Annex A3: Mogden South Sewer Water Recycling Conceptual Design Report

Standard Gate two submission for London Water Recycling SRO

Notice – Position Statement

This document has been produced as the part of the process set out by RAPID for the development of the Strategic Resource Options (SROs). This is a regulatory gated process allowing there to be control and appropriate scrutiny on 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 suite of documents that make up the 'Gate 2 submission.' That submission details all the work undertaken by Thames Water in the ongoing development of the proposed SRO. The intention at this stage is to provide RAPID with an update on the concept design, feasibility, cost estimates and programme for the schemes, allowing decisions to be made on their progress.

Should a scheme be selected and confirmed in the Thames Water final Water Resources Management Plan (WRMP), in most cases it would need to enter a separate process to gain permission to build and run the final solution. That could be through either the Town and Country Planning Act 1990 or the Planning Act 2008 development consent order process. Both options require the designs to be fully appraised and, in most cases, an environmental statement to be produced. Where required that statement sets out the likely environmental impacts and what mitigation is required.

Community and stakeholder engagement is crucial to the development of the SROs. Some high-level activity has been undertaken to date. Much more detailed community engagement and formal consultation is required on all the schemes at the appropriate point. Before applying for permission Thames Water will need to demonstrate that they have presented information about the proposals to the community, gathered feedback and considered the views of stakeholders. We will have regard to that feedback and, where possible, make changes to the designs as a result.

The SROs are at a very early stage of development, despite some options having been considered for several years. The details set out in the Gate 2 documents are still at a formative stage.

Disclaimer

This document has been written in line with the requirements of the RAPID Gate 2 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.

Annex A3: Mogden South Sewer Scheme Conceptual Design Report

Document no: J698-MS-DOC-130002-0B

Thames Water Utilities Ltd
J698

London Water Recycling
13 October 2022

Jacobs

Annex A3: Mogden South Sewer Scheme Conceptual Design Report

Client name:	Thames Water Utilities Ltd		
Project name:	London Water Recycling		
Client reference:	J698	Project no:	B22849AP
Document no:	J698-MS-DOC-130002-0B		
Date:	13 October 2022		

Jacobs U.K. Limited

2nd Floor, Cottons Centre
Cottons Lane
London SE1 2QG
United Kingdom

T +44 (0)203 980 2000
www.jacobs.com www.jacobs.com

Contents

Executive Summary

This report sets out the conceptual design for the Mogden South Sewer scheme. This scheme was identified in the Water Resources Management Plan 2019 (WRMP19) Direct River Abstraction Feasibility Study and WRMP19 Fine Screening process by Thames Water Utilities Limited (TWUL) and identified as a part of the Strategic Resource Option (SRO) London Effluent Reuse by the Regulators' Alliance for Progressing Infrastructure Development (RAPID).

As a part of London Effluent Reuse SRO, Mogden South Sewer scheme was submitted for the standard Gate 1 assessment by RAPID, and it was agreed to be continued to be funded to Gate 2 as part of the standard gate track.

However, source flow of the Mogden South Sewer scheme (i.e., raw sewage from South Sewer near Kempton WTW) was monitored in Gate 2 option feasibility evaluation, and the results show a dry weather flow ranging between 33 and 36 Ml/d which is substantially below the flow required to support a 50 Ml/d scheme. Re-evaluation of costs for a smaller scheme showed increasing Average Incremental Cost (AIC). Therefore, we recommend that Mogden South Sewer exits the RAPID gated process and does not progress into Gate 3, though it should be noted that the South Sewer scheme does provide an undefined wastewater benefit, as it provides headroom in Mogden STW by intercepting and treating flow that would be destined for Mogden STW.

Therefore, the concept design for Mogden South Sewer is largely the same as at Gate 1; however, where conveyance routes, discharge infrastructure and operational philosophy have been refined for Mogden Water Recycling scheme it is equally applicable to Mogden South Sewer scheme and these updates have been included in this concept design report.

Design elements in this report are listed below:

- Sewage Treatment Plant and Advanced Water Recycling Plant co-located at site near Kempton WTW (STW-AWRP site) (Gate-2/WRSE Ref. TWU_WLJ_HI-REU_reuse mogden s sewer)
- Raw Sewage Transfer from South Sewer to AWRP site (Gate-2/ WRSE Ref. TWU_WLJ_HI-REU_reuse mogden s sewer)
- Recycled Water Transfer Pipeline from AWRP site to River Thames (Gate-2/ WRSE Ref. TWU_WLJ_HI-REU_reuse mogden s sewer)
- Wastewater Return Pipeline from AWRP site to South Sewer (Gate-2/ WRSE Ref. TWU_WLJ_HI-REU_reuse mogden s sewer)
- Reverse Osmosis (RO) Concentrate Pipeline from AWRP site to Mogden Sewage Treatment Works (STW) (Gate-2/ WRSE Ref. TWU_WLJ_HI-REU_reuse mogden s sewer)

Table S-1: Scheme Summary

Name	Mogden South Sewer
Gate-2/WRSE Reference	TWU_WLJ_HI-REU_reuse mogden s sewer
Scheme Type	Resource and Conveyance
WRZ	London
Engineering Scope	A portion of untreated sewage would be abstracted from the South Sewer, which runs close to Kempton Park Water Treatment Works (WTW) and would be pumped to a new Advanced Water Recycling Plant (AWRP) located at a site near Kempton WTW (AWRP site). The Recycled Water would then be pumped and discharged into the River Thames upstream of the existing Thames Water Walton WTW intake. Waste stream from Reverse Osmosis (RO) concentrate would be transferred to the existing Mogden Sewage Treatment Works (STW) outfall through a new pipeline, while the other waste stream could be returned to the South Sewer which discharges into Mogden STW inlet works. There is an opportunity that all waste stream could be returned to the South Sewer if capacity of Mogden STW allows.
Benefit	46 Ml/d Dry Year Annual Average (DYAA) and Dry Year Critical Period (DYCP) Deployable Output for the capacity of 50 Ml/d
Mutual exclusivities	Teddington DRA and Mogden Water Recycling schemes up to a combined capacity of 200 Ml/d

Name	Mogden South Sewer
	If Mogden Water Recycling scheme and Mogden South Sewer scheme are using same site for AWRP, there may be mutual exclusivities depending on scheme sizes and area of selected site.
Interdependencies	There are no interdependencies with other options on the Constrained List. To provide an additional resource to London WRZ the following elements may be also required: • Additional capacity to abstract from the River Thames and conveyed to Kempton WTW • Additional treatment capacity at Kempton WTW • Upgrade to raw water systems in West London (not currently in CDR)

1. Introduction

1.1 Background

Thames Water Utilities Limited (TWUL) are engaged in development of Strategic Regional Water Resource Options (SROs) under the guidance of the Regulators' Alliance for Progressing Infrastructure Development (RAPID). RAPID was formed to help accelerate the development of new water infrastructure and design future regulatory frameworks, with collaboration between Ofwat, the Environment Agency (EA) and the Drinking Water Inspectorate (DWI).

Water resource options were developed for the reuse of Sewage Treatment Works (STW) effluent or blackwater (untreated sewage) reuse and direct river abstractions in London as part of TWUL's Water Resource Management Plan 2019 (WRMP19). London Effluent Reuse has been identified as SRO in the Price Review 2019 (PR19) Final Determination (London Effluent Reuse SRO). At PR19, Ofwat announced a development fund for strategic water resource solutions linked to "Gates" to ensure efficient delivery and to protect customers. TWUL has been allocated funds to investigate and develop integrated strategic regional water resource solutions, including London Effluent Reuse SRO, between 2020 and 2025 to support long term resilience. The London Effluent Reuse SRO solution was submitted for the standard Gate 1 assessment by RAPID in 2021, and it will continue to be funded to Gate 2 as part of the standard Gated process in 2022.

London Effluent Reuse SRO incorporates four schemes: two schemes for reuse of final effluent from Mogden STW (Mogden Water Recycling scheme) and Beckton STW (Beckton Water Recycling scheme), a direct river abstraction scheme (Teddington Direct River Abstraction (DRA) scheme) and a fourth, blackwater or sewer mining treatment option within the Mogden STW catchment (Mogden South Sewer scheme). Abstracted effluent or sewage in these schemes is to be treated in each case through an Advanced Water Recycling Plant (AWRP) or a Tertiary Treatment Plant (TTP) and discharged to the River Thames or the River Lee Diversion for abstraction as a water resource.

This report sets out the conceptual design for the Mogden South Sewer scheme which is summarised as follows:

- Untreated sewage would be abstracted from the South Sewer, which runs close to Kempton Park Water Treatment Works (WTW) and would be transferred to a site with a new Sewage Treatment Works and a new Advanced Water Recycling Plant (STW-AWRP site) located near the Kempton WTW for treatment.
- Recycled Water would then be conveyed and discharged into the River Thames upstream of the existing Thames Water Walton WTW intake.
- The waste stream from Reverse Osmosis (RO) concentrate would be transferred to the existing Mogden Sewage Treatment Works (STW) outfall through a new pipeline, while a second pipeline would return waste stream from other treatment processes to the South Sewer which discharges into Mogden STW inlet works. There is an opportunity that all waste streams could be returned to the South Sewer if treatment capacity of Mogden STW allows.

1.2 Scheme Overview and Location

Untreated sewage would be abstracted from the South Sewer running to the Southwest of Kempton WTW in the catchment of Mogden STW (see (1) Figure 1-1). Abstracted raw sewage would be pumped to a new AWRP, which would be co-located with a new STW, at a site near to Kempton WTW (see (2) Figure 1-1). A site for the new STW-AWRP has not been selected. The raw sewage would be treated through STW consists of grit removal, biological nutrient removal (BNR), then to sufficient standard for potable reuse with AWRP treatment technologies proposed as reverse osmosis (RO) and advanced oxidation process.

