within a colony vary in shape and size. Attached zooids posses a roughly oval base and a cylindrical peristome[50]. This species has only been officially recorded in a single lagoon in the UK, Swanpool in Cornwall[50], as such the records of this species found within the dataset provided by the Environment Agency are unusual. This record indicates the presence of this species in a single replicate of the survey undertaken at the Slade Green site, of survey 161276, during 2012. The record is not quantified, and as such states on that the species is "present".

V. pavida is designated as a species of principal importance under Section 41 (England) of the NERC Act (2006). *V pavida* is considered to be a euryhaline species[50] tolerant of salinities ranging from zero to 22 ‰[51]. Whilst germination of the hibernacula stage has been shown to be severely retarded in 36 ‰, the subsequent colony growth rate is high, and thus the mature zooids are considered very tolerant of full salinity[52]. As such, this species has been described as <u>not sensitive</u> in the MarLIN sensitivity assessment [50], and **Minor Sensitivity** to local, medium term salinity increase has been accorded the species.

2.5.3.2 Tentacled lagoon worm (*Alkmaria romijni*)

The tentacled lagoon worm is a small polychaete worm, typically 3-5 mm in length. It inhabits intertidal muddy sediments in sheltered parts of estuaries and lagoons. It is a detritivore, obtaining its food from sediments using its tentacles. It can tolerate salinities of 5–48 ‰, but has a preferred range of 5–20 ‰, and ideally no higher than 18 ‰[53]. *A. romijni* has been recorded from 27 sites around the UK[54], including the site 161276 at South Stifford, in 2012, which forms part of the current baseline description. This species is designated as species of principal importance under the Section 42 (Wales) NERC Act (2006), but **not** under Section 41(England). It has still been considered as a notable species for the purposes of this study.

A. romijni is particularly sensitive to changes in habitat quality and substrate loss is of particular concern. It is unknown to what extent adults are able to burrow to the surface following smothering. Any impacts on habitat quality may have long-term population impacts as recovery is expected to be low. This is largely because adults would be unable to recruit in from elsewhere, as populations of *A. romijni* are often separated by great distances. The

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[50] Carter, M.C. & Jackson, A. (2007). *Victorella pavida* Trembling sea mat. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1302

[51] Evans, N.J., Bamber, R.N., Smith, B.D., Clark, P.F., Taylor, H., Lund, P. & Chimonides, P.J. (2003). Swanpool ecological study, Falmouth, Cornwall. Final Report (No. ECM 775/03).

[52] Carter, M. C. (2004). The biology and genetic diversity of the trembling sea mat *Victorella pavida* (Bryozoa: Ctenostomata) from Swanpool, Falmouth. M.Res Thesis, University of Plymouth.

[53] White, N. (2002). *Alkmaria romijni* Tentacled lagoon worm. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1200

[54] Gilliland, P.M., & Sanderson, W.G. (2000). Re-evaluation of marine benthic species of nature conservation importance: a new perspective on certain 'lagoonal specialists' with particular emphasis on *Alkmaria romijni* Horst (Polychaeta: Ampharitidae). Aquatic Conservation: Marine and Freshwater Ecosystems, 10(1), 1-12.

dispersal potential of larvae is also restricted because larvae are benthic. As the adults prefer muddy sediment, changes in sediment characteristics may also impact on habitat quality and the ability of individuals to create burrows. The species occurs in an environment with seasonal and daily fluctuations in water quality. *Alkmaria romijni* is understood to have a preferred salinity range of between 5 to 20 ‰, as most records and the highest abundances are recorded in the latter range[55]. An increase in salinity from full to >40 ‰ may result in a reduction in the abundance *Alkmaria romijni* of over a period of a year[56]. However, no direct evidence of the effects of hypersaline conditions or effluent on the species was found, as such it is recorded by the MarLIN sensitivity assessment as having "**No Evidence"**. This report accords a precautionary **Minor Sensitivity** to salinity increase.

2.5.3.3 Mud Shirmp (*Apocorophium lacustre*)

Apocorophium lacustre (previously classified as *Corophium* lacustre - Vanhoeffen, 1911) is a crustacean species of the order Amphipoda, and is known to be locally common within the Thames Estuary. The species has been designated as "Rare" under the Red Data Book of Invertebrates (under pre 1994 IUCN guidelines), and as such is protected under Section 41 of the NERC Act. The mud shrimp is a small amphipod which grows up to 6 mm in length, the body is sub- cylindrical and depressed[57]. This species is associated with brackish waters of low salinity, recorded up to maximum of 16 ‰, however recordings of the species in waters of up to full salinity have been made[58]. The species occurs in an environment with seasonal and daily fluctuations in water quality. A recent study has associated *A. lacustre* with fresh waters of a higher conductivity, alongside species such as *Gammarus tigrinus* and *Potamopyrgus antipodarum*[59].

A. lacustre has been encountered at two of the sites assessed within this study, 137940 and 137920 (both in the WFD 2007 classification survey). These sites are located at Greenwich and Woolwich respectively, with a likely salinity range of between 0.3 and 9.3‰. No further information on the sensitivity of the species to localised, mid - long term increases in salinity is available, with no MarLIN sensitivity assessment having been undertaken. In light of the 16 ‰ salinity maximum stated above, this species has been accorded a **Minor-Medium Sensitivity to** salinity increase.

2.5.3.4 Swollen Spire Snail (*Mercuria confusa*)

The data provided (**Table 2.5**) do not record the presence of the swollen spire snail *Mercuria confusa*[60]. However, this rare species is considered 'Endangered' according to the Red Data Book of Invertebrates and its distribution in the UK is restricted to the River Alde in Suffolk and at Barking Creek in the Thames Tideway (where small populations have been recorded). *M. confusa* has very specialised habitat requirements. It is typically found on bare mud exposed

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[55] Gilliland, P.M., & Sanderson, W.G., (2000). Re-evaluation of marine benthic species of nature conservation importance: a new perspective on certain 'lagoonal specialists' with particular emphasis on *Alkmaria romijni* Horst (Polychaeta: Ampharitidae). *Aquatic Conservation: Marine and Freshwater Ecosystems*, **10**(1), 1-12.

[56] Tyler-Walters, H. & White, N. 2017. *Alkmaria romijni* Tentacled lagoon worm. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1200

[57] Wilson, E. (2002). *Apocorophium lacustre* A mud shrimp. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1208

[58] Barnes, R. S. K. (1994). The Brackish-Water Fauna of Northwestern Europe. Cambridge University Press.

[59] Szöcs, E., Coring, E., Bäthe, J. & Schäfer, R. B. (2014). Effects of anthropogenic salinization on biological traits and community composition of stream macroinvertebrates. Sci. Total Environ. 468–469, 943–949.

[60] Until recently known as *Pseudamnicola confusa*

at low tide beneath emergent vegetation such as *Phragmites australis* (a species noted in all four of the saltmarsh survey sites examined in this study) or *Glyceria maxima*. It is sometimes described as a brackish species, but it is not found on salt marshes with typical estuarine snails such as the common Laver spire snail *Hydrobia ulvae*. Instead, it requires water with **very low salinity** (1-5 ‰) and it is typically found in association with freshwater molluscs such as *Lymnaea palustris*, *L. truncatula* and wetland species such as *Zonitoides nitidus* and *Carychium minimum*. Some authorities consider *M. confusa* as a freshwater snail that requires periodic or occasional contact with very slightly saline water. *Mercuria confusa* has not been attributed an AMBI score.

2.5.3.5 European Smelt (*Osmerus eperlanus*)

The European smelt (*Osmerus eperlanus*) is a small to medium size fish that is rarely found offshore and prefers estuarine environments. *O. eperlanus* is designated an NERC Section 41 species under the NERC act (2006), and is also present on the IUCN Red List as a species of Least Concern. The species is tolerant to a wide range of salinities and freshwater populations are also known to occur[61]. Smelt are anadromous and ascend brackish/low salinity rivers between February and April, returning to the sea soon after spawning takes place[62]. Migration is restricted to the lower parts of the river and eggs are deposited on gravel, stones and plant material, preferably in fast-flowing water.

The species is known to be sensitive to a variety of impacts including the pollution of many of the estuaries in which Smelt once prospered and the subsequent collapse of stocks. Overfishing has been a significant threat in some estuaries and habitat loss has also had an impact. This has been most notable where notably where spawning grounds have been destroyed through siltation. Access from estuaries to spawning grounds has also been disrupted by weirs or other barriers. Several of these impacts are present within the Thames Tideway, however important spawning habitats are known to exist between Richmond and Chelsea. Surveys by Colclough *et al*. (1999)[63] show that young of the year occur at a range of sites above Greenwich in both spring and autumn surveys. Evidence from **Table 2.3** indicates that the monitoring location off Woolwich is an aggregation area for (possibly juvenile) smelt and Following a substantial decline in population levels over time, the gravels and shallow waters near Wandsworth[64] are currently considered a significant spawning ground for European smelt within the Thames Tideway. European smelt are considered very sensitive to water quality and prefer brackish/low-salinity environments[65] although as the species considered tolerant of wide salinity changes[66], this report accords the species a **Minor sensitivity.**

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[61] Quigley, D.T.G., Igoe, F. & O'Connor, W. (2004). The European Smelt *Osmerus eperlanus* L. in Ireland: General Biology, Ecology, Distribution and Status with Conservation Recommendations. Biology and Environment: Proceedings of the Royal Irish Academy, Vol. 104B, No. 3, Threatened Irish Freshwater Fishes (Dec., 2004), pp. 57-66

[62] Maitland, P.S. (2003). English Nature Research Reports. Number 516: The status of smelt *Osmerus eperlanus in England*, 83pp

[63] Colclough, S., Dutton, C., Cousins, T. & Martin, A. (1999). A fish population survey of the tidal Thames 1994-1996. London, Environment Agency.

