

Appendix I London WRZ – Modelling of Water Resource Availability Using the Water Resources Management System² (WARMS2)

In order to manage drought, it is necessary to understand the raw water availability during normal conditions and how this may be reduced during a range of different drought conditions. This is important for allowing an understanding of the balance between supply and demand which is critical to ensuring continued water availability during normal and drought conditions. The amount of water available to maintain water supply during drought periods is termed the Deployable Output. Deployable Output is calculated according to a consistent methodology that can be used for any water resource system. To understand how it is calculated for the complex resource system of the Lower River Thames and associated reservoirs it is necessary to understand the basic tools that are used in its derivation and the process followed to determine the deployable output. An equivalent process is followed for the Farmoor reservoir complex and SWOX WRZ.

11 Water Resource Modelling – WARMS2

To calculate the deployable output for the Conjunctive Use areas within TWUL a series of mathematical simulation models have been developed (using industry standard software, Aquator, but incorporating bespoke elements). These models are operated under a single piece of software known as The Water Resources Management System (WARMS2), which allows “what if” behavioural analysis of the TWUL system, using either historical hydrometric records (from 1920 to the present day) or ‘stochastically’ generated records. The methodology is based on the TWUL Resource Zones (as outlined in Appendix A) some of which are discrete zones; the others are the conjunctive use areas of London and The Upper Thames. London’s water resource availability and the basis of its drought management strategy are based on a set of reservoir control curves covering the Lower Thames and Lee Valley, which is termed the Lower Thames Operating Agreement.

11.1 The Lower Thames Operating Agreement (LTOA)

To understand how deployable output is linked to Levels of Service one first needs to understand the Lower Thames Operating Agreement (LTOA). The LTOA is a “Section 20 agreement” (Water Resources Act 1991) between Thames Water Utilities Ltd (TWUL) and the EA. The agreement requires TWUL to operate its abstraction on the Lower Thames such that a prescribed “Target Flow” continues to flow over Teddington weir. In addition, TWUL is required to bring in restrictions which reduce the demand of its customers and thus conserving reservoir storage, the restrictions are as outlined in the table below. These restrictions are based on a Target Level of Service (TLOS) related to the frequency with which it is acceptable to bring these restrictions into force. TLOS are explained in more detail in the section on deployable output below.

Table 1 I1 Target Levels of Service, updated for DP 2022

Target Levels of Service		Frequency
Level 1	<ul style="list-style-type: none"> ○ Media campaign ○ Water Efficiency 	aim for one year in five
Level 2	<ul style="list-style-type: none"> ○ Enhanced media campaign ○ Temporary Use Bans 	aim for one year in ten
Level 3	<ul style="list-style-type: none"> ○ Drought Direction 2011 Order (NEUB) ○ Drought permits 	aim for one year in twenty
Level 4	<ul style="list-style-type: none"> ○ Rota Cuts ○ Standpipes 	Never (in reality this equates to ~ 1 year in 100 years on average)*

11.2 The Lower Thames Control Diagram (LTCD)

The LTCD is used to assist in the management decisions embraced within the agreement and is based on the volume of water in storage for the entire London reservoir system. The LTCD frame has the months of the year as the x – axis and the storage volume as the y – axis. Prior to our last Drought Plan being issued an updated LTCD was agreed with the Environment Agency. The LTCD had previously been updated in 1997, following operational experience of managing droughts which occurred in the mid-1990s. The review prior to our last Drought Plan was related to legislative changes, the potential impacts of climate change, as well as improved hydrological and environmental information. The review of the LTCD also provided an opportunity to optimise water resources and deployable output (DO) in TW's supply area, and to reduce the environmental impact of the abstractions.

This first stage of the review of the LTCD considered the environmental impacts of the abstractions to ensure environmental considerations are suitably accounted for in the subsequent optimisation process.

TW defined the environmental objectives as:

- No deterioration in the impact already associated with the M2 licence and Lower Thames Operating Agreement (LTOA), and
- Opportunities for betterment i.e. reduction of impact.

TW proposed an approach to integrate environmental considerations into the wider optimisation process through consideration of the shape of the existing LTCD curves and amendment of the monthly Teddington Target Flow (TTF) values. The introduction of monthly TTF values was intended to reflect the flow thresholds and expected timings of environmental impacts and were based on key environmental factors identified in the LTOA environmental study undertaken as part of the review. TW worked closely with EA colleagues to determine

the environmental objectives for the LTCD and to develop the methodological approach. A series of alternative TTF values were considered and evaluated against the LTCD shape.

