Final DP22 Appendix F Drought Management Protocols for London and SWOX with worked examples

Name, job title, etc (Abadi Extra Light, size 20)

APPENDIX F. Drought Management Protocols for London and SWOX with worked examples

Table of contents

Figures

Tables

Part 1. Methodology

Introduction

The purpose of Appendix F is to provide a practitioner-level description of the methodology for the protocols for London and Swindon and Oxfordshire (SWOX) Water Resource Zones (WRZs). To demonstrate how it works in practice, the methodology is then applied to five drought years, 2012, 2005, 2006, 1997 and 1976. These drought years provide a range of drought events of differing severity. For each drought, analysis using the drought protocol is provided with a description of the measures that the current methodology indicates would have been required. For information and comparison a description is given of the measures actually taken in the five respective drought years. Conclusions are drawn as to the effectiveness of the protocols.

F1. Outline of Methodology

Common to both London and SWOX protocols are three basic steps, summarised briefly as follows:

- Step 1 - Collation of hydrological data, predictions of drought impact and assessment of potential drought severity in terms of historic frequency of occurrence.
- Step 2 - Risk assessment using the information from Step 1 to derive a composite indicator of risk to security of supply, the Overall Risk Indicator (ORI).
- Step 3 – Assignment of drought level and decision on measures to be taken guided by the output from Step 2.

A description and worked example based on the 2012 drought for the London WRZ shows how the data is processed, and risk levels are assigned. It then shows how the data is combined to produce an overview of the potential drought impact on security of supply, at WRZ level, and the measures that would need to be put into place within a defined time period to mitigate these risks.

F1.1. Step 1 – Hydrological Assessment and Drought Severity Assessment

Step 1 is sub-divided into three parts – 1a, 1b and 1c- as follows.

1a – Hydrological Data Collation

The Environment Agency provides Hydrological data every 2 months to us under normal water resource conditions, but when signs of significant potential for drought to develop have been identified, the data provision will be increased. The data provided comprises of:

Groundwater levels- up-to-date groundwater levels from the Environment Agency's network of key observation boreholes sampling the principal aquifers in the Thames catchment, Table F1.

River flows- primarily from the Lower Thames at Teddington and the Upper Thames at Farmoor.

The above data set essentially constitute the prevailing water resources situation and it is used as the basis (initial condition) for Step 1b.

1b – Predictions

For each of these hydrologic variables- groundwater levels, river flows and reservoir storage- predictions are made using a range of worst case scenarios in respect of rainfall; the resulting groundwater level, river flow and reservoir level trends are referred to as the predicted results for a given scenario.

For the predictions of groundwater levels the groundwater model, Catchmod, is used. For predictions of river flows and reservoir levels, the WARMS model is used, see Appendix I.

1c – Determination of Drought Severity against historic data

An assessment is undertaken of the potential drought severity to indicate the return period or frequency of occurrence of the drought event. This is used as an important guide to assess the conformance between the planned levels of service and the decisions on the proposed measures to be taken in Step 3.

F1.2. Step 2 – Drought Risk Level Assessment

Step 2 comprises a procedure of three sub-steps – 2a, 2b and 2c- described below.

2a – Prevailing and predicted hydrologic risk indicators

Using the output from Steps 1a and 1b, the prevailing and predicted hydrologic data are converted to a corresponding ***prevailing*** and ***predicted*** set of hydrologic risk indicators (see Figure F2) for groundwater levels (R_G), river flows (R_R) and reservoir storage (R_S); where R_G and R_R are evaluated in accordance with the Environment Agency's percentile banding as set out in Table F3. $R_{S,}$ is derived from the Level 1 to Level 4 banding in the LTCD, see Figure F2

2b – Combined hydrologic risk indicator

In order to provide a balanced assessment of the overall risk in terms of the hydrologic indicators, the analysis integrates the three hydrologic risk indicators to provide a combined hydrologic risk indicator, R_C given by:

$$R_C = (R_G \times W_G) + (R_R \times W_R) + (R_S \times W_S)$$

Where W_S, W_G and W_R are monthly weighting factors (the formulation of the weighting factors is given in Section F3.2 below and the factors are shown in Tables F6 and F7 for London and SWOX respectively).

Separate Rc values are calculated for the ***prevailing*** situation and ***predicted*** scenarios.

2c - Overall risk indicator (ORI)

The risk to security of supply and the appropriate measures to be taken are determined by a simultaneous consideration of both the immediate and potential longer-term risks i.e. the prevailing and predicted situation. Thus, using prevailing and predicted R_{C}, the Overall Risk Indicator (ORI) has been developed to provide a balanced assessment of the known immediate ('prevailing') risks and potential worst case ('predicted') risks.

F1.3. Step 3 – Determination of Measures and Drought Event Level (DEL)

The ORI is used as the principal guide to determine the actions and measures to be taken, which in turn is used to determine the Drought Event Level (DEL). Operational aspects, such as outages, also need to be considered before appropriate measures are decided upon. DEL will determine the appropriate level of governance, which ranges from middle, senior management through to director level.

F2. Detailed Description Of Protocol Methodology

F2.1. Step 1-Collation of hydrological data and assessment of potential drought severity

Hydrological and hydrogeological data is systematically monitored throughout the year by both us and the Environment Agency; depending on the time of year and the risk to the security of supply during an event, the reporting of this monitoring by the Environment Agency may be increased or decreased. During a drought event, communication between us and the Environment Agency is increased to ensure that all pertinent information is captured and passed between both parties. This includes river flows, reservoir storage levels, groundwater levels and modelling results.

The sub-steps within Step 1 detail the sources and collation of required data.

Step 1a Hydrologic Data Collation

The most recent ('prevailing') data is obtained to undertake the analysis. We use our reservoir storage figures and the river flow data which is provided by the Environment Agency on a daily basis during drought periods and every week in non-drought periods. Groundwater level data from observation boreholes (OBHs) is obtained from the Environment Agency at varying intervals. Depending on the OBH, this could be weekly, monthly or quarterly. In drought situations groundwater levels for the key regional OBHs are required at least weekly to allow the prevailing conditions to be included in the hydrological assessment and to provide updates to the models to allow the predictions to be undertaken.

Step 1b Predictions

The hydrological data is fed into our WARMS model (as described in Appendix I) to produce the river flow and reservoir storage predictions. The groundwater levels at a limited number of OBH locations in the Thames region are modelled by the Environment Agency using the Catchmod groundwater model. This produces predictions of groundwater levels under varying rainfall scenarios; the one most commonly used for drought prediction is 60% of the Long Term Average (LTA) Rainfall. The 60% scenario is used because it is broadly equivalent to the rainfall that was experienced during the 1976 water year (October 1975 – September 1976), which is the most severe recent drought for which good records are available in the Thames region.

The duration of the predictions can be specified within the model, as one might expect, the longer the simulation period, the more uncertainty that is associated with the forecast. As a general rule, 3 or 4 month predictions are used for SWOX WRZ and 6 months for London WRZ.

Groundwater

The regional observation boreholes (OBHs) available for use in the analysis, are given in Table 1

Table 1 Table of Boreholes Associated with Regional Aquifers

Observation Borehole	Regional Aquifer
Ampney Crucis	Cotswold Limestone
Jackaments Bottom	Cotswold Limestone
Rockley	Chalk- Marlborough Downs; also surrogate for Cotswold Limestone
Gibbet Cottages (Oak Ash)	Chalk- Berkshire Downs
Stonor Park	Chalk- Chilterns West
Ashley Green	Chalk- Chilterns East
Lilley Bottom	Chalk- Chilterns East
Therfield Rectory	Chalk- Chilterns East*
Tile Barn Farm	Chalk- North Downs
Well House Inn	Chalk- North Downs

*The Therfield Rectory OBH is very close to, or even outside, the River Lee/Thames catchment divide and does not usually influence assessment of drought risk to the Thames Water water resource system.

Note, in practice and particularly for the London protocol, at least two regional OBHs would be analysed in order to give a balanced assessment of groundwater level status across the Thames catchment. For example, data from Gibbet Cottages OBH and Stonor Park OBH together provide a good estimate of the catchment's groundwater status upstream of Teddington Weir. This combination is therefore a good indication of the baseflow component available for abstraction. However, for the sake of demonstrating the methodology in the examples that follow only the results from one OBH are used.

The Environment Agency has replaced Oak Ash OBH with Gibbet Cottages OBH in the Berkshire Downs, but the observation boreholes are located very close to each other and therefore the Gibbet Cottages record can be considered an extension of the Oak Ash record. The Well House Inn observation borehole has been replaced by Chipsted OBH.

The groundwater level predictions are used to provide a composite picture of the overall status of groundwater levels in the Thames catchment.

River flow

The Environment Agency provides bi-monthly river gauging data as a matter of routine, but during a drought event will also liaise directly with the control centre on a daily basis; WARMS will be run more frequently to create a rolling picture of the effects of the drought on river flows in the upper Thames at Farmoor and in the lower Thames above Teddington Weir.

Reservoir storage

WARMS modelled data and actual storage values are produced weekly during a drought event and used in the assessment. This allows a rolling picture of the impact the drought event is having on reservoir storage and the potential risks to the security of supply to be produced.

Step 1c Drought Severity Assessment (Frequency of Occurrence)

In parallel with the data collation, there is a separate assessment of the potential drought severity of the event with the aim of establishing conformance to stated levels of service through the frequency of occurrence parameter. This is described below.

Frequency of occurrence is a way of describing in statistical terms the severity of the particular drought in question. A reliable estimation for the London WRZ of frequency of occurrence is the average [naturalised] flow over Teddington Weir for the critical period of a given drought. In other words, the average flow over the critical drought period provides a good approximation to the water resources available over the course of the drought.

For the drought event under consideration, the critical period is approximated by the predicted average flow in the River Thames at Teddington (using a 60% of average rainfall scenario) for a selected period representative of the summer low flow record e.g. April to September, termed a flow window. This value is compared with the equivalent values over the same period for all previous year's records i.e. the historical April to September average flow. The record of these *flow windows* is ranked and the drought severity determined through the position of the drought prediction within the entire ranked series for the 111 years of record (1900 to 2011).

Taking 2012 as an example, the average flow is estimated from April to September assuming a 60% of average rainfall scenario. In this case there would have been no other droughts with an average critical period flow lower than that predicted for 2012 (see Figure 1). In other words, if from early February to September rainfall had averaged only 60%, then the 2012 drought would have ranked most severe over the 111 year historic record. Therefore, to relate this to drought management in practice, the levels of service associated with the actual measures introduced in 2012 are assessed for consistency with the drought severity at the time. In this case, a TUB was introduced in April 2012 for the TWUL supply area. This action was seen to be broadly in line with the planned Levels of Service for a Level 2 measure with a 1 in 20 frequency of occurrence.

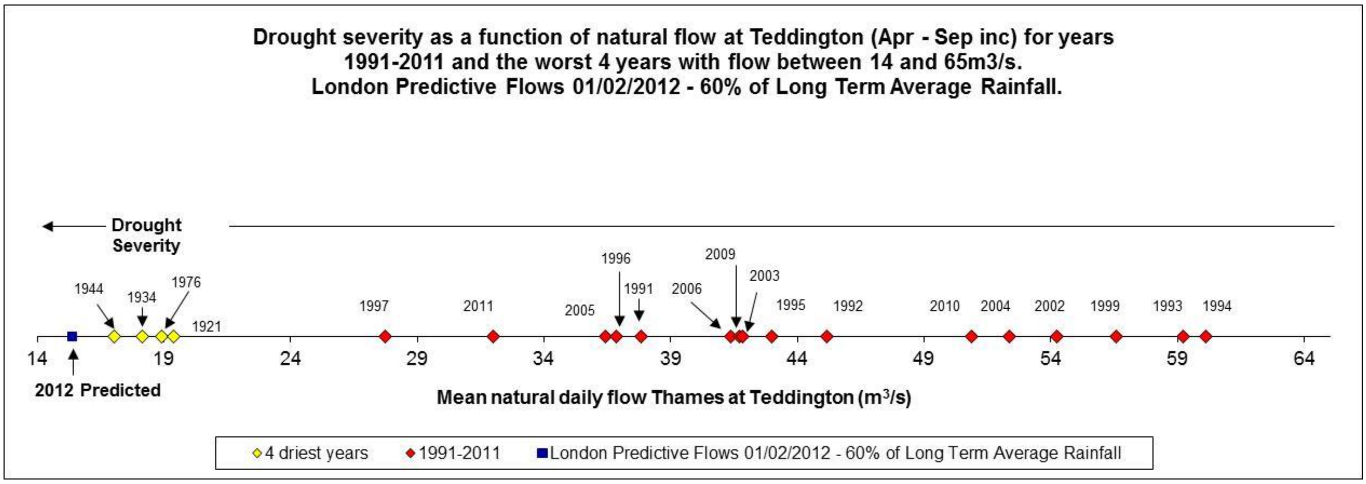

Figure 1 Drought Severity as a Function of Natural Flows at Teddington (April -September) showing 20 Driest Years Since 1900 and 2011 Prediction

F2.2. Step2 Drought Risk Level Assessment

Step 2a Hydrological Risk Indicators Assessment

Each of the drought variables derived from Steps 1a and 1b are assessed for both prevailing and potential or predicted level of risk to security of supply. The prevailing risk is the risk at the time of the assessment and the potential risk is the risk based on a prediction of the situation at a defined point in the future. The data is analysed using the Environment Agency's percentile bandings for groundwater and river flow and our LTCD bandings; the risk level is determined for both predicted and prevailing conditions. For example, in February the prediction would determine the potential situation in August for a 6 month prediction. Five risk levels (R0, R1, R2, R3 and R4) are defined where R0 is negligible risk denoting normal seasonal conditions and R4 is the greatest risk to supply denoting extreme unprecedented drought conditions, see Table 2.

The protocol is designed to outline how an escalating drought risk would be tracked through routine monitoring and analysis and would lead to an escalation of our Drought Event Level (DEL), as shown in Table 10. The protocol is based on an integrated analysis of groundwater levels, river flows and reservoir levels derived from Step 1 above, where the risk indicator for these hydrological variables is denoted by R_G, R_R and R_S respectively.

It should be noted that during periods when there is no drought concern, the prevailing water situation is assessed through Operations normal activities (day to day management), i.e. the prevailing risk is R0.

Table 2 F2 Risk Assessment NomenclatureTable F1 Risk Assessment Nomenclature

Hydrological Measure	Ground Water Level	River Flow	Reservoir Storage
1. Data used	Prevailing or Predicted	Prevailing or Predicted	Prevailing or Predicted

2. Notation	RG	RR	RS
3. Possible range of risk levels	RG 0-4	RR 0-4	RS 0-4

Note: Terms given to the notations R_G, R_R and R_S:

- R_G - Risk levels as determined from Prevailing or Predicted Groundwater Data
- R_R - Risk levels as determined from Prevailing or Predicted River Flow Data
- R_S - Risk levels as determined from Prevailing or Predicted Reservoir Storage Data

The risk levels are based on the percentile ranges used by the Environment Agency for which each band is attributed a specific level, ranging from 0 to 4.

- Table 3 shows the percentile bandings used for Groundwater (R_G) and River Flow (R_R) assessment and their respective Risk Levels. The data used for these figures is obtained from the Environment Agency.
- Figure 2 shows the percentile bands for Reservoir Storage (R_S) assessment and their respective Risk Levels. The data used for these figures is based on our reservoir control curves within the Lower Thames Control Diagram, for example, see Figure F8.

Table 3 F3 Groundwater and River flow Level Percentile Bandings (Actual Values Based on data which is Dependent on the Record Length for each Data Source)

EA bands		Percentile of the band	Groundwater Risk Level RG	River Flow Risk Level RR
	Exceptionally High	95-100%	RG0	RR0
	Notably High	87-95%	RG0	RR0
	Above Normal	72-87%	RG0	RR0
	Normal	28-72%	RG0	RR0
	Below Normal	13-28%	RG1	RR1
	Notably Low	5-13%	RG2	RR2

EA bands		Percentile of the band	Groundwater Risk Level RG	River Flow Risk Level RR
	Exceptionally Low	0-5%	RG3	RR3
	Not on record		RG4	RR4

Reservoir Storage Risk Indicators	LTCD Control Curve Levels
R_S 0	
R_S 0	800/600 Ml/d zone
R_S 1	...Level 1…
R_S 2	…Level 2…
R_S 3	…Level 3…
R_S 4	…Level 4…

Figure 2 Calibration of risk levels (taken from Lower Thames Control diagram). The predicted risk is determined using the information from Step 1b.

The assessed prevailing and predicted risk levels are then placed into ***risk matrices.*** These can be used to monitor the drought position on a weekly or monthly basis depending on the drought severity.

- ## Revision of the LTCD 2016

In 2016 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 of the operating agreement for abstractions from the Lower Thames was timely in light of the recent 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.

The review of the LTCD considered the environmental impacts of the abstractions to ensure environmental considerations were suitably accounted for in the optimisation process.

We defined the environmental objectives as:

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

We 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 are intended to reflect the flow thresholds and expected timings of environmental impacts and are based on key environmental factors identified in the LTOA environmental study [1]undertaken as part of the review. We worked closely with EA colleagues to determine the environmental objectives for the LTCD and to develop the methodological approach. The environmental objectives were combined with the objective of maximising the deployable output for London using the LTCD to give a new set of optimised curves.

For future droughts the assessments described above will be completed using the updated LTCD, however analysis of previous drought events has been completed using the old LTCD which was in use at the time the drought plan methodology was developed.

In order to illustrate the protocol it is easiest to demonstrate each step through use of a specific example. The drought of 2012 is used for illustrative purposes as it provides a good range of hydrological variation.

Table 4 and Table 5 represent the risk matrices derived from analysing the hydrologic data from the 2012 drought; the groundwater, river flow and reservoir levels used are shown respectively in Figure 13, Figure 14 and Figure 15(Section F6.1). The matrices are completed on the basis of the respective prevailing and predicted levels of the hydrological indicators. Thus in Table 4 the groundwater level shown in Figure 13 for March is in band R_G 3 and so the indicator is assigned the value R_G3. The tables are populated for each hydrologic indicator on this basis.

Table 4 Risk matrix of prevailing situation (March 2012)

Prevailing Risk Level at beginning March 2012 (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G				X	
River Flow Levels R_R				X	
Reservoir Storage R_S	X				
Combined Risk Indicator			X		

R_C= (3*0.5) + (3*0.2) + (0*0.3) = 1.5 + 0.6 + 0 = 2.1 (Rounded to 2)

Similarly, for the predicted mode, the predicted groundwater, river flow and reservoir risk levels derived from the graphs in Figure 13, Figure 14 and Figure 15 are shown below in Table 5.

Table 5 - Risk matrix of predicted situation (March 2012)

Predicted Risk Indicator - March 2012 to May 2012 with 60% LTA Rainfall (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels RG					X
River Flow Levels RR					X
Reservoir Storage RS			X		
Combined Risk Indicator				X	

R_C= (4*0.5) + (4*0.2) + (2*0.3) = 2.0 + 0.8 + 0.6 = 3.4 (Rounded to 3)

Step 2b Combined Hydrological Risk Level Assessment (Based on combining individual hydrological risk indicators

The Hydrologic Risk Levels for a chosen month are entered into the Drought Risk Assessment Matrix, this produces one value for the time period- the Combined Hydrological Risk Indicator R_C.

Derivation of Weightings

The three hydrologic variables each have a characteristic annual cycle, which for a given time of year will have greater or lesser significance for drought management. For example, groundwater level is a relatively more important indicator early in the year whilst reservoir storage level becomes increasingly more important later in the year as groundwater and river flows recede. A system has been produced to provide a relative weighting of the hydrological risk indicators to reflect their relative importance on a month by month basis.

The weightings are shown in Table 6 for London and Table 7 for SWOX with their variations through the year. The combined weightings add up to 100% and the relative percentages through the year indicate how the importance of groundwater, river flow and reservoir storage vary as the water resource situation progresses from the end of the winter recharge period through to the summer low flow period and then through to the autumn and the onset of winter with recharge recommencing.

London Weightings

i. Groundwater levels are given the greatest weighting because the Thames system is dependent on groundwater levels for generating the river flow (baseflow) that is required to enable abstraction to maintain storage. That is to say, groundwater level status defines the *longer-term* worst case scenario. Thus, the weighting is greatest in the early months of the year when it is the most reliable indicator of potential drought severity and diminishes thereafter as river flow and reservoir storage reflect the impact of summer rainfall and so provide an increasingly accurate picture of the overall water resources availability towards mid to late summer and early autumn

ii. River flow is of lower relative importance at the start of the year as there is usually sufficient flow in the river to ensure storage can be maintained at 100%. Reservoir storage is weighted at 25% in the first two months of the year and then increases to 30% for the remainder of the year. The relatively lower weighting in January and February is because reservoir storage is generally at 100% in these months and so its importance in determining the likely water resources situation early in the year is of less importance than later in the year

The relative percentages used in the weightings were initially based on expert judgement and have been refined through a process of sensitivity testing to see which weightings gave the best results when undertaking predictions of the drought severity.

Table 6 Weighting factors for London

Month	GW WG	River Flow WR	Reservoir Storage WS
Jan	55%	20%	25%
Feb	55%	20%	25%
Mar	50%	20%	30%
Apr	50%	20%	30%
May	50%	20%	30%
Jun	50%	20%	30%
Jul	50%	20%	30%
Aug	50%	20%	30%
Sep	50%	20%	30%
Oct	50%	20%	30%
Nov	50%	20%	30%
Dec	50%	20%	30%

SWOX Weightings

The same logic as applied to London WRZ is also applied to SWOX in respect of the relative importance of groundwater, river flow and reservoir storage during an annual cycle.

For SWOX the main difference with respect to London weightings is the relatively greater importance given to the river flow indicator. This is because of the nature of the conditions written into Farmoor's abstraction licence which make reservoir levels more sensitive to changes in river flow in a low flow situation compared to the lower Thames situation.

Table 7 SWOX weighting factors

Month	Groundwater	River Flow	Reservoir Storage
Jan	60%	25%	15%
Feb	60%	25%	15%
Mar	55%	20%	25%
Apr	50%	20%	30%
May	50%	25%	25%
Jun	50%	25%	25%
Jul	40%	25%	35%
Aug	35%	30%	35%
Sep	35%	30%	35%
Oct	40%	30%	30%
Nov	45%	30%	25%
Dec	55%	25%	20%

How the Combined Risk Indicator is calculated:

The combined risk indicator is calculated by multiplying the hydrological indicators by their respective weightings. For the prevailing assessment the weighting is used for the current month and for the predictive assessment the weighting is used for the future month for which the prediction is made. The prevailing and predicted combined risk indicators (PrevR_C and PredR_C) are given by the formulae:

$$PrevRC = Prev(R_{\mathbf{G}} \times W_{\mathbf{G}}) + Prev(R_{\mathbf{R}} \times W_{\mathbf{R}}) + Prev(R_{\mathbf{S}} \times W_{\mathbf{S}})$$

$$PredRC = Pred(R_{\mathbf{G}} \times W_{\mathbf{G}}) + Pred(R_{\mathbf{R}} \times W_{\mathbf{R}}) + Pred(R_{\mathbf{S}} \times W_{\mathbf{S}})$$

Where Prev ($R_{(S,G,R)} \times W_{(S,G,R)}$) represents the respective prevailing hydrologic risk indicators multiplied by the weightings for groundwater, river flow and reservoir storage for the current situation. Similarly, Pred ($R_{(S,G,R)} \times W_{(S,G,R)}$) represents the respective predicted hydrologic risk indicators multiplied by the weightings for groundwater, river flow and reservoir storage.

Again taking the 2012 drought example, using the prevailing and predicted hydrologic risk levels given above in Table 4 and Table 5 respectively and weighting system in Table 6, the resulting prevailing and predicted Combined Risk Factors (Rc) are shown in Table 8 and Table 9 below.

Table 8 Drought Risk Assessment Matrix for Prevailing London WRZ Conditions for March 2012

Prevailing Risk Level at beginning March 2012 (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G				X	
River Flow Levels R_R				X	
Reservoir Storage R_S	X				
Combined Risk Indicator			X		

R_C= (3*0.5) + (3*0.2) + (0*0.3) = 1.5 + 0.6 + 0 = 2.1 (Rounded to 2)

Taking the value for R_C of 2, the combined prevailing risk indicator is denoted as R_C2. This is taken forward to the Drought Risk Level Assignment.

As with the prevailing matrix utilising the weighting system in Table F6, and the risk levels determined in Step 2a, the combined **predicted** risk indicator is determined as shown below in Table F9.

Table 9 Predictive Drought Risk Assessment Matrix for London for March 2012 Using 6 Month Predicted Data from March 2012

Drought Risk Assessment Matrix for September 2012 using 6 month predicted conditions from March 2012

Predicted Risk Indicator - March 2012 to August 2012 with 60% LTA Rainfall (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G					X
River Flow Levels R_R		X			
Reservoir Storage R_S					X
Combined Risk Indicator				X	

R_C= (4*0.5) + (1*0.2) + (4*0.3) = 2.0 + 0.2 + 1.2 = 3.4 (Rounded to 3)

Taking the value for R_C of 3, the combined **predicted** risk indicator is denoted as R_C2/3. This is taken forward to the Overall Risk Indicator and the Drought Risk Level Assignment.

Step 2c Overall Risk Indicator (ORI)

The risk to security of supply and the appropriate measures to be taken are determined by a simultaneous consideration of both the prevailing and predicted situation. Using prevailing and predicted R_C, the Overall Risk Indicator (ORI) has been developed as a composite assessment of the known short term risks and potential worst case risks. Thus ORI is expressed as a combination of Prev R_C (0-4) and Pred R_C(0-4), where the R_C indicators are taken from Step 2b (Table 10).

Table 10 Overall Risk Indicator

Combined Prevailing Risk Indicator	Combined Predicted Risk Indicator	Overall Risk Indicator
R_C0	R_C0	ORI 0/0
	R_C1	ORI 0/1
	R_C2	ORI 0/2
	R_C3	ORI 0/3
R_C1	R_C1	ORI 1/1
	R_C2	ORI 1/2
	R_C3	ORI 1/3
	R_C4	ORI 1/4

Combined Prevailing Risk Indicator	Combined Predicted Risk Indicator	Overall Risk Indicator
R_C2	R_C2	ORI 2/2
	R_C3	ORI 2/3
	R_C4	ORI 2/4
R_C3	R_C3	ORI 3/3
	R_C4	ORI 3/4
R_C4	R_C4	ORI 4/4

F2.3. Step 3 Assignment of Drought Event Level (DEL)

The ORI is used as the principal guide for determining the measures to be taken, which in turn is used to set the appropriate Drought Event Level (DEL). Drought Event Level is the indicator that combines the water resources situation as given by the ORI with the operational aspects of drought management and its governance. Assigning DEL also takes into account the supply/demand position (including outages etc.) (In terms of terminology we refer to the Drought Event Levels (DELs) as DEL0 to DEL4 – see Table 11 below)

There is a range of combinations of prevailing risk and potential risk which are used to assign the DEL. As prevailing risk increases during the onset of a drought, the analysis focuses on the potential for the drought to escalate further and so fewer levels of potential risk remain but they become more severe.

For our 2021 Drought Plan update we have updated our Levels of Service and now introduce a full Temporary Use Ban (TUB) at Level 2, where we previously split out a sprinkler and unattended hosepipe ban at Level 2 and then introduced a full TUB at Level 3. This update to our methodology introduces measures earlier, which should increase the resilience of our drought plan. For the examples that are described in this appendix our previous levels of service will be applied, as this is what was included in our Drought Plan methodology at the time. From 2021 the new methodology will be applied.

Table 11 Drought Risk Level and Event Level

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures	Implied Level of Service
ORI0/0	DEL0	No event	No measures introduced	N/A
ORI0/1	DEL1	Senior Manager	Media/Water efficiency campaign	Level 1
ORI0/2	DEL2	Senior Manager	Enhanced Media/Water efficiency campaign/TUB	Level 2
ORI0/3	DEL3	Director	,NEUB and Drought Permits	Level 3
ORI1/1	DEL1	Senior Manager	Media/water efficiency campaign	Level 1
ORI1/2	DEL2	Senior Manager	Enhanced Media/Water efficiency campaign/TUB	Level 2
ORI1/3	DEL3	Senior Manager	Enhanced Media/Water efficiency campaign/TUB, NEUB and Drought Permits	Level 3
ORI2/2	DEL2	Senior Manager	Enhanced media campaign/ TUB.	Level 2
ORI2/3	DEL3	Director	Enhanced Media/Water efficiency campaign/TUB/ NEUB and Drought Permits	Level 3
ORI2/4	DEL3 or DEL4	Director/CEO	Enhanced Media/Water efficiency campaign/TUB, NEUB and Drought Permits/ Emergency Drought Order	Level 3
ORI3/3	DEL 3	Director	Enhanced Media/Water efficiency campaign/TUB, NEUB and Drought Permits	Level 3
ORI3/4	DEL 4	CEO	Enhanced Media/Water efficiency campaign/TUB, NEUB and Drought Permits/ Emergency Drought Order	Level 3
ORI4/4	DEL 4	CEO	Enhanced Media/Water efficiency campaign/TUB, NEUB and Drought Permits/ Emergency Drought Order	Level 4

Based on the example of the assessment for London for March 2012 in which the combined the prevailing risk indicator is R_C**2** and predicted risk indicator level is R_C**3,** ORI is **ORI2/3**, the DEL is determined as **DEL3**. In practice, this would mean that by end of March an enhanced media campaign would be underway and sprinkler ban and Temporary Use Ban would be planned to commence at the earliest most effective time, usually set for early April. It should be noted that the assessment described above would be updated at regular intervals as new field data becomes available.

It is envisaged that most droughts would start off with *prevailing* risk indicator as R_C1, but with varying *predicted* risk indicators (ORI1 to ORI4). Particularly for SWOX, but also for London, even if a drought has a *potential* indicator of R_C3 or R_C4 at the onset of spring, summer rainfall may change the prevailing and/or predicted water situation to R_C2, R_C1 or even back to R_C0. Thus, the methodology needs the flexibility of escalating or downgrading the DEL as the drought progresses.

F3. Implementation of Measures

F3.1. The need for early introduction

Prior to the introduction of the new drought management protocols given in Drought Plan 2010, the introduction of drought measures was guided principally by the prevailing reservoir storage condition through reference to the LTCD for London and to the Farmoor control diagram (FCD) for SWOX. For other WRZs the local WR situation was used together with reference to the situation in London or SWOX as appropriate. The current methodology recognises the need to introduce measures in anticipation of a potentially severe risk to supply. A key feature of the methodology is that it allows early introduction of measures in potentially severe drought episodes in order to:

- Maximise their resource benefit.
- Ensure that the full range of measures that might be required can be implemented in good time, taking into account the sequencing required as well as the need to have certain measures in place before more severe ones can be implemented.

