

# Water Resources Management Plan Level 1 Appendix C

## Technical Note

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### Client signoff

Client	SES Water
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# 1. Introduction

SES Water commissioned Atkins to update its existing household consumption forecast model (here after referred to as the model) to produce a demand forecast for the Water Resources South-East (WRSE) 2024 regional plan and the Company's own 2024 Water Resources Management Plan (WRMP24). The model was originally developed by Artesia Consulting for SES Water's 2019 Water Resources Management Plan (WRMP19). The model is based on micro-component modelling and forecasting. Further details about the model are provided in Section 2.

A non-household demand forecast model was also developed by Artesia Consulting in 2020 for the WRSE region. Further details about this model are provided in Section 3. Outputs from the non-household demand forecast model were incorporated into the model to allow the model to output non-household property and population forecast and non-household consumption forecasts.

Sections 4, 5 and 6 of this technical note outline the updates undertaken to the model between 2020 and 2023. Only a brief outline of the updates is provided in this technical note. Where necessary references have been made to reports which provide more detail of the updates undertaken. The specific reports which were produced when the updates were undertaken are provided as Level 2 appendices to this report (Level 1 Appendix C of the WRMP).

Updates have initially been documented based on when they were undertaken. They have then been further sub-divided based on whether they relate to household or non-household.

The updates to the model include:

- Amending the model base year - this task was undertaken twice, first in 2020 where the model base year was amended to 2019/20 and again in 2023 when the model base year was amended to 2021/22).
- Updating population and property forecasts.
- Incorporating company policy/funded metering assumptions for Asset Management Plan (AMP) period 7.
- Updating external micro-component data.
- Incorporating the latest leakage, water taken unbilled and distribution System Operational Use estimates into the model.
- Review of climate change factors.
- Calculating and incorporating consumption uplift factors.
- Developing and incorporating a non-household demand forecast.
- Incorporating smart metering assumptions for households and non-households.
- Incorporating a template (Data Landing Platform (DLP) template) to enable outputs from the model to be reported to WRSE.

## 2. SES Water's household consumption forecast model

For its 2019 Water Resources Management Plan (WRMP19) SES Water commissioned Artesia Consulting to develop a household consumption forecast. This was produced using micro-component modelling and forecasting, which is suitable for a Water Resource Zone (WRZ) with a low level of water resource planning concern.

The model was developed using best available data from local and national datasets. The model is segmented by property type using unmeasured and measured, with measured households split into existing properties, new builds, optants as well as compulsory, selective, change of occupier and other metering programmes. The model is based on per household consumption and includes linear modelling of key micro-components against occupancy to reflect the variation of per household consumption by occupancy within each household type. The model forecasts are developed from historical industry and UKWIR micro-component datasets and Market Transformation programme predictions.

The property and population forecasts used in the model are taken from estimates provided by Experian.

The model produces forecasts for Normal Year Annual Average (NYAA), Dry Year Annual Average (DYAA) and Dry Year Critical Period (DYCP); with a breakdown of micro-components for each year of the forecast.

Artesia's report 'WRMP19 Household consumption forecast: baseline forecast' describes in more detail how the model was developed. This report is included in Level 2 Appendix C of this report.

## 3. Non-household consumption model

Prior to developing a non-household demand forecast, WRSE commissioned Artesia Consulting to undertake a review of the current methods used by water companies for non-household demand forecasts and compare them to the Water Resources Planning Guideline. This review made a number of conclusions and recommendations from which WRSE developed a specification for the initial non-household demand forecast. The scope of this work was to develop a non-household demand forecasting model and produce a non-household demand forecast for the period 2025 to 2100 that is fully compliant with the Water Resource Planning Guideline. The key tasks carried out against this requirement were:

- Segmentation of customers and base year demand.
- Identification of explanatory factor for each customer segment.
- Assessment of the impact of climate change.
- Assessment of the impact of water efficiency.
- Assessment of demand by other sectors.

A non-household demand forecasting model was then developed for each sector which allowed demand to be forecast over the planning period. The model has been developed at the company and WRZ level and aggregated region level for each sector. It includes multiple scenarios that have been generated to take account of uncertainties in various assessments. It also has been developed to be fully transparent and able to withstand scrutiny at a public inquiry. The outputs have been incorporated into a commonly used tool that allows companies to select the various outputs and scenarios at different levels.

Further details on how the model was developed and the outputs are documented in the Non-household demand forecasts 2020 to 2100 report in Level 2 Appendix B of this report.

## 4. 2020 model updates

In April 2020 SES Water commissioned Atkins to update the model (including both household and non-household components) to enable SES Water to produce a demand forecast for the WRSE regional plan.

To be able to produce a demand forecast for the WRSE regional plan the following tasks were undertaken. These tasks were completed following the guidance provided in the demand forecast method statement which was produced by WRSE<sup>1</sup> and with reference to the then draft Water Resources Planning Guideline (WRPG)<sup>2</sup>. The WRPG has since been finalised<sup>3</sup>.

A report was produced to document the model updates (Demand Forecast Updates for the WRSE Regional Plan) which is included in Level 2 Appendix D of this report.

The updates to the model included:

- Amending the model base year to 2019/20 and the baseline forecast to 2099/2100 (note that WRSE has since truncated the supply demand forecast to the end of the planning horizon at 2075).
- Incorporating base year population and property data and incorporating population and property forecasts produced by Edge Analytics (see Level 2 Appendix A of this report).

<sup>1</sup> Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4

<sup>2</sup> Environment Agency, 2020, Water Resources Planning Guideline, draft for consultation, version 6.8

<sup>3</sup> Environment Agency, March 2023, Water Resources Planning Guideline, Final for publishing, version 12

- Incorporating company policy/funded metering (including the compulsory metering expected in Asset Management Plan (AMP) period 7) assumptions for AMP7
- Reviewing the approach to micro-components and updating where necessary according to latest available guidance and evidence base.
- Incorporating SES Water's leakage estimates, both for unmeasured supply pipe leakage and distribution losses
- Incorporating SES Water's current estimates of Water Taken Unbilled and Distribution System Operational Use.
- Reviewing the climate change factors and amending where necessary according to latest available guidance.
- Developing and incorporating NYAA, DYAA and DYCP (including 1 in 200 and 1 in 500 drought events) uplifts.
- Developing and incorporating a non-household forecast (see Level 2 Appendix B of this report).
- Incorporating the DLP template to enable outputs from the model to be reported to WRSE.

The following sections briefly describe how these tasks were undertaken, including documenting the data used.

## 4.1. Household

### 4.1.1. Re-base to 2019/20

The model was re-based to 2019/20 from 2015/16. Re-basing the model included a review of all model components to update year profiles, re-direct relevant formulas and insert updated data. The model was also extended to 2099/00 (previously the model only forecast to 2080/81).

To re-base the model data was extracted from:

- SES Water's 2019/20 Annual Review.
- Population forecast supplied by Edge Analytics (see Level 2 Appendix A of this report).
- SES Water's WRMP19 Tables.
- Hidden and transient population supplied by Edge Analytics.

In the model base year household properties are split between measured households and unmeasured household. This split was determined by data extracted from SES Water's 2019/20 Annual Review. Measured properties are further sub-divided in the model into the following categories: new properties; properties opting for a meter in-year (optants); and properties metered on change of occupancy.

The number of properties in each of these categories was determined using the following data sources:

- SES Water's 2019/20 Annual Review.
- SES Water's WRMP19 Tables.

Table 4-5 in the Demand Forecast Updates for the WRSE Regional Plan report (Level 2 Appendix D of this report) explains how the number of properties in each of these groups was determined for the base year.

Edge Analytics (as part of the WRSE collaborative study on population) provided data on hidden and transient population for SES Water for the base year (2019/20). The mid-level estimate for irregular migrants, short-term residents and second addresses (not visitors) was incorporated into the model.

### 4.1.2. Population and property forecasts

Property and population forecasts for SES Water were supplied by Edge Analytics (see Level 2 Appendix A of this report). Forecasts were produced for a wide range of scenarios, by using a combination of trend, housing-led (incorporating housing need, housing requirements and actual planned scenarios) and employment-led forecasts, to account for the considerable uncertainty in the projections. From the range of scenarios, there was the need to adopt one as a baseline growth forecast, supported by a selected number of additional growth projections that allows SES Water to account for uncertainty. WRSE agreed on consistent property and population growth scenarios for companies across the region to base their demand forecasts on. Guidance was

provided in a WRSE Method Statement<sup>4</sup>. Further details on the forecasts used in the model are provided in sections 4.1.2.1 and 4.1.2.2.

#### 4.1.2.1. Baseline forecast

For the baseline forecast, the Housing-Plan-P scenario was selected. This scenario was developed using two approaches: a ‘top-down’ approach and a ‘bottom-up’ approach. WRSE adopted the ‘bottom-up’ approach as it is considered to more accurately represent the locations of new growth across Water Resource Zones (WRZs). To determine the proportion of properties in the optants and change of occupier categories, metering data was taken from the SES Water’s WRMP19 Tables.

The following assumptions were applied to the model when determining the proportion of properties in the optants and change of occupier categories:

- For the baseline forecast after AMP7 (2025/26 onwards) there is no metering on change of occupancy. This assumption is based on the WRPG which states ‘*your baseline customer demand should take account of customer demand without any further water efficiency or metering intervention from yourselves...*’:
- The number of change of occupier properties for each year of the baseline forecast has been calculated by adding together the number of properties metered on change of occupier (row 45.4 from SES Water’s WRMP19 Tables) and the number of properties compulsory metered (row 45.3 from SES Water’s WRMP19 Tables).
- For optant metering the baseline forecast only included optant metering beyond AMP7 (2024/25) which was not encouraged by SES Water. Optant metering data for the baseline has been taken from the SES Water’s WRMP19 Tables (row 45.2) and includes optant metering until 2029/30.

As previously mentioned, Edge Analytics provided data on hidden and transient population with the SES Water area for the base year (2019/20). As no year-on-year forecasts were available for this segment of population the base year figures were used throughout the planning period.

Table 4-1 presents the sources of data used to determine base year population and property numbers and also baseline forecasts.

**Table 4-1 - Population and property baseline forecast**

Category	Source
Base year population	Edge Analytics (Housing-Plan-P)
Base year property numbers	SES Water 2019/20 Annual Review
Baseline forecast population	Edge Analytics (Housing-Plan-P)
Baseline forecast property numbers	Edge Analytics data (Housing-Plan-P) calibrated to the SES Water 2019/20 Annual Review data

As the model calibrates the Edge Analytic property data to SES Water’s 2019/20 Annual Review property data, the model deviates from the occupancy rates provided by Edge Analytics, although the rate of change in properties and therefore occupancy rates over the planning period remains consistent with the Edge Analytics forecast. The calibration is required to ensure there is consistency between SES Water’s customer database and the Edge Analytics data.

#### 4.1.2.2. Growth forecasts

Table 4-2 provides a list of the scenarios WRSE decided should be included in the model and the growth forecasts which match these scenarios.

<sup>4</sup> Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4.

**Table 4-2 - Selected growth forecasts for SES Water**

Scenario	Selected growth forecast for SES Water
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H

The household population estimates comprise both people living in households and people living in communal establishments (population 'not in households'), e.g. care homes, long-stay hospitals, students in halls of residence. Even though the property types for these customers may be classed as non-household, the water use is largely domestic, so they are counted as household customers for the purposes of the demand forecast.

### 4.1.3. Consumption

The model generates household consumption through micro-component modelling. Further details on how the model does this is provided in the following report: WRMP19 Household consumption forecast: baseline forecast – Level 2 Appendix C of this report. The micro-component modelling results generated by the model are calibrated to base year household consumption data extracted from SES Water's 2019/20 Post-Maximum Likelihood Estimation (MLE) Water Balance.

Following a high-level review of the micro-component Ownership (O), Volume per use (V) and Frequency of use (F) values included in the model it was apparent external use was lower than expected. With external use representing such a low proportion of household water use it was found that external use was not high enough to apply the assumed Temporary Use Bans (TUBs) savings, which were assumed in the company's then Draft Drought Plan 2021<sup>5</sup> to equate to approximately 3.2 % of DYAA demand (Distribution Input (DI) minus leakage) and approximately 5.4% of DYCP demand (DI minus leakage).

The micro-component data sources presented in Section 3.3 of the WRMP19 Household consumption forecast: baseline forecast report (Level 2 Appendix C of this report) which were not used in the model were reviewed and sensitivity testing undertaken using the various external use values. Table 4-3 lists the data sources presented in Section 3.3 of the WRMP19 Household consumption forecast: baseline forecast report (Level 2 Appendix C of this report). The external use values used in the model come from Table 2.

**Table 4-3 - Micro-component data sources presented in Appendix E2 of SEs Water's Final WRMP19**

Data source	Description
Table 2	Micro-component summary data from 2015/16 metered billed households. A sample of measured billed households, which has associated occupancies and demographic information on the households, collated during an UKWIR Study (this contains 62 households from around England and Wales).
Table 3	2015/16 RV billed households. A sample of RV billed households, which does not have associated demographics (collated from other anonymous Siloette studies carried out by Artesia Consulting, from England and Wales).
Table 4	Micro-component summary for 2002/04 RV billed households. 2002 – 2004 O, V, and F data collected using the Identiflow system (a sample of RV billed households, reporting in WRc Report CP187).

It should be noted that altering the external use OVF values did not impact the overall per capita consumption (PCC) because the model offsets the increase in the external use micro-component by applying an equal percentage decrease across all the other micro-components.

<sup>5</sup> SES Water, March 2021, Draft Drought Plan, for public consultation. Since finalised and published in 2022.

The sensitivity analysis concluded that only the Table 4 external use micro-component OVF values ensure that TUBs savings could be purely attributed to reductions in external use, i.e. the savings are less than the external use values in both the base year and the final year of the planning period. The final year of the planning period would also work using Table 3 OVF values, but not the base year. SES Water decided to use this data because it is more recent than the Table 4 OVF values. Table 4-4 provides the original and revised external use OVF values use in the model.

**Table 4-4 - External use OVF values**

	Ownership	Volume (litres)	Frequency of use per day	O*V*F
Original model values	0.18	285.18	0.07	3.34
Revised model value	0.51	183.03	0.19	17.74

#### 4.1.4. Incorporating company policy/funded metering assumptions

SES Water has an Outcome Delivery Incentive (ODI) linked to household PCC. By the end of AMP7, SES Water has a target PCC of 136.8 litres per head per day for NYAA and 148.5 litres per head per day for DYAA (derived from the overall PCC target of 138.0 litres per head per day, weighted for 1 dry year occurring every 10 years). This target is achieved through metering savings and water efficiency savings.

Metering savings included in the model were updated to match the assumptions stated in SES Water's 2019 Business Plan, which was 14.5% for metering on change of occupier and 2.5% for optant smart metering.

Following the application of the metering savings, the residual of the AMP7 target was achieved through applying water efficiency savings to taps and external use. These micro-components were selected because they are two areas where water efficiency savings can easily be made in the home. For example: turning the tap off whilst brushing your teeth and using collected rainwater or re-using paddling pool water to water the garden.

