TMS23 Enhancement Case: Long Term Water Quality Strategy *Cryptosporidium*

Contents

1. Summary table

The table below summarises the key information included in this Enhancement Case document.

Table 1.1: Enhancement Case summary

Reference	Long Term Water Quality Strategy – *Cryptosporidium* Protection Enhancement Case
Description	This Enhancement Case supports Thames Water's long-term ambition to further reduce public health risks and reliably supply safe drinking water to our customers. It also shares core objectives of the Drinking Water Inspectorate's (DWI) long-term strategic guidance: '…to use treatment processes to make water safe and clean, with the aim of proactively mitigating risks to public health, and to the wholesomeness and acceptability of supplies…'[1] There are two water quality focus areas for AMP8: firstly, replacing Lead in communication (comms) and customer supply pipes is a long-standing enhancement requirement that must continue due to the public health risk posed by Lead in drinking water. Secondly, and the focus of this Enhancement Case, ourselves and the DWI are concerned[2] about our four Large London Process Plants (LPPs[3]) which use slow sand filtration (SSF) as the principal treatment process. Although SSF is an efficient process, it cannot be relied upon in all conditions to consistently remove/inactivate *Cryptosporidium* oocysts – a parasite that can cause a diarrhoeal disease if consumed in drinking water. Despite delivering on operational improvement plans and maintaining our Works appropriately, this parasite is still sometimes detected in final water samples at our (SSF) LPPs - we must act to address this unacceptable situation. It is not possible to fully mitigate either of these public health risks through our base plan. We need to enhance the quality of the water supplied to customers, to ensure that it remains safe to drink and realise our 2050 Vision. *For Cryptosporidium Protection:* we will significantly reduce the public health risk across London posed by *Cryptosporidium* in drinking water, by investing in all four of our SSF LPPs during AMP8 and 9. This is supported by the DWI – see Annex A for copy of Final Decision Letter (DWI Reference: TMS1) – and will be followed by an Enforcement Notice in due course.
Outputs (AMP8)	We will deliver the required level of *Cryptosporidium* oocyst inactivation or removal for this raw water quality challenge at two of our four SSF LPPs by installing additional treatment process(es) *(the remaining two sites will be invested in during AMP9).*
Cost	Totex: £179.1M *(22/23 prices pre frontier efficiency)* Capex: £177.9M *Cryptosporidium* Protection (UV treatment) at Coppermills WTW & Hampton = £170.3M *Cryptosporidium* Protection development costs Ashford Common WTW = £5.3M

[1] Guidance Note: Long term planning for the quality of drinking water supplies, Drinking Water Inspectorate, September 2022
[2] Detailed in correspondence for site and company DWI technical audits, subsequent discussion, and specific enforcement notices
[3] LPP = Large Process Plants – all are in London, 4 operating as SSF Works and 1 (Walton WTW) as a chemical works, without SSFs

Reference	Long Term Water Quality Strategy – *Cryptosporidium* Protection Enhancement Case
	Cryptosporidium Protection development costs Kempton Park WTW = £2.3M Opex: £1.2M Operation of UV Treatment Process at Hampton WTW Yr4&5 = £1.2M[4]
Spend apportionment	100% Water Network+ (London Totex = £313.1M (22/23) to address all four SSF LPPs over two AMPs
Delivery year	*Cryptosporidium* Protection: 2025-2030 (with remaining two sites 2030-2035)
DPC	The case has been assessed as not being suitable, as the construction and operations and maintenance risks could not be passed to a Competitively Appointed Provider (CAP). For more information, please refer to TMS38 Direct Procurement for Customers.

[4] It is expected that the UV treatment process will be running at Hampton WTW from Year 4 but due to the complexity of the build at Coppermills WTW (including interrelation with many other capital projects on site), the UV treatment process will not be in full operation until the end of AMP8

2. Introduction and description of investment

2.1. Our long-term water quality strategy will adapt to achieve customer outcomes

Our Public Health Plan[5] puts 'Water Quality First', to provide safe and reliable drinking water to our customers. This multi-faceted plan, alongside a Drinking Water Inspectorate (DWI) agreed Improvement Programme[6], aims to improve operational performance by understanding and reducing risk through base allowance investment. This plan is delivering through AMP7 and AMP8 – however, it is important that it then persists as part of a long-term strategy, adapting the priorities delivered through our base allowance to provide the public health risk reduction, and in turn further performance improvements our customers deserve.

One of Thames Water's Vision 2050 outcomes is 'we provide safe, clean drinking water'[7] and this is supported by our Public Health Policy, which states that we are 'committed to providing a safe water supply that maintains customer confidence[8].' Water quality and public health risks are numerous and varied, and sometimes transient - our Drinking Water Safety Plans (DWSPs), with Enhanced Hazard Reviews, aim to identify and prioritise water quality hazards to ensure that the most appropriate risk mitigation is put in place, using either temporary or permanent approaches. This risk-based approach for the effective management of drinking water supply assets, drives effective investment strategies - through time, priorities to deliver the customer outcome(s) will change as we deliver on risks and others emerge.

The risk-based approach indicates existing and emerging issues - therefore we need a long term and adaptable water quality strategy, and this Enhancement Case starts to deliver on one of the priorities for the strategy. Emerging issues like PFAS[9], the persistence of micro-plastics and pharmaceuticals in the environment, are likely to need interventions in the future, but further research and investigations are required to understand the risk posed to our customers, the persistence of that threat and the most appropriate interventions needed (and when) to address risk. As an example, pesticide and nitrate investigations have been ongoing under WINEP[10] and are set to continue through AMP8 and beyond – however, they do not always result in investment once the risk is fully understood.

2.2. Thames Water has a multi-faceted AMP8 plan to deliver water quality improvements for our customers

In AMP8, we are planning to deliver improvements in our water quality performance, thereby reducing public health risk, through a prioritised base allowance programme[11] and the elements presented here in this Enhancement Case (highlighted in green for clarity). On the next page, we provide a tabulated summary (Table 2.1) of the context for how this enhancement is set against the data table lines for water quality – it shows where we are and where we are not proposing enhancement expenditure and aims to support the reasoning around why we are focussing on these two priorities.

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[5] This is discussed further in Section 3 and in Figure 3.15
[6] Includes 23 (as of June 2023) DWI Enforcement Notices
[7] Vision 2050, Thames Water, 2023
[8] Protecting drinking water quality and safeguarding public health, Policy No.POL131, Thames Water, Nov 2020 (Appendix A)
[9] PFAS (per-and poly fluoroalkyl substances) is a chemical family consisting of at least 5,000 individual substances. They are sometimes referred to as 'forever chemicals' because of their persistence in the environment.
[10] WINEP: Water Industry National Environment Programme
[11] This is detailed more in the PR24 Water Quality document, submitted separately, but in essence prioritises asset debt issues around treated water storage (service reservoirs and contact tanks), reducing the impact these issues have on water supply resilience and performance against the Compliance Risk Index, and funds continuation of the Public Health Plan (see Page 21)

Table 2.1: AMP8 plan for enhancement for water quality (aligned to Ofwat data tables) (22/23 prices)

Water Quality Improvements	Ofwat data table reference	Units	Enhancement CapEx	Enhancement OpEx	Enhancement Totex	Comments
Improvements to taste, odour & colour (grey solutions)	CW3.91-93	£M	0	0	0	This is not observed as an issue for Thames Water and so investment is being prioritised elsewhere.
Improvements to taste, odour & colour (green solutions); enhancement	CW3.94-96	£M	0	0	0	
Addressing raw water quality deterioration (grey solutions); enhancement	CW3.97-99	£M	0	0	0	Climate change and the associated adverse weather is presenting a raw water challenge to our treatment resilience (see discussion in subsequent sections). We are not proposing any spend against these lines as there is no overall raw water deterioration but an intensification at certain times of the year on our SSF LPPs (primarily *Cryptosporidium*).
Addressing raw water quality deterioration (green solutions); enhancement	CW3.100-102	£M	0	0	0	
Conditioning water to reduce plumbosolvency for water quality; enhancement	CW3.103-105	£M	0	0	0	All supply zones deemed to require water conditioning have orthophosphoric dosing systems at the supplying WTWs. Some ongoing upgrades to existing dosing plants are being done under capital maintenance (base).
Lead communication pipes replaced or relined for water quality; enhancement	CW3.106-108	£M	91.873[12] (85.435)	0	91.873 (85.435)	A programme of 54,000 lead comms pipes replacements (~97% proactive/targeted) is proposed in AMP8.
External lead supply pipes replaced or	CW3.109-111	£M	0	0	0	No specific programme of works proposed on the

[12] This is the cost in the data table. It is accompanied by commentary explaining the difference between it and the cost in this Enhancement Case (shown in brackets). In summary, the lead comms pipe replacement unit rate was reduced through realising efficiencies, lowering the cost to replace 54,000 lead comms pipes, and allowing a more significant customer side trial - the data table had been assured and locked by this time. The Totex for lead related data lines and the Enhancement Case are equal.

Water Quality Improvements	Ofwat data table reference	Units	Enhancement CapEx	Enhancement OpEx	Enhancement Totex	Comments
relined; enhancement						supply side. There is a potential for some external and internal replacements, either directly or indirectly through funding, under the customer trial (see below), but this is not yet known.
Internal lead supply pipes replaced or relined; enhancement	CW3.112 -114	£M	0	0	0	
Other lead reduction related activity; enhancement	CW3.115 -117	£M	2.187[13] (8.625)	0	2.187 (8.625)	We are proposing a customer trial to determine the long term removal of supply side lead pipes
Company-specific; water treatment enhancement line	CW3.130 -131	£M	177.899	£1.216	179.115	Installation of UV at Coppermills & Hampton WTWs, plus development costs for other x2 sites

2.3. Our priorities for AMP8 are primarily delivered through base, but enhancement for *Cryptosporidium* protection is needed to reduce public health risk further

From a water quality perspective in AMP8, we are prioritising our base investment to reduce asset health deficit in parts of our network which present the greatest risk to water quality compliance

and public health according to DWSPs: for example, at service reservoirs, contact tanks, and water treatment works. Investment in water quality drivers needs to be seen in this context – in addition to base, we have identified that there are two priorities which require enhanced investment in AMP8: one as part of an ongoing long-term programme of works, and one which presents a current and sustained, unacceptable risk at certain water treatment works (WTWs), which needs to be addressed as soon as practicable.

This enhancement investment focusses on one of those water quality drivers[14]: removing the risk to public health of active *Cryptosporidium* oocysts entering the drinking water network by enhancing treatment processes at our slow sand filtration (SSF) WTWs in London. This is not to say that these assets have not been operated and maintained appropriately over time, indeed investment in SSFs has been significant over several AMPs. As will be presented in Section 3, as responsible asset managers the investment need has been identified through our normal drinking water risk assessments - we now better understand the risk profile which exists under certain operational site parameters.

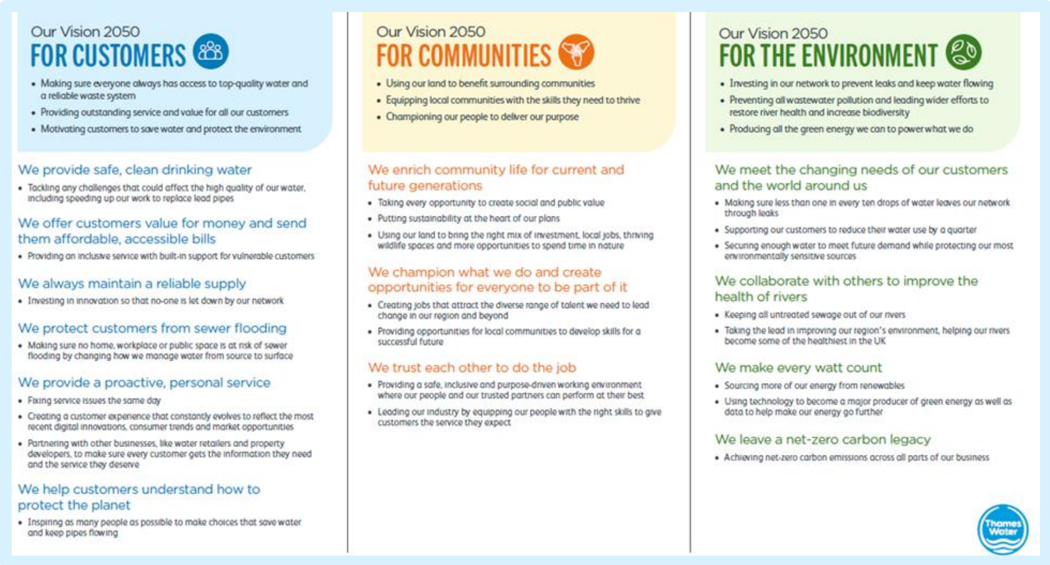
The drinking water we provide is already very high quality, but this takes reliability and compliance to a new level by removing the *Cryptosporidium* risk completely from most of London's water supply.

[13] As per footnote[12] - this is the cost for the customer side trial as populated in the data line, it is uplifted in this Enhancement Case (shown in brackets)

[14] The other proposed water quality investment is eradicating the public health risk of Lead by removing Lead material from communication and supply pipes, over a multi-AMP programme, and can be found in TMS22 Enhancement Case: Long-term water quality strategy: Lead.

Incorporating treatment enhancement for *Cryptosporidium* and Lead Control serves to contribute to our Thames Water Vision 2050 and as part of a multi-AMP delivery plan.

Figure 2.1 Thames Water Vision 2050 (Thames Water, 2023)



It aligns with DWI's long term guidance for drinking water compliance, which sets out an '*approach [which] should be efficient and sustainable and contribute to a lasting legacy of long-term benefit for both the company and its consumers*[15], and to Ofwat's PR24 ambitions to provide a '*price review to support the right long-term solutions for customers*.[16]'

2.4. It is important to consider solutions to investment needs against long-term ambitions, and how they provide best value to customers, communities, and the environment

Cryptosporidium detections at our largest Water Treatment Works (WTW) present an existential threat[17] to a reliable and safe drinking water supply to most of London, with detections being highly criticised by the DWI. Current improvement programmes can only go so far to reduce this risk.

For the public health, regulatory and business risk presented, and the need to have a different approach, this area of investment has been prioritised for AMP8 (with a follow-on investment in AMP9) as part of our long-term water quality strategy.

Customers always prioritise having a constant supply of safe, high-quality drinking water at good pressure. Our 2050 Vision aims to achieve this by ensuring that we tackle any challenges that could affect the high quality of our water, including speeding up our work to replace lead pipe, and investing in innovation so that no-one is let down by our network. Our AMP8 programme therefore aims to continue and build on the AMP7 transformation work to reduce water quality

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[15] Guidance Note: long term planning for the quality of drinking water supplies, DWI, September 2022

[16] PR24 and beyond: Creating tomorrow, together, Ofwat, May 2021

[17] A large breakthrough of active Cryptosporidium oocysts from one of the LPPs could lead to a London-wide Boil Notice/Restriction of Use and have a significant impact on our customers for an extended period – experience of breakthroughs in other parts of England can go on for a number of days

risk and improve public health. Table 2.2 provides details on what this proposed programme will output.

Table 2.2: Summary detail on the approach and what is planned to be delivered in AMP8

Cryptosporidium
Target Site(s) Coppermills WTW and Hampton WTW (AMP8) (rationale for choosing these two sites included in later sections) *The remaining two sites (Ashford Common WTW and Kempton Park WTW) to be delivered in AMP9.* Note: combined, all four SSF Large Process Plants (LPPs) in London, namely Coppermills, Ashford Common, Kempton Park and Hampton WTWs [redacted]
Log Removal / Treatment Enhancement The Engineering Solution currently proposed to provide an improved log removal and *Cryptosporidium* protection is to install an Ultra-violet (UV) contactor on the outlet of each slow sand filter or in combined banks at appropriate locations at the WTWs. UV does not remove *Cryptosporidium* oocysts, it inactivates them to ensure they do not present a health risk – it is a proven technology, and we have experience of successfully deploying such processes at sites in Thames Water – for example, Hambleden WTW in Berkshire and Hornsey WTW in North London; we are also currently installing a small UV-LED treatment process to combat *Cryptosporidium* at a ground WTWs in the Cotswolds.
Complementary Programmes The AMP7 Public Health Plan which focusses on improving water quality compliance and reducing public health risks, funded through base, will carry on through with the aim to move out of 'transformation' with the DWI, closing out all associated Enforcement Notices. This 'fixes [many of] the basics', with this enhancement 'raising the bar'.

3. Need for enhancement investment

This section presents the problem (or driver), the consequence (or potential risk) and the source of the problem, to demonstrate the need for investment.

Figure 3.1: Need for investment summary (further details below)

3.1. Active *Cryptosporidium* oocyst detections in the final water at SSF WTWs

There have been 43 detections of *Cryptosporidium* in the final water of our LPPs since July 2017[18], which supply <85%[19] of water to our London customers. This is unacceptable from public health and compliance to Water Quality Regulations perspectives.

Figure 3.2: *Cryptosporidium* oocysts

Source: http://www.bbc.co.uk/news/uk-england-lancashire-3382395

3.2. Active *Cryptosporidium* oocysts present a public health risk to our customers and a prosecution risk to our business

A Water UK briefing paper in June 2017[20] states that '*Cryptosporidium* is a protozoan parasite that causes a diarrhoeal disease known as cryptosporidiosis. Cryptosporidiosis occurs only in humans, usually caused by the specific species of *C. hominis* and *C. parvum*. People with weak immune systems are likely to be more seriously affected.' *Cryptosporidium* detections impact the Event Risk Index which holds a DWI prosecution risk.

3.3. The source of *Cryptosporidium* is ubiquitous in the environment

Cryptosporidium can be detected in any water source, from human, bird, or animal faeces. It passes between hosts in the form of a small round oocyst, some 4-6 μm in diameter, which can remain viable (infective) for a long period of time in the environment. *C. hominis* and *C. parvum* are particularly prevalent in the Thames Water catchments.

[18] WQ data, Thames Water, 2022 and see Figure 3.11
[19] From APR, Thames Water
[20] *Cryptosporidium* – Water UK Briefing Paper, June 2017

3.4. Conclusion

We have established that *Cryptosporidium* oocysts can be found in any water source, and if any active oocysts manage to breach the water treatment process – notwithstanding being non-compliant with water quality regulations - they can present a public health risk to consumers of drinking water.

It is important to state here, *Cryptosporidium* oocysts can be prevalent at any time of year (either in the environment or sitting dormant throughout the value chain) and can even be transient in water sources (i.e., can be present only occasionally or as one-offs). However, the highest concentrations are more often observed in rivers during wetter periods (especially following low flow hydrological conditions), when higher flows mobilise more contaminants generally.

Therefore, the highest risk periods for our abstraction sites tend to be in the autumn and through the wintertime (if wet), and this is discussed more in 3.12 when we explain the problems this presents.

3.5. Letter of Support / Enforcement Notice issued by the Drinking Water Inspectorate

In recent years, the DWI have rightly been placing increasing significance on the public health risk posed by detections of active *Cryptosporidium* oocysts in final treated drinking water, responding to notifications of detections with an increasingly critical eye and using enforcement action against WTWs which are non-compliant.

Cases of illness potentially- linked to *Cryptosporidium* in drinking water are difficult to reconcile, but we too agree that any oocyst detection in treated drinking water is unacceptable. To this end, DWI have issued a Letter of Support for the installation of UV treatment at the four SSF LPPs[21] (TMS1, see Annex A) with an Enforcement Notice to follow, to prevent active *Cryptosporidium* oocysts in the final treated drinking water (i.e., SP6[22]) and entering the supply network.

There is recognition from the DWI that the work being undertaken as part of the public health transformation programme is making positive improvements to water quality performance through operational interventions but their Letter of Support demonstrates that the residual risk of *Cryptosporidium* oocyst 'breakthrough' is not acceptable and can only be resolved through investment – failure to invest would lead to a continuation of oocyst detections, public health risk and risk of prosecution under the Water Quality Regulations which we would not be able to mitigate through good operational practices alone.