The principal requirement in managing potentially severe drought episodes is to minimise the risk of Level 4 measures, but if this cannot be avoided, then all possible measures must have been implemented in good time in order to minimise the need for Level 4 measures.

F3.2. Sequencing and Timing of Drought Measures

For any drought scenario the timing of when the introduction of the most severe measures is required is predicted by the protocol. This enables determination of when the introduction and sequencing of the lesser measures is required. Thus a time-line can then be used to hindcast from the point at which it is identified that the most severe predicted measure is required.

It is also necessary to consider the measures that are conditional before a subsequent measure can be implemented. This is necessary in order to determine the timing of the introduction of measures, which to conform to the Company's Levels of Service, must follow the sequence:

- Media campaign must precede a Temporary Use Ban.
- Temporary Use Ban must precede a NEUB (DD11 order).
- Temporary Use Ban must precede a drought permit .
- NEUB must precede an Emergency Drought Order (EDO).

Elapsed time to implement drought measures

In order to accommodate the required timeline there may need to be overlap in the process due to the time taken to determine drought orders, particularly for SWOX. For London the plan assumes the periods of time for the individual actions in the process are as follows:

Level 1 measures

- Media campaign 2 weeks

Level 2 measures

- Temporary Use Ban 3

Level 3 measures

- NEUB up to 10 weeks from date of application to granting of order
- Drought Permit up to 10 weeks from date of application to granting of permit
- It should be noted that a high priority drought permit may be determined significantly quicker than 10 weeks.

Level 4 measures

- Emergency Drought Order (EDO) - up to 10 weeks from date of application to granting of order.

The minimum elapsed time for obtaining drought orders and drought permits is summarised below in Table 12. On this basis it can be seen that the minimum elapsed time by which an EDO could be put in place starting from a point where no measures were in place would be 25 weeks.

Table 12 Minimum Elapsed Time for the Determination of Drought Orders and Drought Permits

Measure	Time to Implement (WEEKS)			
Media campaign	2			
Temporary Use Ban		3		
NEUB /drought permit			10	
Emergency drought order				10
Elapsed time (WEEKS)	2	5	15	25

Part 2- Application of protocol to selected drought years

Introduction

The drought years **2012**, **2005**, **2006**, **1976** and **1997** have been selected for the purpose of demonstrating the methodology and reliability of the London and SWOX protocols. These years have been selected in order to demonstrate a range of differing drought severities moving broadly from least severe to most severe.

Each example year commences with a brief description of the key aspects of what actually happened in the drought year in question. This is followed by the application of the methodology described above in Section F2. The analysis shown is based on a selected '*base*' month to illustrate the process at a key decision-making point in the drought. In practice there would be at least a month-by-month update of the forecasts.

For convenience, the procedure followed can be summarised as follows:

Step 1 - Hydrological Assessment and Drought Severity Assessment

1a – Collation of Hydrologic Data- prevailing groundwater levels, river flows and reservoir storage.

1b - Hydrological Predictions- using data from Step 1a as a base, prediction by model simulation future trends

1c – Determination of Drought Severity- using prevailing and predicted streamflow data for Teddington Weir rank average flow against historic data

Step 2 – Drought Risk Level Assessment

2a- Hydrological data assessment to compare prevailing and predicted against standardised bands for R_G, R_R and R_S

2b- Produce combined prevailing and hydrologic risk indicators (R_C)

2c- Combine prevailing and predicted to produce an Overall Risk Indicator (ORI)

Step 3 – Determination of Measures and Drought Event Level

Use ORI as the principal guide for determining the measures to be taken and thus use it to set the appropriate Drought Event Level (DEL)

The examples conclude with a commentary on how the Company would have managed the drought based on the results from the analysis.

F4. 2012 drought example - London WRZ

Background to 2012

The 2011 drought started to build up through 2011. Whilst the winter of 2010/11 did not result in particularly low groundwater levels at the start of 2011, low rainfall during 2011 gave rise to drought concern in many areas although this was largely confined to drought concern for agriculture as groundwater levels were not low enough to result in significant water resources risk. At the end of summer 2011 focus turned to the prospects for the winter and risk of a low winter recharge for groundwater level recovery.

The winter of 2011/12 continued the pattern of very low rainfall and at the end of the winter groundwater levels were exceptionally low across the Thames catchment and across the majority of SE England. It was clear in February 2012 that early imposition of restrictions was required and preparation for more severe drought measures was required. In late winter 2011/12 measures were taken to ensure full recovery of reservoir storage in the Thames Valley and so the levels of Teddington Target flows were reduced to below the LTCD guide levels to ensure storage was healthy in spring 2012. We urged our customers to use water wisely through late winter of 2011/12 and warned of the prospects of water restrictions in 2012 if the situation did not improve. We then implemented a full Temporary Use Ban on 3rd April 2012 in line with the majority of other companies in the South East. Almost immediately the weather changed and unprecedented levels of summer rainfall occurred such that significant groundwater recovery took place in June such that the TUB could be lifted in June 2012.

F4.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

1a/1b – Collation of Hydrologic Data and Predictions

The application of the methodology is demonstrated for 2012 using the graphs and tables shown below. This is followed by the assignment of the Overall Risk Indicator (ORI) and the Drought Event Level (DEL).

The example for London is based on the assessment of:

Groundwater, see Figure 3 showing Gibbet Cottages regional OBH (observed data from January to end of March and predicted to end of September 2012):

River flow, see Figure 4 showing observed flow at Teddington Weir from January to end of September

Reservoir storage for London WRZ, see Figure 5 showing observed storage trend from January to end of February and predicted from March to end of October. TWUL produces the actual reservoir storage data and undertakes predictions through the WARMS model. The five rainfall scenarios shown are for 100%, 80%,70%,60%, and 50% of the Long Term Average (LTA).

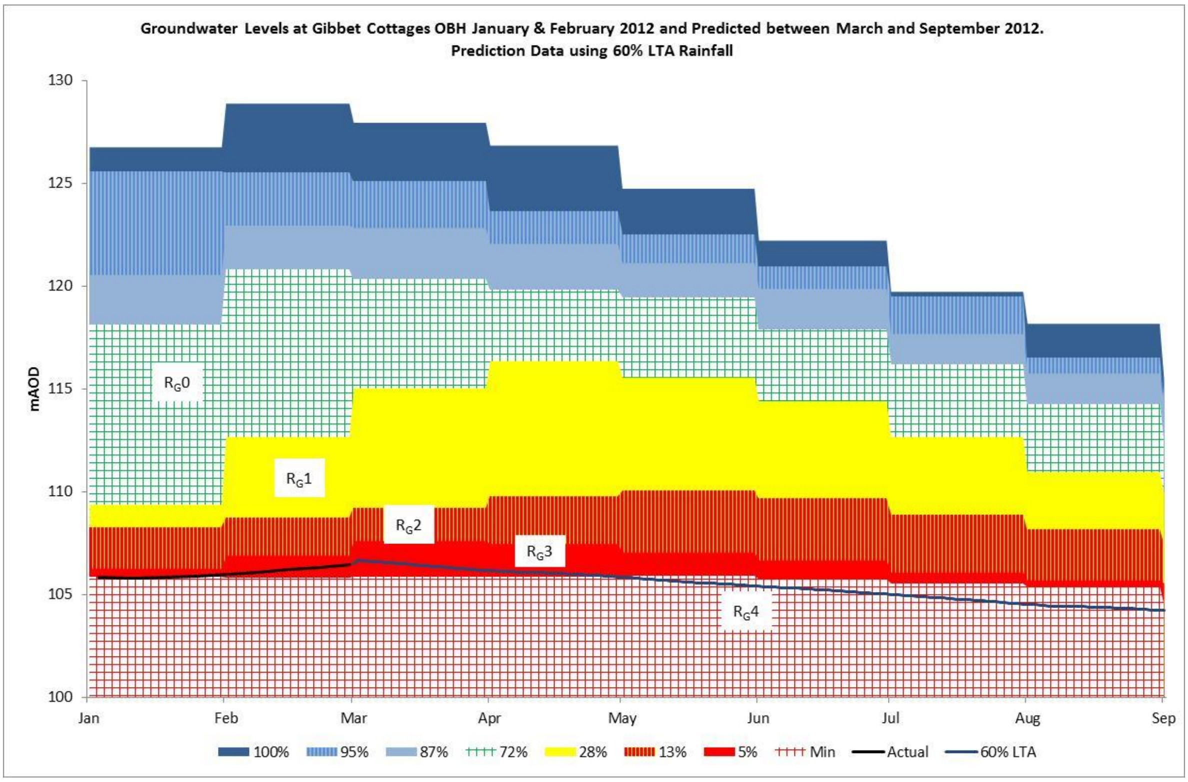

Figure 3 Prevailing groundwater levels for Gibbet Cottages OBH from January to end of March 2012 and predicted levels from March to September 2012 With Forecasts Using 60% of Long Term Average Rainfall

The data provided by the Environment Agency for Teddington Weir on the Lower Thames provides the river flow data relevant for the London abstractions and is instrumental in the Lower Thames Operating Agreement as described in Appendix E.

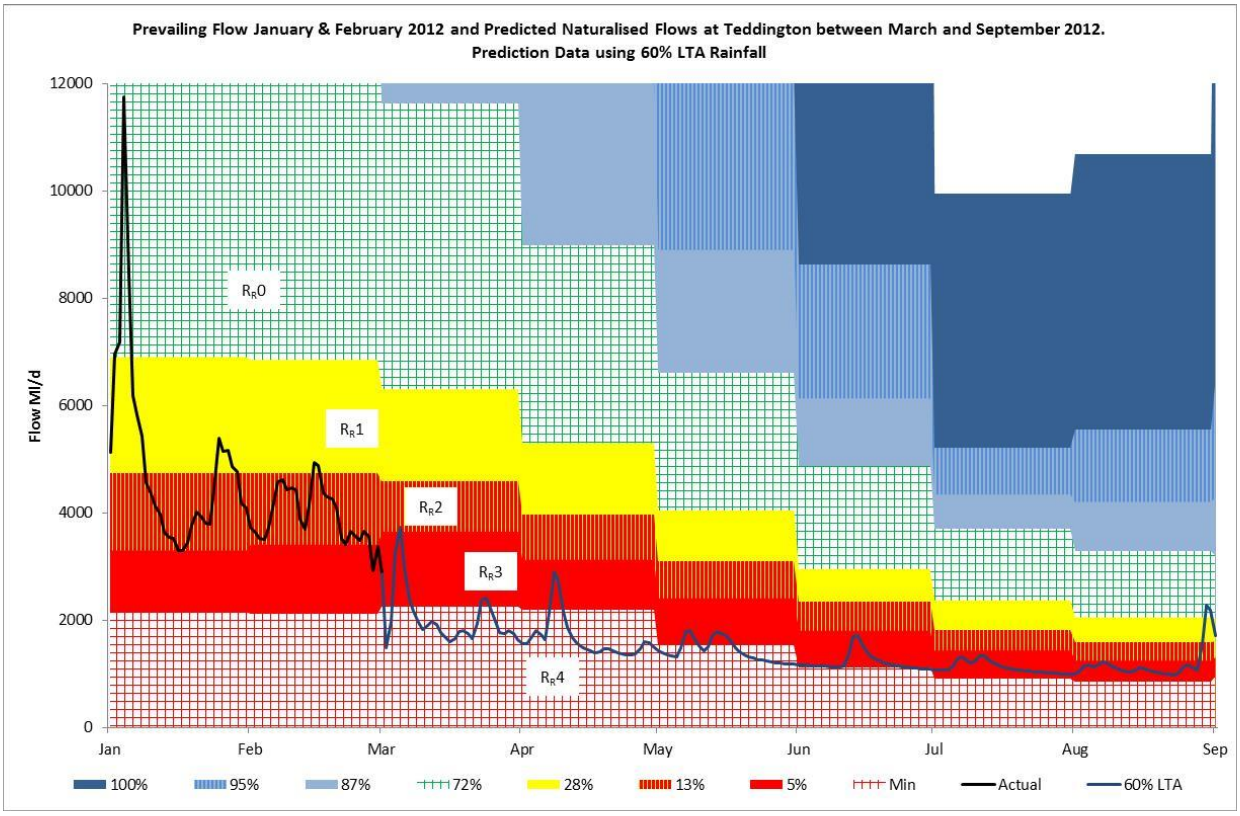

Figure 4 Prevailing flow over Teddington Weir from January and February 2012 to end of September 2012 and predicted flow using 60% of average rainfall between March and September 2012, Bands Based on 1900-2012.

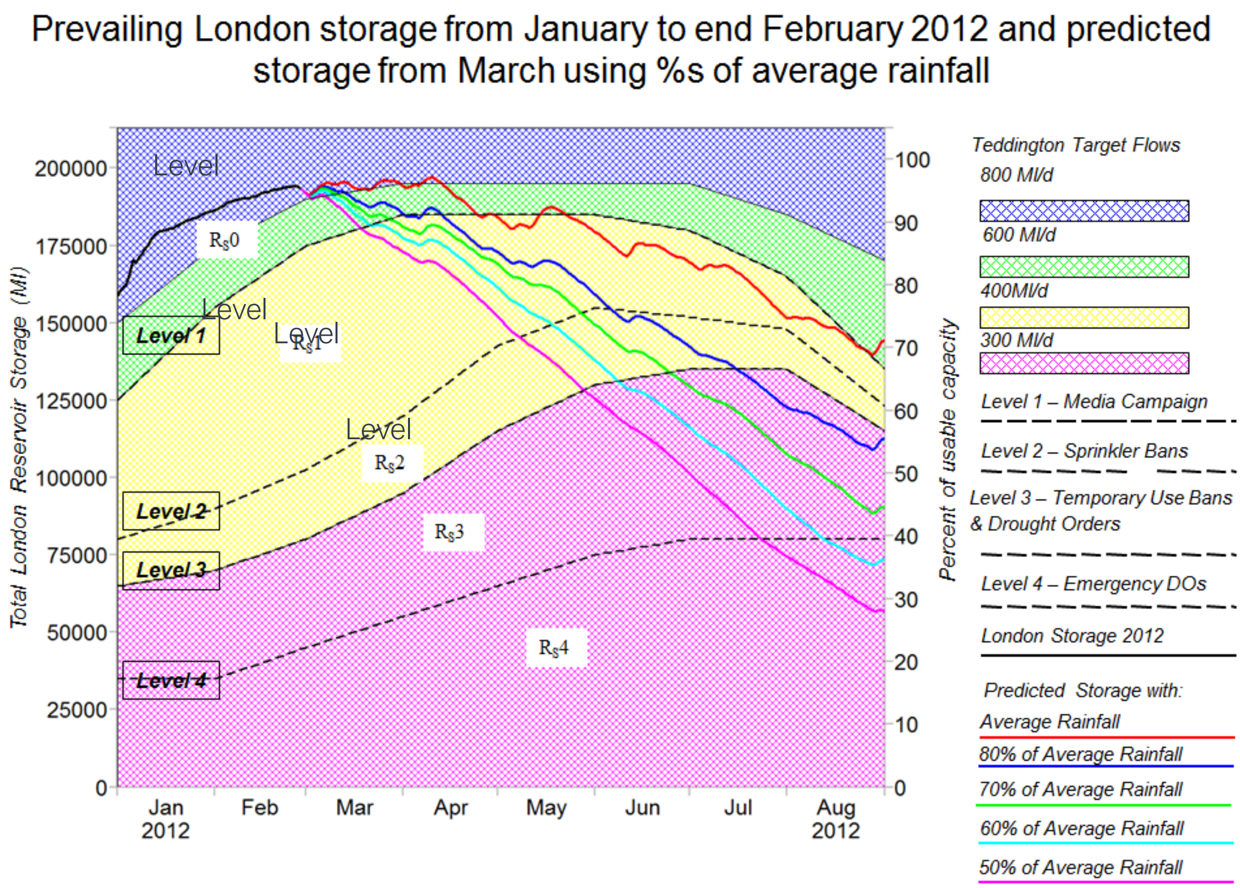

Figure 5 Prevailing London storage from January 2012 to end of February 2012 and Predicted Storage from March to end of August 2012

1c – Determination of Drought Severity against historic data

Figure 6 and Figure 7 inclusive show the potential drought severity in 2012 in relation to the worst droughts on record for the 111 years of record (1900 – 2011) as determined successively over the following 6 month period for each month beginning in February, thus predictions are made for: February to July and March to August. The successive monthly predictions show:

- February; potentially the worst on record, approximately 1 in 111 years
- March; potentially equal to the worst on record, approximately 1 in 111 years

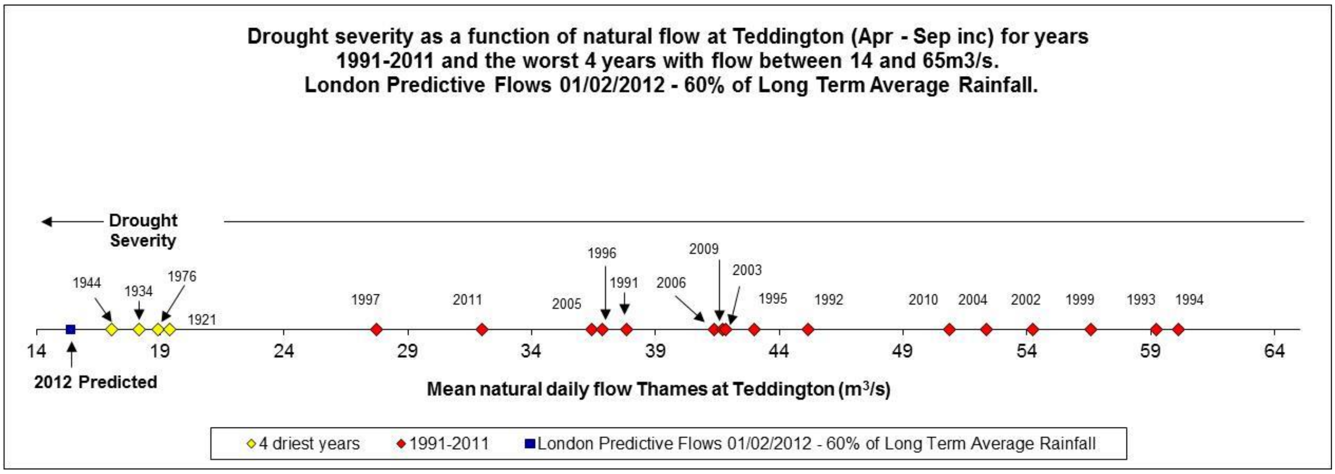

Figure 6 Potential Drought Severity from Feb 2012 Given Current Hydrological Indicators, Produced WARMS Model 6 Month Forecast using 60%LTA Rainfall

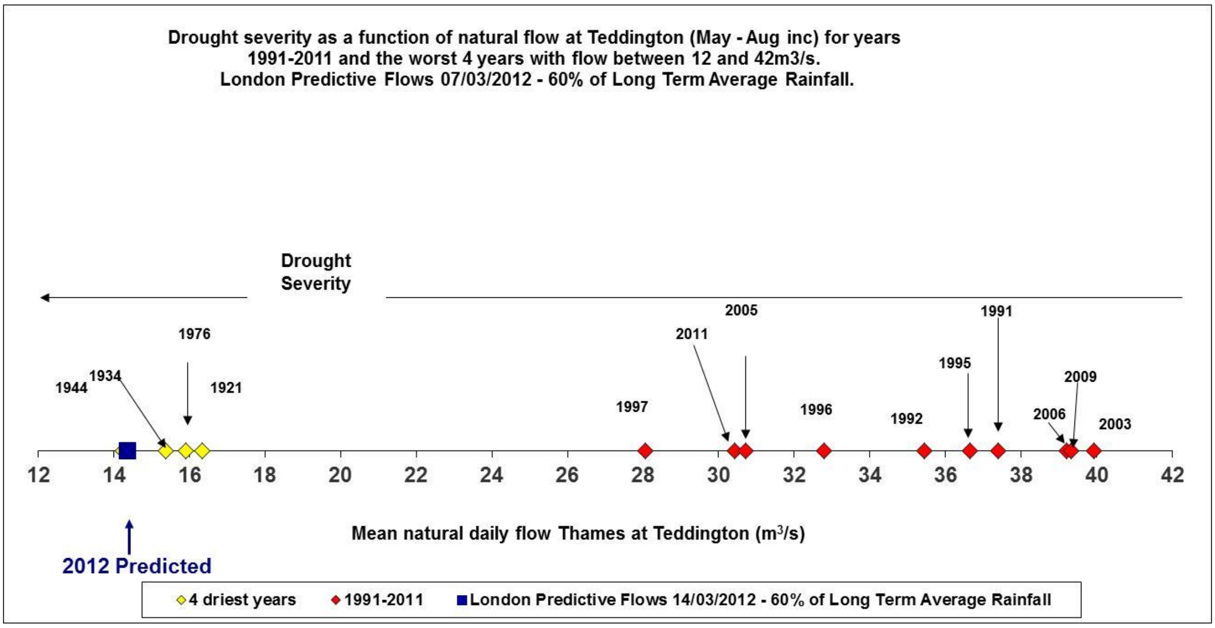

Figure 7 Potential Drought Severity from March 2012 Given Current Hydrological Indicators, Produced WARMS Model 6 Month Forecast using 60%LTA Rainfall

F4.2. Step 2 – Drought Risk Level Assessment

Step 2a/b - Prevailing and predicted hydrologic risk indicators R_G, R_R and R_S

- Figure 3 shows the prevailing and predicted groundwater levels (R_G) at Gibbet Cottages recording a prevailing value bordering on R_G3 in March with a prediction at end of August of R_G4
- Figure 4 shows the prevailing flow for Teddington in March 2012 as R_R3 and predicted flow at end of August R_R3.
- Figure 5 shows the prevailing storage for total London reservoir storage with a prevailing value of R_S0 in February with a predicted value of R_S 4 (60%) at the end of August.

These prevailing and predicted risk indicators have been entered into the matrix as shown in Table 13 and Table 14 below:

Step 2b-produce combined prevailing and hydrologic risk indicators (RC)

The risk values determined in steps 1 and 2a are used to calculate the Combined Risk Indicator. This is also shown in Table 13 and Table 14 where the combined risk is calculated using the formulae shown below for each table. This uses the weightings set out in Table F6 above.

Table 13 shows the Prevailing Risk levels for London in March 2012 with the combined risk indicator calculated as R_C2.

Table 13 F13 Drought Risk Assessment Matrix for Prevailing Conditions in March 2012

London/Lower Thames Drought Risk Assessment Matrix for Prevailing Conditions at beginning March 2012

Prevailing Risk Level at beginning March 2012 (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G				X	
River Flow Levels R_R				X	
Reservoir Storage R_S	X				
Combined Risk Indicator			X		

R_C= (3*0.5) + (3*0.2) + (0*0.3) = 1.5 + 0.6 + 0 = 2.1 (Rounded to 2)

Table 14 shows the Predicted Risk levels for London for a 60% LTA rainfall using the 6 month period from March to August 2012 with the combined risk indicator calculated as R_C3.

Table 14 F14 Drought Risk Assessment Matrix for August Using 6 Month Predicted Conditions from March 2012

Drought Risk Assessment Matrix for September 2012 using 6 month predicted conditions from March 2012

Predicted Risk Indicator - March 2012 to August 2012 with 60% LTA Rainfall (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G					X
River Flow Levels R_R		X			
Reservoir Storage R_S					X
Combined Risk Indicator				X	

R_C= (4*0.5) + (1*0.2) + (4*0.3) = 2.0 + 0.2 + 1.2 = 3.4 (Rounded to 3)

Step 2c- Combine prevailing and predicted indicators to produce an Overall Risk Indicator (ORI)

Using the prevailing and predicted R_C calculated from Step 2b and using Table 10 which outlines the ORI for various combinations of prevailing and predicted risk indicators, an Overall Risk Indicator (ORI) is ascertained. In this example, the prevailing value of R_C2 and predicted value of R_C3 gives an ORI2/3. The current situation at the time of the analysis is a prevailing condition of R_C2 and with an assumption of 60% of average rainfall the situation would worsen to a level R_C3. In summary the risk indicator levels and overall risks are:

Prevailing R_C2

Predicted R_C3

Overall Risk Indicator - ORI 2/3

F4.3. Step 3 – Determination of Measures and Drought Event Level

In this example Step 2b produced an indicator of ORI 2/3. This range of ORI values is then used to determine the Drought Event Level (DEL) through reference to Table 11. This process is also used to assign the associated governance and provide guidance on the potential drought measures that may be needed. This information is then used taking into account the time of year and operational issues such as outage to determine the final measures that would be implemented. Table 15 shows the DEL that is assigned in accordance with the ORI together with the drought measures to be implemented.

Table 15 Potential drought measures from the drought protocol applied in March 2012 data with 6 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI 2/3	DEL 3	Director	Enhanced Media/Water efficiency campaign/sprinkler ban possibly to escalate up to Temporary Use Ban and application for DD11 order and drought permits.

On the basis of the risk assessment (ORI2/3) in March 2012 with the prevailing risk of R_C2 with the potential to escalate to R_C3 within 6 months a media campaign would be needed and a full TUB would be introduced. The drought severity assessment shows that the potential severity was equivalent to 1 in 111 years thereby justifying the introduction of a TUB consistent with the Company's Levels Of Service.

Monthly predictions for 2012 with discussion on measures adopted

In practice the prevailing/predicted assessment would be carried out at least on a rolling monthly basis. To illustrate the month by month changes in DEL level, the prevailing and predicted analysis has been undertaken retrospectively for successive months in 2012 to give a picture of what the protocol indicated as the drought unfolded and whether an application for a DD11 order and drought permit(s) would be required.

Table 16 gives the **prevailing** condition and shows that the prevailing risk level did not reach greater than DEL2 throughout the year.

The prediction three months ahead is shown in Table 17. Whilst for London the 6 month prediction is used for determining whether **early** introduction of measures is required. Note that the 3 month prediction is used as a guide to demonstrate the potential risk of reaching the Level 3 curve on the LTCD within 3 months. The results show that this did not occur during 2012 and so an application for a DD11 order and drought permits were not required.

Table 18 shows the predicted risk level for London looking 6 months ahead. This shows that there was a risk of reaching DEL 4 when looking 6 months ahead and so the preparation (but not necessarily the submission) for a potential DD11 and drought permit implementation would be necessary.

Table 16 Prevailing Risk Level for London during 2012

Prevailing Risk Level for London during 2012

Location	London				
Analysis	Combined Prevailing Rc				
Range	2012				
	R_C0	R_C1	R_C2	R_C3	R_C4
Jan-2012					
Feb-2012					
Mar-2012			X		
Apr-2012			X		
May-2012			X		
Jun-2012		X			
Jul-2012		X			
Aug-2012	X				
Sep-2012					
Oct-2012					
Nov-2012					
Dec-2012					

Table 17 Predicted Risk Level for London during 2012 showing 3 month prediction

Predicted Risk Level for London during 2012 showing 3 month prediction with 60% rainfall

Location	London					
Analysis	Combined 3 Month Predicted Rc					
Range	2012					
	R_C0	R_C1	R_C2	R_C3	R_C4	Predicted from
Jan-2012						
Feb-2012						
Mar-2012						
Apr-2012						
May-2012						
Jun-2012				X		Mar-12
Jul-2012					X	Apr-12
Aug-2012			X			May-12
Sep-2012		X				Jun-12
Oct-2012		X				Jul-12
Nov-2012	X					Aug-12
Dec-2012						

Table 18 Predicted Risk Level for London during 2012 showing 6 month prediction

Predicted Risk Level for London during 2012/2013 showing 6 month prediction with 60% rainfall

Location	London					
Analysis	Combined 6 Month Predicted Rc					
Range	2012/2013					
	R_C0	R_C1	R_C2	R_C3	R_C4	Predicted from
Jan-2012						
Feb-2012						
Mar-2012						
Apr-2012						
May-2012						
Jun-2012						
Jul-2012						
Aug-2012						
Sep-2012				X		Mar-12
Oct-2012					X	Apr-12
Nov-2012			X			May-12
Dec-2012			X			Jun-12
Jan-2013		X				Jul-12
Feb-2013			X			Aug-12

F4.4. Conclusion on 2012 analysis London WRZ

The London protocol indicates that an enhanced media campaign and a full Temporary Use Band are required given the ORI 2/3 status.

With the protocol a media campaign was instigated, along with a Temporary use ban in April 2012. The actual 2012 storage trend never drew down to Level 1 on the LTCD, see Figure 8.

Comparison with what the London protocol would guide the Company to implement and what actually happened in 2012 shows that the measures introduced were in line with the protocol.

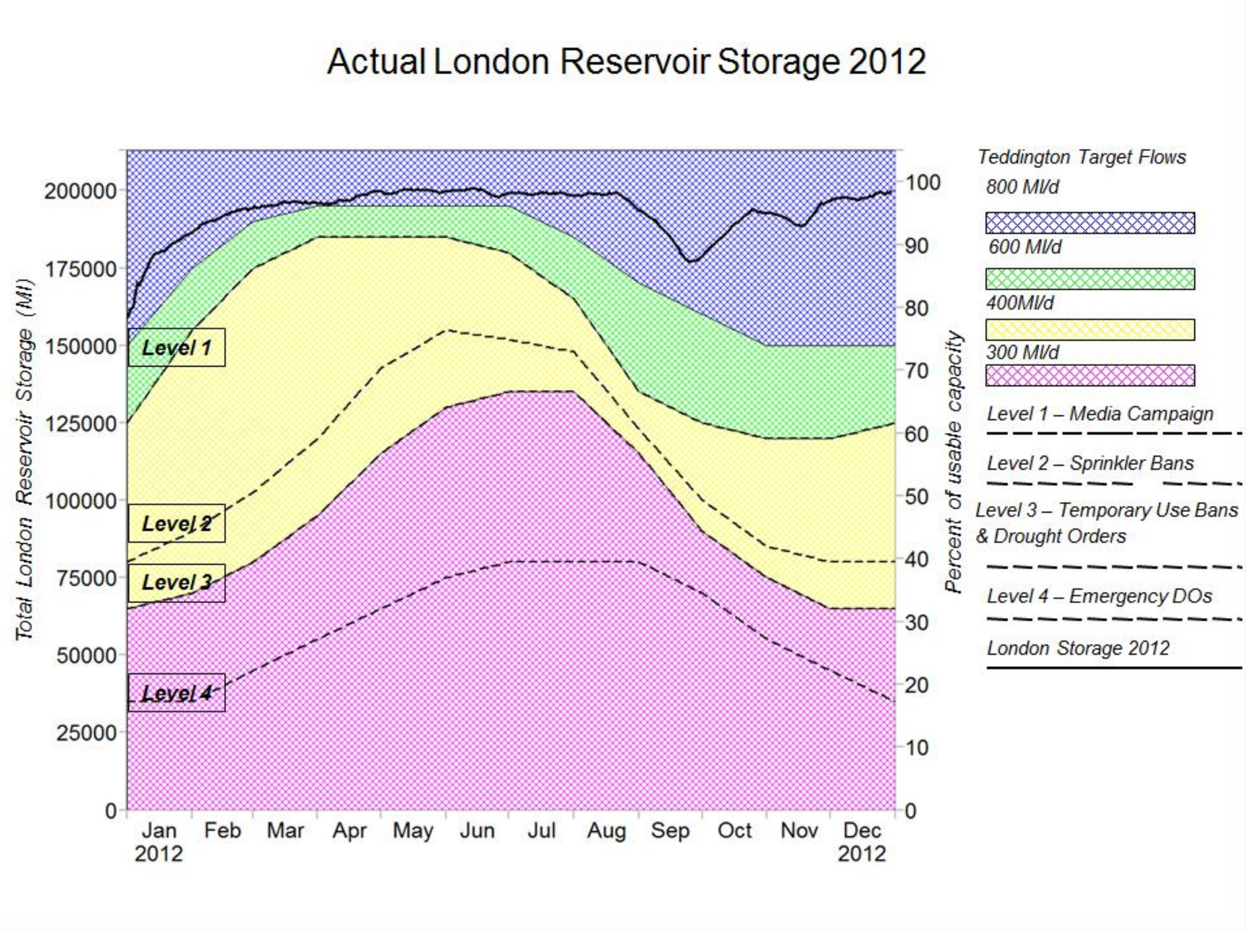

Figure 8 Actual Reservoir Storage for London in 2012

F5. 2012 drought example - SWOX WRZ

Background

Similarly to the pattern for the Chalk of the Thames catchment, aquifer recharge was restricted in the Cotswolds during January to March 2012 and groundwater levels in the Cotswolds Oolites were below average in late January and fell further during February. The resulting low levels in the Cotswolds aquifer signalled the potential for drought in the summer of 2012.

