Thames Water

Final Water Resources Management Plan 2019

Technical Appendices

Appendix K: Process losses

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Process losses

- In this section of the Water Resources Management Plan 2019 (WRMP19) we describe the method for definition of process losses for the Water Resources Management System (WARMS2) model derived from the Thames Water developed Water Treatment Works (WTW) mass balance and resilience models, which are used for water asset management planning purposes
- The process used for derivation of the values in the tables has been included
- We explain how the process losses in Annual Review figures compare to those calculated in WARMS2 for the London Dry Year Annual Average (DYAA) Deployable Output (DO).

A. Introduction

K.1 At any WTW, even very simple plants, for every litre of water that is abstracted from the environment and is treated before passing into the distribution network, a small fraction of the water, known as the waste stream, will be unsuitable for supply. This waste stream carrying the separated raw water contaminants and any additional process water that may be capable of further treatment and recovery.

K.2 The wastewater can arise from plant cleaning, maintenance or for health and safety reasons, for example, eye baths or showers required for health and safety purposes in the event of chemical spillages. The sum of all the waste streams is generally termed the process losses for a plant. The more complex a water treatment plant, with multiple processes, then generally the greater the process losses. Treatment plants are designed to recover, treat and recycle as much of this water as economically possible to limit the volume of water that is lost.

K.3 Process losses are generally presented as a percentage of the raw water that is abstracted, or a percentage of the water that is put into supply. Although these are often presented as a single percentage figure it is important to understand that the process losses will change as a function of the quality of the raw water. As raw water quality deteriorates, then so the volume of the waste stream to remove contaminants also increases resulting in higher process losses, as discussed in Section D: Water Resources Management System of this appendix.

K.4 When considering process losses in the Thames catchment some of these waste streams are treated and discharged to the river directly. Others may be discharged to a sewer and return to a river via a wastewater treatment plant. In many cases this water then supports the flow in the river which can be abstracted downstream. So, whilst this represents a process loss for the WTW itself, it is returned to the environment and is not necessarily lost as a raw water resource.

K.5 In this manner, while individual WTW losses may seem significant, discharge of these losses from the WTW may be supporting downstream abstraction as well as having environmental benefit through increased river flows. In order to meet Environment Agency requirements, and so the operation of wastewater treatment plants, these discharges require the quality of any receiving watercourse to be protected. To increase the recovery of water from these waste streams would require larger, potentially more complex treatment plants. This would incur increased and potentially disproportionate costs for water supply in treating wastewater that already supports downstream abstraction and the environment.

K.6 In our Annual Review we present an operational mass balance for the process losses in the plants linked to reservoir storage (Figure K-1 and Table K-1). The example included here is an operational flow mass balance that reflects the operational practices in that year as well as the climate and water quality conditions. Variability in the mass balance and process losses between years is therefore normal and should be expected.

K.7 We use the simulation computer model entitled WARMS2 to calculate the amount of water we can put into supply as discussed in Section 4: Current and future water supply. This model evaluates the amount of raw water that is available to treat and has input values for WTW capability and process losses.

K.8 Differences between the Annual Review and WARMS2 WTW capability and process losses numbers are a function of operational practices, climate and water quality conditions during the previous year. As noted above, such differences are to be expected.