The Recycled Water would be discharged into the River Thames, upstream of the existing Thames Water Walton WTW Intake (see (3) Figure 1-1). The waste stream from the RO process would be conveyed from the AWRP site back to Mogden STW. The waste stream from the other AWRP process would be returned to the South Sewer which leads to the Mogden STW Inlet Works. It was proposed that RO concentrate would be discharged through the existing Mogden STW Outfall; however, there is an opportunity that all waste streams would be returned to the South Sewer, if Mogden STW has sufficient treatment capacity.

The Mogden South Sewer scheme would supply the London Water Resource Zone (WRZ) (see (4) and (5) Figure 1-1).

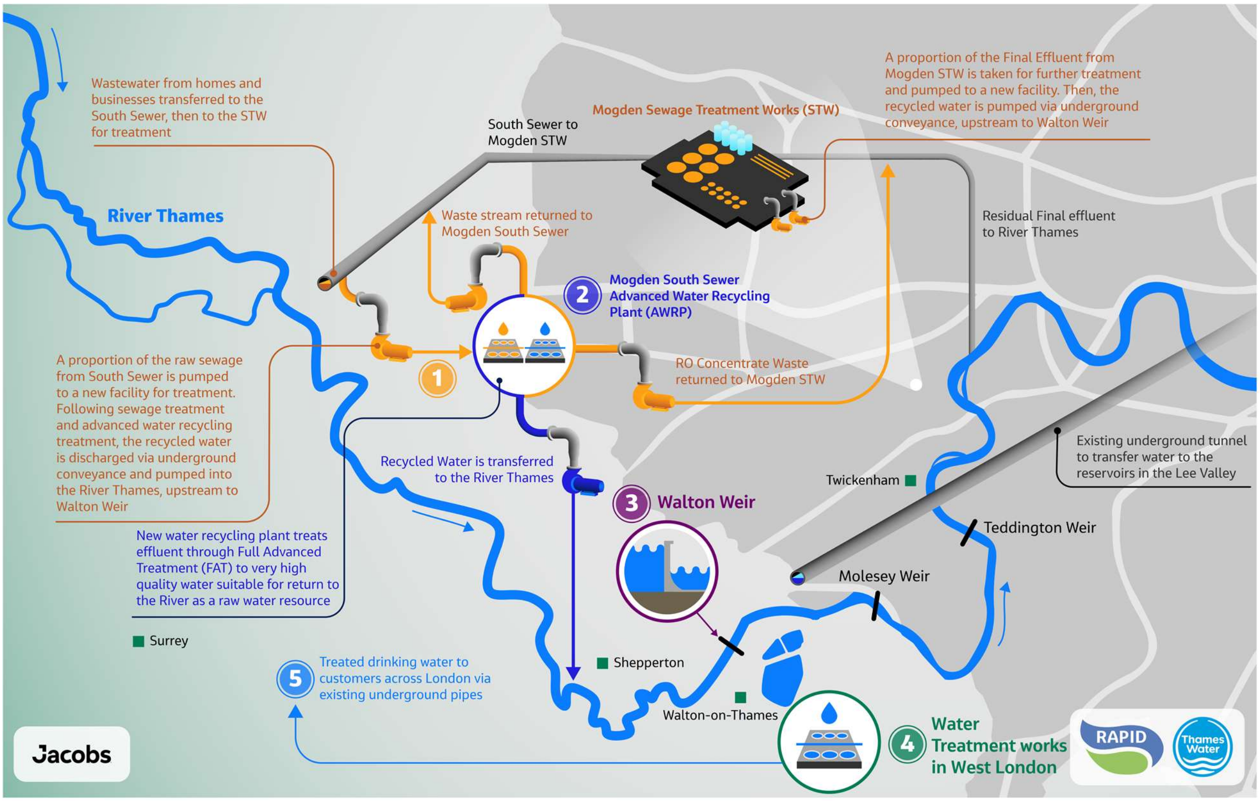

Figure 1-1: Mogden South Sewer Scheme Overview

1.3 Sizing and Phasing

As part of our option feasibility evaluation, source flow of the Mogden South Sewer scheme (i.e., raw sewage from South Sewer near Kempton WTW) was monitored at 2-minute interval from March 2021 through to 2022. The results show a dry weather flow ranging between 33 and 36 Ml/d which is substantially below the flow required to support a 50 Ml/d scheme. The maximum size a Mogden South Sewer scheme could support would therefore be 25-30 Ml/d, subject to further investigation.

It is not expected that phasing of construction would bring cost or social benefits because the anticipated scheme size would be small.

1.4 Links with Other Options, Schemes and Elements

1.4.1 Dependencies

Water resource options require several different elements (from source to treated water transmission) to be implemented for the resource option to deliver benefit. Table 1-1 lists system elements that may be required to deliver a full water resource utilisation for this scheme. Water network reinforcements required irrespective of the specific scheme selected, have not been included.

Table 1-1: Interdependent Elements

Type	Interdependent Elements
Water Sources	N/A
Abstraction and Conveyance	• Additional capacity to abstract from the River Thames and conveyed to Kempton WTW
Water Treatment Works	• Additional treatment capacity at Kempton WTW

Potable Water Network Reinforcement	▪ Potable network reinforcements.

1.4.2 Mutual Exclusivities

The combined capacity/ yield of Teddington DRA scheme, Mogden Water Recycling scheme and Mogden South Sewer scheme is limited to 200Ml/d because the three schemes use final effluent of Mogden STW or sewage from the Mogden STW catchment as a water source. These three schemes could be mutually exclusive when the cumulative capacities exceed the limit. Flow availability of Mogden STW final effluent is discussed in Annex A.4 of the Gate 2 Report (Teddington DRA Conceptual Design Report).

2. Conceptual Design

2.1 Design Principles

During the Gate 2 Conceptual Design process, the All Company Working Group (ACWG) issued "ACWG Design Principles, Process and Gate 2 Interim Guidance" to maintain consistency throughout SROs. The ACWG Design Principles comprise the four principles of the National Infrastructure Commission (Climate, People, Place, Value) with two cross-cutting principles that apply across all four categories.

Thames Water have set out design vision for the London Effluent Reuse SRO. However, design development of the South Sewer scheme was paused in Gate 2 after the source water monitoring as the results of the monitoring showed that the source water was not sufficient to support a 50Ml/d scheme. Therefore, the AWCG Design Principles and the London Effluent Reuse SRO Design Vision were not applied to design development of the South Sewer.

AWCG Design Principles and the London Effluent Reuse SRO Design Vision could be found in Annex A.1, A.2 and A.4 of Gate 2 Report.

2.2 Scheme Components and Operating Philosophy

The conceptual design for each of following option components are developed in this report:

- South Sewer sewage abstraction
- Raw Sewage Transfer Pipeline from South Sewer to STW-AWRP site
- Advanced Water Recycling Plant co-located with Sewage Treatment Works (STW-AWRP)
- Recycled Water Transfer Pipeline from the STW-AWRP site to River Thames
- Waste Stream Collection and Discharge
    - Reverse Osmosis (RO) Concentrate Pipeline from the AWRP site to existing outfall in Mogden STW
    - Wastewater Pipeline from the STW-AWRP site to South Sewer
- Recycled Water Discharge to the River Thames

2.2.1 Source Water Abstraction Design Components

The South Sewer runs from Southwest to Northeast near the West of Kempton Park WTW, leading to the Mogden STW inlet works.

Raw sewage would be abstracted upstream of the waste flow discharge from the Kempton WTW to South Sewer. A pumping station would be installed near the abstraction location to pump raw sewage to the new STW-AWRP site.

2.2.2 Treatment Design Component

The abstraction of raw sewage from the South Sewer would require Biological Nutrient Removal (BNR) and extensive solids reduction (STW phase) prior to advanced water treatment (AWRP phase) which would be co-located with the STW-phase treatment components (STW-AWRP).

A BNR process via conventional Activated Sludge Process (ASP) and Membrane Bioreactor (MBR) would be proposed as the STW phase. As for the AWRP phase, Full Advanced Treatment (FAT) which consists of Reverse Osmosis (RO) and UV Advanced Oxidation Process (UVAOP) would be proposed. FAT is globally accepted as advanced water treatment process for indirect potable reuse.

There are opportunities to consider alternative treatment trains and development as the design work progresses. Therefore, treatment designs described in this report are indicative.

2.2.2.1 Water Quality

2.2.2.1.1 Estimated South Sewer Raw Sewage Quality and Removal

Because Mogden South Sewer raw sewage quality data was not available, general design water quality parameters were estimated through Mogden STW influent loading and final effluent water quality as shown in the table below.

The Prescribed Concentration or Values (PCV) for drinking water, where applicable, are also included in the table.

