Annex A2: Teddington DRA Gate 3 Cost and Carbon Report

J698-AJ-C01X-TEDD-RP-ZD-100002

Standard Gate three submission for London Water Recycling SRO

Notice – Position Statement

This report has been produced as part of the process set out by Regulators' Alliance for Progressing Infrastructure Development (RAPID) for the development of the Strategic Resource Options (SROs). This is a regulatory gated process allowing for control and appropriate scrutiny of the activities that are undertaken by the water companies to investigate and develop efficient solutions on behalf of customers to meet future drought resilience challenges.

This report forms part of a suite of documents that make up the 'Gate 3 submission.' Gate 3 of the RAPID programme represents a checkpoint on the way to solutions being prepared for consent applications. The intention at this stage is to provide RAPID with an update on activities being undertaken in preparation for consent application submission; activities' progress including programme through to completion; and consideration of specific activities to address particular risks or issues associated with a solution. The regulatory gated process does not form part of the consenting process and will not determine whether an SRO is granted planning consent.

Given the stage of the SROs in the planning process, the information presented in the Gate 3 submission includes material or data which is still in the course of completion, pending further engagement, consultation, design development and technical / environmental assessment. Final proposals will be presented as part of consent applications in due course.

Disclaimer

This document has been written in line with the requirements of the RAPID Gate 3 Guidance and to comply with the regulatory process pursuant to Thames Water's statutory duties. The information presented relates to material or data which is still in the course of completion. Should the solutions presented in this document be taken forward, Thames Water will be subject to the statutory duties pursuant to the necessary consenting process, including environmental assessment and consultation as required. This document should be read with those duties in mind.

Contents

List of Figures

List of Tables

1 Executive Summary

1.1.1 This report provides the basis, methodologies and results of cost and carbon estimates for the Teddington Direct River Abstraction (DRA) through Gate 3.

1.1.2 Teddington DRA (the Project) is one of the three schemes in the London Water Recycling Strategic Resource Options (London Water Recycling SRO). Teddington DRA is a water abstraction and transfer scheme supported by water recycling. River water would be abstracted via a new intake facility on the lower River Thames, just upstream of Teddington Weir, and conveyed through a new short pipe several hundred meters long to intercept with the existing Thames Lee Tunnel (TLT). This water would then be transferred to the Lee Valley reservoirs for storage and supply. To compensate for the abstraction and minimise any environmental impacts a proportion of final effluent from Mogden STW would be subject to additional tertiary treatment at a new plant on the STW site and the recycled water conveyed in a new tunnel to a discharge location just downstream of the abstraction point. The discharge would directly compensate flows taken from the new abstraction upstream. The maximum capacity of the Project is 75Ml/d.

1.1.3 Base Capital Expenditures (Base Capex) and Operating Expenditures (Opex) for the Project are estimated using a combination of cost curves from Thames Water's Engineering Estimating System (EES) and bottom-up cost estimates using industry data, quotations and cost rate benchmarking. Cost curves in Thames Water's EES are derived using data input sheets (F909 worksheets), which are Thames Water's costing spreadsheets to input scope information and attain Base Capex values. For the items where appropriate EES cost curves are not available, the estimated costs are verified with supplier quotations or unit rate cost benchmarking and input as override rates.

1.1.4 A Quantitative Cost Risk Assessment (QCRA) was carried out by identifying risk events, cost impacts and likelihood of the risk events occurring. For Gate 3 assessment, the Project capacity has been selected as 75Ml/d and therefore, the risk registers for the components was combined and integrated into a single risks, assumptions, issues, dependencies, opportunities (RAIDO) log. Risks and opportunities were reviewed through a series of workshops covering each project area, specific disciplines, and project wide elements, including programme, client and schedule risks. The RAIDO approach involved expanding on previously scoped items and adding new ones by deliberating on the root cause, impacts, cost and schedule scoring justification. Additional cost impacts were included where possible through granular estimation or provisional costings. Uniform and triangular probability distributions were adopted, including inclusion of custom ranges were possible. In addition, a review of the hazard elimination risk reduction (HERR) register prepared by the Designers under CDM 2015 was reviewed to ensure residual risks from there were also included where they presented a cost or schedule impact potential.

1.1.5 Estimated risk probabilities and cost/schedule impact scoring for each project risk were evaluated using Monte Carlo simulations to deduce a costed risk value.

1.1.6 Optimism Bias (OB) was derived using the methodology outlined in the "Cost Consistency Methodology – Technical Note and Methodology Revision E" (Mott MacDonald, Feb 2022). The OB assessment was undertaken afresh for Gate 3 taking account of project development through Gate 3 on design, consenting strategies, procurement plans, legislation and stakeholder engagement. The estimated OB values have been reviewed with the QCRA outputs and scaled back where appropriate to avoid double-counting in the Costed Risk and OB. OB was evaluated for the conveyance and outfall (recycled water transfer tunnel) scope costs independently of the rest of the Project as the delivery complexity and interfaces does not feature many of the OB categories at lower level of uncertainty that the rest of the Project does therefore it is appropriate to assess a separate and specific "tunnel only" scaled back OB.

1.1.7 Carbon estimates were formulated utilising the Thames Water EES carbon units/references and adapting PAS2080 carbon assessment methodologies for life cycle carbon module considerations, such as modules A4 transportation, A5 construction and B modules for operational carbon emissions. Additionally, a whole-life carbon mitigation assessment was carried out based on the PAS 2080 guidance and principles. Carbon evaluation is for an 80-year period. Carbon for decommissioning is not included as the operational life is expected to be over 100 years.

1.1.8 The capex, opex, costed risk, OB and carbon values have been calculated and are reported consistent with the requirements set out by Water Resources South East (WRSE). A summary of the costs and carbon estimates is listed in Table 1.1 below. All costs and carbon estimates discussed in this report are consistent with the WRSE requirements.

Table 1.1 Summary of Estimated Costs – Teddington DRA

Scheme	Component	Total Capex (£m)	Fixed Opex (£m/year)	Variable Opex (£/Ml)	Embodied Carbon (tCO2e)	Operational Carbon (tCO2e/y)
Teddington DRA	75Ml/d Tertiary Treatment Plant	159.5	0.5	35.7	3,963	133.4
	River abstraction & TLT connection	53.8	0.2	1	3,948	3.4
	Conveyance & outfall (recycled water transfer tunnel)	216.3	0.3	-	21,775	0
	TOTAL	429.7	1.0	36.7	29,686	137

1. "Total capex" is a sum of base capex (including overheads), costed risk and OB.
2. Conveyance elements ("River abstraction and TLT connection" and "recycled water transfer tunnel") were sized for 75Ml/d maximum yield
3. Variable opex is based upon an average year operation of 1092 hours at full capacity and the remaining year. This average is derived from the total forecast utilisation over 47 year period averaged per year; refer to Gate 3 report section 2.25 to 2.37.
4. Price base is 2022/23.

1.1.9 Given the levels of risk and uncertainty inherent in the scheme at this stage of development, the summary capex estimate reported above should be considered as point within a range of potential cost outcomes. Using the American Association of Cost Engineers (AACE) Cost Estimate Classification System, the calculated capex estimate range is £359m to £535m. Other options considered in the WRMP24/WRSE would also have a range on their estimates.

1.1.10 The cost estimate allows for the indirect costs in developing and delivering the Project and Thames Water overheads, these have increased between Gate 2 and Gate 3. The change reflects additional development stage expenditure such as design activities to reflect the tunnel change, the requirement for a pilot plant to test the proposed water treatment processes, the change in proposed consenting route from TCPA to DCO and, increased contractor indirect costs to deliver the larger and more complex scope of a bored tunnel. Contractor indirect costs have also been updated across the whole of the estimate to reflect market conditions and trends.

1.1.11 The derived capex and opex costs are used to generate the Net Present Values (NPV) and Average Incremental Costs (AIC) for the Project and as such deducing the project lifecycle costs. A summary of the AIC values is shown below for the Project at a minimum and maximum utilisation level over an 80-year period. The values used are in 2022/23 cost base and are adjusted to a 2022/23 cost base using the Consumer Prices Index including owner occupiers' housing costs (CPIH) Inflation Indices.

Table 1.2 Summary of Average Incremental Costs (AIC) at Minimum and Maximum Utilisation Level - Teddington DRA

Configuration name	Units	Teddington DRA (75Ml/d yield)
Option benefit	Ml/d	67
Minimum Flow – based on 20% (15 Ml/ (Engineering)d) utilisation for 12 months of the year		
Average Incremental Cost (AIC)	p/m³	65.9
Maximum Flow – full capacity (100% utilisation) for 12 months of the year		
Average Incremental Cost (AIC)	p/m³	68.9

1. Teddington DRA (75Ml/d yield): a combination of the 75Ml/d TTP component, the river abstraction and TLT connection component and the conveyance and outfall (recycled water transfer tunnel) component. Costs for operations of the conveyance component were calculated, assuming it conveys up to 75Ml/d.

2 Introduction

2.1 Background and Purpose of Report

2.1.1 Teddington DRA was identified as one of the three schemes for the London Water Recycling SRO. Thames Water Utilities Limited (Thames Water) have developed the conceptual design for this Project during the gate 3 RAPID process and re-evaluated the estimated costs, risks and carbon associated with the Project. The results of cost and carbon estimating has been included in the Gate 3 submission.

2.1.2 The objectives of this report are to present the latest basis, methodologies and results of cost and carbon estimating for the Teddington DRA (the Project) in the London Water Recycling SRO through Gate 3.

2.2 Project Overview

2.2.1 Teddington DRA is a water abstraction and transfer Project supported by water recycling. River water would be abstracted from the lower River Thames, just upstream of Teddington Weir, and transferred to the existing TLT. This water would then be transferred to the Lee Valley reservoirs for storage and supply. To compensate for the abstraction a proportion of final effluent would be treated and conveyed to a discharge location just downstream of the abstraction point. The discharge would directly compensate flows taken from the new abstraction upstream. The latest Teddington DRA concept design and how it will be constructed is provided in Annex A1. The key components of the Project are:

- Tertiary treatment plant (TTP): TTP will be located in Mogden STW to treat final effluent from the STW and generate up to 75Ml/d of recycled water. The treatment process would include Moving Bed Biofilm Reactor (MBBR) and mechanical filter treatment as a minimum.
- Recycled water transfer: A new approximately 4.2km long tunnelled conveyance route would be constructed to connect the TTP in Mogden STW to the proposed outfall on the riverbank of the River Thames upstream of Teddington Weir. The tunnel would be bored at a depth of around 20-30m. The tunnel, approximately 3.5m internal diameter (ID), would be driven using a Tunnel Boring Machine (TBM). The tunnel would have four shafts: a drive shaft and a recycled water interception shaft in Mogden STW, a reception shaft near the new outfall, and an intermediate shaft at around the midpoint between Mogden STW and the outfall.
- River abstraction and transfer to TLT: The river abstraction would be located approximately 175m upstream of the proposed new outfall. The abstracted river flow would be conveyed to the existing Thames Lee Tunnel (TLT) through a smaller diameter (up to 2.2m ID) pipe installed using a pipe jacking technique. There are currently two potential locations for the connection of the new pipeline into the TLT – one approximately 130m from the river abstraction, and the other approximately 500m.

2.2.2 The Teddington DRA Project will supply the London Water Resource Zone (WRZ), with King George V zone being the beneficiary. Figure 2.1 depicts an overview of the Teddington DRA Project.