[64] Thames Estuary Partnership. Tidal Thames Habitat Action Plan. Accessed through www.thamesweb.com on 14 February 2012

[65] English Nature (2003). The status of smelt *Osmerus eperlanus* in England. English Nature Research Reports Number 516.

[66] Maitland, P. & Lyle, A. (n.d.). The Smelt *Osmerus eperlanus* in Scotland. Accessed from: https://www.fba.org.uk/journals/index.php/FF/article/viewFile/328/231

2.5.3.6 Brown/sea Trout (*Salmo trutta*)

Brown and sea trout are the same species. Brown/sea trout are an anadromous (DA guild) species which, in some but not all populations (as permanently riverine resident ecotypes exist) migrate from the sea in order to spawn in freshwater. This species is designated a NERC Section 41, and is also present on the IUCN Red List as a species of Least Concern.

S. trutta has been recorded twice in the dataset analysed for this report – with a single occurrence at the Chiswick site in spring 2013, and another at the Richmond site, also in spring 2013. The species is not believed to spawn in the transitional waters of the river Thames[67], however adult *S. trutta* will pass through the transitional waters to spawn upstream, and smolt will migrate through the tideway back to the sea (the developmental process that stimulates juveniles to the sea is known as 'smolting'). Factors triggering the 'decision' of an individual to smoltify or not are not well understood. If migration is impossible, smolts may interrupt migration and become resident again[68]. The role of salinity as an environmental trigger to smolting is unknown.

In terms of spawning, the role of flows or salinity as a trigger for spawning is not well understood. As such, a precautionary **Minor sensitivity** to salinity has been accorded to this species.

2.5.3.7 European Bullhead (*Cottus gobio*)

C. gobio is designated an NERC Section 41 species, and is also present on the IUCN Red List as a species of Least Concern. This species is a freshwater obligate (FW guild) with no estuarine requirement, although is known to be able to tolerate slightly brackish waters[69]. The species spawns in freshwaters of upland and lowland streams[70], and is conspicuous in in its absence from any site below Chiswick. As such, *C gobio* is considered to have a **Medium Sensitivity** to salinity increase within the Thames tideway, as an upstream progression and increase of saline ingress may result in a short to medium term shift in the distribution of this species in the most downstream sections of the Upper tideway.

2.6 Summary of environmental features

Table 2.8 below summarises key environmental features identified in the environmental baseline (**Section 2**), their value, likely sensitivity to salinity changes and consequently whether further consideration is required for the assessment undertaken in **Section 3**.

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[67] ZSL (2017). Fish, T. T. & Process, P. Guidance Document Conservation of Tidal Thames Fish through the Planning Process. 1–20 (2016).
[68] Freyhof, J. (2011). Salmo trutta. The IUCN Red List of Threatened Species 2011: e.T19861A9050312. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T19861A9050312.en. Downloaded on 31 May 2017.
[69] Freyhof, J., M. Kottelat & Nolte, A. (2005). Taxonomic diversity of European *Cottus* with description of eight new species (Teleostei: Cottidae). Ichthyol. Explor. Freshwat. 16(2):107-172. (Ref. 55856)
[70] Tomlinson, M. L. & Perrow, M. R. (2003). Ecology of the Bullhead. Conserv. Nat. 2000 River Ecol. No.4.

Table 2.8 Summary of Environmental Features

Feature	Description	Value (High, Medium, Low, Negligible)	Sensitivity to Salinity Changes (Uncertain, Minor, Medium, Major, Negligible)	Further consideration required – see *Section 3* (Yes/No)
Tidal Thames SMINC	The Tidal Thames has been designated as a Site of Metropolitan Importance to Nature Conservation (SMINC). The SMINC has been designated for fish, wintering birds, marine invertebrates and as a green corridor. Tidal tributaries of the Thames Tideway, are considered important fish nursery areas. The most sensitive receptor within the SMINC citation is considered to be fish species, which are set out below.	High	Negligible	No
Proposed Marine Conservation Zone (pMCZ)	The proposed site extends along the greater part of the tidal River Thames from Richmond to the estuary mouth at Southend-on-Sea, and is designed to protect different species and habitats along distinct stretches of the river. As a whole, the site is considered to be an important spawning and nursery ground for various fish species, particularly European smelt (*Osmerus eperlanus*) and European Eel (*Anguilla anguilla).* A geographically restricted, but important population of Tentacled Lagoon Worm (*Alkmaria romijni*) occurs at Greenhithe.	High	Minor	Yes
Intertidal mudflat habitats in the Middle Thames Tideway.	Intertidal mudflats are considered a NERC Section 41 Priority Habitat, however, due to extensive modification, the habitats in the Middle Thames Tideway do not meet the description of intertidal mudflats as described by the UK Biodiversity Action Plan (BAP) group.	Medium	Negligible	No
Saltmarsh Habitat	Intertidal saltmarsh habitat is present, to a limited extent, within the Middle Thames Tideway, but is typically confined by hard engineering. Saltmarsh itself is not sensitive to salinity changes, however, Areas with high structural and plant diversity, particularly where freshwater seepages provide a transition from fresh to brackish conditions, are particularly important for invertebrates and these upper parts of the saltmarsh can be sensitive to salinity changes.	High	Minor	No
Seagrass	There are no seagrass beds in the Upper and Middle Thames WFD waterbodies (personal communication, Environment Agency, 5 May 2017).	N/A	N/A	No
Populations of the brackish water shrimp *Gammarus zaddachi* (a common species and an important food source for fish and birds)	This common species prefers areas of very low salinity, but has adapted to live across a range of salinities in the mid to upper estuary up to the tidal limit. It is found just below the water mark and is highly mobile, migrating upstream and downstream throughout the estuary. As such, it is unlikely that any changes in freshwater flow or salinity will significantly affect the distribution or abundance of the species in the Thames	Medium	Negligible	No

	Tideway. The species has an AMBI score of III, suggesting it is tolerant to excess organic enrichment. Its sensitivity to changes in salinity is considered negligible.			
Populations of mud shrimp *Apocorophium lacustre* (a common species in the Thames Tideway and an important food source for fish and birds)	*Apocorophium lacustre* (previously classified as *Corophium* lacustre - Vanhoeffen, 1911) is a commonly occurring species within the Thames Estuary. The mud shrimp is a small amphipod which grows up to 6 mm in length, the body is sub- cylindrical and depressed [71]. This species is associated with brackish waters of low salinity, recorded up to maximum of 16 ‰,	Medium	Minor	Yes (based on precautionary principle)
Populations of the swollen spire snail *Mercuria confusa* (NERC Section 41 species)	This species is rare in the UK and a small population has been recorded in the Barking Creek, a tributary of the Thames Tideway. It has very specialised habitat requirements and requires water with very low salinity. It is typically found on bare mud exposed at low tide beneath emergent vegetation. It sensitivity to changes in salinity is unknown and would require more primary research.	High	Minor-Medium (Uncertain)	Yes (based on precautionary principle)
Populations of the *Trembling Sea Mat (Victorella pavida)* (NERC Section 41 species)	This species is rare in the UK, with the only confirmed population recorded in the Swanpool lagoon, Cornwall. The single incidence recorded from the sites reviewed the middle Thames Tideway is unusual. V pavida is considered to be a euryhaline species[53] tolerant of salinities ranging from zero to 22 ‰. As such, this species has been described as not sensitive in the MarLIN sensitivity assessment 53, and **Minor Sensitivity** to local, medium term salinity increase has been accorded the species.	High	Minor	Yes (based on precautionary principle)
Populations of the Tentacled lagoon worm (*Alkmaria romijni*) (NERC Section 42 (Wales) species	*Alkmaria romijni* can tolerate salinities of 5–48 ‰, but has a preferred range of 5–20 ‰, and ideally no higher than 18 ‰. *A. romijni* has been recorded from 27 sites around the UK, including the site 161276 at South Stifford, in 2012	Medium (note designation in Wales and not England)	Minor	No
Populations of common, freshwater preferential macroinvertebrates in the Thames Upper Tideway waterbody	The aquatic (freshwater) macroinvertebrate communities in the Thames Upper Tideway are mainly composed of common taxa such as molluscs, crustaceans and fly larvae, but also include the Banded Demoiselle damselfly *Calopteryx splendens* and freshwater gastropod *Bithynia leachii* which have a Global Red List Status and are of Least Concern. Due to their preference to freshwater conditions, they have been attributed a general Medium sensitivity to salinity increases.	Low	Medium	Yes
Populations of common macroalgae	The macroalgal and higher plant communities in the Thames Tideway are likely to be restricted by habitat availability. If a macroalgal community occurs, it is likely to be able to grow on a range of surfaces and composed of euryhaline species (i.e. those able to adapt to a range of salinity	Low (Uncertain)	Negligible	No