Figure K-1: Raw water resource mass balance

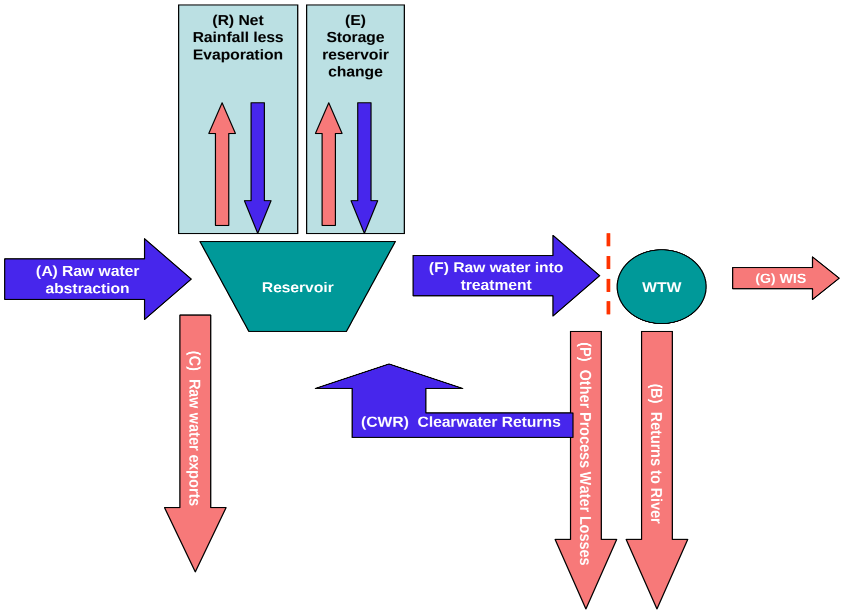


Table K-1: London water balance, units Ml/d

London water balance to calculate process water losses as presented in the Annual Returns				
Ref		**2014/15**	**2015/16**	**2016/17**
A	Raw water abstraction	2294.04	2262.35	2347.61
C	Raw water bulk supply	94.18	81.43	89.03
E	Change in reservoir storage over the year	-13.73	6.43	14.12
R	Net rainfall less evaporation	11.24	8.09	2.39
CWR	Clearwater returns	6.40	13.83	25.20
F	Raw water to WTW (*calculated below*)			
(i)	F = A - C + E + R + CWR	2203.77	2209.27	2300.29
(ii)	F = G + B + P + CWR			
G	Water into supply	2045.80	2070.16	2109.45
B	Returns to river	146.53	64.71	92.42
P	Other process water losses			
	Using equation (ii)			
	P = F - G - B – CWR	5.04	60.57	73.22
	Total losses = P + B	151.57	125.28	165.64
	WARMS2 process water losses from DO calculation	126.19	127.51	127.72
	Difference in Annual Review to WARMS2 modelling assumptions	25.38	-2.23	37.92

B. Water treatment of groundwater sources

K.9 The methodology for the determination of groundwater DO identifies treatment capability and process water losses as key constraints to the amount of water that can be made available. As such the source deployable outputs (SDOs) of groundwater sources that are treated locally, and not transferred to surface water systems for treatment, include process losses as a constraint to supply in their calculation[1]. WARMS2 uses groundwater SDOs in its calculations and does not identify the process losses at each of the groundwater sources.

C. Water treatment of surface water sources

K.10 WARMS2 uses surface water treatment capability and associated process water losses in its calculation of DO as set out in Section 4: Current and future water supply.

[1] Procedure for the Assessment of Groundwater Source Deployable Outputs 2017, Groundwater Resources, Water Strategy, Planning and Assurance

K.11 We have developed mass balance and resilience models for all WTWs in each water supply zone. These models form a structured, auditable basis for defining our WTW capability and process losses. The WTW mass balance and resilience models enable assessment of historical seasonal variations in raw water quality as well as potential future climate change challenges.

D. Water Resources Management System

K.12 The water resource planning model WARMS2 uses a single value for process water losses for each individual WTW; this is an average of the process losses for that WTW, weighted to reflect the impact of variable raw water quality. Where process losses return to the river and increase flow in the river or watercourse downstream, this is included in the available water modelled in WARMS2 and, therefore, the calculation of DO. In the draft WRMP19, WARMS2 used process losses that were developed and used in the Water Resources Management Plan 2014 (WRMP14). However, for the final WRMP19 development of the WTW mass balance and resilience models[2] has progressed, enabling a better understanding of the process losses at the large surface WTWs, which has been incorporated in WARMS2 for the purposes of the calculation of DO for inclusion in the revised draft WRMP.