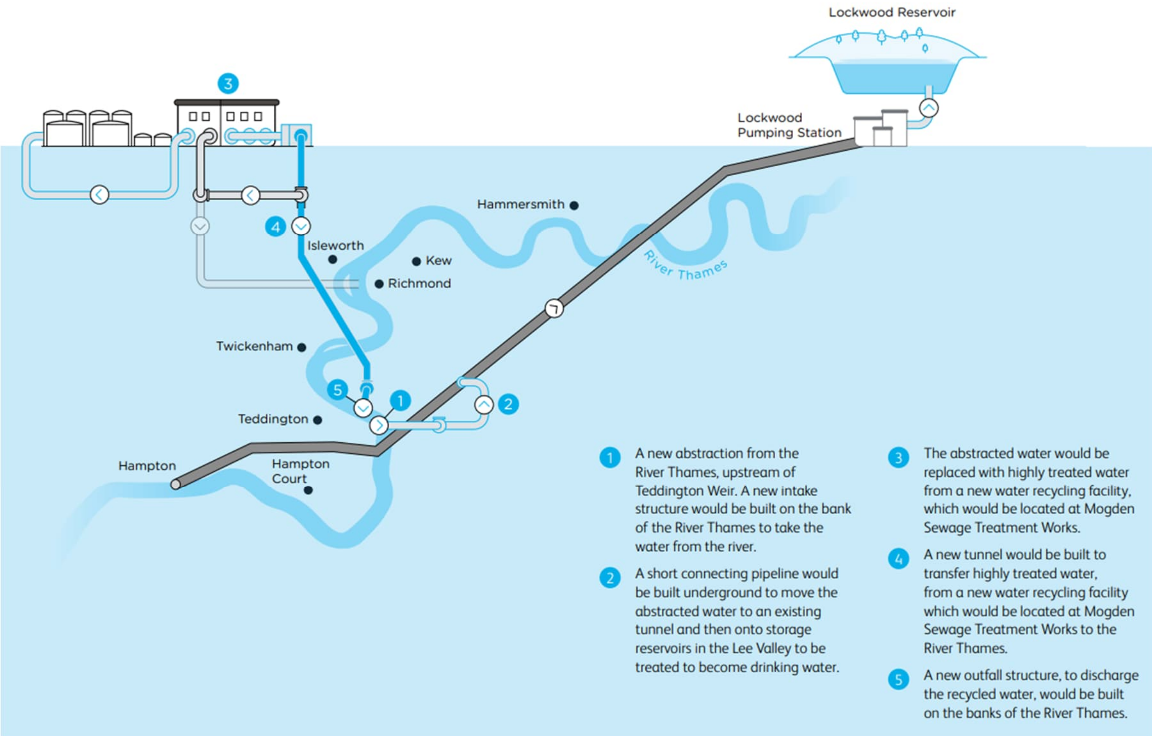

Figure 2.1 Teddington DRA Project Overview

Table 2.1 Teddington DRA Components for Cost Estimate

Components	Gate-3/ WRSE Reference	Scope Summary
75Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	• Tertiary Treatment Plant to yield 75Ml/d recycled water • Final effluent transfer pumping station • Recycled water pumping station • Wastewater return pumping station • Waste stream & effluent abstraction conveyance elements
River abstraction and TLT connection	TWU_KGV_HI-TFR_teddingtondrated/tlt	• Raw water abstraction from River Thames incl. screens & pipeline (sized for 75Ml/d) • Transfer pipeline to TLT and shaft connection / adit (sized for 75Ml/d)
Conveyance & outfall (recycled	TWU_WLJ_HI-TFR_teddingtondramog/ted	• 3.5m-internal diameter tunnel from TTP (in Mogden STW) to River Thames at Teddington

Components	Gate-3/ WRSE Reference	Scope Summary
water transfer tunnel)		Weir for recycled water transfer (sized for 75Ml/d), including shafts and potentially discharge pumps • Includes for tunnel work site within Mogden STW and tunnel within site with shaft adjacent to the TTP
Solutions	**Components**	**Gate-3/ WRSE Reference**
Solution 1	75Ml/d Tertiary Treatment Plant, river abstraction and TLT Connection Conveyance & Outfall (recycled water transfer tunnel)	• TWU_KGV_HI-RAB_teddington dra 75 • TWU_KGV_HI-TFR_teddingtondrated/tlt • TWU_WLJ_HI-TFR_teddingtondramog/ted

3 Cost and Carbon Estimate Methodology

3.1.1 Total capital expenditure (total capex), operating expenditure (opex), embodied carbon, and operational carbon (fixed and variable) values have been estimated for the Project. Total Project cost estimate consists of base capital expenditure (base capex), costed risk and optimism bias (OB). This section provides methodologies to estimate these components for the Teddington DRA Project. Estimates were developed using Thames Water internal estimating process using delivered scheme data generated cost curves, the Engineering Estimating System (EES). In instances where cost model data(s) are not available, supply quotations and bottom-up estimates were used.

3.2 Base Capex Costing

3.2.1 Base capex cost estimates for Teddington DRA are derived using a combination of Thames Water's EES, through its estimating F909 input worksheets, together with bottom-up estimating for components where appropriate cost curves do not exist. Bottom-up estimates have used a range of industry data and published costs data. Costs derived from EES represent less than 30% of the base capex estimate.

3.2.2 Design requirement needs were entered into Thames Water Design Input Template and used as a basis by Thames Water estimating team to provide costs though its internally held F909 for items with available cost curves. Quotation and bottom-up estimates were also entered into the Design Input Template to allow for the Project base capex to be derived. This also includes the addition of contractor and Thames Water overhead costs.

3.2.3 F909 worksheets are Thames Water's input data costing spreadsheets used to calculate cost values by using EES cost curve data. There is also provision for manual/ override inputs where required for requirements without available cost curves.

3.2.4 For the RAPID Gate 3 cost estimates, the baseline of Gate 2 cost input templates have been developed to reflect project development. The Project scope was reviewed and updated as per the current conceptual design through a detailed process of technical review as set out in Figure 3.1. The template was prepared for each of the three components in the Teddington DRA Project in Table 2.1. As Teddington DRA was selected in the WRSE best value analysis and submitted in the WRMP24 plan, Teddington DRA 75Ml/d as a single-phase development was selected as the preferred solution, thus costing for Gate 3 was based on only a 75Ml/d TTP.

3.2.5 The estimating input sheets with either cost curve or bottom-up estimate overrides were processed to populate the AIC calculation tool to deduce the projects whole life costs including Net Present Values. This costing methodology aligns with the guidance prepared for the All Company Working Group (ACWG) to improve cost consistency between SROs and reporting to WRSE.

3.2.6 The Project costs allow for all required scope to deliver the project including planning, development, land acquisition and compensation, construction, specific construction requirements, process design to meet water quality requirements and scope required to deliver mitigations as identified through the Gate 3 environmental assessments.

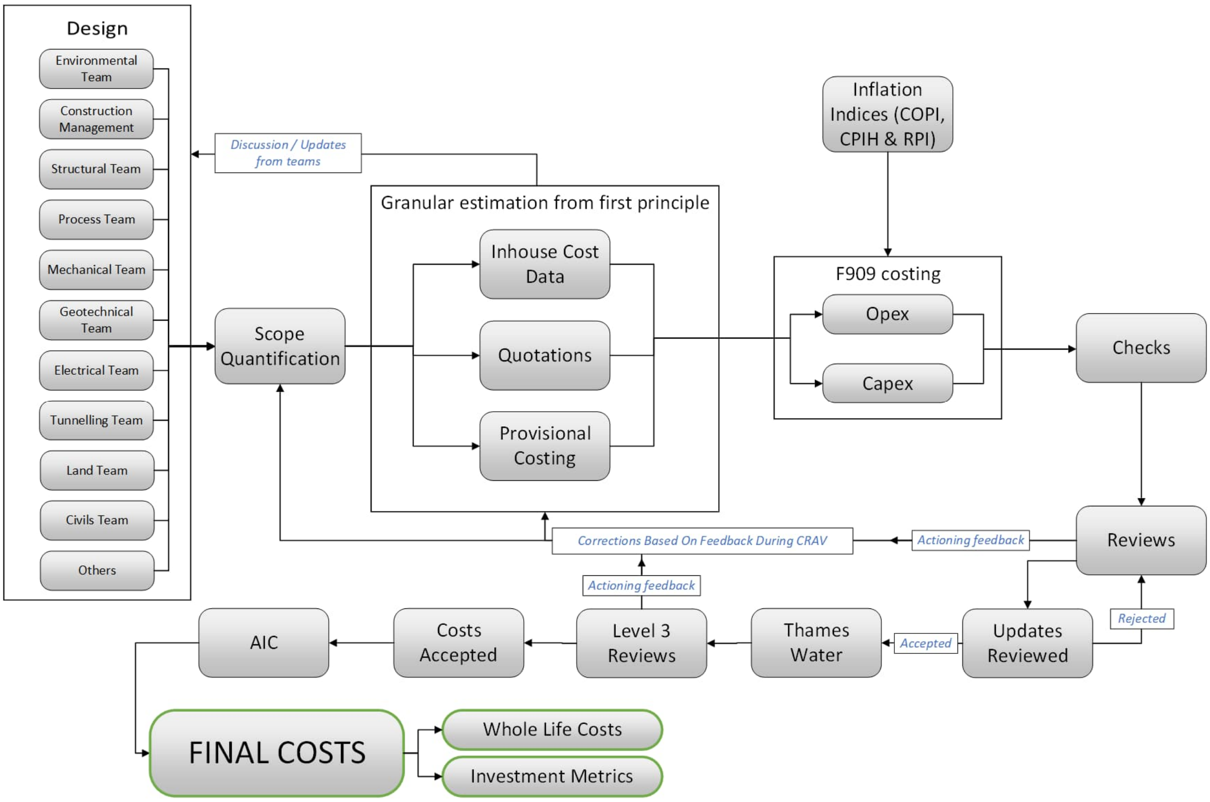

Figure 3.1 Overview of costing process for Teddington DRA.

Engineering Estimating System (EES) Cost Curves

3.2.7 Thames Water costing system, EES, is a database containing capital project cost coefficients, costs and carbon information aligned to various process and asset identifiers, including hierarchy's commonly in operation and used within Thames Water's facilities. The cost variables are derived from historic projects carried out by Thames Water. The historic project costs are analysed and mapped to the applicable process and asset identifiers (infrastructure and non-infrastructure assets) through update cycles to ensure they are relevant to current market cost dynamics and are representative.

3.2.8 A Carbon estimate system also exists within EES and mirrors the cost model structure for infrastructure and non-infrastructure assets. In EES, users select the appropriate cost curve from the library of available items and populate the appropriate yardstick value.

3.2.9 Data in the EES libraries has been collected from Thames Water projects against two key milestones. Target Cost and Final Actual Cost. The data are checked against final drawings to ensure accuracy with all financials validated using the Thames Water corporate financial system.

3.2.10 The data enables EES to produce robust process model(s) from these projects and helps Thames Water to support the three key areas within the business in a repeatable and auditable way:

- High level Estimating for investment purposes
- Benchmarking 'Value for Money' statements
- Regulatory 5 yearly pricing for Business Plans

3.2.11 Projects hold a unique index date/figure when imported into the EES system, and when modelled as a group, the projects are inflated to a common inflation index date.

3.2.12 For Gate-3 costing, all F909s were updated in terms of scope and yardsticks, using the latest available EES, as applied for WRMP24 and PR24 submissions, inflated using construction indices (COPI) and verified using high level bottom-up estimates.

Estimating Uncertainty

3.2.13 A review of estimating uncertainty within the costed scope has been undertaken, taking a matrix range of uncertainty boundaries (Low from -1% to -7% and High from 1% to 10%) to generate a range of estimating uncertainty between low (-ve) value and high (+ve value), this risk profile of estimating uncertainty is included in the QCRA and reflected in the QCRA risk cost value for the Project.

Manual Override Entries

3.2.14 The F909 worksheet allows manual override entries for items not covered by the EES database and where scope development has evolved sufficiently for costs to be derived through more detail cost build up methodology. In instances where quotations and cost build ups from first principle have been adopted, the manual override is used. The override is used due to the variables of the costed elements not having a suitable EES cost curve for the non-standard scope items. Cost rates for these items were entered with manual override, either by obtaining budget quotations from Suppliers or using industry benchmarked cost references.

3.2.15 In instances where the yardstick values required in F909s were outside the upper range of the EES cost curve and where linear increase of the price was expected, a cost rate can be entered based on the pro rata cost rate at the upper limit of the EES cost curve. This can be calculated through a linear extrapolation.

3.2.16 On completion of the costing exercise, about 28% of the estimates were deduced from the EES cost curves (inflated using construction indices), while the remaining 72% were overrides consisting of granular cost build-ups, quotations and provisional costs.

3.2.17 In the F909s worksheet, appropriate cost models were selected from EES costing library as per individual design items identified in conceptual design. Cost curves of Civil, M&E and ICA expenditures were available for each design item/ cost model. Relevant yardsticks/ quantities required were also entered, and the F909s generated Capex costs for Civil, M&E and ICA elements as a sum of base costs and overheads.

3.2.18 Any costs generated using EES rates are inflated with respect to the preferred reporting price base year. In Gate 3, this is FY22/23 in line with Thames Water PR24 price base year submissions.

Indirect Costs and Overheads

3.2.19 In addition to the direct construction costs calculated using EES and manual overrides, as noted above, the cost estimate allows for the indirect costs in developing and delivering the Project and Thames Water overheads.

3.2.20 In the development phase, indirect costs include the initial design of the scheme, obtaining consent, carrying out surveys, consulting with stakeholders and procurement of suppliers to carry out the works. The development indirect costs include actual development costs incurred up to the Gate 3 submission and resource-based forecasts for the remainder of the development phase.