[71] Wilson, E. (2002). *Apocorophium lacustre* A mud shrimp. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1208

	concentrations) such as *Ulva intestinalis.* As a result, populations of common macroalgae are considered to have negligible sensitivity to potential changes in salinity. An increase in salinity is likely to increase the general abundance of macroalgae in the Thames Tideway, however, habitat availability is likely to limit the diversity and extent of any increase in macroalgal cover.			
Phytoplankton community in the Thames Tideway	No data were made available for phytoplankton communities in the Thames Tideway. The interim WFD status for phytoplankton blooms in the Thames Middle waterbody is High. Compared to the freshwater Thames, it is likely that the relatively high sediment load in the Thames Tideway may limit light penetration and thereby growth. In the absence of taxonomic data, the sensitivity of phytoplankton communities to salinity is considered to be very uncertain, but likely to be low considering the generally low salinity of the Tidal Thames.	Low (Uncertain)	Minor	No
Populations of: Cod (*Gadus morhua*) Dover sole (*Solea solea*), Herring (*Clupea harengus*) Whiting (*Merlangius merlangus*) All recorded in the Thames Tideway. (NERC Section 41 species)	Cod, Dover sole, herring and whiting have all been recorded as part of Thames Tideway surveys. Although some of these species are associated with deeper water (e.g. cod, whiting, herring), juveniles can be transported into estuaries. Some NERC Section 41 species do display sensitivity to salinity changes, particularly in juvenile life stages. Most of these species prefer brackish to seawater salinities: • Cod adults prefer higher salinity water, whilst juveniles can survive in lower salinity water as well as marine water (>25ppm), but not freshwater[72,73]. • Dover sole adults prefer higher salinity water and so do sole eggs. Young sole are found in tidal estuaries and prefer low-salinity water[74] (but not freshwater). • Herring typically stays away from the immediate coastal areas[75,76] and their presence in trawls is considered 'incidental'. • Like cod, the preference for juvenile and adult whiting is for brackish salinity (0.5-25ppm) or seawater salinity (>25ppm)[77].	High	Minor	Yes
European smelt (*Osmerus eperlanus*)	European smelt is an estuarine/anadromous species, ascending brackish waters of low	High	Minor	Yes

72 Arnason, T., Magnadottir, B. Bjornsson, B., Steinarsson, A., Thrandur Bjornsson, B. (2013). Effects of salinity and temperature on growth, plasma ions, cortisol and immune parameters of juvenile Atlantic cod (*Gadus morhua*). Aquaculture. 380-383, pp. 70-79.
73 https://www.greateratlantic.fisheries.noaa.gov/hcd/cod.pdf
74 http://safinacenter.org/documents/2014/09/sole-dover-atlantic-ocean-full-species-report-2.pdf
75 Barnes, M.K.S. (2008). *Clupea harengus* Atlantic herring. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/45
76 https://www.greateratlantic.fisheries.noaa.gov/hcd/herring.pdf
77 https://www.greateratlantic.fisheries.noaa.gov/hcd/whiting.pdf

	salinity in the winter or spring, but overall considered tolerant to a wide range of salinities. Following a substantial decline in population levels over time, the gravels and shallow waters near Wandsworth are currently considered a significant spawning ground for European smelt within the Thames Tideway.			
Brown trout (*Salmo trutta*) (NERC Section 41 species)	*S. trutta* has been recorded twice in the dataset analysed for this report – with a single occurrence at the Chiswick site in spring 2013, and another at the Richmond site, also in spring 2013. The role of salinity as an environmental trigger to smelting or spawning is unknown. As such, a precautionary **Minor sensitivity** to salinity has been accorded this species.	High	Minor	Yes
European Bullhead (*Cottus gobio)* (NERC Section 41 species)	This species is a freshwater obligate (FW guild) with no estuarine requirement, although is known to be able to tolerate slightly brackish waters[78]. The species spawns in freshwaters of upland and lowland streams[79], and is conspicuous in in its absence from any site below Chiswick. As such, *C gobio* is considered to have a **Medium Sensitivity** to salinity increase within the Thames tideway, as an upstream progression and increase of saline ingress may result in a short to medium term shift in the distribution of this species in the most downstream sections of the Upper tideway.	High	Medium	Yes
European Eel (NERC Section 41 species, IUCN 'Endangered')	European eel have been recorded in the Thames Tideway in monitoring surveys, and as part of elver monitoring between 2012-2014. It is noted that abundances are typically low. European eel are adults or juveniles are not highly sensitive to changes in salinity.	High	Negligible	No
Populations of common estuarine fish species recorded in the Thames Tideway	In addition to the NERC Section 41 species mentioned above, other species recorded include mullet and sand smelt. Mullet are able to adapt to a wide range of salinities and have a relatively low preference for water quality conditions. Sand smelt is associated with estuaries, unpolluted harbours and saline lagoons, tending to be found over sandy or muddy bottoms, down to 20m depth. The species is considered to be well adapted to a range of salinities.	Low-Medium	Minor	No

[78] Freyhof, J., M. Kottelat & Nolte, A. (2005). Taxonomic diversity of European Cottus with description of eight new species (Teleostei: Cottidae). Ichthyol. Explor. Freshwat. 16(2):107-172. (Ref. 55856)
[79] 1. Tomlinson, M. L. & Perrow, M. R. (2003). Ecology of the Bullhead. Conserv. Nat. 2000 River Ecol. No.4.

3 Assessment

The assessment focuses on in-combination effects between the WRMP19 desalination and abstraction options set out in Section 1.1, with effects considered on local salinity effects and smothering of benthic communities (Section 3.1); long-term spatial effects on salinity along the Thames Tideway (Section 3.2) and effects on level in the area around Beckton and Crossness (Section 3.3).

In-combination effects between the upper Tideway (i.e. Teddington DRA) and mid-Tideway options at the River Lee, Beckton and Crossness STW are not considered as a result of the fact that the reported tidal excursion (Environment Agency, 1997) is between 13 to 14 kilometres (net) and is not expected to overlap.

3.1 Local salinity effects resulting from reuse and/or desalination options

A key concern for the Environment Agency has been the potential for change (increase) in salinity locally as a result of processed brine from reuse options being discharged around the Beckton and Crossness STW discharges. It is noted that any brine discharged will be significantly diluted by the final effluent discharges. The variation in local salinity as a result of brine discharges has been set out in **Table 3.1** below.

Individually, the Beckton reuse option would be expected to reduce the freshwater discharge volume, as a result of the reduction in treated discharge flow. The reduction in freshwater flow to the Tideway would not increase the existing salinity detrimentally from the perspective of smothering of local biota with estimates of a change of 0.1 to 0.3 ‰ or an approximate 2% salinity difference locally.

Considering additional desalination options in isolation, abstraction from the Tideway and return of treated brine via STW discharge should dilute the concentrated brine component and mix it with the STW flow. Beckton desalination is estimated to increase salinity by between 0.2 and 0.4‰ locally with the Crossness option raising salinity by 0.5 to 0.9‰. To put these values into context, Tideway salinity varies over and between tidal cycles from 0.2 to 14.7‰ at Beckton and 0.4 to 16.4‰ at Crossness, depending on freshwater flows and tidal state, noting that the schemes would typically operate at low flow conditions. The ecology of the Tideway in this reach is generally resilient to salinity change and consequently the options will have little influence on salinity within the local receiving environment, or smother local biota.

Table 3.1 Local salinity effects of Beckton and Crossness options

Salinity under low dispersion conditions in the area local to the discharge	**Beckton**				**Crossness**	
	Baseline	Reuse option	Desalination option	Both	Baseline	Desalination option
Low flushing rates and very low water depths (near low water, spring tide, salinity 4‰)[80]	3.7‰	3.8‰	3.9‰	4.1‰	3.7‰	4.3‰
Very low flushing rates and low water depths (near low water, neap tide, salinity 6‰)[81]	5.1‰	5.4‰	5.5‰	5.8‰	5.3‰	6.2‰

80 Tidal velocity of 0.8m/s indicting a (per-minute turnover) mixing cell size of 48m long, 24m wide, and with a local tidal depth of 3.5m at low water spring, 4,000m^3.
81 Tidal velocity of 0.6m/s indicting a (per-minute turnover) mixing cell size of 36m long, 18m wide, and with a local tidal depth of 4.3m at low water neap, 2,800m^3.

3.2 Longer term spatial effects

There is a risk under prolonged low River Thames flows over Teddington Weir of incremental saline ingress up the Thames Tideway (from the Lower Thames Operating Agreement low flow assessment). This effect is manifest as gradual ratcheting of the salinity ingress up the tidal estuary over time. The effect is overturned through the flushing effect of high rivers flows, usually after significant rainfall events in the catchment. The Lower Thames Operating Agreement work found that a flow of at least 2,000 Ml/day appears to, at least temporarily, flush the higher salinity plug from the upper Thames Tideway.