K.13 A worked example has been provided in Table K-2 that gives the output for process losses for Coppermills WTW, which reflects the raw water quality conditions described in paragraph K.16 below. These are derived from the mass balance and resilience model for Coppermills. The model defines the process losses anticipated under different raw water quality conditions, in particular, algal bloom challenges in the stored raw water systems, which can affect the volume of the treatment process water losses and consequentially the output of the WTW. For all sites the Standards Scenario 1 represents the WTW process losses with average water quality data, designed and operated in accordance with the Asset Standard. The Base Case (Scenario 2) represents the current design and operation including any agreed deviations from asset standards[3], with average site water quality data. Algal Scenarios 3 and 4 use the Base Case model with deteriorating water quality expected in a defined period for algal blooms of varying severity.

K.14 In any given year the WTW can experience a severe algal bloom and it is evident that there will be a change in process losses during such a period. Historically in the Thames catchment we have algal bloom challenges during spring and autumn, each bloom lasting four to six weeks, although there is evidence that this is changing. Typically the input to the WARMS2 model is calculated assuming ten months of average water quality in a year and two months of 1 in 1 year algal bloom challenge, e.g. for Hampton, Ashford Common and Kempton Park; but this is different for other WTWs, including for example, Coppermills and Chingford, reflecting differences in the quality of the source waters and the treatment process.

[2] For each WTW, a model of the treatment process from abstraction through to disinfection has been developed to represent water flows through each stage of the process. The models account for factors such as asset capability (e.g. pump and filtration capability), process operation (e.g. filter cleaning times, process water use), and water quality standards (e.g. disinfection policy, potable water requirements). For a range of raw water quality scenarios, the models calculate treated water outputs and process water losses.

[3] These include risk-based exemptions from internal standards that are approved and documented in the Site Operating Manuals for each WTW.

Table K-2: WARMS2 process losses for Coppermills

Coppermills	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Standards	Base case average quality	1 in 1 year algal	1 in 5 year algal
Percentage losses	2.9%	2.9%	4.5%	18.6%
DYAA figure		7.4%		

K.15 At Coppermills the waste flow streams are treated to recover 35 Ml/d of treated water for use. In a severe algal bloom however, the plant is likely to be operating at a reduced throughput as a result of increased filter bed backwashing and recovery time.

K.16 The process losses for Coppermills reflect historical raw water conditions in the north London raw water reservoirs, including algal blooms of varying severity, and assume five months of average water quality and four months of a 1 in 1 year algal challenge, plus three months of 1 in 5 year algal challenge. As a result, the potential DYAA losses amount to 7.4% of the plant water flow minus the 35 Ml/d process losses which can be recovered. The WARMS2 model uses the DYAA 7.4% process losses for Coppermills in the calculation of the London WRZ DO and also takes into account the recovery of up to 35 Ml/d of the wastewater.

E. Process loss figures

K.17 Table K-3 to Table K-12 give details of the WTW process losses that are input into the WARMS2 model and used in the Water Resource Zone (WRZ) DO assessments. As discussed above, they are derived from the WTW mass balance and resilience models.

Hampton WTW

K.18 The washwater treatment process that produces wastewater at Hampton uses a system to collect and clarify the washwater. After clarification the water is discharged to the River Thames under Environment Agency consent.

Table K-3: Process losses for Hampton

Hampton	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Standards	Base case average quality	1 in 1 year algal	1 in 5 year algal
Percentage losses	2.19%	2.32%	8.94%	12.5%
DYAA figure		3.4%		

Ashford Common WTW

K.19 The washwater at Ashford Common is collected and clarified. After clarification the wastewater that is produced is discharged to the River Thames under Environment Agency consent.

Table K-4: Process losses for Ashford Common

Ashford Common	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Standards	Base case average quality	1 in 1 year algal	1 in 5 year algal
Percentage losses	1.92%	1.94%	4.25%	8.81%
DYAA figure		2.3%		

Kempton Park

K.20 Dirty washwater is collected and treated before the wastewater that is produced is discharged back into the River Thames via a tributary. The sludge produced is disposed of directly to a sewer.