A saving of 1.45% was applied to taps and a saving of 3.5% was applied to external use. These savings were applied from 2020/21 to the end of AMP7 (2024/25) and were applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into PCC by dividing by the total population.

## 4.2. Non-household

As previously mentioned in Section 3, Artesia Consulting produced a non-household demand forecast for SES Water (see Level 2 Appendix B of this report). The household demand forecast model was adapted to include this non-household demand forecast using data extracted from SES Water's 2019/20 Annual Review and the non-household demand forecast model produced by Artesia Consulting.

### 4.2.1. Population and properties

#### 4.2.1.1. Base year

Base year non-household population and property data were extracted from SES Water's 2019/20 Annual Review. Data were provided for measured and unmeasured non-households.

#### 4.2.1.2. Baseline forecast

To calculate the population and property baseline forecast, the non-household consumption data supplied by Artesia (see Section 4.2.2) was used along with the base year population and property values to calculate a measured per property consumption (PPC) and PCC. The PCC value was used to calculate the number of properties for each year of the forecast using the following formula:

$$\text{Previous year's number of properties} + (\text{consumption for given year} - \text{previous year's consumption}) / \text{base year PPC}$$

This approach assumed that the increase in non-household consumption through the planning period is a result of the more non-household properties and not the existing non-household properties using more water.

The PCC value was used to calculate the population for each year of the forecast using the following formula:

$$\text{Previous year's population} + (\text{consumption for given year} - \text{previous year's consumption}) / \text{base year PCC}$$

The assumption that 90% of non-household properties would be measured by the end of AMP7 (2024/25), as planned for in SES Water's PR19 Business Plan, was also applied to the model.

Further details of the values used and outputs are presented in Section 8.1.2 of the Demand Forecast Updates for the WRSE Regional Plan in Level 2 Appendix D of this report.

## 4.2.2. Consumption

As previously mentioned in Section 3, Artesia Consulting produced a consumption forecast for SES Water for measured and unmeasured non-households. Three scenario forecasts (Lower, Central and Upper) as well as a baseline forecast were produced. Exact details on how this consumption data was included in the model is provided in the Demand Forecast Updates for the WRSE Regional Plan report in Level 2 Appendix D of this reportLevel 2 Appendix D.

It was decided that the baseline forecast should be used from 2019/20 to 2024/25 and from 2025/26 the central forecast should be used. The reason for using the baseline forecast and the central forecast was because in the central forecast there was an unexplained dip in the measured non-household consumption after the base year, which corrects itself by 2025/26.

## 4.3. Other demand components

Various other components of the model were updated. The following sections provided details of the components which were updated.

### 4.3.1. Leakage

Base year leakage figures were extracted from SES Water's 2019/20 WRMP Annual Review.

According to the WRPG, total leakage should remain constant "from 2025/26 [...] from the start of your plan to the end of the planning period". Therefore, in the model leakage remains constant from the first year of AMP8 (2025/26). Leakage values for the start of AMP8 were extracted from SES Water's Final WRMP19 and these values remain constant through to 2099/00. Between the base year (2019/20) and the start of AMP8 (2025/26) SES Water's 2019/20 Annual Review leakage values have been linearly interpolated. The leakage values used in the model are presented in Table 4-5.

**Table 4-5 - Leakage values**

Component	2019/20 (Base year)	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26
	MI/d						
Measured Non-household - USPL	0.18	0.19	0.20	0.21	0.22	0.22	0.23
Unmeasured Non-household - USPL	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Measured household - USPL	3.41	3.60	3.78	3.97	4.15	4.34	4.52
Unmeasured household - USPL	4.35	3.77	3.18	2.60	2.01	1.43	0.84
Void Properties – USPL	0.41	0.36	0.32	0.27	0.22	0.18	0.13
Distribution Losses	15.52	15.27	15.01	14.76	14.51	14.25	14.00

Total leakage	23.94	23.25	22.56	21.86	21.17	20.48	19.79
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### 4.3.2. Water taken unbilled

Water taken unbilled was extracted from SES Water’s 2019/20 WRMP Annual Review. A figure of 2.01 MI/d has been used for the base year and this remained constant throughout the baseline forecast.

### 4.3.3. Distribution System Operational Use

Distribution System Operational Use has been extracted from SES Water’s 2019/20 WRMP Annual Review. A figure of 2.73 MI/d has been used for the base year and this remains constant throughout the baseline forecast.

### 4.3.4. Climate change

The climate change factors used in the model were those detailed in Artesia’s 2017 report<sup>6</sup> which states:

“Climate change impacts on consumption have been calculated in accordance to UKWIR 13/CL/04/12 Impact of Climate Change on water demand. Median percentage climate change impacts on household demand at 2040, relative to 2012 are published for each river basin within the UK. SES Water sits entirely within the Thames basin. Therefore, the dry year annual average forecasts have a 0.88% increase in consumption over that period. As the base year is now 2015/16 and the final forecast year is 2044/45 the percentage change is shifted along as there has been no further evidence since this report. However, as the forecast period with the base year set at 2015/16 is one year longer the final percentage is slightly larger than the figure printed in the guidance. If the forecast were to be run under a critical period scenario the percentage affected by climate increases from 0.88% to 2.40%. When critical period is selected the appropriate climate change factor is applied in a linear fashion across the forecast period.”

These factors were reviewed with reference to the following guidance, which are referred to in the draft WRPG:

- UKWIR (2009) Assessment of the Significance to Water Resource Management Plans of the UK Climate Projections 2009,
- UKWIR (2013) Impact of Climate Change on Water Demand.

The review showed that no changes were required to the climate change factors used in the model.

## 4.4. Consumption uplift factors

The model includes varies consumption uplift factors, these were revised following latest guidance and incorporated into the model. The following sections outline the factors which were revised, and the methodology used for these revisions. The final revised factors are presented in Table 4-6.

### 4.4.1. Normal and dry year factors

Using the methodology from the UKWIR guidance report number 15/WR/02/9 – household consumption forecasting<sup>7</sup> the consumption uplift factors for Normal Year Annual Average (NYAA) and Dry Year Annual Average (DYAA) were re-calculated. Further details of the stages of the re-calculations are provided in section 10.1 of the Demand Forecast Updates for the WRSE Regional Plan report in Level 2 Appendix D. The revised DYAA and NYAA factors incorporated into the model are presented in Table 4-6.

### 4.4.2. Critical period factor

Using the methodology stated in the UKWIR report Peak Water Demand Forecasting Methodology<sup>8</sup> which is the guidance the WRPG states should be followed, a revised critical period factor has been calculated. Further details of the stages of the re-calculations are provided in section 10.1 of the Demand Forecast Updates for the WRSE Regional Plan report in Level 2 Appendix D of this report. The revised critical period factor incorporated into the model is presented in Table 4-6.

<sup>6</sup> Artesia, 2017. WRMP19 Household consumption forecast: Baseline forecast Final.

<sup>7</sup> UKWIR, 2016, WRMP19 Methods – Household Consumption Forecasting

<sup>8</sup> UKWIR, 2006, Peak Water Demand Forecasting Methodology

### 4.4.3. 1 in 200 and 1 in 500 drought event factors

The peak week factors for 1 in 200 and 1 in 500 drought events were generated by Artesia Consulting and provided in the WRSE Dynamic demand analysis, Phase 2 report (reference: AR1408)<sup>9</sup>. The WRSE Dynamic demand analysis, Phase 2 explored different peak metrics using two data sets: Series 2 DI data and Series 3 DI data. It was agreed that the peak week metrics generated using the Series 3 data set should be used in the demand forecast.

The 1 in 200 and 1 in 500 drought event factors incorporated into the model are presented in Table 4-6.

**Table 4-6 - Summary of factors applied in the household forecast**

Factor	Value
NYAA (measured)	0.9943
NYAA (unmeasured)	1.0429
DYAA	1.0849
DYCP	1.4735
1 in 200	1.260*
1 in 500	1.290*

\*Series 3

## 4.5. WRSE outputs

WRSE provided SES Water with the Data Landing Platform (DLP) template. The model was used to populate the BL Demand worksheet in the DLP template. The BL Demand worksheet included a list of demand components. These components needed to be populated for a number of run scenarios and growth forecasts.

To populate the demand components of the DLP template an additional worksheet was added to the model (called 'WRSE outputs'). This worksheet included the 24 components from the BL Demand worksheet and covered the planning period (2019/20 to 2099/00). For every year of the planning period each component was linked to the corresponding output cell(s) of the model, which are in the 'Scenario selection & outputs' worksheet of the model. The calculated distribution input was originally calculated by adding the various demand components together with the consumption attributed to climate change although it was subsequently (June 2023) realised that the latter was already accounted for in the other components and so was removed from the DI calculation in the latest models used for WRSE investment model runs (SES Water MC HHCF Model v4.19.1.1 onwards). The WRSE outputs worksheet automatically populated with the output data from the model.

Switches were included in the model to allow the user to select the required model run in order to populate the various run scenarios and growth forecasts required in the DLP template.

For each run scenario and growth forecast the data in the 'WRSE outputs' worksheet needed to be manually copied in the corresponding rows of the 'BL Demand' worksheet in the DLP template which would be submitted.

<sup>9</sup> Artesia, February 2021, WRSE Dynamic demand analysis, Phase 2

## 5. 2022 model updates

In April 2022 a new version of the DLP template was issued which included additional components on smart meter installations and the number of household properties. This meant additional data on smart meter installations needed to be incorporated into the model and amendments were required to the 'WRSE outputs' worksheet to capture these new components.

There was also a request from SES Water to update the population and property forecast scenarios and incorporate new consumption uplift factors. The following sections describe the updates made to the model.

### 5.1. Smart meters

The following components were added to the model:

- Total household smart Meters.
- Automated Meter Infrastructure (AMI) - upgrades from basic or AMR meters (household).
- Basic (non-automated) meter installations (non-household).
- Automated Meter Reading (AMR) - installations (non-household).
- Automated Meter Infrastructure (AMI) - installations (non-household).

These components were calculated in a new worksheet in the model called 'WRSE output calc'. The 'WRSE outputs' worksheet was also updated in the model to include these new components.

The following sections describe the assumptions and data used to calculate these components. The components have been separated into household and non-household.

#### 5.1.1. Household

SES Water requested application of the following assumptions when calculating the household smart meter components:

- There will be no smart meters installed until 2023/24.
- In 2023/24 2% of total measured properties will have smart meter installed.
- In 2024/25 5% of total measured properties will have a smart meter installed.
- From 2025/26 all new build properties, meter optants, compulsory metering properties will have a smart meter installed.
- From 2025/26 all meter exchanges will be smart (AMI).
- Meter exchanges will be based on basic meters having a 12-year life span (i.e. basic meters are exchanged 12 years after installation).
- From 2025/26 1/12 of the remaining households with a basic meter will be exchanged annually until all basic meters are upgraded to AMI.

Table 5-1 shows how each household component was calculated, including the data sources used and assumptions applied.

**Table 5-1 - Household smart meter components**

Component	Year(s)	Calculation description
Total household smart Meters (cumulative including existing)	2023/24	Assume 2% of total household measured properties (excluding voids) have a smart meter. Calculated using total measured household - properties (excluding voids) from the 'Scenario selection & outputs' worksheet.
	2024/25	Assume 5% of total measured properties (excluding voids) have a smart meter.

Component	Year(s)	Calculation description
		Calculated using total measured household - properties (excluding voids) from the 'Scenario selection & outputs' worksheet.
	2025/26 onwards	<p>Assume all new build properties, meter optants, compulsory metering properties, metering on change of occupancy properties, selective metering properties and other changes to existing metering properties will have a smart meter installed.</p> <p>The cumulative smart meter installations since the start of the planning periods (excluding upgrades) are calculated. This is then added to the meter upgrades to give the total household smart meters (cumulative including existing).</p> <p>Calculated using total measured household - properties (excluding voids), New build properties – properties, Meter optants – properties, Compulsory metering – properties, Metering on change of occupancy – properties, Selective metering – properties and Other changes to existing metering – properties from the 'Scenario selection &amp; outputs' worksheet.</p>
Automated Meter Infrastructure (AMI) – upgrades from basic or AMR meters (household).	2019/20 to 2024/25	Assume no upgrades to AMI (smart meter).
	2025/24 to 2036/37	<p>The number of existing measured properties remains constant throughout the planning period.</p> <p>The smart meter installations in 2023/24 and 2024/25 and the number new build properties, optant properties and compulsory metering properties in 2025/26 have been subtracted from the existing measured properties values to give the number of existing measured properties with a basic meter in 2025/26. This has then split evenly across the next 12 years.</p> <p>Calculated using total measured household - properties (excluding voids), New build properties – properties, Meter optants – properties, Compulsory metering – properties, Metering on change of occupancy – properties, Selective metering – properties and Other changes to existing metering – properties from the 'Scenario selection &amp; outputs' worksheet.</p>
	2037/38 onwards	All existing metered properties will have a smart meter installed by 2036-37 so upgrades are zero from this date onwards.

### 5.1.2. Non-household

SES Water requested application of the following assumptions when calculating the non-household smart meter components:

- From 2025/26 all meter installations are AMI.
- From 2019/20 to 2024/25 assume 80% of meter installations are basic and 20% are AMR.

Table 5-2 shows how each household component was calculated, including the data sources used and assumptions applied.

**Table 5-2 - Non-household smart meters**

Comment	Years	Description
Basic (non-automated) meter installations (non-household)	2019/20	Assume zero as no previous year data to calculate the number of new non-household properties.
	2020/21 to 2024/25	The number of new non-household properties each year has been calculated. If the number of new non-households is negative, then it has been assumed to be zero. Assume 80% of the new non-household properties will have a basic meter installed. Calculated using Measured non-households – properties in the ‘Scenario selection & outputs’ worksheet.
	2025/26 onwards	All meter installations will be AMI (smart) so zero basic meter installations.
Automated Meter Reading (AMR) - installations (non-household)	2019/20	Assume zero has no previous year data to calculate the number of new non-household properties.
	2020/21 to 2024/25	The number of new non-household properties each year has been calculated. If the number of new non-households is negative, then it has been assumed to be zero. Assume 20% of the new non-household properties will have a basic meter installed. Calculated using Measured non-households – properties in the ‘Scenario selection & outputs’ worksheet.
	2025/26 onwards	All meter installations will be AMI (smart) so zero basic meter installations.
Automated Meter Infrastructure (AMI) - installations (non-household)	2019-20 to 2024/25	All meter installation during this period will be basic or AMR so there will be zero AMI installations.
	2025-26 onwards	The number of new non-household properties each year has been calculated. If the number of new non-households is negative, then it has been assumed to be zero. Assume all new non-household properties will have an AMI installation. Calculated using Measured non-households – properties in the ‘Scenario selection & outputs’ worksheet.