Baseline data show that flow conditions, including local mid-Tideway inputs from STWs and the River Lee, play a significant role in maintaining the salinity regime in terms of the range and pattern of salinities. Flow conditions in the Thames Tideway (using River Thames at Kingston as an indicator) have a substantial effect on salinity levels throughout the mid-Tideway. In addition, there is a local 'plateau' in salinity around Beckton and Crossness STW, probably as a result of anthropogenic freshwater inputs providing a local freshwater contribution and also restricting the level of net saline ingress. Using the available baseline data, assessed under low flow conditions, the approximate net effect of the added volume in this area by anthropogenic sources (STWs) equates to a lowering of salinity levels by 2‰ in the local area.

If these freshwater inputs are reduced (e.g. as a result of direct river abstraction or re-use) then the broader salinity regime of the Thames Middle and Thames Upper has the potential to be influenced, particularly if River Thames river flows are lower than 2,000 Ml/day for more than 100 consecutive days. As a result, the Thames Tideway reach subject to the salinity plateau would shrink and saline ingress accelerate (see **Table 3.2**). As a simplification, based on bathymetry[82], tidal excursion, and mid-tide salinity, there is approximately 14,000Ml of water of ~11‰ in the 6km "plug" of water passing Beckton/Crossness each half-tidal cycle, which equates to 9,500Ml freshwater and the remainder seawater. Maintaining this are the local freshwater inputs together with the transition to freshwater landwards and the transition to full salinity seawater seawards and the gradual movement of water out of the estuary.

Initial evaluation using limited data, supported by Lower Thames Operating Agreement work, suggests that more than a 15 to 20% reduction in (total) freshwater inputs [a reduction of 275 to 372 Ml/d] would see a noticeable change in the salinity regime of the middle Tideway (particularly under sustained low flow conditions (River Thames flows lower than 2,000Ml/d for more than 100 consecutive days), when the reuse and desalination options would be particularly relevant.

Prior to further validation, the frequency, magnitude and duration of the effect cannot be determined. However, the Lower Thames Operating Agreement study has shown that in 2011, there was an approximate 6-month ingress period of higher salinity water at Teddington, coinciding with a period of lower river flows which did not exceed 2000 Ml/day at Kingston during this time. This is similar to WARMS modelling predictions (AR16) that identifies around 1 year in every 10 with more than 200 consecutive days of river flows less than 2,000 Ml/day, to a maximum of 294 days in 1920-21.

Although the estuarine ecology is typically well-adapted to changes in salinity in the Middle Thames, a prolonged period of salinity increases could change community structure in benthic

[82] Simplified representation from Admiralty charts

macroinvertebrates and fish communities, notably in the Upper Thames waterbody (which has some freshwater assemblages) and Middle Thames. A review of potentially sensitive ecological receptors in the estuarine habitats identified no (current) national or international designated habitats and a small number of protected species, notably brown trout, bullhead, European smelt and Swollen spire snail. Brown trout (and its estuarine morphotype, sea trout) will arrive in the Thames Tideway summer and early autumn to spawn. Although the effect of flows or salinity on spawning or smelting cues are not well understood, a precautionary minor impact has been assumed under saline ingress conditions. Bullhead is a freshwater obligate but can tolerate slightly brackish water but cannot reproduce in saline conditions. This species is not recorded downstream of Chiswick and would be displaced further upstream within the Upper Tideway under saline ingress conditions, resulting in a minor impact.

Although European smelt are considered to have minor sensitivity to salinity changes and these would be displaced elsewhere within the Tideway under saline ingress conditions, a minor impact. The swollen spire snail (recorded in Barking Creek adjacent to Beckton STW) requires very low salinity conditions, but its sensitivity to salinity changes is unknown. More primary research would be required to understand potential impacts. A minor-medium (uncertain) impact has been assumed at this stage.

All other communities/species are either tolerant of wide salinity range, or adapted to a wider range of conditions within the Thames Tideway. Nevertheless, there is a potential for disruption of communities through displacement of individual species within the community mosaic due to individual species salinity preferences, resulting in an up to medium impact.

In the absence of high flows to flush the saline ingress, such exacerbation of higher salinities would lead to a shift in overall salinity range and pattern locally and potentially affect local sediment deposition rates and habitat availability and suitability.

Table 3.2 Daily freshwater inputs for the baseline and effect on freshwater contribution from different combinations of WRMP19 options for low flow conditions

Baseline (all mid Tideway sources listed in Table A at the end) (3)	Deephams Reuse (1) (46.5Ml/d) only	Beckton Desalination (150Ml/d only)	Beckton Reuse (300Ml/d) only	Crossness Desalination (300Ml/d only)	Deephams Reuse+ Both Beckton options (reuse and desalination) 496 Ml/d (2)	Both Beckton and Crossness desalination options 450 Ml/d	Beckton and Crossness Desalination and Deephams Reuse	Beckton Reuse and Crossness Desalination 600 Ml/d	Beckton Reuse and Crossness Desalination and Deephams Reuse (2)
1832 Ml/d	1786 Ml/d	1682 Ml/d	1532 Ml/d	1532 Ml/d	1382 Ml/d	1382 Ml/d	1336 Ml/d	1232 Ml/d	1186 Ml/d
Schemes that would reduce freshwater input by more than 20% (>1460 Ml/d)	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Reduction in freshwater input (%)	3%	8%	16%	16%	27%	25%	27%	33%	35%

Note:
(1) Deephams Reuse reviewed as an either/or with Lower Lee DRA, noting that the average daily abstraction rate of the reuse scheme is higher and has been included as a worse case.
(2) Beckton reuse and desalination options unlikely to be undertaken together due to lack of land available at/near Beckton STW and the cost of two separate treated / water tunnels to or via Coppermills
(3) the baseline freshwater flow in the table above is conservative as it assumes current freshwater flow inputs into the local area and has 2016 representations of STW dry weather flow provided by Thames Water. STW flows will increase in future through growth in the sewer catchments and changes in water usage patterns. Thames Water projections of STW growth are included in Appendix A.

3.3 Effects on tidal level locally

The desalination options have the potential to abstract significant volumes of water on the falling ebb tide in the Tideway and could have a detrimental effect through increased exposure of tidal habitats, depending on tidal characteristics and abstraction volumes. This could be particularly important should exposure of intertidal habitats, notably mudflats, include NERC Section 41 Priority Habitats.

The dynamic nature of estuaries and the large water volumes within the tidal prism means that it is difficult to change level locally sufficiently to induce a gradient in the water level that is not readily overcome by the high rate of water movement. The effect is however most likely where larger abstractions are undertaken at slack water (which can occur during both high water and low water), The desalination options individually could potentially result in local lowering. The combination of Beckton abstraction with the reduction in the rate of discharge as a result of the Beckton STW re-use option may also have the potential to drawdown the water surface locally.

In terms of potential magnitude, should the Beckton desalination option be operated to abstract at maximum rate at low water slack (as Thames Gateway Water Treatment Plant is licensed in September-March) this would see a worst case 520m^3/minute reduction (in addition to the TGWTP influenced baseline) equivalent to a 5cm water level reduction within a hectare. If the Crossness desalination option was operated to abstract (n.b. abstraction located at Beckton) at a maximum rate at low water slack (as TGWTP is licensed in September-March) this would see a 1,000m^3/minute reduction, equivalent to a 10cm water level reduction within a hectare. These would be estimated maxima close to the abstraction points, and do not take into account inflow from the wider estuarine environment (which would happen, and reduce magnitude). Dependent on the rate of influx of water to overcome the gradient, which could be expected to reduce the impact to an extent, a depression and vortex could form locally. Cumulatively, the Beckton and Crossness desalination options could interact with each other, which in this analysis would equate to a maximum 15cm water level reduction within a hectare. This effect would decrease substantially beyond any slack water periods due to tidal interactions.

In terms of extent, the effect would be in the immediate area local to the Beckton desalination intake. In addition, using the precautionary principle, we have allowed for a possible 2 kilometre zone of effect. Review of the receptor ecosystems, focussing on the intertidal mudflats in the vicinity of Beckton and Crossness STW, concludes that they are subject to extensive modification. The habitats in the Middle Thames Tideway do not meet the description of intertidal mudflats described by the UK Biodiversity Action Plan (BAP) group. The resultant limited magnitude and extent of changes in level on intertidal mudflat habitats as a result of the WRMP19 options, alone on in combination, is therefore considered Negligible.

4 Conclusions

4.1 Summary

The report considered the potential cumulative effects of re-use, desalination and Direct River Abstraction (DRA) WRMP19 options on the Middle and Upper Thames Tideway. Three types of potential impacts have been considered: immediate changes to local salinity levels; long-term spatial effects on Thames Tideway salinity; and effects on local tidal level associated with the abstraction locations.

Immediate, local salinity effects

Brine introduced as a result of the desalination options is substantially diluted by and transported with STW treated discharge flows prior to discharge to the Tideway. Beckton desalination is estimated to increase salinity by between 0.2 and 0.4‰ locally with the Crossness desalination option raising salinity by 0.5 to 0.9‰ (maximum increase of ~10 to 17% in the receiving water). To put these values into context, Tideway salinity varies over and between tidal cycles from 0.2 to 14.7‰ at Beckton and 0.4 to 16.4‰ at Crossness, depending on freshwater flows and tidal state. The schemes would not be operating at the lower salinity values as these are at times of high river flows. The ecology of the Tideway in this reach is generally resilient to salinity change and consequently the options will have little influence on local biota.