Table K-5: Process losses for Kempton Park

Kempton Park	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Standards	Base case average quality	1 in 1 year algal	1 in 5 year algal
Percentage losses	1.06%	1.05%	1.49%	2.44%
DYAA figure		1.1%		

Walton WTW

K.21 Dirty washwater is collected, chemically treated, clarified and filtered before the wastewater that is produced is discharged back into the River Thames. The sludge is collected and thickened before being disposed of to a sewer. This is a very small percentage of the washwater flow. The receiving sewage treatment works (STW) discharges its final effluent into the River Thames upstream of Teddington weir.

Table K-6: Process losses for Walton

Walton	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Standards	Base case average quality	1 in 1 year algal	1 in 5 year algal
Percentage losses	4.27%	4.99%	15.4%	20.7%
DYAA figure		6.7%		

Hornsey WTW

K.22 The process loss input to WARMS2 is calculated assuming ten months of average water quality in a year and two months of 1 in 1 year water quality challenge. The process washwater is treated through a clarification process. This produces a high quality clarified wastewater stream that can be recovered to the head of the WTW, minimising the process losses. This is recovered about 80% of the time when the WTW is in operation as operationally we will not recover the water if there is a water quality risk (i.e. 20% of the time). Table K-7 shows how this average value for the process losses has been calculated.

Table K-7: Process losses for Hornsey

Hornsey	Scenario 1	Scenario 2	Scenario 3
	Base case average quality	1 in 1 year water quality	Maximum water quality challenge
Percentage loss: water recovery	1.61%	2.08%	17.6%
Average for year with recovery	1.69%		
Percentage losses: no water recovery	15.0%	21.4%	58.1%
Average for year without recovery	16.1%		
DYAA figure	4.6%		

Chingford WTW

K.23 The process washwater is treated through a clarification process. This produces a high quality clarified wastewater stream which can be recovered to the head of the WTW, minimising the process losses. This is recovered about 80% of the time when the WTW is in operation as operationally we will not recover the water if there is a water quality risk (i.e. 20% of the time). This is calculated in the same manner as with the Hornsey WTW, with the average values presented in Table K-8 below.

Table K-8: Process losses for Chingford

Chingford	Scenario 1	Scenario 2
	Average for year with recovery	Average for year without recovery
Percentage losses	0.20%	2.86%
DYAA figure	0.7%	

Gateway WTW

K.24 The Thames Water Gateway WTW is a desalination plant treating water from the Thames tidal estuary. As the raw water is abstracted from the Thames estuary and the process losses are returned to the estuary, there is no recycling of the process losses. As a result of this way that the plant functions, the treated water output from the Gateway WTW is an input into the WARMS2 model without needing to account for modelled process losses.

Shalford WTW

K.25 The process washwater at Shalford is collected, treated and recovered. Residual wastewater flow is treated and discharged to the river under Environment Agency consent. The WTW process loss figures included in Table K-9 and used in the WRZ DO assessments have been reviewed to ensure confidence in the calculated WTW capability and thus the SDO.

Table K-9: Process losses for Shalford

Shalford	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Standards	Base case average quality	1 in 1 year quality challenge	1 in 5 quality challenge
Percentage losses	5.01%	5.01%	7.12%	15.1%
DYAA figure		5.3%		

Farmoor WTW

K.26 The process washwater is treated to a sufficiently high quality so that the resultant wastewater stream can be recovered to the head of the WTW. A process loss value of 6.87 % is used in WARMS2, which accounts for algal blooms that can be prolonged extending to six weeks in spring and autumn. Following the review of raw water quality and mass balance modelling, the process loss calculated is an average of 4 months each of Scenarios 1, 2 and 3.

Table K-10: Process losses for Farmoor

Farmoor	Scenario 1	Scenario 2	Scenario 3
	Base case average quality	1 in 1 year algal challenge	1 in 5 year algal challenge
Percentage losses	2.58%	7.84%	10.2%
DYAA figure		6.9%	

Swinford WTW

K.27 The process washwater is treated to a sufficiently high quality so that the resultant wastewater stream can be recovered to the head of the WTW. A process loss value of 5.73% is used in WARMS2, which accounts for algal blooms that can be prolonged extending to six weeks in spring and autumn. Following review of raw water quality and mass balance modelling, the process loss calculated is an average of 4 months each of Scenarios 1, 2 and 3.