## 5.2. Household properties

The following components were included in the new DLP template:

- New build properties – properties
- Meter optants – properties
- Compulsory metering – properties
- Metering on change of occupancy – properties

- Selective metering - properties
- Other changes to existing metering - properties

These components are already calculated in the model and outputs presented in the ‘Scenario selection & outputs’ worksheet. The ‘WRSE outputs’ worksheet was updated to include these new components and the components were linked to the relevant cells in the ‘Scenario selection & outputs’ worksheet.

### 5.3. Population and property forecasts

As well as the growth forecasts already included in the model (see section 4.1.2.2) two additional growth forecasts were incorporated into the model. These forecasts were taken from the data supplied by Edge Analytics for the 2020 model updates (see Level 2 Appendix A of this report).

The following two growth forecasts were incorporated into the model:

- ONS18-Central Projection (referred to as ‘Principle’ projection (ONS18-P) in Edge Analytic data spreadsheet).
- Housing-Plan-P with OxCam

Table 5-3 provides a list of the revised scenarios included in the model and the growth forecasts which match these scenarios.

**Table 5-3 - Selected growth forecasts for SES Water**

Scenario	Selected growth forecast for SES Water
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H
Owat Common Reference Scenario	ONS-18-P
OxCam 1a, 1b, 2a and 2b	Housing-Plan-P with OxCam

### 5.4. Consumption uplift factors

SES Water requested that 1 in 200 Annual Average (AA) and 1 in 500 AA consumption uplift factors were incorporated into the model. These uplift factors were provided by Artesia Consulting. The uplift factors used were generated using the Series 3 data set. Section 4.4.3 provides further information on the Series 3 data set. Table 5-4 shows the factors which were incorporated into the model. These factors were incorporated into the model in the ‘Base year’ worksheet where the existing uplift factors are included. The model was updated so these new factors can be selected in the ‘Scenario selection & outputs’ worksheet in the same way the existing consumption uplift factors can be selected.

**Table 5-4 - Uplift factors**

Factor	Value
1 in 200 Annual Average	1.024
1 in 500 Annual Average	1.028

## 6. 2023 model updates

In February 2023 SES Water requested the following updates to the model:

- Re-base to 2021/22.
- Incorporate revised household population and property forecasts supplied by Edge Analytics (see Level 2 Appendix A of this report).
- Revise the 'Scenarios selection and outputs' worksheet to align to the latest WRMP table formats.

Re-basing the model included a review of all model components to update year profiles, re-direct relevant formulas and insert updated data. However, only data relating to households was updated. No updates to non-household data were included in this update. These updates are documented in Section 6.1.

Several further amendments to the model were requested in April/May 2023 to provide an alternative, more realistic meter penetration scenario. These were amendments to the following:

- Water efficiency savings.
- Meter penetration.
- Smart meter installations.
- When metering savings are effective.

These amendments all related to household components of the model. No amendments were made to the non-household components of the model. Section 6.2 provides further details of these amendments.

### 6.1. February model updates

The model was re-based to 2021/22 from 2019/20 and new population and property forecasts incorporated into the model. Re-basing the model included a review of all model components to update year profiles, re-direct relevant formulas and insert updated data. The following sections described the data used and any assumption applied when re-basing the model and incorporating new population and property forecasts.

#### 6.1.1. Re-base 2021/22

To re-base the model data was extracted from:

- SES Water's 2021/22 Annual Review
- SES Water's 2020/21 Annual Review
- Population forecast supplied by Edge Analytics
- SES Water's draft WRMP24 Tables.
- SES Water's 2021/22 Post-Maximum Likelihood Estimation (MLE) Water Balance.

How this data is applied in the model has previously briefly been discussed in section 4.1.1 and is also documented in the following the Demand Forecast – 2021-22 rebase update for WRSE Technical Note in Level 2 Appendix C of this report. It should be noted that hidden and transient population data was not updated.

The number of measured properties in each of the following categories: new properties; properties opting for a meter in-year (optants); and properties metered on change of occupancy was determined using SES Water's draft WRMP24 Tables.

The model generates household consumption through micro-component modelling. Further details on how the model does this is provided in the following report: WRMP19 Household consumption forecast: baseline forecast – Level 2 Appendix C of this report. The micro-component modelling results generated by the model are calibrated to base year household consumption data extracted from SES Water's 2021/22 Post-Maximum Likelihood Estimation (MLE) Water Balance.

#### 6.1.2. Population and property forecasts

Updated property and population growth forecasts for SES Water were supplied by Edge Analytics, see Level 2 Appendix A of this report. These forecasts were published in February 2023.

Forecasts were produced for a wide range of scenarios, by using a combination of trend, housing-led (incorporating housing need, housing requirements and actual planned scenarios) and employment-led

forecasts, to account for the considerable uncertainty in the projections. From the range of scenarios, there was the need to adopt one as a baseline growth forecast, supported by a selected number of additional growth projections that allows SES Water to account for uncertainty. WRSE agreed on consistent property and population growth scenarios for companies across the region to base their demand forecasts on. Further details on the forecasts used in the model are provided in sections 6.1.3 and 6.1.4

### 6.1.3. Baseline forecast

For the baseline forecast the same scenario as selected for the 2020 model update was selected (Housing-Plan-P). The description of this scenario is as follows:

*A Housing-led scenario, with population growth underpinned by each local authority's Local Plan housing growth trajectory. Following the final year of data, projected housing growth in non-London areas returns to the average of ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.*

The scenario was updated using the February 2023 forecast supplied by Edge Analytics.

### 6.1.4. Growth scenarios

The following growth scenarios forecasts were incorporated into the model and replaced the previous growth forecast incorporated into the model in 2020.

- OxCam-1a-r-P
- ONS-18-Rebased-L
- Housing-Need-H
- ONS-18-Rebased-P
- OxCam 1a-P

### 6.1.5. Incorporating company policy/funded metering assumptions

As explained in Section 4.1.4, SES Water has an ODI linked to household PCC. The target PCC is achieved through metering savings and water efficiency savings. With the model rebased to 2021/22 it was necessary to amend the water efficiency savings to achieve the target PCC. The revised water efficiency savings applied in the model are presented in Table 6-1. The table shows the original savings applied in 2020 and the revised savings.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25) and have been applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into per capita consumption by dividing by the total population.

**Table 6-1 - Water efficiency savings**

	Water efficiency saving (%)		
	Taps	External use	Shower
Original saving	1.5	3.5	0
Revised saving	6.5	10.5	3.5

## 6.2. April/May model updates

### 6.2.1. Incorporating company policy/funded metering assumptions

As outlined in section 4.1.4, SES Water has an ODI linked to household PCC. The target PCC is achieved through metering savings and water efficiency savings. The water efficiency savings were amended in 2023 (see section 6.1.5). However, SES Water requested that the water efficiency savings originally included in the model should be re-instated. Therefore, the water efficiency savings included in the model are as follows:

- A saving of 1.45% was applied to taps.

- A saving of 3.5% was applied to external use.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25) and have been applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into per capita consumption by dividing by the total population.

## 6.2.2. Metering

### 6.2.2.1. Meter penetration

SES Water's universal metering programme was at 72% for households in 2022/23 and is predicted to reach 85% by 2024/25. SES Water requested this predicted metering percentage is reflected in the model. In addition to there being 85% meter penetration by 2024/25, SES Water also requested that two thirds of this should occur in 2024/25 i.e. meter penetration in 2023/24 should be approximately 76.3%.

To achieve these meter penetration percentages in the model the optant properties and properties metered on change of occupancy (which includes compulsory metering) were adjusted so that the total number of the total number of properties across the plan remained consistent but the required metering penetration targets were achieved. The forecast for new connections was not amended as this is linked to the property forecast from Edge Analytics.

For properties opting for a meter the resultant projection suggests a peak in 2024/25 which could possibly be a result of media campaigns, followed by a drop to a background decreasing level.

For properties metered on change of occupancy the resultant projection suggests a big push on compulsory metering by SES Water in 2024/25 followed by a sharp reduction prior to stopping the policy.

The Demand Forecast – 2021-22 rebase update for WRSE Technical Note in Level 2 Appendix E provides further details of the resultant property projections for each category of properties.

### 6.2.2.2. Smart meters

As previously mentioned in Section 0 the model was updated to include data on the number of smart meters installed.

SES Water requested the following assumption was included in the model:

- 20,000 smart meters will be installed in the last year of AMP7 (2024/25).

Previous assumptions on the installation of smart meters on household properties were removed and replaced with 8.037% of total measured properties being smart metered in 2024/25 under the baseline forecast. Under alternative forecast scenarios the exact figure of smart meters is not always 20,000.

### 6.2.2.3. Metering delay

SES Water identified they have a year's delay between a meter being installed to metered rates being effective (following initial billing for about 10,000 household properties). SES Water is aiming to reduce this, but requested this delay is reflected in the model as it will impact consumption. However, following consideration and further discussions with SES Water it was agreed that the savings achieved through metering, for all household properties, are likely to occur over a number of years. There is likely to be an immediate change to consumption (a reduction) due to an awareness that the customer is being charged for what they use and then a possible further reduction in consumption after seeing their first metered bill a year later. There could even potentially be further reductions with subsequent bills. As SES Water does not have any specific data on when exactly metering savings are achieved it was decided the clearest and readily auditable method would be to incorporate into the model a 1-year delay in the impact of metering for all household properties. As well as taking into account that the full impact of metering on consumption is likely to spread across installation date and receipt of the first few bills this approach also takes into account the fact that not all meters are installed at the start of the year.

Further details on how the updates were incorporated into the model are provided in The Demand Forecast – 2021-22 rebase update for WRSE Technical Note in Level 2 Appendix E of this report Level 2 Appendix E.

## 7. Summary

SES commissioned Atkins to implement various updates to its household consumption forecast model between 2020 and 2023 to allow it to produce a demand forecast for the WRSE regional plan and WRMP24.

The main updates to the model included:

- Re-basing the model, initially to 2019/20 and then to 2021/22.
- Updating population and property forecasts with data produced by Edge Analytics.
- Incorporating SES Water's AMP7 metering and water efficiency strategies.
- Updating external micro-component data.
- Calculating consumption uplift factors and incorporating these and drought event uplift factors produced by Artesia Consulting into the model.
- Incorporating non-household consumption data into the model and developing a non-household property and population forecast which was incorporated into the model.
- Updating other components of baseline demand within the model such as water taken unbilled and leakage.
- Incorporating smart metering assumptions for households and non-households.

To allow outputs of the model to be shared with WRSE, the DLP template was incorporated into the model as an additional worksheet which automatically populated with the output data from the model.

Three versions of the model have been created. These versions include different combinations of demand management savings and different climate change factors for DYAA and DYCP. The latest versions of the model are:

- SES Water MC HHCF Model v4.19.1.1.
- SES Water MC HHCF Model v4.20.2.
- SES Water MC HHCF Model v4.20.3.

A brief explanation about each version of the model is provided in the following sections.

### 7.1. SES Water MC HHCF Model v4.19.1.1

This version of the model includes baseline demand management with DYAA linearly interpolated/extrapolated climate change factor of 0 in 2012 to 0.88 in 2040 applied to by DYAA and DYCP scenarios in 2040.

In this version of the model water efficiency savings have been applied, which means by the end of AMP7 SES Water meets its target PCC of 136.8 litres per head per day for NYAA and 148.5 litres per head per day for DYAA. The water efficiency savings included in this version of the model are:

- A saving of 6.5% applied to taps.
- A savings of 10.5% applied to external use.
- A saving of 3.5% applied to showers.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25). Further information on these water efficiency savings can be found in sections 4.1.4 and 6.1.5.

### 7.2. SES Water MC HHCF Model v4.20.2

This version of the model is an alternative demand forecast (i.e. alternative profile of demand savings) with DYAA linearly interpolated/extrapolated climate change factor of 0 in 2012 to 0.88 in 2040 applied to by DYAA and DYCP scenarios.

In this version of the model the water efficiency savings applied to allow SES Water to meet its target PCC have been converted back to the water efficiency savings originally included in the model when it was updated in 2020. The water efficiency savings included in this version of the mode are:

- A saving of 1.45% applied to taps.
- A saving of 3.5% applied to external use.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25). Further information on these water efficiency savings can be found in sections 4.1.4, 6.1.5 and 6.2.1.

SES Water's latest metering assumptions have also been applied in this version of the model. These include:

- SES Water's latest metering penetration prediction. SES Water predict its universal metering programme will reach 85% by 2024/25 and two thirds of this will occur in 2024/25 i.e. meter penetration in 2023/24 should be approximately 76.3%.
- An assumption that 20,000 smart meters will be installed in the last year of AMP7 (2024/25).
- Incorporating a 1-year delay in the impact of metering for all household properties.

Further information on these metering assumptions can be found in section 6.2.2.

### 7.3. SES Water MC HHCF Model v4.20.3

This version of the model is an alternative demand forecast with climate change formula corrected so it applies the larger 2.4 climate change factor to the DYCP scenario in 2040 rather than the DYAA factor that is applied to both in v4.19.1.1 and v4.20.

In this version of the model the water efficiency savings applied to allow SES Water to meet its target PCC have been converted back to the water efficiency savings originally included in the model when it was updated in 2020. The water efficiency savings included in this version of the mode are:

- A saving of 1.45% applied to taps.
- A saving of 3.5% applied to external use.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25). Further information on these water efficiency savings can be found in sections 4.1.4, 6.1.5 and 6.2.1.

SES Water's latest metering assumptions have also been applied in this version of the model. These include:

- SES Water's latest metering penetration prediction. SES Water predict its universal metering programme will reach 85% by 2024/25 and two thirds of this will occur in 2024/25 i.e. meter penetration in 2023/24 should be approximately 76.3%.
- An assumption that 20,000 smart meters will be installed in the last year of AMP7 (2024/25).
- Incorporating a 1-year delay in the impact of metering for all household properties.

Further information on these metering assumptions can be found in section 6.2.2.

# WRMP Level 2 Appendices of WRMP Level 1 Appendix C

This document, Demand Forecasts, is the Level 1 Appendix C of SES Water's WRMP.

This document has its own, Level 2, Appendices which are presented over the following pages.

# Level 2 Appendix A. Population Growth Forecast



# Population & Property Forecasts

Methodology & Outcomes

July 2020



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## Acknowledgements

Demographic statistics used in this report have been derived from data from the Office for National Statistics, licensed under the Open Government Licence v.3.0.

Note: throughout this document the term 'forecast' is used as a generic term to encapsulate the range of trend projections and plan-led forecasts presented in the analysis.

