Drought Plan 2019
Annex 1: Drought monitoring and trigger levels

July 1, 2019
Version 1

from Southern Water

Contents

Introduction

This is the first of 14 technical annexes that provide extra information to support our Drought Plan. This particular annex describes how we monitor the water resource position in the aquifers, rivers, reservoirs and boreholes in the South East of England. We use these measurements to help track the development of a drought and to help with our supply forecasts.

As each drought is different it is important that we set key trigger levels to each of the monitoring points. The drought trigger levels are used to inform the specific activities the company should undertake as water resources become scarce because of dry conditions.

During these conditions it is important for us to keep communicating with our customers to keep them informed as a drought progresses and also when it has broken. Refer to our communications and engagement strategy in Annex 6 and 8.

This annex has been updated following the River Itchen, River Test and Candover abstraction licence Public Inquiry (the Inquiry) held in March 2018 and the agreement reached between Southern Water and the Environment Agency as part of the inquiry process, formalised in an operating agreement under Section 20 of the Water Resources Act 1991 (S20 agreement). We have provided an overview of the contents on the S20 agreement in our Tehcnical Summary Report. We were notified of the confirmed changes to the River Itchen, River Test and Candover abstraction licences in February 2019 and the licence changes were enacted in March 2019.

Overall concept

Drought triggers are used to identify when a company should change its normal operation and take proportional action in response to a lack of rainfall. Inevitably, this might lead to the introduction of demand-side and supply-side drought intervention measures as set out in this plan. The triggers are used to ensure that measures are introduced in a timely fashion, but are only put in place when they are actually required to manage the risk from a drought.

The phasing, i.e. sequencing, of any action is based on a combination of the effect that each measure has:

- On the amount of water available (supply).
- The amount of water required by customers (demand).
- The impact that this might have on customers or the environment.
- The complexity involved in introducing the measure.

The triggers that have been developed by Southern Water are based on our analysis of a wide range of drought events. The triggers are progressive in nature and therefore intended to reflect the increasing severity of a drought event so that measures that are associated with each set of triggers are only introduced when they are required.

The key stages to the development of a drought are as follows:

1) Stage one is moving from normal conditions to impending drought. At this stage the drought has not yet fully established itself. Sometimes the dry weather conditions break at this point and we return to normal conditions. At other times the dry weather conditions continue and we progress to the next stage.

2) The second stage is referred to as drought conditions. This would have resulted from a continued period of dry weather. If this weather pattern continues then the drought becomes worse and the drought then becomes classified as a severe drought. Many times in the past when we have been in drought conditions the weather pattern has changed bringing with it more rain. When this occurs we will continue to monitor the resource position and the drought classification might change back to impending drought or normal depending on the circumstances.

3) The third stage of the drought is severe drought conditions. This is the final classification of droughts and covers those rare but severe events that we have seen in the past and could experience in the future.

Typically we all usually think of a drought ending when it starts raining again. However depending on how severe the drought was it can take time for the rain to recharge the aquifers and increase river flows. This time delay or lag between the rain and seeing an increase in groundwater levels can be several weeks. Therefore we do not indicate that a drought has ended until conditions have returned to normal.

For each stage of the drought (normal to severe) different activities are undertaken for each of the actions. Table 1 provides an overview of the stages, their approximate return periods and the key interventions. A simple ‘traffic light system’ is used where: yellow represents an impending drought; orange implies drought and red represents severe drought. This colour classification is maintained in all subsequent sections of this Drought Plan.

Since drought management is a phased programme of activities linked to the severity of the drought situation, it is important to understand the complexity, associated lead times and implications of activities in terms of customer, environmental and financial impacts. These attributes are displayed as a greyscale index which is defined in Table 2.

Using these colour schemes, Figures 1 and 2 then set out the activities that we will carry out in each of the four areas below.

1) Monitoring.

2) Forecasting (tools and analyses used).

3) Triggers.

4) Interventions.

The triggers themselves are based on a variety of monitoring data. Analysis tools are then used to translate that data into metrics that can be used as meaningful drought triggers. The range of water resource types within the Southern Water region, as described in the Drought Plan Technical Summary, means that there are a number of different triggers and intervention measures within each drought management area. They are supported by a set of monitoring data and analysis tools that increase in complexity as the severity of a drought situation increases.

It should be noted that all categories are cumulative, that is, monitoring, analysis or intervention measures introduced during less severe drought conditions will continue to be in place as further actions are considered and put in place.

Figures 1 and 2 show that Southern Water uses a combination of three types of triggers. The first two, relating to rainfall and flow/water level are used as hydrometric indicators and checks on the third component, the projected supply/demand balance. These triggers are used in conjunction, and there is no single indicator that is used to classify drought status. This is a deliberate reflection of the mix of resource types and vulnerability that characterise Southern Water's supply area.

The actions taken by the company will vary, depending on the risks and uncertainties including hydrological conditions, time of year, customer response to restrictions and long-term weather forecasts. Hence, Figures 1 and 2 show a range of actions that will be taken to maintain supplies as drought conditions become more severe.

Table 1 Relationship between SWS Drought Plan Stages, approximate return periods, interventions and water industry restriction terminology

SWS Drought Plan stage description	No drought	Impending drought	Drought	Severe drought (phase 1)	Severe drought (phase 2)	N/a (Emergency conditions)
SWS Drought Plan stage	Normal	Stage 1	Stage 2	Stage 3	Stage 4	N/a (covered by emergency plans)
Approximate drought severity return periods	< 1 in 5 year	1 in 5 year to 1 in 10 year	1 in 10 year to 1 in 20 year	1 in 20 year to 1 in 500 year	1 in 20 to 1 in 500 year	> 1 in 500 year
SWS Drought Plan restrictions	Normal water efficiency advice	Voluntary appeals to conserve water	TUBS (phase 1)	NEU (phase 1)	TUBS (phase 2) + NEU (phase 2)	Standpipes / rota cuts
SWS Drought Plan Drought Permits / Orders	Baseline monitoring	Preparation for DP/DOs	Apply for DP/DOs	Apply for and implement DP/DOs	Apply for and implement DP/DOs	Apply for implement emergency DOs
Water industry restriction terminology	N/a	Level 1	Level 2	Level 3	Level 3	Level 4

TUBS – Temporary Use Bans; NEU – Non-Essential Use Bans; DP – Drought Permit; DO – Drought Order

Table 2 Key to greyscale activity coding used in Figures 1 and 2 to show complexity and lead-in time of different measures

Activity	Routine	Enhanced	Complex	Very Complex
Monitoring	Routine – no extra resources required		Requires some extra resources to set up data gathering and reporting systems;	Requires significant extra resources and probable use of external resources:
			1 month lead time	*3 months lead time*
Tools & Analyses	Routine analyses or simple spreadsheets/reports requiring limited extra input	Requires experienced staff to use relatively simple tools specifically for drought purposes.	Requires use of complex tools (GW models, Catchmod etc.), possibly linked to Aquator resource models. Possible need for external resources.	Requires complex tools and probabilistic assessment of future rainfall. Likely to require external resources.
		1 month lead time	*1-3 months lead time*	*3 months lead time (assuming complex tools and analysis already in use)*
Triggers	Simple triggers based on operational judgement	Some complexity requiring evaluation of multiple triggers and simple estimate of supply/demand balance	Triggers evaluate overall forecast risk across surface and groundwater indicators and combine in forecast supply/demand balance	Careful, quantified consideration of all triggers and forecast rainfall risks in conjunction with risk based supply/demand forecast.
Interventions	Activities with limited/no impact on customers using existing SWS systems and operational procurement.	Activities requiring some preparation and inconvenience/interaction with customers	Activities requiring set up of internal organisations, inconvenience to customers and preparation/liaison with external regulators	Activities involving significant inconvenience to customers, complex legislative processes, planning permission and/or significant procurement activities.
	<1 month lead time	*1 month lead time*	*1-3 months lead time*	*3 – 12 months lead time*

Figure 1 Generalised overview of relationships & phasing of drought monitoring & analysis tools

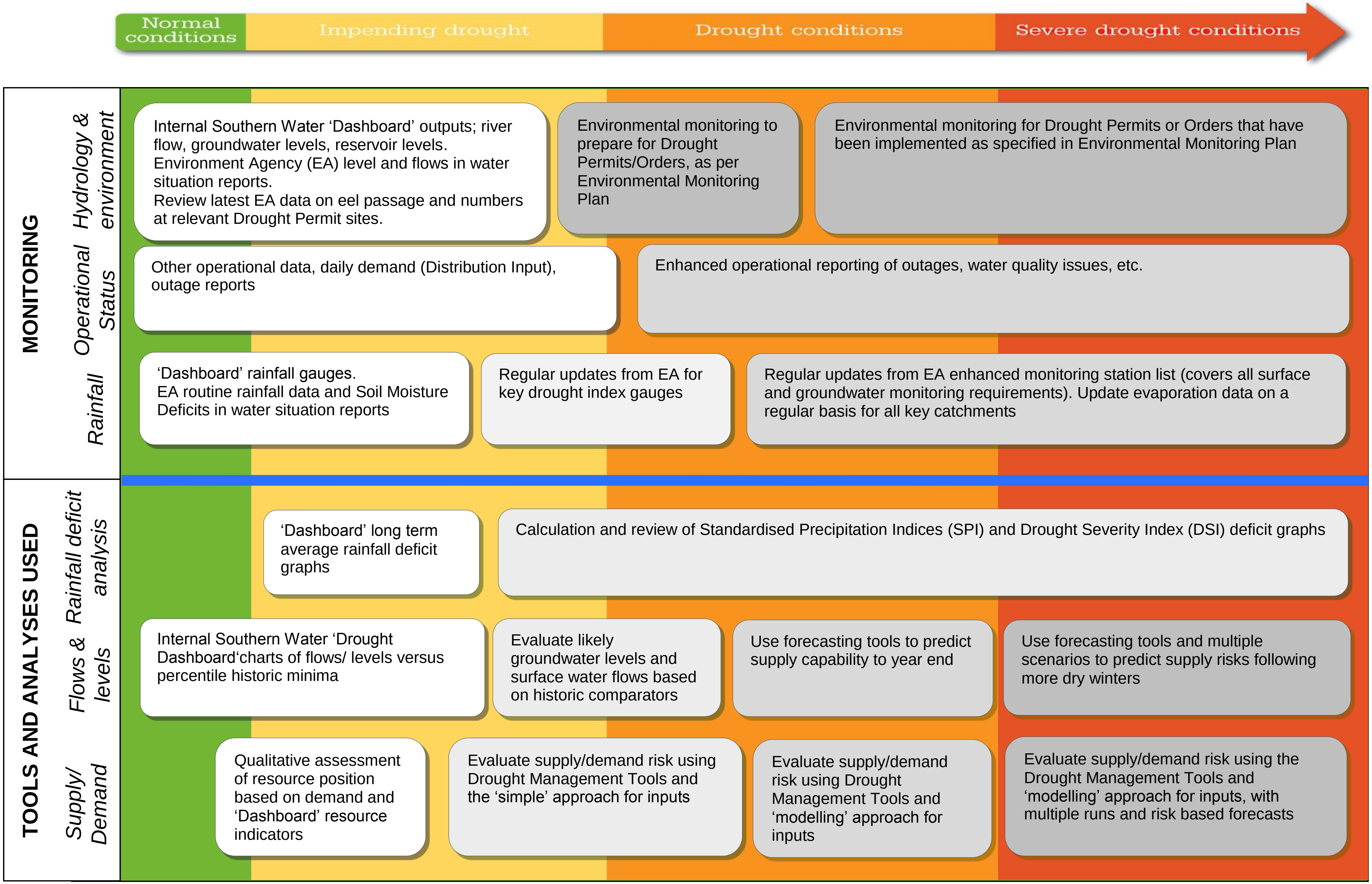
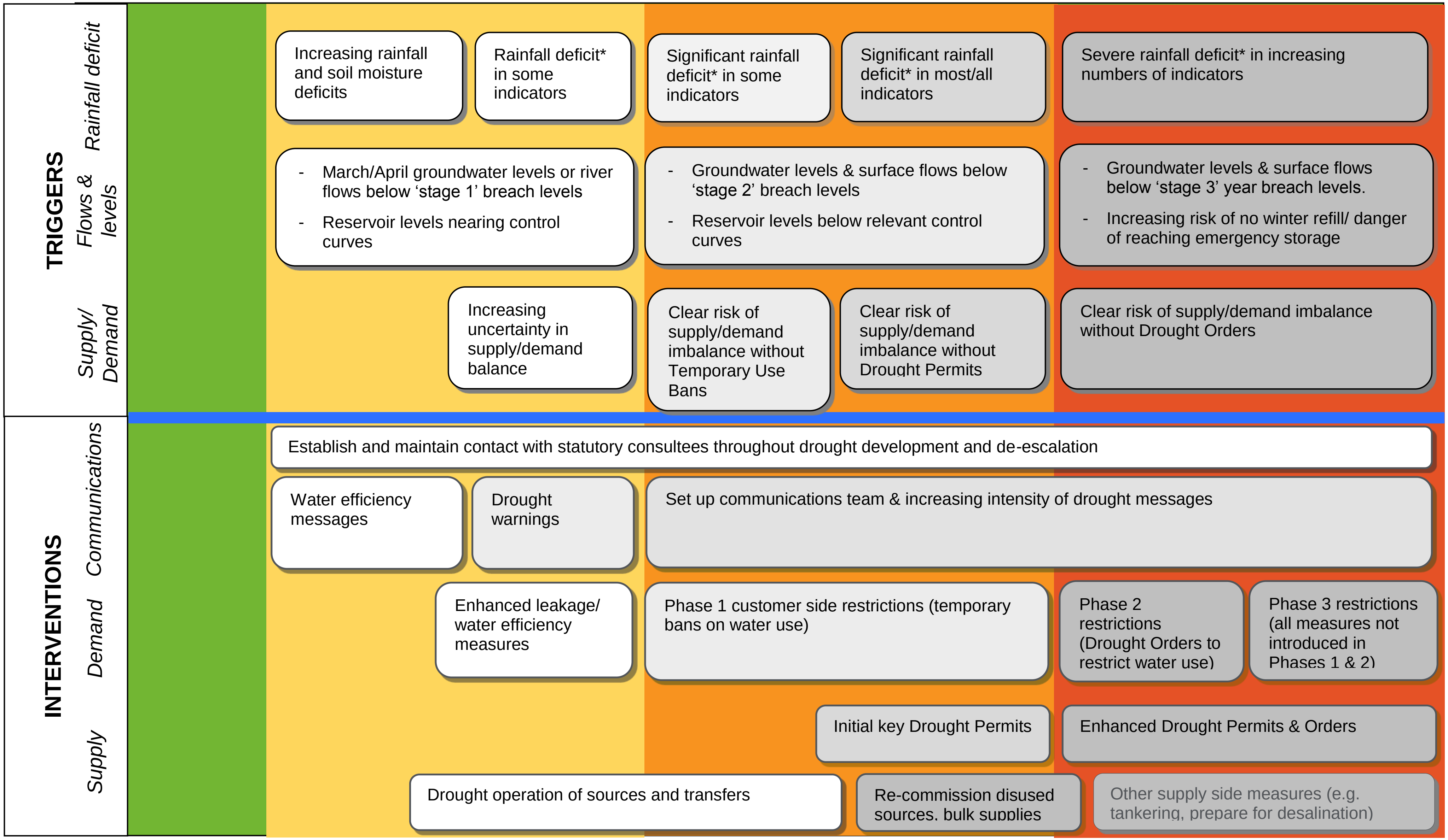


Figure 2 Generalised overview of relationships & phasing of triggers & drought intervention measures



Indicators used to monitor a drought

There are three sets of indicators used to define a water resources drought: rainfall, water levels and flows. Indicators are monitored across the region at distinct locations and typically these monitoring stations have long records of measurements.

Rainfall is monitored at a network of raingauges. Water levels are monitored at groundwater monitoring boreholes and at reservoirs. River flows are typically measured at specially designed gauging stations.

By using these different types of measurements we can then asses the prevailing conditions and water resources situation to decide whether a drought is developing by calculating the rainfall deficit and quantifying the impact on water resources.

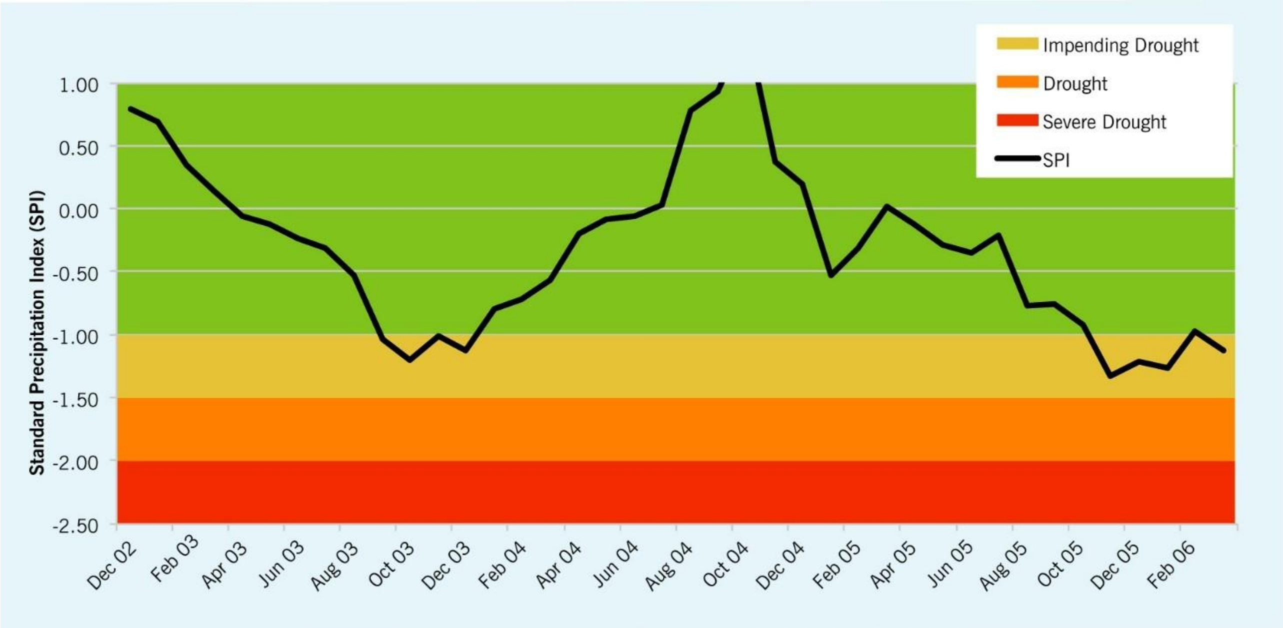
Rainfall deficit

In order for a Drought Permit to be approved the company must demonstrate that an Exceptional Shortage of Rain (ESoR) has led to or is threatening a serious deficiency of supplies of water. Hence it is important that we use specific rainfall gauges as part of our monitoring network and have a robust method of determining the degree of rainfall deficit.