3.2.21 In the delivery phase, the indirect costs cover Thames Water's client team and contractor indirect costs. The Thames Water client indirect costs are predominantly resource based forecasts whilst the Contractor indirect costs for detailed design, preliminaries and fee are benchmarked infrastructure industry percentages.

Base Date

3.2.22 All costs generated are presented at FY22/23 prices. All costs estimated to Q2, 2024 and deflated using CPIH to 2022/23 for comparison. Gate 2 cost have been inflated to 2022/23 using BCIS for comparison purposes.

Assumptions

3.2.23 Key assumptions made at Gate 3 include:

- Programme is based on DCO consent by end of 2027.
- Costs are based upon procurement being design and built (D&B) self-delivered by Thames Water
- Allowance has not been made for early contractor engagement input to the design.
- The Project is fully funded by Thames Water and is not funded through direct procurement for customers (DPC)
- Modifications or improvements to the Mogden STW are excluded from the SRO scope.
- Land is rented for contractor compounds in line with Gate 3 calculation for land rates.
- All permanent land requirements that are proposed to be acquired are priced in line with Gate 3 stage land and property cost estimates prepared for Thames Water for Gate 3.
- Spend profiles are aligned to the Programme in Annex G to facilitate investment decision making and will be refined at Gate 4.

3.3 Quantitative Costed Risk Assessment

3.3.1 A Quantitative Cost Risk Assessment (QCRA) was carried out by identifying risk events, cost impacts and likelihood of the risk events occurring. For Gate 3 assessment, the Project capacity has been selected as 75Ml/d and therefore, the risk registers for the components were combined and integrated into a single risk, assumptions, issues, dependencies, opportunities (RAIDO) log.

3.3.2 The RAIDO log includes for the three components listed in Table 2.1.

Risk Identification and Scoring

3.3.3 Gate 2 risk registers for the Project were initially reviewed and updated by the Risk Management Team in a new introduced RAIDO template (Risks, Assumptions, Issues, Dependencies, Opportunities) for Gate 3. Where applicable, risk entries were added or combined to ensure consistency and avoid duplication.

3.3.4 Once the draft risk registers had been prepared with the adjustment for consistency across components, they were reviewed by different project design teams. This included the process, conveyance, civil, mechanical, construction advisory, hydraulics, planning and environmental design teams, including the costing, procurement, commercial, property teams. The risk entries and scores were updated based on the latest conceptual designs and analysis of regulatory requirements.

3.3.5 In addition, a review of the hazard elimination risk reduction (HERR) register prepared by the Designers under CDM 2015 was reviewed to ensure residual risks from there were also included where they present a cost or schedule impact potential.

3.3.6 Additional cost impacts were included where possible through granular estimation or provisional costings. Uniform and triangular probability distributions were adopted, including inclusion of custom ranges were possible.

3.3.7 At Gate 2 a matrix of cost scores based upon level of impact, together with likelihood evaluation was utilised to derive risk impacts in line with the ACWG QCRA template methodology.

3.3.8 For Gate 3, we increased the maturity of the approach, developing an overall Thames Water project specific cost matrix and a number of risk events were specifically assessed overriding the semi-quantitative approach using custom assessment to align with level of maturity and understanding of the scope, estimate and therefore risk events.

3.3.9 The TDRA QCRA worksheet requires entries of either a “Cost Score” scaled from 1 to 5 depending on the costs expected to be incurred by the individual risk events or a bottom-up level of impact cost. “Probability Percentage” of the risk events is also required to be entered in the spreadsheets, and these two parameters are used in the Teddington DRA QCRA and for the Monte Carlo Simulation to produce the costed risk.

3.3.10 The costed risk is produced for each risk entry based on these three factors: “Cost Score or bespoke bottom-up level of impact assessment”, “Probability

Percentage” and “Time Score” as shown in the risk score matrix in Figure 3.2. Although “Time Score” is not considered in the Monte Carlo QCRA, the schedule impact output is used as input into QCRA in the form of time-related costs, and tabulated on enabling, delivery, or commissioning programme prolongation costs.

Table 3.1 Thames Water Teddington DRA Risk Assessment Matrix – Impact Scoring

		Very Low 1	Low 2	Medium 3	High 4	Very High 5
Construction cost impact	Min £k	-	500	1,000	2,000	3,500
	Max £k	500	1,000	2,000	3,500	5,000
Development cost impact	Min £k	-	50	100	250	500
	Max £k	50	100	250	500	1,000
Construction schedule impact	Min weeks	-	4wk	8wk	12wk	>18wks
	Max weeks	4wk	8wk	12wk	18wk	6mths
Development schedule impact	Min weeks	-	2wk	4wk	6wk	>8wk
	Max weeks	2wk	4wk	6wk	8wk	12wk

					THREATS				
Likelihood	Very Likely	Probably will occur Event is expected to occur in most circumstances	>70%	5					
	Likely	More likely to occur than not Event will probably occur in most circumstances	50-70%	4					
	Possible	Fairly likely to occur Event should occur at some time	30-50%	3					
	Unlikely	Not expected to occur Event could occur at some time	10-30%	2					
	Remote	Unlikely to occur Event may occur in exceptional circumstances	<10%	1					

Figure 3.2 Thames Water Teddington DRA Risk Scoring Matrix – Probability Scoring

3.3.11 While cost scores derived from the risk assessment matrices formed the basis of QCRA in Gate 2, probability and cost impact distributions have been further developed in Gate 3 in accordance with the increased level of maturity of the design and the deeper understanding of the Project risks.

3.3.12 For probability, a binomial distribution with a single trial is the default setting. However, more intricate risks were segmented into 2 or 3 impact scenarios. Where the iteration of the single binomial results in the risk occurring, the impact is determined based on a second event with conditional outcomes.

3.3.13 Cost impacts were modelled using triangular distribution mainly. This differs from uniform distributions used in Gate 2, which are used to a lesser extent in Gate 3 and have mainly been replaced by triangular distributions with not only a minimum and maximum cost impact value, but also a mode or "peak" value. Pre-defined cost scales shown in Table 3.2 have been generally overwritten by bottom-up estimates to suit the level of understanding of the risk based on available information. In addition, discreet distributions were used for risks requiring segmentation into scenarios, which each scenario having either a single, uniform or triangular bespoke distribution.

3.3.14 Estimating uncertainty does not cover risk events but were individually included for each of the project areas in the QCRA to account for the uncertainty associated with design quantities and prices of different scope elements. The estimating tolerances were obtained from the cost estimating team and broken down in accordance with the TW SRO Capital Cost Estimating Procedure.

Risk Mitigation

3.3.15 Risks were assessed in the current, pre-mitigated position as of September 2024 at the time of the risk identification and scoring exercise. Risks will be assessed again in their residual, post-mitigated position as the programme progresses with estimate of any costs associated with the mitigation.

Monte Carlo Analysis

3.3.16 The likelihood of the risk events and the cost ranges estimated to be incurred by the risk events are combined using the Monte Carlo simulation.

3.3.17 Uniform and triangular distributions were used for the QCRA. The range shown in Table 3.2 was allocated as a uniform probability distribution of costs incurred by each risk event (e.g. for the Cost Scoring Scale "3 – Medium" during construction phase, a uniform distribution with equal likelihood of an impact between £1,000k-£2,000k was assumed). More customised distribution were also applied to account for discrete scenario and low probability/ high impact risk events. A Bernoulli distribution was used for the likelihood of the risk event, which were entered as "Probability Percentage" in the risk registers. Each of the identified risks were treated as discrete events, and no dependencies between risk events were considered. Each simulation was run with a minimum of 10,000 iterations with Latin Hypercube sampling, with the 50th percentile (P50), 80th percentiles (P80) and 95th percentile (P95) of the output distribution used as the costed risk for the overall Project.

3.4 Optimism Bias

3.4.1 Optimism bias (OB) was derived using ACWG methodology which sets out recommendations for SROs on the common approach to OB assessment. These recommendations follow the HM Treasury Green Book approach, which defines OB as the "demonstrated, systematic, tendency for project appraisers to be overly optimistic. To redress this tendency, appraisers should make explicit, empirically based adjustments to the estimates of a Project's costs, benefits and duration.".

3.4.2 OB was evaluated for the conveyance and outfall (recycled water transfer tunnel) scope costs independently of the rest of the Project as the delivery complexity and interfaces does not feature many of the OB categories at lower level of uncertainty that the rest of the Project does therefore it is appropriate to assess a separate and specific "tunnel only" scaled back OB. The tunnel only scope is a well understood technology and has little direct relationship to environmental impacts and legislative uncertainty.

3.4.3 The Cost Consistency Methodology recommends that the approach to OB should use an associated excel template "Optimism Bias Template" provided for all SROs. The OB template was developed by Mott MacDonald based on the HM Treasury Green Book and supplementary guidance by the HM Treasury. The OB Template was used to calculate OB percentage rates.

Upper Bound Optimism Bias

3.4.4 The OB template is designed to determine the upper bound OB based on the proportion of the base capex cost that is considered to be standard civil engineering and the proportion that is considered to be non-standard civil engineering. This step is stipulated as "First Stage" in Section 0 in the Cost Consistency Methodology report[1]. ACWG methodology has been followed in assessing standard vs non-standard civil engineering proportions of the Project.

3.4.5 At the initial stage of the assessment, the proportions of non-standard and standard civil engineering base capex had been determined through team workshops, examining natures of individual base capex items, and utilising innovation, unique characteristics, and construction complexity as factors to justify the categorisation, as per the ACWG methodology. The TBM tunnel from Mogden to Burnell Avenue was found to represent by far the largest proportion of the total base capex. Two separate OB assessment were undertaken: the first covering the standard and non-standard proportions of TTP scope, Intake and TLT connection scope, and conveyance and outfall scope (excluding TBM tunnel scope), and a second covering TBM tunnel scope only.

3.4.6 TTP scope was considered "non-standard engineering" due to complexity and interfaces with existing operational infrastructure at Mogden SW. Conveyance and outfall scope elements (excluding TBM tunnel), were considered as an even split between standard and non-standard. Some Intake and TLT connection structures were considered standard, but primarily the scope was considered non-standard due to the complexity and unique characteristics carried by the cofferdam, screens and TLT connection elements.

3.4.7 The upper bound OB percentages shown in Table 3.2 were obtained based on these assumptions, using the OB template.

Table 3.2 Assumed Proportion of Non-Standard and Standard Civil Engineering Capex and Upper Bound Optimism Bias Percentage in Teddington DRA

Components	Gate-3/ WRSE Reference	Component type	Proportion of Non-Standard Civil Engineering Capex	Proportion of Standard Civil Engineering Capex	Upper Bound Optimism Bias %
75Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	Treatment Plant	100%	0%	63%
River abstraction and TLT connection	TWU_KGV_HI-TFR_teddington dra ted/tlt	Tunnel/ Direct River Abstraction	80%	20%	63%
Conveyance and outfall (recycled water transfer tunnel)	TWU_WLJ_HI-TFR_teddington dra mog/ted	Shafts and Outfall (excluding tunnel)	50%	50%	63%
		Tunnel only	75%	25%	50%
Overall*			63%	37%	58%

* The overall proportion of standard/non-standard has been obtained based on a pro-rata cost allocation the three main components.

Confidence Grade Assessment

3.4.8 Subsequently, "Contributory Factors" defined by the HM Treasury Green Book were allocated to "High", "Medium" and "Low" confidence bands according to the OB template. This step is stipulated as "Second Stage" in Section 0 in the "Cost Consistency Methodology – Technical Note and Methodology".

3.4.9 The OB template calculates mitigation factors to lower the upper bound OB according to the allocated confidence grades. Weighting of each contributory factor, which is based on the HM Treasury Green Book guidance, is used in the OB template calculation. The OB template, then, returns "adjusted OB" as a percentage of base capex.

3.4.10 As "Third Stage", it is required to review the confidence grade allocation after Quantitative Costed Risk Assessment (QCRA). The OB confidence grade set out in the second stage should be reassessed against the risk entries in the QCRA, and further scaling-back of the OB should be considered to avoid double-counting, where applicable. It is also required to record the level of OB at the conclusion of the first, second and third stages.