3.6. Customers also consider addressing the *Cryptosporidium* risk is a priority

Research into all our Enhancement Cases has been conducted to understand our customer, community, and stakeholder views on the need for enhancement and as well as their preference of proposed solutions, where appropriate. Our engagement approach has combined an ongoing, iterative triangulation of insights over the course AMP7 as well as targeted research on specific Enhancement Cases for our PR24 plan. A full list of sources used is available in our What Customers, Communities and Stakeholders Want (WCCSW) document[23], which is our single unifying customer insight framework, underpinned by detailed insight. Version 18.3 of the WCCSW document, shows continued support for water quality improvements – indeed, Figure

[21] Namely Coppermills, Hampton, Kempton Park and Ashford Common WTWs
[22] Sample Point 6 is the final sample tap before water leaves the WTWs, otherwise known as the final water statutory sample point
[23] What Customers, Communities and Stakeholders Want, v18. September 2023

3.3 shows that water quality, as you would expect, is in the top three overall priorities for improvement from customers.

Cryptosporidium Protection was tested against 'Reducing risk of serious bacteria in drinking water', which was the original title of this Enhancement Case, and across several sources including: Vision 2050 Customer Research in May 2022 and PR24 Enhancement Options Package Research in September 2022.

Figure 3.3: Snip from WCCSW, v18.3, Thames Water

Specific customer insight supporting the need for this investment is provided below:

Insights: Cryptosporidium Protection	
Support for the need	• Customers prioritise having a constant supply of clean, safe drinking water and to avoid any deterioration in service. (PR19-51) • For water enhancements, safety is a key priority for customers (R14, PR24-12). Hearing that there is a risk of water becoming contaminated by harmful bacteria is alarming to many customers (PR24-12) • Customers feel this could be a 'quick win' for Thames Water as it was perceived to be a simple solution to a safety issue (PR24-12).

3.7. Further discussion of drivers for investment

Public health risk is the most obvious driver for investment, but to ensure that a cross-section of drivers was considered, Table 3.1 below shows the output of analysis across five driver categories.

Table 3.1: *Cryptosporidium* Protection – Drivers for investment

Driver category	*Cryptosporidium* Protection drivers for investment
Customer / Consumer driver	• Provision of drinking water to a higher standard (particular focus on removal / deactivation of *Cryptosporidium* but also overall improved treatment log removal[24]), to reduce risk of potential illness and/or widespread Boil Notice • Customers expect to always have reliable, safe, clean, and 'wholesome' drinking water – their No.1 priority
Legislation compliance driver	• Greater significance to be put on Event Risk Index (ERI) • Water Quality Regulations being applied more rigorously with regards to the significance of *Cryptosporidium* detections in the final water • Compliance to Badenoch and Bouchier[25], and DWI Transformation
Environmental driver	• Climate change & associated adverse weather, combined with higher customer expectations, means having more resilient treatment processes to raw water quality & flow challenges will be required • Abstraction reductions at vulnerable sources (including chalk streams), meaning greater reliance on the output from LPPs
Economic / Cost driver	• Becoming more efficient (including having fewer incidents leading to financial penalties) means having fewer unplanned events • Flexibility to operate LPPs more often to their functional design (lower £/Mld) • System efficiency – able to use cheaper supply routes more often/reliably
Regulatory driver	• Interruptions to service more heavily penalised • Having to issue a Boil Notice to all of London following a *Cryptosporidium* event at an LPP would be an existential threat to Thames Water Operating Licence

We also considered cost drivers in more detail, and those which were outside of management control, and these include:

- Increases in abstraction charges (by the Environment Agency)
- Accelerated inflationary pressures on electricity prices (entering in to long term energy supplier agreements, etc can mitigate this to some degree but not fully)
- Chemical supplier cost inflation, especially those which have single suppliers (again, can be mitigated to some degree through commercial arrangements, etc but not fully)
- National inflation leading to higher supplier, equipment, and labour costs

Thinking further on future controls on costs and potential cost savings which could be realised, some potential examples are presented in Table 3.2 below.

[24] Log removal or reduction relates to the percentage of microorganisms physically removed or inactivated by a given process or processes; for London SSFs this varies between 0.5 and 4 log-reduction depending on the SSF LPP and the time of year (temperature)
[25] Publication(s) is *'Cryptosporidium in Water Supplies, Reports of the Groups of Experts (re)published in 1990, 1995 and 1998 – Badenoch & Bouchier'*

Table 3.2: Controls on future costs and potential cost savings

Possible future cost controls	Future potential cost savings
Reduction in abstraction rates due to less time running SSFs to waste (UV will provide other microbiological performance improvements)	This would positively impact abstraction pumping costs (kwh savings) and over time could lead to a reduction in abstraction licence standing charges
Ensure that future asset health (deficit) capital maintenance investment improves the efficiency and standardisation of pumping assets (especially large abstraction and stored water assets)	This would reduce electricity costs and reduce capital interventions both in terms of frequency and costs (i.e., more reliable assets break down less often and non-bespoke equipment can be procured through more flexible and competitive commercial arrangements)
Promote non-chemical solutions - UV does not rely on chemicals and can impact upstream and downstream chemical use	Reduction in some chemical use could mitigate cost inflation on essential chemicals which have no alternative As UV provides a 'disinfection credit' is may be possible, through trials, to reduce the disinfection dose (both front and back end dosing, or removing back end dosing altogether)

3.8. The need to deliver water quality transformation

Expanding this discussion for an important factor: Thames Water are currently under 'Transformation' with the DWI, with enforcement through >20 Notices[26], some of which are directly or indirectly related to *Cryptosporidium*. For example, 'Notice TMS3952 *Cryptosporidium* All Sites' is focussed on us understanding the risk *Cryptosporidium* presents for our sites and how some sites may have inadequate treatment processes to mitigate this risk – see Table 3.3.

Table 3.3: Extract taken from the TMS3952 DWI Enforcement Notices

For risks associated with:
• Presence of *Cryptosporidium* in final water • Contamination from sources of *Cryptosporidium* • Inadequate identification, assessment, and mitigation of risks in catchment • Inadequate treatment processes Leading to potential breach of Regulation 4

The same Notice asks for a 'review of each water treatment works compliance with the recommendations of the Expert Group on *Cryptosporidium* (Badenoch and Bouchier)' and a relevant example for this is *Section 2.6.2 '…slow sand filtration…not designed to deal specifically with the problem of Cryptosporidium oocyst removal…[but] can be an effective barrier provided that the appropriate level of treatment for the raw water source has been installed and is operated properly'* [27] This supports the use of SSFs as part of the solution but indicates that they require other appropriate treatment(s) to fully safeguard public health.

Another Notice – TMS3966, London Slow Sand Filter Works – highlights deficiencies at the London LPPs specifically, including in protection against Cryptosporidium in drinking water – see

Table 3.4 on the next page.

[26] See DWI page for TMS Improvement Notices Thames Water Improvement Programmes - Drinking Water Inspectorate (dwi.gov.uk)
[27] Publication(s) is *'Cryptosporidium in Water Supplies, Reports of the Groups of Experts (re)published in 1990, 1995 and 1998 – Badenoch & Bouchier'*

Table 3.4: Extract taken from the TMS3966 DWI Enforcement Notice

For risks associated with:
• Failure to comply with regulation 26 and regulation 4 • Failure of the slow sand filtration process • Presence of *Cryptosporidium* in the final water • Biological hazards (including E. coli, Total Coliforms, Enterococci, Clostridium)

The Notice focusses on monitoring, sampling, shutdowns, operating to standards, protection against locally derived contaminants, etc, but also dictates an ongoing risk assessment of treatment effectiveness under Regulation 28 (see 3.5 below); through inference, more analysis and fail safes Lead to more process shutdowns if sites have deficiencies, potentially impacting customer supply – [redacted]

Table 3.5: Section of Notice TMS3966 relevant to this Enhancement Case (*Cryptosporidium* Protection)

For risks associated with:

• Complete the Hazard Reviews required under regulation 28(4) Notice TMS3952 which must include a review of the following relation to all slow sand filters:
    • The age and the condition
    • Ability to adequately remove the maximum raw water quality challenge at all times

Completion of the Public Health Plan - with all the associated DWI Undertakings and Notices signed off - will make a significant difference to operational and maintenance standards, and recirculation projects will also help maintain these standards in changing demand and raw water quality conditions. Despite this, our Hazard Reviews evidence that SSFs, as deployed at our LPPs, cannot achieve water quality expectations around *Cryptosporidium*, and the log removal deficiency will remain, as will the risk to public health.

3.9. Delivering Public Value

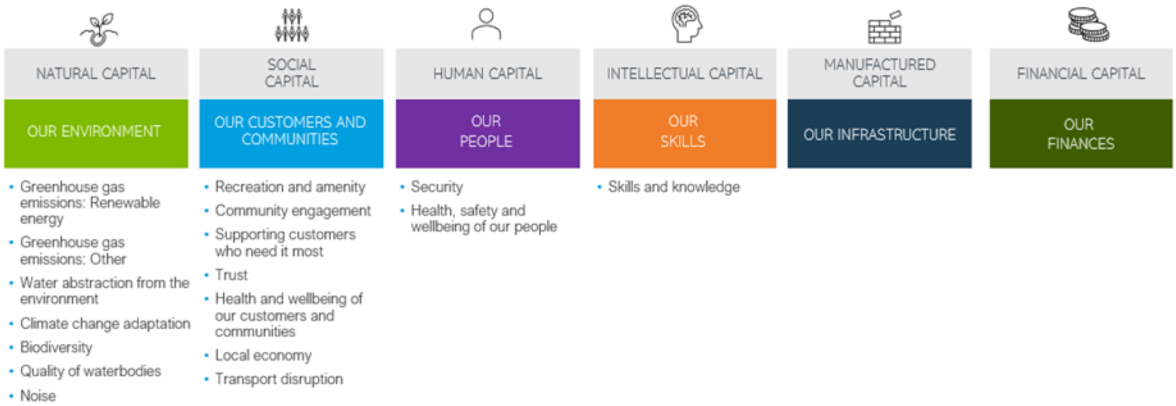
Delivering public value is about maximising the positive impact we have on customers, communities, and the environment, as we provide water and wastewater services. It is about us being a force for good in our communities and the environment.

For us, public value is made up of all things we do to make life better – through our essential service and our wider impact. Delivering public value is fundamental to delivering our purpose 'to deliver life's essential service, so our customers, communities and the environment can thrive.'

To deliver our purpose, we have committed to incorporating public value within our investment thinking. With this approach we can identify every opportunity to make the biggest positive difference to customers, colleagues, communities, and the environment as we deliver our service.

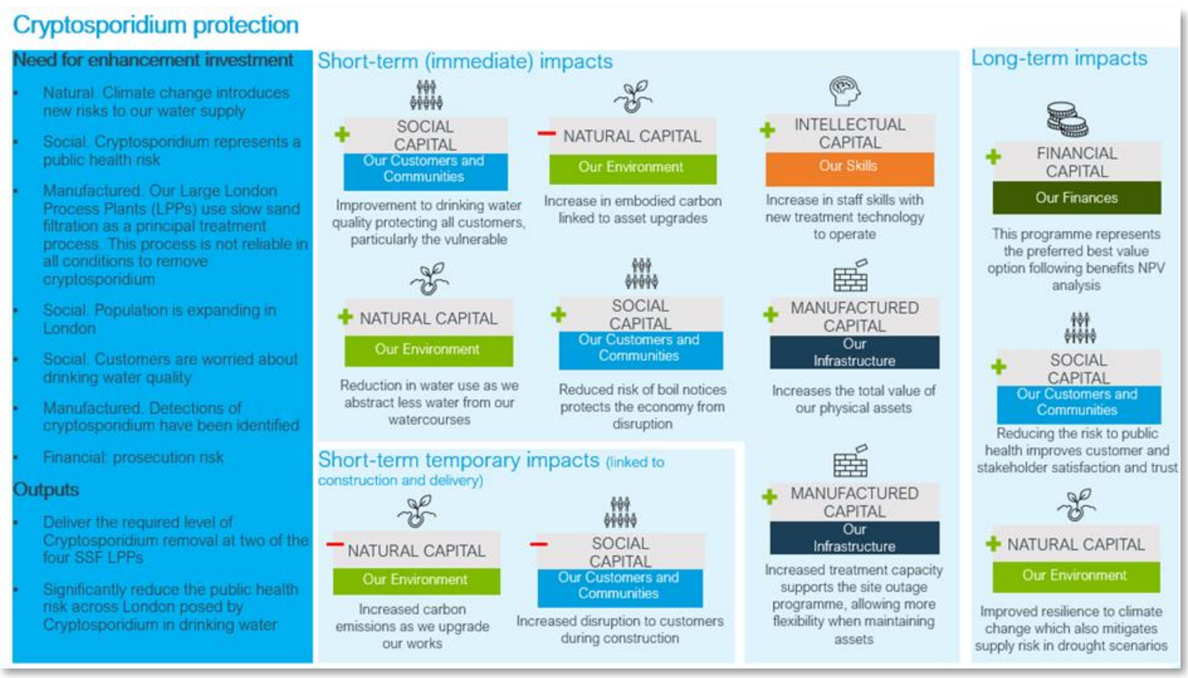
Our public value framework uses the capitals approach, an international decision-making framework. The capitals are categories of value that can be impacted by our activities. Our framework uses this approach to understand how our success is directly or indirectly underpinned by natural, social, human, and intellectual capital, as well as the traditional consideration of manufactured and financial capital. The capitals, along with Thames Water's customer-facing language for them and what is considered under each capital is set out in Figure 3.4.

Figure 3.4: The capitals



We applied the public value framework here to fully understand all benefits and dis-benefits associated to this investment and how those lead to impact on the six capitals. This investment grows value in social, natural, intellectual, and manufactured capital. We discovered a range of short-term (temporary and immediate) and long-term impacts. The theory of change infographic in Figure 3.5 shows how this investment leads to impact on the six capitals and the public value.

Figure 3.5: The short-term (temporary and immediate), and long-term impacts on the six capitals associated with the Cryptosporidium Protection Enhancement Case



3.10. Summary of investment drivers

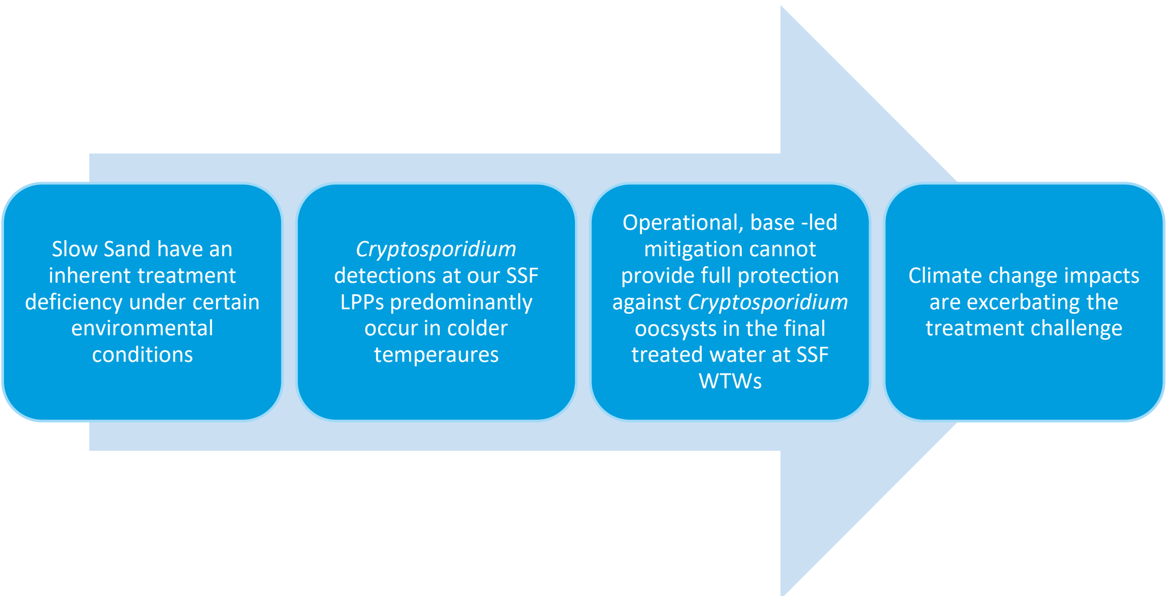
As has been shown, many drivers for investment in our (SSF) LPPs exist to prevent further detections of *Cryptosporidium* in final treated water and protect customers against this public health risk. Figure 3.6 below summarises this section into priority drivers for this investment need before we move on to discuss why this investment should be enhancement.

Figure 3.6: Prioritised investment drivers for Cryptosporidium Protection

3.11. Need for enhancement

This next section will demonstrate that there is an enhancement investment need. Figure 3.7 shows the thought process, and we will step through each element in turn. We will then present customer and stakeholder support for this investment, along with how it does not overlap with any base funding or previously funded projects. Finally, we will present a reminder of the enhancement spend required.

Figure 3.7: Enhancement need summary for *Cryptosporidium* Protection



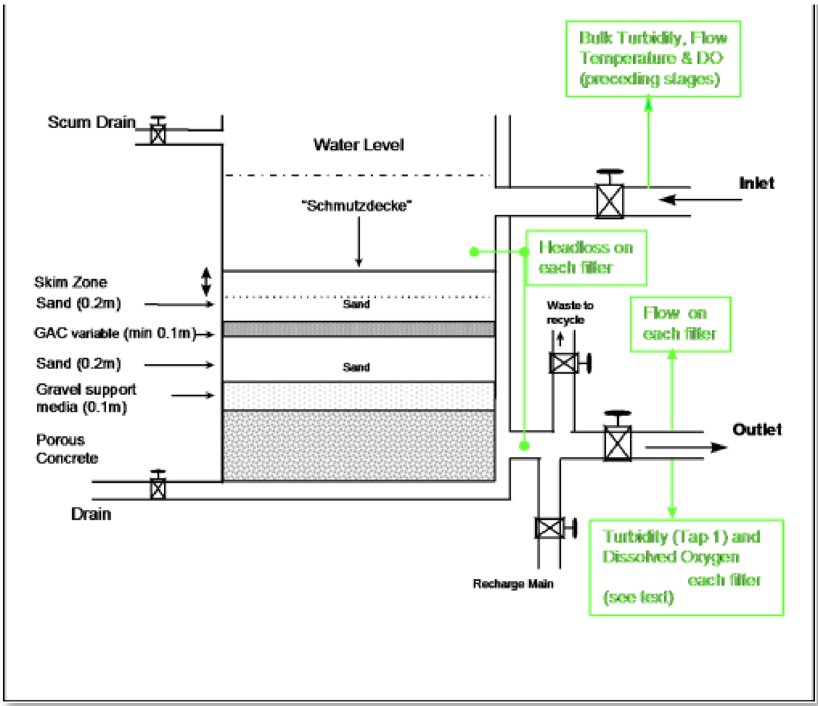
3.12. Slow Sand Filters have an inherent treatment deficiency

Thames Water has five water treatment works with Slow Sand Filters, and it is the four in London which we are focussing on in this Enhancement Case[28] - these LPPs [redacted]. *Cryptosporidium* oocysts can sometimes be detected in the final treated water at these sites, primarily because the biological[30] treatment process used - although overall very efficient and effective - has inherent treatment deficiencies which under certain environmental conditions heighten the risk of breakthrough (see next page for further discussion).

The primary *Cryptosporidium* barrier at our four largest LPPs (Ashford Common, Hampton, Coppermills and Kempton Park WTWs) is Slow Sand Filtration, and these sites have limited upstream treatment, and so are very reliant on managing how the water is sourced onto them (via our storage reservoirs) and operating the SSFs to asset standards.

At Thames Water, our SSFs are large structures ranging in size from 900 – 7,500m^2 surface areas, comprising of a layer of sand, supported by a lower layer of gravel on a porous concrete under drain. Most filters also incorporate a layer of granular activated carbon (GAC) between upper and lower sand layer (for the reduction of pesticides) – see Figure 3.8 for cross-sectional view of our SSFs and Figure 3.9 (on the next page) for an example of a drained SSF being 'rebuilt' prior to refilling and returning to supply.

Figure 3.8: Generalised arrangement of SSF GAC at Thames Water (from Thames Water Asset Design Standard)



[28] Fobney WTW (Reading) uses SSFs as a secondary treatment process, downstream of a chemical and physical multiple barrier system providing a much higher degree of pre-treatment (from a direct river source)

[29] [redacted]

[30] Slow sand filters are an ecological treatment process, relying on a complex community of bacteria, fungi and other microorganisms living in very fine sand to reduce particle counts and bring numbers of detectable indicator organisms down to values that historically have protected customers from waterborne disease.