*The authors of this report do not accept liability for any costs or consequential loss involved following the use of the data and analysis referred to here; this is entirely the responsibility of the users of the information presented in this report.*



# Contents

Acknowledgements.....	i
Contents.....	ii
1 Introduction.....	1
Context.....	1
Regulatory Guidance .....	1
This Document.....	3
2 Framework & Data Inputs.....	4
Forecasting Framework .....	4
Water Company Data .....	5
Demographic Data & Assumptions.....	6
Population.....	6
Fertility & Mortality .....	6
Migration .....	6
Households & Properties.....	7
Labour Force & Jobs .....	7
Consilium Local Plan Data.....	8
3 Methodology .....	14
Forecasting Models.....	14
Scenario Development.....	16
ONS & GLA Trend Projections.....	16
ONS Projections .....	16
GLA Population Projections.....	19
Housing-led Forecasts.....	20
OxCam Arc Scenarios .....	22
Employment-led Scenarios .....	23
Long-term Scenarios.....	25
Macro- and Micro-level Alignment.....	25
4 Scenario Output.....	27
Understanding Limitations .....	27



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Outcomes 2020–2050.....	30
Outcomes 2020–2100.....	40
Appendix A Glossary of Terms.....	41
Appendix B Local Authority Status Log .....	42
Appendix C Projection Accuracy .....	45
Appendix D ONS & GLA Projections .....	46
(i) ONS National Projections.....	46
(ii) ONS vs GLA Projections Compared .....	47
Appendix E OxCam Geography .....	48

# 1 Introduction

## Context

- 1.1 The UK is at a watershed moment in its political, economic and demographic history. The country's decision to exit the European Union (EU) and the electoral mandate given to the new government, has been quickly followed by the unprecedented impact of the Coronavirus pandemic. Predicting when and how the UK recovers from the current crisis and the economic and demographic futures that will result, presents a real challenge. Amidst this uncertainty, the UK government has clearly stated its determination to accelerate the rate of house building, introducing targets and incentives to ensure that an aspirational objective of 300,000 new homes per year is achieved<sup>1</sup>.
- 1.2 Robust evidence on future housing growth and demographic change, are key components of the Water Resources Planning Guidelines (WRPG)<sup>2,3</sup>, issued by the Environment Agency (EA) and Natural Resources Wales, in collaboration with the Department for Environment, Food and Rural Affairs (Defra), the Welsh Government and Ofwat. These guidelines for the development of Water Resources Management Plans (WRMP) are now accompanied by similar documentation for the development of Drainage and Wastewater Management Plans (DWMP)<sup>4</sup>, for which housing and demographic evidence is of equal importance.
- 1.3 A key enhancement to previous WRMP cycles is the EA's development of a new national framework for water resource management, consisting of five regional water resource planning groups: Water Resources South East (WRSE), Water Resources East (WRE), Water Resources South West (WRSW), Water Resources West (WRW) and Water Resources North (WRN). Evidence on future housing and population growth are critical to the collective business planning process, informing each region's Statement of Regional Resource Position (SRRP) and the WRMP24 statements of each member of the regional alliances.

## Regulatory Guidance

- 1.4 The WRPG provides a framework for water companies to follow when developing and presenting their WRMPs. The guidelines summarise the key requirements for population, property and occupancy forecasts that feed into WRMP evidence, emphasising the importance of using housing growth evidence from Local Plans:

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<sup>1</sup> [MHCLG, Planning for the Future \(March 2020\)](#)

<sup>2</sup> [Water Resources Planning Guideline \(May 2016\)](#)

<sup>3</sup> [Water Resources Planning Guideline, Interim Update \(July 2018\)](#)

<sup>4</sup> [Drainage and Wastewater Management Plans \(September 2019\)](#)

*“For companies supplying customers wholly or mainly in England you will need to base your forecast population and property figures on local plans published by the local council or unitary authority.” (section 5.3)*

1.5 The WRPG acknowledges that councils may be at different stages of Local Plan development but states if a local council has:

- *“...a published adopted plan that is not being revised, you must take account of the planned property forecast. You will need to ensure your planned property forecast and resulting supply does not constrain the planned growth by local councils. If you adjust the planned property forecast and select a higher number, you will need to justify why you have selected a higher forecast and provide evidence.*
- *published a draft plan but it has not yet been adopted you must take account and use this as the base of your forecast. You should discuss with your local council whether it expects to make changes to the forecast for the adopted plan*
- *not started or published a draft plan you should use alternative methods such as household projections from Department of Communities and Local Government or derive your own analysis using methodologies outlined in UKWIR (2016) Population, household property and occupancy forecasting” (section 5.3)*

1.6 The WRPG highlights a number of additional requirements concerning the data inputs and assumptions used in the development of population, property and occupancy forecasts. It requests that water companies should:

- *“Clearly describe the assumptions and supporting information used to develop population, property and occupancy forecasts. You should demonstrate you have incorporated local council information (particularly in relation to their published adopted local plans) in England.*
- *explain the methods you have used to forecast property figures after the planning period used by local councils (for example from years 15 to 25 in the planning period).*
- *demonstrate how you have included other sources of information and amended your forecast accordingly” (section 5.3)*

1.7 The WRPG makes explicit reference to the likely uncertainty associated with demographic forecasts, requiring water companies to:

- *“Clearly describe any limitations in your forecast*
- *Demonstrate that you understand the uncertainty associated with your forecasts*
- *Clearly explain the assumptions, risks and uncertainties associated with the results.*
- *If you are using a planning period beyond 25 years and are basing decisions on this forecast, you should explain the range of uncertainties this long-range forecast will have and how your plan will adapt to these.” (section 5.3)*

- 1.8 WRMP demographic evidence must include an indication of the size of the population not captured in published statistics, with the guidance requesting that water companies should:

*“explain the assumptions about how you have derived unaccounted population” (sect. 5.3)*

- 1.9 Finally, the WRPG requests that the methodology for allocation of population and property forecasts to Water Resource Zones (WRZs) is made explicit, requesting that water companies:

*“describe how you have allocated populations to the geographically different WRZs, e.g. using neighbourhood plans or census data to further subdivide the populations” (sect. 5.3)*

- 1.10 To support the WRPG demographic guidance, UKWIR has produced a suite of documents which provide advice on the development of population, property and occupancy forecasting.<sup>5</sup> The UKWIR documentation is in three forms: a **Guidance Manual**; a **Worked Example**; and a **Supplementary Report**. The latter includes a review of engagement with key industry stakeholders and a technical review of potential forecasting approaches that underpin the WRMP guidance methodology. The UKWIR Guidance Manual is not prescriptive in terms of methodological recommendations. It provides guidance on the issues that should be considered at each stage of development but provides scope for water companies to consider and apply methods they deem to be appropriate.

## This Document

- 1.11 Edge Analytics is a Data Science specialist, applying a combination of research, data, technology and analytical models to generate insight that better informs business planning and decision-making. Edge Analytics has a particular expertise in demographic modelling and forecasting and has developed a suite of products to meet the regulatory requirements for evidence-based planning in the water industry.
- 1.12 This document provides a guide to the **VICUS** methodology that has been used to configure and deliver housing and population growth evidence to the water industry’s new regional planning framework, informing WRMP and DWMP processes for individual water companies.
- 1.13 Section 2 provides an overview of the **VICUS** framework, plus a summary of the mix of data sources required to inform the forecasting process: a combination of water industry data, Local Plan housing evidence (**Consilium**), plus population and related demographic statistics.
- 1.14 Section 3 describes the forecasting methodologies employed to derive and present the suite of scenarios, at macro- and micro-level and for a horizon that stretches to 2100.
- 1.15 Section 4 summarises the format and content of the forecasting output that has been produced to inform the WRMP and DWMP planning process, at regional, WRZ and micro-scales.

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<sup>5</sup> [WRMP19 - Methods - Population, Household Property and Occupancy Forecasting \(December 2015\)](#)

# 2 Framework & Data Inputs

## Forecasting Framework

- 2.1 The VICUS forecasting framework for the configuration and delivery of population and property forecasts is illustrated below (Figure 1).

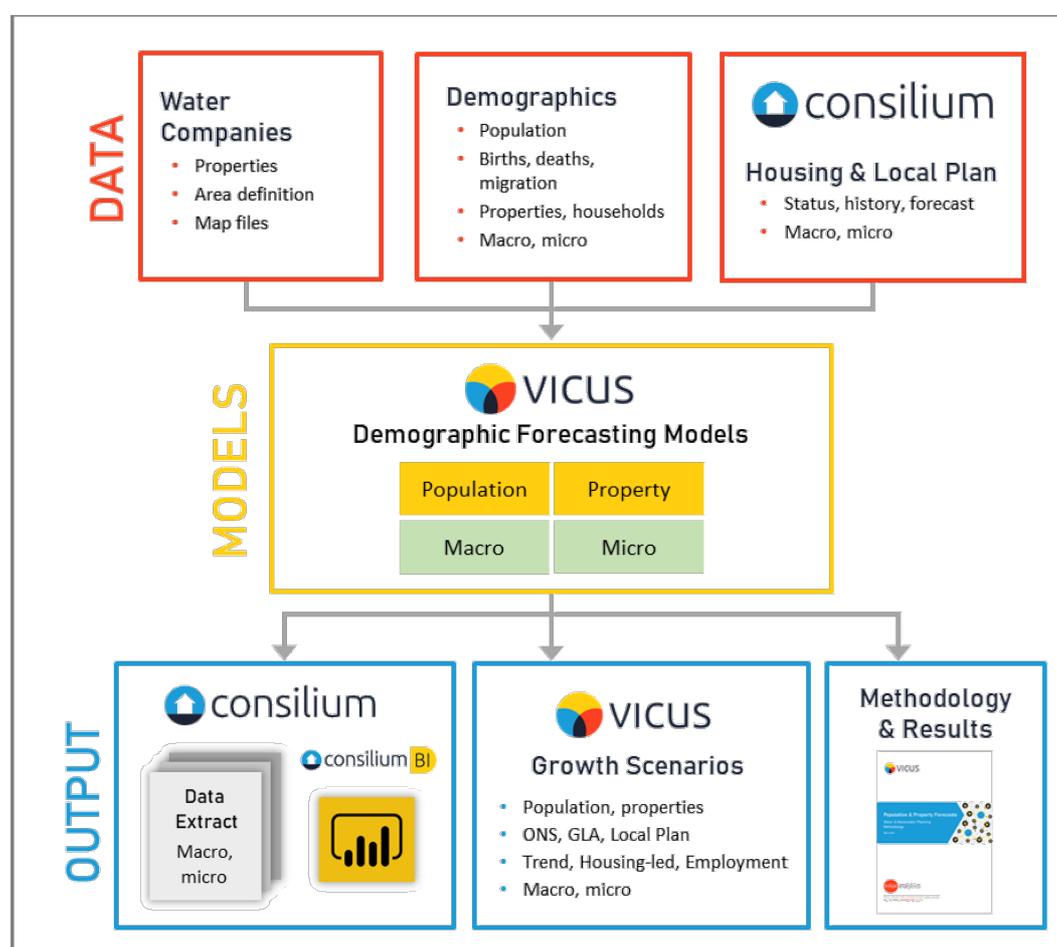


Figure 1: VICUS Forecasting Framework

- 2.2 Robust and timely data inputs are key to the forecasting process, including precise area definitions for water company geographies; Local Plan evidence from all local authorities; plus, historical and base-year demographic statistics on population, births, deaths, migration and properties.
- 2.3 The VICUS model combines all data inputs within best practice forecasting methodologies, enabling macro- and micro-level population and property growth scenarios to be derived under a wide range of assumptions, for scenario horizons that stretch to 2100.

- 2.4 The forecasting framework integrates key housing-led scenarios, alongside complementary evidence produced by the Office for National Statistics (ONS), the Greater London Authority (GLA) and the Welsh Government (WG).
- 2.5 Outputs from the process are delivered as (Microsoft Power BI) Dashboard summaries to encourage wider consumption; as detailed datasets to enable further scrutiny and analysis; and as documentation to ensure transparency and robustness of methodology.

## Water Company Data

- 2.6 Water company geographies do not conform to the administrative areas for which population and other demographic statistics are typically available (e.g. district, ward, output area), so area-matching is a critical component of the forecasting framework.
- 2.7 Boundary files have been provided by individual water companies, for Water Resource Zone (WRZ) geographies (Figure 2) and for a variety of other water and wastewater areas. The Royal Mail's Postcode Address File (PAF) has provided the postcode-level property distributions from which the detailed 'lookup' between water industry and administrative geography has been made, enabling population and property growth forecasts to be apportioned for WRMP and DWMP purposes.

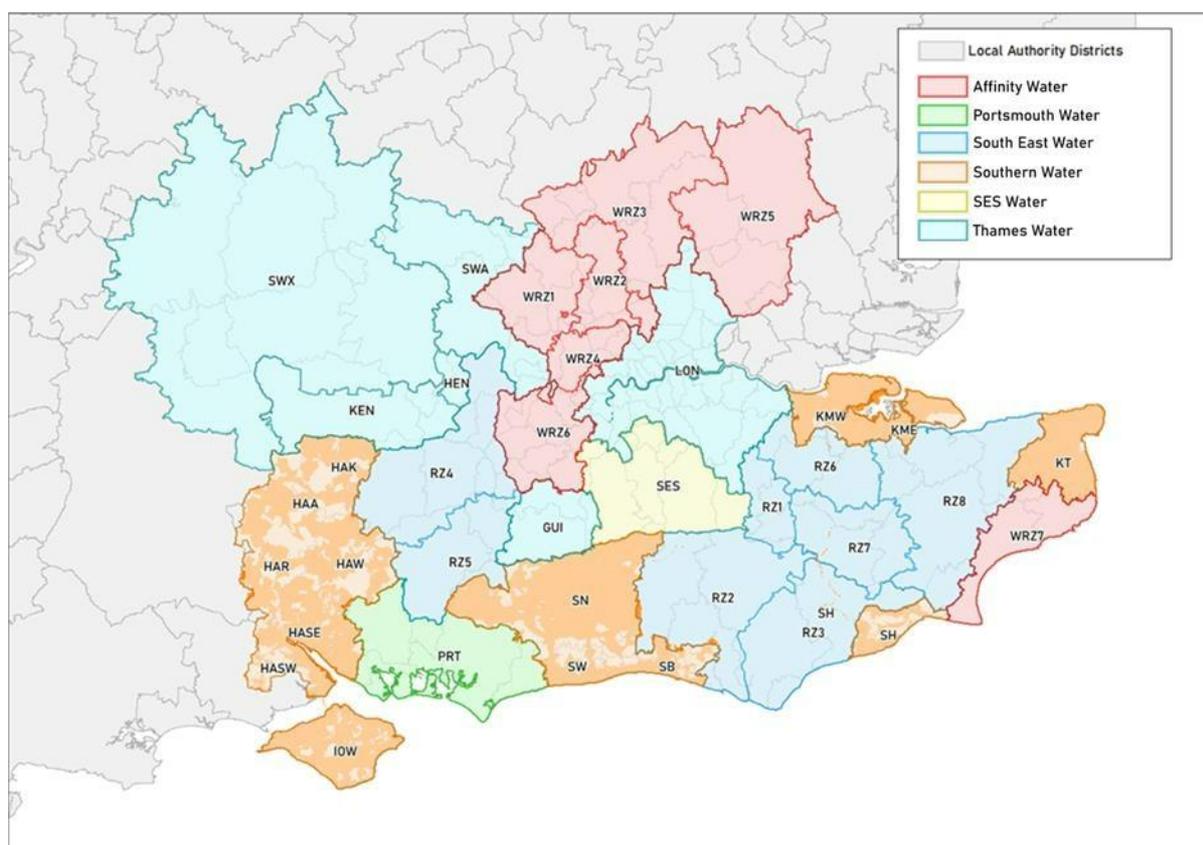


Figure 2: WRSE Water Resource Zone Geography

## Demographic Data & Assumptions

### Population

- 2.8 Data on *historical* population change are drawn from ONS mid-year population estimates (MYE). This data records population by single year of age (0–90+) and sex, with 2018 being the latest MYE available.
- 2.9 Successive ONS sub-national population projections (SNPP) have different base population (e.g. the 2018-based projections have a 2018 base year). For ease of comparison, the scenarios presented within the VICUS framework have been recalibrated to ensure a consistent 2018 base-year population.
- 2.10 In the formulation of its growth scenarios, the Greater London Authority (GLA) has produced a modified set of MYE for its London boroughs, taking account of issues associated with the incorrect treatment of children in estimated migration flows to and from individual boroughs.