3.4.11 For the Gate 3, OB final values of each of the two assessments (“general” and “tunnel only”) were scaled-back to account for design development between Gate 2 and Gate 3 submission, where some OB values would be reduced due to greater certainty in the scope or identification of specific risks. The “Confidence Grade Criteria” were re-scored by the project team to determine the new adjusted OB value at Gate 3

Table 3.3 Level of Optimism Bias at First, Second and Third Stages and the Final OB%

Components	Gate-3/ WRSE Reference	Component type	First Stage (Upper Bound OB%)	Second Stage OB (Scaled-back pre QCRA)	Third Stage OB (Scaled back pos QCRA)	Summary of Changes from Gate 2 to Gate 3
75Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	Treatment Plant	62.48%	33.81%	33.65%	Confidence level of all Procurement contributory factors was improved to mostly Medium at Gate 3, having considered the current procurement strategy (under review), early market engagement activities and quantified costed risk. Project specific factors were improved from Low-Medium to mostly Medium due to increased project knowledge and some survey information, although higher confidence is impeded without full ground investigation results. Confidence in Client specific OB factors also improved from Low-Medium to Medium due to increased confidence in project intelligence and project management, although a lower confidence is to be noted in the OB contribution of project stakeholders, internal and external. A Low to Medium confidence remains in Environment contributory factors. Site characteristics are understood but detailed environmental assessments are required and permitting and planning uncertainties impede a higher level of confidence.
River abstraction and TLT connection	TWU_KGV_HI-TFR_teddington dra ted/tlt	Tunnel/ Direct River Abstraction	62.48%	33.81%	33.65%	

Components	Gate-3/ WRSE Reference	Component type	First Stage (Upper Bound OB%)	Second Stage OB (Scaled-back pre QCRA)	Third Stage OB (Scaled back pos QCRA)	Summary of Changes from Gate 2 to Gate 3
						Confidence level of External Influence factors have moderately increased to Medium due to higher confidences in technology used, but political and regulatory factors remain Low to Medium.
Conveyance and outfall (recycled water transfer tunnel)		Tunnel	49.50%	26.47%	20.48%	A second OB assessment was undertaken for the Conveyance component scope exclusively, resulting in "Design Complexity", "Degree of Innovation", "Environmental Impact", and "Poor Project Intelligence", being scaled back further to Medium to High levels. Other categories were also scaled back further to a smaller extent. Sector knowledge in TBM tunnelling through London Clay was a key contributor to the increase in confidence in this scope element. Notwithstanding, ground investigation results have not been obtained and this uncertainty prevents from higher confidence levels being declared.

First, Second and Third Stages in Optimism Bias assessment were defined in section 6.2 "Cost Consistency Methodology – Technical Note and Methodology Revision E"(Mott MacDonald, 2022).

3.5 Opex Costing

3.5.1 Operating expenditures (opex) are estimated using Thames Water's EES and by calculation of chemical and electricity usage using the Project developed design power requirements assessment. Activities associated with the operation of the Project on completion of construction and handovers such as electricity, chemical and employee headcount etc, were identified and quantified in the Designer Input Template for the costing requirement as part of the conceptual design set-up.

3.5.2 The opex items, including types of chemicals and maintenance work, are selected from the opex cost codes built into the input worksheet. Quantity for each item was entered based on requirements for further costing by Thames Water using its opex unit rate library. Opex requirements not covered within the standard opex cost curves are captured as 'Other' with relevant requirement needs and costs entered as overrides such as Biodiversity Net Gain (BNG) annual management costs.

3.5.3 Power demand for each component within the design scope are captured where applicable and further expressed as a kilo watt hour (kWh) requirement to derive the electricity costs based on applicable electricity unit rate within Thames Water operational areas and by assessing the Project Gate 3 developed load schedules for the scheme in use at full and minimum flow conditions. As per the requirements for WRSE, outputs for opex were categorised into fixed and variable opex for the costing exercise. Treatment process electricity and chemical costs are captured as variable opex, while all operational maintenance, labour, building service power and 'other' costs are regarded as fixed opex.

3.5.4 All opex costs are expressed at a price base year of FY22/23.

3.6 Carbon Estimate Methodology

3.6.1 The carbon estimate methodology follows the guidelines and standard estimating practices of the PAS2080 Guidance (specifically BS EN 17472:2022 for civil engineering works). A whole life carbon (WLC) emissions assessment was completed for a project period of 2022 – 2102 which accounts for a 5-year planning period, 5-year construction period and 70 years of operation (with the first year of operation in 2033). The WLC assessment includes the product, construction and use project stages with further details of the assessment inclusions provided below:

- Capital emissions: embodied material/asset emissions, emissions associated with transportation of materials/assets to site and construction emissions.
- Operational emissions: emissions associated with the estimated annual energy and chemical demand of the project operation.
- Use stage emissions: whilst the use stage accounts for operational emissions as detailed above, it also accounts for emissions associated with asset repair and maintenance and projected replacement.

3.6.2 Capital carbon estimates were performed using the Thames Water's Engineering Estimating System (EES) which holds over 6 million embodied carbon values. Asset specific design information was input into the EES to determine the embodied emissions of each scoped item. This also includes emissions associated with construction. Emissions associated with the transportation of assets and materials to the construction site were subsequently determined independently using projected HGV construction period movements. Transportation emission factors, for HGV usage, as provided within the UK Government GHG Conversion Factors for Company Reporting 2024 were used within this assessment. At this stage of the project, specific details of waste generation and disposal locations have not been fully scoped and therefore, following PAS2080 guidelines[2] 5% of embodied emissions uplift has been applied to waste generating assets/scope items.

3.6.3 Operational emissions were estimated using projected annual electricity consumption and chemical usage. The operation of the project is expected to be variable dependent on the water resourcing demand and therefore annual electricity and chemical consumption is not expected to remain constant across the lifecycle. However, for the purposes of this Gate 3 submissions, operational emissions are based on the maximum utilisation of the Project (100% capacity operating in 'Normal Operation' mode at all times) until greater accuracy on projected whole life electricity and chemical consumption can be completed in the next phase of the project. Greenhouse gas (GHG) emissions associated with electricity demand have been determined based on the UK Treasury Green Book projected grid electricity emissions factors, which are projected to 2100. It is assumed the plant will become operational from 2033 and therefore average grid electricity emissions factors for this first year of operation have been used for summary purposes (see Table 4.3). The electricity demand/consumption of the Project has been prorated based on projected annual plant operation durations/periods across the Project's lifecycle, applying date specific grid electricity emission factors.

3.6.4 Use stage emissions have been determined in adherence with PAS2080 guidelines for repair and maintenance applying a 1.5% and 0.25% of total capital emissions allowance for civil and M&E assets, respectively. This allowance is not reported as an operational emission within this assessment, however it is included within the WLC emissions reporting. Additionally, replacement emissions have been accounted for in alignment with the ACWG standard asset life expectancy[3]with replacement frequencies for assets in line with these frequencies. This Project is not expected to operate as consistently as typical water industry assets and therefore replacement of equipment is unlikely to be as frequent, and will in reality ultimately reduce the overall WLC of the Project.

4 Cost and Carbon Estimate Results

4.1 Capex Estimates

4.1.1 The base capex, costed risk, optimism bias and total capex estimated for the components associated with Teddington DRA are shown in Table 4.1. Detailed breakdowns of the base capex are also found in Appendix A to this report.

Table 4.1 LWR SRO, Teddington DRA – Capex Estimates (2022/23 price base)

Components	Gate-3/ WRSE Reference	Base Capex (£M)	Costed Risk (£M)	Optimism Bias (£M)	Total Capex (£M)
75 Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	109.3	16.9	33.4	159.5
River abstraction and TLT connection	TWU_KGV_HI-TFR_teddingtondrated/tlt	36.9	5.7	11.3	53.8
Conveyance & outfall (recycled water transfer tunnel)	TWU_WLJ_HI-TFR_teddingtondramog/ted	158.8	24.5	33.0	216.3
TOTAL		305.0	47.1	77.6	429.7

Capex Cost Uncertainty

4.1.2 Given the levels of risk and uncertainty inherent in the Project at this stage of development, the summary capex estimate reported above should be considered as point within a range of potential cost outcomes. The reporting of early stage cost estimates as a range is proposed in the RAPID and OFWAT publication "Approaches for estimating and benchmarking costs for large scale water infrastructure projects" published in June 2022.

4.1.3 A recognised construction industry approach to assessing the range of a cost estimate has been defined by the American Association of Cost Engineers (AACE). The AACE Cost Estimate Classification System approach requires:

- selection of an appropriate industry or recommended practice
- review of the maturity of the estimate input information to establish estimate class
- application of the wider expected accuracy ranges within the estimate class unless the narrower ranges can be justified

4.1.4 Following this approach, the Project has been considered as Process Industry and assessed as a Class 3 Estimate with the wider accuracy range within this class being -20% to +30%. When this range is applied to the base cost and costed risk this provides an overall estimate range of £359.3m to £535.3m including OB.

Table 4.2 Teddington DRA – Capex Estimates Cost Range (2022/23 price base)

	Lower (-20%)	Most Likely	Upper (+30%)
Base plus Costed Risk	281.6	352.1	457.7
Optimism Bias	77.6	77.6	77.6
Total Capex (£m - 2022/23 price base)	359.3	429.7	535.3

4.1.5 This approach can also be applied to the WRMP alternative schemes to Teddington DRA, such as Beckton Recycling. As alternative schemes have not been progressed to the same maturity level, it is likely that associated cost estimates would be assessed at a higher Class and therefore have a wider expected accuracy range.

4.2 Opex Estimates

4.2.1 The fixed and variable opex estimated for the components associated with Teddington DRA are as shown in Table 4.3.

4.2.2 It should be noted that the fixed opex costs does not include any flow proportional costs. If a minimum flow (i.e. a sweetening flow) is agreed, then the minimum annual opex cost would be the fixed opex plus the variable opex taken at the minimum flow.

4.2.3 All opex shown here are for the maximum utilisation of the Project (100% capacity operating in 'Normal Operation' mode at all times). For an assessment of the costs in the minimum and maximum, refer to Section 6.

Table 4.3 London Water Recycling SRO, Teddington DRA – Opex Estimates

	Opex - Fixed (£m/year)	Opex - Variable(£/Ml)
TOTAL	1.0	36.7

4.3 Carbon Estimates

4.3.1 The capital carbon and operational carbon emissions estimated for the components associated with the Teddington DRA are as shown in Table 4.4. Details of the carbon estimating methodology are provided in Section 3.6. The WLC emissions associated with the Project have been presented graphically in Figure 4.1.

4.3.2 In summary, the Gate 3 carbon estimate indicates an overall reduction in WLC emissions associated with the Project. This is primarily due to the reduced scope of works and updated treatment selection for the Tertiary Treatment Plant (TTP) sub-component of the Project which has reduced the associated capital emissions. The Gate 3 treatment selection is likely to reduce chemical consumption and has implemented the previous recommendations within Gate 2 GHG mitigations and reduction opportunities to reduce material usage which has greatly reduced the capital emissions of the Project.

4.3.3 However, the operational emissions of the Project on the first year of operation have increased for the TTP due to the use of grid electricity factors for 2033 and an increased project electricity usage based on the maximum utilisation of the Project (100% capacity operating in 'Normal Operation' mode at all times) which has been calculated based on 10 months at min flow 25% and 2 months at max flow 100% to be comparable with other SROs presentation of cost & carbon. Additionally, the replacement emissions associated with the TTP are greater than the previous Gate 2 reporting due the increased lifecycle period (previously 50-years, currently 80-years). Given the nature of the TTP design with the majority of scoped items being mechanical and electrical assets, assets will require replacing more frequently. However, as previously mentioned, it is imperative to note the TTP is unlikely to operate at full capacity for the majority of the project lifecycle and therefore the replacement frequency is likely to be lower thus WLC emissions will also be lower than projected at this stage of the Project.

4.3.4 The capital emissions associated with the abstraction and TLT connection have decreased since the previous Gate 2 assessment due to design specific changes. However, it can be observed the total conveyancing sub-component WLC emissions have increased compared to the previous Gate 2 report. The Gate 3 conveyance route and design was updated following significant feedback made during the public non-statutory consultations on site options. This has resulted in a change of conveyance design and increased construction material which has increased the associated capital carbon emissions of the Project.