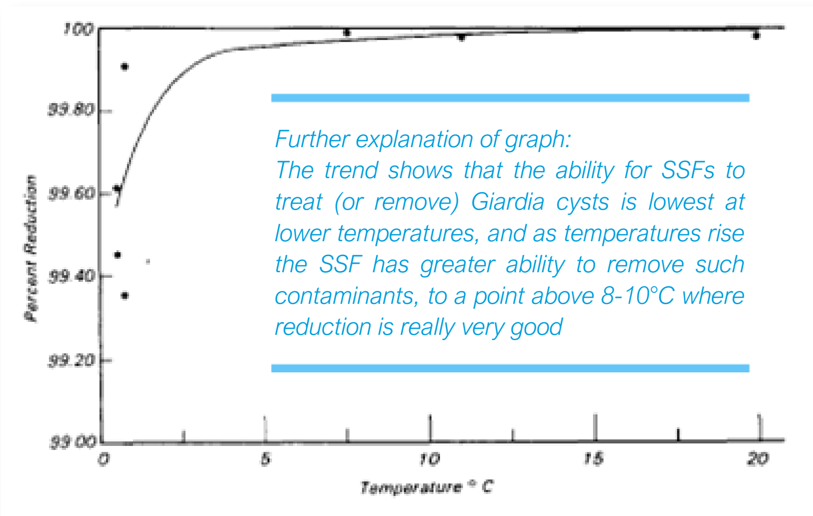
Figure 3.9: An example of a large slow sand filter in London (Hampton WTW) being rebuilt following porous floor maintenance and one adjacent filter in service (RHS of photo)

SSFs are used for the removal of particulate matter (mineral turbidity, algae, etc.) and the partial removal of some dissolved organic and inorganic substances. For these sites, they act as the principal barrier to chlorine resistant pathogens and parasites such as spore-forming bacteria, some viruses and *Cryptosporidium*[31].

There is good evidence that the efficacy of biological SSFs reduces with temperature - see Figure 3.10[32] as an example for *Giardia* cysts (similar organisms to *Cryptosporidium*)[33] – so, under colder conditions, there is a heightened risk of positive detections in the final treated water.

This work builds on earlier studies by WHO[34] which conclude that low temperatures affect the efficiency of SSFs owing to the influence of temperature on both the speed at which chemical reactions take place and the rate of metabolism of bacteria and other micro-organisms.

Figure 3.10: Slow Sand Filter reduction of Giardia cysts at various temperatures (filtration rate

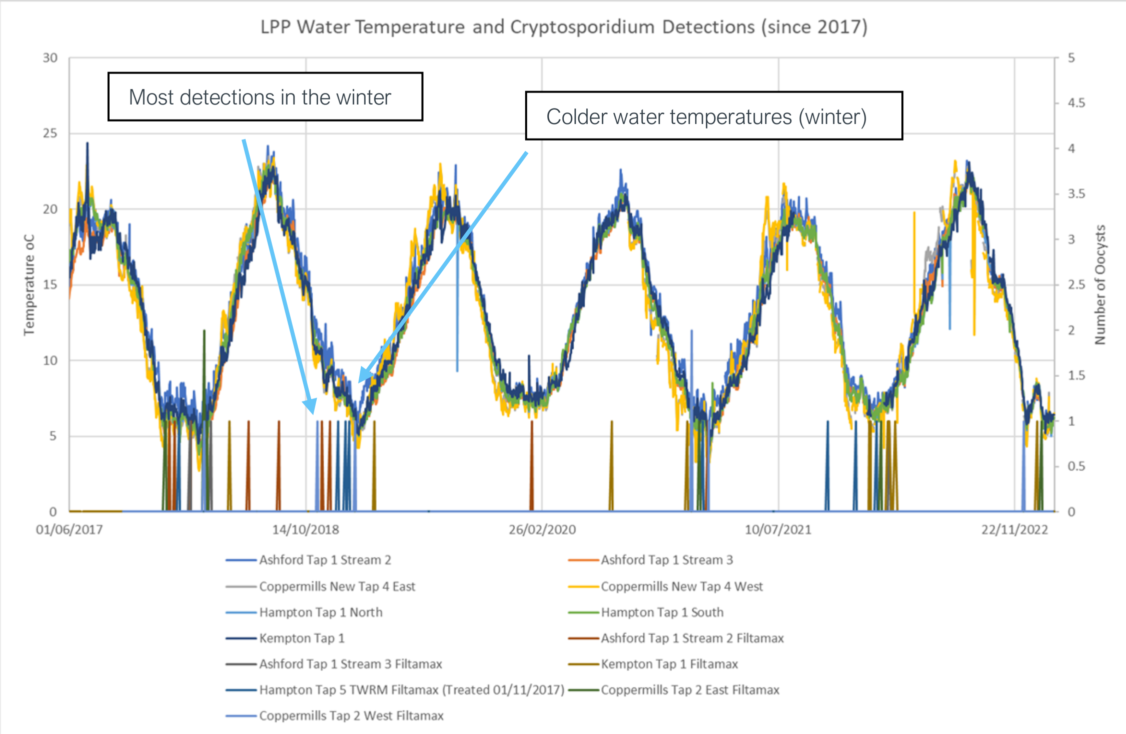


[31] Slow Sand Filtration Asset Standard, Section 2: Design, Thames Water
[32] Slow Sand Filter & Package Treatment Plant Evaluation: Operating Costs & Removal of Bacteria, *Giardia* & Trihalomethanes, Gordon R, Pyper, US EPA, June 1985
[33] *Giardia* cysts are approximately 3x the size of *Cryptosporidium* oocysts, so there is a potentially greater risk of *Cryptosporidium* oocyst breakthrough
[34] HUISMAN, L. WOOD, W.E. (1974): Slow Sand Filtration. Geneva: World Health Organisation (WHO)

3.13. *Cryptosporidium* detections at our SSF LPPs predominantly occur in colder temperatures

Applying this empirical thinking to Thames Water, we see that *Cryptosporidium* detections at LPPs coincide with lower ambient temperatures. In fact, 93% of the 43 detections previously mentioned occurred during the colder months of November to March – Figure 3.11 illustrates this. These internal investigations and analysis indicate that water temperatures below 8°C pose the greatest risk of breakthrough (average winter water temperature in London is 6.8°C[35]).

Figure 3.11: LPP Water Temperature and *Cryptosporidium* detections (June 2012 to November 2022)



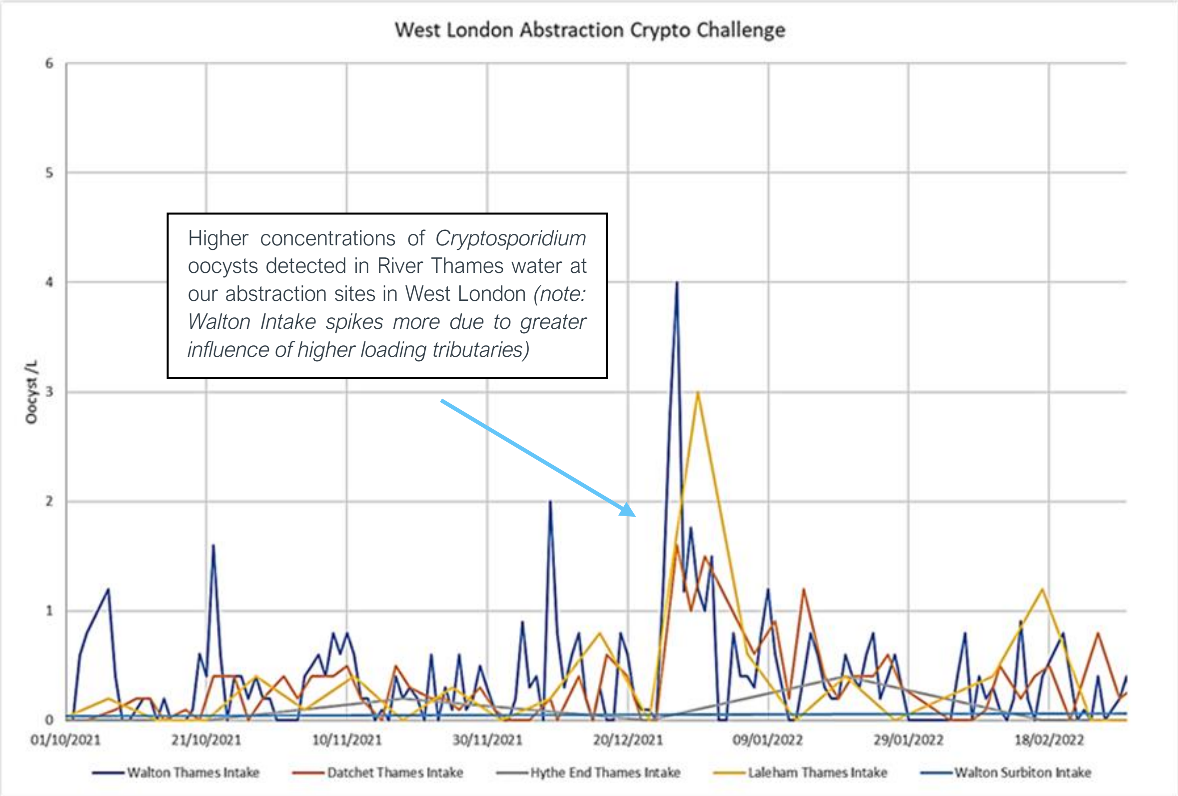
Elevated oocyst concentrations in the raw water during Autumn and Winter exist at a time when storage reservoirs are being refilled. We employ active abstraction management, using online and manually sampled river water quality data, combined with physical observations at our abstraction points and weather forecasts, to start and stop abstraction at our various abstraction points to comply as much as possible with water quality triggers set out in our operational standards.

This does have a positive impact on the water quality in our storage reservoirs, but even with abstraction management, the higher winter river loadings generally (see Figure 3.12 on the next page as a recent example) have the potential to elevate *Cryptosporidium* concentrations transferred to our WTWs at a time when treatment efficacy is challenged (see above), hence the greater number of detections as shown in Figure 3.11.

Note: we also have a high bird population in the summer, introducing a local, point source *Cryptosporidium* risk, so it is a year-round risk, but SSFs are more effective in higher temperatures so we rarely see detections in summer months).

[35] Sea water temperature London (England) today | United Kingdom (seatemperature.info)

Figure 3.12: *Cryptosporidium* loadings at raw water intakes in West London, 2021-22



3.14. Climate change impacts are exacerbating the treatment challenges and supply risk

Climate change will mean more adverse weather conditions and will challenge abstraction and treatment operational management further – with more intense rainfall events affecting raw water quality, especially if following more prolonged drier periods which have significantly reduced raw water storage. Indeed, we have already seen raw water concentrations of *Cryptosporidium* are even more elevated in the Autumn after a dry summer, with low river flows - *Figure 3.13* on the next page shows this for 2022, which was classed as a drought year across most of the UK. This could be for a variety of reasons, for examples:

- More intense initial 'flushing' of contaminants which have built up in the environment over the summer period – more surface run off with less dilution from groundwater fed sources (as levels would be low and ground conditions hard/compacted)
- More likely to have storm discharges into rivers as the wastewater system gets overloaded
- Livestock left out to pasture later in the year, building up 'uncontrolled' run off
- More likely to have higher algal loadings and lower nutrients on biological treatment processes - putting them in an already challenged treatment efficacy position

Therefore, significant resilience risks exist with raw water storage recovery after such low flow (or drought) periods with the knock-on impact to London supply headroom – in such conditions, concentrations of *Cryptosporidium* oocysts within the raw water increase to a concentration that prohibits us from safely[36] abstracting raw water, especially due to the inherent downstream treatment deficiencies detailed earlier. Complying with our abstraction standards, leads to even further reduced raw water storage levels and this also affects the treatability of the water

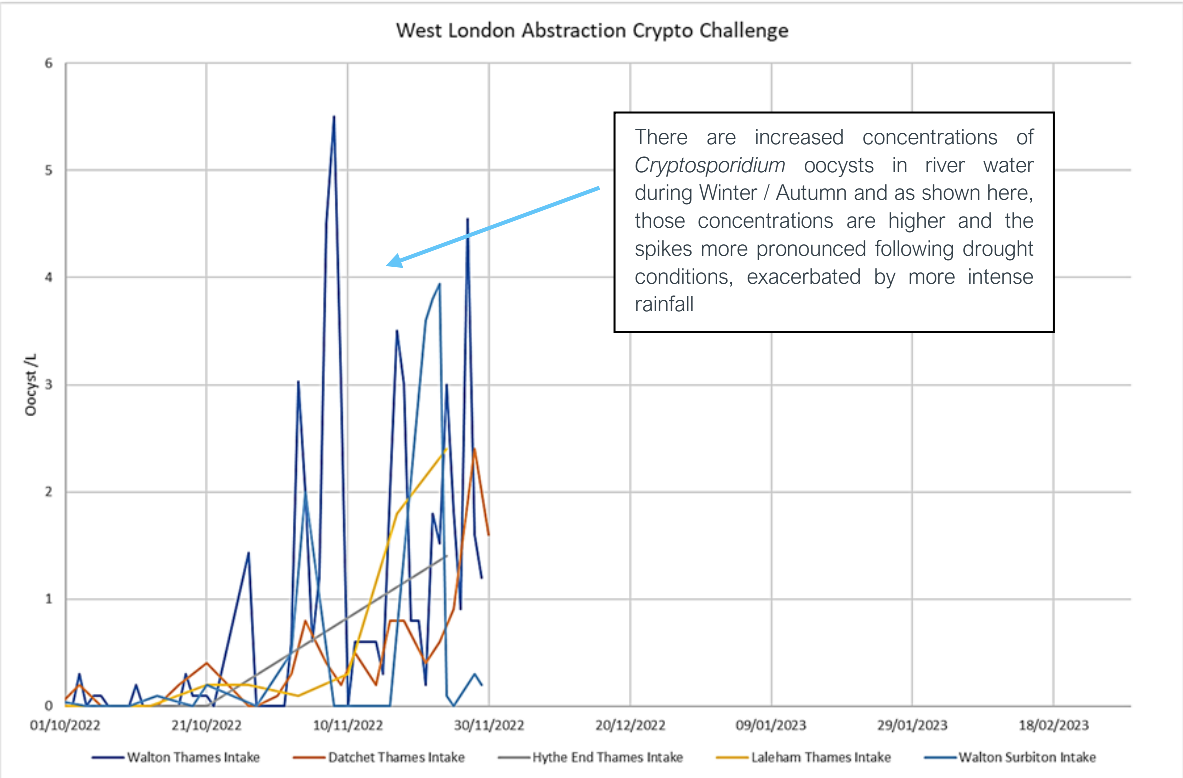
[36] 'Safely' in terms of raw water quality levels of contaminants (and turbidity) being above our abstraction / treatment standards

(potentially higher turbidity and algal loadings and lower dissolved oxygen levels) and the cost to treat (including lower driving head onto WTWs, so water needs to be pumped on sites to maintain output and meet demand).

If there was additional treatment to support the SSFs in such situations (occurs every year, but as stated more pronounced in low flow years) then we would be able to safely abstract water (increasing raw water storage) and treat water with greater concentrations of *Cryptosporidium* oocysts within the raw water. This provides a material benefit, given the increased frequency of extreme weather events driven by climate change (the additional treatment would therefore improve the Company's resilience to drought recovery and long-term climate resilience).

An additional benefit, partly linked to climate change, is that this additional downstream treatment could be temporarily operated in summer months when there is a prolonged micro-biological challenge on returning SSFs into service following maintenance (for example, a bed skim) – hotter, sunnier weather leads to SSF beds being out of service (running to waste) for much longer than they should be and a downstream treatment would give confidence in maintaining pre-disinfection parameters within standards. Again, providing a material impact on the supply resilience through the ability to maintain output as required.

Figure 3.13: Cryptosporidium loadings at raw water intakes in West London, 2021-22



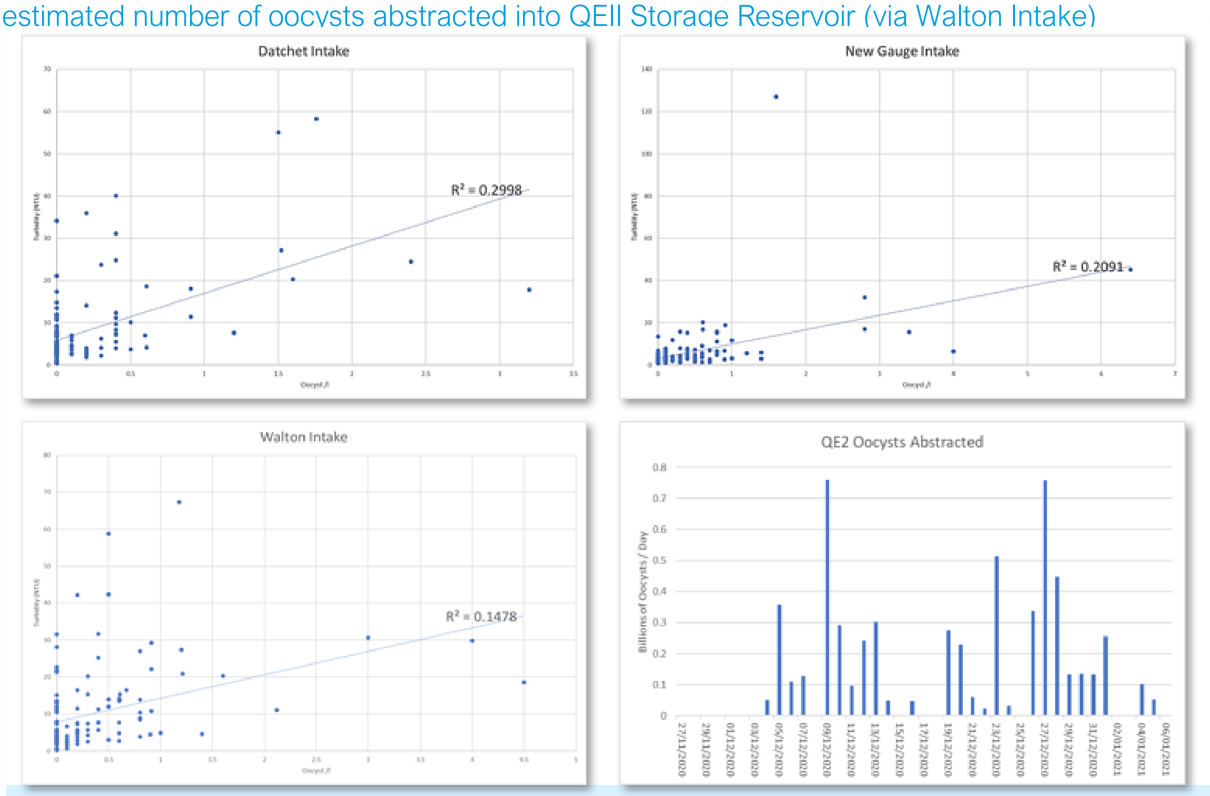
3.15. Operational mitigation can only go so far and taking *Cryptosporidium* onto LPPs is unavoidable

All our LPPs receive water which has been abstracted from the River Thames (Thames Valley/West London) or the River Lee (North London) and then stored in more than 20 large, open, storage reservoirs, before being gravity fed or pumped onto those WTWs to be treated. We always aim to supply our WTWs with the best quality stored water, where possible blending from different reservoirs, to allow for the most effective and efficient treatment. As previously stated, one of the ways to reduce the loading of *Cryptosporidium* (and other contaminants) into our storage reservoirs and onto our treatment works is through abstraction management. As demonstrated in the selection of graphics (Figure 3.14[37]), there is a poor correlation between the concentrations of oocysts and surrogate parameters - such as turbidity and organic carbon – which we currently we use to manage when we stop or restart abstraction (particularly pronounced at Walton, which as stated receives some of the highest oocyst concentration of all of our abstraction sites).

As a result, and by way of example, in 2021 during the refill of the QEII Storage Reservoir (via the Walton Intake abstraction point) following a major engineering project[38], despite following all abstraction targets for surrogate water quality measures, 6 billion *Cryptosporidium* oocysts were abstracted into the reservoir (25% on 2 days and 50% in 5 days).