Specific rain gauges with long term records which continue to be monitored by the Environment Agency (EA) have been identified within each drought management area. The data is analysed to provide two categories of drought triggers:

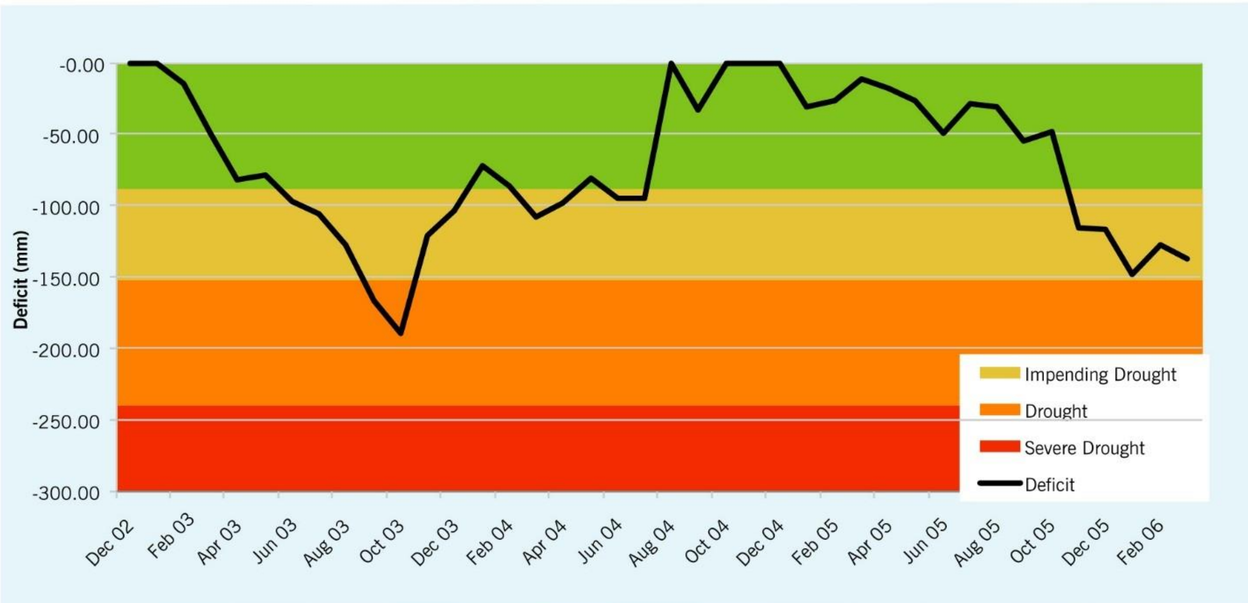
- Southern Water’s standard drought dashboard report contains comparisons against long term average values. These are used during normal conditions and in the lead-in to a drought to monitor general conditions within each area.
- As a drought progresses, analyses of Standard Precipitation Indices (SPI) and cumulative rainfall deficits, expressed as a Drought Severity Index (DSI), are used within each area to provide a more comprehensive coverage against indicators that have been specifically derived to reflect the water resource vulnerability of each area. Examples of these are provided below in Figure 3 and 4 respectively. Both of these parameters are based on internationally accepted approaches to measuring drought severity.

Figure 3 Example of Standard Precipitation Index (SPI) trigger curve



The SPI provides a comparison of rainfall deviation from average values of rainfall at a given site, normalised according to the natural variability (expressed as a standard deviation). It uses cumulative rainfall over a defined preceding period (between 3 and 30 months) to provide indicators of both drought intensity and drought duration. Generally category 1 triggers relate to 'normal' drought conditions, while category 2 triggers relate to severe drought conditions.

Figure 4 Example of Drought Severity Index (DSI) trigger curve



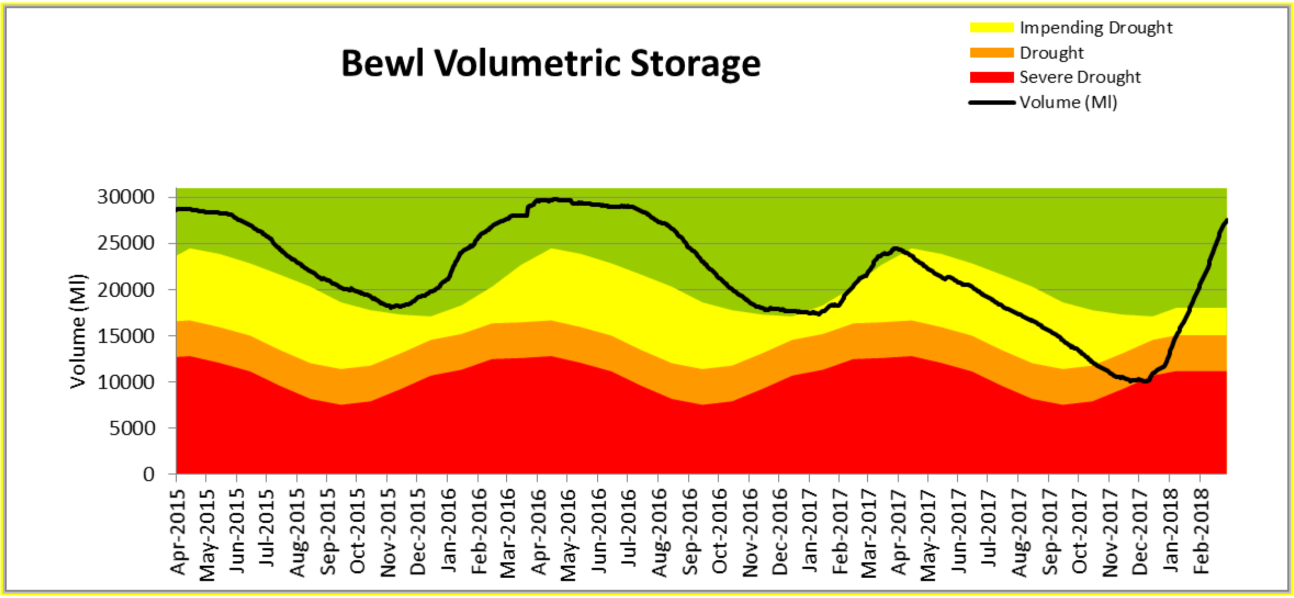
The DSI provides a quantification of the total rainfall deficit that has accumulated for a given drought, and uses different indicators of the start and finish of a drought period to show how this deficit might have affected different types of resources.

Flows and water levels

Each drought management area contains a number of indicators of flows and water levels that are used to understand the approximate state of water resources based on specific monitoring points.

For reservoirs, these use the same control curves that inform the deployable output analyses carried out for the Water Resource Management Plan. These curves allow the company to calculate the available storage and most appropriate abstraction regime. An example of a reservoir control curve is given in Figure 5a below.

Figure 5a Example of a Reservoir Control Curve

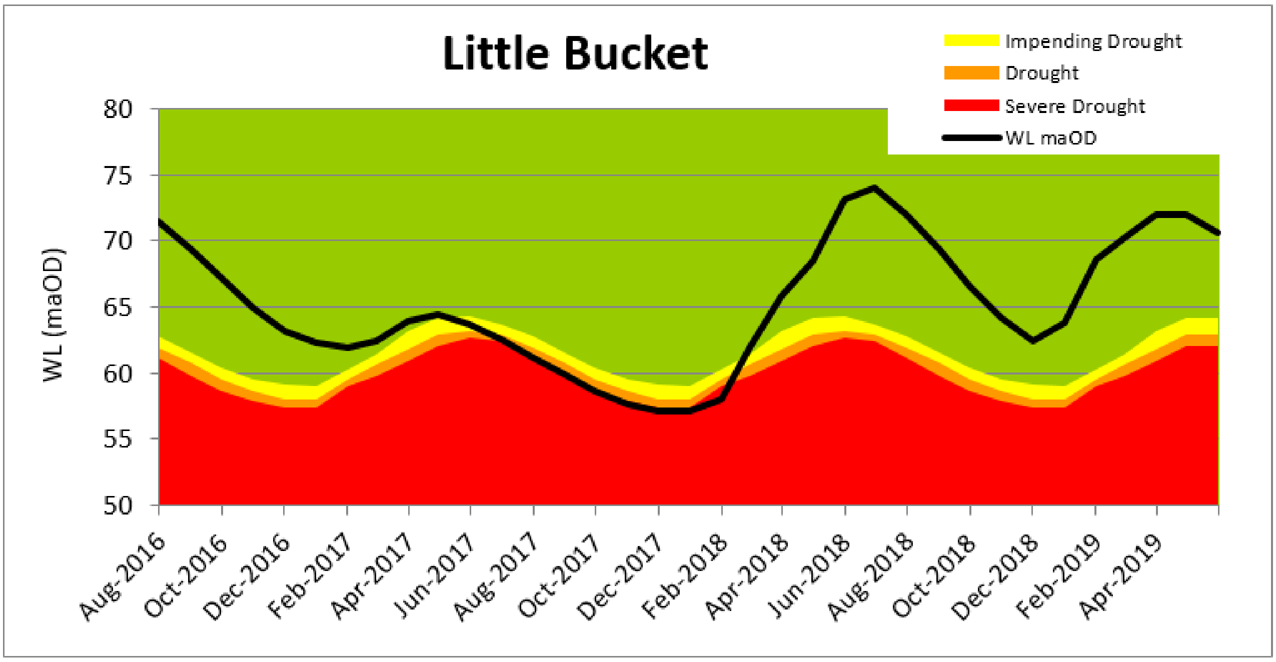


During a drought, the company monitors current reservoir levels and abstraction rates. These are used to understand if reservoir levels have, or are predicted to, fall below the control curves for that reservoir for a given month. In a water resources zone (WRZ) with sources which can be operated conjunctively, it may be possible to take more water from groundwater in order to reduce abstraction from reservoirs to conserve storage. During a drought these scenarios are examined using a series of computer models that simulate the resources available, the supply network and the demands for water that we would anticipate (for a further description see the text below).

For river abstractions and groundwater abstractions, trigger curves have been developed based on percentiles of minimum monthly river flow and groundwater level records.. These curves have been derived so that they are breached with an average frequency equal to the return period used for the trigger value. Generally (Trigger level 1) has been defined to be exceeded at a frequency of 1 in 10 years and Trigger level 2 exceeded at a frequency of 1 in 20 years. These intervals are consistent with our drought and severe drought thresholds and our target levels of service for TUBs and Drought Permits and Orders. For example, if a groundwater record spans 100 years, then the one in 20 year 'trigger curve' is equivalent to a monthly profile that would have been breached (at one or more points) in five years of the groundwater level time series record for that observation borehole. Trigger curves for each area are provided in Appendix A. Examples of a groundwater trigger curves are provided in Figure 5b (which contains both category 1 and category 2 curves, along with historic minimum groundwater levels).

In our Western Area our surface water flow triggers have been designed to be directly linked to drought interventions under the S20 agreement.

Figure 5b Example of groundwater trigger curves



Drought Dashboard

Southern Water maintains a ‘Drought Dashboard’ which is updated on a monthly basis. This dashboard collates the key drought indicator metrics for each of the Water Resource Zones. It tracks and reports how the metrics have varied over time in relation to the trigger curves and also reports the aggregated drought status for each Water Resource Zone.

The metrics which are tracked relate to the key water supply types in each Area / Water Resource Zone, and include:

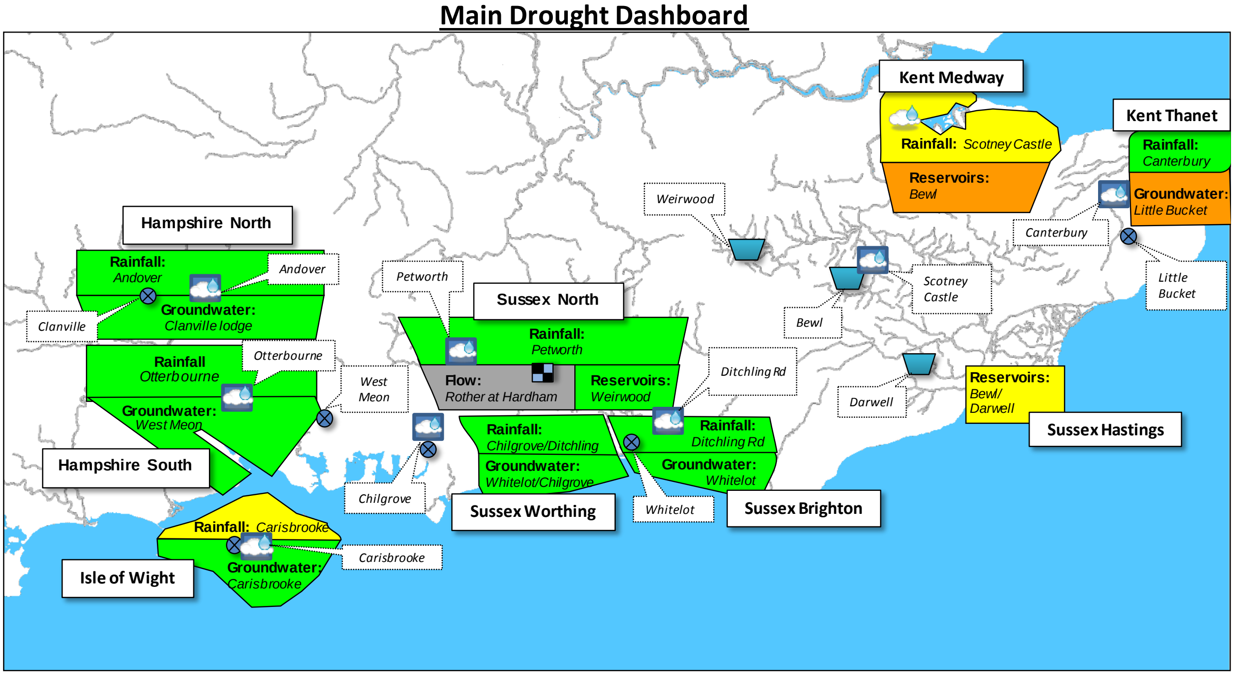
- Rainfall Standard Precipitation Index and Drought Severity Index metrics (short and long duration).
- Groundwater levels.
- Reservoir levels.
- River flows.

An aggregated measure of the drought status of each Water Resource Zone is shown as a colour coded map on the front page of the dashboard (see Figure 6). These aggregated measures are derived from the status of the relevant key metrics for each Water Resource Zone (see, for example Figures 3, 4, 5a and 5b).

It is planned to migrate the dashboard to a new web-based platform which will have improved functionality, graphics and visibility.

The indicator metrics displayed by the drought dashboard are used as one, key part of the overall decision making framework when the company is addressing a drought situation. As a drought progresses, further assessments are made to forecast potential future changes in supply and demand and forecast the degree of risk faced in relation to the supply-demand balance, as discussed below.

Figure 6 Example of Southern Water's drought dashboard aggregated map view



Key decisions related to drought interventions (for example, the imposition of demand restrictions on customers, or applications for Drought Permits or Drought Orders) are made on the basis of comprehensive assessments of future supply-demand risks as well as consideration of environmental impacts of the drought and consultation with key stakeholders.

Any decisions taken that would impact either on customers or the environment, such as restrictions or a drought permit, would be notified to customers and stakeholders through notices in the local papers, press notices on our web sites or announcements in the local media.

Forecasting

Once it is recognised that drought conditions exist and there is a risk that severe drought conditions could develop, forecasting of potential drought conditions are undertaken using the groundwater models (MODFLOW), hydrological models (Catchmod), water resource models (Aquator) and spreadsheet tools described below for the supply/demand balance assessment.

For the modelling assessments, recent historic rainfall and evaporation is initially input to the Catchmod river flow models and, where available, groundwater tools, to establish baseline conditions. Potential rainfall and evaporation scenarios are developed based on historic sequences, and these are input into the models to predict possible resource availability from the current drought situation. The outputs are used in the Aquator water resource models to decide the conjunctive use capability of the supply system if the drought progresses.

Forecasting of potential demand is based on current distribution input values, modified by current leakage levels. These are fed into historic dry year demand 'envelope' curves to produce an unmodified demand forecast. The impact of demand management measures, including Temporary Use Bans, Drought Orders to restrict water use and leakage reduction initiatives are then applied to the forecast as appropriate.

Supply/demand balance

As a drought progresses, we will use a variety of models to examine the current balance between available resources and the forecast demand. The results from this work allows the company to examine the risk that the drought might cause to the balance between supply and demand in the coming months. This will include using the following models:

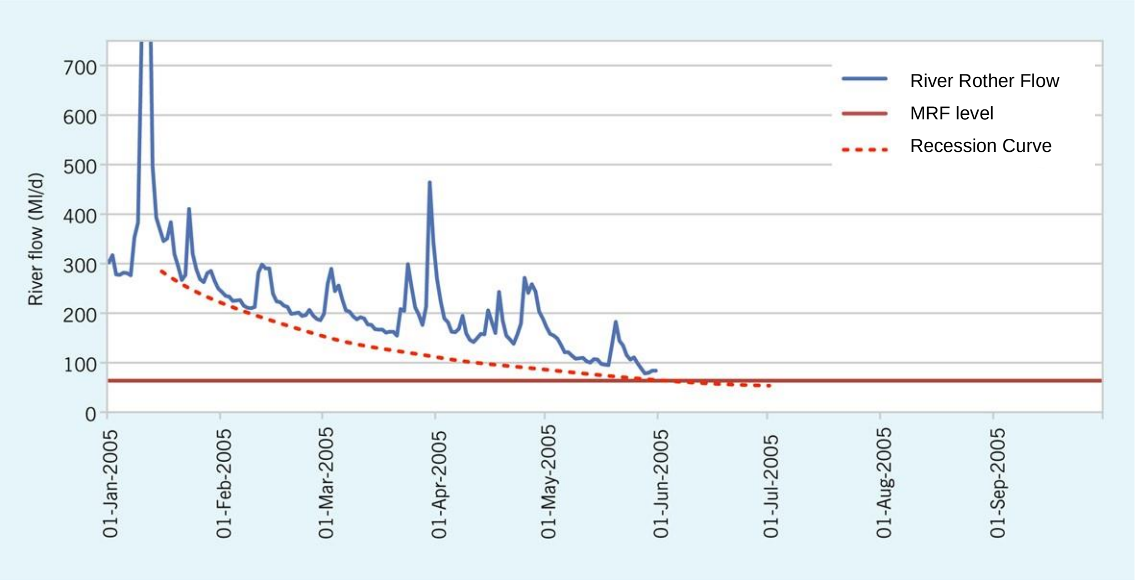
- Supply model for the strategic network (Aquator)
- Rainfall runoff models used to predict river flows (Catchmod)
- Groundwater recharge models (4R)
- Groundwater simulation models (Modflow)
- Bespoke spreadsheet models

Key outputs from this work will include:

- Anticipated potential resource availability over the forecast period for different rainfall scenarios.
- Potential demand 'envelopes' based on latest measured Distribution Input and calculated leakage.
- Current and anticipated operational issues and source outages which could affect the availability of water supplies.
- Security of Supply Index calculations.

There are two levels of approach that are used when carrying out the supply/demand balance analysis. These are described in Figure 10, which shows the 'simple' and 'modelling' approaches that are referred to in Figures 1 and 2. The 'simple' approach uses simple forecasting methods for surface water, such as the river recession curve shown in Figure 7, and standard mass balance models for reservoirs to estimate resource availability. The 'modelling' approach uses a range of modelling tools that are available for forecasting future resource positions. These include Catchmod rainfall-runoff models and groundwater models, which feed into Aquator conjunctive use water resource models. These models can use recent and forecast rainfall and Distribution Input records to estimate future, area wide, conjunctive use resource availability. These are then used to produce risk based forecasts of supply and demand.