The LTCD has four “storage zones” each with an annual profile where specified Teddington target flows must be applied. At the start of the year reservoirs may be full and if storage is in this upper zone the flow constraint at Teddington is 800 MI/d. If the storage then declines, through lack of available water in the river to meet the demands upon the reservoir, and passes into the second zone the target flow is reduced depending on which month of the year it occurs to 600 or 700 MI/d. This allows more water to be available for abstraction and preserve storage. As storage decreases the target Teddington flow also decreases through a 400 - 300 MI/d band to the minimum band value prescribed in the Agreement of 300 MI/d. It should be noted however that the minimum value specified on the Lower Thames abstraction licence is 200 MI/d and so in more extreme cases the residual flow could be reduced to this level by agreement with the Environment Agency.

The LTCD also has four control lines, each with an annual profile that governs the introduction of restrictions upon customers. These are introduced as storage decreases and are as outlined in Table I1. The assumed savings from these restrictions are applied in WARMS2 as a cumulative percentage of demand as storage decreases below each of the control lines.

These elements are then brought together as the **Lower Thames Control Diagram (LTCD)** as seen below.

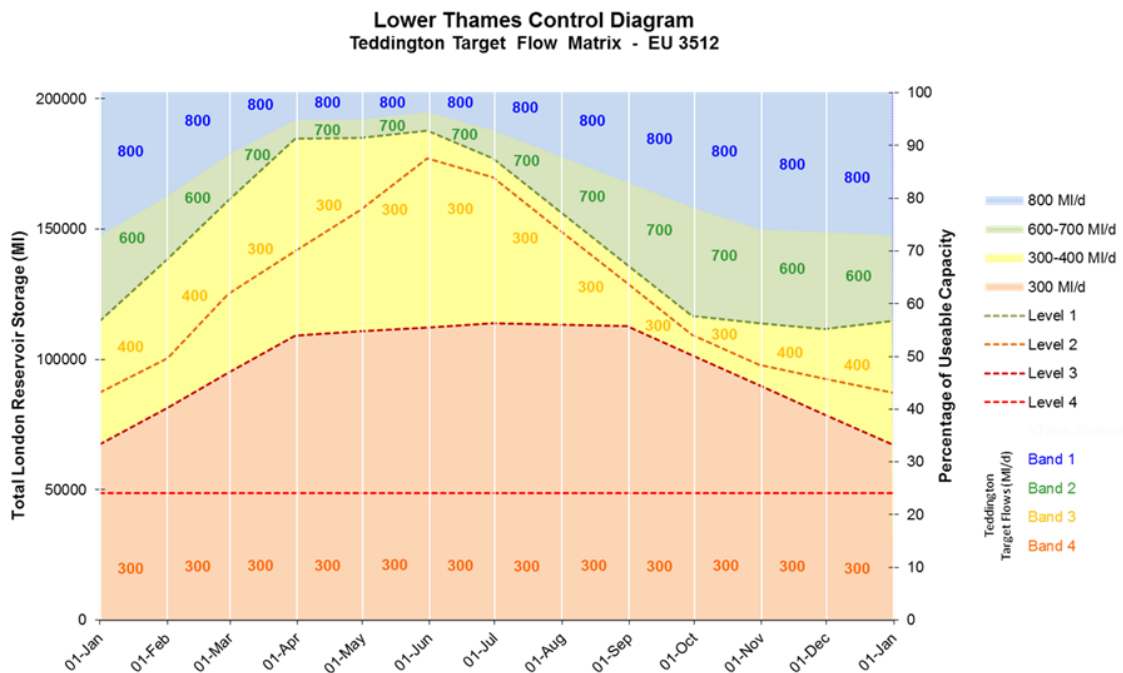


Figure 1 I1 Background Chart of the Lower Thames Control Diagram Indicating the Target flows and Restriction Levels

12 Deployable Output

The definition of Deployable Output is “The output of a commissioned *source* or group of *sources* or of bulk supply for a given level of service as restricted by various constraints including abstraction licence and environmental constraints. Figure I1 shows the environmental constraints and reservoir storage as part of the LTCD.” This is expressed as the frequency of restrictions on water use placed upon customers. Each of the levels should not be exceeded. To calculate the deployable output for the London conjunctive use zone the total London reservoir storage for each day over the period of record, 1920 to date, is calculated and the number of times the level of storage drops below each of the restriction levels is determined. This is dependent upon many aspects of the water resource system.

Water for the London supply area is supplied conjunctively from seven Water Treatment Works (Walton, Ashford Common, Kempton Park, Hampton, Coppermills, Chingford and Hornsey) and a number of smaller groundwater sources. WARMS2 is used to calculate the total deployable output for London. The model has been calibrated using a series of selected historic hydrological and operational data and validated based on the period 2005 to 2010.