The investment being presented here is to enhance the treatment process at our large SSF sites, but as has been shown above, treatment enhancement should not be the only intervention here – a joined up catchment, abstraction, and treatment management plan is required to ensure protection of the drinking water quality now and into the future, adopting the most efficient and effective approach. An example of how we aim to further mitigate the risk of *Cryptosporidium* entering our abstraction and treatment value chain (especially as we wait for treatment enhancements to be installed) is to assist the effectiveness of abstraction management through

Figure 3.14: Selection of graphics showing lack of correlation between turbidity and *Cryptosporidium* at a selection of river abstraction points in West and North London, and the estimated number of oocysts abstracted into QEII Storage Reservoir (via Walton Intake)



better upstream water quality sampling, analysis and insight: we have identified various locations greater ~24 hours 'time of travel' upstream of our abstraction points in West and North London; we are then reducing the time taken to courier samples, analyse and provide results through our

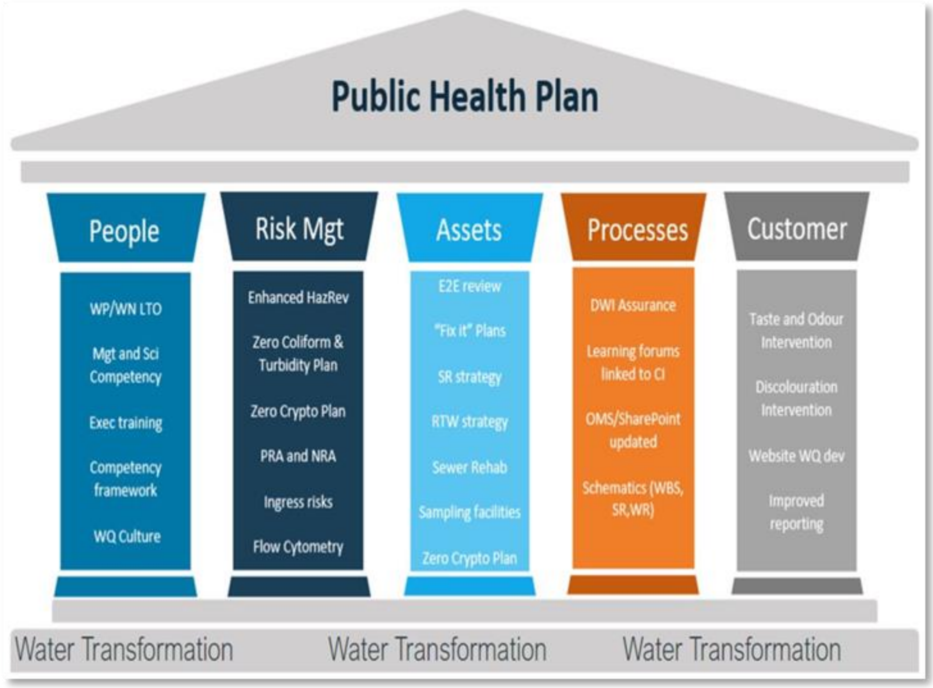
[37] Thames Water, Water Quality data, 2022
[38] The QEII Reservoir clay core improvement project required the reservoir to be drained down to facilitate the work

Laboratory; this then provides more 'real time' insight for our abstraction managers to make more informed decisions on when to stop and restart abstraction.

3.16. Our proposed enhancement funding does not overlap with previously funded projects and there is no base allowance allocated to solving the need

Protecting customers from active *Cryptosporidium* detections, using our existing asset base, is an important part of our base/Botex plan for AMP8. Central to this is the compliant operation of our water treatment works, particularly relevant to those sites identified as at a heightened risk through Drinking Water Safety Plans and associated Hazard Reviews. This is supported by the continuation of the AMP7 'Public Health Plan' – although this is not exclusively directed towards improving performance on *Cryptosporidium*, as it includes other items under 'DWI Transformation' (see Figure 3.15).

Figure 3.15: Public Health Plan 'pillars', which include items directly and indirectly linked to Cryptosporidium performance improvement



As previously stated, managing the risk around *Cryptosporidium* starts from assessing water quality risks at source, and throughout the catchment and abstraction (including raw water storage) value chain. Base funds our Drinking Water Safety Plan (DWSP) assessments (complying with Regulation 27[39]) and the Public Health Plan – by assessing risk and bringing the operation and assets back to functional design – but does not enhance the capability. As such, enhanced treatment is required to support the improvements we are making in how we proactively identify water quality or operational risks, respond to them before they affect compliance or put customers at risk, alongside a performance improvement programme. Therefore, this enhancement has no base allowance / Botex allocated to it.

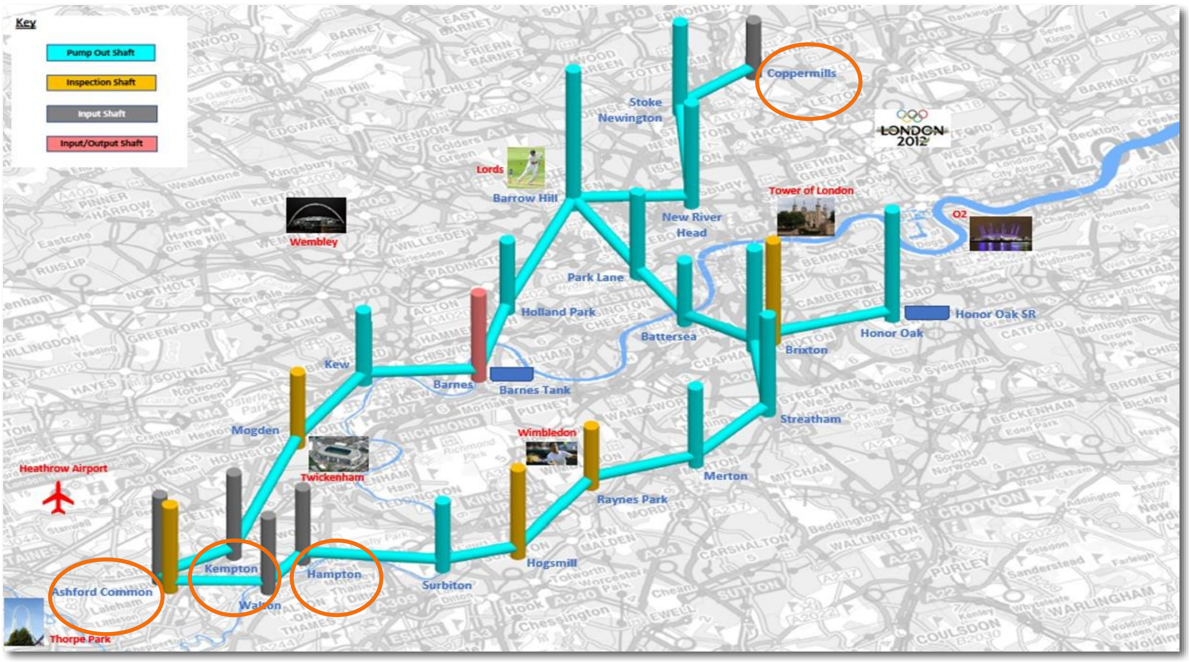
[39] Section 27, Water Supply (Water Quality) Regulations, 2016

3.17. Enhancement is required to install appropriate treatment as soon as practicable, due to the current threat to public health, but deliverability constraints mean a two AMP programme

We propose to install enhanced *Cryptosporidium* Protection at our four London SSF LPPs – namely: Coppermills, Hampton, Kempton Park and Ashford Common WTWs. This enhanced treatment process will take the form of Ultra-Violet (UV) contactors installed downstream of the SSFs to fully inactivate any oocysts which get through the existing treatment process. Inactive *Cryptosporidium* oocysts present no public health risk to consumers. We initially looked at delivering at all sites during AMP8 – unfortunately, there is no practicable way to deliver such extensive and intrusive works across our four largest WTWs in one AMP. To prevent extended outages and supply risk, we aim to deliver the installations alongside other capital and operational investment and the SSF operational programme (includes bed skimming, resands, GAC regeneration and floor refurbishments), meaning that the construction period will be extended over several years, with the WTWs remaining in supply throughout, at the required output. There is also a capacity / lead time supply chain issue with ordering so many UV contactors at once. On the balance of risk, we will target two sites in AMP8 and complete the remainder in AMP9.

Coppermills and Hampton WTWs are two of our largest Works, both with extensive operational and capital investment scheduled for AMP8, so will provide the best value sites for installation of UV treatment alongside other activity. [redacted] and are also the focus of attention from the DWI for various reasons[40]. [redacted].

Figure 3.16: Graphic showing the TWRM route around London with the pumping out shafts, and highlighting the four SSF LPPs requiring enhanced treatment



[40] Coppermills has had Cryptosporidium detections in the final water on three separate occasions over the last two years and Hampton WTW one. Both have also suffered coliform failures and are under Enforcement from the DWI

The reason it is important to undertake this work across all four sites is due to the integrated nature of the London Water Supply System. More than half of the water supplied into the London Water Supply System from these four LPPs is transported via the 83km Thames Water Ring Main (TWRM), with water mixing from all the inputs to be pumped out into the distribution system to supply ~3.5M of the 10.3M customers in London (see Figure 3.16 on the previous page). Being a 'ring', water in the TWRM can travel in different directions and can leave the LPPs in different quantities depending on the demand needs of the day across the wider system – water is also 'pumped on' from the pump out shafts and therefore the supply (from LPPs) can extend far into other systems.

Just delivering the base programme (even with the Public Health Plan discussed a few pages back to improve performance and reduce water quality risk) means that *Cryptosporidium* detections at the four SSF LPPs will persist for reason explained, and that continues to risk the public health of a large percentage of our London customers. Hence, the need for enhancement funding over the next two AMPs.

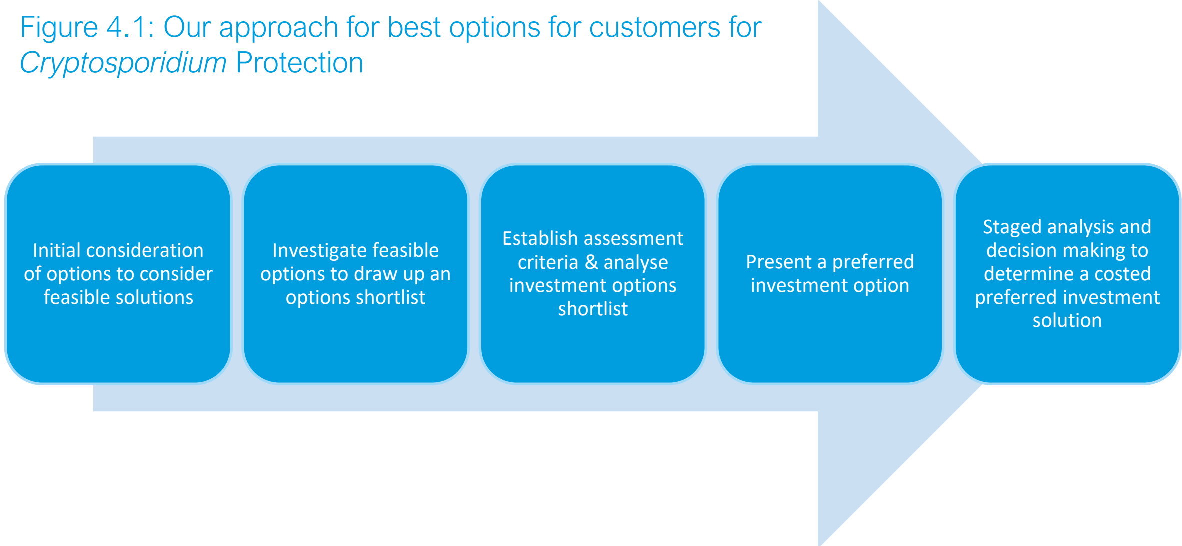
4. Best option for customers

We will now consider the best options for customers to deliver on the need for *Cryptosporidium* Protection in AMP8. The initial proposal was to deliver a multi-AMP programme, prioritising Coppermills WTW in North London for next AMP – as such, the detailed approach to provide the best option for customers is based on delivery at Coppermills WTW.

4.1. *Cryptosporidium* Protection – Optioneering: our approach

To ensure that the solution or solutions chosen to deliver the desired outcomes provide(s) best value for customers, communities, and the environment, we adopted a logical, staged approach for our options development and assessment. Figure 4.1 below sets out this approach.

Figure 4.1: Our approach for best options for customers for *Cryptosporidium* Protection



The long list of potential options which may or may not be effective, feasible or cost beneficial, are included in Annex C, Table , with further narrative provided to aid understanding and this approach is generally based on a *source-to-tap* process flow.

4.2. Initial consideration of options

We started with a qualitative assessment across the seven solution types, by brainstorming what possible solutions may look like and whether these would meet our statutory obligations and/or the investment need for AMP8 as described in Section 3 – reducing to negligible the risk to public health posed by *Cryptosporidium* oocysts in the treated water of our SSF LPPs. The output of this assessment is provided in Table 4.1.

Table 4.1: Initial consideration of Cryptosporidium Protection option categories

Solution type	Option(s) considered	Decision	Rationale
Capital investment	Install online monitoring across Catchment & Sewage Treatment Works at discharge / overflows	Discard *(not deemed as enhancement)*	Integrated catchment monitoring (combining online and manual sampling) linking water quality and flow data (possibly open source) to our abstraction sites is a sound idea and could provide some useful insight into changes in the raw water quality to allow better informed abstraction management (both in terms of avoiding poorly quality water and restarting abstraction into raw water reservoirs sooner to maintain / regain storage). This is something which we will investigate under base but, as stated, using surrogate measures for

Solution type	Option(s) considered	Decision	Rationale
			Cryptosporidium will still mean that oocysts will make it to treatment works – it is hoped that over time technology will allow for better, real-time analysis which may protect them more.
	Invest in tertiary treatment at Sewage Treatment Works (STWs)	Discard	This would particularly target *Cryptosporidium hominis*, however: • Only treats one of the sources of *Cryptosporidium* in the environment • No proven, cost-effective tertiary treatment option • Would not be cost beneficial in catchments with several STWs and/or a greater input from environmental or agricultural sources of *Cryptosporidium*
	Invest in pre-treatment (on the stored water transfer from raw water reservoirs)		If a solution could be found, then this could reduce the overall loading (including *Cryptosporidium*) entering WTWs from the storage reservoirs, however: • Preliminary research could not identify a viable, cost-effective solution • It does not provide full protection for final treated water, as too far up the value chain
	Treatment Works (SSF LPPs only) investment – improve log removal / reduction	Proceed	Compliance with the Water Supply (Water Quality) Regulations 2016, although not prescriptive in the *how*, is absolute and legally enforceable in terms reducing the risk of active Cryptosporidium oocysts in final treated water. Only capital investment at the WTWs will provide compliance to water quality legislation.
	Install treatment in the network (post WTWs)	Discard	This could be within the transmission system, distribution system or at point of use, but potable water compliance is assessed at the final water statutory tap (6) on a WTW, so downstream 'treatment' not legally compliant to the Water Regulations.
Operational measures	Abstraction Management	Discard *(not deemed as enhancement)*	This existing practice uses certain water quality parameters (e.g., turbidity) to manage when to stop and re-start abstracting from river sources; essential for good reservoir storage and water quality and could be combined with improved catchment monitoring (see above). However, as previously explain it is not a good surrogate for the concentrations of *Cryptosporidium* in the raw water – so, it is good operational practice, but has limited benefit to protecting WTWs from high loadings of *Cryptosporidium*.
	Slow Sand Filter Management		This is an operational activity, and through the Public Health Plan and other initiatives both capital maintenance and process compliance improvements are improving the performance of the SSFs across all sites. However, no amount of operational mitigation or improvement measures[41] can fully address the inherent treatment deficiency in SSFs.

[41] The Operations-led Public Health Plan, aims to satisfactorily complete all parameters under DWI Notices (including those relating to *Cryptosporidium* and London SSFs) plus other operational improvements to reduce Public Health risks by improving compliance

Solution type	Option(s) considered	Decision	Rationale
Catchment management	None identified	Discard	No suitable solutions identified to address the Need presented in Section 3 and provide compliance to water quality legislation in final treated water. *Note: catchment management is discussed more in Annex C. Best practice is to manage (improve) water quality as far up stream as practicable: e.g., interventions to mitigate Cryptosporidium risks in the catchment by funding farmers to change farming practices or deploy technology (funding already provided to farmers, primarily for pesticide and nitrate control, but this could be targeted for Crypto protection especially if combined with catchment monitoring).*
Nature-based solutions	None identified	Discard	No suitable solutions identified to address the Need presented in Section 3 and provide compliance to water quality legislation in final treated water.
Behavioural change	Reducing sources of *Cryptosporidium* into the environment (especially upstream of abstraction sites)	Discard *(not deemed as enhancement)*	This could take the form of influencing and / or supporting catchment partners to have a positive impact, through behavioural change, on the environment, therefore reducing the levels of *Cryptosporidium* (and other contaminants) in the raw water abstracted. Difficult to quantify benefits and could take many years to have a tangible impact on raw water quality, particularly as this is only one source of *Cryptosporidium*. *Note: awareness campaigns and farmer events part of base allowance.*
Partnership workings	None identified	Discard*	No suitable partnership(s) identified, given Thames Water's legislative responsibility to adhere to Water Quality regulations.
Modular or adaptive solutions	None identified	Discard	No suitable modular or adaptive solutions identified for this programme. The timescale of water quality compliance is up to 2034/35, which is much shorter than the 2050 considered by our long-term delivery strategy.

**It is important to note, that Catchment Management, coupled with Abstraction Management (further information included in Annex C), are essential, sustainable approaches to reduce the risk posed by Cryptosporidium (and other contaminants) entering our treatment value chain – reducing loadings reduces risk, chemical and energy use, and cost. They are not part of this Enhancement Case as they are delivered through our base allowance, but it is paramount that these practices continue to be improved and innovation introduced to enhance their effectiveness – for example, installing monitors on sewage treatment works outlets and linked to abstraction points (alarming and/or stopping abstraction pumps located downstream of such outlets), or combining time of travel models with enhanced upstream sampling and analysis for Cryptosporidium – again, stopping or restarting abstraction pumping (to maximise the abstraction of higher quality water).*

As detailed in Table 4.1 above, only capital investment – in the form of treatment works investment – can fully solve the need. Operational measures and/or management through the value chain – funded under the base allowance – only serve to mitigate (to a point) the public health risk posed by *Cryptosporidium* introduced into the environment, either naturally or via anthropogenic activities and taken in through treatment works which have inherent efficacy deficiencies.

4.3. Investigate feasible options

From the options initially considered, only one was identified to proceed to further investigate feasibility – i.e., to develop the detailed solution from a set of feasible options or option. We have included a further option in Table 4.2 for comparison: making no increased investment.

Table 4.2: Options considered for feasibility assessment

Investment option		Summary description
Crypto 1	No Enhanced Investment	Rely on operational mitigation and measures, including catchment and abstraction management, to mitigate the risk of active oocyst detections in the final water at SSF LPPs.
Crypto 2	Treatment (at WTWs)	Install treatment or non-treatment 'technology' to provide the required level of inactivation or removal of *Cryptosporidium* oocysts post SSFs, for the raw water challenge received at the following WTWs in London: Coppermills, Ashford Common, Kempton Park and Hampton (all enhancement).