Table 2-1: Estimated Water Quality of South Sewer Raw Sewage

Parameter	Unit	Average	95%ile	Drinking Water Regulatory PCV
General				
BOD	mg/l	187.4		
Suspended Solids	mg/l	249.9		
Total Nitrogen, TN	mg/l	34.4		
Ammonia. NH_3	mg/l	23.4		
Nitrate, NO_3	mg/l	0.0		50
Total Phosphorus, TP	mg/l	7.8		
Orthophosphate	mg/l	5.1		
pH	pH Unit	7.3		6.5-9.5
Alkalinity (as $CaCO_3$)	mg/l	357.5		
Total Dissolved Solids, TDS	mg/l	897.5		
Total Organic Carbon, TOC	mg/l	136.3		No abnormal change
Salts & Anions				
Calcium	mg/l	105.5	127.5	
Magnesium	mg/l	8.6	11.8	
Sodium	mg/l	79.4	110.0	
Potassium	mg/l	17.8	23.0	
Ammonium	mg/l	0.4	1.9	
Barium	µg/l	14.4	22.8	
Strontium	mg/l	0.3	0.4	
Sulphate	mg/l	84.2	104.9	250
Chloride	mg/l	109.0	125.3	250
Fluoride	mg/l	0.5	0.5	
Silica, SiO_2	mg/l	10.5	15.0	
Boron	µg/l	117.6	209.9	
Human made organics				
1,4-Dioxane	µg/l	0.5	0.6	
Disinfection By-products				
NDMA	µg/l	0.004	0.012	
Total THM	µg/l	9.8	10.0	100
Per- and Polyfluoralkyl Substances (PFAS)				
Perfluoropentanoic acid	µg/l	0.024	0.060	0.1†
Total PFAS*	µg/l	0.083	0.178	
*Based on Perfluorodecanoic acid, Perfluorododecanoic acid, Perfluoroheptanoic acid, Perfluorohexanoic acid, Perfluorononanoic acid, Perfluorooctanoic acid, Perfluorooctanesulfonic acid and Perfluoropentanoic.				
†The proposed EU Directive recasting recommends a parametric (limit) value for individual PFAS compounds of 0.1 µg/l and 0.5 µg/l for PFAS in total.				

Suspended Solids

The plant would receive high suspended solids loading. The MBR treatment system is effective in reducing solids, with RO capable of providing a Recycled Water effluent effectively free from suspended solids. However, high solids loading to MBR systems could cause a high level of fouling. Regular membrane fouling reducing measures (backwashing and chemical cleaning) should be practiced based on specific supplier recommendation.

Nitrogen and Phosphorous

The BNR treatment unit would be effective in reducing total phosphorus and phosphate concentrations. This allows for further removal to remove virtually all phosphate through RO process. The reduction of high phosphate concentrations prior to the RO treatment process reduces the risk of accumulated build-up of scalants within the RO membranes which can reduce the recovery of the system. Sulphuric acid dosing to lower pH ahead of the RO membranes would also be provided to address this.

Total Organic Carbon

TOC is to be drastically reduced within MBR system prior to chlorine disinfection to prevent the formation of disinfectant by-products such as THMs. However, it would be proposed to dose pre-formed monochloramine to control biological fouling of the RO membranes, which mitigates the risk of disinfection by-product formation. MBR and RO membranes also provide excellent removal of TOC typically, in excess of 95% removal in potable reuse applications.

Sparingly Soluble Salts & Anions

Concentration of Salts & Anions in the Mogden STW final effluent was assumed as indicative of the raw sewage from South Sewer. A high concentration of chloride would be expected. This is of concern as its 95%ile concentration is just above 50% of the PCV.

Solvents and Industrial Chemicals

The Mogden STW final effluent quality data shows low levels of 1,4-Dioxane, an industrial chemical which can provide treatment challenges. It was assumed raw sewage from South Sewer would not have a 1,4-dioxane concentration higher than the concentration in Mogden STW final effluent. A common target in potable reuse applications is to achieve a finished water quality concentration of 1μg/l.

Endocrine Disrupting Compounds (EDCs) and other Contaminants of Concern (CECs)

These include several contaminants including nonylphenols, per and polyfluoroalkyl substances (PFAS) and N-Nitrosodimethylamine (NDMA) which come under the category of contaminants of emerging concern. There is limited sampling data and, in most cases, no PCV limits have been set by the regulators in UK. The treatment experience in UK is also limited. A multibarrier treatment process provided has been proposed, in alignment with global best practice, for its efficacy in removing these compounds.

Microbiological

There would be significant microbiological loading which would require removal and disinfection prior to discharge.

The STW-AWRP treatment train would provide a multi-barrier disinfection and removal of pathogens (including bacteria, viruses and protozoa). The assumed treatment log removals have been summarised in Table 2-2.

Table 2-2: Pathogen Log Removal Credits for Proposed AWRP Treatment Processes

Pathogen	MBR	RO	UVAOP	Pipeline Cl_2*	Total
Virus	1.5	1.5	6	4	13
Giardia	2	1.5	6	0	9.5
Cryptosporidium	2	1.5	6	0	9.5

* Level of pathogen log removal from conveyance disinfection using sodium hypochlorite or other preferred disinfectant chemical.

Metals

Metals content data within the raw sewage influent was not available at the time of writing, therefore an assessment of metals contents at risk of exceeding the PCVs for discharging water could not be quantitively assessed. However, the proposed treatment would reduce metals to a concentration well below the PCV.

Pesticides and Other Organics

A large number of organic chemicals could be present in the raw sewage from South Sewer, including pesticides such as AMPA (aminomethylphosphonic acid), metaldehyde and glyphosate. The full advanced treatment processes are considered effective in removing pesticides.

2.2.2.1.2 Recycled Water Quality

The proposed STW-AWRP treatment process of RO/UVAOP produces an ultra-pure to deionised water standard. This results in a water that is corrosive and aggressive to transfer and discharge to the receiving water course. Consequently, a remineralisation process using Lime and CO_2 dosing would be included to remineralise the water before discharge to the river.

Recycled Water discharge standard requirement from AWRP for discharge to River Thames was not available. Therefore, the following Recycled Water quality targets were assumed to determine remineralisation requirements. The targets were set based on previous indirect potable reuse scheme designs and research findings for recommended water quality to reduce impacts of corrosion on transfer pipelines.

- Alkalinity of 60 mg/l as $CaCO_3$
- Langelier Saturation Index (LSI) of 0.15

2.2.2.2 Proposed Treatment Scheme

The STW-AWRP treatment train would provide a hybrid treatment for raw sewage. The STW phase, BNR treatment with a conventional ASP and MBR processes, would provide pre-treatment before feeding the AWRP phase, Full Advanced Treatment (FAT) process with RO and UVAOP. Indicative treatment process for this treatment train is shown in Figure 2-1 below.

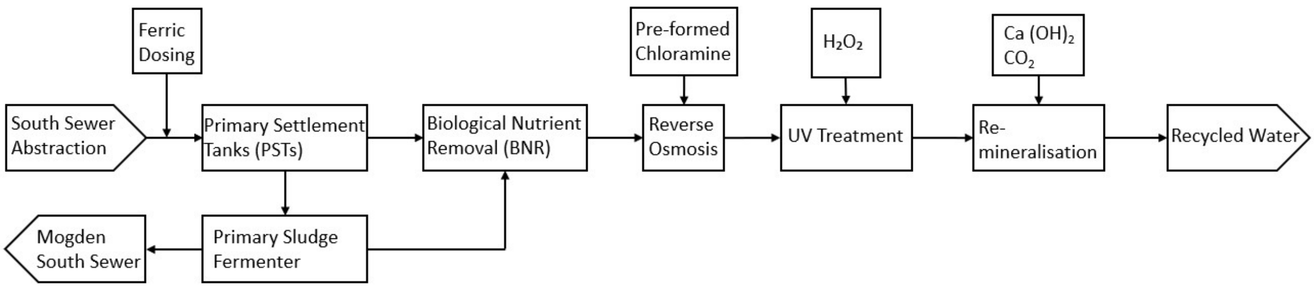

Figure 2-1 Outline of Indicative Treatment Process

Note: This diagram shows outline treatment process outline only. Additional chemical dosing and other auxiliary processes are likely to be required.

The RO and UVAOP combination could provide a multi-barrier protection against pathogens, whilst RO and UVAOP are also capable of removing chemicals and emerging contaminants.

Indicative treatment process for Mogden South Sewer scheme would be:

STW phase

- Inlet works (screens and grit removal system)
- Ferric Dosing (to assist in the removal of phosphate and coagulation of solids)
- Primary Settlement (for solids and BOD removal)
- Fine screening (to reduce MBR membrane fouling)
- Biological Nutrient Removal (BNR) via Activated Sludge Process (ASP) and Membrane Bioreactor (MBR)

- Primary Sludge Fermentation (to provide additional carbon source for biological phosphate removal)
- Odour control unit(s) for inlet works, primary settlement and fermenter processes

AWRP phase

- Pre-formed chloramine dosing (for prevention of bio-fouling on the membranes)
- Anti-scalant and sulphuric acid dosing (for scale prevention on RO membranes and pH control prior to the membranes)
- Reverse Osmosis membranes (for the removal of pathogens, chemicals, anions, metals, and some organics)
- Advanced Oxidation Process (AOP) consisting of UV irradiation and hydrogen peroxide addition (for removal of recalcitrant compounds such as metaldehyde and disinfection purposes)
- Remineralisation with lime (calcium hydroxide) and carbon dioxide

Chlorination of the Recycled Water and the water in the pipeline, together with dechlorination prior to river discharge, may be required for virus reduction.

2.2.2.2.1 Inlet Works

Conventional inlet works including a manual bar screen, mechanical fine screens (6mm) and a grit chamber for grit removal would be used for preliminary treatment of the raw sewage prior to transfer to the primary settlement stage. The inlet works would be equipped with an odour control unit.

2.2.2.2.2 Ferric Addition

Ferric sulphate would be dosed upstream of the Primary Settlement stage to enhance coagulation of solids and chemical removal of phosphorus. Coagulation improves the solids removal efficiency in the primary settlement. Reduction in solids and phosphate concentrates prior to the MBR and RO membrane systems reduces the risk of fouling and chemical cleaning/dosing requirements.

Ferric sulphate could be dosed using a dedicated dosing system including dosing pumps and bulk tank storage.

2.2.2.2.3 Primary Settlement

Screened raw sewage effluent would undergo primary settlement via Primary Settlement Tanks (PSTs). The use of PSTs upstream of the BNR reduces the solids loading and biological treatment requirement of the ASP. Indicative PST design are summarised in Table 2-3.