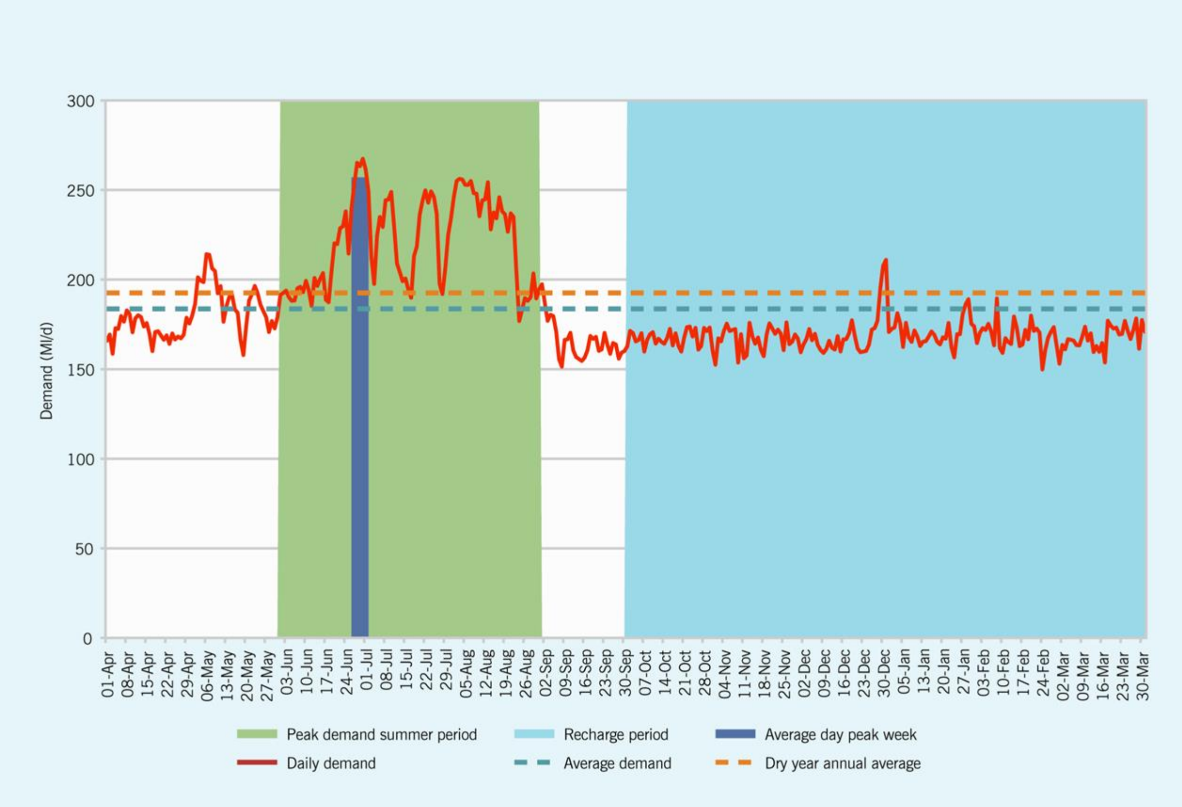
Figure 7 Example of monitoring river flow recession on the Western Rother near Pulborough



It should be noted that two forms of demand data are used for the purpose of drought management, as illustrated in Figure 8:

- Average daily demand; and
- Average day peak week (ADPW) demand.

Figure 8 Example demand profile over a year illustrating demand concepts



The ADPW is used to represent critical peak summer demands and is the average daily demand in the seven continuous days when the highest demand occurs.

Summer demands are influenced by discretionary water use, especially garden watering, although agricultural use and tourism also influence the seasonal variations in demand. Typical daily profiles in household demand for water are shown in Figure 9. Summer demand therefore tends to be higher during hot dry weather than during periods of cool wet weather. High weather-related demand can occur at any time from May to August, although typically the highest demands occur in late July or early August.

The average daily demand is the average demand over an entire year and so takes into account high demands in summer and lower demands in winter. Annual average demand therefore also tends to be higher in years characterised by hot, dry summers.

Figure 9 Typical daily consumption profiles in winter (left) and summer (right) (after WRc 2005)

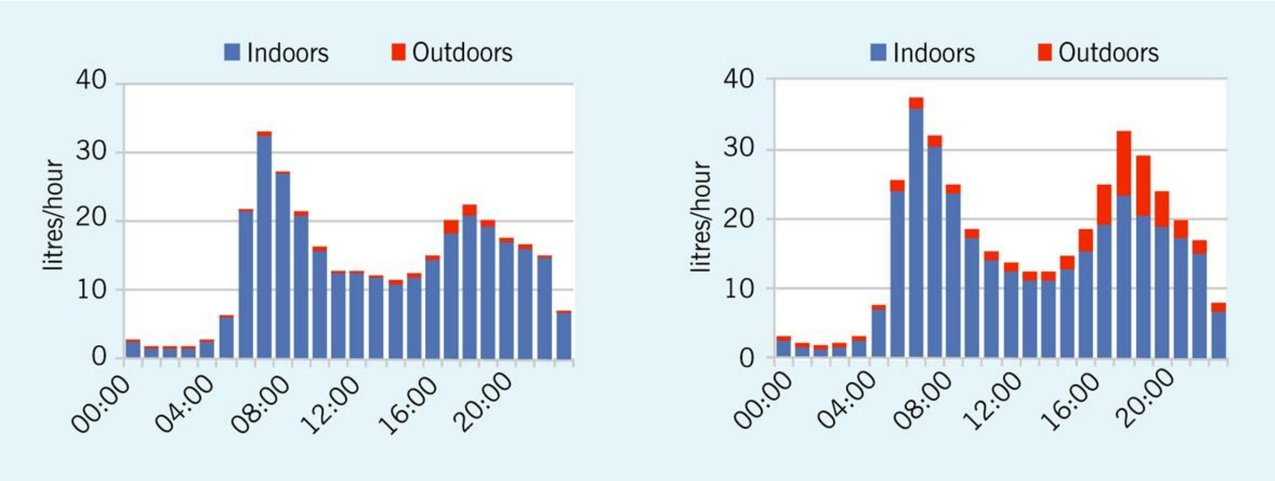
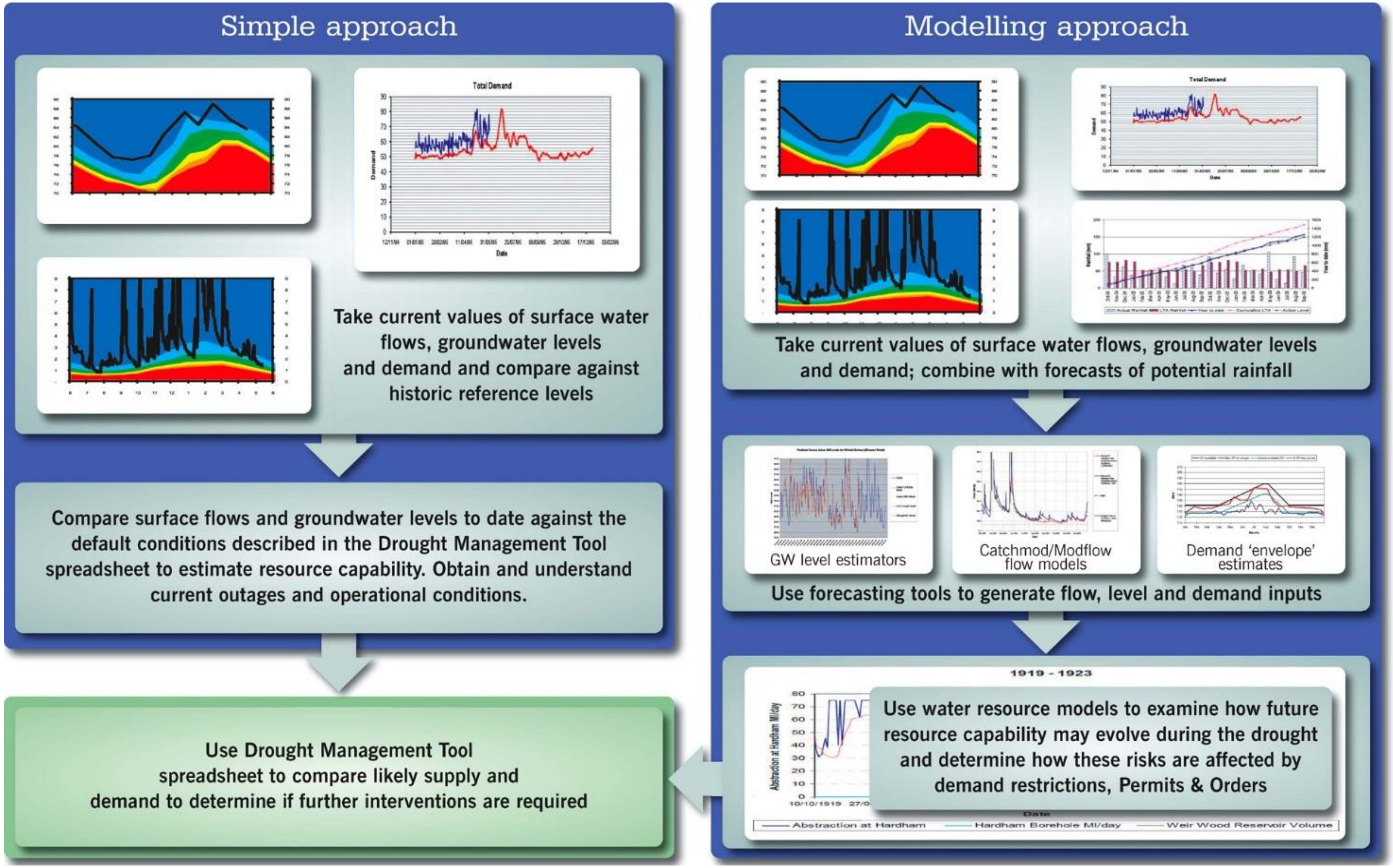


Figure 10 Approach to supply/demand balance analysis during drought conditions



Summary of drought monitoring

The majority of drought monitoring relates to the rainfall, water levels, river flows, demand and operational status information that is required to analyse and compare the current situation against the drought triggers described above. However, it should be noted that this is supported by other types of monitoring that is carried out to support the intervention measures associated with those drought triggers. This includes:

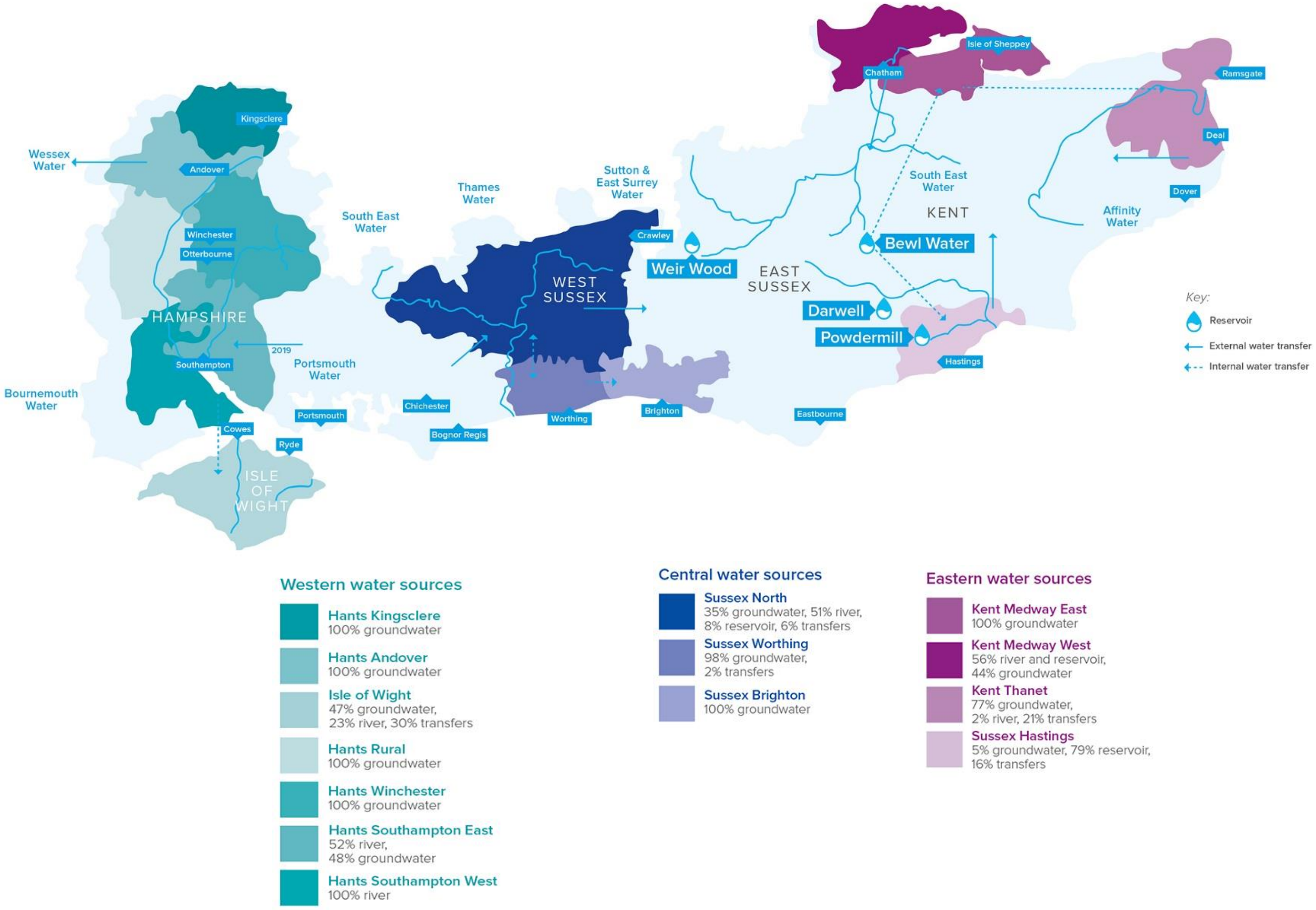
- Environmental monitoring to support potential Drought Permits and Orders. Many of these Drought Permits and Orders will require more drought baseline information to support the update of the environmental assessment that is required as part of the application. Additional information on water quality, ecology or fisheries will therefore be needed in advance of an application. Monitoring is required during implementation of the Drought Permits and Orders, as well as post-drought to assess the impacts of implementation. Further information on this is provided in *Annex 5: Environmental Monitoring Plan.*
- Enhanced operational monitoring to support ongoing tactical supply management decisions (for example to forecast water quality or outage risks that might materialise, or to prioritise borehole pumping regimes).
- Customer and regulatory feedback on the impacts of the drought management activities.

Area specific drought management triggers and activities

Management of drought within the Southern Water region is carried out in relation to three supply areas:

- The Eastern area, which incorporates the Kent Medway East, Kent Medway West, Kent Thanet and Sussex Hastings Water Resource Zones (WRZs).
- The Central area, which incorporates the Sussex North, Sussex Brighton and Sussex Worthing WRZs.
- The Western area, which incorporates the Hampshire Kingsclere, Hampshire Andover, Hampshire Rural, Hampshire Winchester, Hampshire Southampton East, Hampshire Southampton West and Isle of Wight WRZs.

Figure 11 Map of Southern Water's supply area



Although these areas contain a number of separate WRZs, they are managed as semi-integrated blocks because there is significant water transfer capability between the WRZs. This means that an area-wide perspective is required when drought management measures are being considered.

A summary of the monitoring, tools and analyses, triggers and supply-side intervention measures for each area is provided below. It should be noted that demand-side measures are not detailed as these apply equally to each area and follow the phasing indicated in Figure 2.

The following annexes provide more detailed information on the drought management actions that the company will undertake at each trigger level:

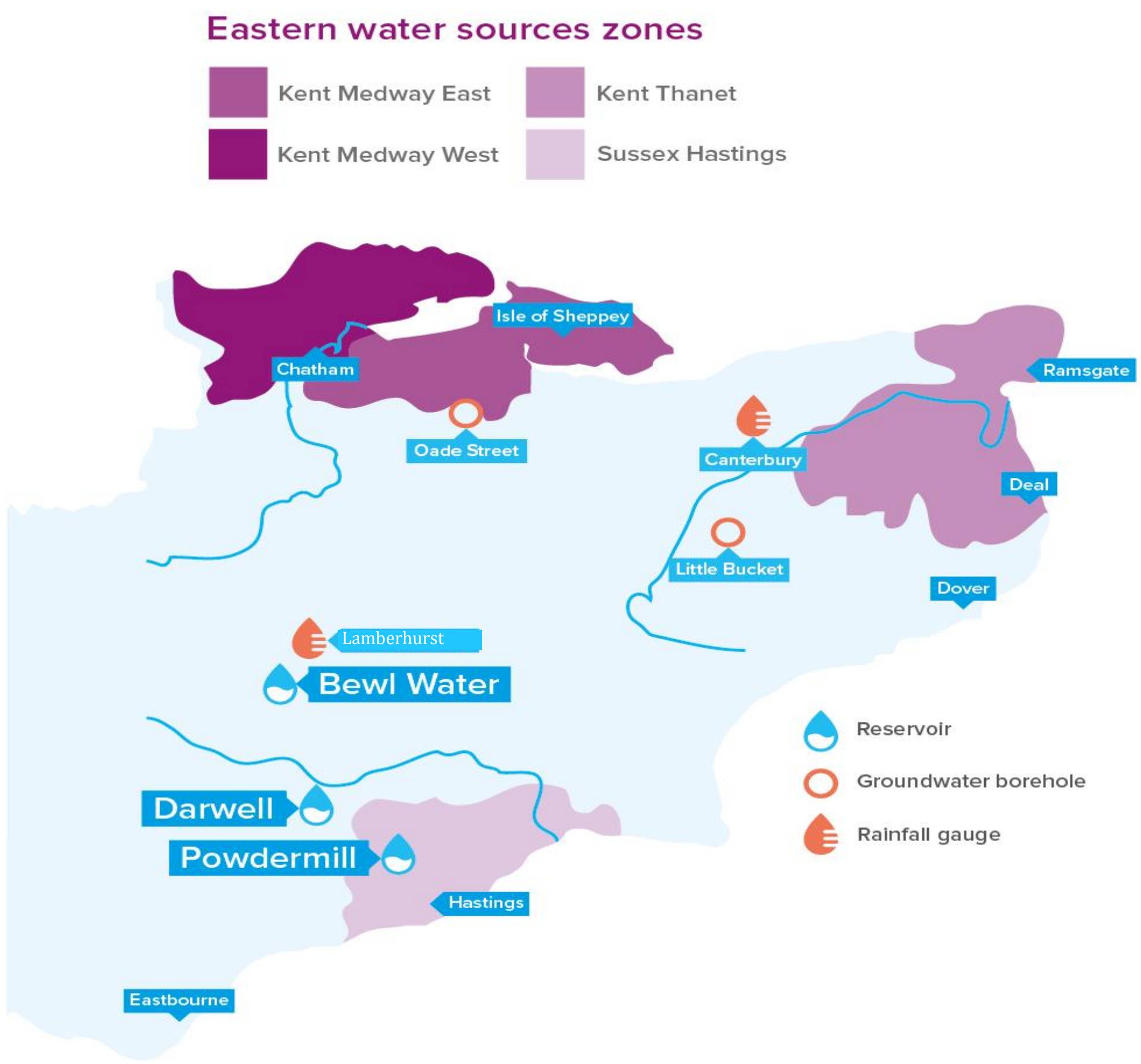
- Annex 3 Demand Side Interventions
- Annex 4 Supply Side Interventions
- Annex 6 Management and communications strategy
- Annex 7 Post drought actions

The following sections provide an overview of the monitoring points and trigger levels used in our three supply areas.

Eastern area

Details of the information, timing and activities involved in drought management for the Eastern area are provided in Figures 15 and 16. A map of the Eastern area is presented below.

Figure 12 Map of Eastern area showing drought monitoring stations



This is the only area with a significant reliance on reservoir storage, so triggers and interventions based on reservoir levels are important. Control curves for the Bewl-Darwell system and Powdermill reservoir are provided in Appendix A and relevant Catchmod forecasting models are available for all of the relevant river reaches that contribute to supply availability for these reservoirs.