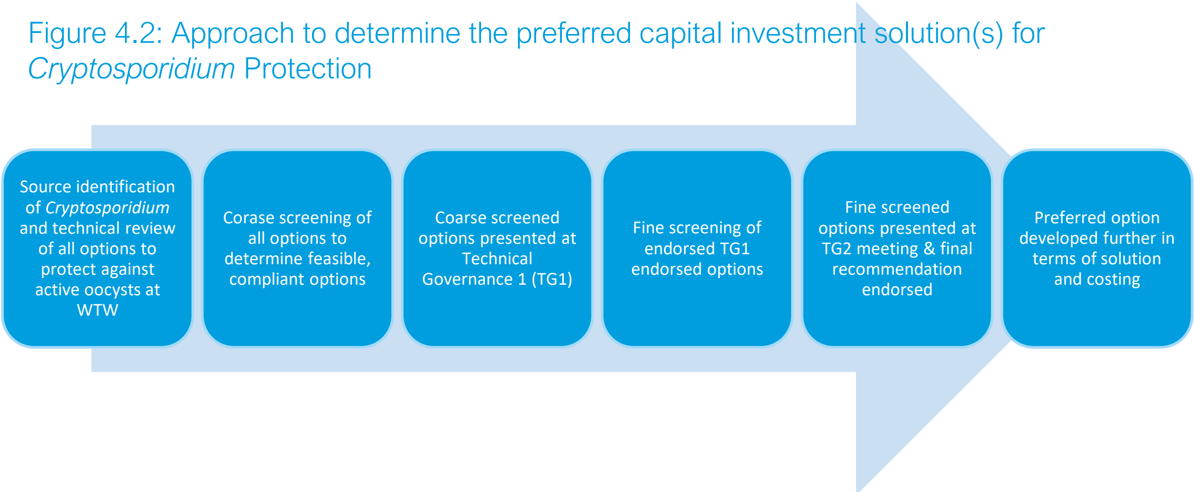
To clarify, the 'Crypto Option 1' is presented as a 'no enhancement investment case' – operational (base) capital maintenance and other activities would continue as they do presently, and the risk of active oocyst detections would remain, hence it will not be progressed beyond this point.

4.4. Capital investment assessment criteria

Capital investment to protect our customers from active *Cryptosporidium* oocysts in the final treated water, supplied from the four SSF LPPs in London: this is only option that reduces the risk to negligible and brings us into compliance with the Water Supply (Water Quality) Regulations and guidance laid out by Badenoch and Bouchier (see section 3).

To determine the most suitable capital investment, Need N50883 (and follow on Need N57360[42]) was raised to our Engineering department to work with Mott MacDonald Consultants to develop a solution for the need at Coppermills WTW – this was presented in a report in January 2023[43], having followed this high-level approach:

Figure 4.2: Approach to determine the preferred capital investment solution(s) for *Cryptosporidium* Protection



[42] The follow on Need was raised to develop the solution costs for the other three SSF LPPs – this followed the issuing of the Coppermills WTW report (see below) and subsequent discussions with the DWI and the Thames Water Executive proposing solving the *Cryptosporidium* risk at more than one SSF LPP in AMP8 and have a programme to complete all by end of AMP9. The preferred solution for the other LPPs was assumed to be the same as Coppermills WTW – there were some amendments to the configuration, but the costing approach was the same (see Section 5 Cost Efficiency for further details)

[43] Coppermills *Cryptosporidium* Log Removal, Thames Water PR24 Report, Mott MacDonald, January 2023

We will now show the results of each of these steps and how each one to reach a preferred solution or solutions, which delivers for our customers.

4.5. *Cryptosporidium* source identification, literature & technical review of treatment options

We have discussed in Section 3 (Need) that most *Cryptosporidium* detections at SSF LPPs occur during the coldest months of the year from November to March. Engineering data analysis also confirmed that these months are also when *Cryptosporidium* loading in the river is highest, suggesting that the source of the detections is high *Cryptosporidium* loading in the raw water.

The study also looked at other potential sources, identifying that there is also the potential for *Cryptosporidium* to enter the system through point loading onto the SSFs – the identified potential mechanisms for this are birds defecating on or drowning in the SSFs, and mammals (such as foxes or rabbits) falling in to the SSFs and drowning. Neither were considered a credible source of the detections to date (there have been no positive tests up to now), however, the study could not eliminate the possibility of this happening in the future, so were considered throughout the optioneering.

An important requirement put on the study, was that any option must improve the log removal of the treatment process by at least 2 (no accounting for dips during challenges). Thames Water's internal limits for *Cryptosporidium* concentration in the final water is 0.01 oocysts per 1000 litres[44], and this can be used as a basis to determine the required log reduction in *Cryptosporidium* concentrations post-SSF, as per the following calculation:

Figure 4.3: Log reduction calculation

- Thames Water limit is 0.01 oocycsts / 1000 litres, which is equal to 10 oocysts / ML.
- Minimum flow through filtamax is 40 L/h, which is equal to 0.00096 ML/d.
- Filtamax is in place for 4 days, so this gives a total volume through the filtamax of 0.00096 x 4 = 0.00384 ML.
- The maximum number of crypto oocysts found in a filtamax at Coppermills downstream of the SSFs is 2No. (see Figure 2.1).
- Therefore the maximum concentration is 2 oocysts / 0.00384 ML = 520.8 oocysts / ML.
- 520.8 oocysts / ML is above the Thames Water limit of 10 oocysts / ML.
- 10 / 520.8 = 0.02. This suggests that Coppermills would need an additional 2-log reduction to achieve the target. Put another way with a further 2-log reduction the concentration should be 100 times lower at 5.2 oocysts / ML, which is below the target.

This can be represented as the following table:

	Unit	Value
Thames Water final water cryptosporidium limit	oocysts/1000 litres	0.01
Thames Water final water cryptosporidium limit	oocysts/ML	10
Minimum flow through filtamax	L/h	40
Minimum flow through filtamax	ML/d	0.00096
Time filtamax is in place	days	4
Total volume through filtamax	ML	0.00384
Maximum number of oocysts found in a filtamax	Number	2
Maximum cryptosporidium concentration downstream of SSFs	oocysts/ML	520.8
Cryptosporidium concentration reduction factor required		0.02
Cryptosporidium log reduction required	log	2

[44] Thames Water, Water Quality Asset Standards

Through a literature search and discussions with treatment experts (internally and externally to Thames Water), a long list of options was developed, and these are presented in Table 4.3.

Table 4.3: Long list of treatment and non-treatment options to protect against Cryptosporidium

Treatment options	Non-treatment options
Do nothing	
Improvements to existing process units	Covered SSFs – covers on rails
Coagulation, flocculation, and clarification	Covered SSFs – hanger (option for PVs)
Post-SSF ozonation	Covered SSFs – solar panels (PVs)
UV	Fencing around SSFs
Ceramic membranes	Net or mesh over SSFs
Polymeric membranes	Increased frequency of falconry
Cartridge filters	Fake hawks or drone hawks
SSF removal and new treatment installation	Laser bird scarers

4.6. *Cryptosporidium* Protection – Coarse screening criteria & results

To assess the (long list) options, assessment criteria were developed with key stakeholders prior to a coarse screening workshop. In addition, prioritised weightings for the assessment criteria were agreed on a scale of 1 – 3 to reflect the relative importance of the criteria. The assessment criteria and weightings were as follows:

Figure 4.4: Coarse screening workshop assessment criteria and weighting priorities

Log reduction - Log removal or inactivation of cryptosporidium oocysts	3
Reliability - Resilience to failure and maintenance/operational complexity	2
Construction - Construction complexity (programme risk)	2
Supply - Ability to keep works in supply	3
Safety - H&S/operator safety	3
Project Risk - Level of relative project risk (unknowns, lack of information, further investigations)	2
Environment - Environmental impacts and energy consumption	2
Stakeholders - Stakeholder impacts incl. neighbours	1
TOTEX - Relative TOTEX rankings estimate based on engineering judgement for coarse screening	1
Size - Footprint, land availability and planning (relative rankings estimate based on engineering judgement for coarse screening)	3
Programme - Delivery programme duration (relative rankings estimate based on engineering judgement for coarse screening)	2
Integration - Ease of integration with existing facilities - civil (incl. waste), mechanical and electrical	2
Other - Additional process benefits	1

Instructions / Details for Use

NOTES

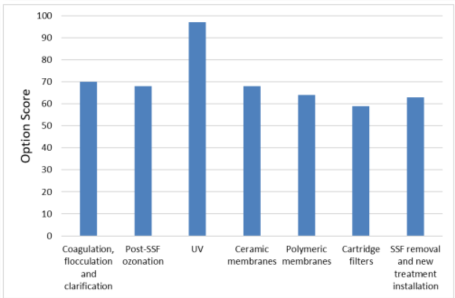
1 Rank of all options and estimated percentage of theoretical best score
2 All scores are 0 - 5
3 Priority on a scale of 1 - 3
4 Tune project set-up using the control panel below; according to the priorities and considerations of the scheme.
5 The focus of different schemes often falls on different disciplines, consequently, to avoid placing undue weight of consideration in the analysis on disciplines which are not core activities of the job, the Concern Weighting allows the project manager to balance the analysis towards or away from one disipline or another.
6 Percentage score provided is a measure of the degree to which the option meets the criteria fully.
7 Normalised percentages are relative scores between options without reference to an external referrant.

During the coarse screening process, if an option was deemed not to confer at least a 2-log reduction in *Cryptosporidium* if it were to be taken forward, they were classed as unsuitable (non-compliant) and not given an overall score.

The full workshop results can be seen in the coarse screening matrix document 100107994-COP-MAT-001[45] – the score and rank of each compliant option are presented in Figure 4.5 below.

Figure 4.5: Score and ranking of the compliant options following coarse screening

Option	Score	Rank
Coagulation, flocculation and clarification	70	2
Post-SSF ozonation	68	3
UV	97	1
Ceramic membranes	68	3
Polymeric membranes	64	5
Cartridge filters	59	7
SSF removal and new treatment installation	63	6



As stated, any option must confer at least a 2-log reduction in *Cryptosporidium* – the list of these options are provided in Table 4.4 below:

Table 4.4: List of non-compliant options (not given an overall score)

Option	Type
Do nothing	n/a
Covered SSFs – covers on rails	Non-treatment option
Covered SSFs – hanger (option for PVs)	Non-treatment option
Covered SSFs – solar panels (PVs)	Non-treatment option
Fencing around SSFs	Non-treatment option
Net or mesh over SSFs	Non-treatment option
Increased frequency of falconry	Non-treatment option
Fake hawks or drone hawks	Non-treatment option
Laser bird scarers	Non-treatment option
Improvements to existing process units	Treatment option

At the workshop it was decided to progress the options ranked first, second and third, and screen out the rest of the options. The options to be progressed were:

- UV (ranked first)
- Coagulation, flocculation, and clarification (ranked second)
- Ceramic microfiltration (ranked joint third)
- Post-SSF ozonation (ranked joint third)

4.7. Technical Governance for coarse screened options

Following the coarse screen workshop, further analysis was undertaken on whether the installation of a post-SSF ozonation process – even though it could be an effective *Cryptosporidium* barrier – may introduce an unacceptable risk of bromate formation (which is a carcinogenic compound). The detailed analysis is available in Annex C, it concludes that considering the necessarily high concentration of ozone dose to be applied and the levels of bromide observed in the raw water, likely bromate concentrations formed would be considerably

[45] This is large, internal document (in Excel) and only the summary is included here – can be made available on request

higher than the Prescribed Concentration or Value (PCV), and so post-SSF ozonation was also screened out.

Therefore, the three remaining coarse screened options – see a summary in Table 4.5 below – were presented at a technical governance meeting to determine which options should be progressed for development for fine screening.

Table 4.5: Coarse screened options considered at Technical Governance for Coppermills WTW[46]

Technology option	Equipment Requirements	Possible location(s)	High Level Cost (£M)	Risks & Opportunities	Decision
Rank 1: UV	At this stage, two options were considered for UV: Option 1 • 1No. UV contactor per SSF outlet = 33No. 24Mld contactors Option 2 • 2No. UV contactor banks: West stream 16No. 24Mld contactors East stream 17No. 24Mld contactors		Supplier provided costs for Option 1: ~£17M CapEx Supplier costs for Option 2 (estimated): £5M-£10M CapEx *Both options for UV contactors only, does not include other required equipment and construction work)*	Risks • Headloss through UV contactors unknown • Option 2: commissioning into an online WTW means flow reduction • Instantaneous peak flow of each SSF could be greater than 24Mld • UV inactivates oocysts, does not remove • Lead times for 33 contactors • Mercury lamp breakages • Power upgrade would be required Opportunities • Potential to combine with other delivery programmes at Coppermills through AMP8 – cost saving • Option1: Sequential commissioning per SSF – maintain site flow • LED UV technology could reduce OpEx & remove mercury risk	Proceed
Rank 2: Coagulation, flocculation & clarification	One design option: • 2No. coagulant storage tanks • 20No. flocculation lanes • 20No. DAF[47] units • Sludge treatment	Due to large footprint only two possible locations: • North of site (outside of the WTW boundary on the	Preliminary CapEx costs: • Clarification process: • £5M-£10M • Steel pipelines: £20M-£50M • Sludge treatment: • £1M-£5M • Total :	Risks • Demolishing existing infrastructure, large footprint & land protected • Very large pipelines • Commissioning into an operational site • Upstream of SSFs – non-zero risk of point source *Cryptosporidium* – would need to cover SSFs too - ?	Discard

46 [redacted]ll costs in this table are supply only, budget costs in today's prices and so significantly under-estimate total capex costs

47 DAF (Dissolved air floatation) - a process in which air is dissolved into…water under high pressure and then released into the bottom of the treatment tank to allow the air to come out of solution in very fine bubbles and float the solids to the surface. A clarification process used to remove particulates from water by means of coagulation, flocculation, and floatation of the resultant sludge away from the clarified water (https://www.owp.csus.edu/glossary/dissolved-air-flotation-daf.php)

	plant (9No. tanks & 1No. centrifuge)	reservoir site) • West side of WTW site	• £50M-£100M	• DAF sludge stream would be challenging to treat & dispose of (sewer already at capacity) Opportunities • Covering SSFs (if required) would provide additional treatment benefits • Solar panels on cover - ?	
Rank 3: Ceramic microfiltration	One design option: • 7No. 100Mld modular units (~3000m^2) • Neutralisation tank & caustic dosing plant	3 possible locations: • Same two locations as clarification • On the site of some of the existing SSFs (removing them from service)	Supplier provided CapEx costs: • ~£100M	Risks • Demolishing existing infrastructure, large footprint & land may be protected • Very large pipework • Large neutralisation tank required to store waste acidic water – requires caustic dosing plant • 5% of flow goes to waste Opportunities • Ceramic membranes have long operating life & high confidence in WQ • Can be considered as viable replacement for RGFs & SSFs – use less space overall	Proceed

The outcome of Technical Governance was that Coagulation, flocculation and clarification was discounted based on it being upstream of the SSFs, and therefore there is still a risk of point loading of Cryptosporidium onto the SSFs from birds or mammals; ceramic microfiltration and UV were progressed to the fine screening workshop.

4.8. *Cryptosporidium* Protection – Fine screening criteria and results

The purpose of the fine screening workshop was to determine which options should be developed for a second Technical Governance meeting. As with coarse screening, assessment criteria (see Figure 4.6) were developed with key stakeholders prior to the workshop; unlike coarse screening, no weightings were applied as all criteria were deemed to be of equal performance.

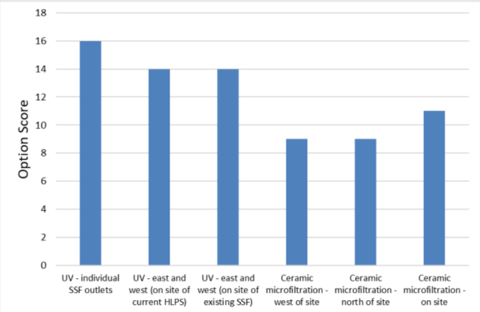
Figure 4.6: Fine screening assessment criteria

Cryptosporidium reduction - Log removal or inactivation of cryptosporidium oocysts, where the minimum calculated log reduction requirement is 2-log reduction
Buildability - feasibility and ease of construction
CAPEX - Capital cost
OPEX - Operational cost

Each option was scored against each criterion on a scale of 0 – 5, and the results[48] are shown in Figure 4.7.

Figure 4.7: Score and ranking of options following fine screening

Option	Score	Rank
UV - individual SSF outlets	16	1
UV - east and west (on site of current HLPS)	14	2
UV - east and west (on site of existing SSF)	14	2
Ceramic microfiltration - west of site	9	5
Ceramic microfiltration - north of site	9	5
Ceramic microfiltration - on site	11	4



At the workshop it was decided that the ceramic microfiltration options should be rejected due to the challenges in construction and the removal of the SSFs (also, maintaining the operation of SSFs is a Thames Water long term strategy). Further to this, the chemical requirements of ceramic microfiltration make this option less favourable. Additionally, the Totex of ceramic microfiltration has been calculated (at a hight level) as being significantly greater than UV.

The following options were therefore progressed to a second Technical Governance meeting:

- UV – individual SSF outlets (ranked first)
- UV – east and west (HLPS[49]) (ranked joint second)
- UV – east and west (SSF) (ranked joint second)

It is important to state here that UV as a treatment process is not new to Thames Water (nor indeed to other water companies in the UK). Operational teams are supportive of such technology, having successfully operated and maintained such equipment at sites across London and the Thames Valley & Home Counties – it can be demonstrated to achieve the expected performance where a *Cryptosporidium* challenge exists.

4.9. *Cryptosporidium* Protection – Technical Governance and final recommendation

The purpose of the second Technical Governance meeting was to present a comparison of UV in the three different locations and provide a recommendation as to which of the three should be developed through final design costing to determine the Totex requirement.

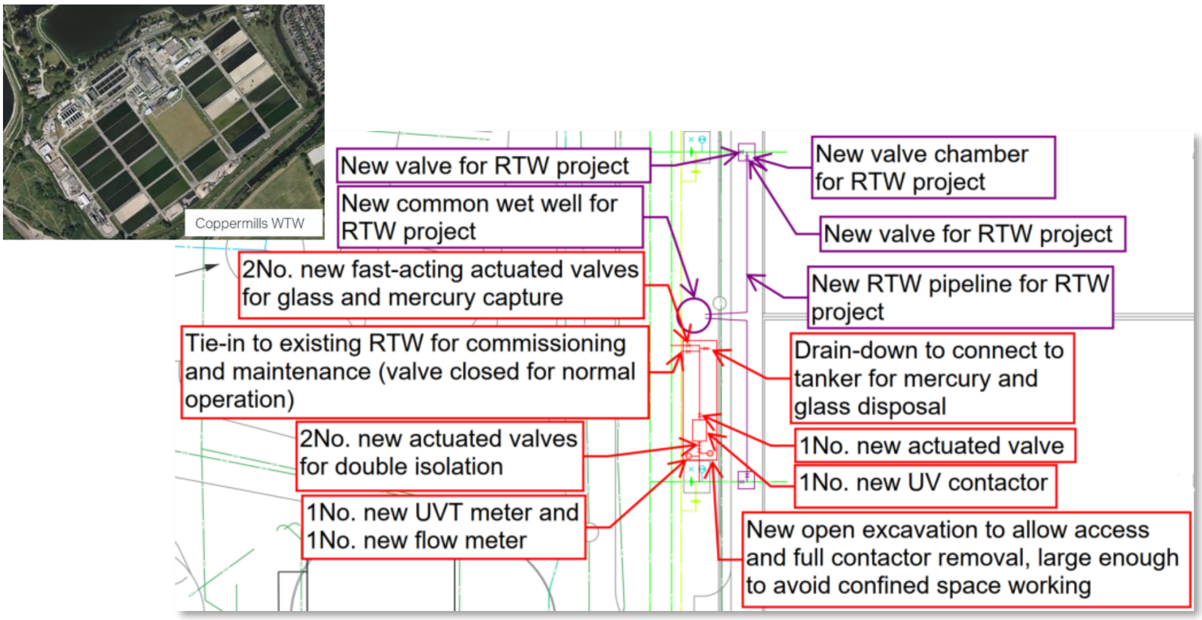
In summary, the following recommendation was given:

- An east and west UV solution may be the cheapest in terms of Capex, but has disadvantages in ease of commissioning and available space; if LED UV technology became an option, it would also be far more challenging for space
- The individual SSF outlet solution would allow sequential commissioning and minimal disruption to the site, and is more likely to allow the option of using LED UV contactors
- It was recommended to install UV contactors on each SSF outlet

[48] See 100107994-COP-MAT-002-Rev1 - Fine screening matrix document for details (available on request)
[49] HLPS – High Lift Pumping Station

This recommendation was endorsed by the attendees, and so the finalised design[50] for costing is as shown in Figure 4.8.

Figure 4.8: Final design for UV contactors on outlet of each SSF for F909 costing at



Cost efficiency is discussed in Section 5 of this document, but it is worth stating that the study recommends that all projects taking place at Coppermills in AMP8[51] are included in a Coppermills 'Master plan', such that an overall integrated design solution can be developed, which will have the potential to minimise disruption onsite as well as significantly reduce costs.