Table K-11: Process losses for Swinford

Swinford	Scenario 1	Scenario 2	Scenario 3
	Base case average quality	1 in 1 year algal	1 in 5 year algal
Percentage losses	1.23%	7.28%	8.67%
DYAA figure		5.7%	

Fobney WTW

K.28 The wastewater from the treatment process is combined and sent to sewer for further treatment at a STW. The WTW process loss figures included in Table K-12 below and used in the WRZ DO assessments have been reviewed to ensure confidence in WTW capability and thus the SDO.

Table K-12: Process losses for Fobney

Fobney	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
	Standards	**Base case average quality**	**1 in 1 year algal**	**1 in 5 year algal**
Percentage losses	5.79%	5.79%	6.32%	8.63%
DYAA figure		5.9%		

F. Process losses derived from mass balance and resilience models and variation from WARMS2

K.29 The WTW mass balance and resilience models are reviewed and updated as part of our business as usual processes, accounting for changes in the WTW capability and process loss figures and used in the WARMS2 model and in the assessment of source and WRZ DO. The process losses now used in the WARMS2 model result from a review, building on those used previously in WRMP14.

K.30 A single representative process loss value is required in WARMS2 to calculate WRZ DYAA DO considering many decades of varying weather and hydrological conditions. The representative process loss values used in WARMS2 are the most reasonable approximation as they account for varying raw water quality conditions that might be expected during varying weather and hydrological conditions. In the event that in a single year the water quality challenge experienced at a WTW is not that of a 1 in 1 year algal bloom challenge but a 1 in 5 year challenge event, or the challenge period is extended, then the actual process losses as indicated in Table K-13 will be higher. Under future climate change scenarios process losses should be anticipated to change. Raw water quality challenge values greater than a 1 in 5 year event have not been presented, but are significantly higher.

Table K-13: Inputs to WARMS2

WTW	Process water losses (%)
West London	
Ashford Common	2.3
Hampton	3.4
Kempton Park	1.1
Walton	6.7
North London	
Chingford	0.7
Coppermills	7.4
Hornsey	4.6
Gateway	Not applicable
SWOX	
Farmoor	6.9
Swinford	5.7
Kennet Valley	
Fobney	5.9
Guildford	
Shalford	5.3

K.31 The Annual Review process loss figures are a representation of the previous year's water quality and climate conditions and therefore should not necessarily be expected to align with the single DYAA figures included in WARMS2. It should be noted that any current differences between the WARMS2 and the Annual Review process loss figures are within the variability that can occur due to raw water quality changes.

K.32 Returns to the river are taken into account in the assessment of DO. Where the wastewater is lost from the river system in terms of supporting water available for abstraction, cost effective recovery systems suitable for the water have been employed. Specific points to note are that the wastewater flows from the west London WTW (see Table K-13) are returned to the river directly or via a STW supporting the flow over Teddington weir. This is accounted for in the WARMS2 model and does not therefore present a loss of raw water resource. Schemes to reduce process losses have not been developed as resource options within this plan.