Groundwater

The Kent Medway East, Kent Medway West and Kent Thanet groundwater sources provide a large proportion of the resource for this area, and this is monitored through the Little Bucket Farm and Oad Street (naturalised to account for nearby abstraction) observation boreholes. Return period 'breach' curves for these boreholes are provided in Appendix A of this document. Source capability assessments for groundwater are based on the drought return period as identified by the two observation boreholes, and the estimates of deployable output that relate to the relevant return period severity.

Rainfall

For rainfall indicators, the key gauges at Lamberhurst and Canterbury have been chosen to be representative of the River Medway/Eastern Rother surface water systems and the Kent Medway/Thanet boreholes respectively. Rain gauges in the Sussex Hastings WRZ were considered, but this WRZ represents a very small proportion of the Eastern area resource availability (mainly just Powdermill reservoir) and are not therefore considered to be representative drought monitors.

In our draft Drought Plan and previous drought plans we used the rain gauge at Scotney Castle as representative of the River Medway / Eastern Rother surface water systems. Although it is still intermittently monitored, Scotney Castle rain gauge has been deregistered by the Met Office owing to deterioration of the equipment and oversheltering by vegetation. Following a review of available alternative rain gauges, including those used to support our 2018 Drought Permit application for Bewl Reservoir we have replaced the Scotney Castle rain gauge with the Lamberhurst rain gauge, which is located about 1km west of Scotney Castle.

Comparisons of long term rainfall records at both gauges suggest similar overall patterns and totals to Scotney Castle and consequently we have now adopted the previous Scotney Castle trigger curves for use at Lamberhurst.

Rainfall indices and associated trigger values are provided in Appendix A of this document. The relatively long storage times involved in the Bewl-Darwell reservoir system and the Kent Medway East, Kent Medway West and Kent Thanet borehole sources means that the SPI and DSI indicators that have been chosen are a combination of moderately long and very long term rainfall deficits.

Four indicators have been selected to reflect rainfall deficits, these are:

- 12 and 30 month rolling deficit standard precipitation indices (SPI); and
- Cumulative rainfall deficit (DSI) with a 12 month termination rule.

We may consider the use of alternative duration SPI metrics as necessary to support our ESoR case for any Drought Permit and Order applications. This follows our lessons learned review following the Mock River Test Drought Permit in Autumn 2018.

Rain gauges that are required to support the Catchmod forecasting tools described above are detailed in Table 3.

Table 3 Additional rain gauges used for incorporation into supply forecasting tools

Eastern area	Central area	Western area
Burwash Common Crowhurst Bridge Farthing Common Goudhurst Ps Great Tong Lower Standen Ps Mersham Newhouse Pembury Penshurst Place Reed Court South Park Farm Southwood Upper Stonehurst Weir Wood West Stourmouth	Applesham Barlavington Cowdray Park Didling East Grinstead Pulborough Hindhead Horsham Wimb. Housedean Farm Jarvis Brook Lower Beeding 4 Ockley 2 Peacehaven 2 Ramsdean Roundhurst Saints Hill Ps Selbourne Upper Stonehurst Wakehurst Place Weir Wood	Afton Blackwater AlverstoneGS Rookley Godshill Knighton Niton Ryde Sandown Shide Ventnor Park Wroxall Boscombe Down Basingstoke

**N.B. excludes the key drought monitoring gauges and all of the gauges used in the Test and Itchen Groundwater Model*

Central area

Details of the information, timing and activities involved in drought management for the Central area are provided in Figures 17 and 18. A map of the Central area is presented below.

Figure 13 Map of Central area showing drought monitoring stations

Groundwater

There is a mix of water resources within the Central area. The largest groups are the Sussex Brighton and Sussex Worthing groundwater sources, which are monitored through the Whitelot Bottom (Sussex Brighton) and Chilgrove (Sussex Worthing) observation boreholes.

Chilgrove sits outside the Worthing WRZ but serves as an indicator of the groundwater levels within the chalk block. Groundwater levels at Whitelot Bottom are affected by abstraction from nearby water supply works, so groundwater levels are ‘normalised’ based on the rules that are contained within the Whitelot Bottom assessment tool.

This tool has been developed using a lagged regression analysis to allow groundwater levels in the western side of the Sussex Brighton WRZ to be estimated based on the previous 24 months rainfall and 6 months abstraction time series and can be used to forecast potential resources in the Brighton chalk block aquifer during drought periods.

The return period ‘breach’ curves used to monitor groundwater conditions at Chilgrove and Whitelot Bottom (abstraction normalised levels) are provided in Appendix A of this document.

Pulborough groundwater and surface flows

The next most important resource in the Central area is the combined run-of river and groundwater abstraction located at Pulborough. This resource is used in both the Sussex North WRZ, and the Sussex Worthing WRZ (via a transfer main between the two zones).

Drought conditions are monitored based on the semi-naturalised flow over the weir (i.e. flow net of the surface abstraction near Pulborough), and groundwater levels in abstraction borehole (ABH) 10. Flows over Pulborough weir form a key drought trigger for the Central area, and the relevant return period 'breach' curves are provided in Appendix A of this document.

Since Pulborough is a conjunctive use source, the risk to the resource comes from a combination of the magnitude and duration of surface water availability, as longer periods of low river levels means there is a greater reliance on the groundwater storage. The curves provided in Appendix A of this document are therefore based on cumulative deviation from the long term mean, rather than absolute river flows. Catchmod models of both the Western Rother and River Arun are available for resource forecasting at this site.

The dominant influence of abstraction on groundwater levels within the Pulborough groundwater basin source means that ABH 10 is used for reference, rather than as a drought trigger.

Weir Wood reservoir

Weir Wood reservoir is a relatively minor resource because of its small surface water catchment area, but it is monitored as part of the overall drought situation assessment. Control curves for the reservoir are provided in Appendix A of this document and a Catchmod based forecasting model of reservoir inflow is available for the reservoir.

Rainfall monitoring

For rainfall indicators, the key rain gauges at Petworth Park, Chilgrove and Ditchling Road have been chosen to be representative of Sussex North, Sussex Worthing and Sussex Brighton WRZs respectively. Two gauges are necessary for the coastal strip represented by the Sussex Worthing & Sussex Brighton WRZs because Chilgrove is located to the west of these WRZs and Ditchling Road has a relatively short record.

Petworth Park rain gauge is a non-telemetered storage rain gauge and consequently up to date data are not always avaliable. When data from Petworth are unavailable we infill the missing rainfall series using a regression relationship developed with the nearby telemetered Hardham rain gauge, also located in the River Rother catchment.

Rainfall indices for Weir Wood reservoir are not considered to be an appropriate part of the drought severity assessment because of the relatively minor contribution of the reservoir resource to the area. Rainfall indices and associated trigger values are provided in A of this document. The analysis carried out for the Whitelot Bottom assessment tool indicated that the Sussex Brighton and Sussex Worthing resources are vulnerable to relatively short droughts of between 12 and 24 months. The nature of the Western Rother and relatively small storage near Pulborough groundwater basin means that the location is also vulnerable to short (as little as 12 month), intense drought. The four indicators that have been selected to represent rainfall deficits are therefore:

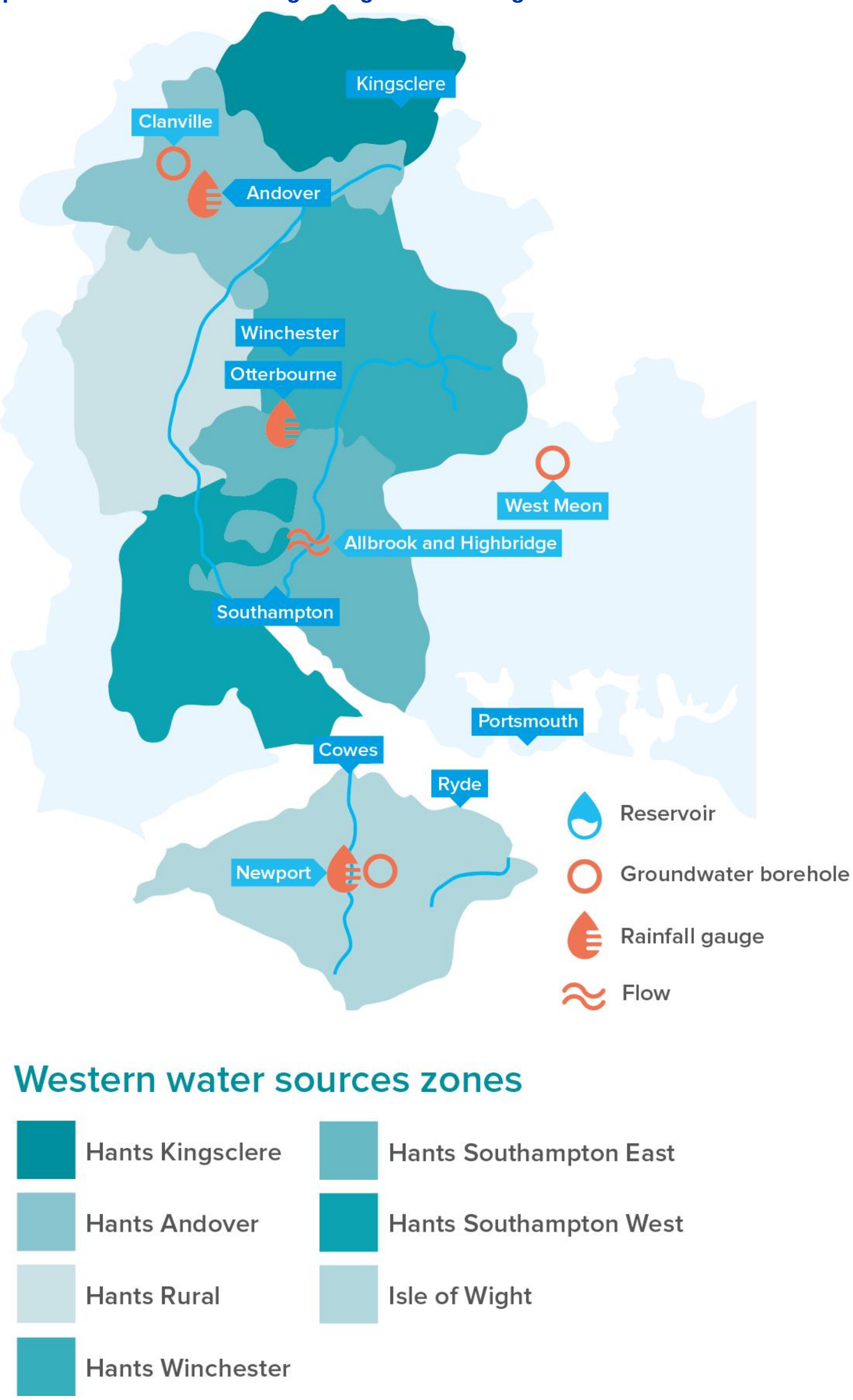
- 12 and 24 month rolling deficit standard precipitation indices (SPI).
- Cumulative rainfall deficit (DSI) with a 12 month termination rule.

Rain gauges that are required to support the Catchmod forecasting tools are detailed in Table 3.

Western area

Details of the information, timing and activities involved in drought management for the Western area are provided in Figure 19 and Figure 20. A map of the Western area is presented below.

Figure 14 Map of Western area showing drought monitoring stations



Resources in the Western area are dominated by the surface and groundwater abstractions on the Rivers Test and Itchen. Unlike the Central and Eastern areas, there is no reservoir storage. Although historically the Hampshire part of the area has been resilient to drought, recent changes to the licence conditions on the Rivers Test and Itchen mean that the region may experience water shortages more frequently.

Groundwater monitoring

Groundwater conditions within the more northern parts of the Hampshire Chalk aquifer are monitored using the Clanville Lodge Gate borehole, and Chalk groundwater conditions on the Isle of Wight are monitored using an observation borehole near Newport (naturalised for abstraction from the nearby groundwater source).

River flows

In the past, resource availability in the Itchen has been monitored through flow records at the Allbrook and Highbridge flow gauge, just downstream of the River Itchen surface water intake. Flow is calculated net of the abstraction from the River Itchen surface water source.

This Drought Plan will also monitor the resource availability in the Test at the Test Total Flow (TTF), which is the aggregate of the total freshwater outflow at the tidal limit to Southampton Estuary. TTF is the location of the new Hands off Flow (HoF) specified in the S20 agreement. At the moment there is no continuous flow gauging there for monitoring purposes so the TTF is estimated using the summation of Ower – River Blackwater, Testwood, Conagar Bridge, and Test Back Carrier gauging stations, and include an allowance for flow along Broadlands Fish Farm carrier. When conditions are such that a drought appears to be likely, the Environment Agency will undertake weekly or more frequent manual flow gauging at Testwood Bridge gauging station to enable flows at TTF to be more accurately calculated (through the summation of Testwood Bridge, Conagar Bridge and Test Back Carrier) as the drought progresses. This will provide a more robust assessment of evolving low-flow conditions and therefore what drought interventions should be put in place. It is noted that through the S20 agreement, the Environment Agency has made a commitment to make provision for continuous monitoring at Testwood Bridge as soon as reasonably practicable.

Drought trigger curves based upon the river flow at Allbrook & Highbridge and TTF are provided in Appendix A, showing at what point demand restrictions would be needed.

As drought conditions develop within the Western area, Catchmod models of the rivers Eastern Yar (at Burnt House) and Medina (at both Shide and Blackwater) are available to forecast supply availability for key resources such as the Medina-Yar Augmentation Transfer and Sandown on the Isle of Wight. The output capacity of the Sandown surface water source and a number of groundwater sources is constrained by licence conditions that relate to river flows, so the Catchmod models form an important part of drought forecasting.

Rainfall

For rainfall indicators, the key gauges at Lower Itchen, Andover and Carisbrooke have been chosen to be representative of the Test and Itchen, northern Hampshire and Isle of Wight resource groups respectively. Rainfall indices and associated trigger values are provided in Appendix A of this document. We have recalculated the rainfall indices for Lower Itchen on the basis now that the Lower Itchen and Test surface water sustainability reductions have happened.

The response of resources to rainfall is markedly different for the high storage, persistent, chalk fed sources of the mainland and the low storage, constrained sources of the Isle of Wight. The Test and Itchen resources are more likely to be affected by a combination of both long term drought, which

reduces groundwater storage and baseflow, and shorter term dry conditions which reduce runoff events.
The Isle of Wight is much more vulnerable to short, sharp drought events such as 1921 and 1976. The indicators that have been selected to represent rainfall deficits are therefore:

- Hampshire: 12 and 30 month rolling deficit standard precipitation indices (SPI).
- Hampshire: total cumulative rainfall deficit indicators (DSI) with a 12 month termination rule.
- Isle of Wight: 6 and 12 month rolling deficit standard precipitation indices (SPI)/
- Isle of Wight: total cumulative rainfall deficit indicators (DSI) with a 12 month termination rule.

As well as the usual supply/demand balance analysis, drought conditions on the Isle of Wight also need to be considered in relation to the need for supplies from the cross-Solent main. Unlike other infrastructure this cannot be repaired quickly if it is damaged, so this risk vulnerability is taken into account when drought measures are being considered for the Isle of Wight and it is clear that indigenous resources will not be able to meet demand under drought conditions.

Forecasting resource availability

Under the S20 agreement we will need to forecast resource availability in the River Test and River Itchen more frequently, particularly during drought periods. Southern Water will use a number of methods to forecast resource availability.

The Test & Itchen Groundwater Model provides explicit, three-dimensional representation of groundwater and surface water processes. However, the model is complex and takes longer to run when compared to Catchmod, Aquator and the other drought management tools. The current version of the groundwater model only produces two output time steps per month and so is unable to fully resolve some rapid runoff events. However, despite these shortcomings we continue to routinly used model outputs for drought forecasting. The Test and Itchen Groundwater model is currently being updated and upgraded and we will review the suitability of the revised model for forecasting purposes when it becomes available.

We are currently undertaking a review and comparison of the Environment Agency Catchmod model for the River Test and may consider use of this model alongside other forecasting tools.

Simple recession analysis of the flows at Allbrook and Highbridge and TTF can also be a useful tool of worsening drought conditions.

Additional rain gauges that are required to support the Catchmod forecasting tools are detailed in Table 3.

Sequencing of drought options for the River Test and River Itchen

The Test, Candover and Itchen Interim Abstraction Scheme (as defined in the S20 agreement) sets out the agreed sequencing of our drought options on the Rivers Test and Itchen. The section 20 agreement is summarised in Section 3.3 of our Drought Plan Technical Summary Report. Our drought actions under the S20 agreement are summarised in Table 4. In addition to being linked to our proposed flow and time triggers a guiding principal of Annex 1 of the S20 agreement is that we should take account of ecological considerations in deciding the order of application for drought permits and orders.

In relation to the drought options listed at item 6 in Table 4, aquatic environmental monitoring of prevailing drought conditions in the River Test and River Itchen will be used to help inform the actual sequencing of Drought Order implementation in any future drought event, as well as taking account of Southern Water’s supply duties.

Our drought monitoring is multi factorial and these flow triggers are used in conjunction with other data (for example rainfall and groundwater levels), and there is no single indicator that is used to classify drought status. The specific actions taken by the company may vary, depending on the risks and uncertainties including hydrological and ecological conditions, time of year, customer response to restrictions and long-term weather forecasts.

We will apply for the River Test Drought Permit at least 35 days before we predict that the TTF will fall below 355 Ml/d. Given our multi-factorial approach, if anything suggests an alternative timeframe for the Drought Permit determination may be needed, this will promptly be discussed and agreed with the Environment Agency during the pre-application period.

In Table 4 and Figures J and K we have set out how each of the agreed actions under the S20 agreement aligns with our proposed drought triggers for flows in the River Test and River Itchen. These actions relate to both supply and demand interventions. We would implement Level 3 water use restrictions (non-essential use bans) via a phased approach. As these restrictions primarily relate to commercial non household activity the phasing (see Table 6 of Annex 3) is designed to reduce impacts on small businesses.

For further information on the demand savings and supply options see Annexes 3 and 4 respectively.