4.10. Cryptosporidium Protection – Replicating the Coppermills WTW solution at other SSF LPPs

Two months after the publication of the study report and recommendation for Coppermills WTW, it was determined that on public health protection grounds, we could not justify limiting *Cryptosporidium* Protection to just one SSF LPP in AMP8. This was supported by the DWI. Therefore, we commenced work on developing and costing solutions for the other three SSF LPPs – namely, Ashford Common, Hampton and Kempton Park WTWs [redacted]. Engineering was asked to provide solutions and costs based on the design principle shown in Figure 4.9. Coarse screening against a long list of treatment and non-treatment options was not undertaken for these sites, as it was deemed that the size, scale, and complexity of these sites were similar to Coppermills, and that the screening process would yield the same fine screening options, those being:

- Individual UV contactors on the outlet of each SSF
- A bank or banks of UV contactors treating all or elements of the flow from the SSFs

[50] See P0867_Coppermill_F909_REV.1 UV Individual SSF Outlets Rev 1 for costing
[51] This would include work being done under the Resilience Programme

Figure 4.9: Design principle for Cryptosporidium protection at SSF LPPs

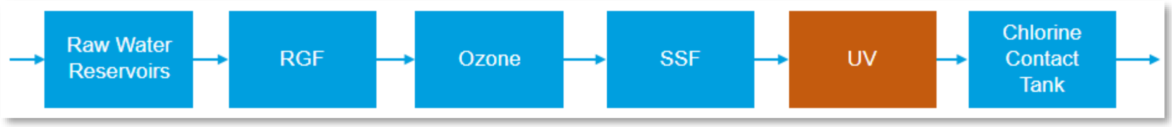


Table 4.6 below was presented at a Technical Governance meeting with a UV treatment solution recommended for the three sites[52]. These recommendations were endorsed and proceeded directly to final design and costing.

Table 4.6: Recommendations & endorsement for a UV solution at Ashford Common, Hampton & Kempton Park WTWs

Ref	Details	Recommended for progression (Y/N)	AMP delivery
1	Provide new UV contactor units on the outlet of individual SSFs	Ashford Common WTW (Y) Kempton Park WTW (Y)	AMP9
2	Provide new combined UV treatment plant(s) treating all or part of SSF outlet flow	Hampton WTW* (Y)	AMP8

**for Hampton WTW the site lends itself to having 3No. UV treatment plants covering the Reidler beds, Central & Eastern beds, and Moorlands beds – due to the configuration of the SSFs, which is not uniform like the other three sites, it is not possible to have a UV contactor on the outlet of each SSF*

Following this endorsement, the endorsed solutions were costed – these are discussed further in the Cost Efficiency Section 5.

Costing up more than just Coppermills WTW provided the opportunity to develop a deliverable programme of works for AMP8 to install *Cryptosporidium* Protection at more than one site and give robust insight on what the investment for AMP9 would look like.

Enhancement is required at all four WTWs, but to prevent extended outages and supply risk, we aim to deliver the installations alongside other capital and operational investment and the SSF operational programme. The construction period will therefore be extended over several years so that the WTWs can remain in supply throughout the instillation. We therefore propose to target two sites in AMP8 and complete the remaining two in AMP9.

Coppermills and Hampton WTWs both have extensive investment scheduled for AMP8 and will provide the best value sites for installation of the UV filters while providing the least disruption to customers in AMP8.

4.11. Expected Benefits – *Cryptosporidium* Protection

4.11.1. Cost benefit Assessment

We determine expected benefits by using the Thames Water public value framework (PVF) and a cost benefit analysis (CBA) of each option. For each investment, we incorporate the PVF outputs into the qualitative decision making of the investment programme, by scoring the public value benefits from strongly negative to strongly positive for each of the feasible solutions. The PVF tool helps each Enhancement Case identify and factor benefits into decision making. The full PVF evaluation is shown later in this section.

[52] See P0867_Ashford, Hampton, Kempton Cryptosporidium log removal TG Pack_Rev.2 (summarised above in Table 4.6)

After using the PVF to identify the range of benefits, we determined monetised benefits across the range of measures. We have followed Ofwat's hierarchy for sourcing robust marginal benefit values from ODI rate research to WINEP and then to other publicly available, robust valuations. The identified benefits across all three options, and those benefits that could be robustly quantified are listed in the tables below.

4.11.2. Benefits that apply

Table 4.7: Benefits that apply to the option scenarios

Benefit	Description of benefit application:
Improved health outcomes, reduce ingestion of *cryptosporidium* through drinking water	Helping our customers stay healthy and well is the primary driving benefit of this case. Considered but not monetised, or quantifiable, as weak customer feedback loop.
Reduce boil water notices	Not issued based on treatment plants, but site specific. WINEP benefit, considered but not quantified, as little to no impact.
Greenhouse gas emissions from construction	Carbon emissions from construction of both option types. Monetised as per The Green Book. Considered but not quantified as both options require similar civil works at all sites.
Reduction in customer contacts	Considered but not monetised or quantified, both options considered the same. Very limited customers contacts from crypto impacted illness.
Reduce unplanned outages	Considered. Monetised as per PC/ ODI metric. Not quantified, as currently no significant detections or impact on Performance Commitment.
Waste to landfill	Considered for both options, as by-products of filtration process do not go to landfill, but as waste by-product to wastewater treatment.

After screening for feasible options, we undertook a workshop to identify and quantify benefits and units across the three different options. This process aimed to determine where benefits varied or remained consistent across the options and why. We determined that there was no significant quantitative variance across the two options that resulted in significant change in quantity across the monetised benefits.

4.11.3. Best option based on cost

We recognised that it is the costs that are fundamentally different between the two options, with Option 2 being about 28% more expensive than the cost of Option 1.

There is also significant uncertainty with the ceramic membrane microfiltration option, as this is a new and untested technology for *Cryptosporidium* removal in the UK and has not been used previously by Thames Water or any water companies in the UK.

4.11.4. Output

Table 4.8: Results for Cryptosporidium Protection CBA (£M 2022-23)

	Option 1: UV	Option 2: Microfiltration
Benefit	+	+
Capex Cost	£157M*	£200M**
Choice:	1	2

**F909 costs for Coppermills and Hampton WTWs (excluding central overhead)*
***High level engineering assessment of alternative costs for both sites, extrapolated from supplier costs for Coppermills WTW*
+ Benefit is equal across both options.

There is no significant incremental benefit difference, with no measurable monetised benefits between the two options. The impact on carbon and natural capital were assessed qualitatively as consistent across both options. There is also a higher degree of uncertainty risk with Option 2 being an untested solution. Therefore, we see no justification for the significant cost increase to customers by selecting Option 2 where there are no measurable monetised benefits to justify the significant increase to customers. We therefore recommend proceeding with UV Option 1.

4.12. Cryptosporidium Protection – Customer & Stakeholder support

The customer insight mentioned in Section 3 also provided some insight to solutions (preferred timings were not tested as it was a given customers expected that anything which presents a risk to drinking water quality should be addressed as soon as possible):

- Hearing that there is a risk of water becoming contaminated by harmful bacteria is alarming to many customers. The solution is also seen as relatively straight forward. (PR24-12)

As previously stated, the DWI are supportive of this investment and have provided a Letter of Support (Annex A) with an associated Enforcement Notice to follow.

It is also important to state here that due to the nature of the investment within the water treatment process on site, it is not applicable for third-party funding and as such this is not discussed any further.

4.13. Public Value Framework – Benefits Analysis

Our public value framework uses a semi-quantitative, multi-criteria analysis approach, where values are weighted using customer preferences[53]. There are nineteen measures in our public value framework which are used to assess an option.

The public value framework assessment includes a wide range of measures such as biodiversity, waterbody quality, recreation, amenity and local economies, while the financial capital measure continues to be captured in other parts of our investment planning processes. The framework considers both short and long-term impacts, looking approximately 30 years ahead.

The degree of impact between the capitals varied. These are outlined in Figure 4.10 (next page) and described below:

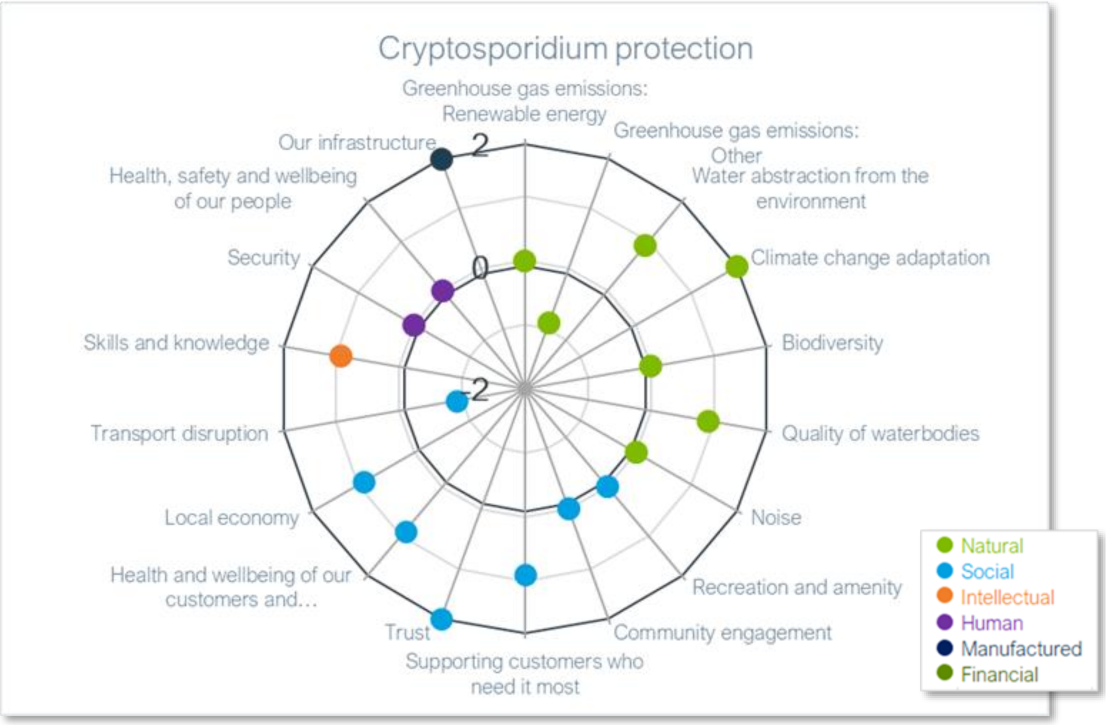
- The investment strongly benefits social capital across one or more measures. Improving our drinking water quality to protect public health improves customer and stakeholder trust and protects London's economy

- The investment strongly benefits natural capital across one or more measures. The solutions secure improved resilience to climate change and provides mitigation against supply risk in drought scenarios. We will also abstract less water from the environment as the improved UV treatment capability results in lower process losses which will mean our SSFs will not need to be run to waste as often

[53] Public value research, May 2022 Verve

- There is also a strong benefit to manufactured capital. The new assets increase the total value of our assets while the increased treatment capacity allows us greater flexibility to maintain other assets on site. We expect this to lead to an improvement in asset health
- There is a slightly positive benefit to intellectual capital. The new treatment technology is the first of its kind in London. The operating workforce in London will gain training and a new set of skills to operate and maintain the new UV assets. We expect this to influence employee wellbeing
- Dis-benefits include an increase in operational carbon output to operate the new treatment technology. Delivery of our services introduces a short-term dis-benefit against transport disruption, as we expect increased road loading with construction deliveries, during the one-off installation period, and increased carbon emissions as we upgrade our works
- An overview on financial capital is included in Section 5
- No change is expected to human capital on balance. The new operating process is expected to introduce risk as a new dis-benefit; however, the improved process efficiency should reduce frequency of maintenance and the accompanying health and safety risk i.e., less SSF skimming

Figure 4.10: Public Value for Cryptosporidium Protection



We will continue to seek public value opportunities through detailed design and delivery, for example through stakeholder engagement.

5. Cost efficiency – Cryptosporidium Protection

5.1. Approach to determining cost efficiency

In this section, we cover the approach we have taken to arrive at our option costs and how we have considered the top-down efficiency of our proposed option for meeting cryptosporidium protection standards.

Firstly, we set out the overall approach we have taken to developing our costs for this case. We describe in detail the bottom-up engineering costing. Next, we demonstrate how we have challenged these bottom-up costs through the application of different operational efficiency levers. We describe the process we have followed and show how we arrived at our costs alongside the supporting evidence, calculations, and key assumptions.

5.2. Bottom-up engineering costing approach

The solutions developed for the need presented in this Enhancement Case, were put through our Engineering team.

Our document TMS33 Capital Cost, Efficiency and Assurance highlights our approach to developing efficient solutions for PR24. We have incorporated best practices from our Business-as-usual (BAU) processes and combined them with new lessons learned. Our goal was to create an approach that is fully integrated into our organization and well-understood. The solutions we have developed provide value to our customers. The core principles guiding our approach are People, Process, and Systems.

5.2.1. People

Our approach aligns with the skills of our people who work on BAU processes and apply their knowledge and experience. The team responsible for developing and costing the PR24 solutions consists of experts from across Thames Water and our supply chain partners. Technical Leads were appointed for each Enhancement Case, ensuring consistency and the right skill set for development.

5.2.2. Process

We have followed the PR24 process approach in an equivalent manner to our systems. By utilizing existing processes, we could focus on designing our assurance plan efficiently. Our PR24 steps align with the business-as-usual gateway steps for engineering projects/programs. Our Efficient solutions that provide value process consists of four main steps: Engineering, Estimating, Assurance, and Efficiency.

5.2.3. Systems

We have used existing systems such as Engineering Estimating System (EES), Sludge Management Tool (SMT), System Outage (London Water Supply), and others. These systems were tailored to support our PR24 approach, providing familiarity to our teams and reducing the need for additional training.

Throughout the process, we have focused on design maturity, gathering data inputs from operational teams on-site, and conducting thorough analysis to improve confidence levels and reduce risks. We have applied assurance and incorporated checkpoints in all our process steps. Estimating was conducted using five different approaches, and assurance steps were taken to enhance confidence in the proposed solutions.

Efficiency has been a key focus, and we have identified initiatives to drive improvements in cost of delivery. Our systems have played a crucial role in supporting our PR24 approach, allowing us to seamlessly integrate our teams and progress into the next AMP period.

Overall, our approach has been centred around leveraging the skills of our people, following a well-defined process, and utilising existing systems effectively.

5.2.4. Applying Efficiency Levers

The methodology for identifying the efficiencies to be achieved in this Enhancement Case, considering the optimism bias associated with achieving the stated results, is outlined in the main annexes section.

We used nine efficiency levers to identify efficiency opportunities across our PR24 Enhancement Cases. Horizontal levers are specific to each Enhancement Case – the relevant ones for this Enhancement Case are presented below - whereas vertical levers are applicable across all Enhancement Cases.

5.2.5. Vertical Levers

Table 5.1 below provides a list of vertical levers which we will utilise across all Enhancement Cases in capital delivery.

Table 5.1: Vertical efficiency levers

Lever	Description	Total Efficiency across the Programme
Programme Optimisation	Programme Optimisation is a strategic view of a programme of works, which identifies Efficiency through grouping and synergies, including process type, geography, site, scope, procurement, delivery route.	<5%
Digital, Tech & Data Analytics	The use of digital technology and solutions to improve project delivery, such as Building Information Modelling (BIM), Asset Information Modal (AIM), digital rehearsals using 4D, the use of augmented and virtual reality. The implementation of digital paperwork solutions, on-site tablets etc. This can be integrated with drones, laser scanning, LIDAR, digital data capture. Data analytics to optimise the solution.	<1%

5.2.6. Horizontal Levers

The main opportunities for efficiency savings in the *Cryptosporidium* Protection Enhancement Case falls primarily in the following horizontal levers:

- Strategic Procurement: Based on the engineering scope for this Enhancement Case, it is anticipated that opportunities for strategic procurement will be limited due to the high repeatability and good pricing agreements established with Thames Water suppliers. The major component for procurement is UV equipment and installation.
- Solution Optimisation: Investing in site data and establishing baseline performance will contribute to defining improved engineering solutions. This investment will enable Thames Water to effectively manage risks and make more informed decisions, thereby allowing for calculated risks to be taken to design and achieve the optimal solution. In this

Enhancement Case, having reliable base data to support modelling, especially within the water treatment aspect, holds the potential to enhance the design process. This data will enable engineers to assess whether a no build/low build or smart build approach can be adopted, resulting in a more refined and optimised solution.

5.2.7. Final Efficiency Potential

The anticipated total efficiency savings across the five core levers applicable to this Enhancement Case is 6.4%. The low to high efficiency range is 2.6% - 11.2%. 6.4% has been incorporated in the anticipated optimism bias necessary for achieving these results.

5.3. We recommend that Ofwat undertake a deep dive on our proposed costs

We have considered the most appropriate approach to assessing efficiency using the framework set out in TMS33 Capital Cost, Efficiency and Assurance. We reviewed the Enhancement Case against each of the criteria to determine whether we could undertake modelling, unit cost comparisons or demonstrate efficiency through our bottom-up engineering estimates.

We believe the only way for Ofwat to effectively assess costs at PR24 would be to carry out a deep dive exercise on our proposed costs. This is predominantly driven by the lack of a suitable cost driver for econometric modelling. This aligns with the approach Ofwat undertook at PR19.

6. Customer protection

Given the materiality of our programme, we propose a Price Control Deliverable (PCD) for this Enhancement Case.

6.1. Price control deliverable

Table 6.1:Price Control Deliverable mechanism - *Cryptosporidium* Protection

<table>
<tr><td colspan="2">Scheme delivery expectations</td></tr>
<tr><td>Description</td><td>Installing and commissioning of UV treatment processes at Coppermills and Hampton Water Treatment Works, to reduce to the risk posed to customers from the potentially harmful Cryptosporidium oocyst parasites.

Cryptosporidium can enter drinking water supply because of:

• Deficiencies in the slow sand filtration treatment process under certain exogenic environmental conditions, where the breakthrough of active oocysts from Slow Sand Filtration remains viable within the water supply.

UV treatment is installed at the end of the water filtration process, upstream of disinfection, to inactivate any Cryptosporidium oocysts (oocysts are resistant to chlorine disinfection). UV irradiates the parasite by attacking the nucleic acid and preventing it from multiplying, thereby rendering it harmless if ingested.

Through this investment, the company will meet the requirements of the DWI Enforcement Notice [to be finalised] for the specified water treatment works.[54]</td></tr>
<tr><td>Output measurement and reporting</td><td>Number of sites with all UV equipment installed and commissioned, reported to zero decimal places.

The company will report in parallel with the APR, covering interim milestones for each site:

• Detailed design complete
• Civil & MEICA works complete
• UV installation complete
• Commission with UV supplier complete</td></tr>
<tr><td>Assurance</td><td>The company must commission an independent, third-party assurer to assure, to our satisfaction, the above conditions have been met.</td></tr>
<tr><td>Conditions on scheme</td><td>The proposed installation will not 'remove' Cryptosporidium oocysts and instead provide inactivation – nonetheless, oocysts will be rendered harmless (inactivated).

Includes only works identified in this Enhancement Case – other needs & associated programmes of work, even if linked from a delivery perspective, are excluded from these works.</td></tr>
</table>

We propose the following delivery profile:

Deliverable	Unit	Forecast deliverables				
		2025/26	2026/27	2027/28	2028-29	2029/30
Sites with UV installed and commissioned	Number	-	-	1	-	1

[54] As previously stated, the details of the Enforcement Notice which will follow the recently issued Letter of Support

Each site requires several blocks of UV equipment to be installed, which will be programmed around planned site outages and other plant operations to minimise any disruption and mitigate impacts on customers across the AMP. Therefore, the UV units will be installed and then commissioned with the supplier in non-sequential blocks across each site.

We confirm that no third-party funding is required for this Enhancement Case.

6.2. PCD payment

We propose to calculate our end of period PCD payment rate based on an average cost:

PCD payment unit	Calculation *22/23 price base*	PCD payment (£M) *22/23 price base*
£m per site	179.114 ÷ 2	89.572

As per Ofwat's guidance, IN 23/05, we consider where the difference between forecast and actual sites is due to sites that are going to be delivered early in AMP9, this amount should be excluded.

We understand Ofwat will apply cost sharing as part of its draft determinations and the end of period reconciliation will occur with the Totex reconciliation models, including the time value of money adjustment.