Table 4.4 London Water Recycling SRO, Teddington DRA – Carbon Estimates

Components	Gate-3/ WRSE Reference	Capital/Embodied Carbon (tCO_2e)	Operational Emissions† (tCO_2e/yr)	Whole Life Carbon (tCO_2e)	WLC Cost (£M) [Central Values]
75 Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	3,963	133.4	20,929	£5.63
River abstraction and TLT connection	TWU_KGV_HI-TFR_teddingtondrated/tlt	3,948	3.4	4,062	£1.09
Conveyance & outfall (recycled water transfer tunnel)	TWU_WLJ_HI-TFR_teddingtondramog/ted	21,775	-	22,092	£5.94

†Based on the first year of operation (2033)

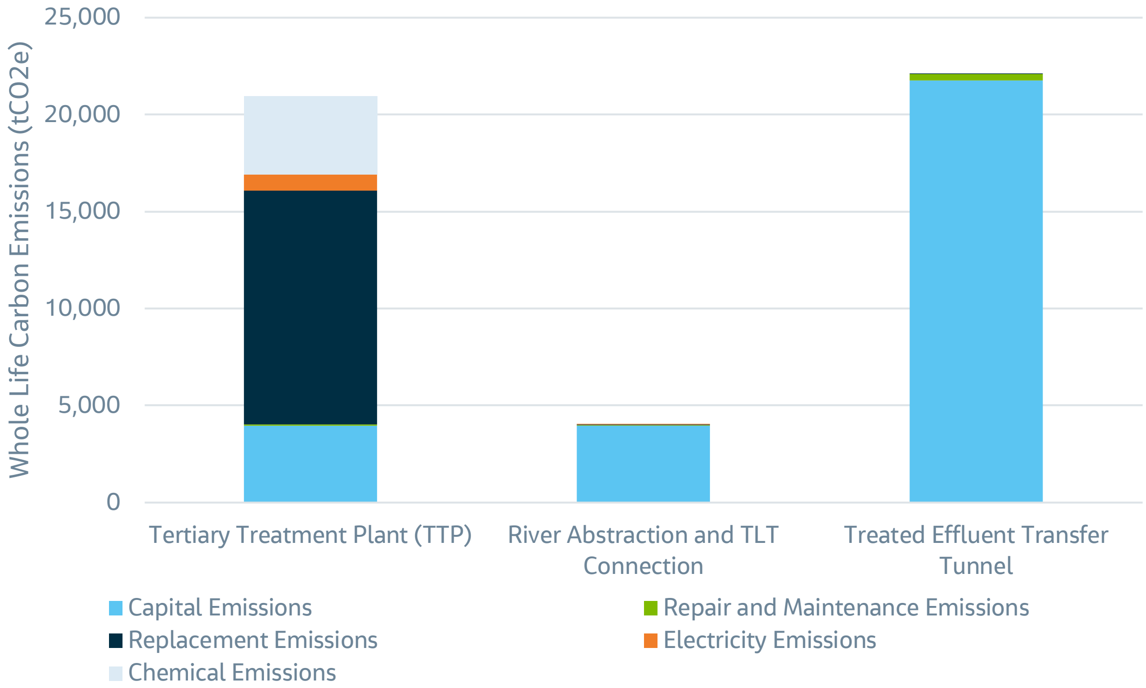

Figure 4.1 Teddington DRA Project 80-year Whole Life Carbon (WLC) Emissions

4.4 Greenhouse Gases Mitigation and Recommendations

4.4.1 WLC assessment of GHG emissions for Teddington DRA has been carried out by a Carbon and Energy Consulting team. The summary below recommends approaches to mitigate capital and operational GHG emissions, with emissions in tonnes of carbon dioxide equivalent (tCO2e) reported and evaluated.

4.4.2 To maximise alignment with PAS 2080 and the Water UK Net Zero 2030 Routemap, it is recommended to follow the emissions hierarchy when deciding which approach to prioritise to mitigate emissions. This prioritises in order of demand reduction, efficiency gains and renewable energy integration before pursuing offsets to remove residual carbon emissions. Due to the complexity and long lifetime of these schemes, it is important to take a holistic approach to carbon mitigation, which uses a combination of approaches.

4.4.3 As part of this assessment, a 'hotspotting' exercise was completed to ascertain the high carbon emissions assets or inclusions within the scope. The purpose of this assessment is to identify opportunities for emissions mitigation or reduction and provide recommendations for further consideration within future design stages. The exercise considered the WLC emissions associated with the asset which includes the capital, repair, maintenance and replacement emissions of the asset.

4.4.4 Within the TTP sub-component, the top seven carbon intensive items, their respective WLC emissions and proportion of the total WLC emissions is summarised in Table 4.5. These scoped items account for 63% of the total WLC of the TTP and therefore any reduction opportunity implemented will greatly reduce the overall Project emissions.

Table 4.5 TTP High Intensity Whole Life Carbon Assets

Asset/Item	Whole Life Carbon (WLC) (tCO2e)	% of Total Whole Life Carbon (WLC) (tCO2e)
MBBR -Filter Media	8,810	42%
MBBR Compressors	1,562	7%
Recycled water Transfer Pumping Station	1,200	6%
Tertiary Mechanical Filter	660	3%
TTP Concrete Support	506	2%
Electrical and MCC Building	330	2%
Eastern Embankment Cut Back	324	2%

4.4.5 The WLC emissions accounts for asset replacement according to standard replacement frequencies. The MBBR filter media accounts for 42% of the total TTP WLC emissions due to the standard replacement frequency. In future stages of design, actual replacement frequencies and resulting emissions should be investigated further as this provides the greatest opportunity for WLC emissions reduction across the TTP. Additionally, further supply chain engagement is recommended to ascertain material specific emissions factors as it is suspected the outputs of the EES may not accurately reflect capital emissions associated with the media.

4.4.6 The pumping station, concrete support and embankment cut represent 10% of the total TTP WLC emissions. Future design stages should consider the use of low carbon materials (concrete and steel) and the reduction of spoil to landfill for the embankment. Identifying alternative reuse opportunities will reduce capital emissions associated with embankment material waste/disposal.

4.4.7 Additionally, further analysis on the projected plant operation and resulting electricity and chemical demand should be completed. Electricity and chemical emissions account for 24% of the total TTP WLC emissions with chemical consumption contributing the majority of these emissions. The electricity emissions account for future grid decarbonisation however further reduction opportunities are available through the use of renewable energy. Further supply chain engagement is recommended to identify low carbon chemicals which are emerging within the UK market.

4.4.8 Within the Conveyance sub-component, the top eight carbon intensive items, their respective WLC emissions and proportion of the total WLC emissions is summarised Table 4.6. These scoped items account for 97% of the total WLC of the conveyance and therefore any reduction opportunity implemented will greatly reduce the overall Project emissions.

Table 4.6 Recycled water Transfer Tunnel High Intensity Whole Life Carbon Items

Asset/Item	Whole Life Carbon (tCO2e)	% of Total Whole Life Carbon (tCO2e)
Recycled water transfer tunnel 2 (2.5km)	5,703	27%
Recycled water transfer tunnel 3 (1.7km)	3,907	19%
Recycled water transfer western drive shaft	3,775	18%
Recycled water transfer eastern shaft	1,850	9%
Recycled water transfer tunnel 1 (0.7km)	1,782	9%
Recycled water transfer Ham Street Playing Fields	1,233	6%
Recycled water transfer Burnell Avenue shaft	1,154	6%
Site clearance	760	4%

4.4.9 The WLC emissions for the items presented in Table 4.6 account for the installation of tunnels using tunnel boring machines (TBM). The tunnel diameter is estimated to be 3.5m in diameter and will result in large amounts of spoil, transportation from sites, emissions associated with the installation equipment and installed materials. The design of the tunnel and route selection is constrained due to the topography and geography of the required conveyance.

4.4.10 However, reduction opportunities can still be identified by establishing alternative low carbon materials, reducing the volume of spoil to disposal and the reuse of materials. Further supply chain engagement is recommended to reduce the energy consumption of the TBMs and identify alternative methods for installation that will reduce carbon intensity.

4.4.11 Operational emissions have been identified as the largest single source of emissions across the Project. Sources of these emissions include grid electricity usage emissions, supply chain emissions from chemicals used in dosing, and process emissions from the TTP processes. However, process emissions have not been quantified in this assessment due to the lack of available industry standard emission factors.

4.4.12 A more detailed assessment of carbon emissions is advised at the next stage, firstly to provide a more complete assessment of the emissions associated with each element of the Project and to include those sources not captured in this assessment. Secondly a detailed opportunity cost analysis should be conducted to identify which interventions would allow the greatest reduction in emissions for the best value. This report provides a high-level inclusion of the possible range of interventions, but further analysis is required to select those most appropriate for the Project.

4.4.13 At this design stage, some scope requirements are largely fixed (e.g. tunnel as TBM delivery). This will limit the opportunity to completely 'design out' embodied carbon for the Project. However, there is still sufficient optioneering time to 'design out' some embodied carbon. Embodied emissions represent the majority share of total GHG emissions in the short term - as such, focusing on reducing embodied emissions will likely yield significant reductions across the early stage of a site's operational life. This can be achieved through close engagement with carbon subject matter experts at the next stages of design and procurement stages. A focus on 'designing out' carbon can reduce both embodied and operational emissions, in particular for building heating and plant efficiency.

4.4.14 Over time, across the lifetime of a site operational emissions will contribute more than embodied emissions, therefore reducing operational emissions will achieve the greatest reduction of GHG emissions in the long term. This approach is also in line with the Water UK and Thames Water pledge of net zero operational carbon by 2030.

4.4.15 Table 4.7 summarises the recommended carbon mitigation approaches, providing a high-level ranking of their potential impact on emissions reduction and alignment with the emissions hierarchy.

Table 4.7 Summary and Ranking of Carbon Emissions Reduction Approaches

Approach to mitigate carbon emissions	Emissions Hierarchy Category	Potential for emissions reduction	Ability for Thames Water to Influence	List of options
Energy management & efficiency (highest priority)	Emissions reduction	High	High	• Improved pump efficiency • Metering • Smart control systems • Catchment level analytics

Approach to mitigate carbon emissions	Emissions Hierarchy Category	Potential for emissions reduction	Ability for Thames Water to Influence	List of options
Operational Resource Efficiency and Chemical Supply	Emissions reduction	High	Low‡	• Supply chain contracts • Reduced resource use
Embodied emissions reduction	Emissions reduction	High	High	• Low carbon concrete • Low carbon steel • Recycled materials • Locally sourced materials
Engineering design	Emissions reduction	Moderate	Moderate	• Conveyance routes • Land use • Process building size and heating requirements
Operation and maintenance optimisation	Emissions reduction	High	High	• Enhanced maintenance on M&E assets to reduce replacement frequency • Optimised operational parameters • Reduced media replacement
Construction emissions	Emissions reduction	Moderate	High	• Reduced transport • Vehicle energy use and alternative fuels • Renewable onsite power • Temporary buildings
Renewable energy on site	Renewable energy	High	Moderate	• Solar • Hydro Turbines • Energy Storage Systems
Procured Renewable Energy	Renewable energy	High	High	• Sleeved PPA • Synthetic PPA • Private Wire PPA • REGO-backed Green Tariffs
Insets	Offset	Low	Moderate	• Grassland restoration • Tree planting

Approach to mitigate carbon emissions	Emissions Hierarchy Category	Potential for emissions reduction	Ability for Thames Water to Influence	List of options
Offsets (lowest priority)	Offset	Low	High	• UK Emissions Trading Scheme (ETS) • Voluntary Offset Market

‡The capability of Thames Water to influent the emissions associated with specific chemicals is low at this time due to supply chain constraints. The proposed design considers efficient chemical usage and therefore the opportunity to influent this further is limited.

4.5 Key Costed Risks

4.5.1 Table 4.8 shows a list of delivery focused key risks with description.

Table 4.8 Delivery focus Key Risks with description

Risk Name	Description	Mitigation plan
Integration with operational assets	The Project requires integration with Mogden STW and TLT critical operational assets. Space to develop at Mogden is very limited and in demand. Potential conflict between the TTP and requirement for STW upgrade for land due to population growth in catchment. Or limitations imposed around the storm tanks to construct the TTP. The project also requires integration with the TLT. The TLT is critical for the Lee Valley stored water system and there is a risk that planned shutdowns to establish a connection are delayed if continuous supply is required during the period scheduled. The construction activities and permanent integration may result in additional operational and programme risks.	A strategic options appraisal is considering opportunities to align with the Mogden masterplan to maximise space at Mogden which may result in changes to TTP layout, design and location within Mogden which could impact on scheme costs and programme Consideration and allowance for enabling and integration works included in the scope and associated delivery programme which will be further detailed and reviewed during Gate 4 as part of further constructability reviews. Asset surveys have been undertaken with TLT inspection by Tunnels Team. Further work planned in Gate 4 to consider required sequence of construction, with further engagement with internal teams.
Consenting duration	Project delays due to extended DCO pre-application stage due to additional rounds of consultation following material design changes.	Engagement and consultation plans have been developed to ensure all stakeholders are engaged with as the project progresses. Non-statutory public consultations and subsequent further public events have been held and further

Risk Name	Description	Mitigation plan
		information will be shared ahead of Statutory Consultation. A full stakeholder engagement plan and resources have been put in place to ensure coordinated and consistent engagement across all stakeholders leading up to DCO application.
Ground conditions	Unforeseen ground conditions due to lack of sufficient detailed GI data, which may result in more onerous tunnel depths or construction techniques. Increased construction costs and increase to the construction programme due to slower production rates, adoption of an alternative construction methodology.	Further progress site surveys and ground investigations to validate the engineering assumptions related to ground conditions in current design and therefore provide greater certainty in the construction methodology and delivery programme.
In-river mitigation measures	The EA has proposed additional in-river mitigation measures to protect fish and aquatic ecology. Significant re-design of the Project may cause delays and potentially increased costs.	The Project is working closely with the NAU/EA on appraising different measures and evaluating benefits. Thames Water has undertaken various appraisals and made recommendations to refine the design. Further work is required through Gate 4 to finalise the measures to be incorporated into the design.
River Thames Scheme	Interactions and overlap with River Thames Scheme (RTS), the EA's flood alleviation masterplan.	Thames Water are working with the RTS team to understand existing interactions and investigate potential cumulative impacts and subsequently explore opportunities to design out any overlap.