In combination, the options are estimated to increase salinity locally by 1.8 to 1.9‰ (approx. 35% change) during average salinity conditions (approx. 3-5‰) and worst case low dilution circumstances. This should again be considered against the highly variable salinity regime of the middle estuary. When these changes are reviewed against the salinity preferences of the existing estuarine ecological communities, which does not include any designated or notable habitats near to the STW outfalls, with most species in the mid-Tideway typically well adapted to changes in salinity, then the resultant influence is considered to be minor.

Upper and Middle Tideway Salinities and Ecology

Baseline local mid-Tideway freshwater inputs play a significant role in maintaining the salinity regime in the Tideway, in terms of both range and pattern. Work undertaken as part of previous studies (notably the Lower Thames Operating Agreement study undertaken by Cascade) has highlighted that if freshwater inputs reduce significantly the local salinity regime could change. There is a risk under prolonged low River Thames flows (potentially exacerbated by Teddington DRA) of gradual saline ingress up the Tideway until flushed out by high river flows.

These initial studies, suggest that more than a 15 to 20% reduction in freshwater inputs (275-366Ml/d, taken up by options) could result in salinity regime modification. This is based on an estimate of the freshwater input required to maintain local salinities in the context of the local tidal excursion of the middle Tideway. This scale of modification would be realised by most options in combination and could result in a collapse of the salinity plateau in the Middle Tideway with a steadier transition from low to high salinity moving seawards in the estuary. Furthermore, the normal summer low flow pattern of saline ingress up the estuary, present in all years with these schemes in operation has the potential to change the salinity pattern of the Middle Tideway to higher (high tide) salinities and less low (low tide) salinities.

In turn, this could change community structure in benthic macroinvertebrates and fish communities, in the Upper and Middle Tideway. A review of potentially sensitive ecological receptors in the estuarine habitats identified no (current) national or international designated habitats and a small number of protected species, notably brown/sea trout, bullhead, European smelt and Swollen spire snail. Brown/sea trout use increased freshwater flows as a smolting cue and the absence of lower salinity water during summer and early autumn as a result of scheme operation could delay smolting or lower success rates, a minor impact. Bullhead and European smelt are considered to have medium and minor sensitivity to salinity changes and these would be displaced elsewhere within the Tideway under saline ingress conditions, a minor impact.

The swollen spire snail (recorded in Barking Creek adjacent to Beckton STW) requires very low salinity conditions, but its sensitivity to salinity changes is unknown. More primary research would be required to understand potential impacts. A minor-medium (uncertain) impact has been assumed at this stage.

All other communities/species are either tolerant of wide salinity range, or adapted to a wider range of conditions within the Thames Tideway. Nevertheless, there is a potential for disruption of communities through displacement of individual species within the community mosaic due to individual species salinity preferences, resulting in an up to medium impact.

In terms of a future ecological baseline of the Thames Tideway, this is slightly uncertain noting that combinations of schemes would potentially be decades away. A proposed MCZ for the Thames Tideway for European smelt, European eel and Tentacled lagoon worm could result in an up to minor impact in future. In addition, the Thames Tideway estuary is currently recovering from historic pollution, which may mean that more sensitive species could have re-settled by the time the schemes are operated together, resulting in a medium impact in future.

Climate change (resulting in sea level rise and drier summers) may result in a more routine and stronger saline ingress in the summer period and communities would have adapted to these regardless of water resource schemes. Further validation of the potential local salinity changes is unlikely to amend these ecological conclusions.

Local tidal height and associated habitats

High rates of abstraction for desalination (31Ml/h Beckton; 62Ml/h Crossness) at low tides are likely to lower tidal levels and increase habitats exposure. The effect is likely to be small for individual options and offset by tidal flux. Options in combination could have an impact on levels, to a potential maximum of around 15cm reduction cumulatively for Beckton & Crossness desalination within a hectare cell. No material impact on associated intertidal habitats is expected due to the fact that this maximum effect is limited to transitional slack tides and the relatively low cover and ecological value of intertidal habitats in the immediate area.

4.2 Uncertainty

It is recognised that there are uncertainties in all of the values and operational practices used in this outline assessment. Should the effects identified be deemed sufficiently significant or where they may significantly influence option choices we would recommend more detailed analysis. A number of assumptions were made to allow consideration of the cumulative issues at this stage, as detailed below and contained in **Appendix A**.

A desalination feed water salinity of 11‰ has been used, based on Mott MacDonald design assumptions; this may be high for normal mid-ebb and low-ebb salinities locally, but includes for the effects of saline ingress up the estuary as low river flows extend. This may increase up to 13‰ during low flow, high spring tides.

The relevant size of the local abstraction effect zone/mixing cell is uncertain and has been based on reported velocities. Where further measured flow data (such as ADCP) are available these could be used within a model to reduce this uncertainty.

More advanced bathymetry and tidal velocity datasets would also enhance the Admiralty Chart based volumes and reported tidal excursion information used to assess the long-term broad scale salinity effect. The Environment Agency do not operate any AQMS stations seawards of Cadogan Pier (Chelsea) and no other long term short interval continuous monitoring of conductivity or salinity are known in the middle Tideway from which to verify the local salinities used here, the presence of the salinity plateau around Beckton or the saline ingress pattern and control characteristics recorded in the upper Tideway in 2011. Although a 2D hydrodynamic model could be used to represent salinity patterns and effects of WRMP options, there would be difficulties in validating the salinities in the model and preventing model error propagation when run for the 200 days necessary to corroborate the long-term salinity effect of reducing freshwater input to the middle Tideway. There is confidence that there would be an effect on salinity from multiple options, but where the cut-off lies is subjective and also dependent on the consequent effect on sedimentation rates.

Simple fluid dynamics could readily be used with local bathymetry data and tidal velocity data to determine the extent of drawdown of individual desalination options and the potential for their overlap and interaction.