6.3. ODI impacts

There are no common or bespoke Performance Commitments that are appropriately protect customers in the event of non- or under-delivery of this Enhancement Case. Although *Cryptosporidium* could impact the 'customer contacts about water quality' Performance Commitment, we have not seen any specific historic impact from this type of event.

6.4. Time incentive (TI)

For late delivery, we propose a time incentive payment rate based on the PCD payment:

TI payment unit	TIM calculation	TI payment (£M)
£M per site	89.572 x 3.5%	3.135

We propose the time incentive payment should be calculated from the difference between forecast deliverable and actual deliverable for each year of the AMP.

7. Adaptive Planning – Long Term Water Quality

We will show how the need and best value, efficient solution for customers is set against a long term delivery strategy and how adaptive planning will ensure that the outcome can still be effectively delivered under different future scenarios.

Adaptive planning provides a framework for exploring how sensitive a plan may be to alternative scenarios, risks, and uncertainties, to ensure that the plan is flexible and resilient to different futures. The approach identifies where thresholds and trigger points for alternative adaptative pathways exist, providing the basis for monitoring and review of the strategy and interventions, mitigating the risk that short-term decision making might reduce or jeopardise choices in the future.

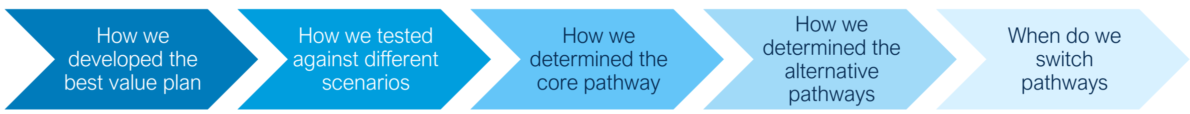
Adaptive pathways provide clarity on the decisions that may need to be taken to address future uncertainties, and agility/flexibility to the latest data; for example, climate science, population growth, or understanding and innovation in the range and type of options that may be deployed. This avoids the risk of being 'locked-in' to specific and inflexible solutions and helps communicate and make more timely decisions on investment.

Adaptive planning is central to Ofwat's LTDS (Long Term Delivery Strategy) guidance. We have followed this guidance by prioritising no- or low-regret activities, demonstrating the benefits of planned investment against future uncertainties and risks; and deferring investment until the benefits are more certain. Our approach to adaptive pathway planning has considered:

- A range of plausible futures
- A broad range of feasible solutions that could be deployed to meet the future scenarios
- Thresholds and trigger points that determine alternative decisions or pathways
- A framework for monitoring against those thresholds and trigger points
- Those solutions that are common to all futures and which may form the core of the strategy formulation
- The range of alternative decision or pathways and the potential trade-offs and risks of investing in emerging options sooner or later

7.1. Best value pathway

The chevron graphic shows how we have structured our narrative on adaptive planning. We identified and showed our best value pathway for this Enhancement Case in the last section, and here we identify potential turning points from that pathway, presenting any alternative(s).



Firstly, our best value pathways for *Cryptosporidium* Protection are provided as a reminder in Table 7.1 (next page), shown in terms of cost and replacement/protection rate per AMP for both elements.

For *Cryptosporidium* Protection this involves complying with the DWI Notice to install technology to prevent active *Cryptosporidium* oocyst being detected in the final water at our 4 SSF LPPs. Previously discussed deliverability restrictions, means that the work required will occur at two sites in AMP8 and the remaining two in AMP9 – our LTDS has no Water triggers before 2035 so adaptive planning will not be applied to *Cryptosporidium* Protection as the work does not extend beyond AMP9.

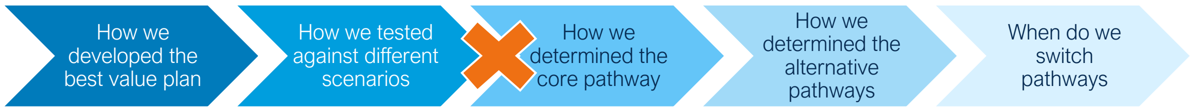
Table 7.1: Best value pathway for each element of this Enhancement Case (22/23 prices)

		AMP8	AMP9	AMP10	AMP11	AMP12
Cryptosporidium Protection	LPPs protected	2/4	4/4	n/a	n/a	n/a
	Totex	£179.114M*	£134.007M**	n/a	n/a	n/a

**Coppermills and Hampton WTWs **Ashford Common and Kempton Park WTWs*

7.2. How we defined scenarios for *Cryptosporidium Protection*

If undertaking a full adaptive planning review, we would now proceed to focus on the subsequent four chevrons, starting with scenario testing.



However, this is the point at which we stop for this Enhancement Case. As stated, this investment is split over only two AMPs, and over such a relatively short period the 'common reference scenarios' in Ofwat's LTDS guidance would not have any material impact on the investment; for the sake of completeness our initial thinking on adaptive planning (to reach the conclusion not to proceed) was:

- Climate change: The *Cryptosporidium* challenge exists now and although an adverse climate change scenario could exacerbate the existing issue further (e.g., even more frequent low flow scenarios, followed by excessive system 'flushing'), installing UV technology is a comprehensive solution and so is appropriate in all scenarios
- Technology: Following our current successful experience with UV technology at some of our WTWs for *Cryptosporidium* inactivation, we would commit to the proposal submitted by our Engineering department (through the best value process) and install the same/similar technology at Coppermills and Hampton WTWs in AMP8; for consistency of operation, supply chain, maintenance, etc across our LPPs, the same technology would be installed at the remaining two sites in AMP9, thereby meaning there is not a scenario where this could change
- Growth: This has zero impact on the investment
- Abstraction reductions: Again, this has zero impact on the investment

7.3. Adaptive pathway summary

In summary the main insights from our adaptive pathway planning for this Enhancement Case is:

- *Cryptosporidium* Protection was not put through the adaptive planning process due to being delivered over only two AMPs (AMPs 8 and 9)

8. Annex A – Summary & Introduction

DWI Letter of Support, reference TMS1 (Enforcement Notice available in due course)

Drinking Water Inspectorate
Area 1A, Nobel House
17 Smith Square
London SW1P 3JR
Enquiries: 0330 041 6501
E-mail: DWI.Enforcement@defra.gov.uk
DWI Website: www.dwi.gov.uk

DWI reference: TMS1

30 August 2023

Ms Caroline Sheridan
Asset Strategy and Planning Director
Thames Water Utilities Ltd
Clearwater Court
Vastern Road
Reading
Berkshire
RG1 8DB

Dear Ms Sheridan

Periodic Review 2024: Thames Water Utilities Ltd

DWI Scheme reference: TMS1 - Ashford, Kempton, Hampton and Coppermills WTWs - *Cryptosporidium*

Final Decision Letter – Support Proposed Scheme

The Inspectorate has completed its detailed assessment of the scheme proposed by Thames Water Utilities Ltd to install UV treatment process to secure or facilitate compliance with the wholesomeness standard for drinking water quality reasons at Ashford, Kempton, Hampton and Coppermills WTWs (and associated assets as applicable). A summary of the outcome of our assessment of this scheme is attached.

The detailed assessment considered the outcome of the risk assessment report(s) dated 9 June 2022, 17 May 2023 and 16 June 2023, that were submitted to the Inspectorate as required by regulation 28(1) of the Water Supply (Water Quality) Regulations 2016 (as amended) for Ashford, Kempton, Hampton and Coppermills WTWs (and associated assets as applicable).

Based on the information submitted by the company, the Inspectorate **supports** the need for this scheme, for water quality reasons, and the supported scheme shall be included by the company in its Final Business Plan, subject to the caveats listed in the attachment.

Consequently, a blank regulation 28(4) notice template has been attached to this letter for the company's review. I would be grateful if the company could add measures as appropriate, to this template and submit the completed template to DWI.Enforcement@defra.gov.uk by 30 November 2023.

I am copying this letter to

- Paul Martin, Ofwat;
- Richard Thompson and Anne Dacey, Environment Agency;
- Alice Laycock and Emma Clancy, CCWater.

Yours sincerely

Nicholas Adjei

Deputy Chief Inspector, on behalf of the Secretary of State for Environment, Food and Rural Affairs

Cc Marsha Darby, Thames Water Utilities Ltd
Cc Simon Benton, Principal Inspector (Enforcement), Drinking Water Inspectorate
Cc Andy Hartshorn, Company Liaison Inspector, Drinking Water Inspectorate
Cc Martin Bird, Principal Inspector, Drinking Water Inspectorate

8.1. Protecting drinking water quality and safeguarding public health Policy POL131

Protecting drinking water quality and safeguarding public health

At Thames Water, we're committed to providing a safe water supply that maintains customer confidence. This policy is endorsed by our Executive Leadership Team and our employees will be responsible for its delivery.

To protect public health while carrying out our supply activities and providing the best value for our customers, we'll:

- Aspire to be, and be recognised as, the industry leader for our approach to protecting drinking water quality and safeguarding public health
- As a minimum comply with all drinking water quality regulatory requirements and internal standards
- Maintain a risk-based approach for the effective management of our drinking water supply assets, and use this knowledge to drive effective investment strategies
- Identify and manage any public health risks, from catchment to consumer, by employing a risk-based drinking water safety plan approach, which delivers timely mitigation of risks
- Work in partnership with all stakeholders including regulators, health agencies and our customers, seeking advice from qualified external experts where required
- Ensure our customers' needs are understood and satisfied, with any complaints resolved as quickly as possible
- Embed a quality management system to assure compliance with all our public health procedures
- Ensure operational practices and responsibilities are documented and reviewed regularly in accordance with our quality management system
- Exercise effective reporting mechanisms and transparently report activities relevant to public health and regulatory compliance
- Empower all employees to act where a water supply risk exists to protect public health
- Ensure that all employees and contractors are trained to be both competent and confident to carry out assigned work; we'll monitor this through regular audit and assessment
- Managers will create an environment where our employees and contractors are motivated, supported and competent to deliver the best for our customers
- Ensure that our Executive Team, and where appropriate members of the Thames Water Board, undertake training in drinking water quality and public health protection matters
- Provide the resources needed to maintain resilient assets and reduce single points of failure and vulnerability
- Respond and manage incidents, in an appropriately timely manner and in accordance with our established incident protocols, to resolve any public health issues
- Participate in discussion and research to influence the development of industry regulations, guidelines, best practice and other standards relevant to public health
- Ensure that our approach to public health protection continuously improves by utilising internal and independent external audits, as well as practice exercises and adopting incident learning

Scope

All employees and contractors involved in the supply of drinking water.

Roles

- All employees and contractors involved in the supply of drinking water are responsible for understanding, implementing, maintaining and continuously improving our approach to water quality and public health protection, and identifying investment needs. They must ensure that their actions align with this policy and speak up if there is deviation from it.
- Managers shall ensure all employees understand their responsibility for maintaining our approach to water quality and public health protection.
- Executives must conduct all business in line with this policy and our core business values.
- The Asset, Digital & Transformation Director is accountable for this policy, for ensuring that it's regularly reviewed and that our performance to these commitments is reported routinely to our Executive team and the Thames Water Board.

Contacting us

For questions, comments or feedback relating to this policy, you can contact us through https://www.thameswater.co.uk/contact-us

If you have any concern about any issues relating to our protecting drinking water quality and safeguarding public health performance or management arrangements, you can contact the policy sponsor.

For concerns regarding dishonest or unethical behaviour, please contact us on any of the following:

- Speak to us in confidence 07747 640 072 investigations@tha
- Report anonymously 0800 917 6936 thameswaterspeakup.co.uk
- Write to the CEO Thames Water Utilities Ltd Clearwater Court Reading RG1 8DB

If you are an employee of Thames Water, you can also speak with your Line Manager.

Useful references

- Asset Management policy
- Environment policy
- Disinfection of Drinking Water Code of Practice

Key legislation:

- Water Industry Act (1991)
- Water Supply (Water Quality) Regulations (2016) as amended

Policy Exec Sponsor: John Beaumont, Director of Asset Management

Approval date: November 2020

9. Annex B – Need for enhancement investment

9.1. Further information on SSFs

SSF LPPs provide most of London's water supply served by Thames Water [redacted] Ashford Common WTW, for example, is one of the most cost efficient sites in the country, being nearly 3 times cheaper (@£23.23/Mld) than the industry average of £65.65/Mld [redacted]

An example of the history and longevity of SSFs for treating water to a high standard is Hampton WTW. It was initially built in 1855 after the 1852 Metropolis Water Act banned abstraction down stream of Teddington Weir, initially as three neighbouring WTWs by the Grand Junction, West Middlesex, and Southern & Vauxhall water companies before being merged and control by the Metropolitan Water Board in 1904. Filtration was the primary treatment process from its inception, with slow sand filtration starting to be installed from the 1890s. Expansion, remodelling and a multi-barrier approach occurred over the years, but it remains a fact that slow sand filtration has been deployed largely unchanged for over 130 years, acting as the 'work horse' of the water purification process at Hampton WTW. The other three SSF LPPs are very similar in terms treatment technology, utilising SSFs for 116 years (Kempton) and over 51 years at Ashford Common and Coppermills WTWs. The last major change to the LPPs multi-barrier process was in the 1990s with the installation of ozonation and granular activated carbon primarily for pesticide treatment (causing health hazards and taste odour issues).

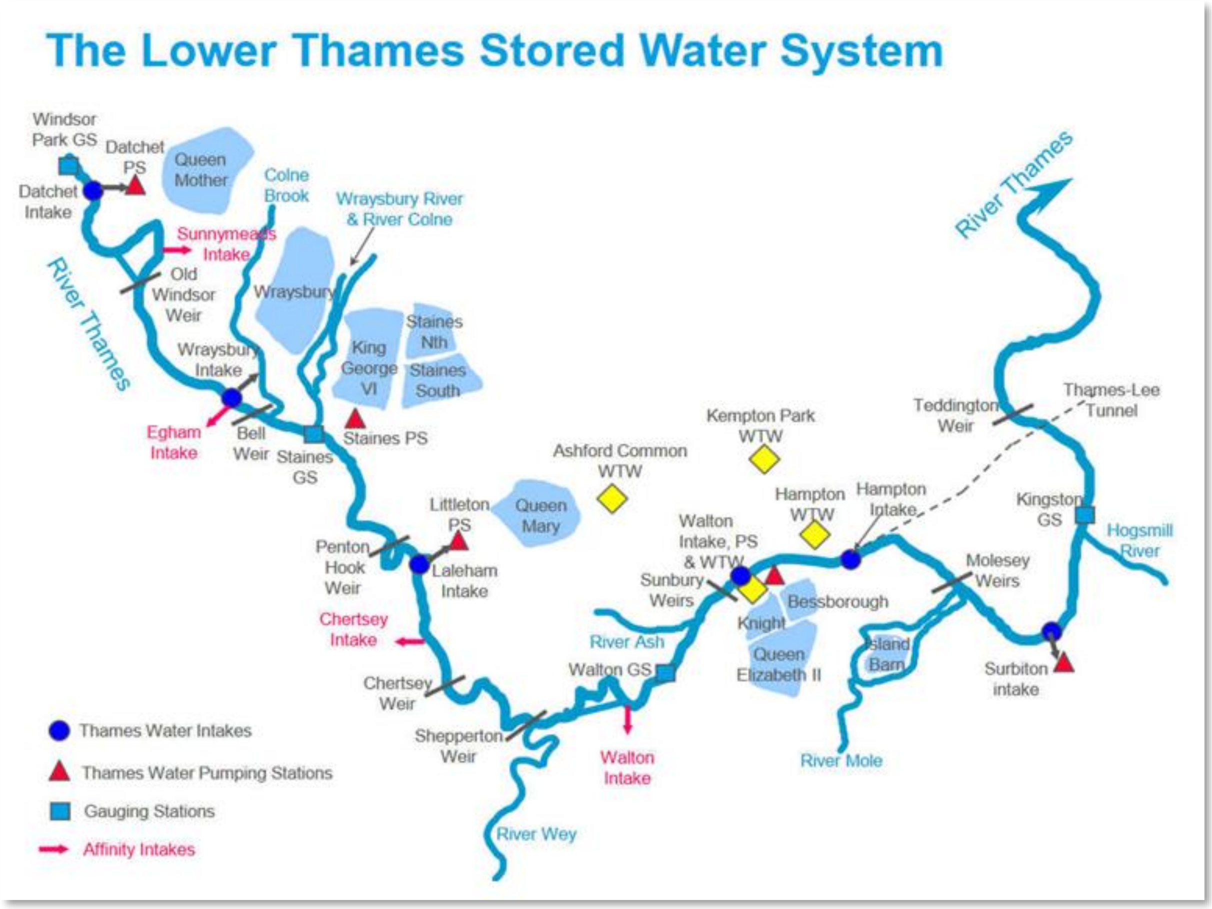
In summary, this legacy technology (SSFs) has not been supported with any fundamental changes for the last 30 years and as water quality compliance expectations and legislation has increased significantly over that time, the problem is becoming more acute, and improvements are overdue.

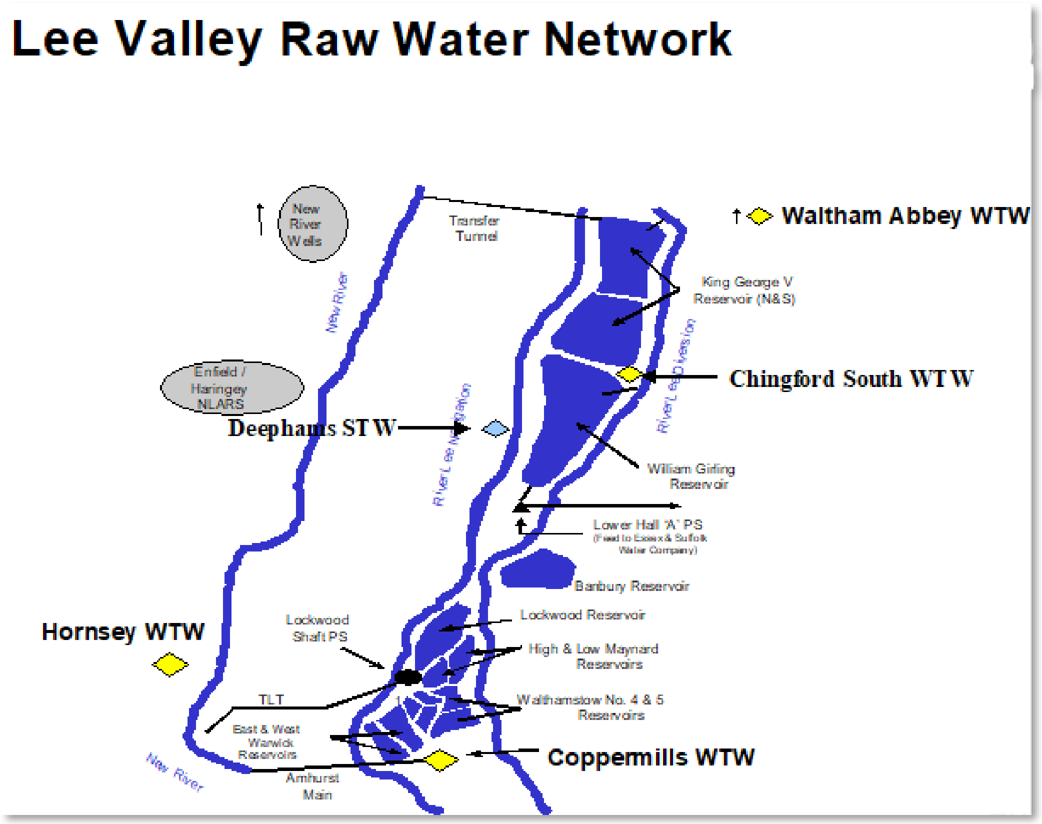
Figure 9.1: Labour intensive SSF cleaning well in to the 1950s at Hampton WTW

9.2. Schematics of abstraction points, storage reservoirs and WTWs in London

1. Lower Thames Stored Water System – showing abstraction points to the West of London which supply, via storage reservoirs to 4 x LPPs in West London (Ashford Common, Hampton & Kempton Park are SSF Works; there is also the Thames Lee Tunnel intake at Hampton which transfers River Thames water into the North London reservoir system and into Coppermills WTW
2. Lee Stored Water System – showing abstraction points down the River Lee which supply, again via storage reservoirs, Coppermills WTW

[55] Taken from company supplied Ofwat data (APR)


The Lower Thames Stored Water System
Windsor Park GS
Datchet PS
Datchet Intake
Queen Mother
Colne Brook
Wraysbury River & River Colne
Sunnymeads Intake
Old Windsor Weir
Wraysbury
River Thames
Wraysbury Intake
King George VI
Staines Nth
Staines South
Egham Intake
Bell Weir
Staines GS
Staines PS
Ashford Common WTW
Kempton Park WTW
Teddington Weir
Thames-Lee Tunnel
River Thames
Littleton PS
Queen Mary
Penton Hook Weir
Laleham Intake
Chertsey Intake
Walton Intake, PS & WTW
Hampton WTW
Hampton Intake
Kingston GS
Hogsmill River
Molesey Weirs
Sunbury Weirs
Bessborough
Knight
River Ash
Queen Elizabeth II
Island Barn
Surbiton intake
Walton GS
Chertsey Weir
Shepperton Weir
Walton Intake
River Mole
River Wey
Thames Water Intakes
Thames Water Pumping Stations
Gauging Stations
Affinity Intakes


Lee Valley Raw Water Network
New River Wells
Transfer Tunnel
Waltham Abbey WTW
New River
King George V Reservoir (N&S)
Chingford South WTW
Enfield / Haringey NLARS
River Lee Diversion
Deephams STW
River Lee Navigation
William Girling Reservoir
Lower Hall 'A' PS
Banbury Reservoir
Lockwood Reservoir
Lockwood Shaft PS
Hornsey WTW
High & Low Maynard Reservoirs
TLT
Walthamstow No. 4 & 5 Reservoirs
East & West Warwick Reservoirs
Coppermills WTW
New River
Amhurst Main

10. Annex C – Best options for customers

10.1. Initial consideration of options followed by narrative

To determine feasible solutions to solve the need(s), a qualitative assessment of the two elements of the case was undertaken, across thirteen potential option categories and mirroring (from Option 3 onwards) a 'source-to-tap' process flow. Table summarises our conclusions, with relevant follow on narrative discussing the high level likely effectiveness, feasibility, and cost benefit of the various potential options.