5 Cost Benchmarking

5.1.1 Unit rate benchmarking was carried out for requirements within the design scope items that were estimated using external cost data. These are items that were not priced using the EES cost curves. This was done to ensure that override costs captured within the Designer Input Template are indicative and increase confidence with final costs. The benchmarking centred around cost references used for the costing exercise such as bottom-up estimates, quotations and reference unit rates. They were checked against industry standard costs to ensure they were indicative.

5.1.2 EES cost curves undergo periodic checks and audit, thus requirements priced with them have some degree of confidence grading aligned with them within Thames Water.

5.2 Unit Rate Benchmarking

5.2.1 The unit cost rate of some items was estimated either with a “bottom-up” approach or reference to an all-inclusive cost rate at Gate 3, identifying and summing up possible cost items to arrive at the total unit cost rate. The cost estimates were for items which were not derived from EES cost curves due to either unsuitable cost curves for the non-standard item or more accurate Supplier quotations available. The following benchmarking were carried out:

- Benchmarking of the abstraction eel-friendly band screens using supplier quotations for the preferred type of screens which differ in cost range from the standard EES band screen cost curves.
- Tunnelling rate used for the conveyances were reviewed against rates from the UK Research and Innovation, British Tunnelling Society and Infrastructure and Projects Authority. This was to ensure that the unit rates used for the estimation are fit for purpose and was within acceptable cost tolerances.
- Benchmarking of the unit rates used for the cost build-up for the storm tanks alterations.

5.2.2 Opex benchmarking is typically not performed at this level of detail due to the uniqueness of a company’s operating philosophy. This is owing to the difference in working practices, such as staffing levels, approach to risk for maintenance activities and regional power costs. At this stage, it is not viewed as practical to carry out detailed opex benchmarking until a greater understanding of the configuration of schemes and expected utilisation values are confirmed.

6 Net Present Value (NPV) and Average Incremental Cost (AIC)

6.1.1 Capex and opex costs have been used to generate the NPV and AIC values for the elements using the Treasury Green book with a declining schedule of discount rates and a 100-year period. The ACWG had agreed with RAPID that for consistency across all SRO's, NPV and AIC costings would be completed via the same methodology for inclusion in the Gate 3 for direct comparison with the other schemes and SRO's.

6.1.2 The NPV and AIC values were analysed for the following configuration:

- Teddington DRA (75Ml/d yield): a combination of the 75Ml/d TTP component, the river abstraction and TLT connection component, and the recycled water transfer tunnel component. Costs for operation of the conveyance component were calculated assuming it conveys up to 75Ml/d.

6.1.3 NPV and AIC for each component were calculated for the estimated utilisation level, using "One Scheme AIC RevG Template" as per ACWG review and agreement.

6.1.4 The costs for all stages (i.e. Planning, Development and 'Construction & Operation') were included in the "Input" tab. If modelling a real option, the stages will get reprofiled on the 'AIC calc' tab to ensure the Planning, Development and 'Construction & Operation' are done consecutively.

6.1.5 The inputs required for the calculation were:

- Option reference ID: The WRSE Option ID.
- WACC: Weighted Average Cost of Capital used. In the 2019 Final Determination20, Ofwat allowed a real return on capital of 2.92%. The All Company Working Group (ACWG) agreed to applying a WACC of 2.92%, which has therefore been used on all NPV and AIC calculations in this report.
- Operational Year: The year in which Recycled water is to be first produced following the end of construction stage. This was taken from the WRSE Input Template in the tab "Summary" from column N "*Opex Start Year*".
- Optimism Bias: As per Final OB% in Table 3.3.
- Deployable Output (DO): A minimum and maximum utilisation was calculated for each configuration. The maximum utilisation was based on the DO of the maximum capacity of the configuration continuously for 365 days, 24 hours per day (*e.g*. Teddington DRA 75Ml/d TTP component has a DO of 67Ml/d for the 1 in 500 year average). This value was taken from the WRSE Input Template in the tab "Summary" from column U "*DO: 1 in 500 average*".
- Minimum Flow: If operation is stopped completely during non-drought periods, the TTP will require 6 to 8 weeks or more to re-establish biomass in the MBBR. Therefore, during times when the Project is not required to supply water, there will be a requirement to continue to run the TTP at reduced levels to maintain the operability of the TTP (i.e. Hot Standby mode). During Hot Standby mode, the TTP would operate at a minimum of 15Ml/d to maintain biofilm within the MBBR, though the required flow rate will be confirmed through the pilot plant testing and further investigations. The recycled water produced during non-drought periods will be discharged through existing Mogden STW outfall at Isleworth Ait in the tidal reach of

River Thames. During this period, the conveyance route will be kept dry; recycle water in the conveyance route will be pumped and returned into the STW.

6.1.6 A profile of the Project components costs over 100 years were computed. The costs were split into capital (including maintenance and replacement costs), operating (both fixed and variable costs) and financing costs. The NPV of all costs was then calculated using the Treasury Test Discount Rate as set out in the HM Treasury "Green Book" (Appraisal and Evaluation in Central Government, HM Treasury 2003). This is 3.5% for years 0-30 of the appraisal period, 3.0% for years 31-75, and 2.5% for years 76-125. The outputs of this analysis are NPV finance (capex), NPV opex, NPV WAFU (Water Available for Use, in m^3 for the resource benefit over the 100-year period) and AIC (in p/m^3). The outputs were given for both the minimum utilisation scenario and maximum utilisation scenario. Note that the opex values are input as costs at maximum utilisation taken from the WRSE input template and adjusted by the percentage for minimum utilisation.

6.1.7 To calculate the NPV and AIC for each configuration, which is a combination of treatment component and conveyance component, these values were then summed to provide the results in Table 6.1.

Table 6.1 NPV and AIC for Teddington DRA Project at various configuration sizes (all costs adjusted for 2022/23 cost base)

Configuration name	Units	Teddington DRA (75Ml/d yield)
Option benefit	Ml/d	67
Total planning period option benefit (NPV WAFU)	Ml	472,561
Total planning period indicative capital cost of option (CAPEX NPV)	£m	338.9
Minimum Flow – based on Hot Standby mode for 12 months of the year		
Total planning period indicative operating cost of option (OPEX NPV)	£m	20
Total planning period indicative option cost (NPC)	£m	311.5
Average Incremental Cost (AIC)	p/m³	65.9
Maximum Flow – full capacity for 12 months of the year		
Total planning period indicative operating cost of option (OPEX NPV)	£m	33.8
Total planning period indicative option cost (NPC)	£m	325.3
Average Incremental Cost (AIC)	p/m³	68.9

Configuration name	Units	Teddington DRA (75Ml/d yield)
Total Carbon over 80-year period and no discount rate		
Embodied Carbon	tCO_2e	29,686
Variable Operational Carbon – Max Flow	tCO_2e/yr.	136.8

6.1.8 The solution costs detailed have been developed in line with relevant HM Treasury Green Book guidance. All values in Table 6.1 have been adjusted to FY22/23 cost base for accurate comparison with the Final Determination allowance, using Thames Water's Internal Business Plan (IBP) deflationary factors, based upon a combination of the relevant RPI, CPIH and CPI (forecast) annual average index values. A lifecycle carbon assessment has been carried out here without discount factors, and no adjustment for inflation as per the NPV costs. Carbon values are calculated in Section 4.3 for maximum utilisation presented at first year of operation using Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions. In Table 6.1 above, Operational carbon values are assessed over the 100-year period from first year of operation at the minimum and maximum utilisation levels for the specific scheme. Note that Table 6.1 does not include carbon emissions from electricity. Refer to Section 4.3 for full carbon values.

7 The Journey from Gate 2 to Gate 3

7.1 CAPEX

7.1.1 A comparison between Gate 2 and Gate 3 costs is provided in Appendix A.

7.1.2 The major changes between Gate 2 and Gate 3 are as follows;

- Amending the tunnelling technique from Gate 2, which proposed pipejacking, to the use of a tunnel boring machine (TBM). This change has reduced the need for intermediate shafts to a single shaft, reducing interactions and associated risks, in the public realm from construction of the Project.
- The identification of a new tunnel drive shaft and materials handling area within Mogden STW.
- Adjustments to the recycled water treatment technology from nitrifying sand filters (NSF) to moving bed biofilm reactor (MBBR).
- The inclusion of suitable space for working areas and potential development within the River Thames to accommodate ongoing design outcomes relating to the raw water abstraction and recycled water discharge infrastructure.
- Confirmation that the sweetening flow (15Ml/d of recycled water) generated through hot standby of the TTP during non-drought conditions will be discharged through the existing final effluent channel to Isleworth Ait.
- Additional development stage expenditure such as design activities to reflect the tunnel change, the requirement for a pilot plant to test the proposed water treatment processes and the change in proposed consenting route from TCPA to DCO.
- Increased contractor indirect costs to deliver the larger and more complex scope of a bored tunnel. Contractor indirect costs have also been updated across the whole of the estimate to reflect market conditions and trends.

7.1.3 As the Project has developed with design maturation, a greater level of detail has been derived to inform the costed scope and updated quotations attained resulting in refinement of inclusions and detail in costed scope, reduction of risks and a shift of delivery confidence represented by OB, to risk or costed scope. Key changes to project elements in costed scope are noted below.

Tertiary Treatment Plant

7.1.4 Development of the mechanical, electrical and instrumentation and control (MEICA) design and civil requirements during Gate 3 has refined scope items including;

7.1.5 Increases in capex:

- Increased requirement for a tunnel drain pumping station within the shaft at Mogden.
- Pipe bridges have been added replacing allowances.
- Updated quotations for process equipment
- Developed detail for works to the eastern embankment adjacent to the storm tanks to facilitate the TTP plant at Mogden.
- Potential renewable energy source for an energy recovery turbine.

- Refinement of requirements for diversion of existing infrastructure.

7.1.6 Decreases in capex:

- Allowances for the Civil works around the storm tanks for the TTP platform developed into a greater level of detail in scope, this had a reduction in the costs and allowances priced in Gate 2.
- The Nitrifying Sand Filter (NSF) technology replaced with a Moving Bed Biofilm Reactor (MBBR). Overall, a reduction in cost was seen with the MBBR when compared to the NSF.
- Refined MEICA components led to some further reductions.
- Refined requirements for a new power supply to the site boundary at Mogden. Revised power assessment shows sufficient power within the nearby facility and as such DNO power supply to the site boundary is not needed as previously assumed in Gate 2.
- Refined land clearance and removed temporary land requirements at Mogden.

River Abstraction and TLT Connection

7.1.7 Development of the MEICA design and civil requirements during Gate 3 has refined scope items including;

7.1.8 Increases in capex:

- Intake structure cost updated based off refined level of design.
- Developed design for electrical components for site at Burnell Avenue developed costed scope with increases since Gate 2.
- Developed building requirements to house MCC and equipment at Burnell Avenue.
- Developed options for TLT connection with up-to 2.2m diameter, 460m length pipe jacked tunnel to existing shaft at Tudor Drive.
- Modified land clearance, temporary land and permanent land to match design development.

7.1.9 Decreases in capex:

- Updated supplier quotations including intake screen.
- Removed abstraction pumping station in baseline costs, this is potentially still required and is being further investigated with Risk and OB covering the cost change if it was priced back in.
- Updated power requirements costed scope.

Conveyance and Outfall (Recycled Water Transfer Tunnel)

7.1.10 Development of the MEICA design and civil requirements during Gate 3 has refined scope items including;

7.1.11 Increases in capex:

- The tunnel from Mogden to the River Thames construction method was changed from pipejacking to a TBM. The tunnel diameter was increased from 1.8m to 3.5m (internal diameter), and the total length changed to

4.97km. These factors resulted in an overall increase in the cost of tunnelling at Gate 3.