Table 4 Summary of the Test, Candover and Itchen Interim Abstraction Scheme (as defined in the S20 Agreement) sequence of drought actions

<table>
<tr><th>Ref</th><th>Activity</th><th colspan="4">Comment</th></tr>
<tr><td>1</td><td>Utilisation of SWS water sources and bulk supplies</td><td colspan="4">Prior to any application for a drought permit or order, SWS will utilise its own existing water sources available to supply the Hampshire and Isle of Wight Water Resource Zones within the terms of their respective licences. This will include water available under the Portsmouth Water bulk supply scheme. We anticipate that these actions would be undertaken during normal conditions and into Stage 1 of a drought as our Level 1 (impending drought) triggers are reached or forecast to be approached from our routine drought monitoring or forecasting.</td></tr>
<tr><td>2</td><td>Level 1 water use restrictions</td><td colspan="4">Escalate demand-side water efficiency measures including media campaigns. This escalation is likely to occur if our Level 1 (Impending drought) flow triggers or 90 day triggers are reached and our forecast suggests continued recession of flows to other trigger levels.</td></tr>
<tr><td>3</td><td>Level 2 water use restrictions</td><td colspan="4">Implement partial temporary use bans (TUBs) pursuant to section 76 IA 1991 unless it is agreed with the Environment Agency that it is unnecessary because savings will be minimal. In accordance with the S20 agreement we would implement Level 2 restrictions at Trigger Level 2 on the River Test just before the Hands of flow of 355Ml/d is reached and the Test surface water Drought Permit is used. Our drought Trigger Level 2 on the River Itchen (206Ml/d) has been set to ensure TUBS are in place before the Candover Augmentation Scheme Drought Order.</td></tr>
<tr><td>4</td><td>Test surface water Drought Permit</td><td colspan="4">Abstract from Test surface water below the Environment Agency's proposed Total Test Flow (TTF) Hands off flow (HoF) of 355 Ml/d down to 265 megalitres per day (Ml/d) pursuant to a drought permit. In accordance with the S20 agreement formal pre-application actions for the Test surface water Drought Permit a 60 day TTF trigger has been set at least 60 days before the HoF is expected to be reached to trigger the preparation of a Drought Permit application. We would then submit the Test surface water Drought Permit application when our 35 day trigger is reached in order to allow sufficient time, in accordance with the timeline in the S20 agreement, to allow the permit application to be determined prior to being required. The drought permit would be needed just after our Level 2 (Drought) River Test Flow Trigger is reached at the Hands off Flow volume of 355Ml/d.</td></tr>
<tr><td>5</td><td>Level 3 water use restrictions</td><td colspan="4">In the S20 agreement there is no formally defined flow trigger for application of Level 3 water use restrictions but if flows continue to recede below our Level 2 (drought) and towards our Level 3 (severe drought) River Test flow trigger we may apply for a drought order to authorise partial Non-Essential Use (NEU) restrictions (Level 3 phase 1 drought restrictions).</td></tr>
<tr><td rowspan="2">6</td><td colspan="2">Candover augmentation scheme</td><td>Test surface water drought order</td><td>Level 3 phase 2 drought restrictions</td><td>Lower Itchen drought order</td></tr>
<tr><td colspan="2">When flows fall below 205 Ml/d at Allbrook and Highbridge abstract up to 27 Ml/d (limited to 20 Ml/d in certain months). Discharge to the River Itchen downstream of the Candover stream but retaining an environmental flow to the Candover Stream Our Level 3 Itchen trigger is set at flows at which this might occur (205Ml/d)</td><td>When TTF falls below 265 Ml/d abstract down to a baseline of 200 Ml/d pursuant to a drought order.</td><td>When flows fall below 200 Ml/d at Allbrook and Highbridge implement full TUBS and NEUs (Level 3 phase 2 drought restrictions).</td><td>When flows fall below 198 Ml/d at Allbrook and Highbridge, as a measure of last resort, abstract below the 198 Ml/d HoF to a floor of 160 Ml/d. Coincident with this, Portsmouth Water will also need to abstract below the Riverside Park HoF of 194* Ml/d.</td></tr>
</table>

This table summarises the sequence of actions. **For full details of all the S20 agreement conditions, refer to the signed S20 agreement**

Figure 15 Relationships & phasing of drought monitoring & analysis tools for the Eastern area

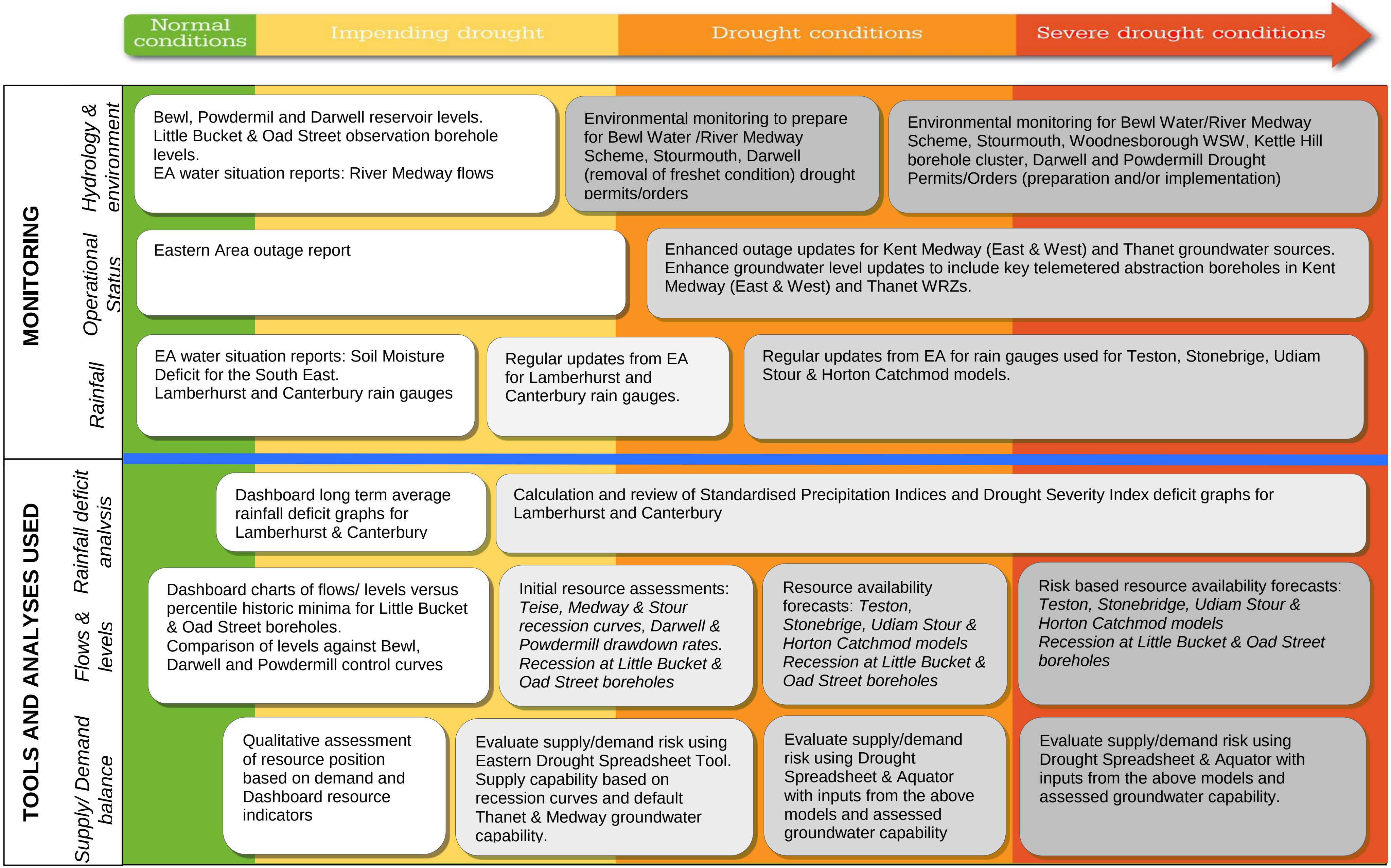


Figure 16 Relationships & phasing of triggers & supply side intervention measures for the Eastern area

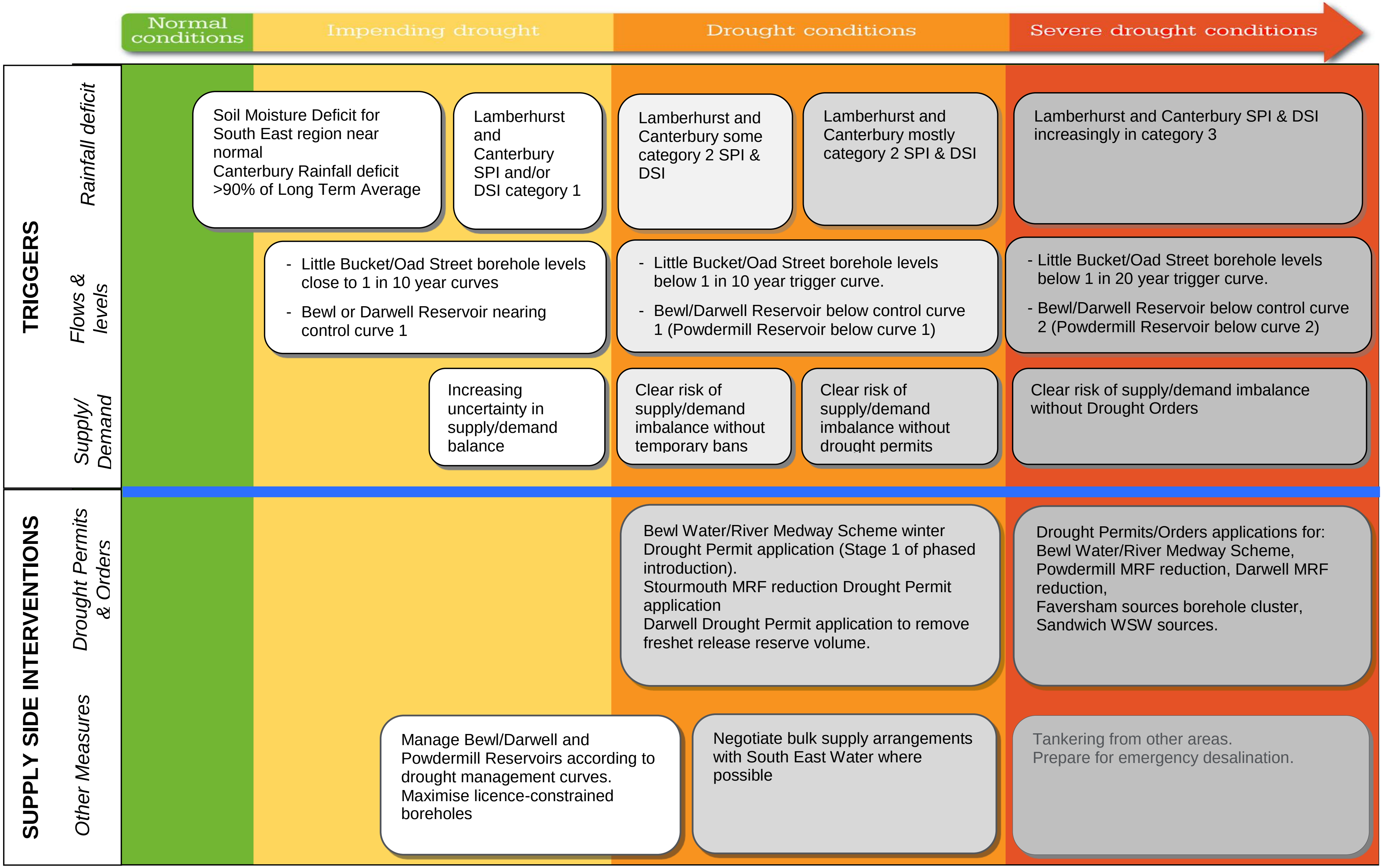


Figure 17 Relationships & phasing of drought monitoring & analysis tools for the Central area

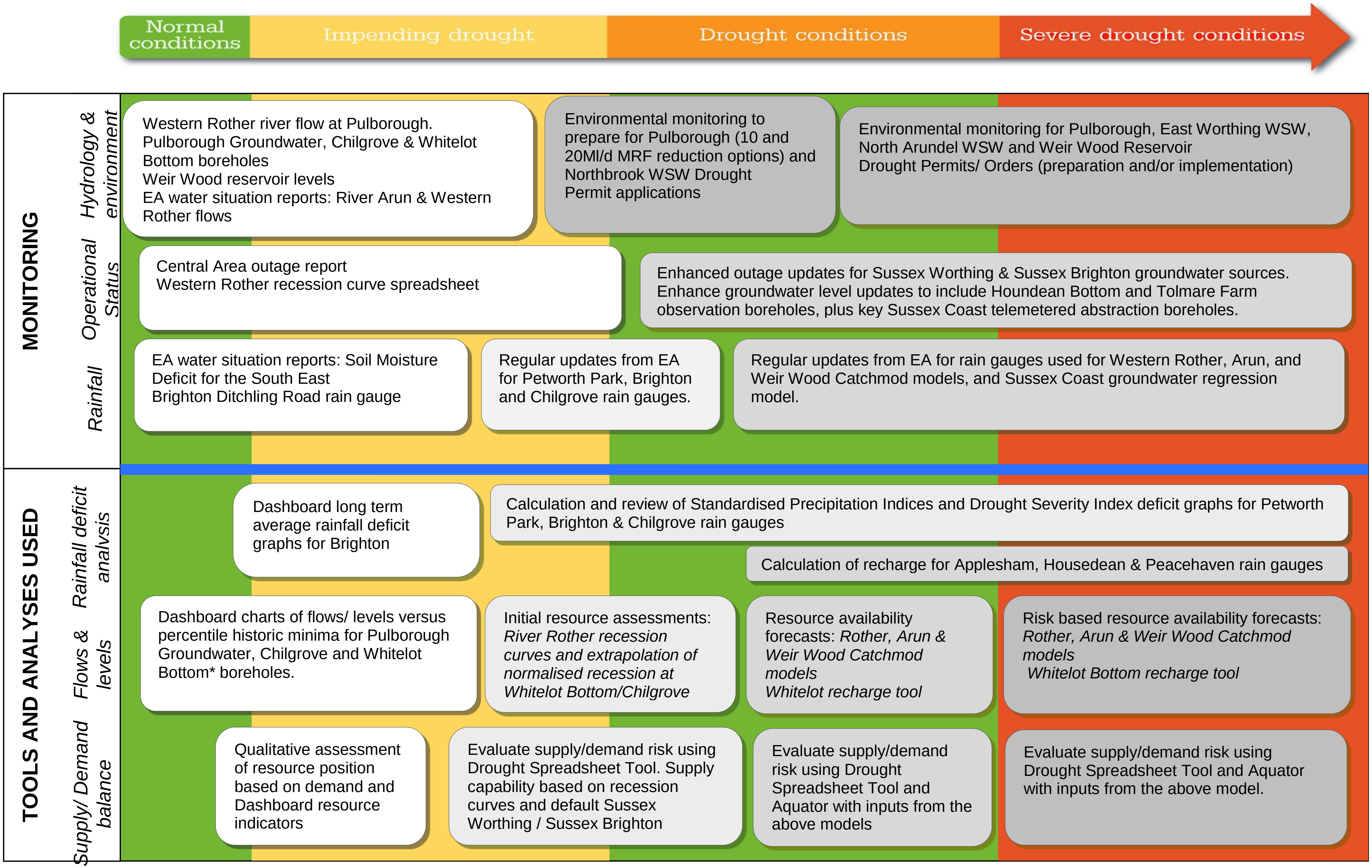


Figure 18 Relationships & phasing of triggers & supply side intervention measures for the Central area

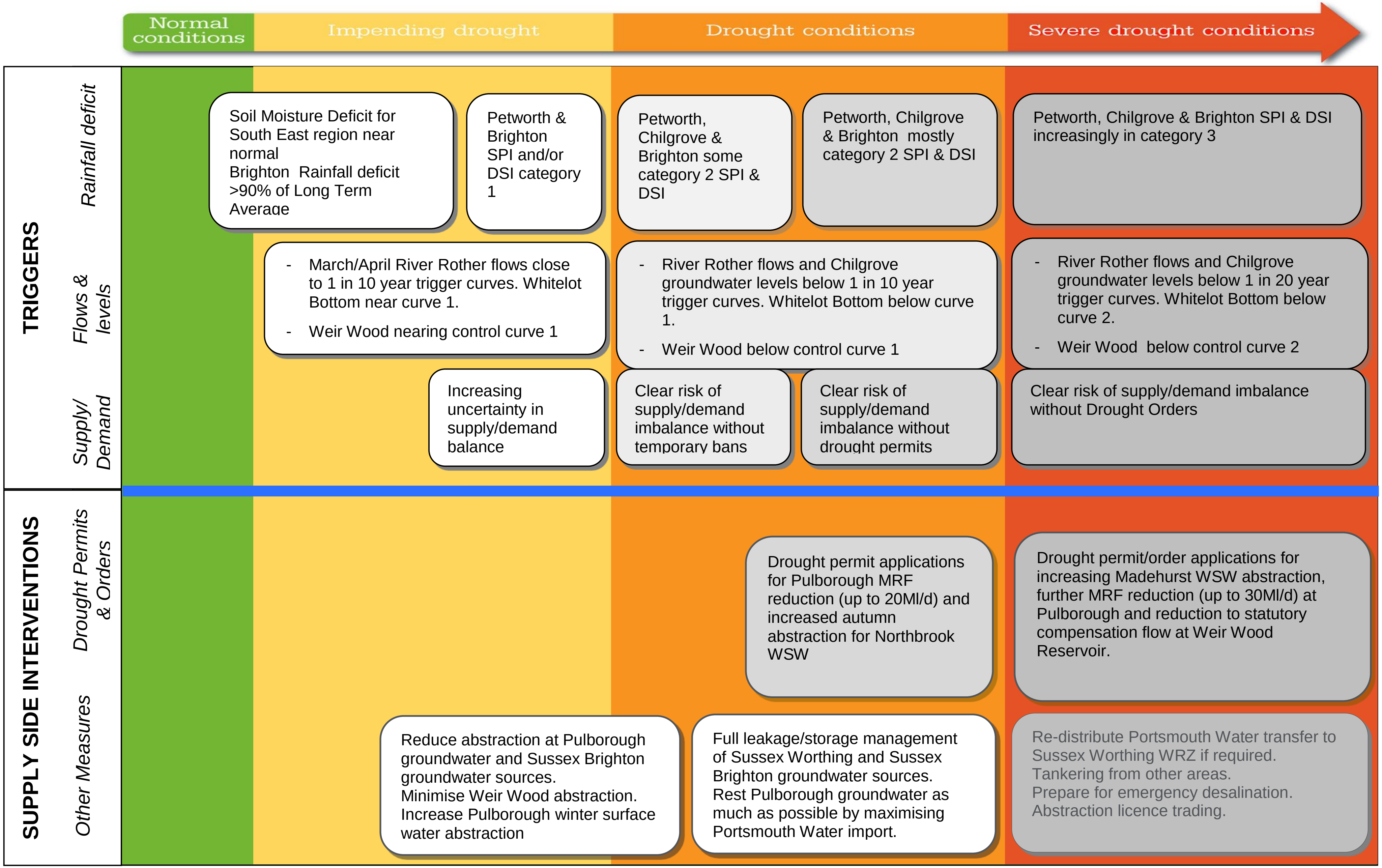


Figure 19 Relationships & phasing of drought monitoring & analysis tools for the Western area