Largely driven by the London water resources situation but reinforced by the SWOX situation, Thames Water responded by implementing a media campaign early in 2012 requesting wise use of water. Further measures were implemented by Thames across its supply area with the introduction of a TUB on 3rd April. The unprecedented rainfall in April, June and July led to the very unusual situation of significant groundwater recovery in summer 2012. This removed the threat of significant drought in SWOX for the summer of 2012. This rainfall provided sufficient surface run off and groundwater recovery to enable Farmoor to remain full through the summer.

F5.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

1a/b – Collation of Hydrologic Data and Predictions

As for the London examples, the application of the protocol to the SWOX WRZ, based on Farmoor reservoir storage, has been undertaken using March as the base year. In contrast to London the period over which the prediction is undertaken is reduced to a 3 or 4 month prediction in recognition of the fact that the Farmoor water resources system responds much more quickly than the London system.

The application of the methodology is demonstrated for 2012 using the graphs and tables shown below. The following section then goes on to describe the assignment of the Overall Risk Indicator and the Drought Event Level.

It should be noted that because of the importance of the implementation of drought measures for London, in a potentially severe drought demand management measures will be implemented on a company-wide basis. This may result in the earlier implementation of demand management measures for SWOX than the SWOX protocol determines.

Figure 9 shows the prevailing groundwater level data for January 2012 to end of March 2012 and a forecast groundwater level to end of September using the 60% average rainfall scenario from March 2012.

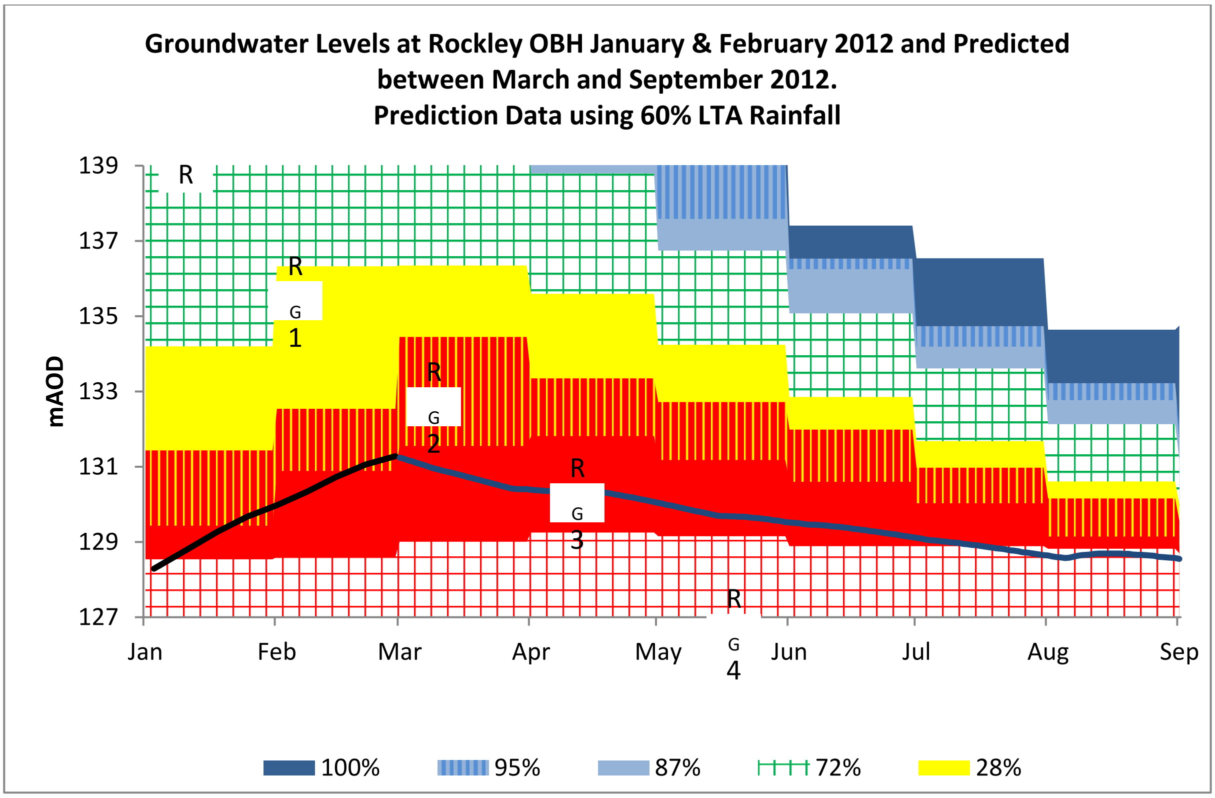

Figure 9 Groundwater Levels at Rockley showing actual data from January to end of March and predicted data from March to end of September 2012 and Bands showing % Based on EA data.

Figure 10 shows the prevailing flow data at Farmoor from January 2012 to end of August and a river flow prediction (based on 60% average rainfall) from WARMS (see Appendix I) between March and August 2012. The 200 Ml/d trigger for instigating drought permit orders is predicted to be reached at the end of July, almost 20 weeks into the future.

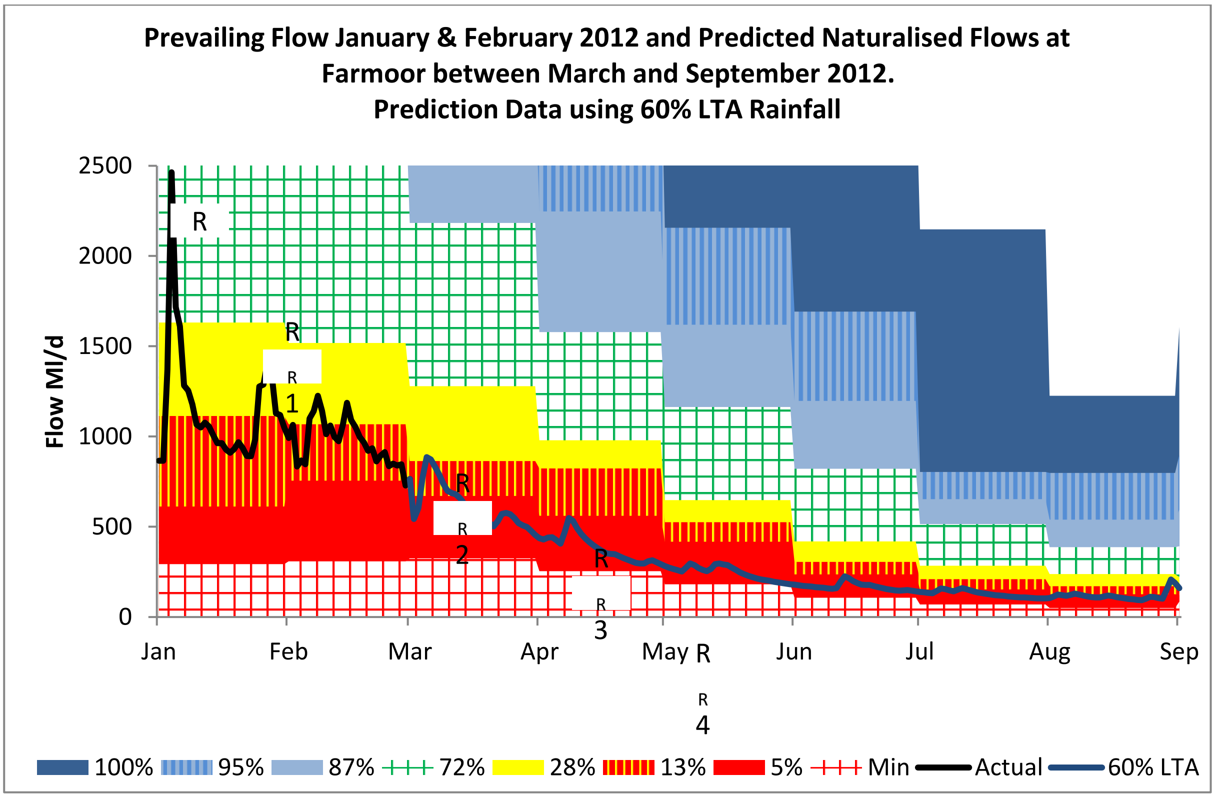

Figure 10 Prevailing flows at Farmoor from January to end of March 2012 and predicted flow from March to end of September 2012. Forecast Data from WARMS for 2012 with 60% Average Rainfall

Figure 11 shows the prevailing storage from January to 2012 and the WARMS reservoir storage level prediction using the 60% rainfall scenario undertaken in February, superimposed onto the Farmoor control diagram.

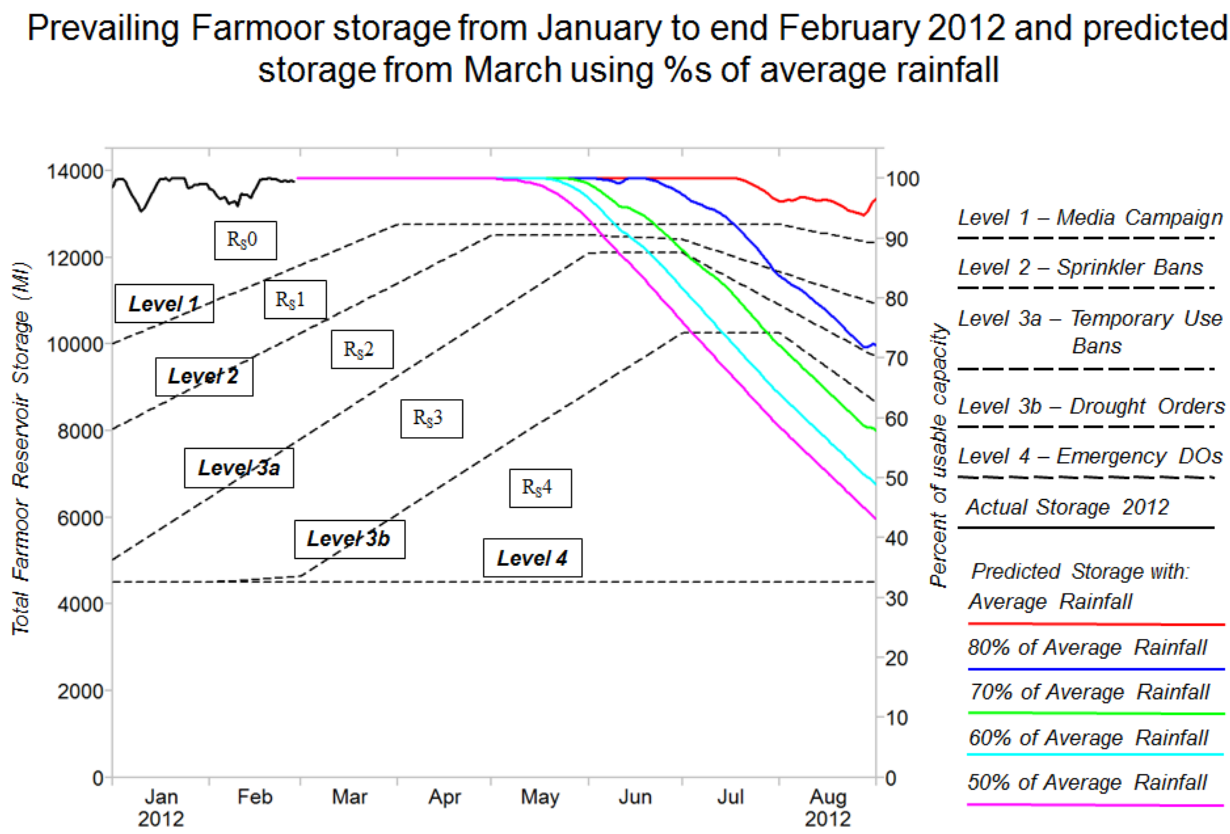

Figure 11 Predicted Reservoir Storage Showing prevailing storage from January to end of February 2012 and predicted storage using WARMS with a 60% rainfall scenario for March to end of August 2012

1c – Determination of Drought Severity against historic data

The drought severity assessment has been undertaken for London in view of the much longer period of record for London when compared to Farmoor. The assessment for London shows that the measures that would also be imposed companywide based on the new protocol are broadly in line with the Levels of Service.

F5.2. Step 2 – Drought Risk Level Assessment

2a/b – Prevailing and predicted hydrologic risk indicators R_G, R_R and R_S and Combined Prevailing and predicted hydrologic risk indicator R_C

Using the results from Step 1, Table 19 and Table 20 show respectively the analyses for the prevailing and predicted Rc values for March 2012.

Table 19 Drought Risk Assessment Matrix for Prevailing Conditions at Farmoor in March 2012

Farmoor/Upper Thames Drought Risk Assessment Matrix for Prevailing Conditions at beginning March 2012

Prevailing Risk Level at beginning March 2012 (UT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G				X	
River Flow Levels R_R			X		
Reservoir Storage R_S	X				
Combined Risk Indicator			X		

R_C= (3*0.55) + (2*0.20) + (0*0.25) = 1.65 + 0.4 + 0.0 = 2.05 (Rounded to 2)

Table 20 Drought Risk Assessment Matrix for 3 Month Prediction to June using 60% LTA

Drought Risk Assessment Matrix for June 2012 using 3 month predicted conditions from March 2012

Predicted Risk Indicator - March 2012 to May 2012 with 60% LTA Rainfall (UT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G				X	
River Flow Levels R_R				X	
Reservoir Storage R_S	X				
Combined Risk Indicator			X		

R_C= (3*0.5) + (3*0.25) + (0*0.25) = 1.5 + 0.75 + 0 = 2.25 (Rounded to 2)

2c – Combine prevailing and predicted indicators to produce an Overall Risk Indicator

The combined prevailing and predicted risk assessment gives rise to the following ORI:

- Prevailing R_C2
- Predicted R_C2
- ORI 2/2

F5.3. Step 3 Assignment of Drought Event Level (DEL)

In this example Step 2b produced an indicator of ORI 2/2. As shown in Table 21 this ORI value then gives rise to a Drought Event Level (DEL) of 2 through reference to Table 11.

Table 21 Potential drought measures from the drought protocol applied in March 2012 data with 3 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI 2/2	DEL2	Senior Manager	Enhanced Media/Water Efficiency Campaign Sprinkler Ban (under the powers afforded by Temporary Use Ban legislation).

On the basis of the assessment ORI level of 2/2 in March with the prevailing risk of R_C2 and the prevailing & predicted risk in London a TUB would be introduced.

F5.4. Conclusions for SWOX 2012

The measures undertaken for SWOX would have been driven from the results of the London protocol discussed above, namely an enhanced media campaign and a full TUB, matching the measures actually adopted in 2012.

Whilst at the end of March, the 200 Ml/d trigger for submitting drought permits was predicted to be reached by July (60% LTA scenario), in reality the water situation did not deteriorate over the summer due extremely heavy rainfall. Figure 12 shows the actual reservoir storage for Farmoor for 2012, which clearly demonstrates the benefit of the rainfall and runoff over the summer of 2012.

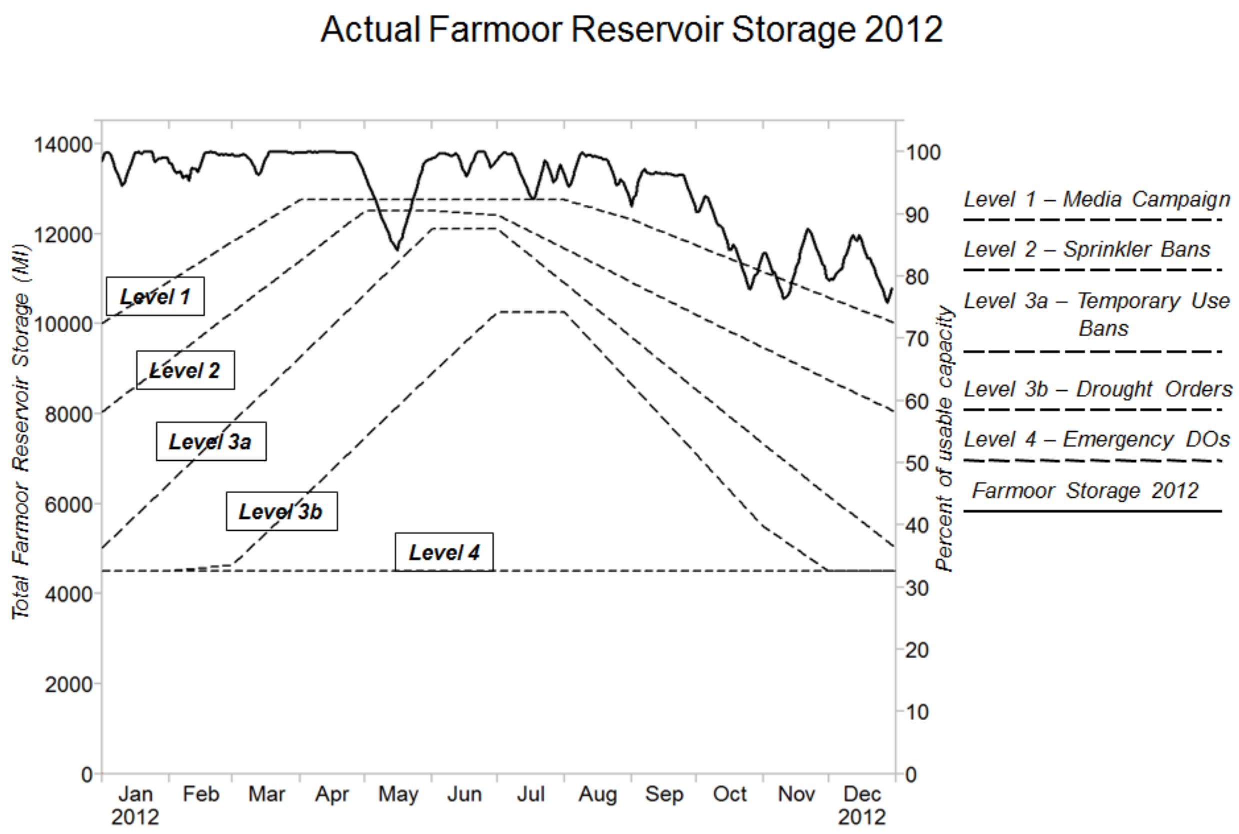

Figure 12 Actual Reservoir Storage for Farmoor in 2012

F5.5. 2005 drought example - London WRZ Background to 2005

After poor recharge occurred in late 2004 and early 2005, this resulted in low groundwater levels at the start of the year. Groundwater levels across the company area were therefore below average at the end of the recharge period, but not exceptionally so. This meant that there was the risk that the dry spell could become significant in terms of a water resource shortage. However, whilst Lower Thames river flows were below average in the spring, WARMS modelling showed the probability of reaching Level 3 to be marginal.

Rainfall during the summer of 2005 provided sufficient surface run off, particularly as a result of a significant event in April, to maintain storage in the London reservoirs in the early part of the summer. There was close liaison throughout 2005 between us and the Environment Agency regarding the requirement for introduction of restrictions. We did not consider that the imposition of restrictions was necessary, although a number of other companies in the South East had imposed restrictions. In view of the potential for benefits from the late spring recharge and increased surface flows, the situation was fundamentally different to that for many of the other companies in the South East. Other companies in the South East are much more reliant on groundwater and consequently, unless prolonged and substantial, summer rainfall has negligible benefit on groundwater levels and associated baseflows. In the event, reservoir storage only very briefly fell below the Level 1 curve on the LTCD, showing that no effective risk to security of supply arose.

F5.6. Step 1 - Hydrological Assessment and Drought Severity Assessment

1a/1b – Collation of Hydrologic Data and Predictions

The application of the methodology is demonstrated for 2005 using the graphs and tables shown below. This is followed by the assignment of the Overall Risk Indicator (ORI) and the Drought Event Level (DEL).

The example for London is based on the assessment of:

Groundwater, see Figure 13 showing Ashley Green regional OBH (observed data from January to end of April and predicted to end of December):

River flow, see Figure 14 showing observed flow at Teddington Weir from January to end of February

Reservoir storage for London WRZ, see Figure 15 showing observed storage trend from January to end of February and predicted from March to end of August. TWUL produces the actual reservoir storage data and undertakes predictions through the WARMS model. The five rainfall scenarios shown are for 100%, 80%,70%,60%, and 50% of the Long-Term Average (LTA).

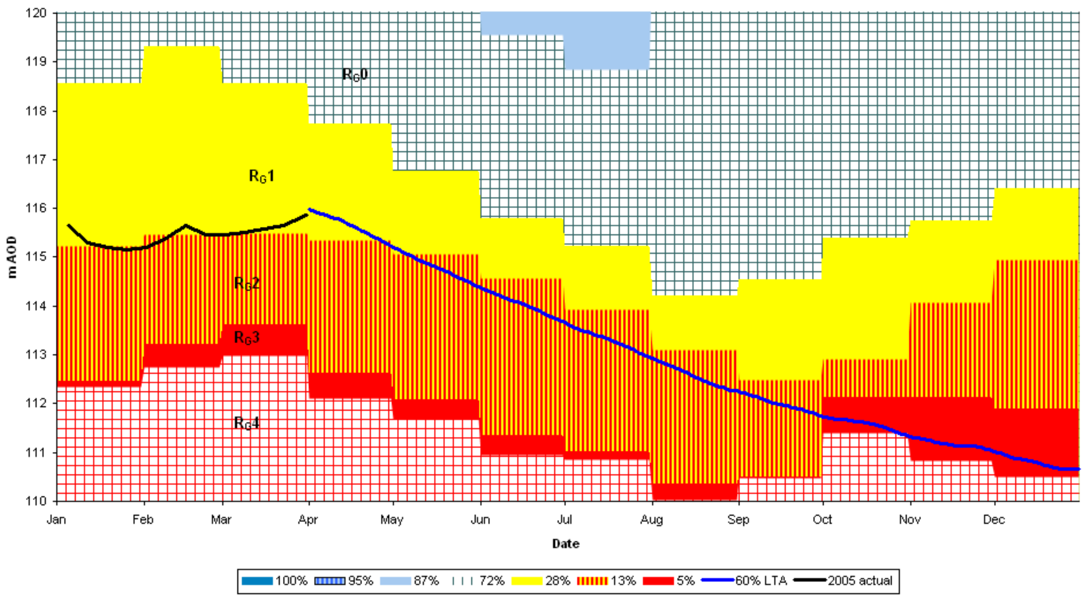

Figure 13 Prevailing groundwater levels for Ashley Green OBH from January to end of March 2005 and predicted levels from April to December 2005 With Forecasts Using 60% of Long Term Average Rainfall.

The data provided by the Environment Agency for Teddington Weir on the Lower Thames provides the river flow data relevant for the London abstractions and is instrumental in the Lower Thames Operating Agreement as described in Appendix E.

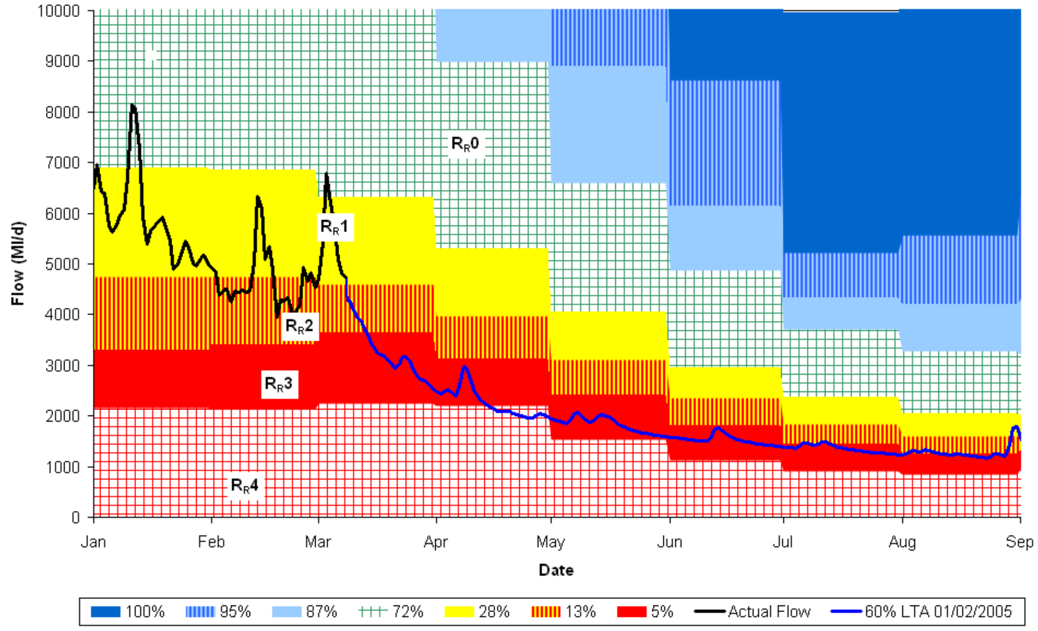

Figure 14 Prevailing flow over Teddington Weir from January to end of February 2005 and predicted flow using 60% of average rainfall between March and August 2005, Bands Based on 1900-2006.

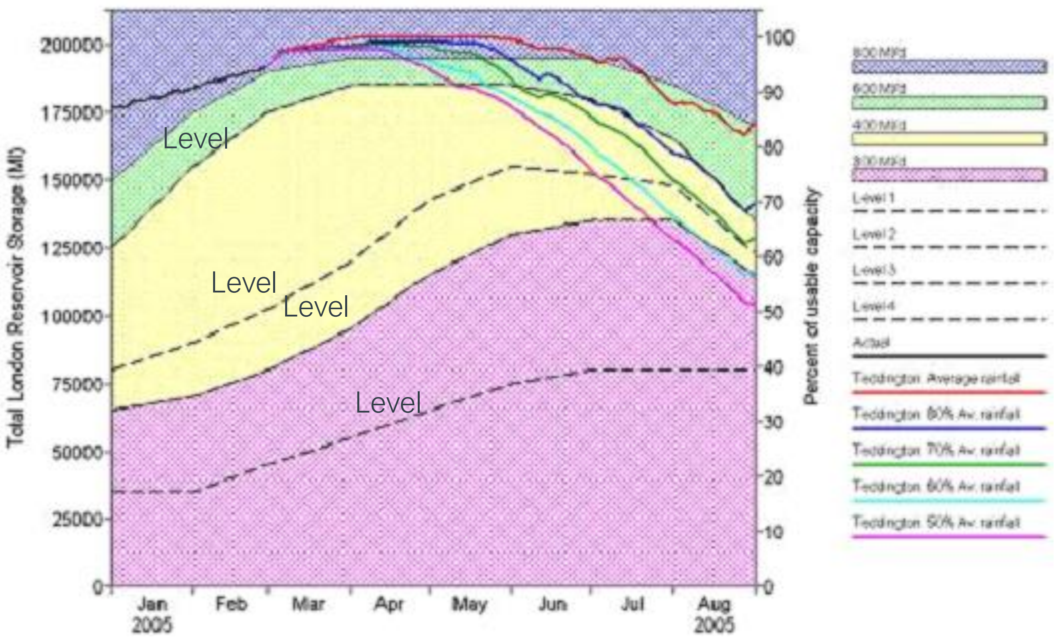

Figure 15 Prevailing London storage from January 2005 to end of February and Predicted Storage from March to end of August 2005

1c – Determination of Drought Severity against historic data

Figure 16, Figure 17 and Figure 18 Figure 6show the potential drought severity in 2005 in relation to the worst droughts on record for the 109 years of record (1900 – 2008) as determined successively over the following 6 month period for each month beginning in February, thus predictions are made for: February to July; March to August; and April to September. The successive monthly predictions show:

- February to July; potentially the 4th worst on record, approximately 1 in 27 years
- March to August; potentially the 5th worst on record, approximately 1 in 22 years
- April to September; potentially the 7th worst on record, approximately 1 in 16 years

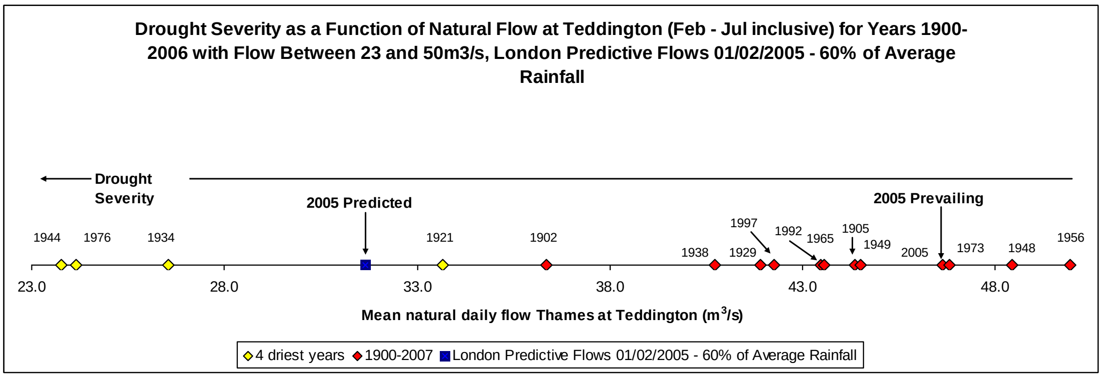

Figure 16 Potential Drought Severity from February 2005 Given Current Hydrological Indicators, Produced WARMS Model 6 Month Forecast using 60%LTA Rainfall

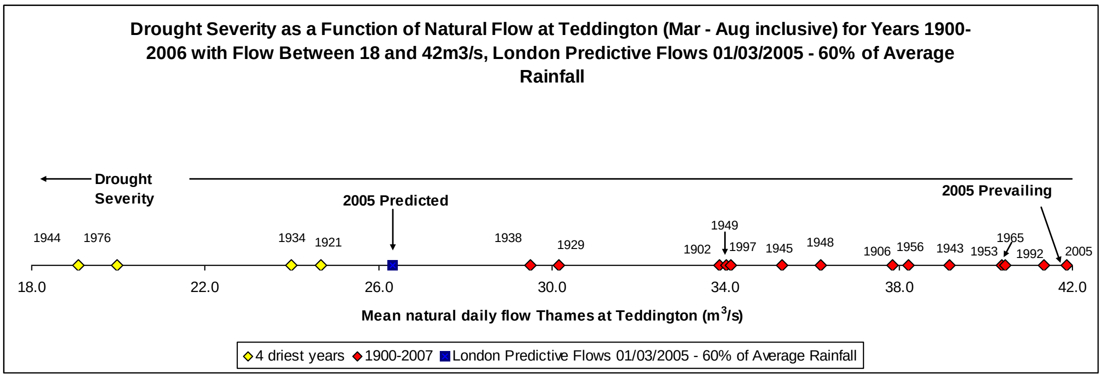

Figure 17 Potential Drought Severity from March 2005 Given Current Hydrological Indicators, Produced WARMS Model 6 Month Forecast using 60%LTA Rainfall

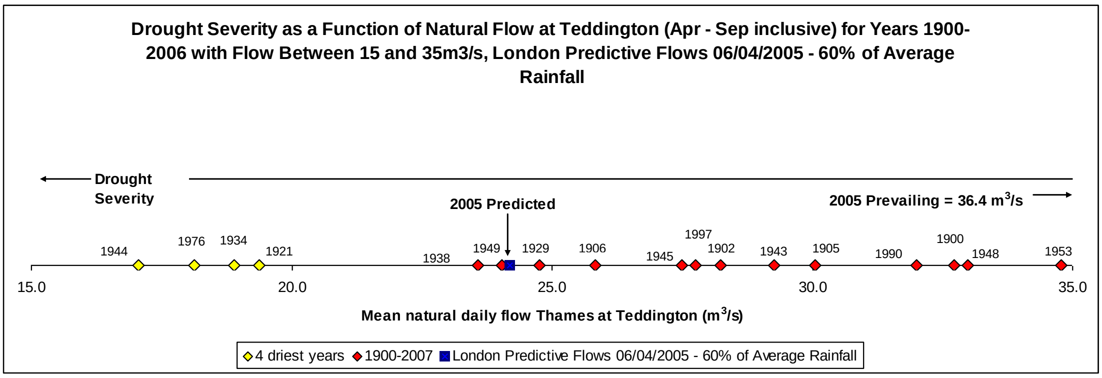

Figure 18 Potential Drought Severity from April 2005 Given Current Hydrological Indicators, Produced WARMS Model 6 Month Forecast using 60%LTA Rainfall

F5.7. Step 2 – Drought Risk Level Assessment

Step 2a/b - Prevailing and predicted hydrologic risk indicators R_G, R_R and R_S

- **Figure** 13 shows the prevailing and predicted groundwater levels (R_G) at Ashley Green recording a prevailing value bordering on R_G1/R_G2 in February with a prediction at end of August of R_G2.
- Figure 14 shows the prevailing flow for Teddington in February 2005 as R_R2 and predicted flow at end of August bordering on R_R2/ R_R3.
- Figure 15 shows the prevailing storage for total London reservoir storage with a prevailing value of R_S0 in February with a predicted value of R_S3 (60%) at the end of August.