Table 2-3: Indicative Primary Settlement Tank Configurations

Scheme Size	50 Ml/d
Tank Diameter	25.5m
Tank Side Wall Depth (SWD)	5.5m
Total Surface Area	2,050 m^2
Total Volume	11,27 m^3

Primary sludge would be drawn-off and transferred to the Primary Sludge Fermenter via the Primary Sludge Transfer Pumping Station. Primary tank effluent would gravitate to the MBR. The PSTs would be equipped with an odour control unit.

2.2.2.2.4 Fine Screening

Primary effluent would undergo screening via a 2mm fine screen. The screens would remove materials which can cause abrasive damage to the membranes downstream. Automatic self-cleaning via regular backwash sequences would be recommended. The dirty backwash water would be transferred to the wastewater return pumping station.

2.2.2.2.5 Membrane Bioreactor (MBR)

Primary tank effluent would then undergo a BNR using the Activated Sludge Process (ASP) and Membrane Bioreactor (MBR) systems. The MBR process consists of a conventional aeration volume with downstream membrane filtration, generally using Micro-filtration or Ultra-filtration membrane modules. ASP could consist of anaerobic, anoxic and aerobic zones to provide initial denitrification followed by nitrification prior to membrane filtration. The indicative MBR and ASP configuration is summarised in Table 2-4.

Table 2-4: Indicative MBR and ASP Configurations

Scheme Design	50 Ml/d
ASP Design	
No. Basins	6 No. Duty
Total Volume	14,000 m^3 (2,500 m^3 per basin)
Dimensions per Basin	21m W x 17m L x 7m SWD
No. Passes	3 per basin
MBR Design	
Permeate Capacity	50.8 Ml/d
Total No. Trains	5 No. Duty + 1 No. Standby
Membrane Flux Rate	26.9 Lmh
Total No. Membrane Modules	3,768 (628 modules/train)
Total Membrane Area	129,520 m^2 (21,586 m^2 per train)

The MBR would be equipped with aeration basin blowers, air scour blowers, feed pumps, MBR RAS pumps and other ancillary equipment required.

The MBR plant would also have a dedicated backwash plant, composed of duty/standby backwash pumps and a set of duty/standby air scour blowers. Each membrane would need to be backwashed frequently to remove fouling. Waste from the backwash process would drain via gravity to a backwash holding tank to be recirculated back to the aeration basins.

A Clean in Place (CIP) plant would be provided for periodic (every two months, whilst in use) cleaning of the MBR membranes to remove both organic and inorganic fouling. The system would consist of a CIP solution recirculation pumping system, heated water tank and dedicated chemical dosing pumps fed from the bulk sodium hypochlorite and citric acid storage tanks. The resultant spent CIP chemical solution effluent would feed into the MBR neutralisation tank where it could be neutralised using caustic soda and sodium bisulphite prior to discharge to the wastewater return pump station.

2.2.2.2.6 Pre-formed Chloramine Addition

Pre-formed monochloramines would be added upstream of the MBR for the purpose of bio-fouling control. Monochloramine has the added benefit of reducing the risk of disinfection by-products such as THMs or HAA (Halogenic Acetic Acid).

Monochloramines would be prepared on-site by batching sodium hypochlorite solution with liquid ammonium sulphate. Separate feed systems would be required for both chemicals involved.

2.2.2.2.7 Primary Sludge Fermenter

The primary sludge formed as part of the Primary Settlement stage would undergo fermentation using Single Stage Fermenters. Fermentation would anaerobically dissociate complex particulate and soluble substrates within the primary sludge into an effluent rich in short-chain volatile fatty acids (SCVFAs). Volatile fatty acids (VFAs) could be a requisite for BNR bioreactors as they would help develop stable populations of phosphate accumulating organisms (PAOs) and denitrifying bacteria. The VFA-rich fermenter effluent would be fed directly to the anaerobic zone of the bioreactor to enhance biological phosphorus removal (EBPR) process. The fermenter would be equipped with an odour control unit.

Residual sludge produced during fermentation, along with scum formed on the top of the fermenter, would be pumped to the wastewater return pumping station to be returned to the South Sewer for treatment in the Mogden STW.

Table 2-5: Indicative Fermenter Tank Configurations

Scheme Design	50 Ml/d
Total No. Tanks	2 No. Duty
Tank Diameter	18.2 m
Tank Volume per Unit	1,287 m^3
Capacity per Unit	20.4 m^3/h
	306 kgDS/hr

2.2.2.2.8 Reverse Osmosis Membranes

Permeate from the MBR system would pass forward into a RO Feed Tank, from which an RO Transfer Pump Station would discharge flows through a cartridge filtration prior to the Reverse Osmosis. The RO Feed tank is commonly applied upstream of RO systems to provide sufficient feed flow for efficient operation. Each RO train would be fitted with a designated RO feed pump which would feed the RO train at the pressure required for the chosen membrane selectivity. Indicative RO plant configurations are shown in Table 2-6.

Table 2-6: Indicative RO Plant Configurations

Scheme Design		50 Ml/d
Permeate Capacity		50Ml/d
Total No. Trains		3 No. Duty + 1 No. Standby
Membrane Flux Rate		17.7 Lmh
Total No. Pressure Vessels		712 (178 No. per Train)
Pressure Vessels per Train	Stage 1	101
	Stage 2	51
	Stage 3	26
Total Membrane Area (based on 6 elements per pressure vessel with 37.16 m^2 each)		157,320 m^2 (39,330 m^2 per train)

To achieve a minimum system recovery of 85%, prevention of the formation of foulants and scalants, such as calcium phosphate, would be required by adjusting pH in the feed water. Control of pH in the feed water could be achieved by a trim sulphuric acid dosing system.

A CIP system would also be provided for bimonthly RO membrane cleaning whilst the plant is in use. The system may consist of a cleaning solution, recirculation pumping system, heated water tank and dedicated chemical dosing pumps fed from the bulk sulfuric acid and scale inhibitor storage tanks. The resultant spent CIP chemical solution effluent then would feed into the RO neutralisation tank where it would be neutralised using caustic soda prior to discharge to the wastewater return pumping station.

It was assumed that RO concentrate would be discharged to the existing Mogden STW final effluent outfall. However, there is an opportunity to return the concentrate to South Sewer if Mogden STW has sufficient treatment capacity.

An interstage turbocharger may be utilized with the RO system to capture energy from the residual pressure in the RO concentrate. In addition, alternative energy recovery devices (ERDs) could be considered for comparison to the use of an interstage turbocharger.

2.2.2.2.9 Advanced Oxidation Process - Hydrogen Peroxide Dosing and UV Activation

In the UV/ H_2O_2 process, UV light dissociates hydrogen peroxide into hydroxyl radicals which subsequently oxidize organic contaminants. Advanced Oxidation Processes (AOPs), such as UV/ H_2O_2, is effective for breaking down recalcitrant organic chemicals including 1,4-dioxane and N-Nitrosodimethylamine (NDMA).

UVAOP requires high UV does, typically in excess of 500 mJ/cm². The UVAOP would be capable of providing a minimum NDMA log destruction of 1.2 log and a 1,4-dioxane log destruction of 0.5 log, which are common design criteria for UVAOP systems in potable reuse applications.

A hydrogen peroxide dosing system may also be provided consisting dedicated dosing pumps fed by bulk chemical storage tank.

Indicative UVAOP system configurations are shown in Table 2-7.

Table 2-7: Indicative UVAOP System Configurations

Scheme Design	50 Ml/d
Total No. Trains	2 No. Duty + 0 No. Standby
Hydrogen Peroxide (H_2O_2) Dose	4 mg/l
Total No. Lamps (low pressure, high output)	1,152
Total Duty Load	262.1 kW

2.2.2.2.10 Remineralisation (Lime and CO_2)

Following UVAOP treatment, remineralisation would reduce the corrosivity and acidity in disinfected water stream with lime and carbon dioxide dosing. Remineralisation process would involve preparation of a saturated lime solution which is mixed with carrier water (RO permeate) and dosed to the main RO permeate. After addition of lime, the RO permeate would be then dosed with CO_2. This could be done by saturating a small stream of carrier water with CO_2 (stored in liquid form onsite) and delivering this to a static mixer.

It should be noted that RO permeate with low pH and high CO_2 content may occur, and it could require Carbon dioxide stripping as part of the remineralisation process. Conversely, remineralisation chemical dosing requirements will be reduced. The requirement for a decarbonator treatment will need to be investigated further.

2.2.2.2.11 Chemical Dosing

Chemical dosing would be required throughout the plant for optimum performance, water quality management and to maximise membrane life. Chemicals which would be required for the plant operation were listed in section 2.1.2.3.

Chemical deliveries to the AWRP would be in a common hard standing area which would drain to a dedicated chemical spill tank so that any accidental spills can be contained.

2.2.2.2.12 Process Unit Summary

Indicative process units are listed in the following table.