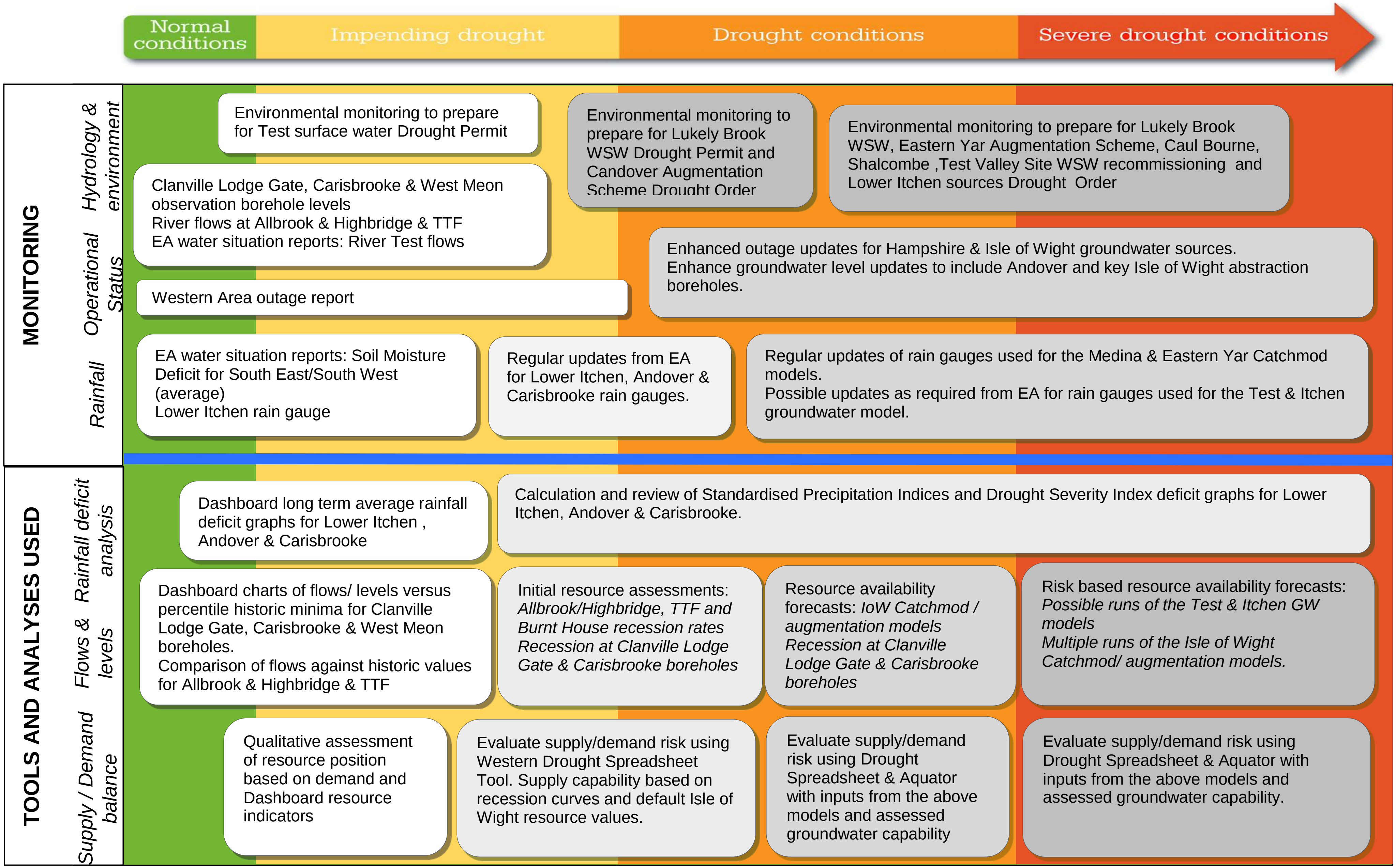
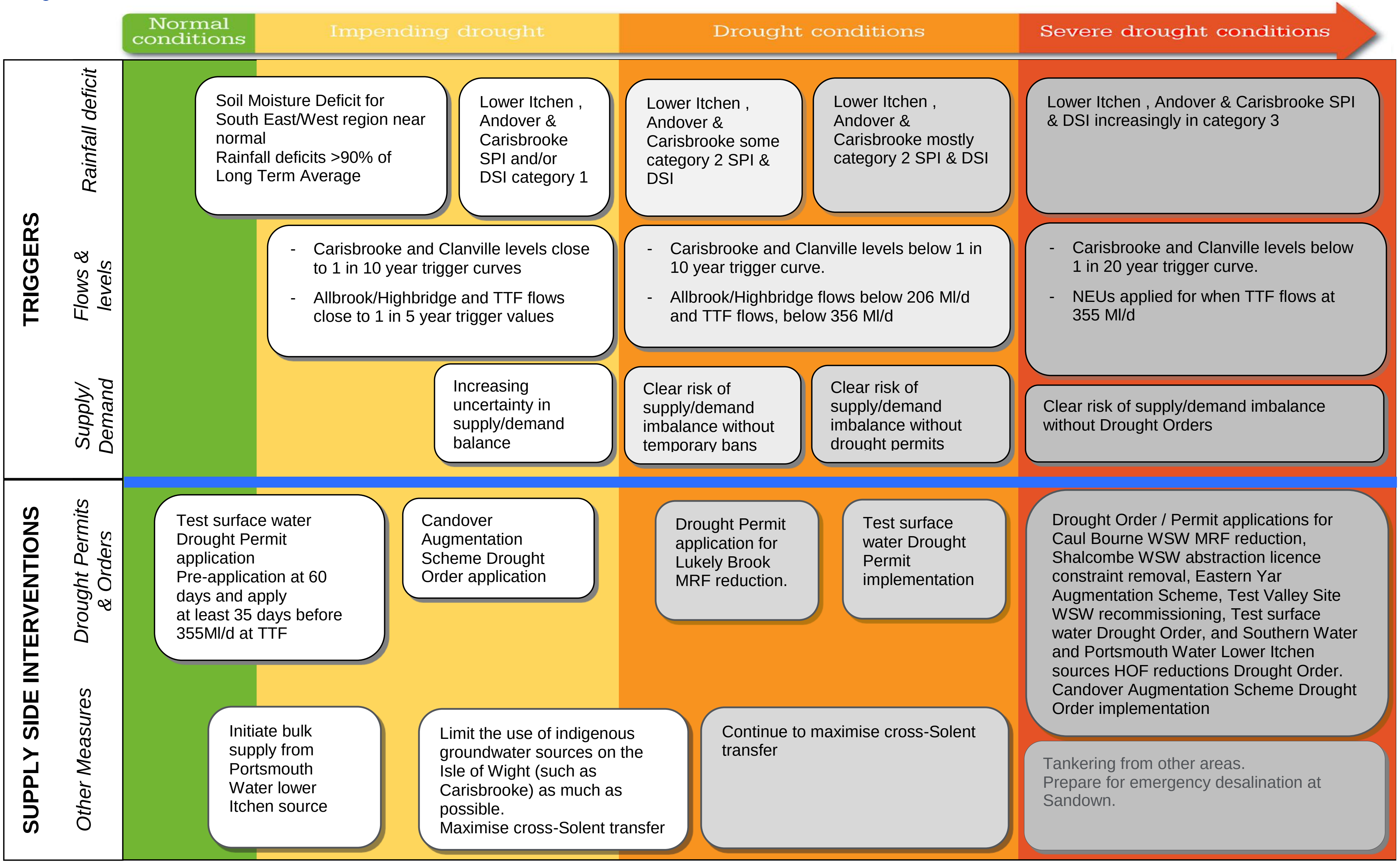


Figure 20 Relationships & phasing of triggers & supply side intervention measures for the Western area



Appendix A Drought triggers and indicators

Rainfall drought indices

Two indices have been used as triggers for this Drought Plan. These are the Standard Precipitation Index (SPI) and a Drought Severity Index (DSI) which uses SPI for start and termination rules.

The Standard Precipitation Index[1] is an internationally recognised approach to categorising rainfall deficit, which is essentially a comparison of rainfall deviation from average values, normalised according to the natural variability (expressed as a standard deviation) of rainfall at a given site. SPI gives a good indication of the status of rainfall variation from the norm over a given period (e.g. 6, 12, 24 months), and it is based on the following equation:

$$SPI_t(n) = \frac{R^m(n) - \bar{R}^m(n)}{s^m(n)}$$

Where:

$SPI_t(n)$ is the standardized precipitation index in period t (month m) of duration n months.

$S^m(n)$ is standard deviation of n month duration rainfall ending in month m.

$\bar{R}^m(n)$ is mean rainfall of duration n months ending in month m.

The second indicator, the DSI, provides a direct quantification of the cumulative amount of rainfall deficit from the start of a drought until the point where the drought is considered to be over. There are a number of approaches to calculating the start and end point of the drought (the 'termination rule'). Following analysis of water resources and rainfall over the whole of the region served by Southern Water, it was decided that a DSI-SPI approach[2] would be most suitable. In this case, the drought commences when SPI<0 for a given period, and terminates when SPI is either >0 for a period that ends in winter, and >0.5 for a period that ends in summer.

All of the DSI calculations simply measure cumulative rainfall deficit, but variations in the length of time covered by the termination rule will affect when that cumulative calculation stops. If a termination rule with a short period is used, for example 3 months, then this will mean that the drought has to be relatively intense and the DSI indicator will tend to lend weight to shorter, sharper droughts such as 1976. If the termination rule uses a longer period, say 6 months, then the DSI indicator will tend to lend more weight to longer droughts where there may be some periods of higher rainfall in the sequence. For the purposes of drought monitoring, a 12 month termination rule has been selected for all areas, as this represents the best approach for starting and ending a drought that lasts for multiple seasons and hence is reflective of general groundwater conditions.

The duration of the SPI indicator and the drought termination rule used for the DSI indicator has been analysed and tailored to reflect the specific vulnerability of the mix of resources that are present within each area. We may consider the use of alternative duration SPI metrics as necessary to support our ESoR case for any Drought Permit and Order applications. This follows our lessons learned review following the Mock River Test Drought Permit in Autumn 2018.

All of the rainfall indices essentially reflect a rainfall deficit, so are not geared towards particular times of year (except for the summer DSI rules referred to above). The trigger indices therefore consist of

[1] Guttman, N.B. (1998), Comparing the Palmer Drought Index and the Standardized Precipitation Index. J. Amer. Water Resource. Assoc., 34, 113-121
[2] Goldsmith, H., Mawdsley, J., and Homann, S. (1997), Drought, climate change and water resources in north east England. BHS 6th National Hydrology Symposium, Salford, 1997, 13-22

single values, as shown in Table A.1. This table presents the rainfall trigger indices for each area calculated using rainfall data from rain gauges representative of that area for which long-term records are available. In general terms, category 1 has been selected to provide exceedance at intervals of about 1 in 10 years, while category 2 has been selected to provide exceedance at intervals of about 1 in 20 years. The exception to this is Andover, because drought interventions in northern Hampshire are only required on an exceptional basis. The indices for southern Hampshire have been recalculated now that the Lower Itchen and Test sources sustainability reductions have happened.

Table A Rainfall trigger indices

Eastern area				
Lamberhurst	Units	Category 1	Category 2	Comments
12 month SPI	SPI	-2.0	-2.4	River Medway Scheme river flows indicator
30 month SPI	SPI	-2.1	-3.0	River Medway Scheme reservoir indicator
DSI (12 month SPI)	mm	-336	-517	Reflects cumulative deficit (mainly for reservoirs)
Canterbury STW	Units	Category 1	Category 2	Comments
12 month SPI	SPI	-1.6	-1.9	Short term
30 month SPI	SPI	-1.6	-1.9	Long term groundwater
DSI (12 month SPI)	mm	-189	-288	Reflects cumulative deficit (mainly for reservoirs)

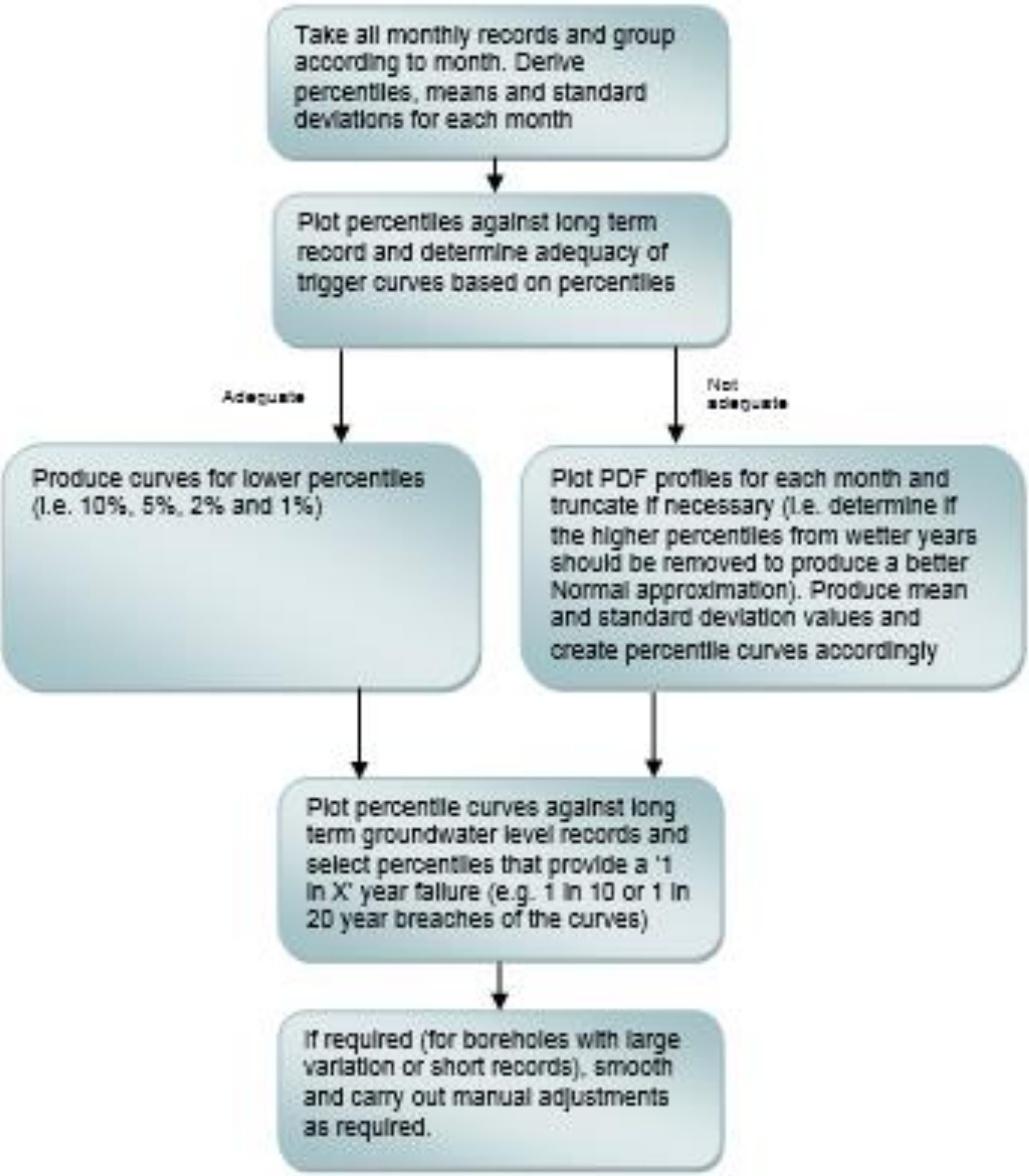
Central area				
Petworth Park	Units	Category 1	Category 2	Comments
12 month SPI	SPI	-1.7	-2.2	Reflects low single year river flows
24 month SPI	SPI	-1.9	-2.2	Reflects long term river recession
DSI (12 month SPI)	mm	-264	-328	Represents cumulative recharge deficit
Brighton (Ditchling Road)	Units	Category 1	Category 2	Comments
12 month SPI	SPI	-1.8	-2.1	Important for Brighton chalk block drought
24 month SPI	SPI	-2.0	-2.3	Important for all coastal groundwater
DSI (12 month SPI)	mm	-324	-400	Represents cumulative recharge deficit
Chilgrove	Units	Category 1	Category 2	Comments
12 month SPI	SPI	-1.7	-2.2	Important for Brighton chalk block drought
24 month SPI	SPI	-1.8	-2.3	Important for all coastal groundwater
DSI (12 month SPI)	mm	-267	-400	Represents cumulative recharge deficit

Western area				
Lower Itchen	Units	Category 1	Category 2	Comments
12 month SPI	SPI	-2.3	-2.6	Short term
30 month SPI	SPI	-1.9	-2.4	Long term groundwater
DSI (12 month SPI)	mm	-247	-289	Represents cumulative recharge deficit
Andover	Units	Category 1	Category 2	Comments
12 month SPI	SPI	-2.3	-3.5	Designed not to trigger category 2 without severe (>1 in 50 yr) drought
30 month SPI	SPI	-1.9	-3.1	
DSI (12 month SPI)	mm	-372	-494	Represents cumulative recharge deficit
Carisbrooke	Units	Category 1	Category 2	Comments
6 month SPI	SPI	-2.0	-2.4	Reflects river flows
12 month SPI	SPI	-2.1	-2.4	Reflects groundwater (low storage)
DSI (12 month SPI)	mm	-240	-350	Represents cumulative recharge deficit

Drought triggers – groundwater

Drought trigger curves for groundwater have been developed from Environment Agency (EA) monthly average groundwater level data in the relevant observation boreholes. These boreholes have been selected on the basis of location, aquifer type, monitoring record and currency of monitoring by the EA. The approach to developing the curves is provided in Figure A below.

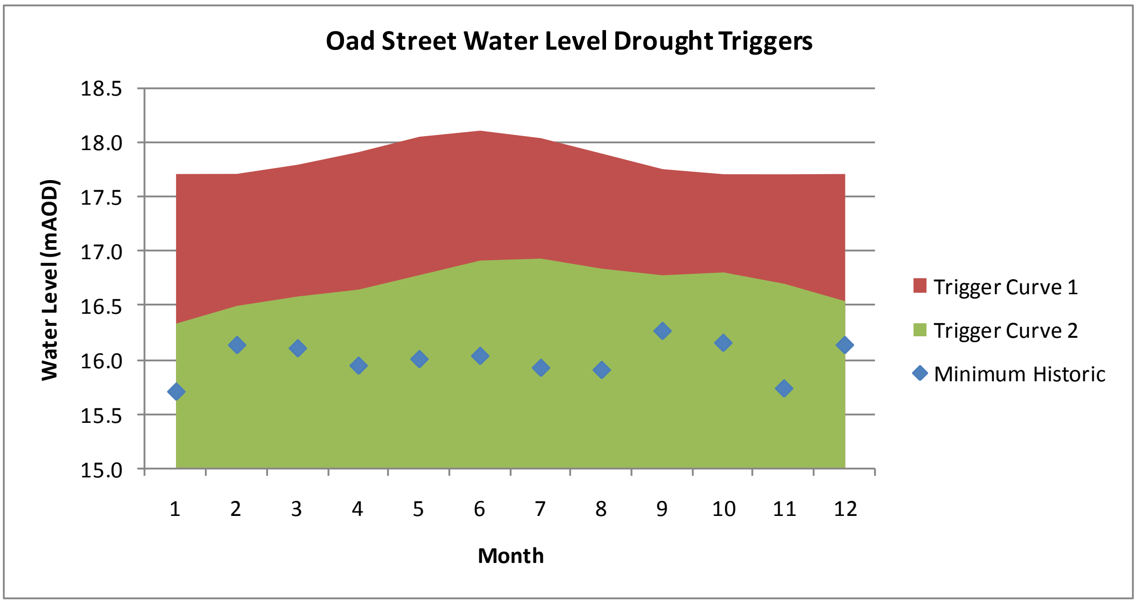
Figure A Trigger curve development



Plots showing the drought trigger curves for boreholes within each area are provided below.

Eastern area

Figure B Oad Street drought trigger curves

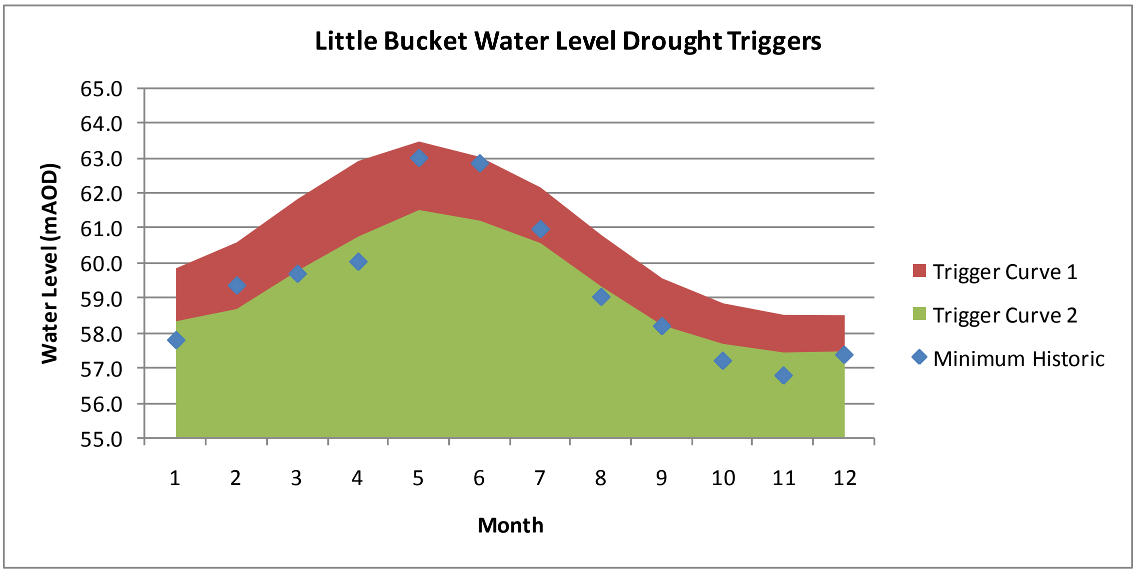


These boreholes are based on relatively short groundwater level records. Category 1 has been selected to provide exceedance at intervals of about 1 in 10 years. Category 2 has been selected to provide exceedance at intervals of about 1 in 20 years.