### Fertility & Mortality

- 2.11 Historical statistics on births (by sex) and deaths (by age and sex) are drawn from the ONS MYE dataset. Age-specific fertility rates (ASFR) and age-specific mortality rates (ASMR) are derived from these historical birth and death statistics, in combination with area-specific population data.
- 2.12 Long term assumptions on changes in age-specific fertility and mortality are determined by the ONS National Population Projection (NPP) series, the latest of which is the 2018-based round of projections.
- 2.13 Forecasts of future births and deaths are based on the application of ASFR and ASMR schedules (and their associated long-term assumptions) to the changing ‘population-at-risk’ in an area.

### Migration

- 2.14 Historical statistics on both internal and international migration are drawn from the ONS MYE dataset, providing inflow and outflow data by five-year age group and sex.
- 2.15 Different scenarios apply different assumptions on the future impact of migration, typically drawn from the 2001–2018 historical time-period (e.g. 5-year history, 10-year history, 18-year history).
- 2.16 Forecasts of internal migration are based on the application of age-specific migration rate schedules to the changing ‘population-at-risk’ in an area. International migration is forecast as a fixed annual balance between emigration and immigration effects.
- 2.17 ONS and GLA scenario assumptions on migration are reproduced within the VICUS framework. Housing-led scenarios use migration as the balancing factor which matches population growth to planned changes to an area’s housing stock.

## Households & Properties

- 2.18 The household and dwelling (property) implications of each population growth trajectory are estimated through the application of household representative rates, communal population statistics and a dwelling vacancy rate.
- 2.19 A household representative rate is defined as the “*probability of anyone in a particular demographic group being classified as being a household representative*”. The household representative rates used in the VICUS framework have been drawn from the Ministry for Housing, Communities and Local Government’s (MHCLG) 2014-based household projection model, which is underpinned by the ONS 2014-based sub-national population projection.
- 2.20 Following the financial crash of 2007/08, there has been a reduction in the rate of household formation amongst young adults. In the housing-led scenarios presented within the VICUS framework, the potential for a return to higher rates of household formation amongst young adults is considered, returning household representative rates to their 2001 levels by 2039.
- 2.21 Forecasts of household and property numbers exclude the population 'not-in-households', i.e. those living in communal establishments<sup>6</sup>. These data are drawn from the MHCLG 2014-based household projections, using statistics from the 2011 Census. For ages 0–74, the number of people not-in-households in each age group is fixed throughout the forecast period. For ages 75–85+, the proportion of the population not-in-households is recorded, so the population not-in-households for ages 75–85+ varies across the forecast period depending on the size of the age-group population.
- 2.22 The relationship between household and properties is modelled using a 'vacancy rate', sourced from the 2011 Census.
- 2.23 All scenarios have been calibrated to ensure a consistent 2020 property total. The base year property total for each individual output area (OA) has been drawn from the Royal Mail’s PAF. As a validation step and to avoid inappropriately small property numbers, 494 OAs (out of a total of 181,408 in England & Wales) had their PAF address count total replaced with a 2011 Census dwelling count.

## Labour Force & Jobs

- 2.24 The relationship between population change and employment is modelled using key assumptions on economic activity, unemployment and commuting.
- 2.25 Economic activity (participation) rates are the proportion of the population that are actively involved in the labour force, either employed or unemployed and looking for work. For each area, economic activity rates by five-year age group (ages 16–89) and sex have been derived from Census statistics, with forecast adjustments made in line with the Office for Budget Responsibility’s (OBR) analysis of labour market trends in its 2018 Fiscal Sustainability Report<sup>7</sup>.

<sup>6</sup> Communal establishments include prisons, residential care homes, student halls of residence and certain armed forces accommodation.

<sup>7</sup> [OBR, Fiscal Sustainability Report 2018](#)

- 2.26 The unemployment rate is the proportion of unemployed people within the total economically active population. For each local authority area, historical unemployment rates are sourced from ONS model-based estimates, utilising data on unemployment benefit claimant counts.
- 2.27 A commuting ratio indicates the balance between the level of employment and the number of resident workers within a local authority area. A commuting ratio greater than 1.00 indicates that the size of the resident workforce exceeds the level of employment available in the area, resulting in a net out-commute. A commuting ratio less than 1.00 indicates that employment in the area exceeds the size of the labour force, resulting in a net in-commute.

## Consilium Local Plan Data

- 2.28 The development of growth forecasts to inform WRMP24 plans must be underpinned by evidence on Local Plan housing growth for those Local Planning Authorities (LPA) that overlap the WRZ geography. The Local Plan development process is often lengthy and complex, with each LPA at a different stage of plan development. MHCLG and Homes England continue to apply pressure to accelerate housing delivery, whilst the UK's exit from the EU and the current pandemic crisis, create considerable uncertainty regarding future economic and demographic change.
- 2.29 Edge Analytics' **Consilium** database has been developed to enable the collection, processing, organisation and delivery of Local Plan evidence, for all LPAs across the UK (including National Parks and Development Corporations). Data is collected at a macro level, providing Local Plan evidence for individual LPAs, and at micro level, providing site-specific housing growth locations.
- 2.30 Local Plan evidence comes in a variety of forms, with considerable variation between LPAs. The Consilium database has sought to bring order, coherence and consistency to the evidence, with a classification of housing documentation and statistics detailed below (Table 1). This classification reflects the format and content of LPA evidence and includes historical **completions**, housing **need**, housing **requirement**, housing **supply** and planned **delivery**.
- 2.31 For each LPA that falls within WRZ boundaries, Consilium provides a summary of all Local Plan housing evidence, presenting information on: Local Plan status; historical and planned housing growth trajectories (including LPA and MHCLG completion statistics); housing need; housing requirements and targets; plus housing growth locations (site data). Also included within Consilium is the MHCLG's Housing Delivery Test and the latest LPA 5-year land supply calculations.
- 2.32 The site data provides geocoded information on housing growth locations, the number of planned units and the likely phasing (timing) of development. This information is key to the configuration and calibration of the micro-level, 'bottom-up' forecasts.
- 2.33 A 'Status Log' indicating the date at which Local Plan information was last accessed for each LPA is provided in Appendix B.

Table 1: Consilium - Housing Data Classification

1	Completions	Historical housing completions (net), sourced from Local Authority data and the MHCLG (Live Table 122).
2	Local Housing Need (LHN)	Minimum housing need, as calculated using the MHCLG 'standard method', which is based on the 2014-based household growth projections, with an adjustment to account for affordability.
3	Objective Assessment of Need (OAN)	A measure of future need, as calculated by the planning authorities (used prior to the introduction of the LHN).
4	Requirement	As set out in the NPPF, the housing requirement (provision target) identifies the extent to which the identified need can be met over the plan period.
5	5 Year Supply	The 5-year land supply is a calculation of whether there is a deliverable supply of homes to meet the planned housing requirement over the next 5 years.
6	HLA	The land availability assessment is carried out by planning authorities to assess the availability, suitability and achievability of sites and broad locations for potential housing development.
7	Planned Delivery	Planning authorities should produce a trajectory of expected housing delivery over the plan period, with the anticipated rate of development for specific sites (where appropriate). Housing trajectories are often published as part of the Local Plan and are updated annually in monitoring/land supply reports.

2.34 Consilium data is sourced from published documentation/statistics or directly from Councils, if not readily available. All site data is converted to a standard Consilium format, with all housing growth sites given a geocode (if not provided by the original source information).

2.35 Accompanying the forecasting outputs, the following Consilium data is provided:

- MS Excel spreadsheets / database extracts
- All relevant Local Plan documentation
- GIS files of housing growth sites (where available)
- Consilium-BI Dashboard powered by Microsoft's Power BI technology.

2.36 Examples of the macro- and micro-level Consilium data extracts are provided (Figure 3, Figure 4), together with an example of the Consilium-BI area reports: 'Housing & Population Growth History' and 'Local Plan Status & Housing Growth' (Figure 5, Figure 6).