These prevailing and predicted risk indicators have been entered into the matrix as shown in Table 22 and Table 23 below:

Step 2b-produce combined prevailing and hydrologic risk indicators (RC)

The risk values determined in steps 1 and 2a are used to calculate the Combined Risk Indicator. This is also shown in Table 22 and Table 23 where the combined risk is calculated using the formulae shown below for each table. This uses the weightings set out in Table 6 above.

Table 22 shows the Prevailing Risk levels for London in February 2005 with the combined risk indicator calculated as bordering between R_C1 and. R_C2.

Table 22: F22 Drought Risk Assessment Matrix for Prevailing Conditions in February 2005

Prevailing Risk Level In February 2005 (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G		X	X		
River Flow Levels R_R			X		
Reservoir Storage R_S	X				
Combined Risk Indicator		X	X		

R_C = (1*0.60) + (2*0.15) (0*0.25)= 0.6 + 0.3 +0+ = 0.9 (Rounded to 1) OR

Rc=(2*0.60) + (2*0.15) + (0*0.25) = 1.2 + 0.30 + 0 =1.50 (Rounded to 2)

Table 23 shows the Predicted Risk levels for London for a 60% LTA rainfall using the 6 month period from March to August 2005 with the combined risk indicator calculated as bordering between R_C2 and R_C3.

Table 23 Drought Risk Assessment Matrix for August Using 6 Month Predicted Conditions from February 2005

Predicted Risk Indicator - February 2005 to August 2005 with 60% LTA (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G			X		
River Flow Levels R_R			X	X	
Reservoir Storage R_S				X	
Combined Risk Indicator			X	X	

Rc= (2*0.45) + (2*0.25) + (3*0.30) = 0.9 + 0.50 + 0.9 = 2.35 (Rounded to 2) OR R_C = (2*0.45) + (3*0.25) + (3*0.30) = 0.9 + 0.75 + 0.9 = 2.55 (Rounded to 3)

Step 2c- Combine prevailing and predicted indicators to produce an Overall Risk Indicator (ORI)

Using the prevailing and predicted R_C calculated from Step 2b and using Table 10 which outlines the ORI for various combinations of prevailing and predicted risk indicators, an Overall Risk Indicator (ORI) is ascertained. In this example, the prevailing value of R_C1 bordering on R_C2 and predicted value of R_C2 bordering on Rc3 gives an ORI1/2 of bordering on ORI 2/3. The current situation at the time of the analysis is a prevailing condition of R_C2 and with an assumption of 60% of average rainfall the situation would worsen to a level R_C3. In summary the risk indicator levels and overall risks are:

- Prevailing R_C1 bordering on Rc2
- Predicted R_C2 bordering on Rc3
- ORI1/2 bordering on ORI 2/3

F5.8. Step 3 – Determination of Measures and Drought Event Level

In this example Step 2b produced an indicator of ORI 1/2 or possibly ORI 2/3. This range of ORI values is then used to determine the Drought Event Level (DEL) through reference to Table F11. This process is also used to assign the associated governance and provide guidance on the potential drought measures that may be needed. This information is then used taking into account the time of year and operational issues such as outage to determine the final measures that would be implemented. Table 24 shows the DEL that is assigned in accordance with the ORI together with the drought measures to be implemented.

Table 24 Potential drought measures from the drought protocol applied in February 2006 data with 6 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI1/2 bordering on ORI 2/3	DEL 2 bordering on DEL 3	Senior Manager/Director	Enhanced Media/Water efficiency campaign/sprinkler ban possibly to escalate up to Temporary Use Ban and application for DD11 order and drought permits.

On the basis of the risk assessment (ORI1/2) in February with the prevailing risk of R_C1 with the potential to escalate to R_C2 within 6 months a media campaign would be needed and a sprinkler ban would be introduced. The drought severity assessment shows that the potential severity was equivalent to 1 in 15 years thereby justifying the introduction of a sprinkler ban consistent with the Company's Levels Of Service.

F5.9. Conclusion on 2005 analysis London WRZ

The London protocol indicates that an enhanced media campaign and a sprinkler ban would have been introduced in 2005 but not a full Temporary Use Ban; given the border line nature of the assessment, a Temporary Use Ban would have been made ready to set in train if subsequent assessments had tended towards the ORI 2/3 status.

If the London protocol had been in place in 2005, it is likely that the Company would have at least instigated a media campaign at the end of February given ORI 1/2 The actual 2005 storage trend never drew down to Level 1 on the LTCD, see Figure 19, but hovered around the 800/600 curve for most of the summer.

Comparison with what the London protocol would guide the Company to implement and what actually happened in 2005 shows that the measures introduced in line with the protocol would have been greater as Thames Water did not actually introduce a sprinkler ban in 2005.

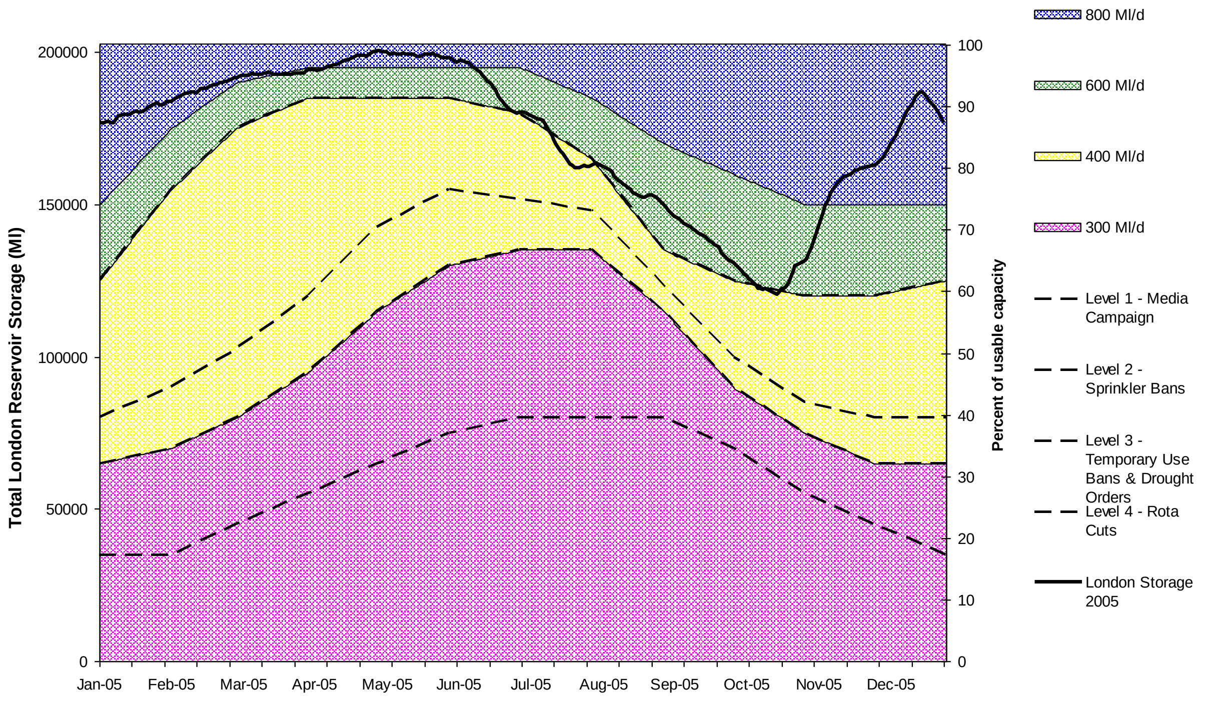

Figure 19 Actual Reservoir Storage for London in 2005

F6. 2005 drought example - SWOX WRZ

Background

Similarly to the pattern for the Chalk of the Thames catchment, aquifer recharge was restricted in the Cotswolds during January to March 2005 and groundwater levels in the Cotswolds Oolites were below average in late January and fell further during February. The resulting low levels in the Cotswolds aquifer signalled the potential for drought in the summer of 2005.

Largely driven by the London water resources situation, we responded by implementing a media campaign early in 2005 requesting wise use of water. Further measures were not implemented across our supply area. Measures were not required in SWOX at any time in 2005 in view of the early summer rainfall and associated recovery in groundwater levels in the Cotswolds during April. This removed the threat of significant drought in SWOX for the summer of 2005. This rainfall provided sufficient surface run off and groundwater recovery to enable Farmoor to remain full through the summer.

F6.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

1a/b – Collation of Hydrologic Data and Predictions

As for the London examples, the application of the protocol to the SWOX WRZ, based on Farmoor reservoir storage, has been undertaken using February as the base. In contrast to London the period over which the prediction is undertaken is reduced to a 3 or 4 month prediction in recognition of the fact that the Farmoor water resources system responds much more quickly than the London system.

The application of the methodology is demonstrated for 2005 using the graphs and tables shown below. The following section then goes on to describe the assignment of the Overall Risk Indicator and the Drought Event Level.

It should be noted that because of the importance of the implementation of drought measures for London, in a potentially severe drought demand management measures will be implemented on a company-wide basis. This may result in the earlier implementation of demand management measures for SWOX than the SWOX protocol determines.

There is no groundwater prediction available for 2005 for the SWOX zone, and so to illustrate the methodology, the prediction for 2006 has been used because the groundwater levels at Rockley were very similar at the end of 2005 to those at the end of 2006 and so the predicted levels would be broadly similar. Figure 20 shows the prevailing groundwater level data for January 2006 to end of February 2006 and a forecast groundwater level to end of August using the 60% average rainfall scenario from February 2006.

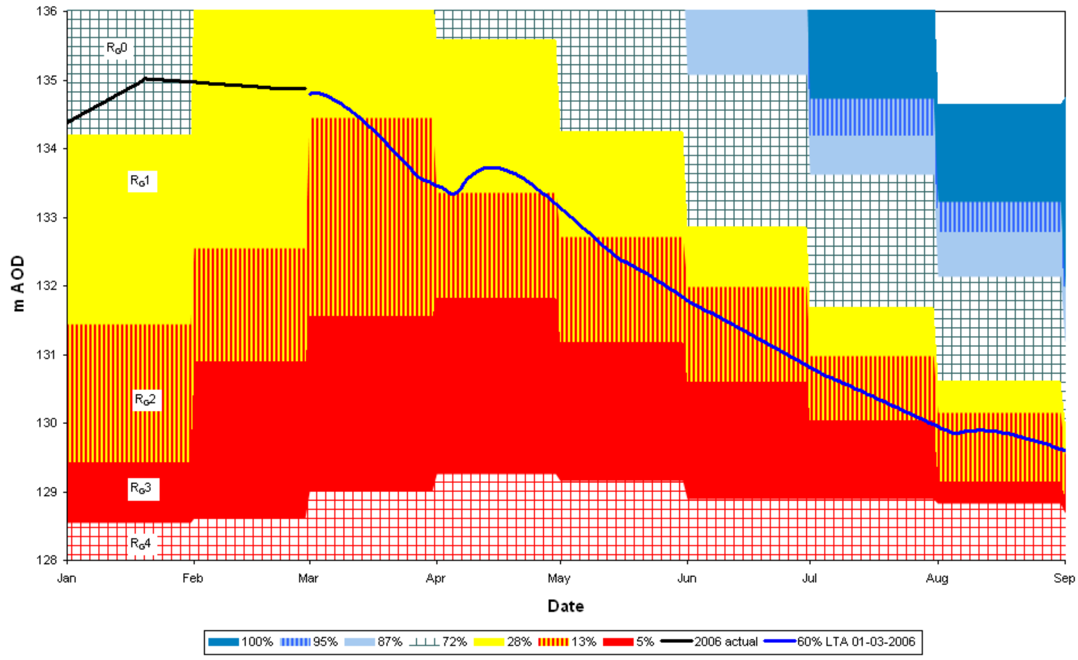

Figure 20 Groundwater Levels at Rockley showing actual data from January to end of February and predicted data from March to end of August 2006 (used as a surrogate for 2005) and Bands showing % Based on EA data.

Figure 21 shows the prevailing flow data at Farmoor from January 2005 to end of February and a river flow prediction (based on 60% average rainfall) from WARMS (see Appendix I) between

March and August 2005. The 200 Ml/d trigger (see Main Report Section 4.4) for instigating NEUB and drought permit orders is predicted to be reached in mid-August, over 20 weeks into the future.

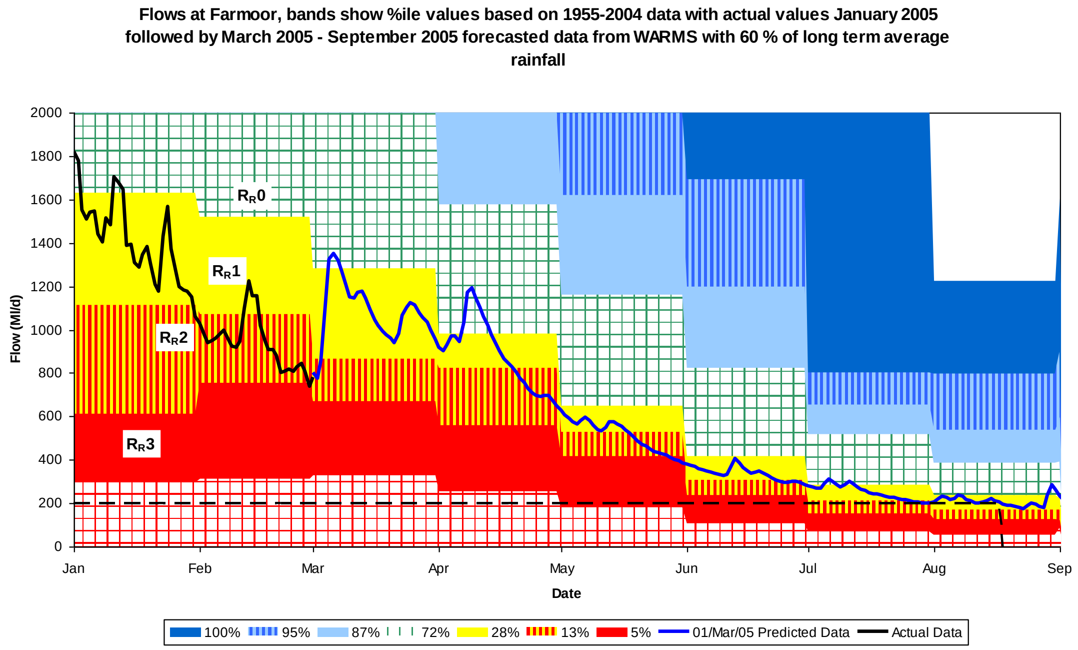

Figure 21 Prevailing flowsat Farmoor from January to end of February 2005 and predicted flow from March to end of August 2005. Forecast Data from WARMS for 2005 with 60% Average Rainfall

Figure 22 shows the prevailing storage from January to 2005 and the WARMS reservoir storage level prediction using the 60% rainfall scenario undertaken in February, superimposed onto the Farmoor control diagram.

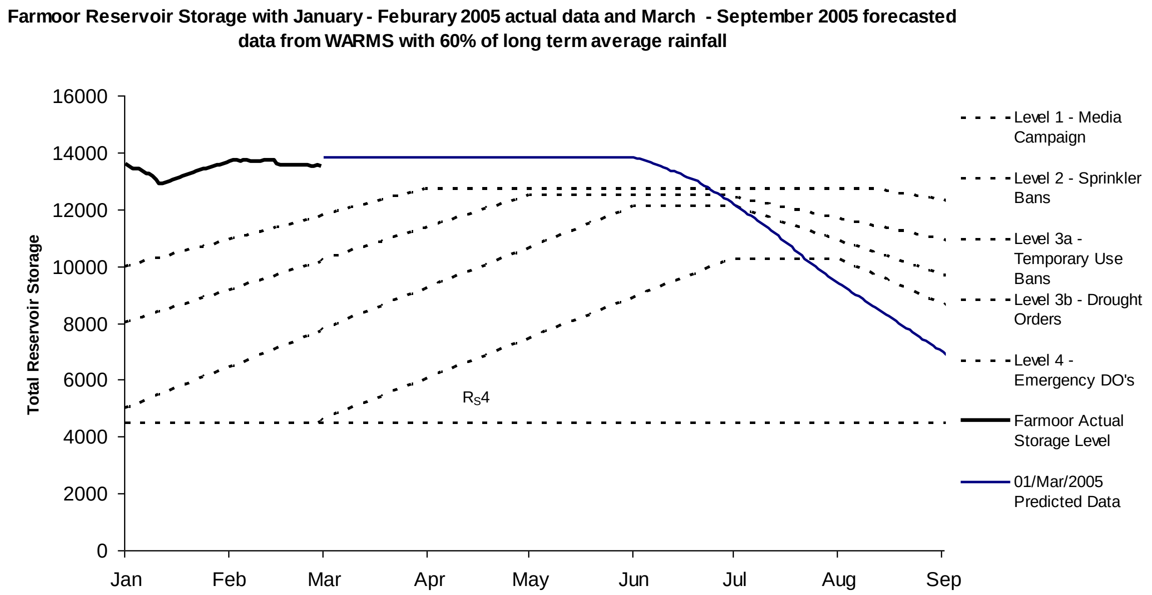

Figure 22 Predicted Reservoir Storage Showing prevailing storage from January to end of February 2005 and predicted storage using WARMS with a 60% rainfall scenario for March to end of August 2005

1c – Determination of Drought Severity against historic data

The drought severity assessment has been undertaken for London in view of the much longer period of record for London when compared to Farmoor. The assessment for London shows that the measures that would be imposed company wide based on the new protocol are broadly in line with the Levels of Service.

F6.2. Step 2 – Drought Risk Level Assessment

2a/b – Prevailing and predicted hydrologic risk indicators R_G, R_R and R_S and Combined Prevailing and predicted hydrologic risk indicator R_C

Using the results from Step 1, tables Table 25 and Table 26 show respectively the analyses for the prevailing and predicted Rc values for January and May 2005

Table 25 Drought Risk Assessment Matrix for Prevailing Conditions at Farmoor in February 2005

Prevailing Risk Level In January 2005 (UT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G		X			
River Flow Levels R_R			X		
Reservoir Storage	X				
Combined Risk Indicator R_C		X			

R_C = (1*0.6) + (1*0.25) (0*0.15= 0.6 + 0.25+0= 0.85 (Rounded to 1)

Table 26 Drought Risk Assessment Matrix for 4 Month Prediction to May using 60% LTA

Predicted Risk Indicator – February to May 2005 with 60% LTA (UT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G			X		
River Flow Levels R_R			X	X	
Reservoir Storage Rs	X				
Combined Risk Indicator R_C			X		

R_C = (2*0.5) + (2*0.25)+ (0*0.25) =1.0 + 0..50 + 0= 1.50 (Rounded to 2) OR

R_C = (2*0.5) + (3*0.25)+ (0*0.25) =1.0 + 0.75 + 0= 1.75 (Rounded to 2)

2c – Combine prevailing and predicted indicators to produce an Overall Risk Indicator

The combined prevailing and predicted risk assessment gives rise to the following ORI:

- Prevailing R_C1
- Predicted R_C2
- ORI 1/2

F6.3. Step 3 Assignment of Drought Event Level (DEL)

In this example Step 2b produced an indicator of ORI 1/2. As shown in Table 27 this ORI value then gives rise to a Drought Event Level (DEL) of 2 through reference to Table 11.

Table 27 Potential drought measures from the drought protocol applied in January 2005 data with 4 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI1/2	DEL 2	Senior Manager	Enhanced Media/water efficiency campaign with sprinkler ban (under the powers afforded by Temporary Use Ban legislation).

On the basis of the assessment ORI level of 1/2 in February, with the prevailing risk of R_C1 and the potential to escalate to R_C2 within 3 months plans would be made to introduce a company-wide sprinkler ban. However, this would be overridden by company-wide measures derived from the London protocol.

F6.4. Conclusions for SWOX 2005

The measures undertaken for SWOX would have been driven from the results of the London protocol discussed above, namely an enhanced media campaign and a sprinkler ban, thereby exceeding the measures actually adopted in 2005 under the historic protocol.

Whilst at the end of February, the 200 Ml/d trigger for submitting drought permit applications was predicted to be reached by mid- August (60% LTA scenario), in reality the water situation did not deteriorate over the summer to a sufficient extent to warrant such measures and the revised protocol would have recognised this position. The actual flow at Farmoor over 2005 shows that baseflows were indeed close to the 200 Ml/d level by August, but due to frequent periods of rainfall providing inputs of surface runoff, there was never a sustained low flow period to warrant an application for drought permits. Figure 23 shows the actual reservoir storage for Farmoor for 2005, which clearly demonstrates the benefit of the rainfall and runoff over the summer of 2005.

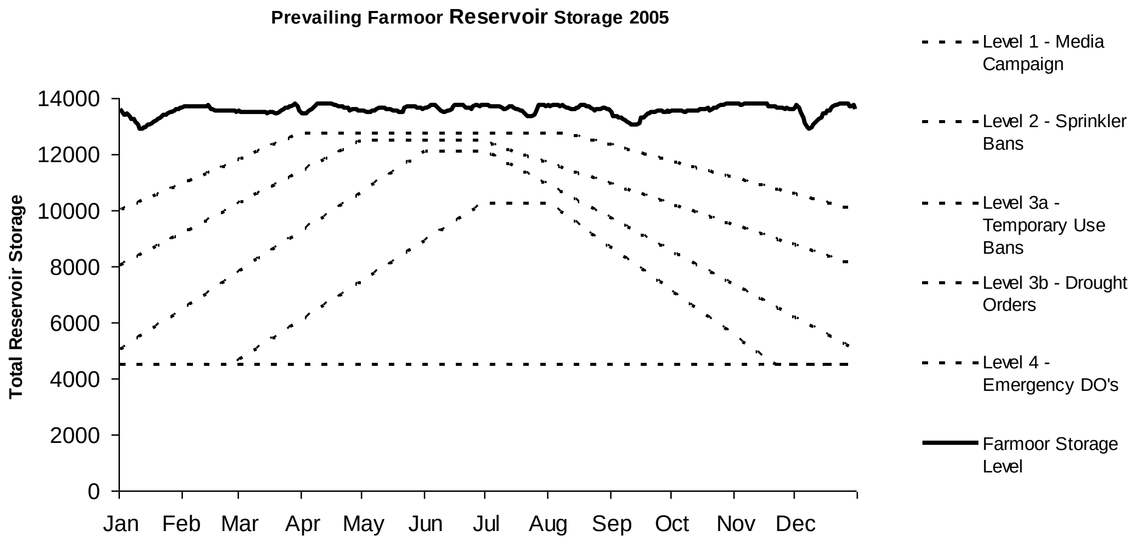

Figure 23 Actual Reservoir Storage for Farmoor in 2005

F7. 2006 drought example - London WRZ

Background to 2006

Based on the water situation assessment undertaken at the end of February 2006 (note that this was prior to the development of the new methodology), we introduced an enhanced media campaign and sprinkler/hosepipe ban on 3 April 2006. At this time we also started to prepare an application for an Ordinary Drought Order (ODO) to ban non-essential use. We made the decision to introduce early the demand management measures in line with advice from the EA and Defra.

Application for an ODO was made in June and the Public Hearing held in July. The Inspector advised Defra to accept the application in August. However, we withdrew the ODO application on the basis that the intervening wetter conditions had meant that the risk to security of supply had significantly abated rendering such extreme measures affecting our commercial customers unnecessary. The conditions improved over the autumn and winter of 2006 and the hosepipe ban was lifted in January 2007 following the onset of significant recharge in all aquifers in the Thames Water supply area.

F7.1. Step 1 Hydrological Assessment and Drought Severity Assessment

1a/1b – Collation of Hydrologic Data and Predictions

The example for London is based on the assessment in February 2006 i.e. this has been chosen as the base month, and a six month forecast from beginning of March to end of August 2006 is used to provide the predicted hydrological data.

The application of the methodology is demonstrated for 2006 using the graphs and tables shown below. The following section then goes on to describe the assignment of the Overall Risk Indicator and the Drought Event Level

Figure 24 shows the prevailing groundwater situation for the Oak Ash OBH in January and February 2006 and prediction from March to August 2006 (NB the Oak Ash OBH has since been replaced by Gibbet Cottages regional OBH).

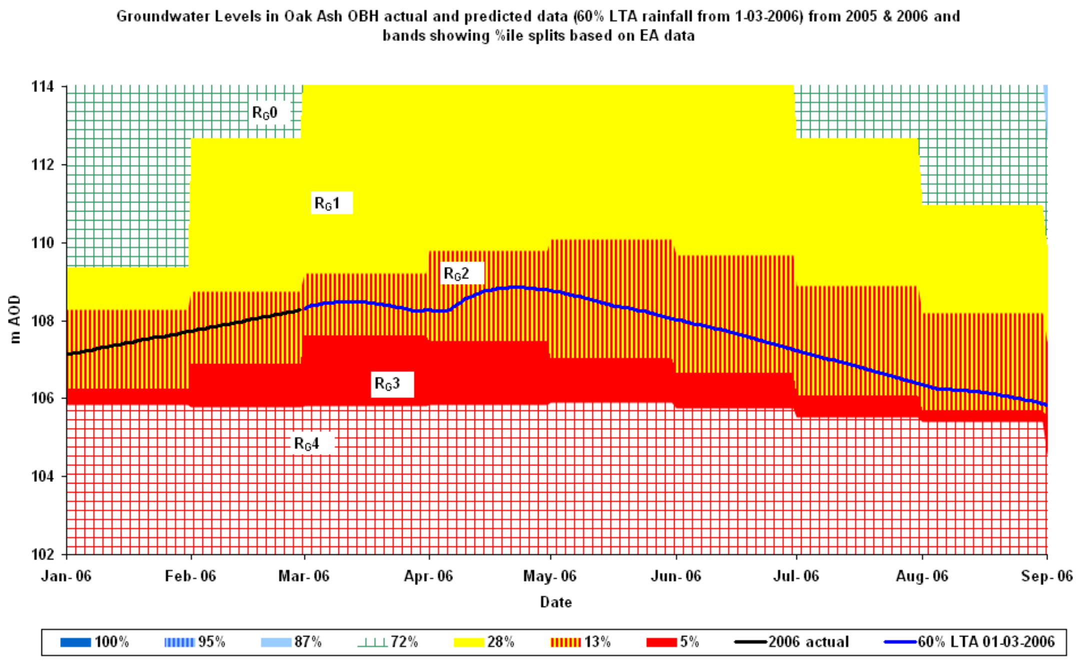

Figure 24 Prevailing groundwater levels from Oak Ash OBH from January to end of February and predicted levels from March to end of August 2006 With Forecast Using 60% of Long Term Average Rainfall.

Figure 25 below shows Teddington Weir flows for January and February 2006 and predicted trend from March to end of August 2006.