Appendix A – Study features

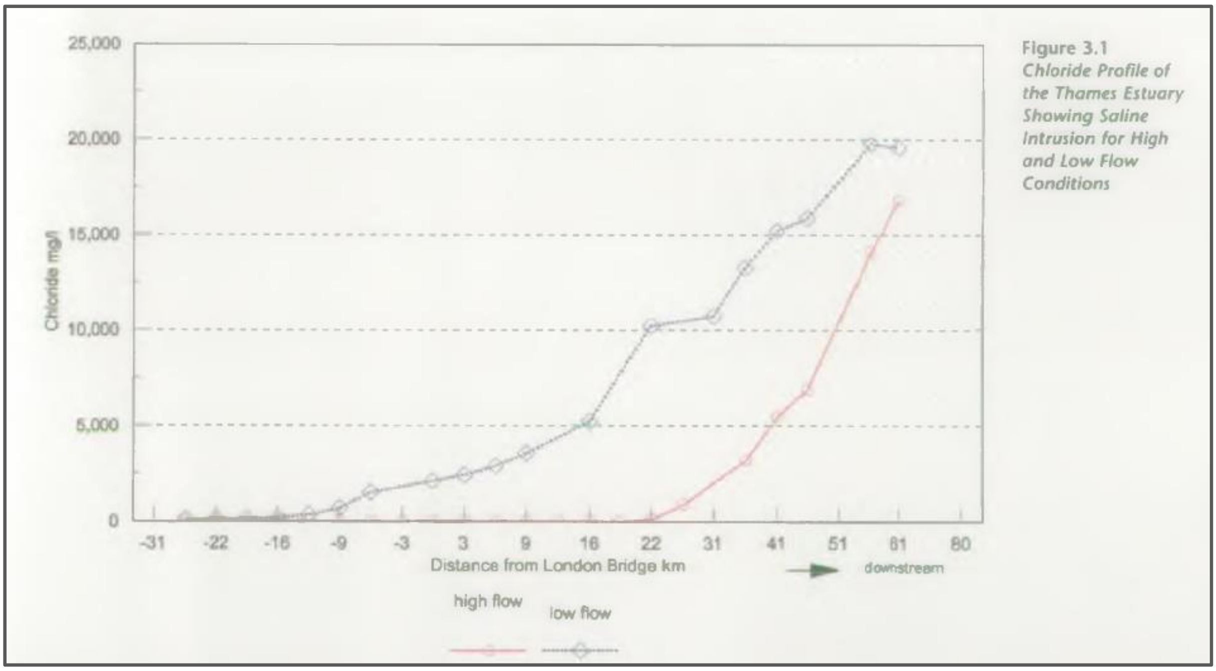
Table A

Input/ abstraction	Flow rate Input	Reduction	Rate	Conditions/ operational practice/ notes
Baseline (at times of operation of WRMP19 options)				
River Lee	✓	×	285Ml/d Q95 (daily record of Low Hall and Lea Bridge gauges combined in period 1/1/1995-30/9/2015)	Note 1995 is 1st full year of gaugings at Lea Bridge
River Roding	✓	×	17Ml/d Q95 (Redbridge gauge in period 1/1971-30/9/14)	-
River Beam	✓	×	6Ml/d Q95 (Bretons Farm gauge in period 1/1971-30/9/14)	Note 1971 is 1st full year of gaugings at Bretons Farm
River Ingrebourne and Riverside STW	✓	×	River: 8Ml/d Q95 (Gaynes Park gauge in period 1/1971-30/9/14)	Note gauge is upstream of STW discharge
	✓	×	Riverside STW: 92Ml/d (2016 DWF, SOLAR)	99Ml/d (2036 DWF, SOLAR); 103Ml/d (DWF, consent)
Rivers Darent and Cray	✓	×	19Ml/d Q95 (daily record of Darent at Hawley and Cray at Crayford gauges combined in period 1/1971-30/9/14)	Note Hawley gauge dataset [online] to 30/9/2014
Thames Gateway WTP	×	✓	≤40Ml/h; ≤200Ml/d [licence]	1Apr-31Aug abstraction ceasess1h before low tide [licence] Assume abstraction is on ebb tide for 3h before seasonal cut-off
	✓	×	Process brine of 28.2Ml/d via Beckton STW final effluent	Continuous release (14.1% of influent, as used for WRMP options)
Beckton STW	✓	×	1,111Ml/d (2016 DWF, SOLAR)	1,205Ml/d (2036 DWF, SOLAR); 1,344Ml/d (DWF, consent)
Crossness STW	✓	×	494Ml/d (2016 DWF, SOLAR)	520Ml/d (2031 DWF, SOLAR); 597Ml/d (DWF, consent)
Potential WRMP19 options				
Beckton Reuse 300Ml/d	×	✓	300Ml/d net reduction in Beckton STW final effluent flows	Continuous over the daily cycle
Beckton Desalination 150Ml/d	×	✓	Abstraction rate from Tideway 31.2Ml/h for 3 hrs periods twice a day at ebb tide; 187.4Ml/d	Operational assumptions as per TGWTP
	✓	×	Process brine of 26.5Ml/d via Beckton STW final effluent 10.3Ml/d waste stream (non-brine) returned to Beckton STW.	Continuous release
Crossness Desalination 300Ml/d	×	✓	Abstraction rate from Tideway at Beckton, 62.5Ml/h for 3 hrs periods twice a day at ebb tide; 373.6 Ml/d	Operational assumptions as per TGWTP
	✓	×	Process brine of 53Ml/d via Crossness STW final effluent 20.6Ml/d waste stream (non-brine) returned to Crossness STW.	Continuous release
Deephams Reuse 46.5Ml/d	×	✓	46.5Ml/d net reduction in Deephams STW final effluent flows	
Lower Lee DRA 35Ml/d	×	✓	35Ml/d average daily abstraction; peak 150Ml/d	Continuous

It is noted that under prolonged and protracted low flows that baseline river flows will be less than Q95 values stated here and STW effluent baseline flows would also be lower.

Appendix B

Figure B Figure 3.1 as derived from Environment Agency (1997)



Appendix C – Macroinvertebrate Monitoring Sites

Table C.1 Showing *location and time periods of* selected Upper-Tideway *macroinvertebrate* sites

Site Code	Name	Easting	Northing	Dates
141814	Isleworth	516878	176025	2007-2012
137942	Kew Street	519100	177900	2007-2012
141813	Barnes	521579	176670	2007-2012
141812	Battersea	526725	176836	2007-2012

Table C.2 **Showing *location and time periods of* selected Middle-Tideway *macroinvertebrate* sites**

Site Code	Name	Easting	Northing	Dates
137959	SOUTH_BANK_CENTRE_IT_(5)	530800	180300	2000-2009
137940	GREENWICH_IT_(7)	538300	178000	2005-2007
142047	GREENWICH_ST	538300	178000	2005-2007
137920	WOOLWICH_(435)	543300	179600	2001-2012
137970	WOOLWICH_IT_(8)	542700	179300	2002, 2005-2007
137971	WOOLWICH_ST_(8)	542900	179400	2001, 2005-2007
137972	WOOLWICH_TBP	543300	179600	2000-2002
148799	Marine_Rec	544569	179941	2007
161276_Beckton 1	NA	544687	180129	2012
148940	Marine_Rec	544924	181241	2007
161276_Beckton 2	NA	544865	181183	2012
137934	CROSSNESS_IT_(10)	549200	180900	2000-2008
137935	Marine_Rec	549400	180900	2000-2008
161276_Crossness 1	NA	549409	180911	2012
148959	Marine_Rec	551202	180600	2007
161276_Crossness 3	NA	550816	180422	2012
148963	Marine_Rec	552423	178044	2007
161276_Slade Green	NA	552242	178116	2012

Site Code	Name	Easting	Northing	Dates
148965	Marine_Rec	554640	177885	2007
161276_Darrent	NA	554219	178282	2012
148969	Marine_Rec	561146	177363	2007
161276_South Stifford	NA	559474	177012	2012

Appendix D – Macroinvertebrate Species Lists

Table D.1 Total abundance of most common 20 species from all Upper-Tideway sites (2007-2012, all surveys)

Barnes	**#**	**Battersea**	**#**	**Isleworth**	**#**	**Kew**	**#**
Oligochaeta	24493	Oligochaeta	16562	Oligochaeta	27213	Nais	15455
Gammarus zaddachi	15662	Gammarus zaddachi	6170	Gammarus zaddachi	21877	Oligochaeta	12412
Potamopyrgus antipodarum	2215	Potamopyrgus antipodarum	2692	Potamopyrgus antipodarum	5092	Gammarus zaddachi	11801
Radix balthica	1567	Crangon crangon	493	Asellus aquaticus	1845	Radix balthica	8037
Helobdella stagnalis	485	Palaemon longirostris	287	Chironomidae	1486	Potamopyrgus antipodarum	1104
Chironomidae	459	Radix balthica	270	Radix balthica	880	Limnodrilus	822
Theodoxus fluviatilis	445	Sphaerium corneum	131	Sphaeriidae (Pea mussels)	777	Chironomidae	452
Sphaeriidae (Pea mussels)	360	Theodoxus fluviatilis	112	Corbicula fluminea	608	Branchiura sowerbyi	443
Erpobdellidae	360	Chironomidae	94	Pisidium	517	Theodoxus fluviatilis	427
Gammaridae	241	Sphaeriidae (Pea mussels)	91	Gammarus pulex	400	Glossiphonia complanata	414
Glossiphonia complanata	237	Gammaridae	51	Theodoxus fluviatilis	358	Helobdella stagnalis	395
Asellus aquaticus	157	Erpobdellidae	46	Gammaridae	290	Psammoryctides barbatus	370
Erpobdella	155	Trocheta pseudodina	45	Helobdella stagnalis	276	Tubifex tubifex	366
Pisidium	140	Helobdella stagnalis	24	Erpobdella	213	Sphaeriidae (Pea mussels)	277
Erpobdella testacea	92	Hydrobiidae	23	Glossiphonia complanata	207	Pisidium	223
Sphaerium corneum	80	Eriocheir sinensis	22	Erpobdellidae	154	Gammaridae	165
Palaemon longirostris	62	Hypania invalida	22	Caenis luctuosa	118	Erpobdella testacea	125

Barnes	#	**Battersea**	#	**Isleworth**		#	**Kew**	#
Asellidae	60	Gammarus	18	Erpobdella testacea		100	Erpobdella octoculata	115
Pisidium subtruncatum	59	Glossiphonia complanata	17	Palaemon longirostris		88	Erpobdellidae	88
Sphaerium	58	Erpobdella testacea	16	Erpobdella octoculata		85	Erpobdella	87

Table D.2 Species recorded from all Mid-Tideway sites

Species Name / Taxon	
Abra alba	Corophiidae
Abra nitida	*Corophium*
Abra tenuis	*Apocorophium lacustre*
Acariformes	*Corophium volutator*
Achelia echinata	*Crangon crangon*
Actiniaria	*Crassicorophium bonnellii*
Alitta succinea	*Cyathura carinata*
Alkmaria romijni	Decapoda
Ampharete grubei	*Dero*
Ampharete lindstroemi	*Diptera*
Amphibalanus improvisus	*Doto*
Amphiblestrum auritum	*Einhornia crustulenta*
Anaitides mucosa	*Electra crustulenta*
Animalia	*Electra monostachys*
Aphididae	*Electra pilosa*
Apocorophium lacustre	Elmidae
Araneae	*Elminius modestus*
Aricidea minuta	Enchytraeidae
Ascidiacea	*Enteromorpha*
Asellus	*Eriocheir sinensis*
Asellus aquaticus	*Eteone longa*
Aspidelectra melolontha	*Eusarsiella zostericola*
Athecata	*Farrella repens*
Balanidae	Formicidae
Balanus crenatus	Gammaridae
Balanus improvisus	*Gammarus*
Barnea candida	*Gammarus salinus*
Boccardiella ligerica	*Gammarus tigrinus*
Bryophyta	*Gammarus zaddachi*
Callopora dumerilli	Gastropoda
Campanulariidae	*Gracilaria*
Capitella	*Harpacticoida*
Ceramium	*Hediste diversicolor*
Ceratopogonidae	*Heterochaeta costata*
Chironomidae	*Heteromastus filiformis*
Chlorophyta	Hydractiniidae
Cirripedia	*Hydrobia ulvae*
Cladophora	Hydrobiidae
Clitellio arenarius	*Hydrozoa*