Consilium: Housing Growth Locations

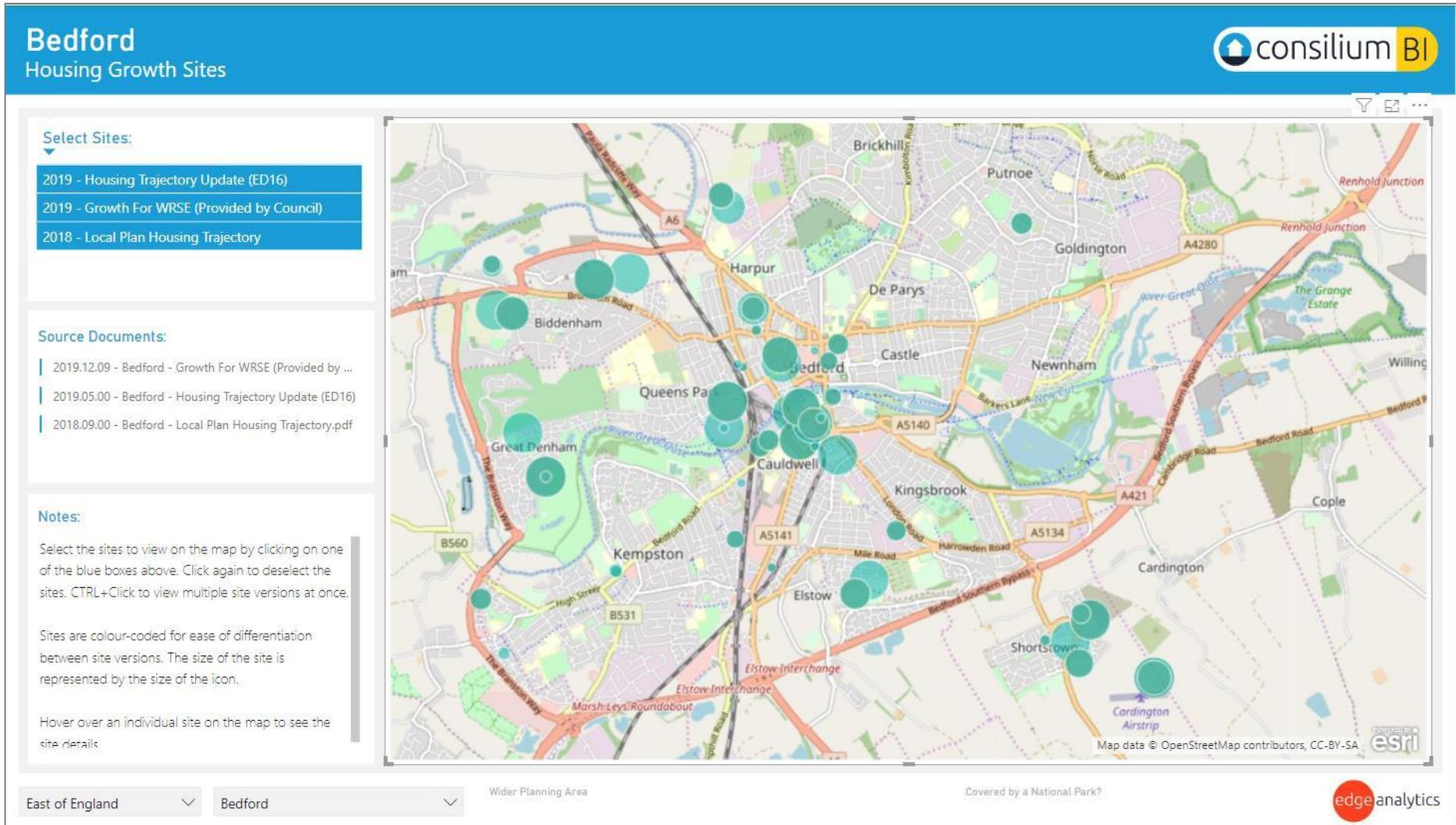


Figure 4: Consilium – Site Data – Example Only

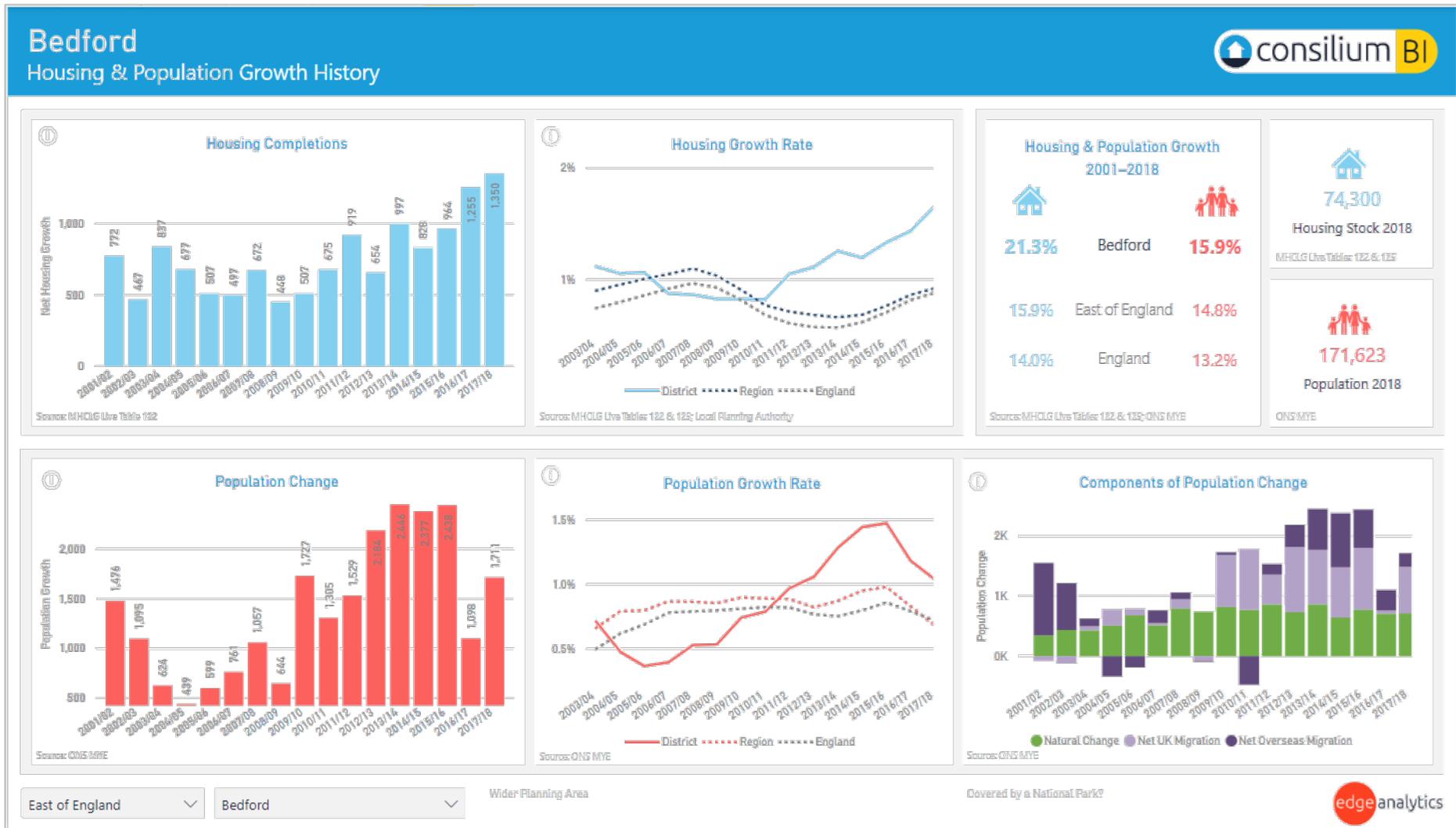


Figure 5: Consilium-BI Dashboard - Area History - Example Only

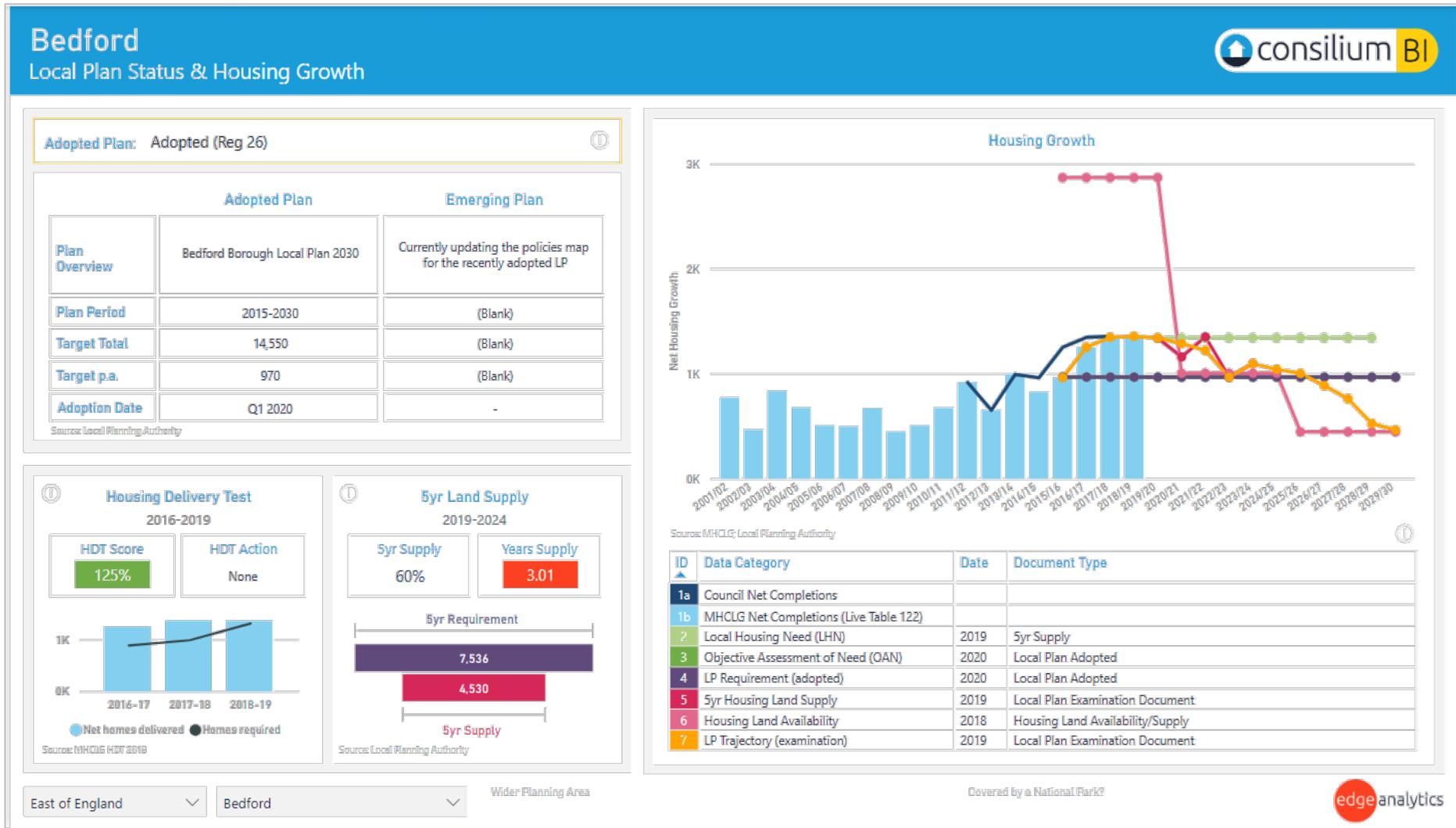

East of England
Bedford
Wider Planning Area
Covered by a National Park?

Figure 6: Consilium B- Dashboard – Local Plan Status – Example Only

# 3 Methodology

## Forecasting Models

- 3.1 The VICUS modelling framework combines a database of data inputs with a suite of forecasting software, enabling macro- and micro-level population and property growth scenarios to be derived under a wide range of assumptions, for scenario horizons that stretch to 2100 (Figure 1). The forecasting framework integrates housing-led scenarios, alongside trend projections which include published output from ONS, GLA and WG.
- 3.2 The key element of the framework is the cohort-component model, which uses fertility, mortality and migration components to derive population projections by single year of age, for each year of a (flexible) forecast period. The cohort-component method has a long and established history in demography and is widely used by national statistical agencies and the research community.
- 3.3 The household model and labour force models are separate software components, but they have a high degree of dependency upon population outputs from the cohort component model, enabling the derivation of property and employment forecasts.
- 3.4 The household model uses a combination of household representative rates, communal population statistics and a dwelling vacancy rate to estimate the household and dwelling (property) implication of each population growth trajectory.
- 3.5 The labour force model uses key assumptions on age-specific rates of economic activity (participation), unemployment and commuting, to estimate the relationship between population change and employment.
- 3.6 Importantly, the household and labour force models can be run in ‘housing-led’ or ‘employment-led’ mode, using pre-determined forecasts of housing or employment to estimate the likely population growth associated with each. Migration provides the balancing factor, altering population growth to meet annual housing or employment growth targets.
- 3.7 The ‘housing-led’ approach is particularly important in the evaluation of alternative trajectories of housing growth derived from the range of Local Plan evidence published by LPAs. A ‘housing-led’ scenario is also an important element of the suite of output published by the GLA.
- 3.8 Where data on site-level housing developments is available from an LPA, the ‘housing-led’ approach reverts to a combined ‘top-down’ and ‘bottom-up’ methodology, aligning macro and micro forecasts of population change to the location and phasing (timing) of planned additions to the dwelling stock.
- 3.9 The use of micro-geographies in the forecasting methodology enables accurate aggregation of all scenario output to water company planning areas.

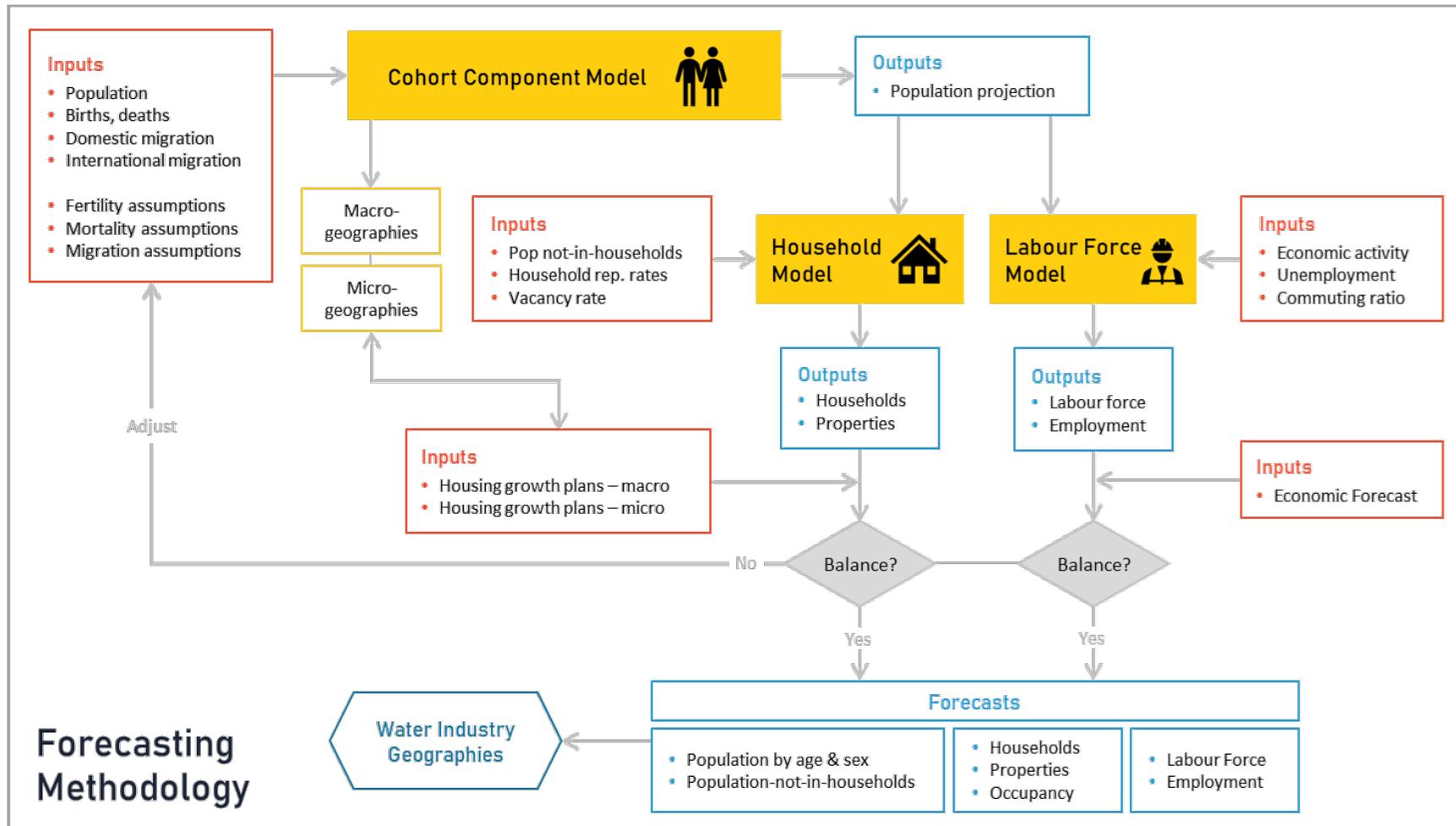


Figure 7: VICUS – Forecasting Methodology

## Scenario Development

- 3.10 The VICUS framework has been used to configure and calibrate a range of scenarios, for both the 2020–2050 WRMP plan-period, plus the long-term 2020–2100 outlook. Each scenario has a growth trajectory for 2020–2050, coupled with three alternative growth scenarios for 2050–2100.
- 3.11 The range of outcomes is necessary to enable consideration of the uncertainty associated with the demographic components of population change, the effects of different scales and phasing of future housing growth, plus the impact of alternative data inputs and assumptions applied by ONS and GLA.
- 3.12 The 2020–2050 scenarios can be broadly classified into three groups (Table 2):
- **Trend projections (ONS, GLA)**
  - **Housing-led forecasts (Local Plan, GLA, OxCam)**
  - **Employment-led forecasts**
- 3.13 Growth scenarios for 2050–2100 are underpinned by fertility, mortality and migration assumptions from the ONS 2018-based NPP, configuring a principal, low and high growth outcome (Table 3).
- 3.14 For ease of comparison, the scenarios presented within the VICUS framework have been recalibrated to ensure a consistent 2018 base-year population (the latest MYE available from ONS). In addition, all scenarios have been calibrated to ensure a consistent 2020 property total, with base year property totals aligning to the Royal Mail’s PAF statistics.
- 3.15 All scenarios produce statistics on population, households, population not-in-households and dwellings (properties) and occupancy. In addition, all 2020–2050 scenarios can produce output on estimated labour force and employment outcomes. A more detailed description of each of the scenarios follows, preceding an illustration of the range of growth outcomes for the WRSE area of operations.

## ONS & GLA Trend Projections

### ONS Projections

- 3.16 ONS produces its sub-national population projections (SNPP) every two-years, following publication of the ‘national’ population projection (NPP)<sup>8</sup>. The NPP provides the constraining total for the SNPP. A cohort-component methodology underpins the formulation of the population projections.
- 3.17 ONS projections are classified by their base-date, with the latest round of projections being the 2018-based scenarios. At each successive round of the ONS projections, revisions to key assumptions on fertility, mortality and international migration are made, with the support of an expert panel of advisors<sup>9</sup>. The impact of these assumptions on the UK national projections in the 2014-based, 2016-based and 2018-based round of projections is illustrated in Appendix D.