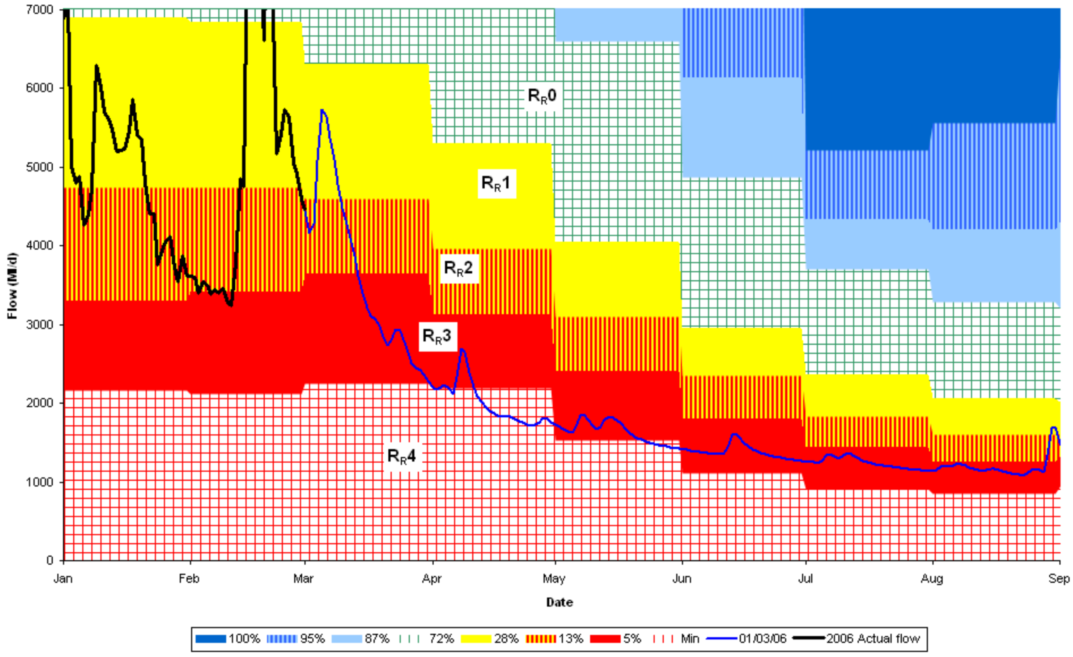

Figure 25 Prevailing flow January and February 2006 and Predicted River Flow Over Teddington Weir between March and September 2006, Bands Based on 1900-2006 Data for 60% LTA

Figure 26 shows the prevailing storage for December 2005 to end of February 2006 and the WARMS reservoir storage level predictions for a range of rainfall scenarios between March and end of October 2006.

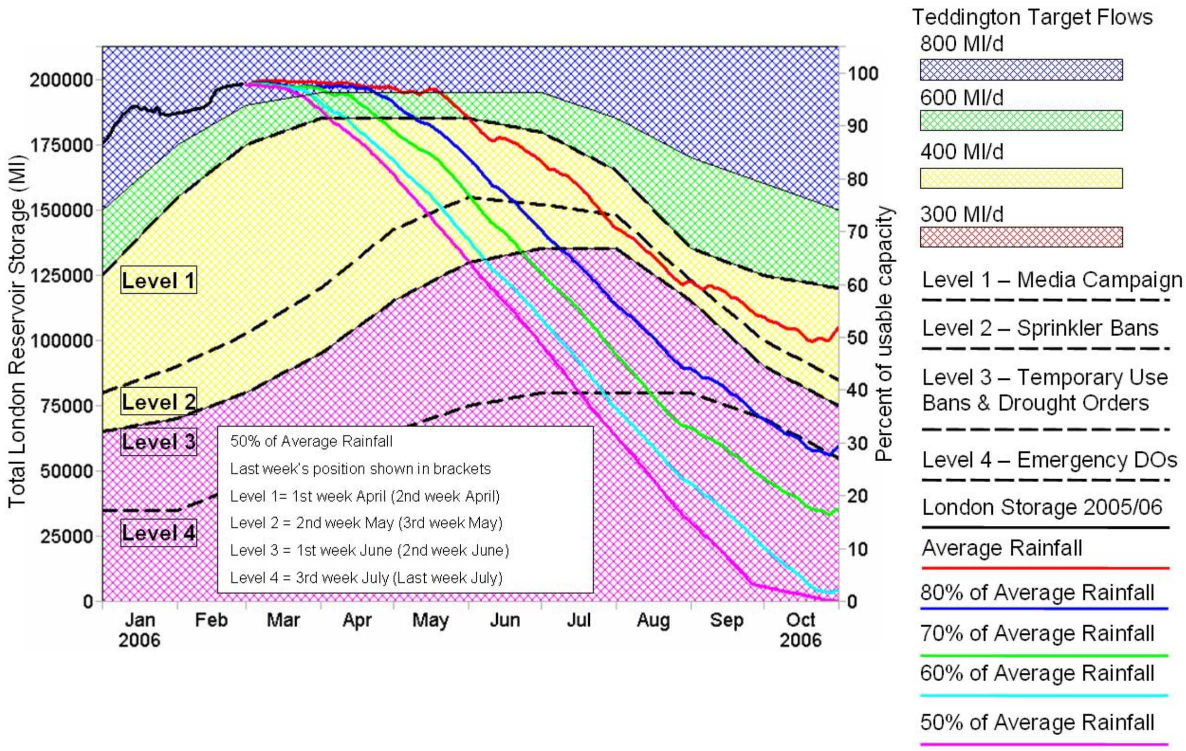

Figure 26 Prevailing storage for London from January 2006 to end of February 2006 and Predicted Storage from March to end of 2006

F7.2. 1c – Determination of Drought Severity against historic data

The figures below (Figure 27, Figure 28 and Figure 29) show the potential drought severity in 2006 for the 60% rainfall scenario in relation to the worst droughts on record for the 109 years of record (1900 – 2008) as determined successively over the following 6 month period for each month beginning in February, thus predictions are made for February to July, March to August and April to September. The successive monthly predictions show:

- February to July; potentially the worst on record, approximately 1 in 109 years
- March to August; potentially the 3rd worst on record, approximately 1 in 36 years
- The April to September; potentially the 6th worst on record, approximately 1 in 18 years

Thus the situation in April, when the hosepipe ban would be implemented, with a drought of approximately 1 in 18 years, is in line with the 1 in 20 year level of service for a Level 3 event.

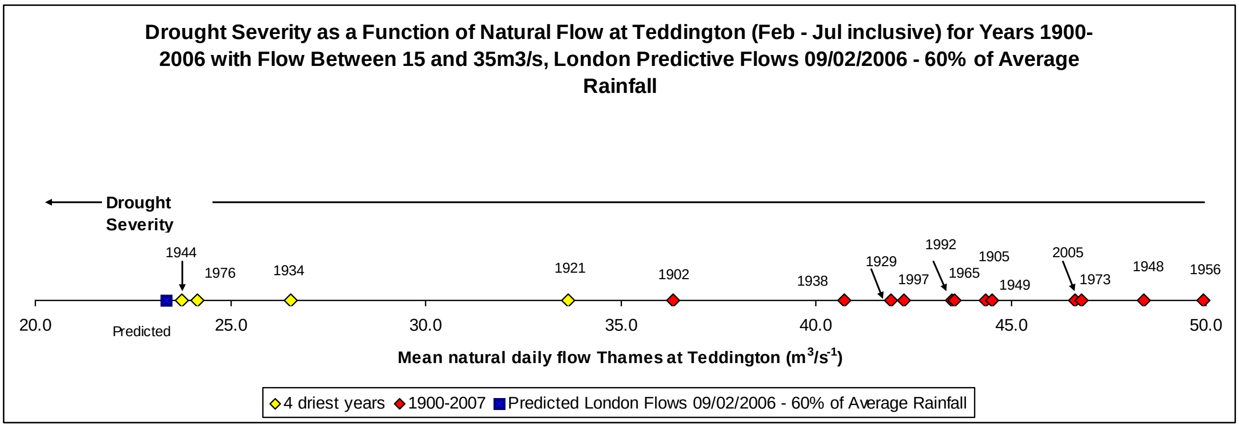

Figure 27 Potential Drought Severity from February 2006 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

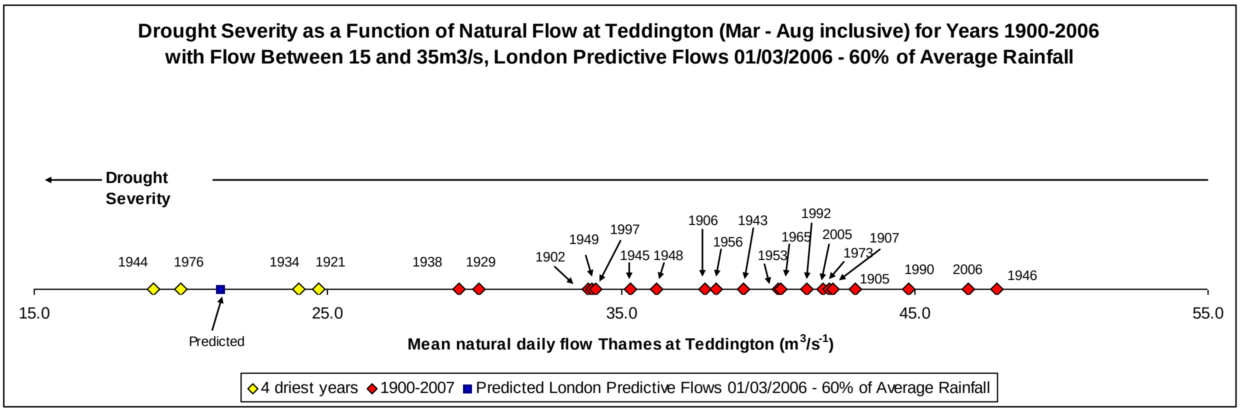

Figure 28 Potential Drought Severity from March 2006 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

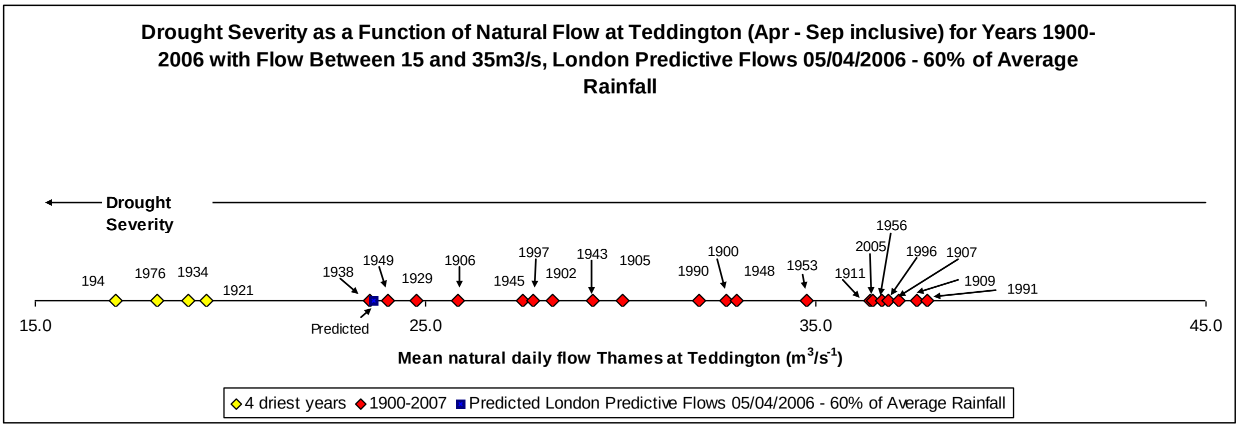

Figure 29 Potential Drought Severity from April 2006 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

F7.3. Step 2 – Drought Risk Level Assessment

F7.3.1. Step 2a- Prevailing and predicted hydrologic risk indicators RG, RR and RS

Figure 24 shows the groundwater levels (R_G) at Oak Ash at the end of February recording a prevailing value of R_G2 and predicted groundwater levels at Oak Ash from March to September 2006. It shows the level just remaining at R_G2 through to end August.

Figure 25 shows the actual river flows that occurred at Teddington at the end of February 2006. The February flows were depressed recording a prevailing value of, R_R2. The predicted flows over Teddington from March to August 2006 are also shown giving a predicted value of R_R3 at the end of August

Figure 26 shows the prevailing storage for total London reservoirs at the end of February recording a prevailing value of R_S0 and predicted storage for total London reservoirs between February and August 2006 showing a predicted value of R_S4 in August.

F7.3.2. Step 2b-produce combined prevailing and hydrologic risk indicators (RC)

Using the results from Step 2a, Table 19 and Table 20 show the combined risk, calculated using the formulae shown below for each table using the weightings set out in Table 6 above.

Table F2 Drought Risk Assessment Matrix for Prevailing Conditions in February 2006

Prevailing Risk Level In February 2006 (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G			X		
River Flow Levels R_R			X		
Reservoir Storage R_S	X				
Combined Risk Indicator			X		

$R_C = (2*0.60) + (2*0.15) + (0*0.25) = 1.2 + 0.30 + 0 = 1.5$ (Rounded up to 2)

Table 28 shows the Predicted Risk levels for London for a 60% LTA Rainfall using the 6 month period from February 2006 to August 2006 with the combined risk indicator calculated as R_C3.

Table 28 Drought Risk Assessment Matrix for August Using 6 Month Predicted Conditions from February 2006

Predicted Risk Indicator - February to August 2006 with 60% LTA (LT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G			X		
River Flow Levels R_R				X	
Reservoir Storage R_S					X
Combined Risk Indicator				X	

$R_C = (2*0.45) + (3*0.25) + (4*0.30) = 0.9 + 0.75 + 1.20 = 2.85$ (Rounded to 3)

F7.3.3. Step 2c- Combine prevailing and predicted indicators to produce an Overall Risk Indicator (ORI)

The prevailing and predicted R_C values give the following results:

- Prevailing R_c2
- Predicted R_C3
- ORI 2/3

F7.4. Step 3 – Determination of Measures and Drought Event Level

In this example Step 2b produced an indicator of ORI 2/3. This ORI value is then used to determine the Drought Event Level (DEL) through reference to Table 11. This process is also used to assign the associated governance and provide guidance on the potential drought measures that may be needed. This information is then used taking into account the time of year and operation issues such as outage to determine the final measures that would be implemented. Table 29 shows the DEL that is assigned in accordance with the ORI together with the drought measures to be implemented.

Table 29 Potential drought measures from the drought protocol applied in February 2006 data with 6 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI2/3	DEL 3	Director	Media/ water efficiency campaign Sprinkler and Temporary Use Ban; preparation of DD11 order and drought permits

As an example of how the timeline would operate in practice, Table 30 sets out the timescales (to the nearest week) for ensuring a DD11 order and drought permits would be ready for the start of August. Allowing a minimum 10 week lead in period gives an application date as end of 2^{nd} week in May. Given the DEL 3 level at the end of February, an enhanced media campaign would have been in place by early March and the timing of the introduction of a Temporary Use Ban would be set in early April to ensure its maximum benefit early in the gardening season, thereby requiring the formal notice period of 3 weeks to commence by start of 2^{nd} week in March. Thus, if it is decided to submit DD11 and drought permit applications in May for implementation at start of August, maximum water use restrictions would have been in place for at least one month. However, there is sufficient flexibility in the methodology to allow us to wait a month before committing. The next sub-section explains the rationale for decision making during the course of a drought.

Table 30 Application and Determination Dates for a ODO to Ban Nonessential Use in London for 2006

Protocol	Temporary Use Ban- formal notice	DD11 order
Minimum lead-in period (weeks)	3	10
Latest application date	2nd week of March	End of 2nd week of May
Implementation date	1st week of April	1-Aug

Monthly predictions for 2006 with discussion on measures adopted

In practice the prevailing/predicted assessment would be carried out at least on a rolling monthly basis. To illustrate the month by month changes in DEL level, the prevailing and predicted analysis has been undertaken retrospectively for successive months in 2006 to give a picture of what the protocol indicated as the drought unfolded and whether an application for a DD11 order and drought permit(s) would be required.

Table 31 gives the **prevailing** condition and shows that the prevailing risk level did not reach greater than DEL2 throughout the year.

The prediction three months ahead is shown in Table 32. Whilst for London the 6 month prediction is used for determining whether **early** introduction of measures is required. Note that the 3 month prediction is used as a guide to demonstrate the potential risk of reaching the Level 3 curve on the LTCD within 3 months. The results show that this did not occur during 2006 and so an application for a DD11 order and drought permits would not have been required.

Table 33 shows the predicted risk level for London looking 6 months ahead. This shows that there was a risk of reaching DEL 3 when looking 6 months ahead for much of the summer and so the preparation (but not necessarily the submission) for a potential DD11 and drought permit implementation would be necessary.

Table 31 Prevailing Risk Level for London during 2006

Location	London			
Analysis	Combined Prevailing RC			
Range	2006			
	DEL 1	DEL 2	DEL 3	DEL 4
Jan-06	X			
Feb-06		X		
Mar-06		X		
Apr-06	X			
May-06		X		
Jun-06	X			
Jul-06	X			
Aug-06	X			
Sep-06	X			
Oct-06	X			
Nov-06	X			
Dec-06	X			

Table 32 Predicted Risk Level for London during 2006 showing 3 month prediction

Location	London				
Analysis	Combined 3 month predictive RC				
Range	2006 – 2007				
	DEL 1	DEL 2	DEL 3	DEL 4	Predicted from
Jan-06		X			Oct-05
Feb-06					
Mar-06					
Apr-06		X			Jan-06
May-06		X			Feb-06
Jun-06		X			Mar-06
Jul-06		X			Apr-06
Aug-06		X			May-06
Sep-06		X			Jun-06
Oct-06		X			Jul-06
Nov-06		X			Aug-06
Dec-06		X			Sep-06

Table 33 Predicted Risk Level for London during 2006 showing 6 month prediction

Location	London				
Analysis	Combined 6 month predictive RC				
Range	2006 – 2007				
	DEL 1	DEL 2	DEL 3	DEL 4	Predicted from
Jan-06					
Feb-06					
Mar-06					
Apr-06			X		Oct-05
May-06					
Jun-06					
Jul-06		X			Jan-06
Aug-06			X		Feb-06
Sep-06			X		Mar-06
Oct-06			X		Apr-06
Nov-06			X		May-06
Dec-06			X		Jun-06
Jan-07			X		Jul-06
Feb-07			X		Aug-06
Mar-07			X		Sep-06

Location	London				
Analysis	Combined 6 month predictive RC				
Range	2006 – 2007				
Apr-07		X			Oct-06

F7.5. Conclusion for 2006

The London protocol indicates that an enhanced media campaign and a combined sprinkler/Temporary Use Ban would have been introduced by April 2006. At the same time preparations for a DD11 order and drought permits be underway, given the 6-month predictions.

The month by month assessment shows that we would not have actually applied for either a DD11 order or drought permits because the increase in rainfall after February meant that later assessments would show that Rc3 was not predicted within the 3 month trigger for a DD11 order application. This assessment is borne out by the actual reservoir storage that occurred in 2006 which shows that even the Level 1 curve on the LTCD was not crossed during the summer apart from a short period in April (Figure 20).

Application of the London protocol would also have resulted in the preparation for implementation of supply side measures including the Thames Gateway desalination plant and NLARS in February for actual implementation when reservoir storage started to decline and the trigger of 3000 Ml/d natural flow for 10 days at Teddington was reached. The WBGWS would also have been prepared for implementation and would have been implemented if the situation had worsened such that London reservoir storage had dropped to the Level 2 curve on the LTCD. In the event the WBGWS was prepared in 2006 but the situation did not deteriorate to a state where it was triggered.

Comparison with what the London protocol would introduce and what actually happened in 2006 (Figure 30) shows that the measures would have been similar with the notable exception that the application for an ordinary drought order for non-essential (now DD11 order) would not have been submitted because of the beneficial effects on water resources of the early summer rainfall as described above.

The drought event of 2006 was the first in which we departed from the historical approach and introduced early restrictions. However, a holistic protocol had not been developed at the time, but had the current London protocol been available it indicates that a NEUB application (based on the rolling 3-month prediction) would not have been made.

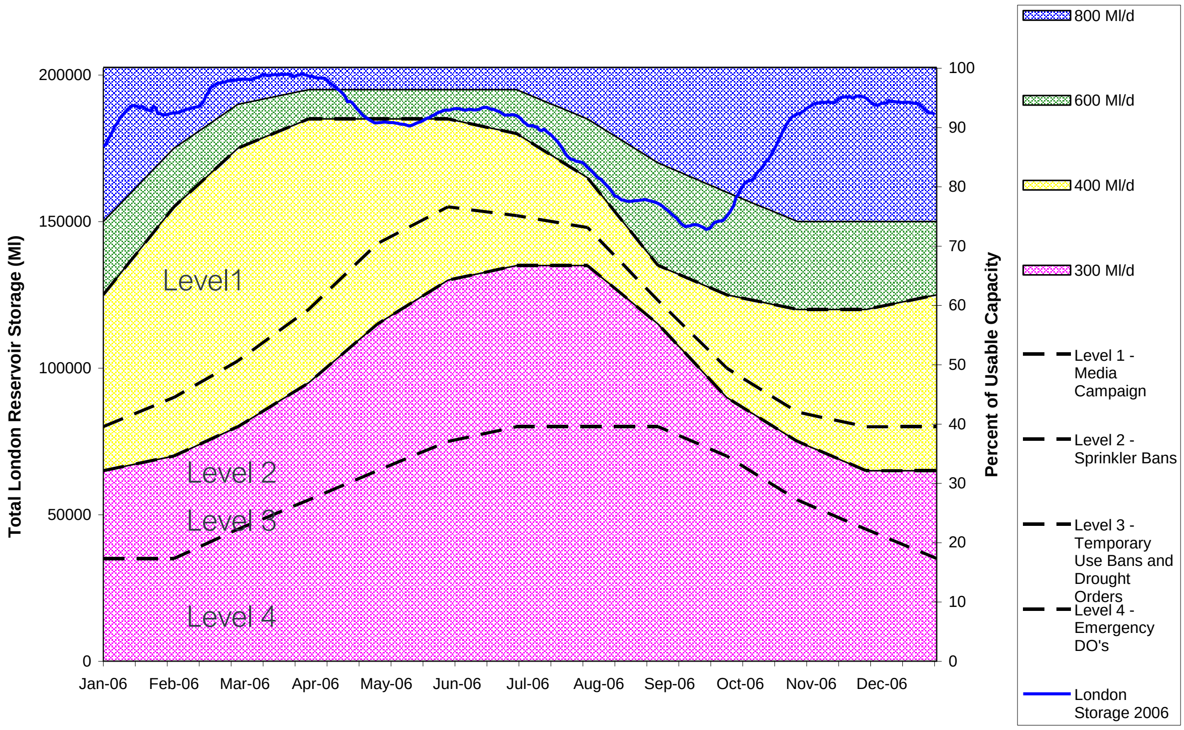

Figure 30 Prevailing Storage for London (January – December 2006)

F8. 2006 drought example - SWOX WRZ

Background

The winter of 2005/6 saw below average rainfall levels and so aquifer recharge was limited in the Cotswolds during December 2005 to March 2006. This meant that groundwater levels in the Cotswolds Oolites were below normal in January and fell further during February. The resulting low levels in the Cotswolds aquifer signalled the potential for severe drought in the summer of 2006.

As discussed above in Section F6, driven by the London water resources situation, we responded by strengthening the media campaign in February following the messages given to customers during 2005 requesting wise use of water. The decision to implement a hosepipe ban was taken in March and the implementation of the hosepipe ban was announced at the beginning of March. The ban was introduced company-wide on 3rd April.

No further measures were implemented in the SWOX WRZ in 2006 in view of the early summer rainfall and associated recovery in groundwater levels in the Cotswolds. Therefore, there was no need for escalation to further measures such as an ordinary drought order for a NEUB as was the case for London.

F8.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

F8.1.1. 1a/b – Collation of Hydrologic Data and Predictions

The application of the methodology is demonstrated for 2006 using the graphs and tables shown below using February as the base year. The following section then goes on to describe the assignment of the Overall Risk Indicator and the Drought Event Level.

Figure 31 shows the prevailing groundwater level data for January 2006 at Rockley and a groundwater level prediction based on a 60% average rainfall prediction from February 2006. As for 2005. Rockley has been used as a surrogate for a Cotswolds groundwater level prediction in the absence of a prediction for the Cotswolds for 2005.

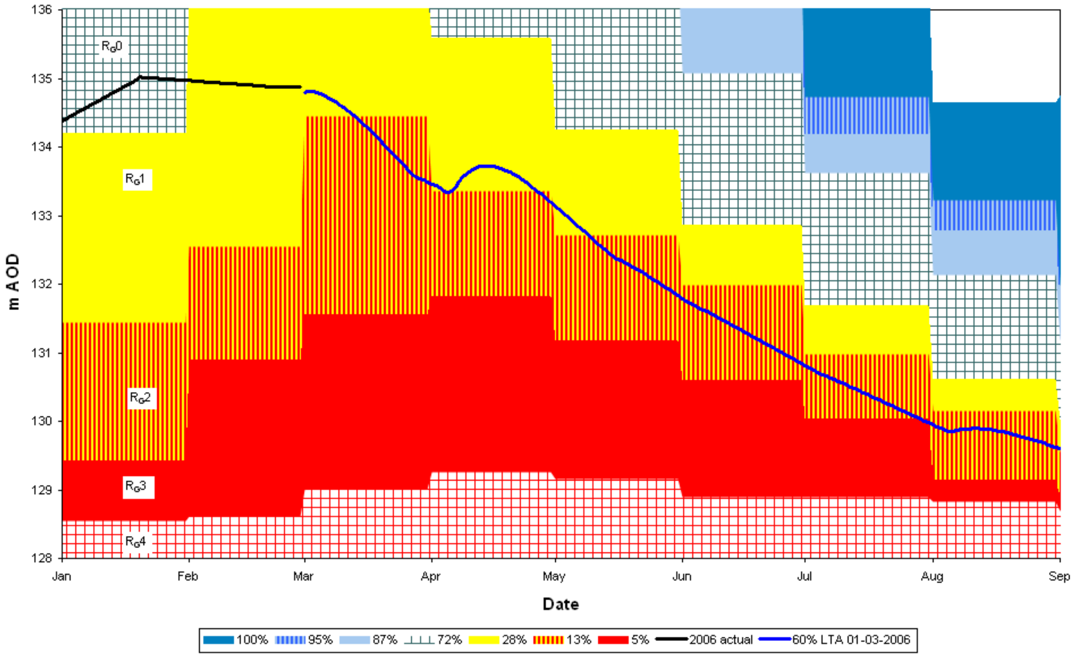

Figure 31 Groundwater Levels at Rockley showing actual data for January and February and predicted trend from March to end August 2006 and Bands showing % Based on EA data.

Figure 32 shows the prevailing flow data (River Thames at Farmoor) for January 2006 and a 60% average rainfall prediction from February 2006 from WARMS modelled trend. The 200 Ml/d trigger for application of DD11 and drought permits (see Main Report Section 4.4) is shown predicting late May as the point at which the flow at Farmoor reaches the trigger. Note that, because of the lower groundwater levels in February compared to those of 2005, the 200 Ml/d trigger is predicted several weeks earlier in 2006 compared to 2005. This prediction would mean that the Company would at least start to prepare for drought permit applications for SWOX in early March in readiness for a possible submission in late May.

In reality, due to the above average rainfall in May resulting in a significant input of recharge to the Cotswold aquifer and subsequent significant rainfall during the course of the summer, flow at Farmoor remained substantially above the 200 Ml/d trigger throughout the remainder of 2006. The revised SWOX protocol would have taken this into account and, as a result, applications for drought permits would not have been instigated.

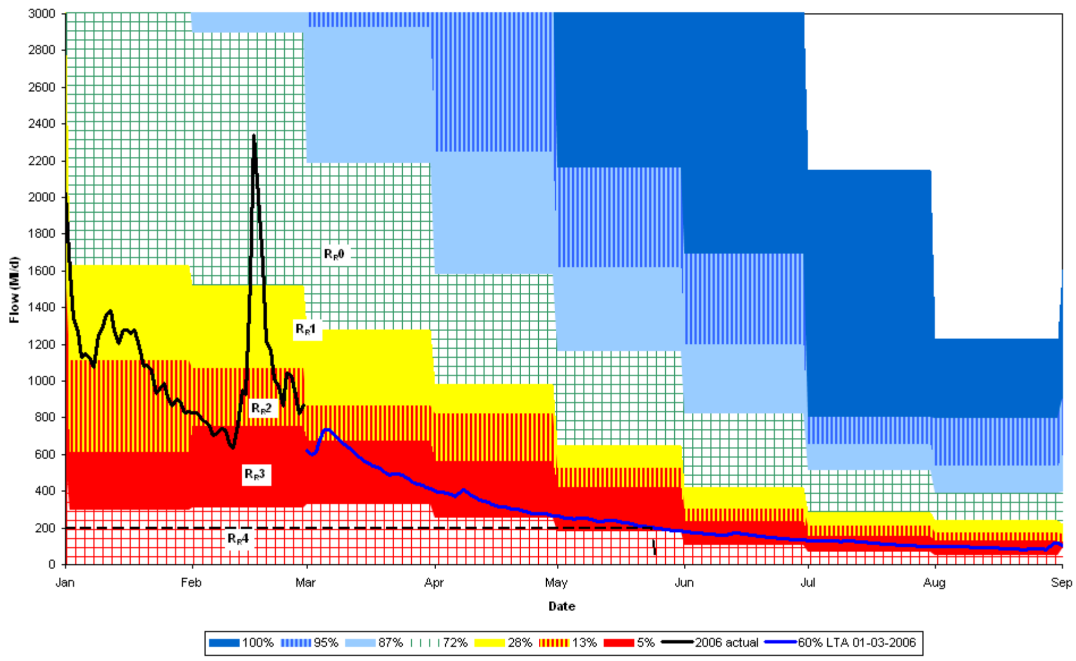

Figure 32 Prevailing flow January and February 2006 and Predicted River Flow at Farmoor between March and end of August, Bands Based on 1900-2006 Data for 60% LTA January to end of February

Figure 33 shows the prevailing storage from November 2005 to January 2006 and the WARMS reservoir storage level prediction for a range of rainfall scenarios undertaken in February, superimposed onto the Farmoor control diagram.