Cochliopidae	*Jaera albifrons*
Collembola	*Janira maculosa*
Conopeum	*Lanice conchilega*
Conopeum reticulatum	*Lekanesphaera hookeri*
Conopeum reticulum	*Lekanesphaera rugicauda*
Copepoda	*Limnodrilus*
Cordylophora caspia	*Limnodrilus hoffmeisteri*
Lymnaea peregra	*Psammoryctides barbatus*
Macoma balthica	*Pseudoparatanais batei*
Magelona filiformis	Psychodidae
Manayunkia aestuarina	*Pygospio elegans*
Marenzelleria	Rhodophyta
Marenzelleria viridis	*Sabellaria spinulosa*
Maxillopoda	*Schizomavella auriculata*
Mediomastus fragilis	*Scrobicularia plana*
Melita palmata	*Sertularia*
Mesopodopsis slabberi	*Sertularia cupressina*
Microprotopus maculatus	*Sphaeroma rugicauda*
Mollusca	*Sphaerosyllis bulbosa*
Monocorophium acherusicum	*Sphaerosyllis taylori*
Mya arenaria	Spionidae
Myrianida	*Streblospio*
Mysida	*Streblospio shrubsolii*
Mysidae	*Tapes philippinarum*
Mysta picta	*Tharyx*
Mytilidae	*Tharyx killariensis*
Mytilus edulis	*Tharyx* "species A"
Naididae	Tipulidae
Nais	*Tubifex costatus*
Nais elinguis	*Tubifex tubifex*
Nematoda	Tubificidae
Nemertea	*Tubificoides amplivasatus*
Neoamphitrite figulus	*Tubificoides benedii*
Neomysis integer	*Tubificoides heterochaetus*
Nephtys	*Tubificoides pseudogaster*
Nephtys hombergii	*Turbellaria*
Nereididae	*Uncinais uncinata*
Oligochaeta	*Victorella pavida*
Ophiura	
Ophryotrocha	
Palaemonidae	
Palaemon longirostris	
Palaemon macrodactylus	
Pandeiidae	
Paranais litoralis	
Petricola pholadiformis	

Pholadidae	
Phyllodocidae	
Polydora caeca	
Polydora ciliata	
Polydora cornuta	
Pomatoschistus	
Potamopyrgus antipodarum	

Appendix E – Macroinvertebrate Indices

Table E.1 Showing AMBI scores and Simpsons Diversity for selected Mid Tideway macroinvertebrate sites

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Site code	137959												
S	2.00	5.00	2.00	2.00	3.00	4.00	2.00	3.00	1.00	1.00			
1-(AMBI/7)	0.23	0.17	0.14	0.14	0.49	0.50	0.79	0.50	0.14	0.14			
1 - Lambda'	0.25	0.76	1.00	1.00	0.69	0.32	0.06	0.64	0.00	0.00			
Site code	137940												
S						7.00	6.00	12.00					
1-(AMBI/7)						0.20	0.17	0.75					
1 - Lambda'						0.27	0.74	0.79					
Site code	142047												
S						13.00	8.00	8.00					
1-(AMBI/7)						0.58	0.69	0.21					
1 - Lambda'						0.80	0.24	0.79					
Site code	137920												
S		7.00	9.00	11.00	7.00	19.00	6.00	9.00	5.00	2.00	5.00	6.00	9.00
1-(AMBI/7)		0.17	0.48	0.49	0.18	0.60	0.56	0.81	0.29	0.57	0.63	0.59	0.57
1 - Lambda'		0.31	0.74	0.49	0.57	0.51	0.62	0.55	0.83	1.00	0.50	0.20	0.67

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Site code	137970												
S			2.00			4.00	5.00	1.00					
1-(AMBI/7)			0.14			0.15	0.21	0.14					
1 - Lambda'			0.02			0.43	0.36	0.00					
Site code	137971												
S	2.00				4.00	8.00	7.00						
1-(AMBI/7)	0.59				0.31	0.59	0.58						
1 - Lambda'	0.13				0.66	0.21	0.46						
Site code	137972												
S	4.00	2.00	4.00										
1-(AMBI/7)	0.15	0.14	0.57										
1 - Lambda'	0.42	0.67	0.04										
Site code	148799												161276_Beckton 1
S								4.00					3.00
1-(AMBI/7)								0.49					0.14
1 - Lambda'								0.90					0.51
Site code	148940												161276_Beckton 2
S								12.00					15.00
1-(AMBI/7)								0.39					0.55
1 - Lambda'								0.74					0.45

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Site code	137927												
S	6.00	14.00	5.00	3.00	2.00	13.00	8.00	3.00	7.00				
1-(AMBI/7)	0.21	0.54	0.31	0.79	0.57	0.60	0.25	0.14	0.16				
1 - Lambda'	0.27	0.16	0.93	0.60	1.00	0.80	0.51	0.38	0.65				
Site code	137934												
S	5.00	3.00	3.00	6.00	2.00	1.00	5.00	4.00	8.00				
1-(AMBI/7)	0.14	0.14	0.14	0.19	0.14	0.14	0.14	0.14	0.28				
1 - Lambda'	0.17	0.38	0.43	0.43	0.13	0.00	0.05	0.06	0.62				
Site code	137935												161276_Crossness 1
S	4.00	3.00	4.00	1.00	2.00	9.00	2.00	7.00	11.00				12.00
1-(AMBI/7)	0.15	0.24	0.30	0.14	0.14	0.40	0.14	0.15	0.15				0.18
1 - Lambda'	0.10	0.28	0.73	0.00	0.44	0.66	0.09	0.03	0.53				0.59
Site code	148959												161276_Crossness 3
S								8.00					4.00
1-(AMBI/7)								0.38					0.58
1 - Lambda'								0.89					0.20
Site code	148963												161276_Slade Green

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
S								10.00					7.00
1-(AMBI/7)								0.54					0.17
1 - Lambda'								0.73					0.14
Site code	148965												161276_Darrent
S								12.00					3.00
1-(AMBI/7)								0.35					0.86
1 - Lambda'								0.64					0.15
Site code	148969												161276_South Stifford
S								13.00					13.00
1-(AMBI/7)								0.50					0.43
1 - Lambda'								0.46					0.66

Appendix F – Saltmarsh plant species recorded

Site Id	Sample Date	Taxon Name	Macrophyte - Percent Cover
152311 Quadrat 1			
152311	21-Jul-2010	*Aster tripolium*	25

Site Id	Sample Date	Taxon Name	Macrophyte - Percent Cover
152386 Quadrat 1			
152386	19-Jul-2010	*Aster tripolium*	15

Site Id	Sample Date	Taxon Name	Macrophyte - Percent Cover
152311	21-Jul-2010	*Elytrigia atherica*	2
152311	21-Jul-2010	*Glaux maritima*	5
152311	21-Jul-2010	*Plantago maritima*	35
152311	21-Jul-2010	*Triglochin maritima*	40
152311 Quadrat 2			
152311	21-Jul-2010	*Aster tripolium*	20
152311	21-Jul-2010	*Elytrigia atherica*	1
152311	21-Jul-2010	*Glaux maritima*	2
152311	21-Jul-2010	*Plantago maritima*	35
	21-Jul-2010	*Triglochin maritima*	8
152311 Quadrat 3			
152311	21-Jul-2010	*Aster tripolium*	40
152311	21-Jul-2010	*Cladophora*	1
152311	21-Jul-2010	*Elytrigia atherica*	1
152311	21-Jul-2010	*Glaux maritima*	3
152311	21-Jul-2010	*Plantago maritima*	50
152311	21-Jul-2010	*Triglochin maritima*	5
152389 Quadrat 1			
152389	19-Jul-2010	*Bolboschoenus maritimus*	100
152389	19-Jul-2010	*Beta vulgaris*	2
152389	19-Jul-2010	*Elytrigia atherica*	100
152389	19-Jul-2010	*Elytrigia atherica*	100
152389 Quadrat 2			
152389	19-Jul-2010	*Bolboschoenus maritimus*	1
152389	19-Jul-2010	*Elytrigia atherica*	100
152389	19-Jul-2010	*Phragmites australis*	100
152389	19-Jul-2010	*Phragmites australis*	100
152389	19-Jul-2010	*Phragmites australis*	100
152389	19-Jul-2010	*Aster tripolium*	5