The model is run using demands appropriate for the defined operational scenario being evaluated. The strategy for abstraction is defined by the Lower Thames Control Diagram that is applied to the defined scenario. The output from each run includes details of the dates and duration of restrictions occurring during the given period. These are then compared against maximum frequencies of occurrence specified in the Target Levels of Service (TLOS) being evaluated. For example, during a run of 91 years, if the permissible number of occurrences of restrictions is, on average, one year in twenty (e.g. a hosepipe ban), then 4 incidents are allowed, to meet the Target Level of Service. If the model output shows that restrictions have occurred more than 4 times for this duration, the TLOS has been exceeded.

If the system fails to meet the TLOS based on the given demand, the model is automatically run again with a reduction in demand apportioned across the water resource zone, and the output is compared against the TLOS as before. Alternatively, demands are increased to maximize output until restrictions are imposed to the prescribed level of service. This process is repeated until the TLOS is met with restrictions being applied for the prescribed period. Thus the highest demand at which the TLOS is satisfied is the Deployable Output for the conjunctive use system. This is done automatically within WARMS2. One of the crucial drought events within the Thames catchment is that of 1933 – 1934. The hydrology during this period produces the minimum storage over the hydrological period examined with draw down starting in 1933 and not fully recovering until 1935, as shown in the diagram below.

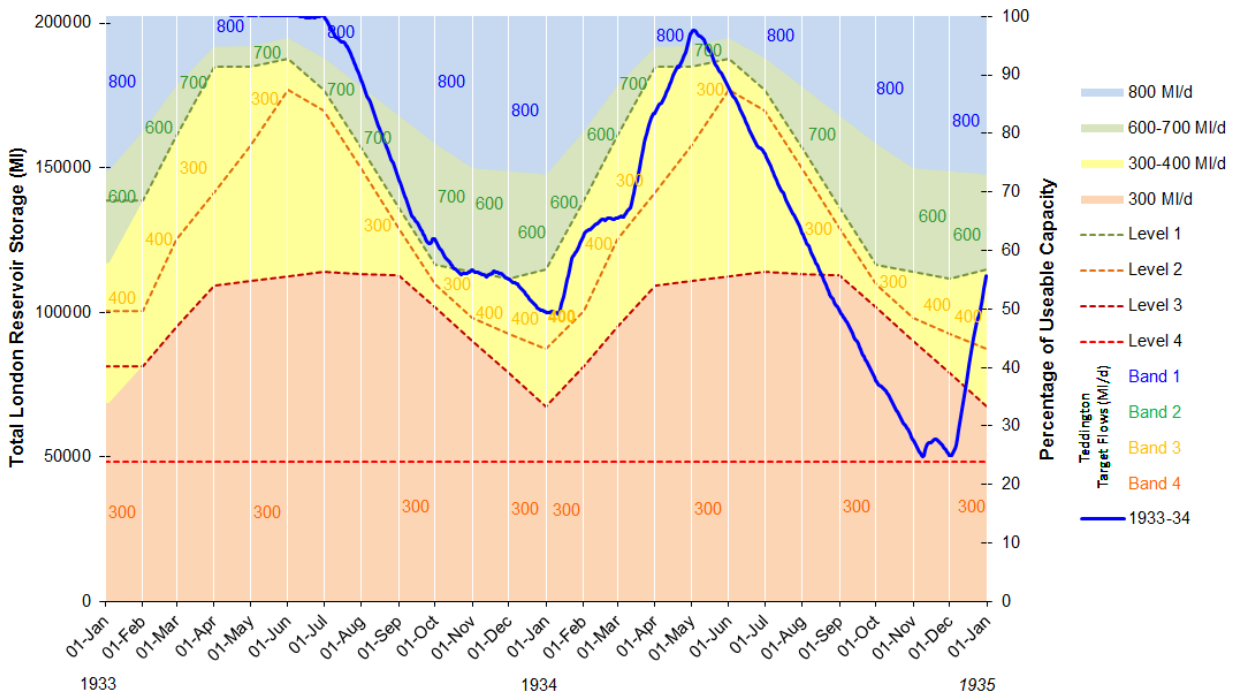


Figure 2 I2 Example of the use of the Lower Thames Control Diagram 1933 and 1934

This above description outlines how scenarios are used to inform the ability of the resources available to accommodate drought periods. If a drought of greater severity than has been experienced over this historic period is encountered, then more severe drought measures are required.

A similar approach to that for the Lower Thames and London is adopted for Farmoor reservoir and the Upper Thames resource system.