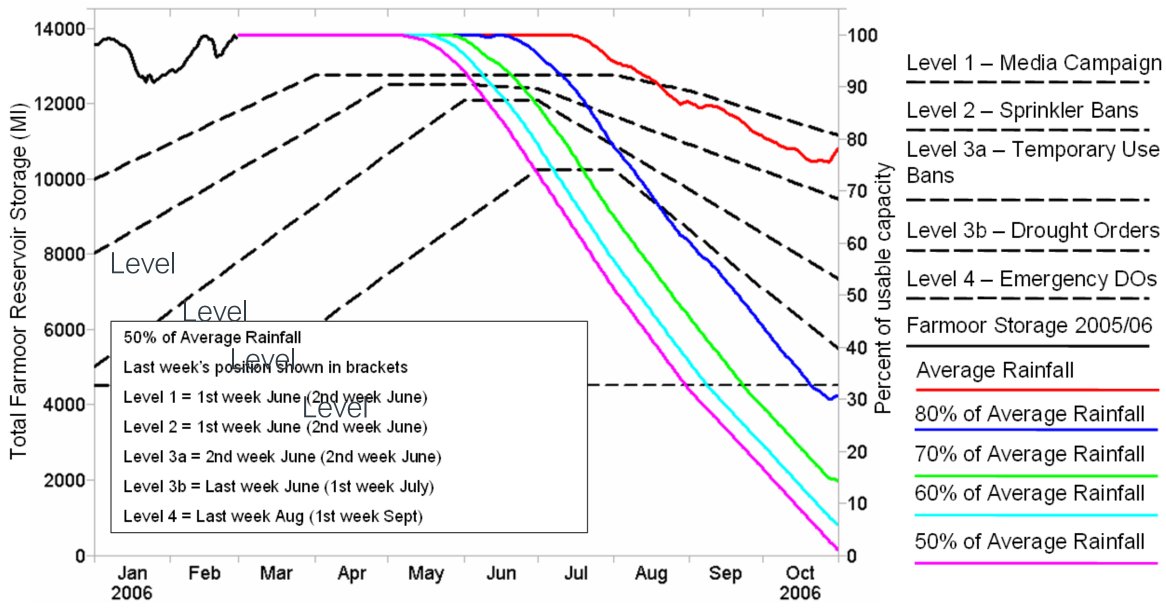

Figure 33 Predicted Reservoir Storage Showing prevailing storage from January to end of February 2006 and predicted storage using a 60% scenario from March to October 2006

F8.1.2. 1c – Determination of Drought Severity against historic data

The drought severity assessment has been undertaken for London (Section F6.1) in view of the much longer period of record for London when compared to Farmoor. The assessment for London above shows that the measures that would be imposed company-wide, in this case, a Temporary Use Ban and possibly NEUB, are broadly in line with Level 3 of the Company's Levels of Service.

F8.2. Step 2 – Drought Risk Level Assessment

F8.2.1. 2a/b – Prevailing and predicted hydrologic risk indicators R_G, R_R and R_S

Table 34 and Table 36 show the resulting risk matrices using the risk levels from the hydrological variables discussed in Step 1.

Table 34 Drought Risk Assessment Matrix for Prevailing Conditions SWOX WRZ in February 2006

Prevailing Risk Level In February 2006 (UT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G		X			
River flow R_R			X		
Reservoir Storage R_S	X				
Combined Risk Indicator R_C		X			

R_C = + (1*0.6) + (2*0.25) + (0*0.15) = 0.6 + 0.50 + 0 = 1.1 (Rounded to 1)

Table 35 Drought Risk Assessment Matrix for Feb using 3 Month Predicted (May) using 60% LTA

Predicted Risk Indicator - April 2006 to July 2006 with 60% LTA (UT)					
	R0	R1	R2	R3	R4
Groundwater Levels R_G			X		
River flow R_R				X	
Reservoir Storage R_S					X
Combined Risk Indicator R_C				X	

R_C = (2*0.5) + (3*0.25) + (4*0.25) = 1.0 + 0.75 + 1.0 = 2.75 (Rounded to 3)

F8.2.2. 2c – Combine prevailing and predicted indicators to produce an Overall Risk Indicator

The combined prevailing and predicted risk assessment gives rise to the following ORI:

- Prevailing R_C1
- Predicted R_C3
- ORI 1/3

F8.2.3. Step 3 Assignment of Drought Event Level (DEL)

In this example Step 2b produced an indicator of ORI 1/3. This ORI value then gives rise to a Drought Event Level (DEL) of 3 through (Table F28) reference to Table 11.

Table 36 Potential drought measures from the drought protocol applied in February 2006 data with 3 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI1/2	DEL 3	Senior Manager	Enhanced Media/water efficiency campaign Sprinkler ban/Temporary Use Ban/drought permit;

On the basis of the assessment ORI level of 1/3 in February, with the prevailing risk of R_C1 and the potential to escalate to R_C3 within 3 months an enhanced media campaign followed by sprinkler ban/Temporary Use Ban should be implemented. However, from the London protocol described above, the corresponding end of February assessment was ORI 2/3 giving rise to a company-wide enhanced media campaign in early March and a Temporary Use Ban starting early April. These early measures would therefore override the measures derived by the revised SWOX protocol. However, in the unlikely event that London was at a less advanced stage in the drought by end of February, then the measures given by the SWOX protocol would be employed, namely enhanced media campaign followed by Sprinkler / Temporary Use Ban.

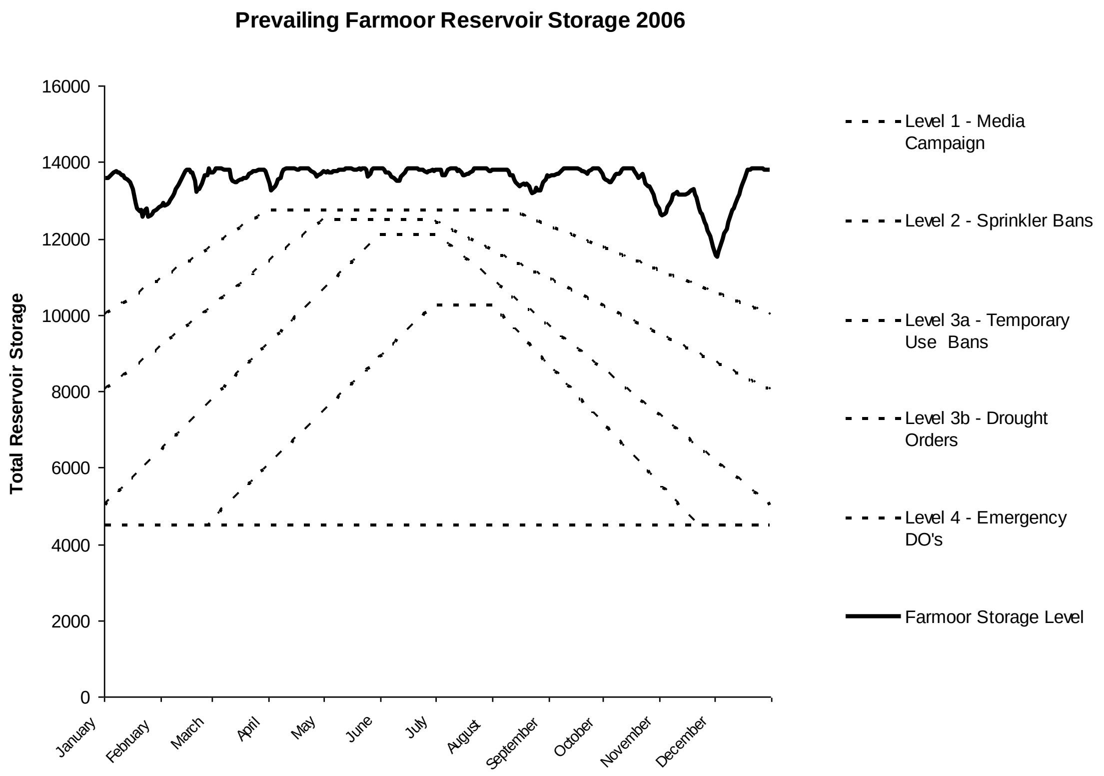

Figure 34 Actual Reservoir Storage for Farmoor in 2006

F8.3. Conclusions for SWOX 2006

The London protocol overrides the results of the SWOX protocol if the former indicated water use restrictions at an earlier stage. Thus in this 2006 example, the SWOX WRZ along with the rest of Thames Water's supply area would be experiencing by early April a full Temporary Use Ban preceded by an enhanced media campaign in March.

As, noted above, although the 200 Ml/d trigger was predicted in February to be reached in May, due to wetter conditions returning in May, flow in the River Thames stayed substantially above the 200 Ml/d trigger during the remainder of 2006. The benefits of this are shown by the high storage level in Farmoor reservoir (Figure 34). Consequently, applications for drought permits were not instigated.

F9. 1976 drought example - London WRZ

Background

The autumn of 1975 was unusually dry and was followed by an exceptionally dry winter and spring. These conditions contributed to severely reduced groundwater recharge. River flows were extremely low (some of the lowest on record) in the Thames. The spring and early summer of 1976 continued to be very dry and hot which meant there was no effective surface runoff contribution to river flows and so both river flows and groundwater levels became severely depressed in the summer.

The resource situation and management of the event in 1976 resulted in the phased imposition of a hosepipe ban across the company area in July 1976.

Dates of hosepipe ban introductions:

- 19 July 1976 in Vales Division (Upper Thames area).
- 17 July 1976 for Lambourn Division
- 24 July 1976 extended to the whole region.

Measures to increase abstraction from the Lower Thames were required, including back-pumping over Teddington and Molesey weirs. It should be remembered that at this time the LTOA did not exist and the public water supply arrangements at the time were very different from those of today, including the resource availability (for example Farmoor Stage II reservoir was not available in early 1976). The pre-privatised legislative controls in force at the time were also very different, for example, Drought Permits did not exist. Therefore, it is difficult to compare the actions taken in 1976 with those that would be taken under the present regulatory regime.

The Drought Act 1976 came into force from 6 August 1976 with the General Guidance on 10 August. Five Orders were then made under the Act that covered the Authorities and Water Company areas on 13 September 1976, this covered, hosepipe bans amongst other bans on non-essential use. Level 4 option equivalents were being planned for the autumn of 1976 but sustained rainfall in September prevented the Level 4 options from being required.

The hosepipe ban was lifted in all areas in November 1976 following the significant rainfall after the drought broke in late August 1976. Normally, effective rainfall does not occur until late September or early October.

F9.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

F9.1.1. 1a/b – Collation of Hydrologic Data and Predictions

The 1976 example is illustrated using the assessment with February as the base month. The Environment Agency has provided historic data for the groundwater levels at Oak Ash and also modelled the predicted effect of 60% LTA rainfall for groundwater levels from the start of February 1976 (Figure 35).

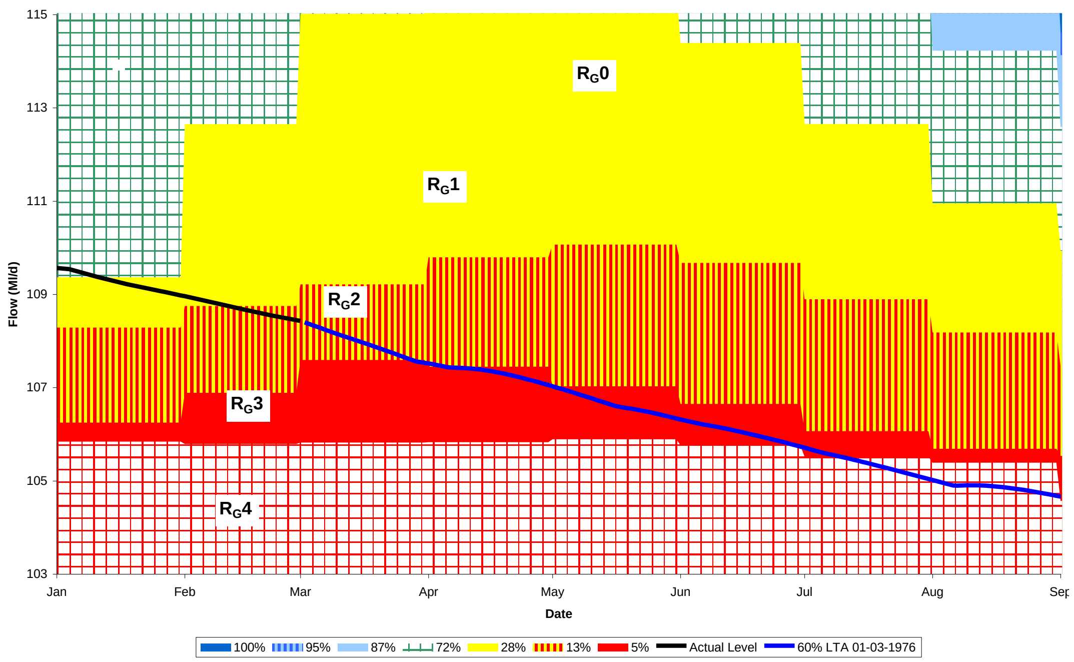

Figure 35 Oak Ash OBH-Prevailing for January and February 1976and predicted for March to August 1976 using 60%, of 30 year Long Term Average Rainfall.

The prevailing river flows from January and predicted river flows assuming 60% of average rainfall from the start of February for Teddington Weir during 1976 and are shown in Figure 36 .

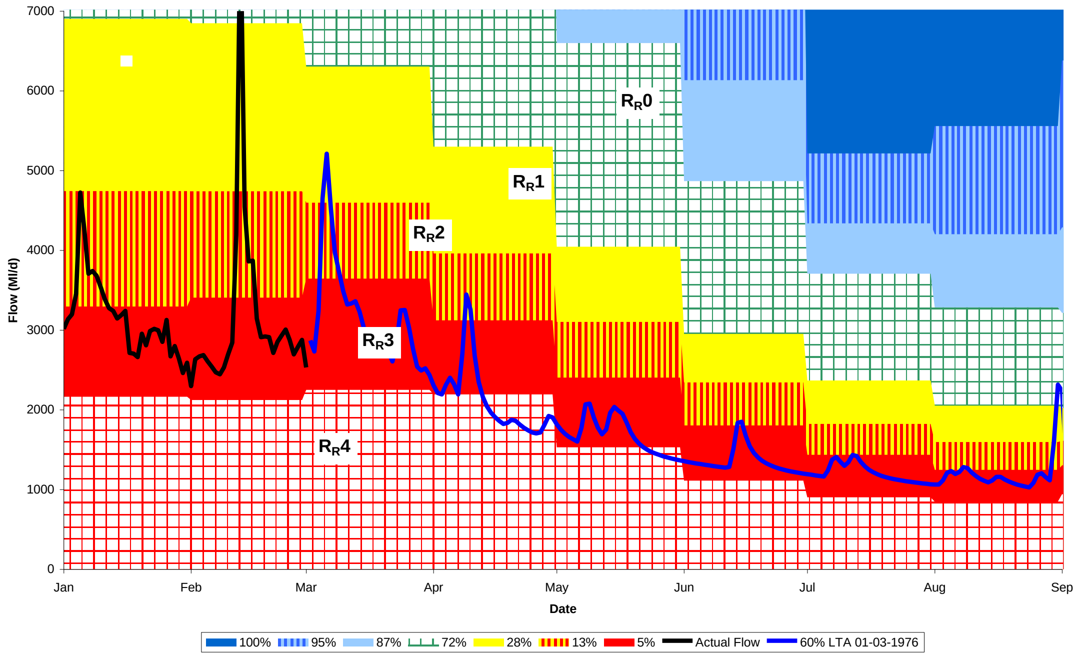

Figure 36 Flows over Teddington Weir, observed for January and February 1976 and predicted from March to August 1976 using 60% LTA. Bands show %ile splits based on 1900-2006 data.

The prevailing London storage for January and February 1976 and the predicted reservoir storage using 60% LTA rainfall is shown in Figure 37.

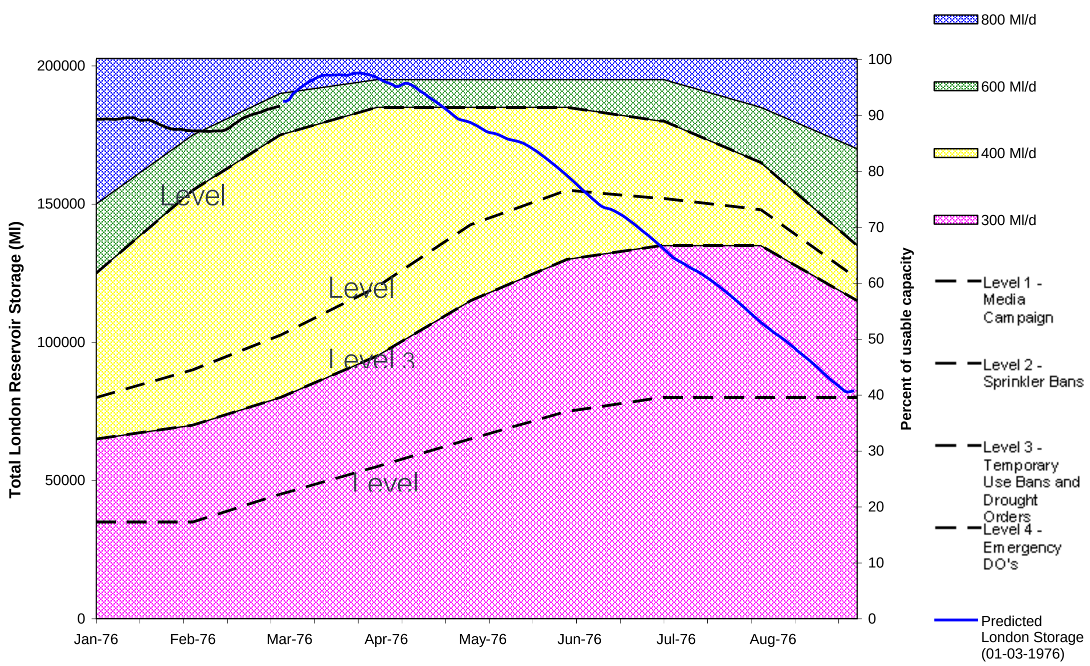

Figure 37 London reservoir storage -prevailing for January and February and predicted storage from March to August 1976

F9.1.2. Step 1c – Determination of Drought Severity against historic data

The figures below (Figure 38, Figure 39 and Figure 40) show the potential drought severity in 1976 for the 60% rainfall scenario in relation to the worst droughts on record for the 108 years of record (1900 – 2008) as determined successively over the following 6 month period for each month beginning in February, thus predictions are made for February to July, March to August and April to September. The successive monthly predictions show:

- February to July; potentially the 3rd worst on record, approximately 1 in 36 years
- March to August; potentially the 3rd worst on record, approximately 1 in 36 years
- The April to September; potentially the 3rd worst on record, approximately 1 in 36 years

Thus, the situation in April, with a drought of approximately 1 in 36 years, justifies the imposition of measures for a 1 in 20 year level of service for a Level 3 event.

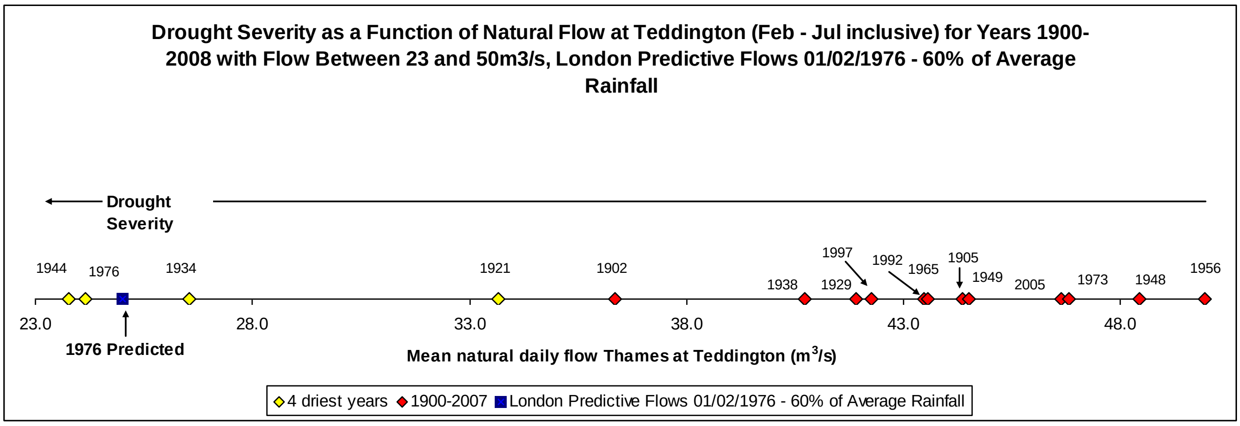

Figure 38 Potential Drought Severity from February 1976 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

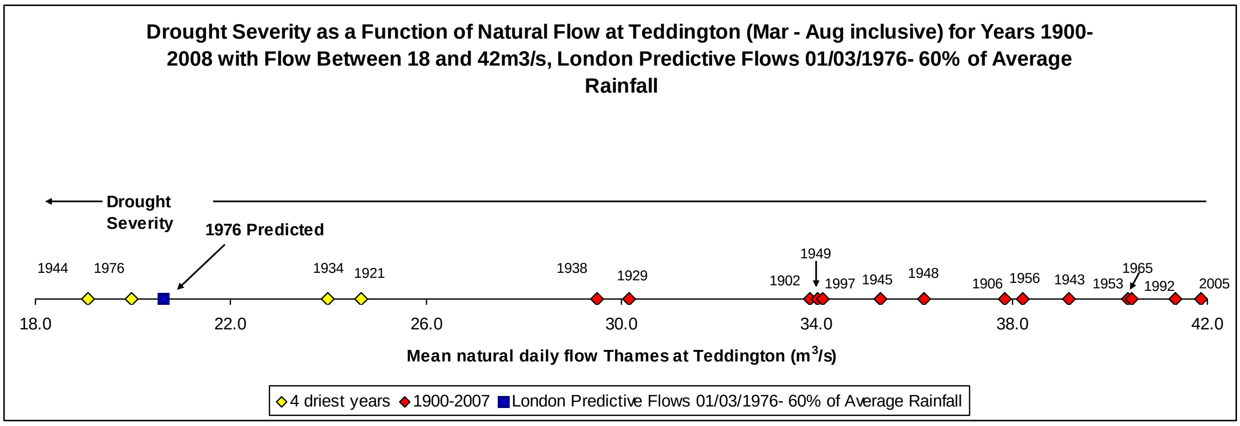

Figure 39 Potential Drought Severity from March 1976 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

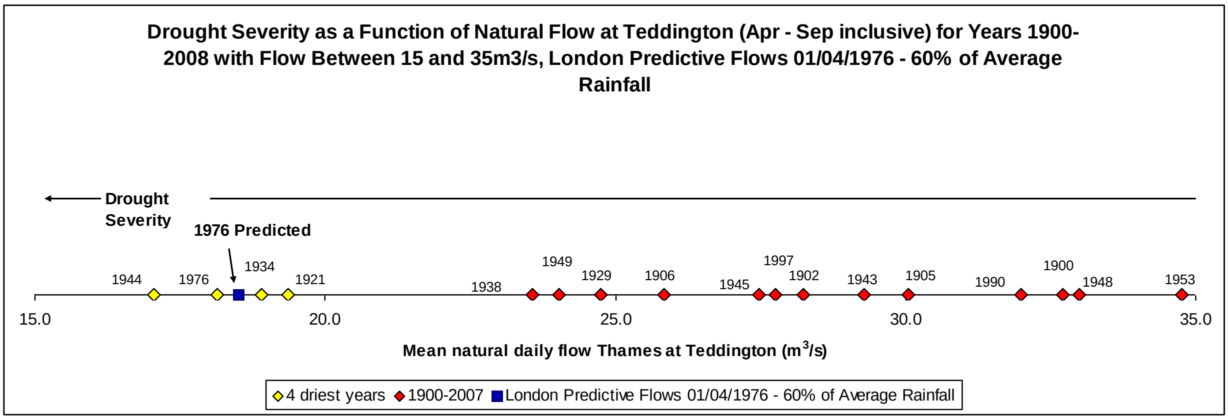

Figure 40 Potential Drought Severity from April 1976 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

F9.2. Step 2 – Drought Risk Level Assessment

F9.2.1. Step 2a- analyse the data to produce standardised bands RG, RR and RS

Figure 35 shows the prevailing groundwater situation for Oak Ash in January 1976, and the predicted trend from March 1976 given 60% rainfall over 6 months to August 1976, this shows that the groundwater level is predicted to decline from R_G2 to the R_G4 band at the end of August.

Figure 36 shows the river flow over Teddington Weir in January 1976, with prevailing R_R3 and also predicted R_R3 in August

Figure 37 shows the reservoir storage levels for London in February1976 still at the R_S0 band and the modelled storage recession showing the predicted risk level bordering on R_S3 and R_S4 by end of August, the latter band has been chosen to err on the worst case side.

F9.2.2. Step 2b-produce combined prevailing and hydrologic risk indicators (RC)

The risk ratings derived from Step 2a are placed into the risk indicator matrix as shown in Table 37 and Table 38.

Table 37 Prevailing Risk Combined Indicator for February 1976

Prevailing Risk Indicator – February 1976						
		R0	R1	R2	R3	R4
	Groundwater Levels R_G			X		
	River Flow Levels R_R				X	
	Reservoir Storage R_S	X				
	Combined Risk Indicator R_C			X		

R_C = (2*0.55) + (3*0.15) + (0*0.30) = 1.1 + 0.45 + 0 = 1.55 (Rounded to 2)

Table 38 Predicted Risk Combined Indicator for March to August 1976 using 60% LTA

Predicted Risk Indicator - March 1976 to August 1976 with 60% LTA (LT)						
		R0	R1	R2	R3	R4
	Groundwater Levels R_G					X
	River Flow Levels R_R				X	
	Reservoir Storage R_S					X
	Combined Risk Indicator R_C					X

R_C = (4*0.45) + (3*0.25) + (4*0.3) = 1.8 + 0.75 + 1.2 = 3.45 (Rounded to 4)

F9.2.3. Step 2c- Combine prevailing and predicted indicators to produce an Overall Risk Indicator (ORI)

Using the R_C calculated from Step 2b and Table 11, an ORI can be ascertained. Thus from Table 38 and Table 39, the ORI value is derived as follows:

- Prevailing Rc = R_C2
- Predicted Rc = R_C4
- Therefore ORI= ORI 2/4

The derived ORI 2/4 conveys a number of items of information and will be used in Step 3. In this example, the value of ORI 2/4 describes the current situation at the time of the analysis as a prevailing condition of R_C2 and R_C4 at the end of the 6 month predicted period:

F9.3. Step 3 Assignment of Drought Event Level (DEL)

The ORI has been set to 2/4 this means that the Drought Event Level would be set at either DEL3 or DEL4. Either way, governance would start at director level and the following measures would either be in place or under consideration:

- By end of February a DEL 3 or DEL 4 would trigger an enhanced media campaign in early March, and allowing a formal three week notification period, this would be followed by a sprinkler ban and Temporary Use Ban in early April.
- Preparation for a company-wide or London WRZ NEUB would be underway in March as well as drought permit applications. The guide for submitting the applications for these orders is a 3-month prediction of reaching a DEL3, which allows for the minimum 10 week lead in period; actually implementing these measures would be guided by the risk of London reservoir storage drawing down to the Level 3 curve on the LTCD. Note that the guide for applying for an Emergency Drought Order (EDO) is the real risk of reaching Level 4 on the LTCD coupled with the prevailing situation, which would include the risk of reservoir storage falling below the Level 3 curve on the LTCD. Attainment of the implementation of DD11 and drought permit orders is considered a necessary requirement for the EDO application.
- In terms of the Company's Levels of Service the introduction of and preparation for the above measures would be consistent with a drought severity of frequency of occurrence of approximately 1 in 36 years. Although this analysis is for the London WRZ, these measures would be applied company-wide.

The above assessment shows a snapshot of the water situation at the end of February 1976. In practice, such an assessment would be undertaken during drought periods at least on a monthly basis. Table 39Table 31 shows the full prevailing assessment for each month of 1976. The table shows that prevailing R_C3 (DEL 3 measures) risk level was reached in July and remained until the end of October. The situation improved to R_C2 in November and December.

As noted above, the 3-month prediction of attaining DEL3 risk level is used as the guide trigger for submitting DD11 order and drought permit applications. Table 35, shows the 3 month predictions successively through 1976. This indicates that in April it was predicted that the risk level would worsen in July to DEL 3 from a DEL 2 risk in June. Note that this assessment is consistent with the prevailing risk levels given in Table 34. Thus, given the assessment in April, D11 and drought order applications would be submitted in that month.

The monthly 6-month assessment for London is to give a longer term view of risk and to make early preparations for possible measures. Table 41shows the 6 month predictions successively through 1976. This indicates that the risk assessed in January indicated the potential for a DEL 4 risk level in July. This would have alerted us to start preparing for the possibility of the full allocation of demand and supply –side measures. Despite the assessment in February showing the worst case 6-month risk level was reduced to DEL 3, early preparations for the possibility of an EDO application would be made.

Table 39 Combined Prevailing Values for London for 1976

Location	London			
Analysis	Combined Prevailing			
Range	1976			
	Rc1	Rc2	Rc3	Rc4
Jan-76				
Feb-76	X			
Mar-76		X		
Apr-76		X		
May-76		X		
Jun-76		X		
Jul-76			X	
Aug-76			X	
Sep-76			X	
Oct-76			X	
Nov-76		X		
Dec-76		X		

Table 40 Combined Predicted Values for London for 3 month predictive for 1976

Location	London				
Analysis	Combined 3 month predictive				
Range	1976 – 1977				

	DEL 1 Options	DEL 2 Options	DEL 3 Options	DEL 4 Options	Predicted from
Jan-76					Oct-75
Feb-76					
Mar-76					
Apr-76		X			Jan-76
May-76		X			Feb-76
Jun-76		X			Mar-76
Jul-76			X		Apr-76
Aug-76			X		May-76
Sep-76			X		Jun-76
Oct-76			X		Jul-76
Nov-76			X		Aug-76
Dec-76			X		Sep-76
Jan-77		X			Oct-76

Table 41 Combined Predicted Values for London for 6 month predictive for 1976

Location	London				
Analysis	Combined 6 month predictive				
Range	1976 – 1977				
	DEL 1 Options	DEL 2 Options	DEL 3 Options	DEL 4 Options	Predicted from
Jan-76					
Feb-76					
Mar-76					
Apr-76					Oct-75
May-76					
Jun-76					
Jul-76				X	Jan-76
Aug-76			X		Feb-76
Sep-76			X		Mar-76
Oct-76			X		Apr-76
Nov-76			X		May-76
Dec-76			X		Jun-76
Jan-77			X		Jul-76

Feb-77	X			Aug-76
Mar-77		X		Sep-76
Apr-77				Oct-76

The overall impact of applying the above measures over the drought period is simulated in Figure 41, which shows the response of London reservoir storage to the full demand and supply-side measures that would have been introduced by the protocol described above. It can be seen that the storage trend crosses the Level 3 curve in early August, which would trigger the implementation of NEUB measures and, if necessary, the use of drought permit options. Note that the protocol had triggered the application for these orders at the end of April and so allowing the 10 week lead in time for the determination process to be completed.