Table C.1: Initial consideration & description of option categories to solve the need(s)

Ref.	Option Category	Option Description *Cryptosporidium* Protection
1	Do nothing	Stop work to improve LPP performance, either proactively or part of DWI transformation
2	Reactive	Deliver Public Health Plan by satisfactorily completing all parameters under DWI Notices (including those relating to *Cryptosporidium* and London SSF), and take a reactive approach to Drinking Water Safety Plan (Hazard Review) risks
Note	*Source water*	*Different catchments pose different Cryptosporidium risks at different times of the year and/or climate cycle*
3	Catchment Partnerships and raising awareness	Influencing and/or supporting catchment partners to have a positive impact, through behavioural change, on the environment and therefore reducing the levels of *Cryptosporidium* (and other contaminants) in the raw water we abstract
4	Catchment Interventions Catchment funds	Mitigate *Cryptosporidium* risks in the catchment by funding farmers to change farming practices or deploy technology
5	Catchment Interventions (nature-based solutions)	Mitigate *Cryptosporidium* risks in the catchment with nature based catchment technology
6	Catchment monitoring (including Sewage Treatment Works (STW) discharges & overflows)	Integrated catchment monitoring (combining online and manual sampling), linking water quality and flow data (possibly open source) to our abstraction sites
7	Tertiary treatment at STWs	Installing appropriate tertiary treatment (e.g., UV) at STWs upstream of abstraction points to target *Cryptosporidium hominis* in particular
8	Abstraction Management	Using existing and/or new water quality parameters to manage when to stop and re-start abstracting from river sources
9	Pre-treatment (stored water)	Install *Cryptosporidium* treatment for stored water transfer to reduce loading onto WTWs
10	Treatment (at WTWs)	Install a barrier or treatment solution at WTWs (e.g., UV or chemical coagulation process)
11	Treatment (in the Water Network)	n/a - *Potable water assessed at statutory sample tap (6) on a WTW, so downstream 'treatment' not appropriate*
12	Network Investment (including possible customer side pipe removals)	n/a - *Potable water assessed at statutory sample tap (6) on a WTW, so downstream 'treatment' not appropriate*
13	Point of use protection	n/a - *Potable water assessed at statutory sample tap (6) on a WTW, so downstream 'treatment' not appropriate*

10.1.1. Option 1 – Do Nothing

For Cryptosporidium, there cannot be 'do nothing' option, as there are numerous related regulations water companies must legally comply with, so:

Cryptosporidium – we have a legal obligation under the Water Supply (Water Quality) Regulations 2016 (Section 27[56]) to assess catchment & supply system risks, and then have appropriate downstream measures (Section 26) to protect the quality of drinking water; we also have number of DWI Enforcement Notices with associated activities and actions to enable close within a designated timeframe. Adopting a 'do nothing' approach would be a failure to comply with the regulations and would Lead to prosecutions and a threat to our operating licence.

10.1.2. Option 2 – Reactive

Cryptosporidium – this approach would employ a reactive-only approach to respond to risks and maintain the minimum compliance to water quality regulations, and just fulfil the obligations of the current (and future) DWI Enforcement Notices – this would mean a stop to other aspects of the Operations-Public Health Plan and probably keep the company in transformation with the DWI for many years, being under ever increasing scrutiny (a different approach would be to extend activities to include the more proactive elements of the Public Health Plan from AMP7 through AMP8 which would bring many positive impacts on the operation, maintenance, and risk reduction of our above ground assets). However, either the purely reactive, or a more proactive approach, would not solve the inherent treatment deficiency of the SSFs and detections of *Cryptosporidium* at the final sample taps at our four (SSF) LPPs in London will continue, risking public health and leading to DWI prosecutions.

10.1.3. Option 3 – Catchment partnerships and raising awareness

Cryptosporidium – this is around working with a variety of partners across all catchments (prioritising those which feed abstraction points in West and North East London – i.e., those supplying raw water to our SSFs Works). It is a low to no cost option which aims to educate, influence, and support those how can make a positive impact on the environment and therefore the raw water quality we abstract, for a wide cross-section of contaminants. A recent example is that for metaldehyde (slug treatment) where we worked with farmers to use effective alternatives.

10.1.4. Option 4 – Catchment interventions / Catchment funds

Cryptosporidium – these funding options for farmers are aimed primarily at pesticide and nitrate control but could assist with reducing *Cryptosporidium* loadings from agricultural sources too. Farmers can be funded to deploy alternative technology, land and/or animal management to mitigate water quality risks. As an example, Figure 10.1[57] shows some interventions cattle farmers to mitigate Cryptosporidiosis entering the environment, including changes to husbandry practices and vaccination treatments for cattle.

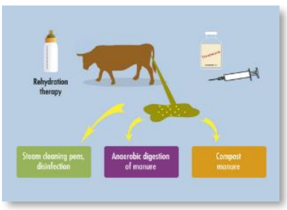


Figure 10.1: (left) Interventions to Reduce the Impact of Cryptosporidiosis in Cattle and Environmental Contamination, (above) Extracts from Thames Water Catchment Fund Handbook

[56] Section 27(2): 'Every water undertaker…must carry out a risk assessment of each of its treatment works and connected supply system in order to establish whether there is a significant risk of supplying water from those works or supply system that could constitute a potential danger to human health or is likely to be unwholesome'

[57] Trends in Parasitology, March 2020, Vol. 36, No. 3

10.1.5. Option 5 – Catchment interventions – nature-based solutions

Cryptosporidium – working in partnerships (part funding) or direct funding nature-based catchment interventions designed to slow or re-direct high run off and/or river flows, especially at higher water flow in times of higher *Cryptosporidium* periods and downstream of potentially higher contamination sources. The same (or alternative) interventions could also provide low maintenance and nature enhancing 'treatment' for *Cryptosporidium*.

10.1.6. Option 6 – Catchment monitoring (including Sewage Treatment Works discharges & overflows)

Cryptosporidium – general improvements in monitoring across the catchment for both water quality and flow data are important to understand risk, opportunities and provide insight to make better abstraction and treatment decisions. From a *Cryptosporidium* perspective, it could be relatively simple to provide existing data from potential point sources such as STW discharges (storm and dry weather flow) and overflow data, to abstraction teams downstream – in the future, this could also be extended to water quality monitoring and semi-automate starting and stopping of river pumping at abstraction points.

10.1.7. Option 7 – Tertiary treatment at STWs

Cryptosporidium - tertiary treatment technology to 'treat' *Cryptosporidium* is available and has been successfully installed at sewage treatment works throughout the world. It could be useful for future direct re-use schemes – i.e., where sewage effluent is further treated before being piped to a storage reservoir or direct to a water treatment works – but would be less beneficial if discharged in to rivers or in catchments with more environmental or agricultural sources of *Cryptosporidium*.

10.1.8. Option 8 – Abstraction Management

Cryptosporidium – abstraction management is already undertaken to manage water quality and storage levels in our storage reservoirs and is particularly important during low flow or flood conditions in rivers. Online water quality monitoring and manual sampling complement visual inspections of the river intake and discussions with the Environment Agency, and abstraction teams then use standard response procedures to determine when, where and how much to start/stop or increase/decrease river pumps. As stated in Section 3 (need for investment), using turbidity as an on-line water quality parameter is not an accurate indication of the *Cryptosporidium* concentrations in raw water due to poor correlation, but good abstraction management is essential to for good reservoir storage and water quality, and protect the environment from which water is abstracted.

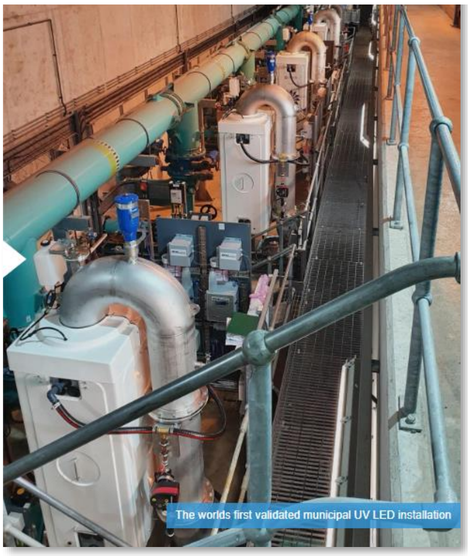
10.1.9. Option 9 – Pre-treatment (stored water transfer)

Cryptosporidium – this approach would install *Cryptosporidium* treatment in between the outlet of the storage reservoir(s) and water treatment works to either partially or totally remove/de-activate *Cryptosporidium*. This could be physical or chemical treatment process or perhaps a more nature-based one. It is not deemed a viable, cost-effective option due to stored water quality and would not protect final treated water as there are open bodies of water (including SSFs) which could be exposed to *Cryptosporidium* contamination, although to a much lower level.

10.1.10. Option 10 – Treatment (at WTWs)

Cryptosporidium – installing UV (see Figure 10.2 as an example)[58] or membranes post SSFs on the WTWs is the only way to provide the required level of in-activation or removal of *Cryptosporidium* from final treated water. An alternative could be front end chemical coagulation and covering SSFs – coagulation could have additional benefits like improvements in resistance of the treatment process to high turbidity and/or algal loadings. There is of course an argument to challenge the suitability of SSFs as a treatment process and whether they should be exchanged for an alternative(s); the counter argument is that in general terms they offer very effective and efficient treatment and this especially the case on London's LPPs which are some of the largest WTWs in the country – our long term asset strategy is to retain SSFs and reduce loadings of contaminants through upstream interventions or assist with post filter technology.

Figure 10.2 UV LED technology deployed to inactivate *Cryptosporidium* – see footnote [58]



10.1.11. Selected feasible options – further narrative

All options have been screened, see Table C.2 below, to identify a short list of feasible options to be taken through to detailed cost benefit analysis. These factors facilitated decision-making and enabled the choice of a preferred solution.

Table C.2 Selected options with decision on whether to progress further

Option		Comment	Progress?	Enhancement?
1	Do nothing	*Cryptosporidium* – unacceptable public health risk, does not comply with minimum standards set out in water quality legislation, and does not solve the need for investment	Reject	n/a
2	Reactive	*Cryptosporidium* – does not address inherent treatment issues with SSFs which exist now and present a risk to public health & water quality	Reject	n/a

[58] Take from: UV LED - Typhon deliver Mercury Free UV Disinfection using UVC LED (typhontreatment.com)

		compliance, even with operational mitigation		
3	Catchment Partnerships and raising awareness	*Cryptosporidium* – difficult to quantify benefits and could take many years to have a tangible impact on raw water quality. However, it is probably the right thing to do to have a wider positive impact on the environment and engender good relationships with our communities.	Potential	No *Awareness campaigns & farmer events covered under base allowance*
4	Catchment Interventions Catchment funds	*Cryptosporidium* – Catchment funding is already provided to farmers, primarily for nitrate and pesticide control, but this could be targeted for *Cryptosporidium* protection, especially if combined with catchment monitoring (see point 6)	Potential	No *Catchment Funds funded through base allowance*
5	Catchment Interventions (nature-based solutions)	*Cryptosporidium* – as with other catchment interventions (see Options 3 & 4) nature based solutions could provide multi-benefits, but for *Cryptosporidium* better information around sources of contamination is required before having confidence of the benefits	Reject	n/a
6	Catchment monitoring (including Sewage Treatment Works (STW) discharges & overflows)	*Cryptosporidium* – could provide a relatively simple way to use existing (internal) data to make better informed abstraction decisions	Potential	No *Any scheme would be covered under base allowance*
7	Tertiary treatment at STWs	*Cryptosporidium* – only treats part of the problem and would not be cost beneficial in catchments with more environmental or agricultural sources of *Cryptosporidium*	Reject	n/a
8	Abstraction Management	*Cryptosporidium* – essential for good reservoir storage and water quality; should be combined with improved catchment monitoring (see Option 6)	Potential	No *Any scheme would be covered under base allowance*
9	Pre-treatment (stored water transfer)	*Cryptosporidium* – not deemed a viable, cost-effective solution and does not give total protection for final treated water	Reject	n/a
10	Treatment (at WTWs)	*Cryptosporidium* – installing appropriate treatment post SSFs is the only way to guarantee Cryptosporidium de-activation or removal in/from final treated water	Preferred (see further optioneering below table)	Yes *This would be enhancement*

10.1.12. Discussion of the preferred option for *Cryptosporidium* Protection and further investment

Our preferred option for *Cryptosporidium* Protection:

- (Option 10 - Enhancement): Install an appropriate treatment option post SSF (namely UV) at Coppermills, Hampton, Ashford Common and Kempton Park WTWs

- There are more options to support – not replace – the preferred solution, but these would be delivered through our base allowance. These are centred around up upstream 'interventions' which will have an impact on more than just *Cryptosporidium* loadings and treatment efficiency onto the WTWs, but on their own or even combined would not achieve the need; however, there is merit in considering them in the context of *Cryptosporidium* protection and are listed below with some detail on the outputs / benefits they could provide:

- (Option 3 - Base): Catchment Partnerships
  - The Smarter Water Catchment initiative is to be extended in AMP8 and the farmer and other catchment education programme led by the Catchment team – both activities, especially the latter, can reduce agricultural and other *Cryptosporidium* sources
- (Option 4 - Base): Catchment Interventions
  - Although primarily focussed on controlling and investigating pesticides and nitrates entering the environment from agricultural practices, through providing funding to farmers through the Catchment Fund and targeted catchment sampling investigations, we are proposing an investigation to understand *Cryptosporidium* sources better in some catchments and it is expected that some Catchment Fund applications will benefit *Cryptosporidium* loadings. These are funded through our base allowance.
- (Option 6 - Base): Catchment Monitoring
  - As mentioned for Option 4, we propose to build our expertise in catchment management to increase our team of catchment technicians to work with landowners to manage risk from livestock (*C. Andersoni, C. parvum* and *C. baileyi*) at source; internally, we propose to building an automatic linkage between sewage treatment works and combined storm overflows, time of travel models and abstraction systems to minimise the risk from *C. hominis*.
- (Option 8 - Base): Abstraction Management
  - (Linked to Option 6) We propose to establish enhanced catchment monitoring for *Cryptosporidium* oocysts by building a sampling programme from points at least 24 hours upstream of abstraction points and equipping the laboratory to turn these samples around within an enhanced timescale. We will then use this data with established time of travel models to develop and implement our intelligent abstraction system – minimising the abstraction of *Cryptosporidium* oocysts into the raw water storage reservoirs
  - We propose to expand our Computational Fluid Dynamics (CFD) studies to understand whether there are any further opportunities to maximise retention within the raw water storage reservoirs – for example, by the installation of bubble mixers

10.1.13. Post Coarse Screening workshop review of post-SSF ozonation – further details

At the workshop it was discussed that while the installation of a post-SSF ozonation process may be an effective *Cryptosporidium* barrier, it could also introduce an unacceptable risk of bromate formation.

Therefore, after the workshop a high-level calculation was done to assess this risk as follows:

- Based on Twort[59] the Ct value required at 5°C (a standard winter temperature for water at Coppermills) for ozone to achieve a 2-log reduction in *Cryptosporidium* is 32 mg.min/l. With a 10 minute contact times this means the ozone residual at the outlet of the contact zone is 3.2 mg/l
- Assuming a half-life for ozone of 2.5 minutes, this means an initial ozone does of 3.2 x 2^4 = 51.2 mg/l
- Based on water quality data the highest concentration of bromide seen at Coppermills is around 0.1mg/l – at such a high ozone concentration it is likely that a bromate concentration for higher than the PCV (prescribed concentration or value) of 10 µg/l would be formed

As a result of this, it was deemed by key stakeholders post-workshop that ozonation would not be a viable option, and therefore this option was also screened out.

10.1.14. Further narrative supporting capital investment as a best value solution for Cryptosporidium

We believe that this is the best value option for customers, although not the least cost. The least cost option would be to make no increased investment, but this is unacceptable to our customers and the DWI as it does not protect consumers from the public health risk presented by *Cryptosporidium*. The proposed (full) capital investment of ~£313M provides a UV treatment solution post-SSF at Coppermills, Hampton, Ashford Common and Kempton Park WTW in London, reducing to negligible the risk of *Cryptosporidium* active detections in [redacted] treated water supplying Londoners. We have estimated c.£200k for the catchment elements, but they will be funded through the base allowance as have benefits above just *Cryptosporidium* protection. This proposed treatment approach deals effectively and sustainably with the seasonal risk from *Cryptosporidium* oocysts but has two other major benefits, both of which help protect water quality and both of which significantly improve the resilience of supply to customers into the long term. The three benefits arising from the treatment element of our proposal are:

- Water Quality: The installation and seasonal operation of post SSF UV units would effectively, decisively, and sustainably eliminate the seasonal risk from *Cryptosporidium* by inactivating any that pass through the SSFs
- Summer Resilience: The installation and operation these individual post SSF UV units would enable individual SSFs to be returned to service more reliably during the summer, by improving microbiological compliance following a filter bed skim; this would result in increased certainty of return to service times, to provide a significant benefit during the summer, when supply headroom within London is very low
- Climate change resilience: Notes included in main document

[59] *Twort's Water Supply*, Johnson M., Ratnayaka D. and Brandt M., 6th Edition, 2009, Section 6.63

[60] [redacted]

For the treatment solution, risks and uncertainties do exist but not with the efficacy of the treatment process – this is proven and used within the company already (improvements with lamp technology will undoubtedly reduce running costs, especially if combined with photo-voltaic installations). The deliver of these solutions will not be without risk though - to be successful will rely on the delivery programme being effectively planned around SSF cleans and rebuilds, and other programmes of works and outages on sites (for example, recirculation project at Coppermills WTW). Examples of what will need to be considered:

- Working across sites co-currently and flexibly
- AMP7 planning and design
- Buying UV contactors up front
- Commissioning in 'blocks' or waiting until later in the AMP to commission all sites, alongside suppliers

With co-ordinated and innovative planning, including applying some of the suggestions above, delivery and outage should not be a blocker. Nor should any weather impact – for example, summer drought, coupled with high demand – as SSFs need to be removed from supply to clean and rebuild (GAC regeneration or re-sand or floor inspections) to comply with asset standards and water quality regulations, so it is more around effective planning over the 5 year period.

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