Table 2-8: Indicative 50 Ml/d Process Unit and Structure Sizes

Process Item	Approximate Building / Structure Area (m^2)	Approximate Length (m)	Approximate Width / Diameter (m)	Approximate Height Above Ground (m)
Inlet Works & Coagulation Dosing Chamber	1560	130	12	12
Primary Settlement Tank (4 tanks)	707 (per tank)	-	26 (per tank)	10
BNR Plant	16,992	236	72	8
MBR Plant		75	30	6
Primary Sludge Fermentation (2 tanks)	113 (per tank)	-	12 (per tank)	7
Equalisation Tank	968	45	22	10.0
RO Feed Pumping Station	347	23	15	10
Reverse Osmosis Building	2587	65	40	12

Process Item	Approximate Building / Structure Area (m^2)	Approximate Length (m)	Approximate Width / Diameter (m)	Approximate Height Above Ground (m)
UV Advanced Oxidation Building	588	37	16	6
Remineralisation	958	51	19	15
Chemical Storage	1283	32	40	12
Recycled Water Pumping Station	347	23	15	6
Wastewater Return Pumping Station	74	12	6	6
RO Concentrate Pumping Station	74	12	6	6
Administration Building	569	37	15	8

2.2.2.3 Waste Streams Management

An indicative list of the STW-AWRP waste streams would be as follows:

- Primary Settlement Sludge - sludge drawn off from the PST and pumped to the Primary Sludge Fermenter via primary sludge pump station. This sludge stream does not form part of the final waste stream composition.
- Fermenter sludge and scum residual - sludge drawn off from the fermenter tanks and pumping to the wastewater return pump station.
- BNR/MBR Waste Activated Sludge (WAS) - sludge wasted as part of the BNR process. WAS would be pumped to the wastewater return pump station via a WAS pump station.
- MBR Backwash flow - as part of the membrane maintenance, MBR membranes would be backwashed frequently throughout full flow operation.
- MBR plant neutralised cleaning chemical - CIP sequences would occur bimonthly during AWRP operation periods resulting in neutralised spent chemical cleaning solution.
- RO plant neutralised cleaning chemical - CIP sequences would occur bimonthly during AWRP operation periods resulting in neutralised spent chemical cleaning solution.

The waste streams above would be collected in the Wastewater Return Pumping Station to be pumped back to the South Sewer, except the RO concentrate stream which would be conveyed to the existing final effluent outfall at Mogden STW.

Projected quality parameters of the combined wastewater are shown in Table 2-9. The RO concentrate has not been included within this waste stream. It was assumed that the Mogden STW would have sufficient capacity to accept the wastewater; however, further assessment would be required for confirmation.

The projected RO concentrate quality and flow are shown in Table 2-10. If the Mogden STW has sufficient treatment capacity to receive waste streams including RO Concentrate, all waste stream could be returned to South Sewer.

Table 2-9: Projected STW-AWRP Combined Wastewater Flow and Composition (except for RO Concentrate)

Parameter	Units	Waste Stream Concentration
Flow	Ml/d	0.9
pH	-	6.7
Alkalinity (as $CaCO_3$)	mg/l	281
Suspended Solids	mg/l	17,668
Suspended Solids (Load)	kg/d	15,952
Total Dissolved Solids, TDS	mg/l	808

Total Organic Carbon, TOC	mg/l	5,585
Total Organic Carbon, TOC (Load)	kg/d	5,043
Nitrate, NO_3	mg/l	5.8
Nitrate, NO_3 (Load)	kg/d	5.2
Total Nitrogen, TN	mg/l	636
Total Nitrogen, TN (Load)	kg/d	575
Phosphate, PO_4	mg/l	1.3
Phosphate, PO_4 (Load)	kg/d	1.2

Table 2-10: Projected RO Concentrate Flow and Composition

Parameter	Units	50 Ml/d Design
Concentrate Flow	Ml/d	8.8
pH	pH Unit	7.2
Alkalinity (as $CaCO_3$)	mg/l	1,360
Suspended Solids	mg/l	6.5
TDS	mg/l	4,894
Total Organic Carbon	mg/l	4.9
Nitrate (NO_3)	mg/l	47
Total Nitrogen	mg/l	60
Phosphate	mg/l	0.3

2.2.3 Conveyance

2.2.3.1 Conveyance of Raw Sewage from South Sewer to the STW-AWRP site

A pipeline to transfer raw sewage from South Sewer abstraction location to the STW-AWRP site would be required. The length of the pipeline would be approximately 1.8km with trenchless installation and may include pipe jacked crossings.

2.2.3.2 Conveyance of Recycled Water from the STW-AWRP site to the River Thames

A 5.9km trenched pipeline is proposed to pump the Recycled Water from the STW-AWRP to the discharge location at the River Thames. This pipeline would also require short sections of trenchless installation for river and road crossings depending on location of the AWRP site.

There is a potential to be gravity fed; however, the pipeline internal diameter would need to be larger. A more detailed hydraulic assessment of this opportunity will be required following site selection.

2.2.3.3 Conveyance of Waste Streams

The waste stream from the STW-AWRP cannot be discharged directly to the River Thames, so the following two conveyance pipelines would be required from the proposed STW-AWRP to the Mogden STW inlet works for treatment:

1. **Wastewater Return Pipeline**: A 1.8km pipeline to carry a waste stream from the CIP system back to the South Sewer downstream of the abstraction location. This pipeline would follow the same route as the Raw Sewage Transfer Pipeline and would discharge into downstream manhole on the South Sewer.
2. **RO Concentrate Return Pipeline**: A 6.4km pipeline to carry RO concentrate back to Mogden STW. This would be discharged into the final effluent channel for Mogden STW. However, if the Mogden STW has sufficient treatment capacity, this pipeline would be combined with the Wastewater Return pipeline, and RO concentrate could be also discharged into the South Sewer.

2.1.1.1 Shafts

Indicative shaft details are listed tables below.

Table 2-11: STW-AWRP to Mogden STW RO Concentrate Return Pipeline Indicative Shaft Details

Shaft	Shaft Internal Diameter (m)	Approximate Ground Level (m AOD)	Approximate Shaft Depth (m)	Approximate Shaft Base Level (m AOD)
Mogden STW Shaft Site	10	6.1	13.8	-7.7
Shaft Site 2	10	9.4	16.9	-7.5
Shaft Site 3	10	10.0	17.4	-7.4
Shaft Site 4	10	11.7	18.7	-7.0
Shaft Site 5	10	13.4	20.3	-6.9
Shaft Site 6	10	13.4	19.9	-6.4
Shaft Site 7	10	19.6	24.9	-5.3
Shaft Site 8	10	19.9	24.6	-4.7
Shaft Site 9	10	17.7	21.3	-3.6
Shaft Site 10	10	17.6	20.6	-2.9
STW-AWRP Shaft Site	10		18.0	-2.2

Table 2-12: STW-AWRP to River Thames Recycled Water Transfer Indicative Shaft Details

Shaft	Shaft Internal Diameter (m)	Approximate Ground Level (m AOD)	Approximate Shaft Depth (m)	Approximate Shaft Base Level (m AOD)
Shaft Site 13	8	11.0	3.3	7.7
Shaft Site 14	8	10.8	3.2	7.6
Shaft Site 15	8	9.1	2.4	6.7
Shaft Site 16	8	9.9	3.1	6.7

2.1.1.1.1 Mogden STW Shaft Site

The proposed shaft site at Mogden STW would be located within Thames Water-owned land at Mogden STW.

A shaft would be required for construction of the trenchless pipeline with the launch of the TBM and extraction of spoil. The shaft could be constructed to the South of the existing storm tanks and to the North of the existing embankment in the STW. The shaft at this compound would have an internal diameter of 10.5m.

2.1.1.1.2 Mogden STW to STW-AWRP Intermediate Shaft Sites

Several intermediate shafts would be required along the route to launch and receive the TBM undertaking the tunnel construction. Drive shafts would be used to facilitate access to the pipeline, launch the TBM, remove spoil, store materials and jacking pipes and provide ventilation during construction.

The intermediate shafts would have an internal diameter of 10.5m and would be capped with a concrete cover after completion of the works. The shaft concrete cover would be permanent and would be positioned below the ground surface to minimise impacts on current use of the land, with access covers for personnel and plant accessible at ground surface.

2.1.1.1.3 STW-AWRP Shaft Site

The final site in the tunnelling drive would be located inside the proposed STW-AWRP site compound and could be used as a reception shaft to retrieve the TBM. The shaft would be sized with an internal diameter of 10m.

2.1.1.1.4 Shafts between STW-AWRP and the River Thames

Most of the conveyance section between the STW-AWRP and the River Thames would be constructed using open-cut pipeline installation and two short sections would be pipe jacked in order to cross a road and a watercourse.

The two sections of pipe jacking would be launched from shafts while the remaining open-cut sections would be constructed using trenched excavations. Sections in road would have to be constructed using trench boxes which minimise the working width at the compromise of a reduced construction rate.

It is proposed to construct a pipe jacked tunnel section for the trenchless crossings, in total approximately 50m for one crossing and 175m for the other trenchless section. The pressurised Recycled Water pipeline would pass within the pipe jack tunnels at the road and watercourse crossings.

The open-cut trench section terminates at the discharge site near the River Thames and would not require a separate shaft connection.

2.1.1.2 Recycled Water Discharge Arrangement

It was proposed that Recycled Water would be discharged into the River Thames upstream of the Walton WTW Intake. The Recycled Water would then blend with the main river flow before being abstracted downstream.

The outfall would be designed to reduce the delivery velocity in the Recycled Water Transfer Pipeline to discharge velocity into the river at less than 0.3m/s. This low velocity is intended to minimise disturbance to river sediments as well as to avoid introducing turbulent currents that may disturb boats or other craft using the river.

The buried structure is intended to be unobtrusive, although access covers and covers to valve spindles would be visible at ground level in the embankment adjacent to the river. The Recycled Water would discharge at the surface of the river. The riverbank at this location would extend over the river edge as a vertical timber wharf. Vertical bars would be fitted under the wharf structure to prevent unauthorised access and to prevent accumulation of debris when not in use.

Modelling work is being carried out to confirm suitable discharge velocities for to ensure that there are no adverse effects on scouring and on the fish. Design of the outfall is to be further developed through feedback from modelling results and conversations with regulatory authorities and local communities.

2.1.1.3 Conveyance Profile and Existing Infrastructure

The conveyance profile from the Mogden STW to the STW-AWRP is in a generally rising gradient. The conveyance would be built using 14 to 25m deep pipe jacks to avoid major services and the significant urban complexity along the route. The outfall discharge point at the River Thames would be lower than the new STW-AWRP site. Therefore, there is an opportunity to convey Recycled Water in a gravity pipeline.