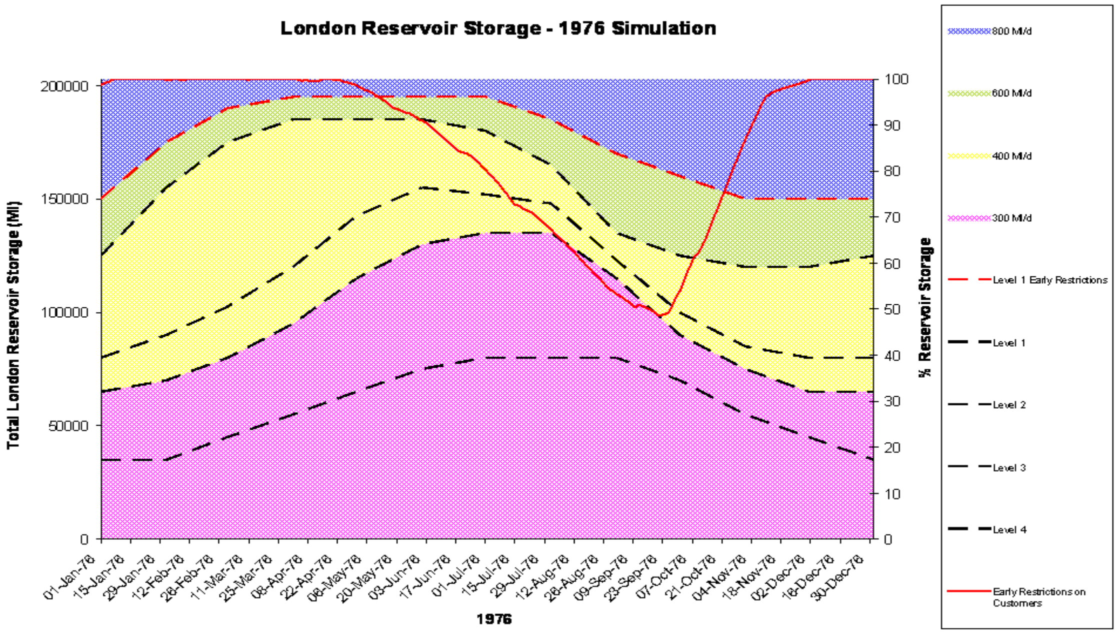

Figure 41 Simulated London reservoir storage 1976

F9.4. Conclusions for 1976

The London protocol would have alerted us from very early on in the 1976 event to the potential for a severe drought in the summer. An ORI of 2/4 combined with a drought severity of 1:36 as early as February would have meant that the measures actually underway by early April would have been an enhanced media campaign together with sprinkler ban Temporary Use Ban with applications being prepared for NEUB and drought permits. The sprinkler ban/Temporary Use Ban would be applied company-wide.

The month-by-month assessments indicated that a NEUB and drought permits for London would have been applied for at the end of April, ready to be implemented, if the Level3 curve on the LTCD had been reached in July. Confirmation of this requirement is given by the fact that Rc3 is reached in July and continues to October. Had the drought persisted in 1976 the measures implemented under the protocol early in the year would mean that an EDO application could have been made had it been required and would have allowed measures to be put in place at the appropriate time to ensure risk of Level 4 measures would be minimised.

The full range of supply side measures would have been introduced. The early imposition of demand management measures would have been supplemented by the Thames Gateway desalination plant and NLARS at a point when reservoir storage started to decline and the trigger of 3000 Ml/d natural flow for 10 days at Teddington was reached. WBGWS would have been implemented at the Level 2 curve on the LTCD or earlier depending on agreement with the Environment Agency, drought permit applications would have been made in late April and implemented, if considered necessary, when Level 3 curve on the LTCD was reached.

In terms of the tools used with the protocol's methodology, the drought severity index works well for this period, the modelled severity coming out very close to the severity actually seen in 1976 between April and October.

F10. SWOX WRZ 1976 Example and Analysis

Background

Following a dry summer in 1975 there was very little effective rainfall over the Upper Thames area during the winter of 1975/76 and so groundwater levels did not recover over the recharge period and were consequently very low at the start of the summer of 1976. The spring and early summer of 1976 continued to be very dry and hot which meant there was no effective surface runoff contribution to river flows at Farmoor and so river flows became dangerously low in the summer. Note that only Farmoor Stage I reservoir was in operation during 1976 and the Gatehampton groundwater source did not exist.

The resource situation and management of the event in 1976 resulted in the phased imposition of a hosepipe ban across the company area in July 1976 with restrictions being implemented slightly earlier in the Upper Thames area than for the rest of the company.

Dates of hosepipe ban introductions:

- 19 July 1976 in Vales Division (Upper Thames area).
- 17 July 1976 for Lambourn Division
- 24 July 1976 extended to the whole region.

Measures to increase abstraction from the Upper Thames were required including diversion of flows from the River Cherwell to above Kings Weir and then back pumping into the Farmoor reach of the River Thames. It should be remembered that at this time the public water supply arrangements were very different from those of today, including the resource availability (for example Farmoor B reservoir was not available in early 1976). The pre-privatised legislative controls in force at the time were also very different, for example Drought Permits did not exist. Therefore, it is difficult to compare the actions taken in 1976 with those that would be taken under the present regulatory regime, although it is certain that severe measures such as ODOs and drought permits would have been required to facilitate the measures that were implemented in 1976 to preserve reservoir storage at Farmoor.

As is mentioned above in Section F8 relating to London, Level 4 option equivalents were being planned for in the autumn of 1976. Similar measures were being planned for the Upper Thames but sustained rainfall in September prevented the Level 4 options from being required.

The hosepipe ban was lifted in all areas in the November of 1976 following the significant rainfall after the drought broke in late August 1976. Normally effective rainfall does not occur until late September or early October.

F10.1.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

F10.1.1.1. 1a/b – Collation of Hydrologic Data and Predictions

The application of the methodology is demonstrated for 1976 using the graphs and tables shown below. The following section then goes on to describe the assignment of the Overall Risk Indicator and the Drought Event Level.

Figure 42 shows the prevailing groundwater level data for January 1976 at Rockley and a groundwater level prediction based on a 60% average rainfall prediction from February 1976. As for 2005 and 2006, Rockley has been used as a surrogate for a Cotswolds groundwater level prediction in the absence of a prediction for the Cotswolds for 1976.

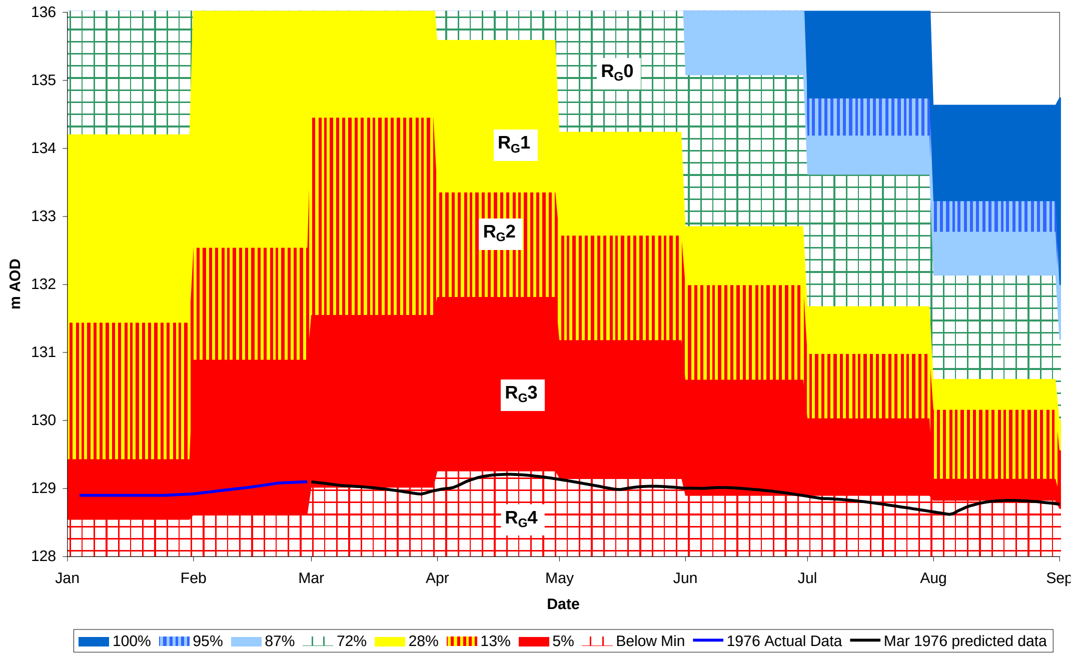

Figure 42 Groundwater Levels at Rockley showing actual data for January and February 1976 and predicted trend from March to August 1976.Bands showing % based on EA data.

Figure 43 shows the prevailing flow data for January 1976 and a 60% average rainfall prediction from February 1976 from WARMS modelled data. The predicted point on the graph for the 200 Ml/d trigger (see Main Report Section 4.4) is 2nd week of April, however, the actual observed 200 Ml/d occurred in the latter half of April, at which time drought permit applications for SWOX would be submitted.

The hydrograph also shows the predicted 100Mld trigger reached in the last week in July and so preparations would need to be underway for an Emergency Drought Order submission during the early summer. In fact, the actual 100 Ml/d trigger was reached in the last week of July, and so in this reconstruction of events, the application would have been submitted at this time.

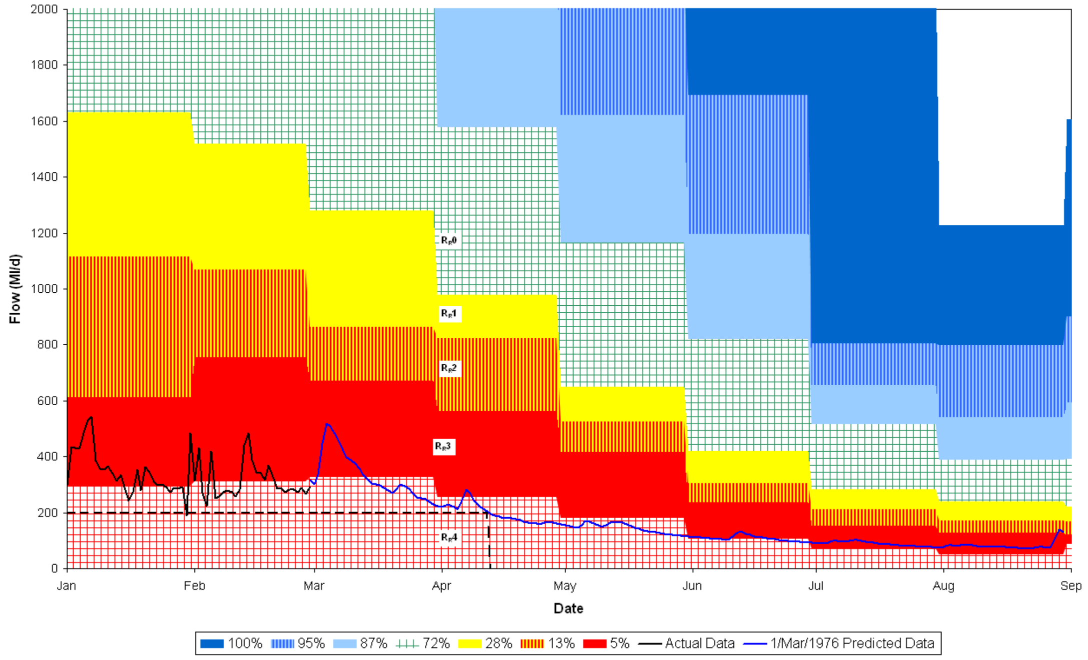

Figure 43 - Prevailing Flows from January to end of February 1976 and predicted flows from March to end of August at Farmoor using 60% LTA.

Figure 44 shows the prevailing storage for January and February 1976 and the WARMS reservoir storage level prediction for the 60% rainfall scenario undertaken in March, superimposed onto the Farmoor control diagram.

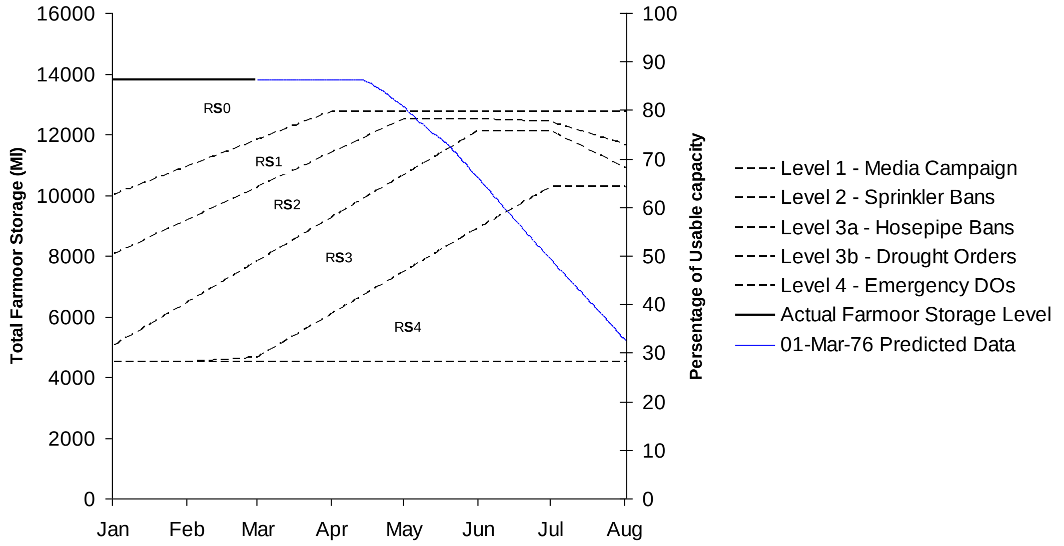

Figure 44 Actual Prevailing storage levels at Farmoor in January and February 1976 then Predicted Farmoor Reservoir Storage from March to August 1976

F10.1.2. 1c – Determination of Drought Severity against historic data

The drought severity assessment has been undertaken for London (Section F8.1) in view of the much longer period of record for London when compared to Farmoor. The assessment for London shows that the measures that would be imposed company wide based on the new protocol, in this case a sprinkler and Temporary Use Ban with escalation to DD11 order, are in line with the Levels of Service.

F10.2. Step 2 – Drought Risk Level Assessment

F10.2.1. 2a/b – Prevailing and predicted hydrologic risk indicators RG, RR and RS

The prevailing and predicted risk levels associated with the three hydrologic variables are shown in Figure 42, Figure 43 and Figure 44 with the corresponding Rc values are worked out below in Table 42.

Note that, in respect of the new drought permit/NEUB application trigger of 200 Ml/d naturalised flow on the River Thames at Farmoor, Figure F33 above shows this level of flow to be predicted for 2nd week in April with a prevailing flow at the end of February of about 280 Ml/d. Even though Farmoor reservoir was full, the new trigger would indicate that preparations should be in hand for NEUB and drought permit applications well before April.

Table 42 Drought Risk Assessment Matrix for Prevailing Conditions at Farmoor in February 1976

	R0	R1	R2	R3	R4
Groundwater Levels R_G				X	
River Flow Levels R_R					X
Reservoir Storage R_S	X				
Combined Risk Indicator R_C				X	

R_C = (3*0.6) + (4*0.25)+ (0*0.15)= 1.8 + 1.0+0 = 2.8 (Rounded to 3)

Table 43 Drought Risk Assessment Matrix using 3 Month Prediction (May)using 60% LTA

	R0	R1	R2	R3	R4
Groundwater Levels R_G					X
River Flow Levels R_R				X	
Reservoir Storage R_S					X
Combined Risk Indicator R_C					X

R_C = (4*0.5) +(3*0.25) + (4*0.25) = 2.0 + 0.75+1.0 = 3.75 (Rounded to 4)

F10.2.2. 2c – Combine prevailing and predicted indicators to produce an Overall Risk Indicator

The combined prevailing and predicted risk assessment gives rise to the following ORI:

- Prevailing R_C3
- Predicted R_C4
- ORI 3/4

F10.3. Step 3 Assignment of Drought Event Level (DEL)

In this example Step 2b produced an indicator of ORI 3/4. This ORI value then gives rise to a DEL 4 (Table 44) through reference to Table 11.

Table 44 Actioned and Potential drought measures from the revised SWOX protocol applied in February 1976

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Actioned /Potential Drought Measures
ORI3/4	DEL 4	CEO	-Enhanced media/water efficiency campaign start early March in line with company-wide campaign triggered by London protocol. -Sprinkler/Temporary Use Ban; imposed early April triggered by London protocol. - Possible application of drought permits/DD11 in early April if worst case scenario becomes reality. - Preparation for EDO and possible application

On the basis of the ORI 3/4 (3-month predicted Rc) in February, the water situation already appears more serious than for the London WRZ with an ORI of 2/4 (6-month predicted Rc) at end of February. However, it is important to note that in practice an assessment would be carried out on at least a monthly basis and so we would have been fully aware of the potentially serious water situation developing several weeks before the end of February.

Because the existing Farmoor reservoir was not fully commissioned in 1976, it is not meaningful to show the actual storage trend for this test year. However, the storage trend that results from applying the measures triggered by the revised protocol is simulated

Figure 45 shows the impact of the drought permits being implemented upon storage reaching Level 3b on the FCD and their strategic importance for the SWOX WRZ.

The protocol triggered the submission of the EDO in late July, however, because of the supply and demand-side measures introduced and the above average rainfall starting in September, reservoir storage fell no lower than 50% before rising rapidly in early October, consequently, there was never the need for Level 4 measures.

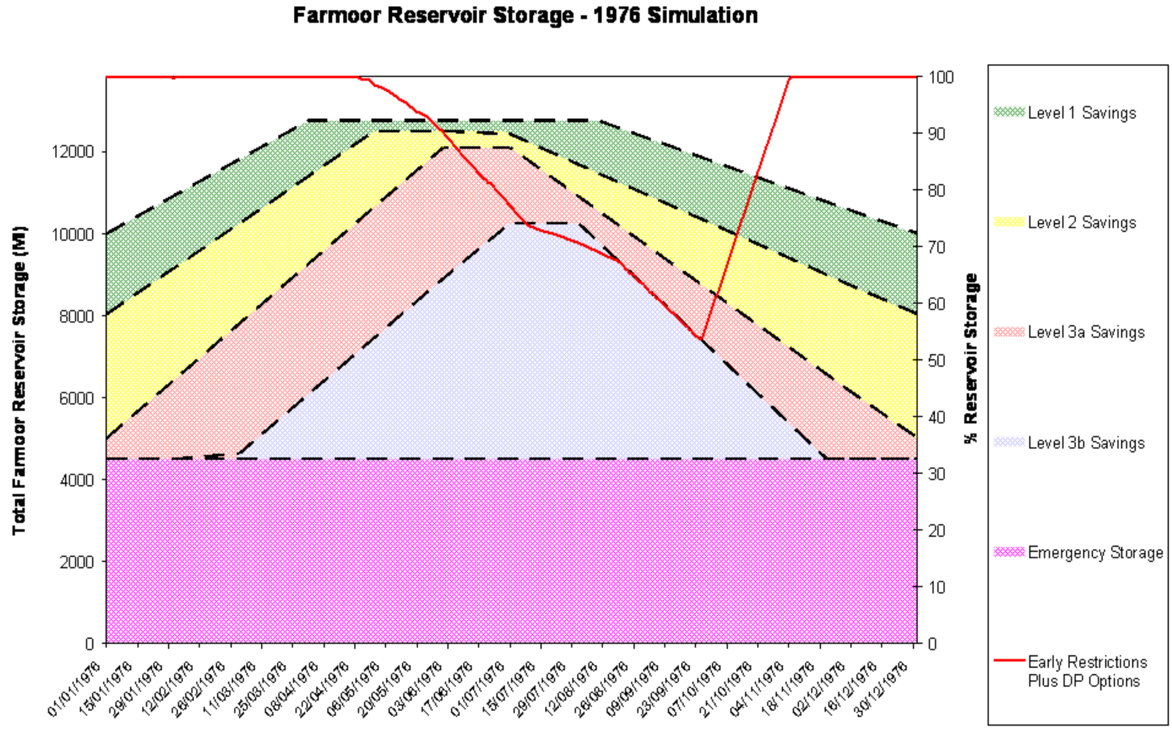

Figure 45 Simulated Reservoir Storage for Farmoor in 1976

F10.4. Conclusions for SWOX 1976

Our protocol indicates that for SWOX WRZ a Temporary Use Ban would be required and implemented at the earliest opportunity to maximise the savings that could be accrued. As shown above, the Temporary Use Ban was introduced company-wide via the London protocol in early April. In addition, preparation for company-wide NEUB applications would be required with their submission made in late April following the imposition of a sprinkler/Temporary Use Ban in early April.

Given that the 200 Ml/d trigger had been predicted for 2nd week in April, preparation for drought permit applications would be undertaken in March to allow submission of drought permits in late April; as can be seen in Figure 46, the trigger for their latest implementation was reached in early July. This timing would have allowed about 10 weeks for determining the applications.

The 1976 test year shows the revised SWOX protocol in combination with the London protocol, to be capable of initiating appropriate measures in a timely sequence to allow for full imposition of demand-side measures to facilitate the implementation of drought permit options. Key to this process is the use of the new triggers based on threshold flows in the River Thames at Farmoor.

F11. 1997 drought example - London WRZ

Background to 1997

The rainfall during the latter half of 1996 was below the LTA rainfall leading to very low groundwater levels and low flows in the Thames. At the start of 1997 regional groundwater OBHs were showing very low groundwater levels across the Thames catchment. This led to concern over the potential for reservoir storage to be maintained for the summer period until the onset of the recharge season. An enhanced media campaign was put in place to encourage customers to save water and a hosepipe ban was under consideration but never actually implemented as the reservoir storage level did not justify such a measure. Late and sustained rainfall in late winter and during the summer not only increased the flow in the Thames allowing reservoir storage to recover, but also resulted in minor, but important, recharge of groundwater levels particularly in the Cotswold aquifer.

F11.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

F11.1.1. 1a/b – Collation of Hydrologic Data and Predictions

The 1997 example is illustrated using the assessment with February as the base month, as for 2006 and 1976. The EA have provided historic data for the groundwater levels at Oak Ash and also modelled the OBH to show the predicted effect of 60% LTA rainfall on the groundwater levels from the start of Feb 1997. This is shown in Figure 46.

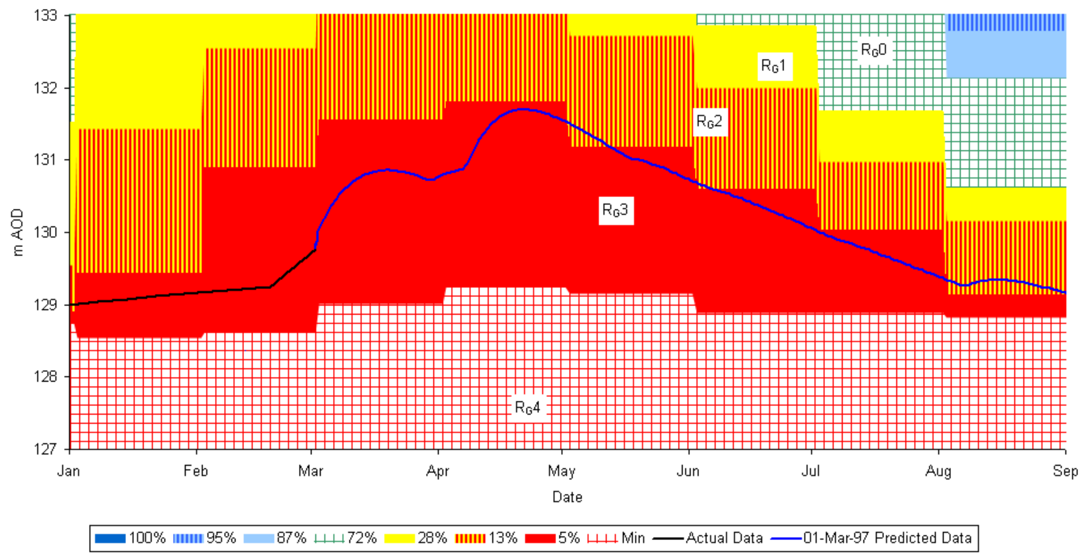

Figure 46 Oak Ash OBH., observed data for January and February 1997 and predicted for March to August 1997using 60% LTA. Bands show %ile splits based on EA data

Figure 47 below shows the prevailing river flows over Teddington Weir from January to end of February 1997 and predicted flows from March to August 1997 assuming 60% of average rainfall.

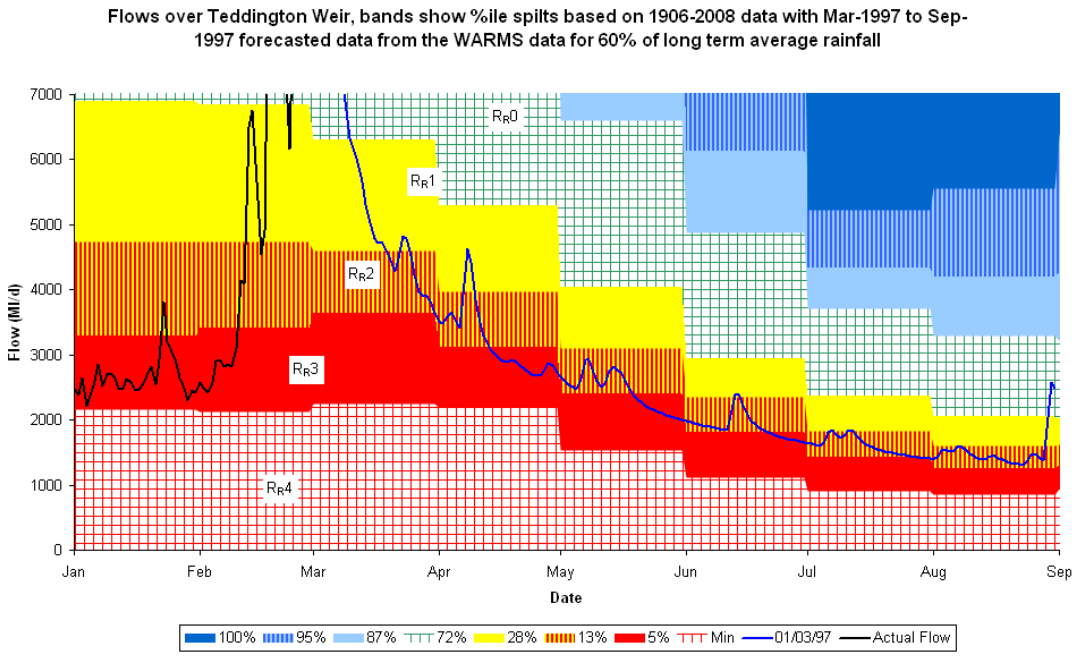

Figure 47 Flows over Teddington Weir, observed for January and February 1997 and predicted from March to August 1997 using 60% LTA. Bands show %ile splits based on 1906-2008 data.

The prevailing London storage for January and February 1997 and the predicted reservoir storage with 60% LTA rainfall from March to August 1997 is shown in Figure 48.

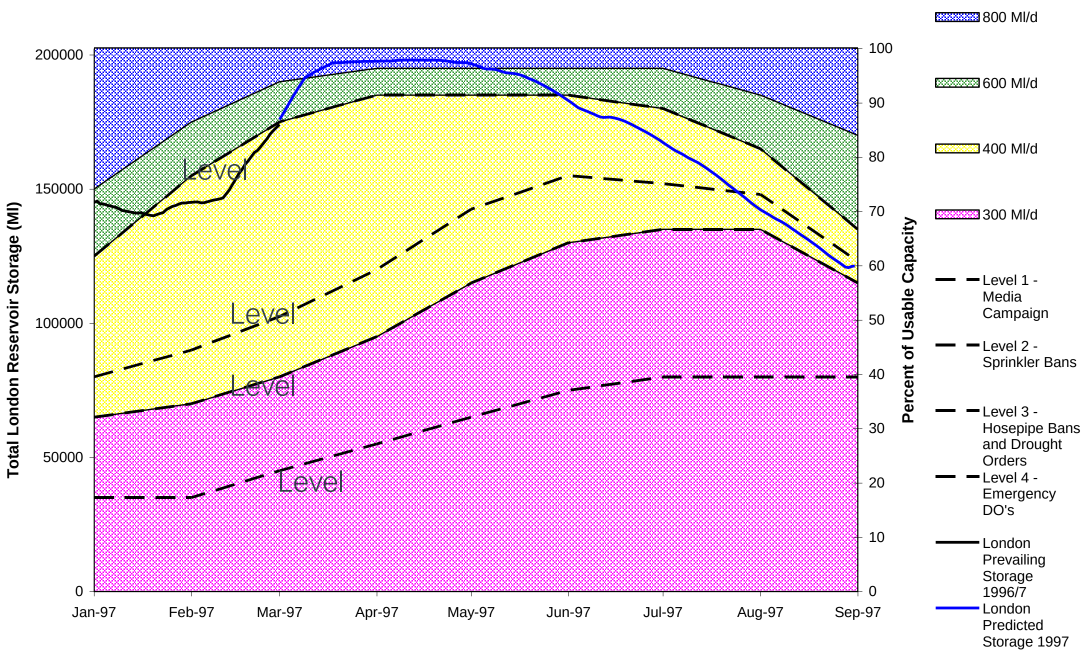

Figure 48 London reservoir storage- Prevailing for January and February and predicted from March to August 1997

F11.1.2. 1c – Determination of Drought Severity against historic data

The figures below (Figure 49, Figure 50 and Figure 51) show the potential drought severity in 1997 for the 60% rainfall scenario in relation to the worst droughts on record for the 108 years of record (1900 – 2008) as determined successively over the following 6 month period for each month beginning in February, thus predictions are made for February to July, March to August and April to September. The successive monthly predictions show:

- February to July; potentially the 3rd worst on record, approximately 1 in 36 years
- March to August; potentially the 7th worst on record, approximately 1 in 15 years
- The April to September; potentially the 5th worst on record, approximately 1 in 22 years

Thus, the situation in April, with a drought of approximately 1 in 22 years, is in line with the 1 in 20 year level of service for a Level 3 event. NB the prediction of drought severity shows a decline in the level of severity from February to March and it worsening again in April. This is because of a significant event in late February/early March which led to a model prediction in March based on a situation where the river flows had increased significantly and this gave rise to a prediction showing a greater improvement in the resource situation than actually occurred across the catchment.