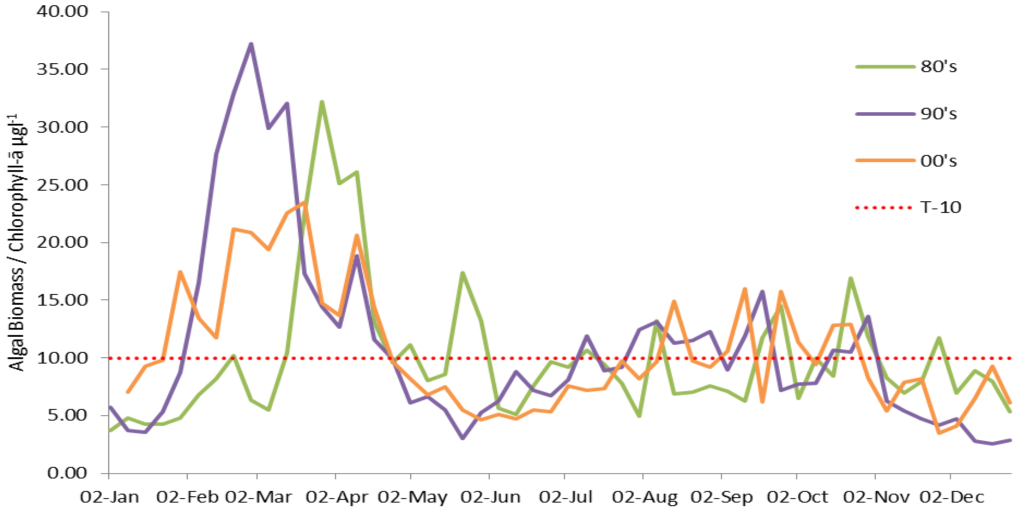
G. Implications of climate change

K.33 It is evident that our water supplies and WTW outputs are vulnerable to seasonal raw water quality and the impacts of climate change affecting it. Therefore as well as raw water resource availability, the water quality challenge and how this may change in the future is an important factor to take into account. We have an ongoing programme working with subject matter experts to develop decision support tools to predict raw water quality (algal) behaviours in the future.

K.34 Algae can, in some cases, significantly affect the ability of surface water WTWs to produce drinking water and increases the cost of the necessary treatment. The UKWIR study regarding climate change implications for water treatment[4] predicts algae will be more problematic for public water supply as a result of climate change and therefore is likely to further increase water process losses.

K.35 In partnership with Imperial College London a study has been conducted to investigate the frequency and severity of algal events in raw water reservoirs. Using 30 years of data from the early 1980s onwards we have looked for patterns of reservoir algal behaviour correlated to climate.

Figure K-2: Changing pattern of algal blooms over past three decades



Source: Imperial College, Merle Anderson, MSc Storage Reservoirs, Algal Blooms and Climate change, June 2013

K.36 By looking at the resilience of our raw water storage and supply network we have found that algal bloom severity and longevity appear to be changing, depending on the individual reservoir's physical structure and management. For example, deeper reservoirs have better control measures to manage the raw water quality and therefore are more resilient to the impacts of climate change.

K.37 The National Environment Research Council (NERC) has funded a five year interdisciplinary UK wide droughts and water scarcity research programme to support improved decision making. Following the 2011/12 UK drought experience, a MaRIUS[5] project was initiated to investigate the potential for, and assess the impact of, future droughts. The span of the MaRIUS project is large and covers physical and social science topics including the effects on water quality from nutrient concentration in rivers and algal concentrations in reservoirs.

K.38 We have engaged the Centre of Ecology and Hydrology (CEH), developers of the Protech model, to undertake a quantitative assessment of two of our raw water storage reservoirs in the London WRZ to determine a revised volume of raw water available for treatment.

[4] UKWIR, 11/CL/08/02: Climate Change Implications for Water Treatment, 2011
[5] Managing the Risks, Impacts and Uncertainties of drought and water Scarcity

Following the results of this assessment we will continue to model the remaining 24 raw water storage reservoirs to assess the overall volume of treatable raw water storage and the impact on our existing supply/demand balance.

K.39 The WRZs that could potentially be shown to be vulnerable by this research are London and Swindon and Oxfordshire (SWOX) due to their reliance upon storage reservoirs. This vulnerability may also have knock on adverse impacts on other WRZs reliant on London and SWOX for system resilience.

K.40 The primary aim of our work in this area is to better inform our evaluation of our system resilience and to be able to base judgements on fact based empirical modelling. Although this work is at an early stage, our initial results indicate that as we further develop our understanding of the way we operate our reservoir network we shall be in a position to make better, more informed decisions and be able to better target investment to improve system resilience in future WRMPs.

H. Summary

K.41 Through the development and use of WTW mass balance and resilience models, we have undertaken a thorough review of likely process losses using up-to-date information and modelling. This has enabled updating and improvement of data used in WARMS2, and in the calculation of WRZ and source DO, to contribute to its improved understanding and the production of a reliable assessment of DO.