- The number of shafts was reduced from eight to four, with the remaining shafts being the Mogden drive shaft, the Mogden interception shaft, the Ham Street intermediate shaft, and the Burnell Avenue reception shaft. The shaft diameter and depths were increased, which resulted in an overall increase in cost for the required shafts at Gate 3. The maximum depths were used as a basis for the costing as a worst-case scenario to a avoid any cost uncertainties with construction.
- Refined design for the outfall and required temporary construction works increased costed scope at Gate 3.
- Added HV power cable for power supply to the TBM.
- Added temporary ventilation requirement for the intermediate shaft.
- Land clearance, temporary/permanent land etc have been updated to match design requirements.
- Refined cost allowances from Gate 2 to Gate 3 for environmental impacts such as relocation and creation of habitats.

7.1.12 Decreases in capex:

- Removed discharge pumping station requirements at Burnell Avenue, this is not being priced in baseline capex within Gate 3 scope, and potential need is being further investigated with risk and OB covering the cost change if it was priced back in.
- Removed standby generator required at Burnell Avenue.

7.2 OPEX

Tertiary treatment plant

- Reduced costs for ferric dosing due to superseding the NSF requirement in Gate 2 with MBBR in Gate 3. The minimum flow was also reduced having an impact on chemical costs with a reduction in Gate 3.
- Refined power requirements based off Gate 3 developed power requirements load schedule.
- Pumping station for transfer of water from downstream shaft to outfall is not being priced in baseline capex within Gate 3 scope as it is priced as not required with potential for it to be required only.
- Refined and updated land management costs for BNG requirements.

River Abstraction and TLT Connection

- Increased M&E and civil maintenance costs, based off the Gate 3 developed design total M&E capital costs.
- Reduced total power supply required for the site, based off refine power requirement assessment at Gate 3.
- Increased employee requirement for operation and maintenance.

Conveyance and Outfall (Recycled Water Transfer Tunnel)

- Reduced electricity requirements as pumping station for discharging water from downstream shaft to outfall is not being priced in baseline capex within Gate 3 scope.
- Increased civils maintenance cost, based off the total Gate 3 civil costs, with the increased tunnel diameter and changed shaft requirements contributing towards this cost.
- As pumping station is not being priced in baseline capex, reduced M&E maintenance costs, based off the total Gate 3 M&E capital costs.
- Reduced employee requirements, as pumping station is not being priced in baseline capex and employees requirement reduced.

7.3 Optimism Bias

7.3.1 In Gate 2, the OB assessment was divided into three components: tertiary treatment plant, recycled water transfer tunnel, and river abstraction and TLT connection. OB factors were scaled back further from Gate 1 to account for design development leading to greater certainty and identification of specific risks.

7.3.2 In Gate 3, the OB assessment has been divided into two assessments: a TBM tunnel only assessment for the Mogden to Burnell Avenue conveyance section, and a general assessment that excludes the TBM tunnel. For the general assessment, the first step involving the classification of scheme components as standard or non-standard was still undertaken based on the main three project areas as defined in Gate 2; however, an average based on Capex proportions was derived to establish a single Upper Bound OB for this worksheet.

7.3.3 TTP scope was considered non-standard engineering in both Gate 2 and Gate 3 assessments. While in Gate 2 pipelines were considered 25% standard, in Gate 3, the TBM tunnel has been considered as 75/25% standard/non-standard, whereas the remaining shafts and outfall scope is considered 50/50% standard/non-standard. Finally, the river abstraction and TLT connection is considered 80% non-standard.

General assessment

- Procurement: confidence levels increased in average from Low-Medium to Medium. Procurement strategy under review and early market engagement activities initiated.
- Project specific: confidence levels increased in average from Low-Medium to Medium. Design development resulting in increased project knowledge. Planning and permitting uncertainties as well as lack of full ground investigation results prevents from higher project specific confidence levels.
- Client specific: moderately increased confidence in project intelligence and project management factors, although lower confidences remain regarding project stakeholders.
- Environmental: minor confidence improvements due to planning uncertainties and outstanding detailed environmental assessments.

- External influence: confidence levels moderately increased in average within Low-Medium ranges due to regulatory and political uncertainties being considered.

Conveyance & Outfall (Recycled Water Transfer Tunnel)

- Confidence in design complexity, degree of innovation, environmental impact, and poor project intelligence contributory factors further improved with respect to the general assessment due to sector knowledge in TBM tunnelling through London Clay and the inherent characteristics of this scope element.

7.4 Costed Risk

7.4.1 The costed risk methodology and maturation has evolved during Gate 2 in the following ways:

- Risk registers for different components combined into a RAIDO log.
- Matrix based pre-defined cost scores individually reviewed and overwritten by custom score ranges where level of maturity allowed informed estimates, generally in the form of bottom-up estimates.
- Probability modelling developed beyond Uniform distribution. Generally triangular distributions modelled with minimum, most likely, and maximum cost impact values. Discrete distributions developed for more complex risk entries, with Single, Uniform or Triangular distributions defined at each scenario.
- Estimating tolerances included for each project area (TTP, conveyance and outfall, and river abstraction and TLT) to account for price and quantities uncertainties.
- Project running costs associated with programme delays were added to the bottom-up estimates.

7.4.2 A summary of the key risks is included in section 4.5. The following are the key changes adopted at Gate 3

- Higher itemisation of risks with respect to Gate 2 based on design developments.
- Uncertainty in permitting conditions resulting in additional process units significantly increasing costed risk of TTP and of the project overall.
- Interactions between the TTP and the operational site at Mogden STW and the spatial requirements for this project and development within Mogden STW.
- Thames-Lee Tunnel shutdown provisions for connections.
- Connection to TLT requiring an additional shaft at Tudor Drive.
- Adopted Intake structure requirements against EA acceptability criteria.
- Disposal and handling of excavated material being more onerous than anticipated.
- Noise mitigation measures during construction requiring additional measures.
- River outfall structure requirements against EA acceptability criteria.
- Settlement impact under Mogden STW structures.

8 Best Value Plan

8.1.1 Different options' costs, relative to one another, are key factors in considering which options should be considered Best Value, and so included in our Water Resources Management Plan. Each of the SROs may be subject to elements of design/scope change and there are inherent uncertainties in the option costing processes, meaning that cost estimates may go up or down through the option development process. Acknowledging this, work was undertaken in the course of producing the Thames Water WRMP24 and WRSE Regional Plan in which the sensitivity of option selection decisions to cost change was tested. The WRSE investment model was used to investigate this, due to the complexity of the planning problem which it posed. Teddington DRA is selected in the WRSE "Least Cost" plan, as well as the Best Value plan. WRSE investment model runs were undertaken to identify whether the Teddington DRA scheme would still be selected in a "Least Cost" plan, were its cost to be incrementally increased.

8.1.2 In the first stage of this testing, the cost of the project was increased until it was no longer selected. The first alternative set of options which was selected instead of the Teddington DRA was a relatively large selection of groundwater schemes, accompanied by transfers from Affinity Water and SES Water. This alternative set of options is not seen as a viable alternative, as it is too high risk, requiring the delivery of multiple novel ASR schemes and the Grand Union Canal SRO, and being contingent on the successful delivery of demand reduction by Thames Water, Affinity Water and SES Water. Each of these dependencies brings risk, which is seen as unacceptable overall. As such, this alternative set of options was excluded from selection in the short-term, and the cost increment was increased until an alternative to Teddington DRA was selected. It was found that Teddington DRA would need to cost between £844m and £929m (in 2022/23 prices, indexed according to the BCIS CE Cost Index, i.e., in a "like for like" cost basis as presented in the Gate 3 reporting) for a different solution (Beckton Recycling) to be included within a "least cost" plan.

8.1.3 Therefore the increase in cost, driven principally by a change in construction technique to minimise surface impacts to local communities around shafts sites, is not of a sufficient scale to result in another water recycling scheme becoming best value. Teddington DRA remains the preferred scheme on the grounds of cost and carbon which can be traced back to the treatment type and lengths of the conveyance elements which forms the options scope. The differences in the other best value metrics are not deemed substantial and therefore the difference in cost remains the deciding factor and in the selection of Teddington DRA as best value.

8.1.4 Further information on the assessment of Teddington DRA against its alternatives from a cost and wider best value perspective can be found in Section 10 of the published WRMP[4]

8.1.5 It is also important to recognise that it is different options' relative costs, rather than absolute costs, which are of relevance in option selection decisions. As explained through this report, the cost estimate for the Teddington DRA has increased between Gate 2 and Gate 3. Some of the same factors which have caused this cost inflation would likely impact the Beckton Recycling scheme in a similar way, and it is important to bear this in mind when appraising the cost increase and its impacts. This highlights the importance of continuing to investigate the alternatives to the Teddington DRA, in order to ensure that important decisions are made with adequate information.

Appendix A: Cost and Carbon Estimates

A.1.1 Gate 2 & 3 Capex Costs Summary - from WRSE Input Templates

A.1.2 Noted the Gate 2 values were reported in Gate 2 at a Cost Base of FY20/21 as per cost Outputs. This was inflated to FY22/23 in line with the Gate 3 submissions.

Cost Price Base: 2022/23

Components	Gate-3/ WRSE Reference	Gate 2 Base Capex (£M)	Gate 3 Base Capex (£M)	G3 – G2 Base Capex (£M)	% Difference
75 Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	£88.4	£109.3	£20.9	+24%
River Abstraction and TLT Connection (75 Ml/d)	TWU_KGV_HI-TFR_teddington dra ted/tlt	£25.7	£36.9	£11.1	+43%
Conveyance & Outfall (Recycled Water Transfer Tunnel)	TWU_WLJ_HI-TFR_teddington dra mog/ted	£62.2	£158.8	£96.6	+155%
TOTAL		£176.3	£305.0	£128.7	+73%

Notes;

1. Base Capex includes planning, development and delivery overheads as well as Contractor overheads.

Components	Gate-3/ WRSE Reference	Gate 2 Costed Risk (£M)	Gate 3 Costed Risk (£M)	G3 – G2 Costed Risk (£M)	% Difference
TOTAL 75 Ml/d TTP, River abstraction & TLT connection and Conveyance & Outfall.		£46.2	£47.1	£0.9	+2%

Notes;

1. At Gate 3 the QCRA was combined for all Project components and so is only presented for Total value comparison.

Components	Gate-3/ WRSE Reference	Gate 2 Optimism Bias (£M)	Gate 3 Optimism Bias (£M)	Gate 3 – Gate 2 Optimism Bias (£M)	% Difference
75 Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	£38.0	£33.4	-£4.7	-12%
River Abstraction and TLT Connection (75 Ml/d)	TWU_KGV_HI-TFR_teddington dra ted/tlt	£10.4	£11.3	£0.9	+8%
Conveyance & Outfall (Recycled Water Transfer Tunnel)	TWU_WLJ_HI-TFR_teddington dra mog/ted	£22.5	£33.0	£10.6	+47%
TOTAL		£70.9	£77.6	£6.8	+10%

Components	Gate-3/ WRSE Reference	Gate 2 Total Capex (£M)	Gate 3 Total Capex (£M)	Gate 3 – Gate 2 Total Capex (£M)	% Difference
75 Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	£158.5	£159.5	£1.1	+0.7%
River Abstraction and TLT Connection (75 Ml/d)	TWU_KGV_HI-TFR_teddington dra ted/tlt	£38.2	£53.8	£15.6	+41%
Conveyance & Outfall (Recycled Water Transfer Tunnel)	TWU_WLJ_HI-TFR_teddington dra mog/ted	£96.7	£216.3	£119.6	+124%
TOTAL		£293.4	£429.7	£136.3	+46.5%

Notes;

1. Total Capex includes Risk apportioned pro-rata to each of the 3 Project components for simplicity of sumarising Total Capex comparison.