Site Id	Sample Date	Taxon Name	Macrophyte - Percent Cover
152386	19-Jul-2010	*Cladophora*	2
152386	19-Jul-2010	*Puccinellia maritima*	20
152386	19-Jul-2010	*Spergularia marina*	4
152386	19-Jul-2010	*Triglochin maritima*	70
152386 Quadrat 2			
152386	19-Jul-2010	*Aster tripolium*	15
152386	19-Jul-2010	*Cladophora*	1
152386	19-Jul-2010	*Glaux maritima*	10
152386	19-Jul-2010	*Puccinellia maritima*	50
152386	19-Jul-2010	*Spergularia marina*	3
152386	19-Jul-2010	*Triglochin maritima*	30
152386 Quadrat 3			
152386	19-Jul-2010	*Aster tripolium*	10
152386	19-Jul-2010	*Cladophora*	2
152386	19-Jul-2010	*Puccinellia maritima*	45
152386	19-Jul-2010	*Spergularia marina*	4
152386	19-Jul-2010	*Triglochin maritima*	45
152399 Quadrat 1			
152399	21-Jul-2010	*Aster tripolium*	8
152399	21-Jul-2010	*Atriplex hastata*	2
152399	21-Jul-2010	*Atriplex portulacoides*	10
152399	21-Jul-2010	*Glaux maritima*	3
152399	21-Jul-2010	*Plantago maritima*	4
152399	21-Jul-2010	*Puccinellia maritima*	10
152399	21-Jul-2010	*Triglochin maritima*	70
152399 Quadrat 2			
152399	21-Jul-2010	*Aster tripolium*	3
152399	21-Jul-2010	*Atriplex hastata*	2
152399	21-Jul-2010	*Atriplex portulacoides*	60

Site Id	Sample Date	Taxon Name	Macrophyte - Percent Cover

Site Id	Sample Date	Taxon Name	Macrophyte - Percent Cover
152399	21-Jul-2010	*Elytrigia atherica*	1
152399	21-Jul-2010	*Glaux maritima*	1
152399	21-Jul-2010	*Plantago maritima*	1
152399	21-Jul-2010	*Puccinellia maritima*	10
152399	21-Jul-2010	*Triglochin maritima*	30
152399 Quadrat 3			
152399	21-Jul-2010	*Aster tripolium*	10
152399	21-Jul-2010	*Atriplex hastata*	4
152399	21-Jul-2010	*Glaux maritima*	6
152399	21-Jul-2010	*Plantago maritima*	1
152399	21-Jul-2010	*Puccinellia maritima*	40
152399	21-Jul-2010	*Triglochin maritima*	50

Appendix E: Deephams Reuse Summary of Position

Summary of position following discussion between the Environment Agency and Thames Water on water environment effects of the Deephams STW Reuse option.

Thames Water's Water Resources Management Plan 2019 position

The Deephams STW Reuse option was included as a preferred option in the adaptive pathway of Thames Water's adopted Water Resources Management Plan 2019[19] (WRMP19) subject to further investigations. The preferred option in the adaptive pathway has a transfer rate of 46.5 Ml/d from Deephams STW to the reuse outfall.

The Environment Agency's representation[20] on Thames Water's revised draft WRMP19[21] included "Recommendation 2 - Ensure that the Deephams option is feasible and does not pose a risk to the environment". That recommendation outlined, at R2.2, concerns over environmental impacts on downstream habitats from reduced flows from Deephams STW; and at R2.3, in the estuarine Thames Tideway.

In response, in its final WRMP19 Thames Water set out a programme of further research to ensure the option is compliant with the Water Framework Directive (WFD) Regulations[22] before being progressed, at paragraph 11.244 of Section 11 *Preferred Plan* to confirm the WFD assessment.

Further work has been undertaken by Thames Water since publication of WRMP19[23] with extensive collaborative working with the Environment Agency throughout. This collaborative working built on the WRMP19 comment log[24], through a series of 10 meetings with Hertfordshire and North London Area Environment Agency staff, leading to adoption of a Methodology Report for the assessment which included scope development, assessment criteria and assessment methods.

Revised Draft Summary of Position

Following completion of the further studies by Thames Water and discussion with the Environment Agency[25] on the findings it has been established that a Deephams STW Reuse option has potential environmental risk. As such, after detailed discussion of the findings with the Environment Agency, Thames Water has withdrawn the option as the preferred WRMP19 option and also as a feasible option[26] from future WRMPs in the medium-term period to c.2060.

At times of operation, a Deephams STW Reuse option would reduce flow in reaches of the River Lee downstream of Deephams STW. For the stretch of the Lower Lee impacted by the scheme, the WFD classification[27] for hydrological regime is 'Does not support Good'. In the Water Resources National

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[19] Thames Water (2020) Final Water Resources Management Plan 2019 Section 11: Preferred plan *https://www.thameswater.co.uk/media-library/home/about-us/regulation/water-resources/technical-report/preferred-plan.pdf*
[20] Environment Agency (2018) Environment Agency Evidence Report (Annex 1)
[21] Including the WFD Compliance Assessment set out as Appendix BB of Thames Water's revised draft WRMP19.
[22] Water Environment (Water Framework Directive) (England and Wales) Regulations 2017. SI 2017 No. 407
[23] As reported in: Thames Water (2021) Deephams STW Reuse Option Assessment – Phase 3 WFD Compliance Assessment. Report prepared by Ricardo in associated with Atkins Ltd. Draft issued 15 April 2021
[24] Environment Agency (2018) Environment Agency Evidence Report (Annex 1)
[25] 30 April 2021: Project meeting between Thames Water, Environment Agency, Ricardo, and Atkins Ltd
15 July 2021: Project meeting between Thames Water, Environment Agency, Ricardo, and Atkins Ltd
22 September: Regular strategic meeting between Environment Agency and Thames Water
13 October 2021: Project meeting between Thames Water, Environment Agency, Ricardo, and Atkins Ltd
[26] Environment Agency, Natural Resources Wales and Ofwat (2021) Water Resources Planning Guideline Section 8.22 states: *You should confirm that there is no risk of deterioration from a potential new abstraction or from increased abstraction at an existing source before you consider it as a feasible option.*
[27] WFD classification as reported by Environment Agency Catchment Data Explorer: https://environment.data.gov.uk/catchment-planning/WaterBody/GB106038077852

Framework[28], the Environment Agency utilised a bespoke spreadsheet tool (Waterbody Abstraction Tool) to estimate water balance deficits in 2050; and some of the reaches downstream of a Deephams STW Reuse option have been identified to have a water balance deficit. For the Lower Lee, the calculated deficit is substantial and ranges between 425-521Ml/d under a range of scenarios for the reach impacted by this scheme.

The flow reduction associated with a Deephams STW Reuse Option is therefore contrary to the environmental ambition for these waterbodies as laid out by the Environment Agency Waterbody Assessment Tool (2021) and adopted by WRSE, if the scheme were implemented before major licence reductions on the River Lee. No further work on the environmental risks of a Deephams STW Reuse option before this point, or work to identify bespoke mitigation of the risks, will satisfactorily resolve the risk in the absence of a compensatory scheme.

Background to current position

Through the Water Resources National Framework, the proposed approach to define the longer-term aquatic environment requirements of catchments is to use flow indicators and in so doing to develop potential future flow targets. A Deephams STW Reuse option needs considering in that context. A Deephams STW Reuse option would operate intermittently, as a strategic asset, at times of sustained low river flow and environmental drought. As such it would adversely change the flow regime of the Lower River Lee compared with flow targets as detailed in the Environment Agency Waterbody Assessment Tool (2021) and that cannot be off-set by other flows generated by the remaining Lower Lee watercourses.

Since WRMP19 Thames Water has undertaken further environmental data collection and assessment of the aquatic environment study area for a Deephams STW Reuse option, in regular and extensive consultation with the Environment Agency. Thames Water's assessment of the potential effects on the aquatic environment of a Deephams STW Reuse option was set out in the context of WFD Regulations compliance. Such compliance is in terms of demonstrating both the avoidance of WFD deterioration, and the avoidance of introducing impediment to achieving WFD targets set out in the River Basin Management Plan (RBMP). In the key WFD water body[29], which is hydro-morphologically designated as heavily modified, the current, second cycle, RBMP (2015) overall ecological potential is Bad, with Bad status individually listed for both fish and the dissolved oxygen. The latest published interim classification (2019) of the water body remains Bad ecological potential, with Bad status individually listed only for fish.

In that context, Thames Water's WFD Regulations compliance assessment identified that without mitigation there is a risk to WFD Regulations compliance at times of operation of a Deephams STW Reuse option for water resources purposes. The effects of the option on flow were investigated in a holistic assessment of water quality effects; and on in-channel aquatic ecology through flow effects on wetted habitat and linked water quality impacts. That assessment identified only water quality pathway effects on in-channel aquatic ecology. Water quality modelling undertaken as part of the assessment identified effects on dissolved oxygen in the Lee Navigation and downstream River Lee at Hackney Marshes. Without mitigation, the effects on dissolved oxygen at times of operation was assessed as having the potential to deteriorate the status of macro-invertebrates and fish in the Lee Navigation and downstream River Lee.

Setting out a detailed approach to confirming or mitigating the dissolved oxygen effect is not appropriate because mitigating the dissolved oxygen effect and in so doing confirming the WFD Regulations compliance of the option does not resolve the effect of the option on achieving the advised flow targets. The extensive programme of monitoring that would be required to secure acceptability of mitigation of effects on flow targets sufficient to enable a Deephams STW Reuse option, for example through flow augmentation elsewhere in the catchment, is not considered by Thames Water to represent value for money to customers.

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[28] Environment Agency (2020) Meeting our future water needs: a national framework for water resources. Version 1. 16 March 2020

[29] GB106038077852 Lee (Tottenham Locks to Bow Locks/Three Mills Locks) river water body

Thames Water