<sup>8</sup> [ONS Subnational Population Projections for England: 2018-based](#)

<sup>9</sup> [National population projections, how the assumptions are set: 2018-based](#)

Table 2: VICUS – Scenario Definition, 2020–2050

ID	Scenario	Description	URL	
Trend Projections	1	ONS-14	ONS 2014-based sub-national population projection (SNPP), using a six-year history (2008–2014) to derive local fertility, mortality and internal migration assumptions, with a long-term UK net international migration assumption of +185k p.a.	<a href="#">ONS 2014</a>
	2	ONS-16	ONS 2016-based Principal sub-national population projection (SNPP), using a five-year history (2011–2016) to derive local fertility, mortality and internal migration assumptions, and a long-term UK net international migration assumption of +165k. In line with the ONS 2016-based national population projection (NPP), this round of projections includes a reduced UK fertility outlook compared to ONS-14 and a dampened rate of improvement in life expectancy compared to ONS-14.	<a href="#">ONS 2016</a>
	3	ONS-18	ONS 2018-based Principal sub-national population projection (SNPP), using a five-year history (2013–2018) to derive local fertility & mortality assumptions and a long-term UK net international migration assumption of +190k. Unlike earlier rounds of SNPP, the 2018-based Principal projection uses a two-year history (2016–2018) of internal migration assumptions, following recent changes to the methodology used for its estimation, which have only covered the latest 2 years. In line with the ONS 2018-based national population projection (NPP), this round of projections includes a reduced UK fertility outlook compared to ONS-16 and a dampened rate of improvement in life expectancy compared to ONS-16.	<a href="#">ONS 2018</a>
	4	ONS-18-Alt	ONS 2018-based Alternative Internal Migration sub-national population projection (SNPP), produced by ONS as a comparison with the Principal projection. It uses a five-year average of internal migration (2013–2018), combining 3 years of data based on the old methodology and 2 years based on the new methodology. All other assumptions are consistent with ONS-18.	
	5	ONS-18-High	ONS 2018-based High International Migration sub-national population projection (SNPP), incorporating a High long-term UK net international migration assumption of +290k p.a., with all other assumptions consistent with ONS-18.	
	6	ONS-18-Low	ONS 2018-based Low International Migration sub-national population projection (SNPP), incorporating a Low long-term UK net international migration assumption of +90k p.a., with all other assumptions consistent with ONS-18.	
	7	ONS-18-10Y	ONS 2016-based 10yr Migration (all types) sub-national population projection, using a ten-year history (2008–2018) to derive internal migration assumptions, with all other assumptions consistent with ONS-18.	<a href="#">GLA</a>
	8	GLA-18-Central	Greater London Authority (GLA) 2018-based Central population projection, incorporating: GLA's own adjustments to the mid-year population estimates of London Boroughs; local fertility and mortality assumptions, trended in line with the ONS 2018-based NPP assumptions; internal and international migration assumptions derived from a 10-year history (2008–2018). This scenario includes projections for London Boroughs and for all other local authority areas.	
	9	GLA-18-15Y	GLA 2018-based long-term trend projection, incorporating internal and international migration assumptions derived from a 15-year history (2003–2018), with all other assumptions consistent with the Central scenario. This scenario includes projections for London Boroughs and for all other local authority areas.	
	10	GLA-18-5Y	GLA 2018-based short-term trend projection, incorporating internal and international migration assumptions derived from a 5-year history (2013–2018), with all other assumptions consistent with the Central scenario. This scenario includes projections for London Boroughs and for all other local authority areas.	
Housing-led Forecasts	11	GLA-Housing	GLA 2018-based Housing-led projection, based on data from the 2016 Strategic Housing Land Availability Assessment (SHLAA). Beyond 2041, housing growth is aligned to the 2035–2041 average. Whilst the housing-led approach is applied to each London Borough, the population projection for Greater London, in total, remains consistent with the Central scenario. This scenario includes projections for London Boroughs only and is combined with the Central scenario for all other local authority areas when aggregated to WRZ geographies.	<a href="#">GLA Housing</a>

ID	Scenario	Description	URL	
Housing-led Forecasts	12	Completions-18Y	A Housing-led scenario, with population growth underpinned by a continuation of the rate of housing growth recorded in each local authority's 18-year completions history (2001–2019).	<a href="#">MHCLG Live Table 122</a>
	13	Completions-5Y	A Housing-led scenario, with population growth underpinned by a continuation of the rate of housing growth recorded in each local authority's 5-year completions history (2014–2019).	
	14	Housing-Need	A Housing-led scenario, with population growth underpinned by the trajectory of housing growth associated with each local authority's Local Housing Need (LHN) or Objectively Assessed Housing Need (OAHN). Following the final year of data, projected housing growth in non-London areas returns to the ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.	
	15	Housing-Need-r	A Housing-led scenario, consistent with the Housing-Need scenario, but with household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.	
	16	Housing-Req	A Housing-led scenario, with population growth underpinned by the trajectory of housing growth associated with each local authority's housing Requirement. Following the final year of data, projected housing growth in non-London areas returns to the ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.	
	17	Housing-Req-r	A Housing-led scenario, consistent with the Housing-Req scenario, but with household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.	
	18	Housing-Plan	A Housing-led scenario, with population growth underpinned by each local authority's Local Plan housing growth trajectory. Following the final year of data, projected housing growth in non-London areas returns to the ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.	
	19	Housing-Plan-r	A Housing-led scenario, consistent with the Housing-Plan scenario, but with household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.	
Employment-Led Forecasts	20	Employment-1	An Employment-led scenario with 1.0% pa growth in London to 2030 and 0.5% pa thereafter; 0.8% pa growth in the South East and East of England to 2030, 0.4% thereafter.	
	21	Employment-2	An Employment-led scenario with 0.5% pa growth in London to 2030 and 0.25% pa thereafter; 0.4% pa growth in the South East and East of England to 2030, 0.2% thereafter.	
OxCam Housing-Led Forecasts	22	OxCam-1a-r	'New Settlement' 23k dpa scenario, with c.4.2k dpa above Housing Plan distributed between Cherwell (20%), Aylesbury Vale (20%), Central Bedfordshire (40%), South Cambridgeshire (20%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.	
	23	OxCam-1b-r	'Expansion' 23k dpa scenario, with c 4.2k dpa distributed between: Milton Keynes: (30%) Luton (15%), Bedford (15%), Oxford (10%), Cambridge (10%), Northampton (10%), and Peterborough (10%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.	
	24	OxCam-2a-r	'New Settlement' 30k dpa scenario, with c.11.2k dpa above Housing Plan distributed between Cherwell (20%), Aylesbury Vale (20%), Central Bedfordshire (40%), South Cambridgeshire (20%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.	
	25	OxCam-2b-r	'Expansion' 30k dpa scenario, with c 11.2k dpa distributed between: Milton Keynes: (30%) Luton (15%), Bedford (15%), Oxford (10%), Cambridge (10%), Northampton (10%), and Peterborough (10%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.	

- 3.18 To illustrate the impact of the 2018-based set of assumptions on growth outcomes, the 2014-based and 2016-based ONS projections are included in the VICUS scenario suite, for comparison.
- **ONS-14**
  - **ONS-16**
  - **ONS-18**
- 3.19 The inclusion of the 2014-based projection is important, as a considerable portion of the Local Plan evidence published by LPAs across England has been formulated using this growth scenario as a starting point in the housing need calculation.
- 3.20 Whilst the local variations in the relative contribution of international migration and natural change (births minus deaths) are influenced by the *national* assumptions applied, the *internal* migration variations have been influenced by a methodological change introduced in the 2018-based projections. ONS has implemented an improved process for recording student moves, post-graduation. As a result, internal migration profiles (particularly in local authorities with a University) have altered since 2016. The 2018-based 'Principal' projection has therefore used a two-year history (only) to calibrate its internal migration assumptions for each LPA, rather than the customary five-year history that has routinely been used in previous SNPP rounds.
- 3.21 To consider the effect of this methodological change upon population growth outcomes and to evaluate the potential for lower or higher assumptions on future growth through international migration, ONS has published four variant scenarios to accompany the ONS-18 Principal outcome. Given the uncertainty associated with international migration (in particular) in the post-Brexit and post-coronavirus world, each of these scenarios is presented for consideration within the VICUS suite:
- **ONS-18-Alt** (5-year internal migration history)
  - **ONS-18-10Y** (10-year migration history)
  - **ONS-18-High** (High international migration)
  - **ONS-18-Low** (Low international migration)
- 3.22 At a national (England) level, the ONS-18-Alt and ONS-18-10Y scenarios have identical outcomes to the ONS-18 Principal scenario, they only differ in the impact of the different internal migration assumptions at local authority level. Comparison between the ONS-18 suite of output and the equivalent GLA scenarios, is presented below.

## GLA Population Projections

- 3.23 Alongside the ONS projections, the GLA also publishes its own suite of projections<sup>10</sup>. The latest round of scenarios is 2018-based and includes a 'Central' scenario, plus variants which consider both a short-term (5-year) and a long-term (15-year) history for the formulation of migration assumptions. Once again, a 'cohort-component' methodology underpins the formulation of the population projections.

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<sup>10</sup> [GLA Population and Household Projections](#)

- **GLA-18-Central**
- **GLA-18-15Y**
- **GLA-18-5Y**

- 3.24 These scenarios include projections not only for the 33 London Boroughs (LB) but also for all other local authority areas. The GLA methodology differs from the ONS approach in a number of key areas.
- 3.25 In formulating its own demographic analysis, the GLA has made adjustments to the ONS mid-year estimates for London Boroughs, primarily to account for what it has identified as over-inflation of individual cohorts of children aged 0–14. This results in a base-year (2018) population that differs from the ONS total for all London Boroughs. The VICUS methodology has rebased all scenarios to a common (ONS) base population in 2018, to facilitate a consistent comparison of growth trajectories.
- 3.26 With regard to migration, the GLA uses a 5-, 10- (Central) and 15-year history from which to derive scenario assumptions, compared to 2- (Principal), 5- and 10-year histories for the ONS projections. The GLA also derives its own area-specific fertility and mortality assumptions, but these follow the ONS trend throughout the projection period.

## Housing-led Forecasts

- 3.27 Housing-led forecasts provide a different perspective on future population growth. Under these scenarios, the population impact of a pre-determined trajectory of housing growth is considered.
- 3.28 The starting point for a housing-led scenario is a trend projection, which is modified year-on-year to ensure reconciliation between population change and the capacity of the housing stock. The relationship between housing growth and population change is determined by the changing age-structure of the population, projected household representative rates (occupancy), a vacancy rate, plus the changing size of the population not-in-households.
- 3.29 In a housing-led forecast, if the demographic trend does not match the capacity of the housing stock, then the trend is altered, through higher or lower migration. If the capacity of the housing stock exceeds the population growth trend, then additional growth through migration will result. Likewise, if the capacity of the housing stock does not meet the requirements of the population growth trend, then growth is reduced through out-migration.
- 3.30 The VICUS framework incorporates a suite of housing-led forecasts, recognising the uncertainty associated with the future scale, distribution and phasing of growth across all English local authority areas. This suite of scenarios is designed to illustrate the likely population growth impact of different levels of housing growth and how these compare to the trend outcomes of the ONS and GLA scenarios.
- 3.31 A key component of any housing-led scenario is the average ‘occupancy’ associated with the changing housing stock. The general ‘ageing’ of the UK population results in a reduction in average household size, with the older population typically having smaller household sizes compared to the younger population. Since the financial crash of 2007/08, a counter trend brought about by both financial constraints and a mismatch between demand and supply of new homes, has seen a reduction in the

speed at which young adults are able to form new households, resulting in a dampening of the rate of occupancy reduction. These factors are considered in the housing-led scenario analysis.

3.32 The simplest housing-led scenario is one in which past rates of housing growth are continued. Using MHCLG's published data tables, in combination with Council statistics, the Consilium database has compiled a history of housing growth for each individual local authority. From this information, two VICUS scenarios have been configured. The first, a housing-led scenario based on a continuation of the rate of growth recorded in each local authority's 18-year housing completions history (2001–2019); the second, a housing-led scenario based on a 5-year completions history (2014–2019).

- **Completions-18Y**
- **Completions-5Y**

3.33 Under each of these scenarios the average annual housing growth calculated from the completions histories continues for the full duration of the 2020–2050 forecast period.

3.34 WRMP guidance has mandated that water companies need to consider population and property forecasts derived from the Local Plans published by LPAs. Local Plan development encompasses a complex mix of processes, documents and data. Consilium collates evidence from all LPAs, enforcing a consistent classification on the derived data (Table 1), enabling the formulation of scenarios that consider housing need, housing requirement and planned delivery.

3.35 The Planning Advisory Service (PAS) defines housing need as *“total housing that would be provided... if land supply was not constrained by planning”*. The 'Objective Assessment of Need' (OAN) was the original process established to formulate each local authority's housing need. To simplify the planning process, MHCLG introduced a 'standard method' for calculating a minimum local housing need (LHN), based on the 2014-based household growth projections, with an adjustment to account for affordability. Modifications to the LHN methodology are due for publication in 2020.

3.36 A housing requirement is defined in the National Planning Policy Framework (NPPF) and Planning Policy Guidance (PPG) as a 'policy target' (what policy requires), as opposed to housing need (what people or the market requires). A housing requirement identifies the extent to which an identified need can be met over the designated plan period.

3.37 Planned delivery of housing is also defined in the NPPF. All LPAs are required to produce a trajectory of expected housing delivery over a plan period, with the anticipated rate of development for specific sites (where appropriate). Housing trajectories are often published as part of the Local Plan and are updated annually in monitoring/land supply reports. It can be the case that these trajectories are supply-based and may be similar to the housing land *supply* figures.

3.38 Whilst LHN is deemed to be a 'minimum' housing need, the general trend is for housing need to present higher housing growth than the requirement, which in turn is often higher than the planned delivery. These rules do not hold in all cases. Three housing-led scenarios are presented:

- **Housing-Need**
- **Housing-Req**
- **Housing-Plan**

- 3.39 Local Plan evidence on future housing growth is typically formulated for 10–15-year period, shorter than the 2020–2050 outlook required by the WRMP. Under each scenario, following the final year of plan data available, projected housing growth in non-London local authority areas returns to a long-term annual growth average by 2050. This annual growth average has been derived from a combination of the ONS-14 and ONS-16 scenarios. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.
- 3.40 With all housing-led scenarios, household representative rates, drawn from the MHCLG’s 2014-based household model, determine the relationship between the changing age structure of the population and the number of households. However, these rates are based on time-period when household formation amongst young adults (in particular) was subject to both financial and supply constraints.
- 3.41 A key objective of all Local Plans is to redress the imbalance in the demand and supply of new homes and thus lift the rate of household formation amongst affected groups. To model the potential for a return to higher rates of household growth amongst young adults, household representative rates for 25–44 year-olds have been returned to their 2001 levels by 2039, remaining fixed thereafter. Three additional scenarios have been formulated to test the sensitivity of the household representative rate adjustments:
- **Housing-Need-r**
  - **Housing-Req-r**
  - **Housing-Plan-r**
- 3.42 The GLA includes its own housing-led outcome in its suite of scenarios<sup>11</sup>. Its scenario is based on data from the 2016 Strategic Housing Land Availability Assessment (SHLAA) providing housing growth totals, with phasing, for each London Borough. Beyond 2041, housing growth is aligned to the 2035–2041 average.
- **GLA-Housing**
- 3.43 The GLA-Housing scenario adopts an alternative method for determining occupancy rates in the changing housing stock, setting upper and lower bounds for average household size in each local authority. Plus, whilst the housing-led approach is applied to each London Borough, the population projection for Greater London, in total, remains consistent with the GLA-18-Central scenario.
- 3.44 This scenario includes projections for London Boroughs only and is combined with the GLA-18-Central scenario for all other local authority areas when aggregated to WRZ geographies.

## OxCam Arc Scenarios

- 3.45 The OxCam ‘Arc’ covers 26 Local Authority Districts (Appendix E), extending between Oxford, Milton Keynes and Cambridge. It has been identified as an area of huge economic potential<sup>12,13</sup>. To support

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<sup>11</sup> [GLA Housing-led Population Projections](#)

<sup>12</sup> Savills (2019) The Oxford-Cambridge Innovation Arc [Savills](#)

<sup>13</sup> MHCLG (2019) The Oxford-Cambridge Arc, Government ambition and joint declaration between Government and local partners [OxCam Arc](#)

the Arc's economic growth potential, a requirement for up to one million new homes has been estimated to 2050, together with improvements to the transport infrastructure of the region. However, with the UK's exit from the European Union and the unprecedented, short-term effects of the COVID-19 crisis, there is considerable uncertainty around the timing of infrastructure and housing delivery.