An initial review of service information indicates that there would be a number of different services passing in close proximity to shafts and tunnel routes in the Mogden STW to the new STW-AWRP section. Services such as telecommunications, water and gas mains were identified but would not have major impact on engineering design as the tunnel depth could be selected to avoid the conflicts.

The trenched sections of pipeline between the new STW-AWRP and the outfall could be more impacted by utilities diversions as the pipe would be constructed just below the ground level. At the future stage of design, engagement is required with utility providers to understand the likely mitigation measures and the extent of diversionary works required.

2.1.1.4 Pumping Stations

Pumping stations (PS) are required for raw water abstraction, inter process and Treated Effluent pumping. The key pumping requirements would be as follows.

- **Raw Water Abstraction Pumping Station:** To abstract raw sewage from the existing South Sewer near the Kempton WTW and transfer to the proposed STW-AWRP site. This PS would be located at the raw sewage abstraction site on the South Sewer.

- **Recycled Water Pumping Station:** To transfer Recycled Water from the proposed STW-AWRP near the Kempton WTW to the discharge location on the River Thames upstream of Walton Intake. This PS would be located within Mogden STW.
- **Wastewater Return Pumping Station:** To transfer waste stream from the CIP system in STW-AWRP back to the South Sewer downstream of the abstraction location. This PS would be located within the new STW-AWRP site.
- **RO Concentrate Pumping Station:** To transfer RO Concentrate from the STW-AWRP site to Mogden STW. If RO Concentrate could be returned to South Sewer together with the CIP wastewater, the Wastewater Return Pipeline and RO Concentrate Return Pipeline would be combined together, and the Wastewater Return PS and RO Concentrate Return PS could also be combined together. This PS would be located inside the new STW-AWRP site.

2.1.2 Operating Philosophy

The water recycling schemes would operate intermittently as required during periods of drought in the Thames Water Drought Plan framework. Anticipated operational utilisation rates are set out in section 4.1 in the Gate 2 Report.

It was assumed that the water recycling schemes would be utilised and operated as one of the strategic drought schemes in the Thames Water Drought Plan and that the trigger of utilisation would be same as the strategic drought schemes in the current Drought Plan. Strategic drought schemes are sources of water that are permitted for use during drought period but are not used as part of day to day' baseline supply. Thames Water Draft Drought Plan 2022 lists five strategic drought schemes including Thames Gateway Water Treatment Works (TGWTW).

In the Thames Water Drought Plan, utilisation of the strategic drought schemes is triggered by:

- Naturalised flow over Teddington Weir receding down to 3000Ml/d on average for 10 days during the course of a drought event (defined as having a Drought Event Level (DEL) equal to or greater than DEL1), and
- Reservoir storage levels having fallen to the 800-700/600Ml/d flow requirement at Teddington Weir.

2.1.2.1 Operating Modes

Operations of international and domestic water reuse and desalination plants, including the Thames Water Gateway Desalination plant, were reviewed. Interviews with technical and operational staff from these plants were held to assess practicability of various operational modes.

The types of operating modes considered were:

- **Normal Operation:** Treatment plant and conveyance assets are operating in normal automatic control (25-100% of maximum capacity) and delivering Recycled Water or Treated Effluent to the intended discharge location.
- **Hot Standby:** Operating mode where a plant runs at a proportion of total flow (25% or less of maximum capacity), with a 'duty' stream under Normal Operation and with parts of the plant in standby and is able to return into Normal Operation mode within a day to two weeks. Conveyance assets would transfer part of, or all Treated Effluent/ Recycled Water generated in the plants for "sweetening".
- **Cold Standby:** Operating mode where process units are available to return to Normal Operation mode within several weeks. Recycled Water or Treated Effluent would not be produced or be produced in minimal amount of flow which would be run to waste. Conveyance assets would be drained down.
- **Care and Maintenance:** Operating mode under which the asset is not delivering any water, but maintenance is carried out in order to keep the plant serviceable and able to return into Normal Operation mode within a few months. Process assets would be in preservation mode to allow maintenance only, and any maintenance flows from the plant would be run to waste. Conveyance assets would be drained down.
- **Non-operational:** Treatment plant and conveyance element are out of service and there is minimal ongoing expenditure.

Non-operational mode would pose major risks to the treatment plant. Fully offline treatment assets are unlikely to be suitable for restart without major replacement works and lengthy re-commissioning which could be costly and not practicable. The Cold Standby mode may not be recommended as it would offer negligible benefits over the Hot Standby mode posing higher risks due to the conveyance assets being drained down.

2.1.2.2 Operating Models

Three operating models were assessed at Gate 2.

- **Continuous Sweetening Flow Model:** The system would be in Hot Standby mode during non-drought periods and would generate Treated Effluent/ Recycled Water at lower rate (i.e., 25% of full capacity or less) to enable timely recommissioning when supply is required.
- **Cautious Restart Model:** The system would be in Hot Standby mode during non-drought periods for approximately 6 months of the year (in the months of high likelihood of droughts) to facilitate timely recovery to Normal Operation mode. During the other 6 months, the system would be in Care and Maintenance mode, with the conveyance drained and any flows through the plant for maintenance would be discharged back to the STW inlet. Alternatively, the conveyance system could be kept full, and a very small sweetening flow slowly discharges at the proposed outfall following periodic operation of the plant. However, additional chlorination would likely be required to prevent biomass build-up. The process and conveyance assets would require relatively complex ramp-up procedures each year from Care and Maintenance mode to Hot Standby mode.
- **Infrequent Restart Model:** The system would be in Hot Standby mode during non-drought periods for approximately 3 months of the year (in the months of highest likelihood of droughts) to facilitate timely recovery to Normal Operation mode. During the other 9 months, the system would be in Care and Maintenance mode, with the conveyance drained and any flows through the plant for maintenance would be discharged back to the STW inlet. The process and conveyance assets would require relatively complex ramp-up procedures each year from Care and Maintenance mode to Hot Standby mode.

The Continuous Sweetening Flow model, which would have high operational costs, but with lower operational complexity and risks, would be recommended for all the London Effluent Reuse SRO schemes at this stage. Details of operating model will be further reviewed and optimised in terms of costs, carbon output, environmental impacts, operational complexity, reliability and security.

The Mogden South Sewer scheme has a sewage treatment phase (STW) upstream of the AWRP. The biological processes in STW could not have a period offline as it would take several weeks to months to fully establish the biological process once the biomass in the process has been lost.

2.1.2.3 STW-AWRP Chemical Consumption

The STW-AWRP would require the following chemicals for treatment and cleaning purposes.

Process Treatment Chemicals:

- Ferric Sulphate
- Ammonium Sulphate
- Sodium Hypochlorite (incl. CIP requirement)
- Sulphuric Acid
- Anti-Scalant
- Hydrogen Peroxide
- Sodium Bisulphite (incl. neutralisation requirements)
- Lime

CIP/CEB Chemicals:

- Citric Acid
- RO CIP Chemicals (incl. Sodium Tripolyphosphate, Sodium Dodecilsulphonate and Sodium EDTA)

Chlorine dosing and dechlorination may be required for Recycled Water conveyance, subject to further assessment.

2.1.2.4 Maintenance Requirements

2.1.2.4.1 STW-AWRP Units

In addition to conventional STW maintenance, STW-AWRP would require maintenance of AWRP. Key maintenance requirements for AWRP would be as follows:

- AWRP general maintenance – continuous, automated WQ monitoring of feed water, permeate and concentrate. Frequent MEICA maintenance for all pumps, instruments, valves, etc. and normal fault finding and resolution to ensure strict WQ parameters.
- Replacement of RO membranes – expected every 5 years (assuming suitable maintenance including automated flushing cycles and chemical cleaning regimes (CIP))
- Replacement of UF membranes – expected every 5 years (assuming suitable maintenance including automated flushing cycles and chemical cleaning regimes (CIP))
- Replacement of UV lamps – expected every 5 years
- Energy Recovery Devices – turbines / pressure exchange modules require frequent inspections and troubleshooting to ensure efficient generation of recovered energy.

2.1.2.4.2 Conveyance

When in use the pressurised pipelines would operate as balanced systems with the pumps at the upstream end, ensuring the pipelines remain primed with adequate hydraulic head to drive flows to/from the STW-AWRP. The flow rate and pressure in the pipelines could be controlled by using pumps with Variable Speed Drives.

The conveyance pumpsets would have duty and standby units and the control system would be designed to ensure utilisation is spread equally between the pumps to equalise wear.

When the scheme is in “Care & Maintenance” mode, the pipelines would be pumped dry, with residual volumes drained out manually at all wash-out hydrants and left drained.

Multiple discharge locations from each washout would be required, and all pumpsets may have a smaller “priming pump(s)” for use during the change from “Care & Maintenance” mode to “Hot Standby” for re-filling and priming the pipelines. The pumps would need regular maintenance and periodic operation and would need to be run on regular cycles to maintain operability when the system is in “Care & Maintenance” mode.

The Outfall Structure would be designed to require minimal maintenance. Inspection would be carried out to ensure that the structure including access covers has not been damaged either accidentally or by vandalism and that it does not represent a hazard to the public. The valve operation would be checked, and a visual internal inspection of the buried structure would be carried out. The inspection would monitor the build-up of silt inside the structure and check for the accumulation of debris.

2.1.3 Inter Site Control Requirements

A communications link between the Raw Sewage Abstraction Pumping Station and the STW-AWRP would be provided to ensure the abstraction pumps are inhibited on power loss at the STW-AWRP or process failure.

Connection to the wider Thames Water Production Planning system could also be provided to regulate operating capacity based on the water levels in the river or the reservoirs.