Figure C shows the drought triggers for Little Bucket. Little Bucket has been developed using truncated normal distribution analysis. This has resulted in winter trigger levels that are actually below historic minima, but this has been checked and is considered appropriate given the length of record. The shape matches that of a simple percentile assessment, but the difference between ‘Category 1’ and ‘Category 2’ is larger and more representative of the return periods quoted.

Oad Street provides a good indication of the groundwater resource for the Chalk sources within the Kent Medway East and Kent Medway West WRZs. This has an ‘unusual’ profile, as the Medway groundwater sources actually respond to multi-season droughts, so minima can occur at points of the year that would not normally be seen in indicator boreholes. It should be noted that these triggers have been developed from ‘normalised’ sequences that allow for the fact that there are nearby abstractions that affect groundwater levels. This has been achieved using recharge/level regression modelling that includes the relevant monthly groundwater abstraction rates (see Whitelot Bottom for an example of this approach).

Figure C Little Bucket drought trigger curves



Central area

These boreholes are based on good, long term groundwater level records. Category 1 has been selected to provide exceedance at intervals of about 1 in 10 years. Category 2 has been selected to provide exceedance at intervals of about 1 in 20 years.
Chilgrove has been derived using unadjusted percentile calculations.

Whitelot Bottom is based on percentiles, but these have been calculated from a long time series (back to 1920) that has been derived using the Whitelot Groundwater Regression Tool. This tool 'normalises' to compensate for groundwater abstraction at local Water Supply Works, and in order to calculate normalised levels for comparison against the triggers that are shown, the following calculation is required:

*'Normalised' Level (m) = Recorded Level (m) + (0.0017 *Abs)*

Where:

Abs = total abstraction (in Ml) over the past 6 months.

Figures D and E show the drought trigger curves for Chilgrove and Whitelot Bottom

Figure D Chilgrove drought trigger curves

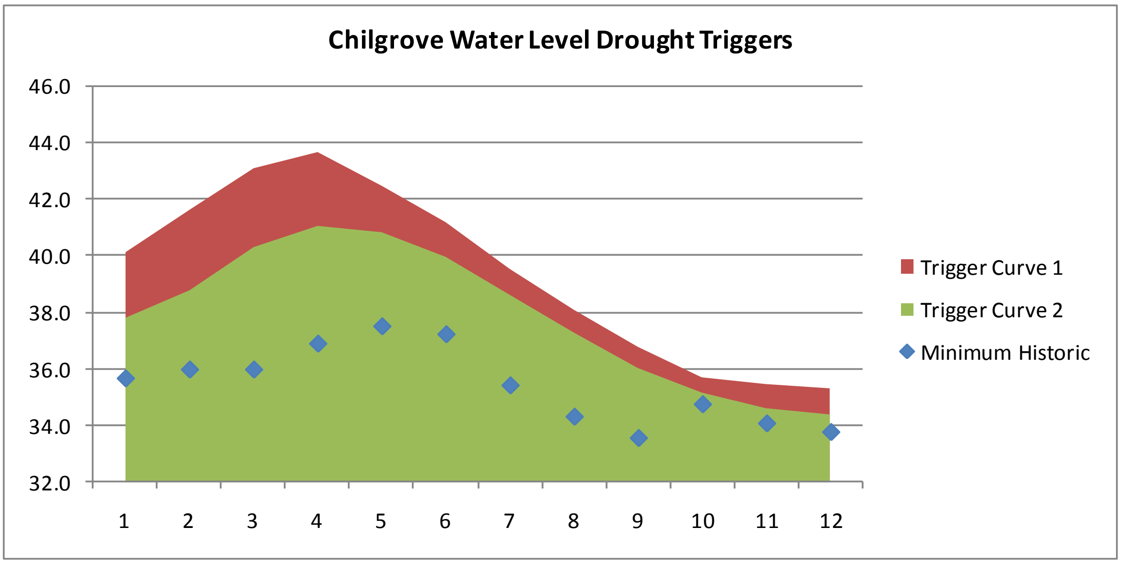
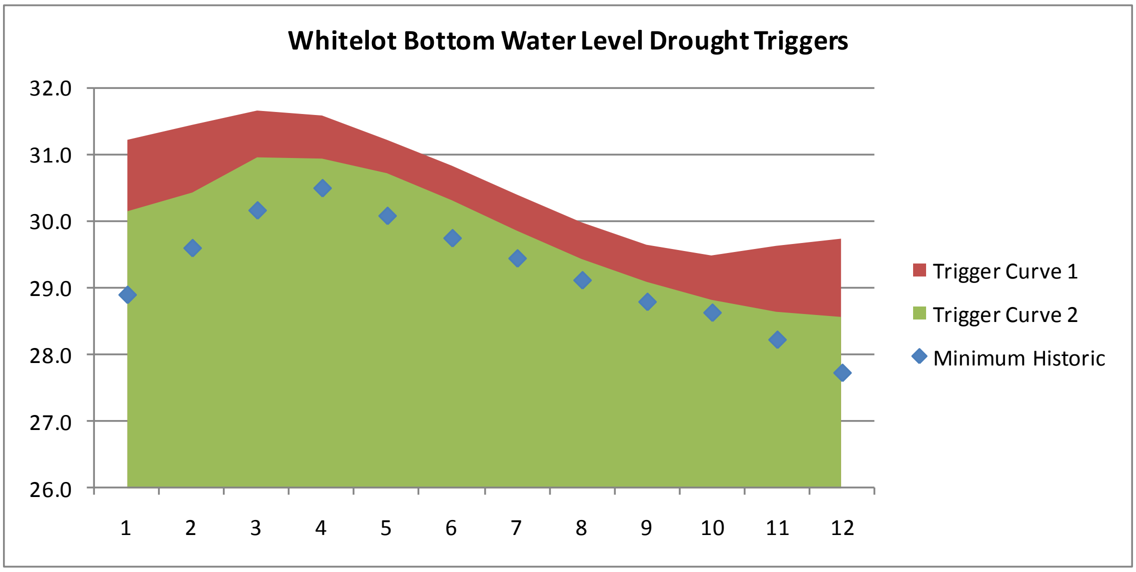


Figure E Whitelot Bottom drought trigger curves



Western area

The West Meon and Clanville Lodge Gate records are used as drought triggers for Hampshire, and have medium length time series records (back to the 1970s). Trigger 1 has been selected to provide exceedance at intervals of about 1 in 10 years. Trigger 2 has been selected to provide exceedance at intervals of about 1 in 20 years.

Clanville Lodge Gate has been developed using truncated normal distribution analysis, overall there is little difference between the recorded minimum historic level and the Category 2 trigger as limited groundwater level data are available for extreme low level values in the available historic record. The trigger values have been set such that they are representative of the return periods quoted. As with Little Bucket, the analysis has resulted in winter trigger levels that are actually below historic minima, but this has been checked and is considered appropriate given the length of record.

The trigger curves for West Meon have also been developed using truncated normal distribution analysis. The percentile based trigger curves are relatively close to each other and the historic minimum as there are few extreme low level values available in the historic record. Figures F and G show the trigger levels for West Meon and Clanville Lodge Gate.

Figure F West Meon drought trigger curves

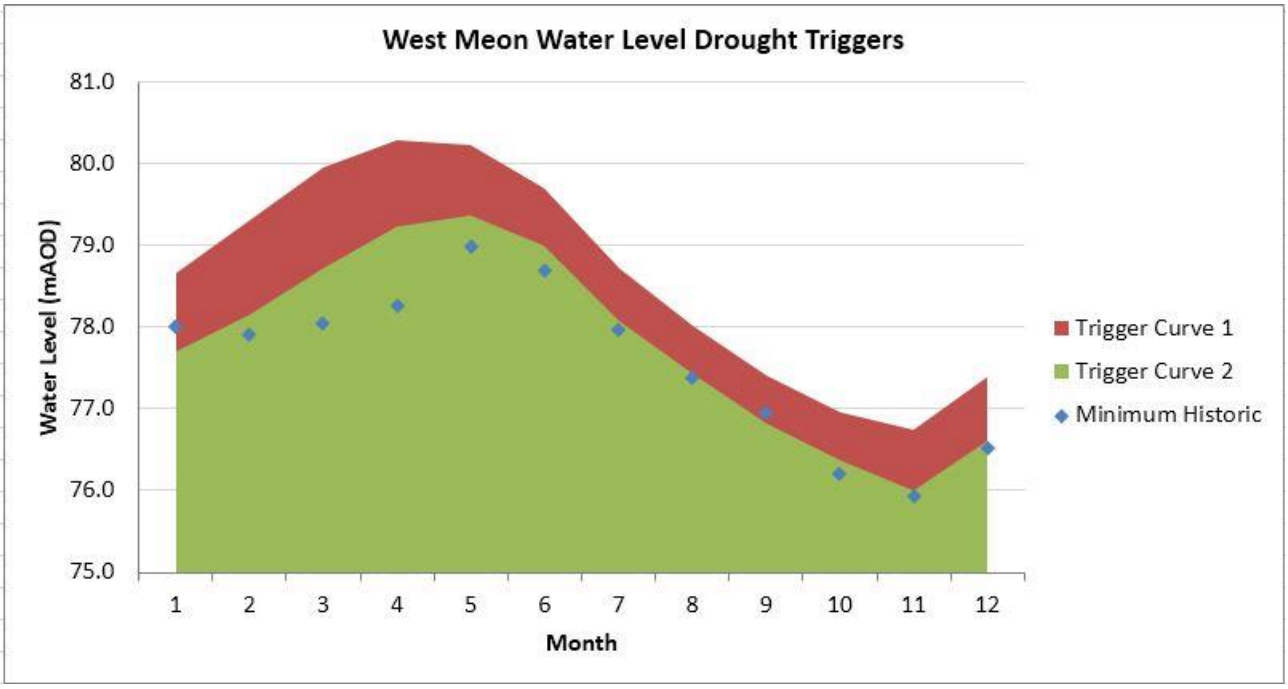
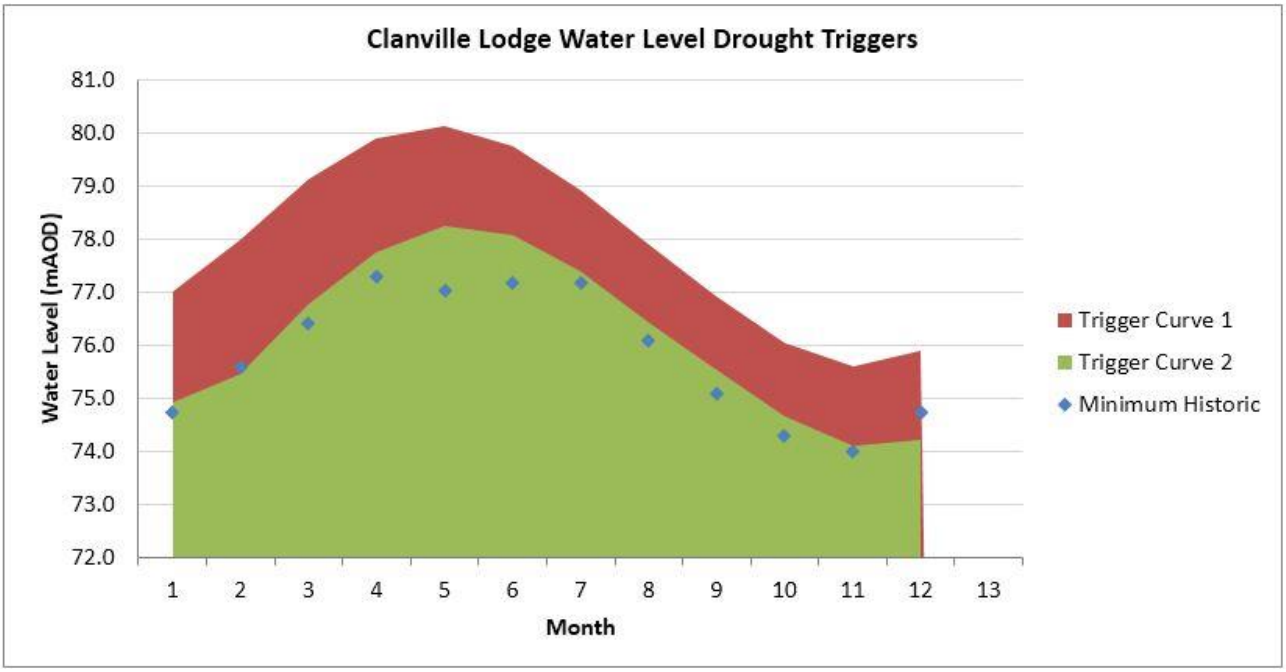
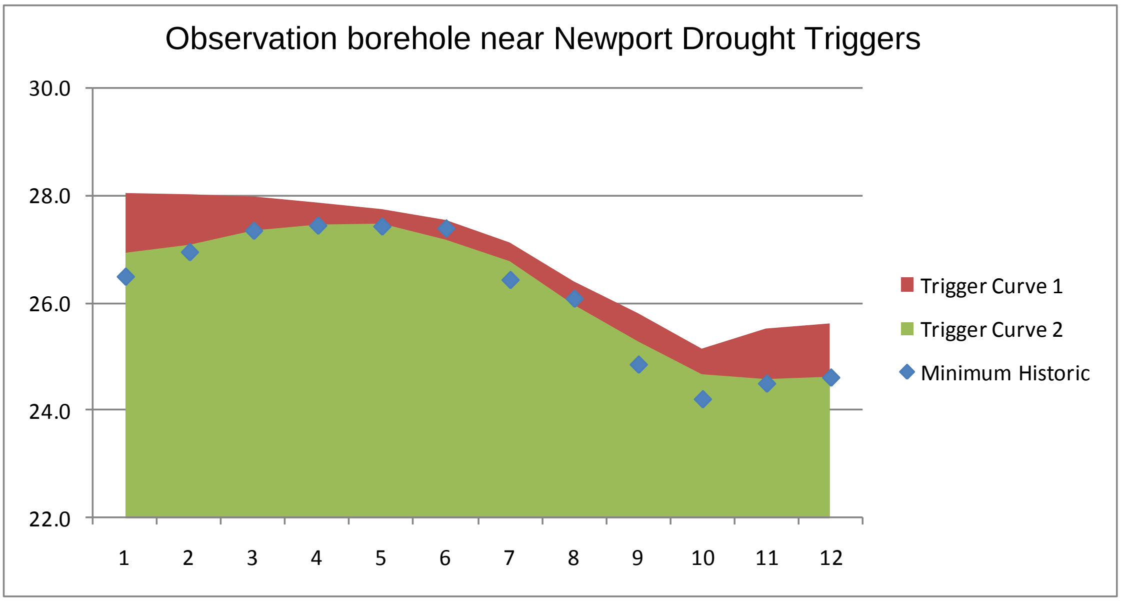


Figure G Clanville Lodge Gate drought trigger curves



For the Isle of Wight, an observation borehole near Newport has been used. This has a relatively short record (back to 1986), so there is little difference between percentiles as there are few extreme low level values in the record. This borehole is affected by nearby abstraction, so has been derived from 'normalised' groundwater levels that allow for the impact of the source, as described for Oad Street and Whitelot Bottom in the Eastern and Central areas respectively. Figure H shows the drought triggers for this observation borehole.

Figure F Observation borehole near Newport drought trigger curves



Drought triggers – river flows

Central area

The River Rother trigger curve has been calculated using the following approach:

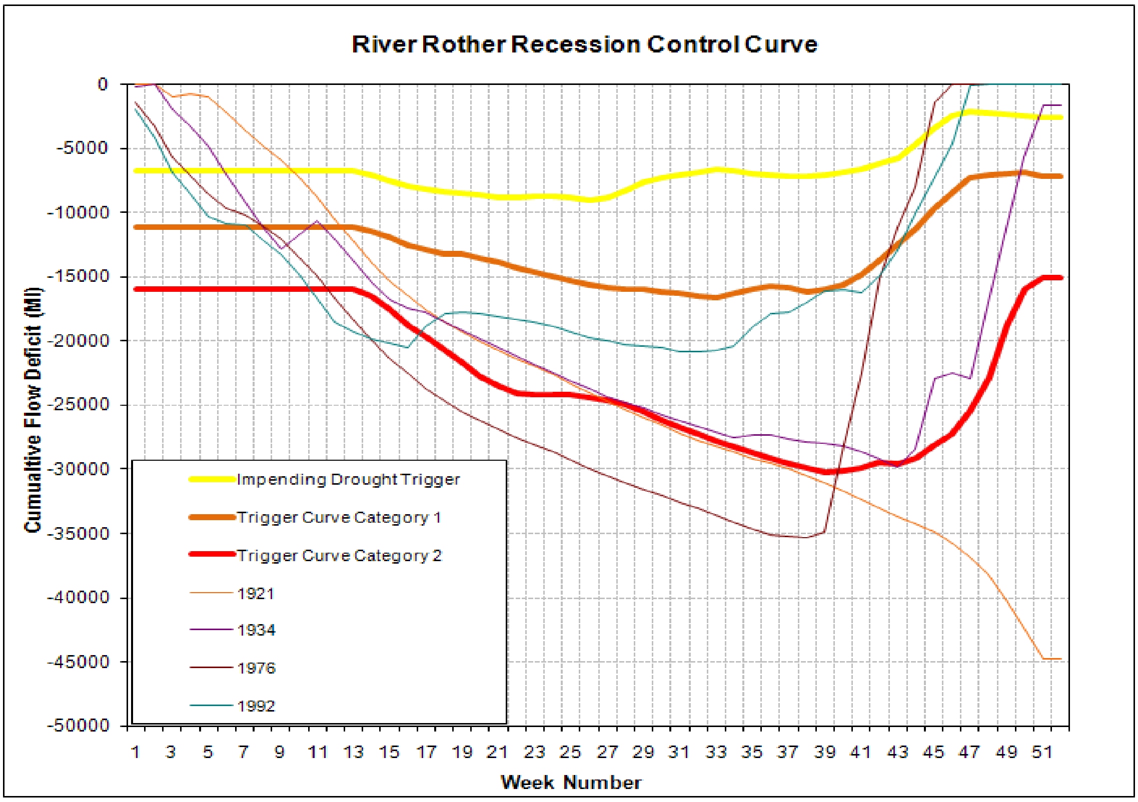
- The Q75 for monthly flows are calculated based on the 1961-1990 period.
- The difference between these and actual in-month totals are calculated and added on a cumulative basis.
- The trigger curves are calculated based on percentages from these deficit profiles.
- As with the groundwater triggers, relevant percentiles have been selected to represent a 1 in 10 year (Category 1) and 1 in 20 year (Category 2) frequency of exceedance.

This approach addresses and balances all the operational needs for this indicator, namely that:

- It should provide an indicator of how severe the recession is during the early part of the year.
- It should indicate how long river flows have been below the threshold at which abstraction starts to become limited during the summer. This is important as it provides an indicator of the stress that the key groundwater storage site in Sussex North WRZ has experienced as a result of abstraction during the drought.
- It should indicate the timing of the recharge period, and in particular when this is late enough to cause concerns over the next year's recession.