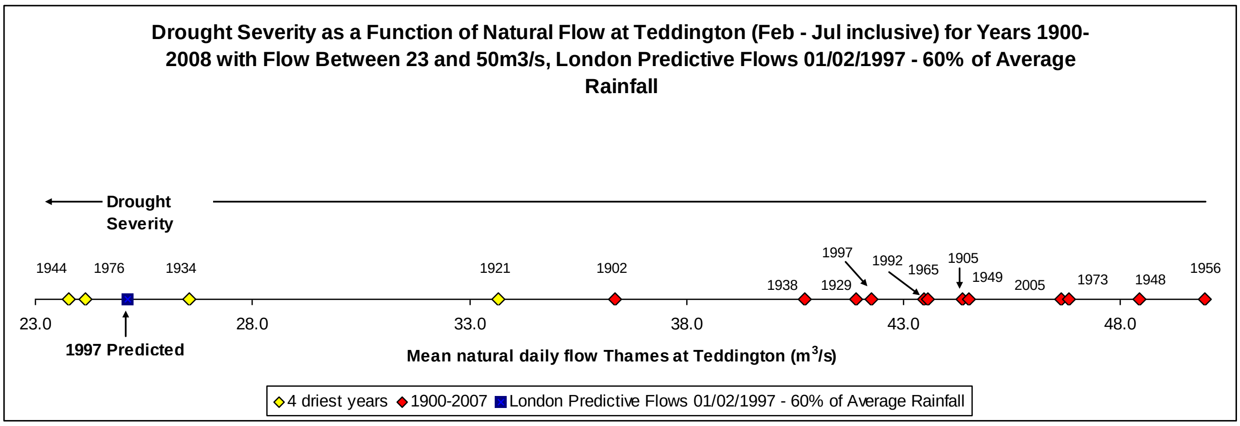

Figure 49 Potential Drought Severity from February 1997 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

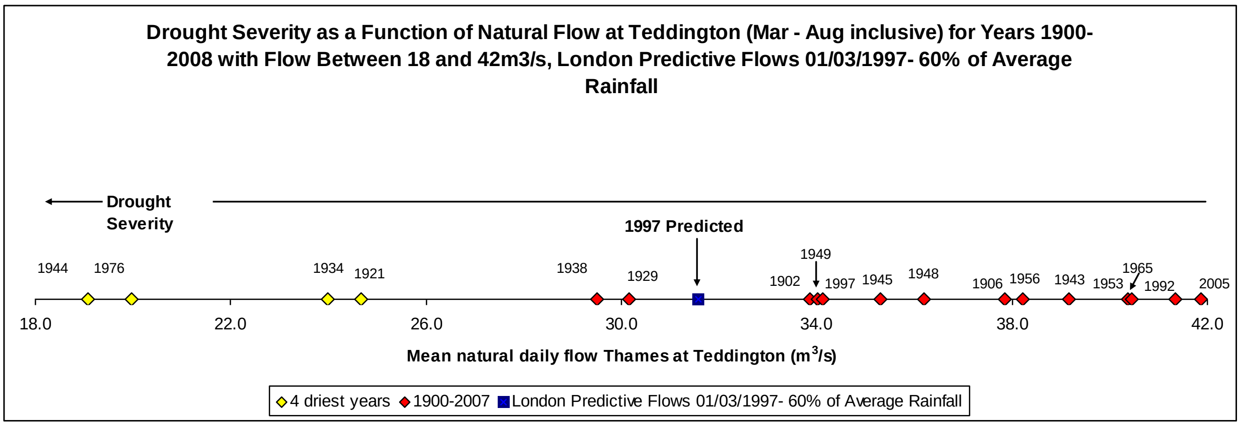

Figure 50 Potential Drought Severity from March 1997 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

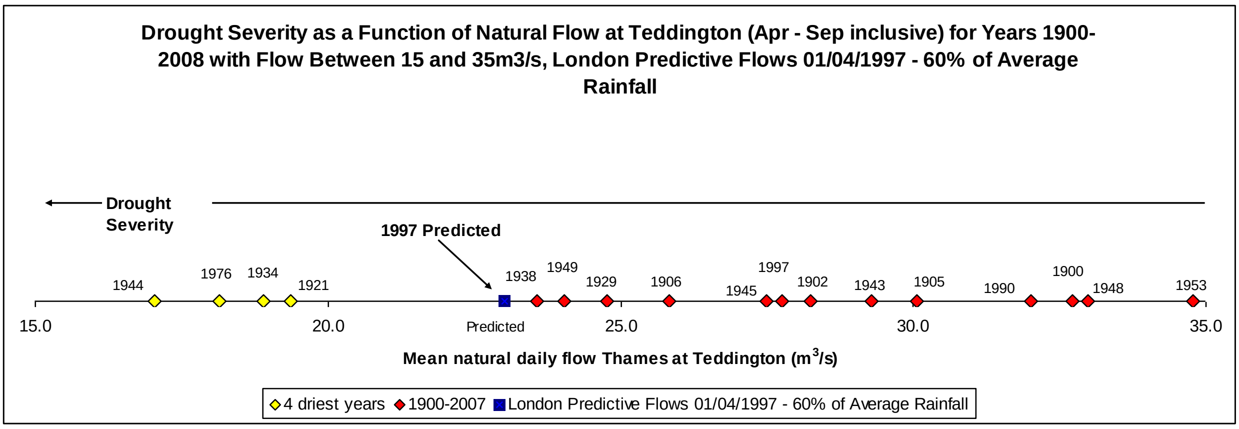

Figure 51 Potential Drought Severity from April 1997 Given Current Hydrological Indicators, Produced WARMS Model 6 Months Forecast at 60%LTA Rainfall

F11.2. Step 2 – Drought Risk Level Assessment

Step 2a- prevailing and predicted hydrologic risk indicators, R_G, R_R and R_S

Figure 46 shows the prevailing situation from January 1997 and the predicted trend for Oak Ash OBH GW levels from February 1997 given 60% rainfall over 6 months to August 1997, this shows that the GW level is predicted to decline to R_G4 in August 1997.

Figure 47 shows the prevailing situation from January 1997 and the predicted river flow at Teddington from February 1997, the flow stays mainly in R_R3. At the end of August 1997 the predicted risk level was R_R3

Figure 48 shows the prevailing reservoir storage for January and the modelled reservoir storage from February 1997. The London reservoirs were only 75% full at the start of the year but the 60%

scenario shows a recovery and subsequent decline to the predicted risk level of R_S2 by the end of August.

F11.2.1. Step 2b-produce combined prevailing and hydrologic risk indicators (R_C)

The risk matrices resulting from Step 2a are given in Table 45 and Table 46.

Table 45 Prevailing Risk Combined Indicator for April 1997

Prevailing Risk Level In April 1997						
		R0	R1	R2	R3	R4
	Groundwater Levels R_G				X	
	River Flow Levels R_R	X				
	Reservoir Storage R_S		X			
	Combined Risk Indicator R_C			X		

R_C = (3*0.55) + (0*0.15) + (1*0.30) = 1.65 + 0.0 + 0.3 = 1.95 (Rounded to 2)

Table 46 Predicted Risk Combined Indicator for April to October 1997 using 60% LTA

Predicted Risk Level In Apr 1997 To Oct 1997						
		R0	R1	R2	R3	R4
	Groundwater Levels R_G				X	
	River Flow Levels R_R				X	

	Reservoir Storage R_S			X		
	Combined Risk Indicator R_C				X	

R_C = (3*0.45) + (3*0.25) + (2*0.3) = 1.35+ 0.75 + 0.6 = 2.7 (Rounded to 3)

In summary the risk indicator levels and overall risk are:

- Prevailing R_C2
- Predicted R_C3
- ORI 2/3

F11.3. Step 3 Assignment of Drought Event Level (DEL)

In this example Step 2b produced an indicator of ORI 2/3. This ORI value then gives rise to a Drought Event Level (DEL) of 3 (Table 47) through reference to Table 11.

Table 47 Potential drought measures from the drought protocol applied in February 1997 data with 6 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI2/3	DEL 3	Director	Media/water efficiency campaign Temporary Use Ban with sprinkler ban; preparation of DD1 order and drought permits

On the basis of the assessment ORI level of 2/3 in February, with the prevailing risk of R_C2 and the potential to escalate to R_C3 within 6 months, the introduction of NEUB and drought permits could be required and so measures to ensure these could be obtained at the right time need to be introduced. Therefore, plans would be made to introduce a company-wide sprinkler and temporary use ban. In practice the risk of Level 3 measures would mean a close monitoring of the situation and further assessment in March. The timing of the introduction of a temporary use ban would be determined in order to ensure its maximum benefit and so would be likely to be introduced early in the season to ensure garden watering was minimised, therefore it would be introduced earlier in April.

Table 48 shows the full 'prevailing' assessment for each month of 1997. The table shows that Rc3 risk level was not reached throughout the year illustrating that an escalation to measures greater than the Temporary Use Ban was not required.

Table 49 shows the 3 month predictions successively through 1997. This indicates that Rc3 was within 3 months for the May prediction and so consideration would have been given to an application for a NEUB and drought permits. In view of the prevailing storage at the time, it is unlikely that the application would have been made but the situation monitored closely and reviewed in the following month when, as the protocol shows the risk of Level 3 measures diminished in June.

Table 50 shows the 6 month predictions successively through 1997. This indicates that the risk assessed in February indicated the potential for Level 4 within 6 months and so the requirement for implementation of early measures would have been apparent at an early stage. However, there was no further risk of DEL4 shown within 6 months.

Table 48 Combined Prevailing Values for London for 1997

Location	London Based on Oak Ash			
Analysis	Combined Prevailing			
Range	1997			
	R_C1	R_C2	R_C3	R_C4
Jan-97		X		
Feb-97		X		
Mar-97	X			
Apr-97		X		
May-97		X		
Jun-97		X		
Jul-97	X			
Aug-97	X			
Sep-97	X			
Oct-97		X		
Nov-97		X		
Dec-97	X			

Table 49 Combined Predicted Values for London for 3 month predictive for 1997

Location	London Based on Oak Ash				
Analysis	Combined 3 month predictive				
Range	1997 – 1998				
	R_C1	R_C2	R_C3	R_C4	Predicted from
Jan-97					
Feb-97					
Mar-97					
Apr-97		X			Jan-97
May-97		X			Feb-97
Jun-97		X			Mar-97
Jul-97		X			Apr-97
Aug-97			X		May-97
Sep-97		X			Jun-97
Oct-97		X			Jul-97
Nov-97		X			Aug-97
Dec-97		X			Sep-97
Jan-98		X			Oct-97

Table 50 Combined Predicted Values for London for 6 month predictive for 1976

Location	London Based on Oak Ash				
Analysis	Combined 6 month predictive				
Range	1997 – 1998				
	R_C1	R_C2	R_C3	R_C4	Predicted from
Jan-97					
Feb-97					
Mar-97					
Apr-97					
May-97					
Jun-97					
Jul-97			X		Jan-97
Aug-97				X	Feb-97
Sep-97		X			Mar-97
Oct-97			X		Apr-97
Nov-97		X			May-97
Dec-97		X			Jun-97
Jan-98		X			Jul-97
Feb-98			X		Aug-97
Mar-98			X		Sep-97

Apr-98			X	Oct-97

F11.4. Conclusions for 1997 London protocol

A risk level of DEL 3 early in 1997 would signal the potential severity of the drought and would precipitate the early introduction of demand-side measures. This would mean that an enhanced media campaign would have been required in February and a Temporary Use Ban would be imposed company-wide at the optimum time to have the maximum impact on demand, therefore the ban would be implemented in early April.

The month by month assessment shows that the Company would not have actually applied for either a NEUB or Drought Permits because the increase in monthly rainfall improved prevailing and predicted Rc and consequently DEL levels. This is shown by the storage trends in the London Reservoirs (Figure 52).

The protocol would also have resulted in the preparation of supply side measures in February such as the Thames Gateway desalination plant and NLARS. Actual implementation would have been actioned by the 3000 Ml/d trigger (Section 6.2 in the Main Report).

Comparison with the measures in 1997 and what the London protocol indicates shows that the measures under the London protocol would have been more extensive in the early part of the potential drought than those implemented in 1997.

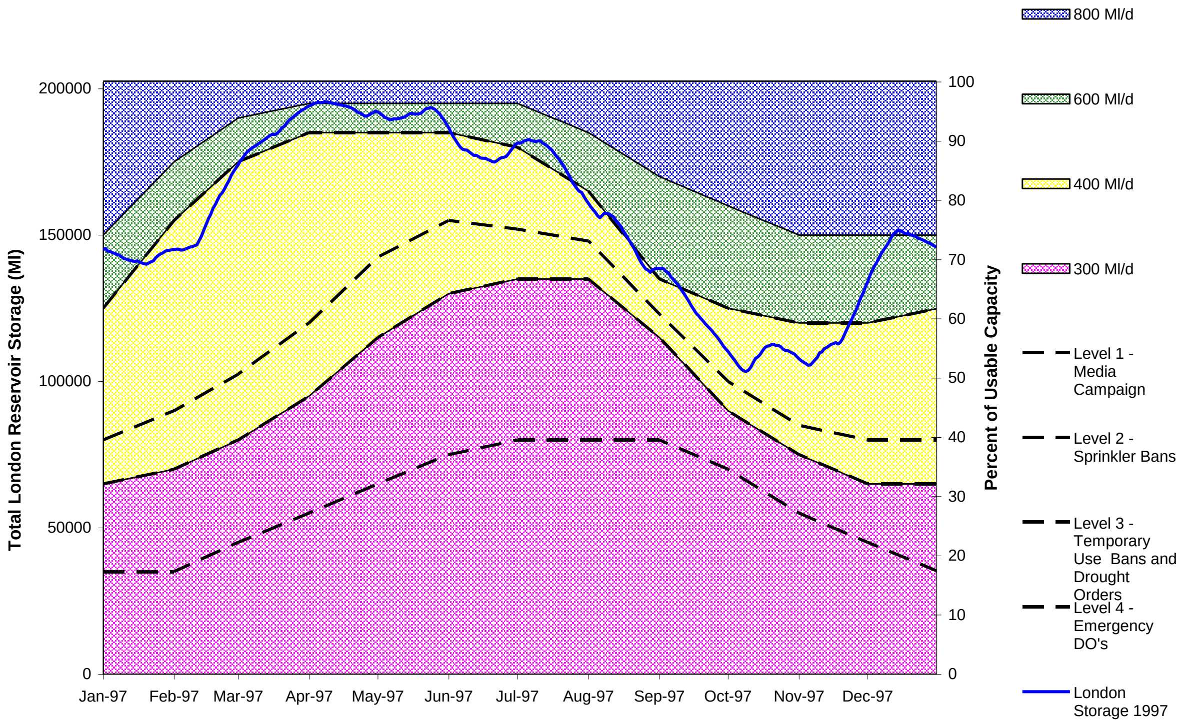

Figure 52 Actual Storage for London (January to December 1997)

F12. Farmoor 1997 Example and Analysis

Background

Following a dry summer in 1996 there was very little effective rainfall during the winter of 1996/97 with the result that groundwater levels did not recover over the period to the end of January and so the prospect of a severe drought in the Upper Thames for 1997 was clearly apparent. As discussed for the London example above, at the start of 1997 regional groundwater OBHs were showing very low groundwater levels across the Thames catchment. An enhanced media campaign was put in place to encourage customers to save water and a hosepipe ban was under consideration but not implemented as reservoir storage was maintained throughout the summer and so it was not required. Late and sustained rainfall in February and March had a more significant beneficial effect for the Upper Thames than for London leading to marked groundwater recovery in the Cotswolds so that further measures were not required for Farmoor throughout 1997 and the threat of drought receded almost entirely.

F12.1. Step 1 - Hydrological Assessment and Drought Severity Assessment

F12.1.1. 1a/b – Collation of Hydrologic Data and Predictions

The application of the methodology is demonstrated for 1997 using the graphs and tables shown below. The following section then goes on to describe the assignment of the Overall Risk Indicator and the Drought Event Level.

Figure 53 shows the prevailing groundwater level data for January and February 1997 for Rockley OBH and a groundwater level prediction based on a 60% LTA rainfall scenario from March to August 1997. As for 2005, 2006 and 1976, Rockley has been used as a surrogate for a Cotswolds groundwater level prediction in the absence of a locally based Cotswolds Oolite OBH.

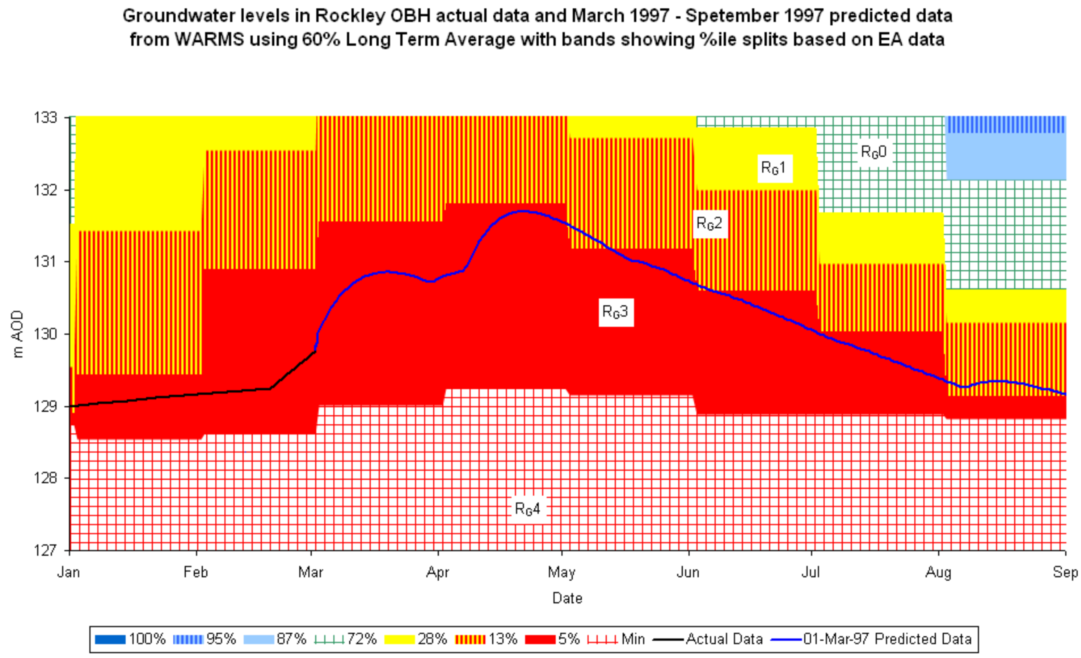

Figure 53 Groundwater Levels at Rockley showing actual data for January and February with predicted trend from March to August 1997. Bands show % based on EA data.

Figure 54 shows the prevailing flow data on the River Thames at Farmoor from January 1997 to end of March and a predicted trend from March to end of August (60% LTA rainfall scenario). The 200 Ml/d trigger (see Main Report Section 4.4) line is also shown which indicates that it might be reached in late June. This would alert us to start preparing for NUEB and drought permit applications for SWOX, but their submission would not be triggered unless and until the observed flow had reached the 200 Ml/d trigger criterion. In the event, the increase in monthly rainfall maintained river low at Farmoor above the trigger level over the summer period. The trigger was actually reached in October for a brief spell, but by then water resources recovery was well underway throughout the catchment going into the early winter.

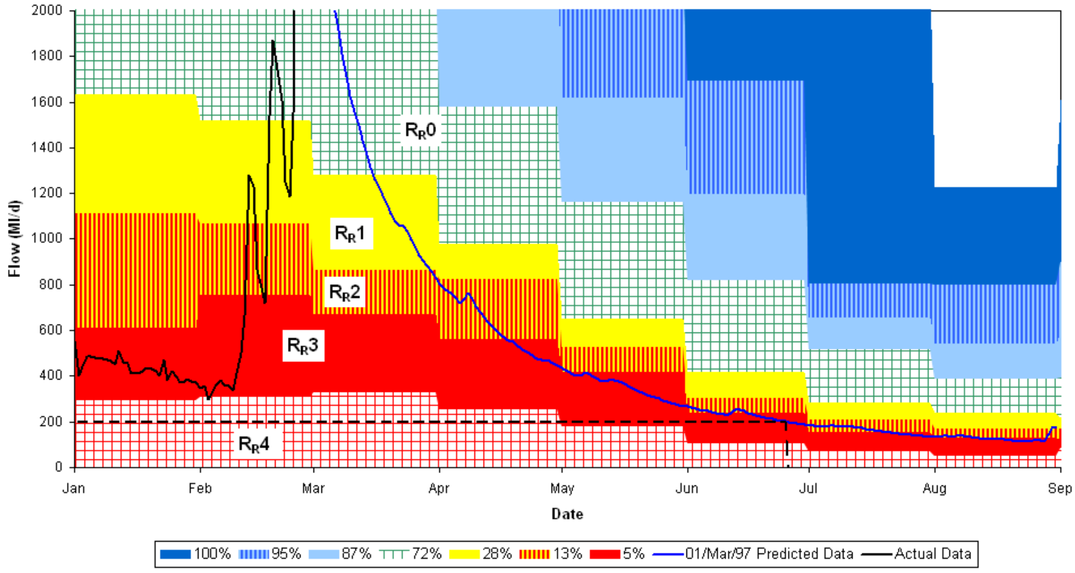

Figure 54 Flows at Farmoor, prevailing data from January to end of February 1997 and predicted flows from March to end of August 1997. Based on 60% LTA

Figure 55 shows the prevailing storage for January and February1997 and the WARMS Farmoor reservoir storage level prediction from March to August 1997.

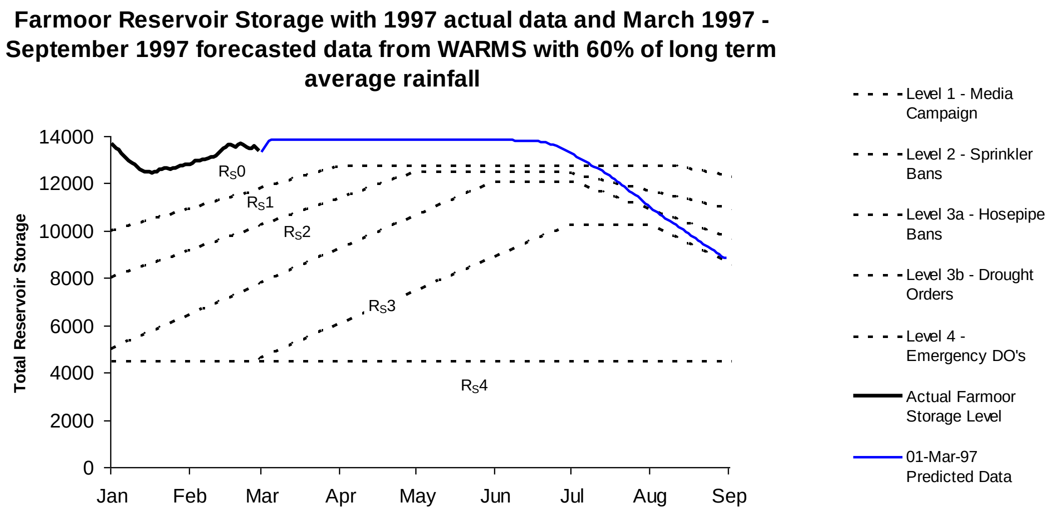

Figure 55 Predicted Reservoir Storage Showing March to August 1997

F12.1.2. 1c – Determination of Drought Severity against historic data

The drought severity assessment has been undertaken for London in view of the much longer period of record for London when compared to Farmoor. The assessment for London shows that the measures that would be imposed company-wide would be enhanced media campaign and Temporary Use Ban, in line with the potential drought severity of 1:36 estimated at the end of February.

F12.2. Step 2 – Drought Risk Level Assessment

F12.2.1. 2a/b – Prevailing and predicted hydrologic risk indicators R_G, R_R and R_S

The risk matrices resulting from Step1 are shown in Tables F46 and F47.

Table 51 Drought Risk Assessment Matrix for Prevailing Conditions at Farmoor in February 1997

Prevailing Risk Level In February 1997						
		R0	R1	R2	R3	R4
Figure F19	Groundwater Levels R_G				X	
Figure F27	River Flow Levels R_R	X				
Figure F23	Reservoir Storage R_S	X				
	Combined Risk Indicator R_C			X		

R_C = (3*0.6) + (0*0.25) + (0*0.15) = 1.8 + 0.0 + 0= 1.8 (Rounded to 2)

Table 52 Drought Risk Assessment Matrix for Feb using 3 Month Predicted (May)using 60% LTA

Predicted Risk Level end of May 1997					
	R0	R1	R2	R3	R4
Groundwater Levels R_G				X	
River Flow Levels R_R			X		
Reservoir Storage R_S				X	
Combined Risk Indicator R_C				X	

R_C = (3*0.5) + (2*0.25) +(3*0.25)= 1.5 + 0.5 + 0.75 = 2.75 (Rounded to 3)

F12.2.2. 2c – Combine prevailing and predicted indicators to produce an Overall Risk Indicator

The combined prevailing and predicted risk assessment gives rise to the following ORI:

- Prevailing RC2
- Predicted RC3
- ORI 2/3

F12.3. Step 3 Assignment of Drought Event Level (DEL)

In this example Step 2b produced an indicator of ORI 2/3 (Table 45). This ORI value then gives rise to a Drought Event Level (DEL) of 3 through reference to Table 11.

Table 53 Potential drought measures from the drought protocol applied in February 1997 data with 3 month predicted data

Overall Risk Indicator Level	TW Drought Event Management Level	Governance Controller	Potential Drought Measures
ORI2/3	DEL 3	Director	Enhanced media/water efficiency campaign/ sprinkler/ Temporary Use Ban Introduce ODOs/DPs 1. Preparation for DD11 EDO and possible application drought permit

On the basis of the assessment ORI level of 2/3 in February, with the prevailing risk of R_C2 and the potential to escalate to R_C3 within 3 months a company-wide sprinkler and Temporary Use Ban would be introduced and preparations made for a NEUB and drought permit applications.

F12.4. Conclusions for 1997 SWOX protocol

The revised protocol indicates that for SWOX a Temporary Use Ban would be required following the protocol assessment in February. As is mentioned above for the London situation a Temporary Use Ban would be implemented company-wide in early April, which is in line with the protocol assessment for Farmoor. Following significant rainfall in February and March and during the summer of 1997, the need for further measures in SWOX did not materialise, as indicated by Farmoor Reservoir levels (Figure 56). That is to say, in terms of the assessment, prevailing , and hence, predicted hydrological variables would have all improved progressively throughout the summer The focus for SWOX would have switched to close monitoring as the prospect of more severe measures would have been removed entirely because of the resultant groundwater level recovery.

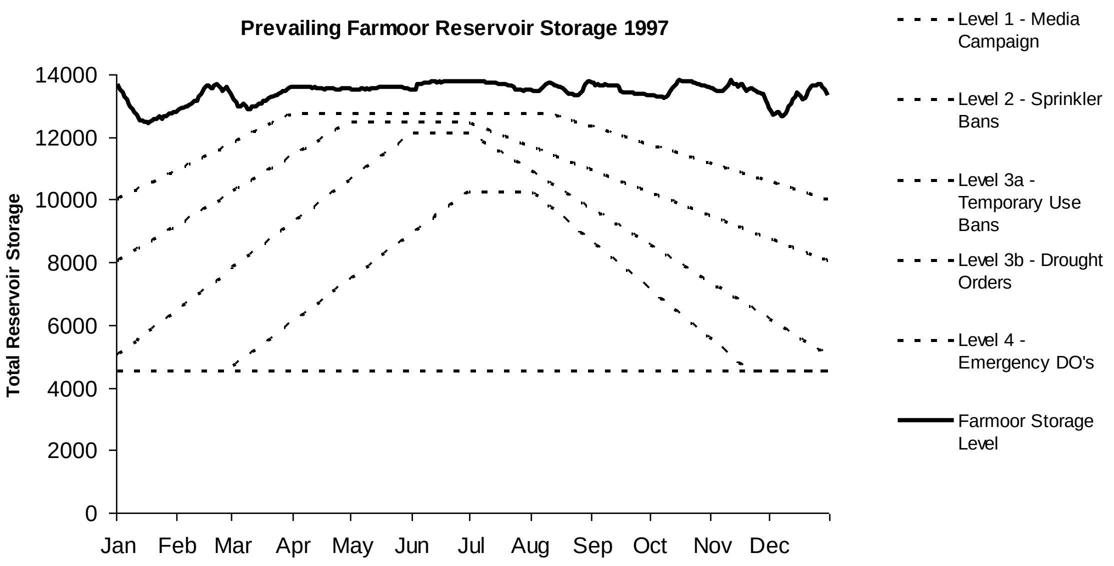

Figure 56 Actual Reservoir Storage for Farmoor in 1997

F13. Overall Conclusions

The analysis above of 2012 suggests that our Drought Plan was used effectively to bring in drought measures. Looking at the historic droughts, when the current Drought Protocol was not in place, the above analyses of selected recent drought years shows that if the London and revised SWOX protocols had been in use at the time, appropriate measures would have been implemented at an earlier stage than was actually the case. Furthermore, the timelines for gaining regulatory approval of drought orders and permits would have been accommodated. This demonstrates that the London and revised SWOX protocols ensure both a timely response to the early onset of drought and that appropriate measures are put in place when the risk of significant drought is predicted. The protocols also have the flexibility to ensure that where the situation improves, for example, due to late winter recharge or significant summer rainfall, the escalation to the next level of measures is not implemented but the situation continues to be monitored closely to determine whether escalation is required later in the year.

The revised SWOX protocol with the 200 Ml/d trigger has been shown to be a useful addition to our drought plan. In the predictive mode, it provides a very useful early warning guide to the possibility of needing to require either a NEUB or drought permits. And if and when reached, the trigger provides a robust point on the River Thames recession that enables sufficient time (minimum of ten weeks) for the application process for these orders to be granted.

The 100 Ml/d trigger does provide a useful guide for implementation of drought permits. The trigger for the actual implementation of drought permits would be either reaching 100 M/d. Generally by the time drought permit options were needed the NEUB measures would already be in force, triggered by the London protocol. If in the unlikely event that this is not the case, then the 100 Ml/d / trigger criteria would be used to guide NEUB implementation.

In appreciating the substantial changes we have made to drought management methodology since 2006, it is instructive to compare the effects on the timing of demand-side measures when applying the historical protocol for the London WRZ (see Appendix E1) compared to that of the existing protocol. Table F 56 shows a comparison of the historic and existing protocols on the timing of the introduction of demand-side measures for the five droughts analysed above.

In order to make the comparison meaningful it has been assumed that:
new powers (TUB and NUEB) and existing Levels of Service apply to both protocols; the historical protocol is based on the actual [prevailing] storage level trend on the existing LTCD as given in the drought years analysed above; the protocol is based on a 60% LTA rainfall scenario.

It can be seen from the table that the Drought Plan protocol introduces measures between two and four months earlier than the historical protocol. With the revision to our levels of service for our Drought Plan 2021, a full TUB would be implemented at Level 2, bringing forward the measure further when compared to the historical protocols.

Table 54 Historic versus Drought Plan protocols- comparison of implementation of demand-side measures (this is not necessary for 2012 as the Drought Plan protocols were used)

Example drought years	Historic protocol NB Levels 1-4 refer to Levels of Service restrictions	Drought Plan protocol NB Levels 1-4 refer to Levels of Service restrictions
2005	July- Level 1 Media /water efficiency campaign. -	February- Level 1 Media/water efficiency campaign. April- Enhanced media/water efficiency campaign; Level 2- unattended hosepipe & sprinkler ban.
2006	May- Level 1 Media /water efficiency campaign. -	February- Level 2 Enhanced media/water efficiency campaign. April- Level 3 TUB.
1976	May- Level 1 Media /water efficiency campaign. July- Level 2 Enhanced media/water efficiency campaign; unattended hosepipe & sprinkler ban. August- Level 3 TUB & DD11.	February-Level 2 Media/water efficiency campaign. April – Level 3 TUB. July – Level 3 DD11.
1997	July- Level 1 Media/water efficiency campaign.	February- Level 2 Enhanced media/water efficiency campaign. April- Level 3 TUB.