2.1.4 Power Requirements

There would be two sites requiring new power supplies:

- Raw Sewage Abstraction Pumping Station
- STW-AWRP

The Raw Sewage Abstraction Pumping Station would require power to satisfy the pumping capacity at full design flow. The power supply to the pumping station may be arranged with incoming DNO supply stepped down as required.

The STW-AWRP power supply could be arranged as a High Voltage (HV) incoming supply terminating at a new HV substation within the STW-AWRP site. From the HV substation, cable feeders would supply individual step-down transformer(s) located outside the main treatment works building(s). Within the building(s), local 400V MCCs may distribute power for all Low Voltage (LV) services and provide power to externally located LV plant and equipment.

In the event of a supply failure, the STW-AWRP would require standby power to ensure a controlled shutdown.

2.1.5 Greenhouse Gas Mitigation, Energy Recovery and Renewable Energy Opportunities

Estimates of capital carbon (embodied carbon) and operational carbon for London Effluent Reuse schemes could be found in section 6 of the Gate 2 Report and Annex A.5 of the Gate 2 Report.

To maximise alignment with PAS 2080 and the Water UK Net Zero 2030 Routemap, the emissions hierarchy, which is detailed in the figure below, would be followed when deciding which approach to prioritise to mitigate emissions. This prioritises in order 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.

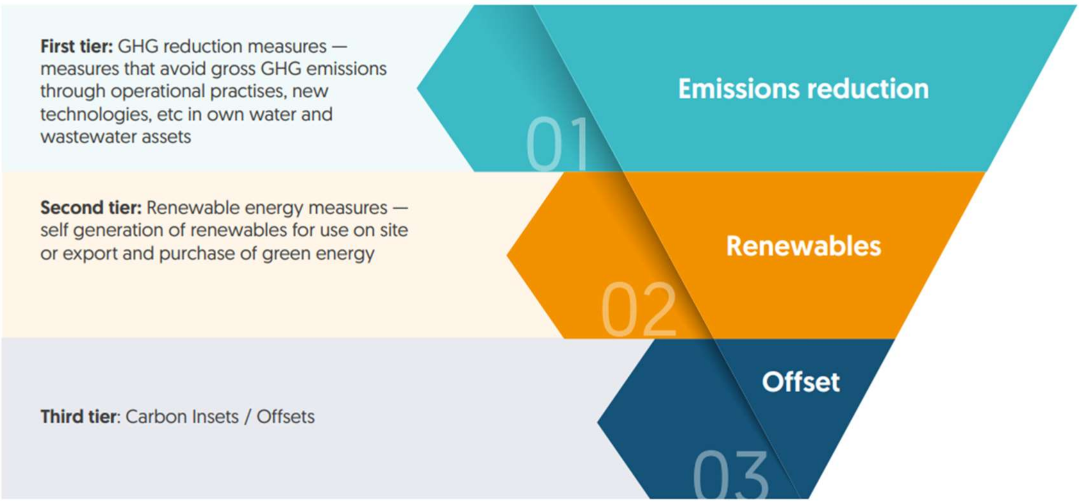

Figure 2-2: Emission Reduction Hierarchy

Capital emissions represent the majority share of total Greenhouse Gas (GHG) emissions in the short term - as such, focusing on reducing capital emissions will likely yield significant reductions across the early stage of a site's operational life. A focus on 'designing out' carbon can reduce both capital and operational emissions, in particular for building heating and plant efficiency.

While annual operational emissions are less than those released due to material sources, over time, across the lifetime of a site operational emissions would contribute significantly. Therefore, reducing operational emissions will achieve the great reduction of GHG emissions in the long term. This approach is also line with the Water UK and TWUL targets of net zero operational carbon by 2030.

It should be noted that operational GHG emissions from electricity demand would be zero for London Effluent Reuse SRO because all electricity purchased would be zero carbon via either a Renewable Energy Guarantee of Origin (REGO) contract or Power Purchase Agreement (PPA) as per Water UK Net Zero 2030 commitment. However, carbon values reported in section 6.5 and Annex A.5 of Gate 2 Report include electricity carbons for operation.

Table below lists the potential GHG mitigation approaches, providing a high-level ranking of their potential impact on emissions reduction, including potential influence on reduction of scope 2 and scope 3 carbon, and alignment with the emissions hierarchy.

Table 2-13: Summary and Ranking of Potential Carbon Emission Reduction Approaches for London Effluent Reuse schemes

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
Renewable energy on site	Renewable energy	High	High	- Solar - Wind - Storage
Procured Renewable Energy	Renewable energy	High	High	- Sleeved power purchase agreement (PPA) - Synthetic PPA - Private Wire PPA - REGO-backed Green Tariffs
Resource Efficiency and Chemical Supply	Emissions reduction	High	Low	- Supply chain contracts - Reduced resource use
Embodied emissions reduction	Emissions reduction	Moderate	High	- Low carbon concrete - Low carbon steel - Recycled materials - Locally sourced materials
Engineering design	Emissions reduction	Moderate	Moderate	- Conveyance routes - Land use - Building size - Building heating
Construction emissions	Emissions reduction	Low	Moderate	- Reduced transport - Vehicle energy use - Renewable onsite power - Temporary buildings
Insets	Offset	Low	Moderate	- Peatland restoration - Grassland restoration - Tree planting
Offsets (lowest priority)	Offset	Low	High	- UK Emissions Trading Scheme (ETS) - Voluntary Offset Market

2.2 Opportunities and Future Benefits Realisation

Key opportunities identified in the conceptual design are listed in the table below.

Table 2-14: Key Opportunities - Mogden South Sewer Conceptual Design

Category	Opportunity
Conveyance Design	Some of conveyance system could potentially be designed as gravity pipelines due to potential high elevation of the STW-AWRP site compared with South Sewer and the discharge location on the River Thames.
Process System Design	There is an opportunity to rationalise and develop best outcome treatment requirements through pilot work and/or full engagement with stakeholders and regulators with regards to expectation of treatment processes, customer acceptability and engagement and environmental outcomes.
Waste stream discharge	There is an opportunity to return the RO concentrate as well as the wastewater back to the South Sewer for treatment at the Mogden STW if the Mogden STW has sufficient treatment capacity to receive RO concentrate.

3. Scheme Delivery

3.1 Overview of Construction Process

3.1.1 STW-AWRP

The new STW-AWRP was proposed to be constructed near Kempton WTW for treatment of raw sewage. However, specific site was not selected before the design pause of this scheme.

It was assumed that construction elements for treatment facilities would be above ground, single storey and would be either reinforced concrete or steel-clad buildings housing treatment and mechanical, electrical and instrumentation control automation (MEICA) equipment. However, underground tanks and multi-storey building may need to be considered if size of available land is limited.

3.1.2 Conveyance

3.1.2.1 Raw Sewage Transfer Pipeline and Wastewater Pipeline Construction

The pipeline to transfer the raw sewage from the South Sewer to the new STW-AWRP would be constructed using open cut trenching methods. The total length of this pipeline would be approximately 1.8km, and it may include one trenchless crossing for a railway.

The Wastewater Return would transfer CIP wastewater from the STW-AWRP back to the South Sewer downstream of the raw sewage abstraction location. The route for this pipeline would be the same as for the Raw Sewage Transfer Pipeline in majority of the section, where both pipes could be installed in the same trench.

In order to abstract the flows from the sewage network a new pumping station would need to be constructed to receive flow from a manhole on the South Sewer.

3.1.2.2 Recycled Water Transfer Pipeline Construction

The Recycled Water conveyance option between the STW-AWRP and the outfall on the River Thames would be constructed using open-cut trenching methods. There are two areas of the pipeline which will likely require trenchless construction methods. Depending on the ground conditions and the land available at both the drive and reception shafts, these two trenchless sections could be constructed using a variety of methods such as Horizontal Directional Drilling, Auger Boring or Micro-tunnelling. The site compounds for these trenchless areas may be used for pipe and material storage during the construction of this pipeline section.

The working width in highways and urban areas would need to be reduced though it could lengthen the construction schedule.

3.1.2.3 RO Concentrate Pipeline Construction

The RO Concentrate Return was proposed as a combination of open cut trenching and trenchless methods from the STW-AWRP site to Mogden STW. This pipeline would be approximately 7.5km.

This conveyance route may include areas of roadworks which could require partial road closures. This pipeline route also would include sections of trenchless crossings where a number of different techniques could be employed, such as pipe jacking, horizontal directional drilling and auger boring.

3.1.2.4 Outfall Construction

The proposed outfall is intended to discharge Recycled Water into the River Thames. The outfall structure would be designed to be unobtrusive and would be mostly buried in the riverbank.

An open excavation would be required to construct the outfall structure. The work site and excavation would be secured during construction by security hoarding around the site perimeter and access to the site would be controlled.

The foundations of the structure would be below the river level and a temporary U-shaped steel sheet pile wall may need to be built out from the riverbank 2 to 3m into the river to allow a dry excavation for construction. Depending on the particular ground conditions at the site the steel sheet pile wall may be extended around the whole excavation perimeter. A blinding layer of concrete would be laid across the bottom of the excavation to give a stable working level.

The new outfall structure would be constructed from reinforced concrete. The Recycled Water Transfer Pipeline would be cast into the wall of the structure.

The structure base, walls and internal weir could be cast in situ. The top cover slabs are likely to be precast concrete planks and could be cast off site and craned into place. Once complete, the structure would be backfilled to the original ground profile and the temporary sheet piles would be removed. The riverbank profile on either side of the structure and over the outfall would be reinstated.

3.2 Transportation of Construction Materials and Spoils

Several temporary site compounds would be required along the route of the pipeline to facilitate the storage of construction materials and spoil from excavations and trenchless installation. Depending on the trenchless technique used, material would be transported from the front of the drilling machine back to the drive shaft and hoisted up to the surface for storage or removal.