Figure I shows the trigger curve for the River Rother. For comparative purposes, cumulative deficit lines for historic drought sequences have been plotted against the trigger curves.

Figure I River Rother drought trigger curve



Western area

For our Western area we use a combination of groundwater, rainfall and river flow indicators to provide a drought stage status for this supply area. Drought triggers have been developed for the River Test and River Itchen in Hampshire to reflect our target levels of service (set out in Table 1), while honouring the agreed sequencing of actions and thresholds detailed in the Test Candover and Itchen Interim Abstraction Scheme as defined in the S20 agreement (summarised in Table 4). For further information on the demand savings and supply options see Annexes 3 and 4 respectively.

Figure J and Figure K show the trigger curves for the River Itchen and River Test. For comparative purposes observed drought sequences have been plotted against the trigger curves. The triggers are further tested in Annex 2. Note that for the Itchen (Figure J) the Level 2 Trigger (at 206Ml/d) for TUBs is only just above the Level 3 Trigger (205Ml/d) for the Candover Drought Order.

Figure J and Figure K compare our drought triggers to past historic low flow drought events, specifically 1975/76, 2005/6 and 2011/12 to indicate the actions that would have been taken under the S20 agreement. We have not included forecast (synthetic) drought events on these plots, however, our 60 day and 35 triggers for the River Test have been derived from an analysis of historic and synthetic drought recessions. During active drought management we would supplement these trigger levels by forecasts of flow recessions based on our existing water resource modelling tools. These forecasts will be used to estimate drought progression and ensure our actions under the S20 agreement are carried out in sufficient time.

The Level 1 (impending drought) trigger curve has been developed using the annual minimum flow from the 2000 year naturalised flow simulated with the Test and Itchen groundwater and river flow model (run 178), adjusted to account for abstraction demands and bulk supply actions. As with the groundwater triggers, relevant percentiles have been selected from this profile to represent a 1 in 5 year frequency of exceedance. Minimum values have been applied to the resultant profile to ensure an appropriate sequencing with later actions. These triggers have been tested against both the observed record and stochastic Aquator model output (run INQ022, pre S20 agreement) to reconfirm the frequency with which they are likely to be reached.

Our 60 day trigger for the River Test has been set at a constant flow of 535Ml/d based on recession analysis to provide a minimum 60 day time between the flow threshold being reached and the Hands off Flow condition occurring to allow a River Test Drought Permit pre-application in accordance with the S20 agreement. Our 35 day trigger is similarly set to allow sufficient time, in accordance with the timeline in the S20 agreement, for the permit application to be determined prior to being required.

The Level 2 (drought) trigger has been set as a constant flow target to ensure the subsequent sequencing of the Test Candover and Itchen Interim Abstraction Scheme (as defined in the S20 agreement) is applied. The threshold on the Test is just above that for the implementation of the River Test Drought Permit (at 356Ml/d). The threshold on the Itchen is just above implementation of the Candover Drought Order (at 206Ml/d) and the implementation of Non Essential Use Bans (NEUs). Based on modelling, the frequency with which these triggers will be reached are consistent with Southern Water’s level of service (1 in 20 years).

The Level 3 (severe drought) trigger has also been set at a constant flow target. This trigger level is based on the threshold for implementation of Level 3 Restrictions (NEUs). The S20 agreement stipulates that NEUs can be applied for once flows on the River Test have reached 355 Ml/d. However, it is also intended that they will be put in place before the trigger for the Test Surface Water Drought Order has been crossed (265 Ml/d). Therefore, for the purpose of visualisation, a flow threshold in between these two limits has been shown here. However, the flow recession will be closely monitored during the drought to ensure an appropriate implementation of Level 3

Restrictions. A threshold of 205 Ml/d has been set on the Itchen to ensure Level 3 Restrictions are in place when the Candover Drought Order is triggered.

Figure J Allbrook and Highbridge drought trigger curve showing how triggers relate to actions under the S20 agreement

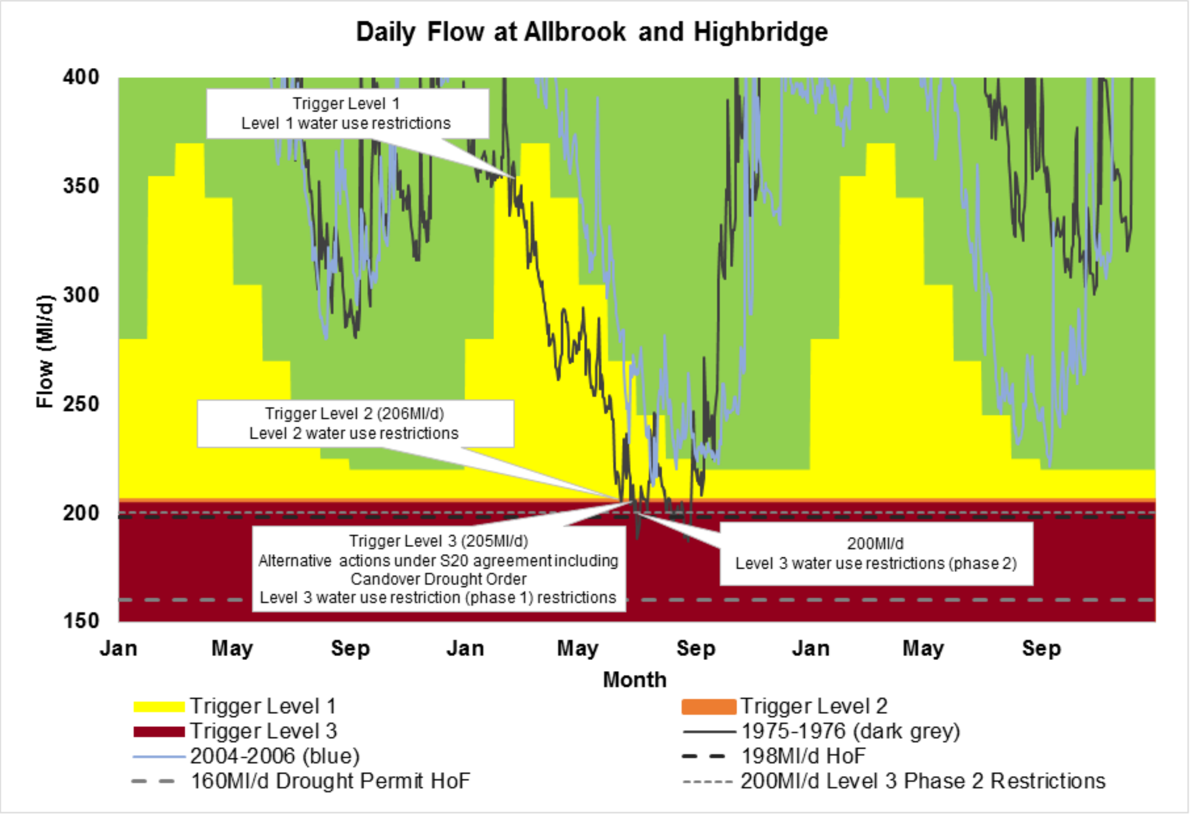
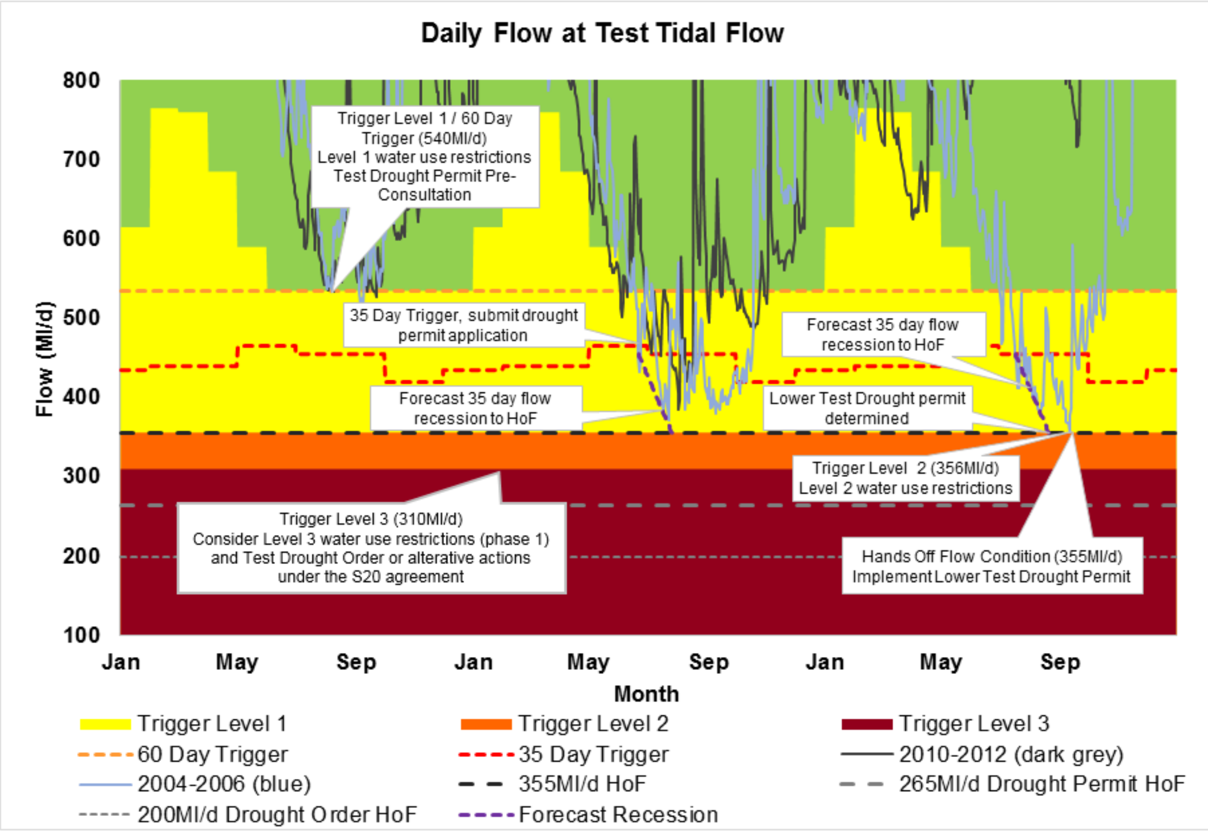


Figure K Test Tidal Flow (TTF) drought trigger curve showing how triggers relate to actions under the S20 agreement



Drought triggers – reservoirs

The drought triggers for reservoirs are based on the operational curves that were used within the PR09 Water Resources Management Plan resource capability assessments. These are based on conventional reservoir yield analysis – i.e. they manage the risk within the WRZ by imposing demand restrictions to ensure that the Deployable Output of the system can be maintained. Category 1 and Category 2 refer about to 1 in 10 and 1 in 20 year exceedances respectively.

For the Bewl-Darwell reservoir system, there are secondary control curves that seek to optimise the transfer of water between the two reservoirs in order to optimise the overall deployable output of the system. The transfers are started when Darwell levels fall below a certain value, but controlled based on remaining levels within Bewl. Figures L, M, N and O show these triggers for our four reservoirs.

Eastern area

Figure L Bewl Water reservoir control curves

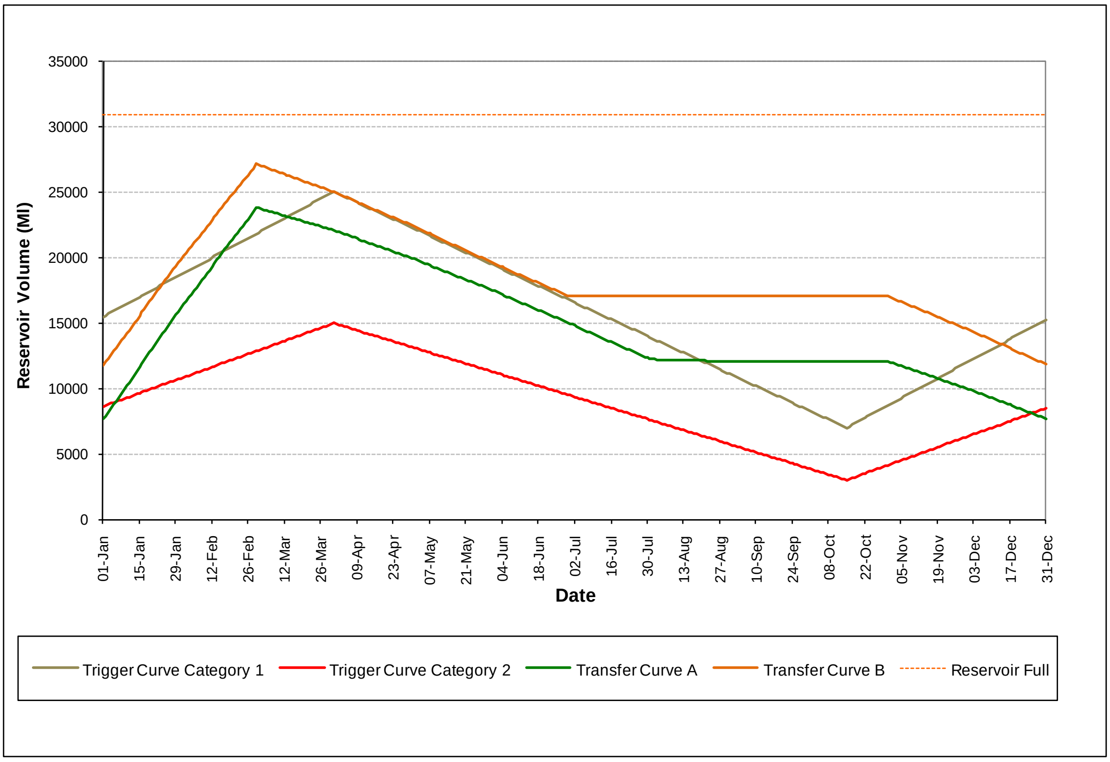


Figure M Darwell reservoir control curves

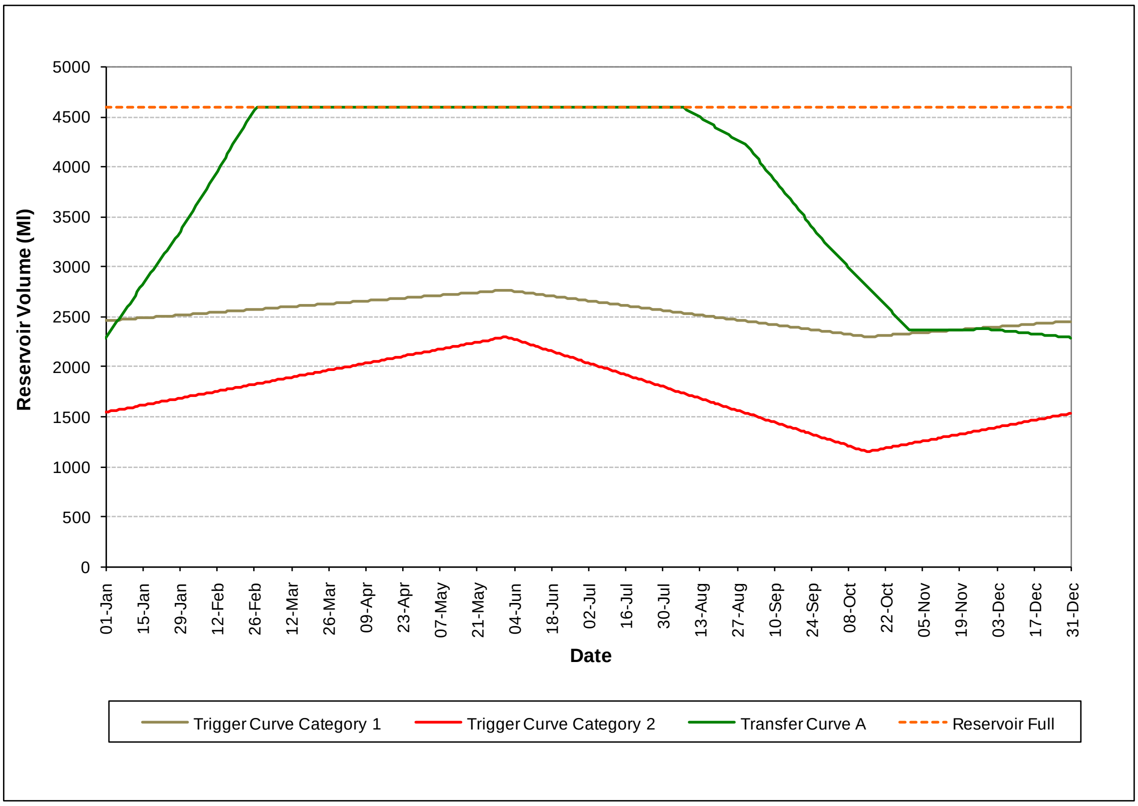
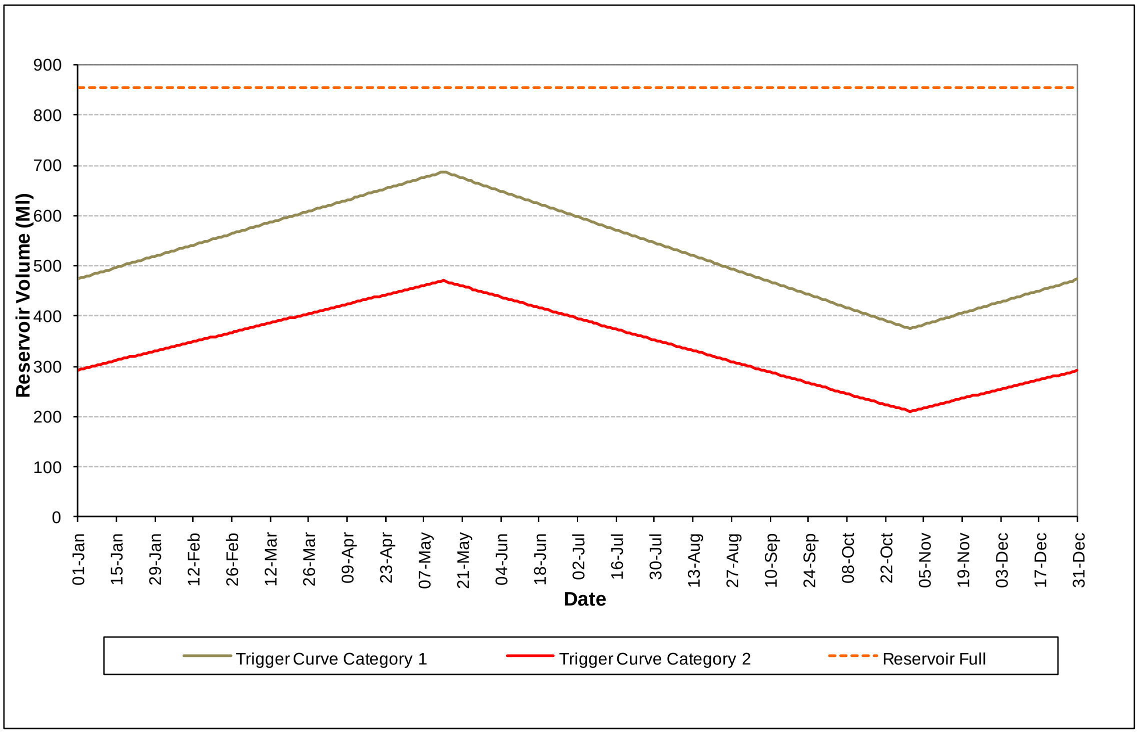


Figure N Powdermill reservoir control curves



Central area

Figure O Weir Wood reservoir control curves