Components	Gate-3 WRSE Reference	Gate-2 Max Fixed Opex (£M/yr.)	Gate-3 Max Fixed Opex (£M/yr.)	% Difference %	Gate-2 Max Variable Opex (£/ML)	Gate-3 Max Variable Opex (£/ML)	% Difference
Teddington DRA							
TOTAL 75 Ml/d TTP, River abstraction & TLT connection and Conveyance & Outfall.		£0.7	£1.0	+45.6%	£186	£36.7	-80.3%

Notes;

1. Opex presented for whole scheme only at Gate 3 as all components combined due to single scheme size.

Components	Gate-3/ WRSE Reference	Gate 3 - Total Embodied Carbon (tCO2e)	Gate 3 - Max Fixed Operational Carbon (tCO2e/yr)
75 Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	3,963	133.4
River Abstraction and TLT Connection (75 Ml/d)	TWU_KGV_HI-TFR_teddington dra ted/tlt	3,948	3.4
Conveyance & Outfall (Recycled Water Transfer Tunnel)	TWU_WLJ_HI-TFR_teddington dra mog/ted	21,775	-
TOTAL		29,686	136.8

Components	Gate-3/ WRSE Reference	Gate 3 Variable Operational Carbon Excluding Electricity (tCO2e/Ml/yr)	Gate 3 Variable Operational Carbon From Electricity (tCO2e/Ml/yr)	Gate 3 Variable Operational Carbon Total (80y Average) (tCO2e/yr)
Teddington DRA				
75 Ml/d Tertiary Treatment Plant	TWU_KGV_HI-RAB_teddington dra 75	0.67	0.18	60.7

Components	Gate-3/ WRSE Reference	Gate 3 Variable Operational Carbon Excluding Electricity (tCO2e/Ml/yr)	Gate 3 Variable Operational Carbon From Electricity (tCO2e/Ml/yr)	Gate 3 Variable Operational Carbon Total (80y Average) (tCO2e/yr)
River Abstraction and TLT Connection (75 Ml/d)	TWU_KGV_HI-TFR_teddington dra ted/tlt	0	0.01	0.43
Conveyance & Outfall (Recycled Water Transfer Tunnel)	TWU_WLJ_HI-TFR_teddington dra mog/ted	0	0	0

Appendix B; Optimism Bias Template

Contributory factors	Base Optimism Bias (Pre QCRA)											SCALED BACK OB									
	Combined Upper Bound Optimism Bias (%)	Non-Standard Civil Engineering				Standard Civil Engineering				Adjusted Optimism Bias (%)	Scoring comment	Associated costed risk	Change as a result of considering the costed risks	Combined Upper Bound Optimism Bias (%)	Non-Standard Civil Engineering			Standard Civil Engineering			Adjusted Optimism Bias (%)
		Proportion of Non-Standard Civil Engineering Capex				Proportion of Standard Civil Engineering Capex									Proportion of Non-Standard Civil Engineering Capex			Proportion of Standard Civil Engineering Capex			
		Upper Bound				Upper Bound									Upper Bound			Upper Bound			
		Lower bound				Lower bound									Lower bound			Lower bound			
	Result from:	Not required	Not required	Not required	Mitigation Factor	Not required	Not required	Not required	Mitigation Factor	Result from:				Result from:	Not require	Not require	Not require	Not require	Not require	Not require	Result from:
		High	Medium	Low		High	Medium	Low							High	Medium	Low	High	Mediu m	Low	
Description	*Calculated cell*	*Insert proporti*	*Insert proporti*	*Insert proporti*	*Calc ulate*	*Insert proporti*	*Insert proporti*	*Insert proporti*	*Calc ulate*	*Calculated cell*	*Describe the*	*List the risks from QCRA*	*Outline how the OB*	*Calculated cell*	*Insert proporti*	*Insert proporti*	*Insert proporti*	*Insert proport*	*Insert proport*	*Insert proport*	*Calculated cell*
Procurement																					
Complexity of contract structure																					
Late contractor involvement in design																					
Poor contractor capabilities																					
Government guidelines																					
Disputes & claims occurred																					
Information management																					
Other																					
Procurement combined	0.00%	Average Mitigation Factor			#DIV/0!	Average Mitigation Factor			#DIV/0!	#DIV/0!				0.00%	Average Mitigation Factor			Average Mitigation Factor			#DIV/0!
Project specific																					
Design complexity																					
Degree of Innovation																					
Environmental impact																					
Other																					
Project specific combined	0.00%								#DIV/0!	#DIV/0!				0.00%	Average Mitigation Factor			Average Mitigation Factor			#DIV/0!
Client specific																					
Inadequacy of the Business Case																					
Large number of stakeholders																					
Funding availability																					
Project management team																					
Poor project intelligence																					
Other																					
Client specific combined	0.00%	Average Mitigation Factor			#DIV/0!	Average Mitigation Factor			#DIV/0!	#DIV/0!				0.00%	Average Mitigation Factor			Average Mitigation Factor			#DIV/0!
Environment																					
Public relations																					
Site characteristics																					
Permits / consents / approvals																					
Other																					
Environment combined	0.00%	Average Mitigation Factor			#DIV/0!	Average Mitigation Factor			#DIV/0!	#DIV/0!				0.00%	Average Mitigation Factor			Average Mitigation Factor			#DIV/0!
External influences																					
Political																					
Economic																					
Legislations/regulations																					
Technology																					
Other																					
External influences combined	0.00%	Average Mitigation Factor			#DIV/0!	Average Mitigation Factor			#DIV/0!	#DIV/0!				0.00%	Average Mitigation Factor			Average Mitigation Factor			#DIV/0!

Optimism Bias (summary) output for All Project Components except Conveyance and Outfall (Recycled Water Transfer Tunnel)

Non-Standard Civil Engineering; 85%

Standard Civil Engineering; 16%

Contributory factors	Combined weight (calculated value - do not adjust)	Base Optimism Bias (Pre QCRA)		
		Combined Upper Bound Optimism Bias (%)	Adjusted Optimism Bias (%)	Adjusted Optimism Bias (%)
		Result from:	Result from:	Result from:
		62.48%	33.81%	33.65%
Description	*Fixed values - do not adjust*	*Calculated cell*	*Calculated cell*	*Calculated cell*
Procurement				
Procurement combined	13.0%	8.12%	3.803%	3.803%
Project specific				
Project specific combined	31.0%	19.37%	9.069%	9.069%
Client specific				
Client specific combined	34.0%	21.24%	12.044%	12.044%
Environment				
Environment combined	8.5%	5.31%	4.302%	4.141%
External influences				
External influences combined	13.5%	8.43%	4.590%	4.590%

Optimism Bias (summary) output for Conveyance and Outfall (Recycled Water Transfer Tunnel) only Project Component

Non-Standard Civil Engineering; 25%

Standard Civil Engineering; 75%

Contributory factors	Combined weight (calculated value - do not adjust)	Base Optimism Bias (Pre QCRA)		
		Combined Upper Bound Optimism Bias (%)	Adjusted Optimism Bias (%)	Adjusted Optimism Bias (%)
		Result from:	Result from:	Result from:
		49.50%	26.47%	20.48%
Description	*Fixed values - do not adjust*	*Calculated cell*	*Calculated cell*	*Calculated cell*
Procurement				
Procurement combined	13.0%	6.44%	2.966%	2.966%
Project specific				
Project specific combined	31.0%	15.35%	7.072%	4.117%
Client specific				
Client specific combined	34.0%	16.83%	9.441%	7.964%
Environment				
Environment combined	8.5%	4.21%	3.397%	2.652%
External influences				
External influences combined	13.5%	6.68%	3.594%	2.784%

Appendix C: AIC Tables

Cost Profile WRMP24 Table

Water Company	Thames Water Utilities Limited	Version	Gate 3 Issue	Back to title page	Cost Base	01/10/2022

Table 5a: WC Level - Option Level Cost Profile Table

Table Instruction	Option ID	Option Name	Cost Metric (£m)	Cost Sub-metric (£m)	Asset Life: Estimated average number of years an asset is considered useable before its value is fully depreciated.	Total/Fixed/Variable	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	[illegible]
Complete for all options (Feasible and preferred)	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Capex			Total		0.9600501	0.9600501	3.18005	6.66	21.73848	22.68426	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Opex			Total		0	0	0	0	0	0	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Financing Cost			Total		0.014016731	0.04205019	0.102496	0.24616	0.699495	1.554556	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Discount Rate			Total		0.035	0.035	0.035	0.035	0.035	0.035	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Discount Factor			Total		0.966183575	0.9335107	0.901943	0.871442	0.841973	0.813501	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Capex	Costed Risk		Total		0	0	0	0	0.890308	3.858001	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Capex	Optimism Bias		Total		0	0	0	0	1.76152	7.633254	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Net Present Cost (NPC)			Total		0.013542736	0.03925431	0.092445	0.214515	0.588956	1.264632	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Total NPC			Total	325.3894098							

Table 5b: WC Level - Option Level Unit Cost Profile Table

Table Instruction	Option ID	Option Name	Cost Metric (£m)	Cost Sub-metric (£m)	Asset Life: Estimated average number of years an asset is considered useable before its value is fully depreciated.		2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	[illegible]
Complete for all options >£100m (Feasible and preferred)	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Opex	Cost		Fixed		0	0	0	0	0	0	0	0	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Opex	Cost		Variable		0	0	0	0	0	0	0	0	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Land (Non depreciating)			Fixed		0	0	0	0	0	0	0.089288	0.185861	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Planning and Development (Non depreciating)			Fixed		0.9600501	0.9600501	3.18005	6.66	23.5	30.31752	31.00603	0	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Fencing (10)		10	Fixed		0	0	0	0	0	0	0.000944	0.001966	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	ICA (Instrumentation, Control & Automation) (10)		10	Fixed		0	0	0	0	0	0	0.08832	0.183847	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Plant and Machinery (15)		15	Fixed		0	0	0	0	0	0	0.006492	0.013515	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	M&E (Mechanical and Electrical) Works on Pumping Stations and Treatment Works (20)		20	Fixed		0	0	0	0	0	0	0.445819	0.928016	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Steel/Timber/GRP Structures (30)		30	Fixed		0	0	0	0	0	0	0.045429	0.094565	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Brick/Concrete Office Structures (50)		50	Fixed		0	0	0	0	0	0	0.009661	0.02011	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Treatment and Pumping Station Civils (incl. Intakes) (60)		60	Fixed		0	0	0	0	0	0	1.113868	2.318626	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Roads and Car Parks (60)		60	Fixed		0	0	0	0	0	0	0.104572	0.217677	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Reinforced Concrete Tanks / Service Reservoirs (80)		80	Fixed		0	0	0	0	0	0	0.013385	0.027863	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Pipelines (100)		100	Fixed		0	0	0	0	0	0	0.946627	1.970497	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Tunnels (100)		100	Fixed		0	0	0	0	0	0	1.812881	3.773691	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Embankment Works (250)		250	Fixed		0	0	0	0	0	0	0.274082	0.570528	[illegible]
	TWU_TED_HI-RAB_RE1_CNO_teddington dra 75; TWU_TED_HI-TFR_teddingtondrated/tlt; TWU_WLJ_HI-TFR_teddingtondramog/ted	Teddington DRA	Costed Risk			Fixed		0	0	0	0	0.890308	3.858001	4.609777	1.382514	[illegible]

Acronyms and Glossary

Term	Definition
ACWG	All Company Working Group
AIC	Average Incremental Cost
AMP	Asse Management Plan
AOP	Advanced Oxidation Process
AWRP	Advanced Water Recycling Plant
Base Capex	Base Capital Expenditure
Capex	Capital Expenditure
CDR	Conceptual Design Report
CPES	Conceptual & Parametric Engineering System
CPI	Consumer Price Index
CPIH	Consumer Price Index Including Owner Occupiers' Housing Costs
DO	Deployable Output
DRA	Direct River Abstraction
EES	Engineering Estimating System
ID	Internal Diameter
KGV	King George V Reservoir
MBBR	Moving Bed Biofilm Reactor
Ml/d	Mega litres per day
NPV	Net Present Value
NSF	Nitrifying Sand Filter
OB	Optimism Bias
Opex	Operating Expenditure
PR	Price Review
QCRA	Quantitative Costed Risk Assessment
RAIDO log	Risk, Assumption, Issue, Dependency and Opportunity
RAPID	Regulators' Alliance for Progressing Infrastructure Development
RO	Reverse Osmosis
RPI	Retail Prices Index
SRO	Strategic Regional Water Resource Option

Term	Definition
STW	Sewage Treatment Works
TTF	Teddington Target Flows
Thames Water	Thames Water Utilities Limited
TLT	Thames Lee Tunnel
Total Capex	Total Capital Expenditure
UF	Ultrafiltration
WAFU	Water Available for Use
WRMP	Water Resource Management Plan
WRSE	Water Resources South East
WTW	Water Treatment Works
WACC	Weighted Average Cost of Capital

[1] ACWG Cost Consistency Methodology. https://www.wrse.org.uk/media/u4gf5pye/acwg-cost-consistency-methodology.pdf
[2] Guidance Document for PAS2080, April 2023, pg 61
[3] All Company Working Group (ACWG) Standard Asset Life Classes for Water Resource Planning
[4] Programme Appraisal and Scenario Testing

It's everyone's water