Areas for temporary storage of the spoil to enable excavations or micro-tunnels to proceed for 24 hrs per day would be required, while awaiting transport off site by lorry during daytime working hours. If a slurry machine is used for tunnelling, further space may be required for separation of spoil from the slurry mix before it is transported off site; however, this is unlikely as the tunnelling is expected to be in London Clay.

For open cut trenching sections, it is usual that the excavated soil is put back into the trench as embedment material. If this is the case, then this spoil could be stored adjacent to the open pipeline trench during construction. Any unused spoil would need to be moved to the temporary compound sites for storage prior to removal.

Construction Materials and Spoil would be generally transported off site using HGVs. However, it could be subject to the site selected for STW-AWRP.

3.3 Delivery Programme

Table below shows approximate indicative duration of programme elements. Potential schedule for contract management elements could be found in Annex F of the Gate 2 Report.

Realistic procurement periods have been assumed within delivery programme based on experience within the construction industry. Potential programme savings could be made by:

- Utilising standard products and equipment could result in shorter procurement durations.
- Work elements were assumed to be sequential with minor overlap (e.g. civil work followed by MEICA work in treatment plant construction, no concurrent shaft construction, etc.). This also represents the most robust schedule for project delivery. A contractor may decide to undertake works concurrently potentially leading to a shorter overall construction duration for these elements.
- There is 3 - 6 months of commissioning at the end of each main construction component (e.g. conveyance, treatment plant, river abstraction, etc.). Commissioning could happen concurrently as parts of construction stage. Therefore, there is an opportunity to reduce these periods when designs mature.
- The working calendar was assumed to be 5-day work week with no allowance for night working. If planning consent can be granted for 24-hour or weekend working, construction duration could be reduced.
- Conservative production rates for construction schedules were used.

Table 3-1: Indicative Duration of Programme Elements (Mogden South Sewer)

Project Phase	Approximate Duration (months)
Pre-Construction Stage	17
Detailed Design	17
Procurement	11
Enabling Works	11
Construction Stage	27
Commissioning Stage	17
System Commissioning Works	17
Performance Testing	6
Defects Period	11

4. Water Resources

The Deployable Output (DO) for Mogden South Sewer scheme was estimated as 46Ml/d, for both the Dry Year Annual Average (DYAA) and the Dry Year Critical Period (DYCP) for the capacity of 50Ml/d. Details of the estimation of DO for the London Effluent Reuse SRO could be found in the Thames Water draft Water Resources Management Plan 2024. However, flow monitoring in Gate 2 showed inadequate source flow to supply 46Ml/d DO for Mogden South Sewer scheme. Actual DO could be less than 25Ml/d and subject to further design and analysis. This scheme will benefit the London WRZ.

5. Assumptions and Risks

The information presented in this document 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.

5.1 Key Assumptions

Key assumptions that have been made in this conceptual design report are listed below:

- The STW-AWRP site would be available near the Kempton WTW for development of the AWRP.
- All regulation and licensing considerations can be achieved.
- Black water treatment "sewer mining" (FOG + advanced primary + aeration + MBR + GAC) does not produce any liquid waste streams to be discharged, as these would be recirculated and treated through the works. Solids waste streams would be treated / discharged in line with STW catchment practice.
- For the pipe-jacking operations, it was assumed that there would be adequate land to construct the shafts and to store construction materials, and that this would be acceptable to the authority having jurisdiction.
- For the open-cut pipeline sections, it was assumed that the trenching locations and the temporary compound locations would be acceptable to all stakeholders but that engagement with stakeholders may impact on routes and design.

5.2 Key Risks

Key risks associated with this scheme are listed as follows:

- There is a risk that there is insufficient hydraulic and/or process capacity to treat AWRP waste streams in Mogden STW.
- RO concentrate produced by the AWRP cannot be returned to Mogden STW inlet works and will require disposal to discharge.
- There is a risk that requirements for water treatment will be more onerous for the Mogden Water Recycling scheme.
- There is a risk that pipeline or shaft construction will encounter unexpected ground conditions.

6. Glossary and Abbreviations

Term	Definition
London Effluent Reuse SRO	Term to describe the Strategic Resource Option group for all four schemes as set out in the PR19 Final Determination.
London Effluent Reuse Scheme	Term when describing an individual option of the SRO.
Beckton Water Recycling scheme	Option to develop a water reuse/recycling plant at Beckton STW including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Mogden Water Recycling scheme	Option to develop a water reuse/recycling plant at a site near Kempton WTW for Mogden STW effluent including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Mogden South Sewer scheme	Option to develop a sewage reuse/recycling plant at a site near Kempton WTW for untreated sewage from South Sewer which discharges into Mogden STW, including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Teddington DRA scheme	Option to develop a water reuse plant at Mogden STW taking effluent for tertiary treatment then discharging to River Thames including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Final Effluent	Water treated and discharged from existing secondary treatment process in Beckton Sewage Treatment Works or Mogden Sewage Treatment Works
Treated Effluent	Water treated in the proposed Tertiary Treatment Plant (TTP)
Recycled Water	Water treated in the proposed Advanced Water Recycling Plant (AWRP)
catchment	The area of region where all water flows to a single point, e.g., for a wastewater catchment, all wastewater flows to a single STW for treatment.
component	The key engineering items that contribute to each option e.g., pipeline, advanced water recycling plant.
concentrate	The concentrated waste stream produced by the Reverse Osmosis membranes.
conveyance	Refers to the assets which make up a transfer of fluid from one location to another, e.g., pipeline, tunnel, pumping station and outfall.
scheme	Refers to the overall system for one of four 'Options' within the London Effluent Reuse SRO for providing water resource benefit to the region, e.g., Beckton Water Recycling, Mogden Water Recycling, Teddington DRA and Mogden South Sewer.

Acronym	Definition
ACWG	All Company Working Group
ADF	Average Daily Flow
AMP	Asset Management Plan
AOP	Advanced Oxidation Process
APS	Asset Planning System (Thames Water system)
ASP	Activated Sludge Process
AWRP	Advanced Water Recycling Plant
BNG	Biodiversity Net Gain
BOD	Biological Oxygen Demand
CCPs	Critical Control Points
CDC	Coagulation Dosing Chamber
CDM	Construction Design Management
CDR	Conceptual Design Report
CEB	Chemically Enhanced Backwash
CEC	Contaminants of Emerging Concern
CIP	Clean in Place

Acronym	Definition
CS	Chemical Storage
DAF	Dissolved Air Floatation
Defra	Department for Environment, Food and Rural Affairs
DEL	Drought Event Level
DI	Ductile Iron
DNO	Distribution Network Operator
DO	Deployable Output
DPC	Direct Procurement for Customers
DRA	Direct River Abstraction
DWI	Drinking Water Inspectorate
dWRMP	Draft Water Resource Management Plan
DWSP	Drinking Water Safety Plan
DYAA	Dry Year Annual Average
DYCP	Dry Year Critical Period
EA	Environment Agency
EDC	Endocrine Disrupting Compounds
EIA	Environmental Impact Assessment
ELV	Emission Limit Value
ENG	Environmental Net Gain
EPB	Earth Pressure Balance
EQS	Environmental Quality Standard
EQT	Equalisation Tank
FAT	Full Advanced Treatment
FEPS	Final Effluent Pumping Station
FOG	Fats, Oils and Grease
GAC	Granular Activated Carbon
GHG	Greenhouse Gas
GIS	Geographic Information System
HGV	Heavy Goods Vehicle
HSE	Health and Safety Executive
HV	High Voltage
ICA	Instrumentation Control and Automation
ID	Internal Diameter
KGV	King George V Reservoir
LSI	Langelier Saturation Index
M&E	Mechanical & Electrical
MBR	Membrane Bioreactor
MCC	Motor Control Centres
MCF	Mechanical Cloth Filter
MEICA	Mechanical, Electrical, Instrumentation, Control and Automation
Ml/d	Mega litres per day
NIC	National Infrastructure Commission
NSFs	Nitrifying Sand Filters
NTU	Nephelometric Turbidity Unit
PACl	Polyaluminium Chloride

Acronym	Definition
PCV	Prescribed Concentration or Value
PFAS	Per- and Polyfluoroalkyl Substances
PR19	Price Review 2019
PRoW	Public Right of Way
PS	Pumping Station
RAPID	Regulatory Alliance for Progressing Infrastructure Development
REM	Remineralisation
RGF	Rapid Gravity Filtration
RO	Reverse Osmosis Building
ROPS	RO Feed Pumping Station
ROT	RO Feed Tank
RPv1	Regional Plan version 1
RWPS	Recycled Water Pumping Station
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SINC	Sites of Importance for Nature Conservation
SOC	Strategic Outline Case
SOLAR	Strategic Overview of Long term Assets and Resources
SPA	Special Protection Area
SRO	Strategic Resource Option
SSSI	Site of Special Scientific Interest
STT	Severn Thames Transfer
STW	Sewage Treatment Works
TBM	Tunnel Boring Machine
TDS	Total Dissolved Solids
TEPS	Treated Effluent Pumping Station
THM	Trihalomethanes
TLT	Thames Lee Tunnel
TN	Total Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solid
TTP	Tertiary Treatment Plant
TWUL	Thames Water Utilities Ltd
T2AT	Thames to Affinity Transfer
UF	Ultrafiltration Building
UFPS	UF Feed Pumping Station
UV	Ultraviolet
UVAOP	UV Advanced Oxidation Process Building
WRMP19	Water Resource Management Plan 2019
WRMP24	Water Resource Management Plan 2024
WRSE	Water Resource South East
WRZ	Water Resource Zone
WTW	Water Treatment Works