- 3.46 Councils within the Arc are already seeking to manage significant increases in the rate of house building to meet targets set out in current Local Plans. Achievement of one million homes by 2050 would present a further step-change in housing delivery requirements.
- 3.47 An accompanying report<sup>14</sup>, presents housing-led scenarios for OxCam local authorities that are underpinned by current Local Plan evidence. In addition, the report examines the potential impact of higher housing growth across the OxCam Arc, achieving close to 1 million homes by 2050.
- 3.48 The OxCam *Housing & Population Growth* report focuses on the development of the Arc and identifies how different levels and distribution of new housing might impact upon population growth in both WRSE and WRE geographies.

## Employment-led Scenarios

- 3.49 Demographic and economic change are intertwined and whilst fertility, mortality, migration and household occupancy effects can be modelled very effectively over long-term horizons, forecasting economic growth is more problematic and typically such forecasts have a much shorter, 1–5-year outlook horizon.
- 3.50 Economic forecasting within the current political and social environment is particularly challenging. There are a multitude of organisations that are engaged in the derivation of forecasts of short-term economic change. HM Treasury publishes a regular review of forecasts for the UK economy, with the latest release in April 2020, in the midst of COVID-19 lockdown. Short-term forecasts of GDP growth (and other variables) are 'averaged' from up to 40 financial and economic institutions. The latest average indicates -5.8% decline in UK GDP in 2020, with a +5% recovery in 2021. In both years, there is a 5 percentage-point range around the average, indicating the very uncertain economic outlook within a very short-term horizon.
- 3.51 The Office for Budget Responsibility (OBR) is the UK's official financial watchdog, providing "*independent and authoritative analysis of the UK's public finances*". Biannually, the OBR publishes 5-year forecasts for the UK economy to inform spring and autumn Budget Statements, accompanied by the annual publication of its Economic and Fiscal Outlook (EFO). The March 2020 EFO estimated average GDP growth of 1.4% to 2024, with an annual average employment growth of 0.5% between 2019–2024, plus a 1.5% annual rise in the unemployment rate.

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<sup>14</sup> Edge Analytics (2020) OxCam Housing & Population Growth, draft v1

- 3.52 The COVID-19 crisis has prompted the development of a coronavirus reference scenario, reflecting the HM Treasury evidence but with a sharper GDP decline and recovery in 2020/21, reverting to a 1.4% annual average, 2022–2024.
- 3.53 The current social and economic conditions have created an unprecedented but relatively short-term, interruption to normal life. Water resource planning needs to consider a much longer-term perspective on economic and demographic change. The GLA has previously published its own long-term projections of growth in employment across the 33 London Boroughs. The latest round of projections, published in 2017 estimated an average annual growth of 0.9% in workplace-based employment to 2030, declining to a 0.5% average to 2050.
- 3.54 In addition to its EFO output, the OBR also publishes its Fiscal Sustainability Report (FSR), providing a long-term outlook on economic change and its impact upon public debt<sup>15</sup>. Its long-term employment growth projections vary depending upon the degree to which international migration (and therefore the speed of population ageing) affects the UK economy. High migration outcomes estimate a 0.5% pa employment growth nationally to 2030, 0.4% to 2050. Under low-migration outcomes a 0.3% pa growth is projected across the UK to 2030, declining to 0.1% pa thereafter.
- 3.55 These forecasts of economic change are underpinned by a range of survey statistics which record historical change in employment, unemployment and business counts. These sources include: regional counts of workforce jobs by industry; Annual Population Survey (APS) workplace and labour force statistics; Business Register & Employment (BRES) survey; UK Business Count survey; and the 2011 Census. Achieving a consistent perspective on historical change from these datasets is challenging, particularly when drilling down to local areas, where sample surveys can produce large annual fluctuations.
- 3.56 Within the VICUS framework, the labour force model uses key assumptions on age-specific rates of economic activity, unemployment and commuting, to estimate the relationship between population change and employment. An employment-led scenario requires a trajectory of future employment growth, from which a population growth impact can be estimated.
- 3.57 Two employment-led scenarios have been derived for the WRSE region, using a combination of: historical evidence, to determine growth ratios between England, London, the South East and the East of England; GLA projections, to benchmark London growth rates; and OBR forecasts, to provide a high and low outcome to long-term growth:
- **Employment-1**
  - **Employment-2**
- 3.58 Under the Employment-1 scenario, employment growth in each London borough grows at 1.0% per year to 2030, declining to 0.5% per year to 2050. At the same time, employment growth in all local authority districts outside London grows at a lower rate of 0.8% per year to 2030, reducing to 0.4% per year thereafter.

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<sup>15</sup> OBR (2018) Fiscal Sustainability Report [OBR July 2018](#)

- 3.59 Lower growth is modelled under the Employment-2 scenario, with employment growth in each London borough growing at 0.5% per year to 2030, declining to 0.25% per year to 2050. At the same time, employment growth in all local authority districts outside London grows at a lower rate of 0.4% per year to 2030, reducing to 0.2% per year thereafter.

## Long-term Scenarios

- 3.60 For each of the 25 scenarios presented in Table 2, a long-term growth outlook is considered, extending the scenario horizon to 2100. Growth scenarios for the 2050–2100 period are aligned to the ONS 2018-based NPP, configuring a principal, low and high growth outcome (Table 3).

Table 3: VICUS – Scenario Definition, 2050–2100

Scenario	Description
Principal ('-P')	The Principal long-term scenario incorporates the mortality and fertility assumptions of the ONS 2018-based NPP Principal scenario, plus its Principal net international migration assumption of +190k p.a. for the UK in total.
Low ('-L')	The Low long-term scenario incorporates the mortality and fertility assumptions of the ONS 2018-based NPP Principal scenario, plus a Low net international migration assumption of +90k p.a. for the UK in total.
High ('-H')	The High long-term scenario incorporates the mortality and fertility assumptions of the ONS 2018-based NPP Principal scenario, plus a High net international migration assumption of +290k p.a. for the UK in total.

- 3.61 The key determinants of growth rates under these scenarios are assumptions relating to fertility, mortality and international migration. In each of the three long-term outcomes, fertility and mortality rates trends are consistent with the NPP Principal scenario. For international migration, the Principal scenario is based on an assumption of +190k annual net growth through international migration, with the High and Low variants assuming +290k and +90k per year respectively.

## Macro- and Micro-level Alignment

- 3.62 Where data on site level housing developments is available, the housing-led forecasting approach is able to utilise both a combined 'top-down' and 'bottom-up' methodology. This means that micro-level forecasts of population change can be directly linked to the location of planned housing growth and the phasing over time of that growth.
- 3.63 A 'top-down' forecast is produced providing an indication of population and property growth for an aggregate area (local authority district). This is used as a constraint for a 'bottom-up' forecast which takes account of micro-level housing intelligence. The Consilium data provides information on the extent of new housing growth and its likely spatial and temporal distribution.

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- 3.64 Housing allocations typically have a location and a likely phasing over time combined with information on site area and density. Used in combination with estimates of new dwelling occupancy this allows the population forecasts to reflect, at a micro scale, the impact of new housing developments.
- 3.65 For new housing allocations where specific geographical location detail is not provided the model allocates these sites across aggregate areas in proportion to the existing property distribution.
- 3.66 The Consilium site data is used in conjunction with digital map data and existing micro-level housing stock data for the proportional assignment of micro-level forecasts to various water planning geographies. These proportions are modified over time to take account of the revised distribution of properties resulting from planned new development sites.
- 3.67 Typically, site level trajectories are provided for a relatively short-term period. When site level data is no longer available the modelling approach reverts to a 'top-down' approach.

# 4 Scenario Output

## Understanding Limitations

- 4.1 The UK is at a watershed moment in its political, economic and demographic history. The country's exit from the EU and the unprecedented global impact of the current pandemic, presents a significant challenge for predicting demographic futures for water resource planning. However, as the virus situation improves and the country returns to a new normal, the UK government will continue its objective of building up to 300,000 new homes per year. This will have important effects upon the growth and distribution of population in the WRSE communities.
- 4.2 The analysis detailed in this report and in accompanying data deliverables, has presented a *suite* of trend projections, housing-led and employment-led forecasts which estimate the potential scale and distribution of future demographic change. In the interpretation of these outputs, it is important to recognise some of the methodological and data differences that exist between scenarios and therefore the challenge of producing the consistency required for effective comparison.
- 4.3 In all trend projections and housing-led forecasts, the future population of an area is strongly influenced by its base population. Projections of the number of adults, particularly the older-age population, are usually more reliable than those for children because of the challenges associated with the estimation of future levels of fertility and working-age migration.
- 4.4 The WRMP scenario horizon stretches to 2100. As the process of population change is cumulative, the reliability of growth scenarios will reduce over time. Furthermore, growth scenarios for areas with small populations will generally be less reliable than those for areas with large populations, because the former will typically be affected more by migration.
- 4.5 The ONS and GLA *projections* provide an illustration of what will happen if a pre-determined combination of assumptions on fertility, mortality and migration are met. Projections are trend-based and are, therefore, not policy-based forecasts of what local or national government expects to happen. There are many economic, political and social factors that could influence population change, including policies adopted by both national and local government, or factors that are outside of any government's control (e.g. coronavirus).
- 4.6 Appendix C illustrates the UK's national population projection accuracy since 1950. Historically, the UK population has risen more than projected, due to one or other of: under-estimation of international migration; a failure to anticipate higher fertility rates; or a failure to anticipate continued improvements in life expectancy. More recently, successive projections have demonstrated greater convergence, compared to earlier years.

- 4.7 The effects of dampened fertility and mortality assumptions upon population change are very evident in the successively lower growth outcomes of the ONS-14, ONS-16 and ONS-18 projections (Appendix D (i)). A return to higher rates of fertility and/or an upturn in the rate of improvement in life expectancy, would reverse the trend towards lower growth suggested by the ONS-18 outcomes.
- 4.8 The size of migration flows (both internal and international) and the uncertainty of future trends, means that migration assumptions have a greater influence upon growth outcomes than fertility and mortality assumptions.
- 4.9 In the absence of a population register, the estimation of international migration (into and out of the UK) has long presented a real challenge to ONS<sup>16</sup>. Estimating *base-year* immigration and emigration effects, both nationally and locally, requires a complex mix of data inputs and assumptions, and is subject to estimation methodologies that are under constant review. This methodological uncertainty in the base data, coupled with the considerable uncertainty that now exists around future population exchanges with the EU and other countries, makes the international migration assumption the most sensitive in all trend scenarios.
- 4.10 The UK government had originally hinted at a +100k per year target for net international migration but this has never been established as policy. The +190k per year within the ONS-18 principal scenario, is a more reasonable assumption of future international migration to the UK, ensuring the necessary replenishment of its workforce to compensate for the accelerating process of demographic ageing in the resident population.
- 4.11 In relation to *internal* migration flows, the financial crash of 2007/08 resulted in constraints on movement due to lending restrictions, acute housing affordability issues and an under-supply of new homes. This had a particular impact upon the net outflow of migrants from London, a situation that has now begun to reverse itself with the renaissance in house building. This should mean that later trend projections are a more reliable indicator of future internal migration outcomes. However, the ONS-18 projections incorporate the effects of a methodological change to the estimation of internal migration, which makes comparison with other scenarios more difficult.
- 4.12 There are also methodological differences between the ONS and GLA trend projections presented here, which make a direct comparison of growth outcomes a challenge. The GLA has modified its base year populations, has calculated its own base fertility and mortality parameters (although following the long-term ONS trend) and its own migration assumptions.
- 4.13 To improve comparability, the VICUS framework has sought to align base year population and property totals to ensure consistency of growth comparison across scenarios. This alignment reveals that, despite the ONS and GLA each presenting a 2018-based scenario configuration, the GLA trend scenarios result in higher growth outcomes for the UK standard regions which overlap WRSE geographies (Appendix D (ii)).
- 4.14 Whilst projections provide an illustration of growth under a given set of fertility, mortality and migration assumptions, local planning policies can modify past trends. To illustrate how Local Plans

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<sup>16</sup> [ONS - Long-Term International Migration estimates methodology](#)

have been formulated to meet particular local needs/requirements for new housing growth, the housing-led scenarios are presented as a direct contrast to the trend outcomes. But there is inevitable inconsistency and uncertainty with regard to the evidence which underpins these scenarios.

- 4.15 Local Plans are at different stages of development and completeness. There is limited consistency of timing or content of Council Local Plan publications and data. And whilst some areas have plan data for 5 years, others for up to 15 years, the majority of Local Plan housing growth is weighted more heavily towards the short-term horizon. It has been necessary to fill the data gaps required for the WRMP 2050 planning horizon, using trend scenario evidence to estimate housing growth for the period after which plan data expires. These factors are reflected in the shape of the growth curves associated with the Housing-Plan scenarios.
- 4.16 The use of household representative rates as a determinant of occupancy is a key component of the modelling approach, applied across all scenarios, trend, housing-led and employment-led. These rates, drawn from MHCLG's 2014-based household model are available to 2039 only, remaining constant thereafter. Modification of these rates ('r' scenarios in the analysis that follows) has enabled the estimation of population impacts resulting from higher rates of household formation amongst young adults, dampening the housing-led population growth in all cases. The 'r' scenario is an attempt to illustrate how lower average occupancy (and therefore lower population growth) might result from the higher Local Plan trajectories. This is achieved by allowing household representative rates for young adult age-groups to 'return' to their 2001 position (prior to the financial crash of 2008)<sup>17</sup>.
- 4.17 In all cases, the housing-led growth outcomes detailed below are substantially *higher* than the latest, 2018-based trend projections published by the ONS. The amalgamated WRSE Local Plan evidence suggests an unprecedented level of housing growth to 2030. Some of this growth is to meet a 'backlog' from previous under-supply but the majority is designed to satisfy a housing 'need', meeting the requirements of future population growth.
- 4.18 The ONS 2014-based population projections (and accompanying household projections) have been a key input to MHCLG's housing need policies and the formulation of Local Plan housing requirements. For the WRSE in total, the population growth profile estimated by the ONS 2014-based projections, reveals an expectation of continued population growth through a mixture of natural change (higher births than deaths), internal migration and international migration. The housing-led scenarios, coupled with the 'r' assumption of higher rates of household formation amongst young adults, return an overall population growth that is higher, but not too dissimilar to, the ONS 2014-based outcome.
- 4.19 Contrast the ONS 2014-based outcome, to that of its 2018-based variant. With revised demographic inputs which assume falling fertility and lower life expectancies, natural change has a much smaller impact upon population change, quickly reverting to a population decline in parts of the WRSE. Whilst international migration is projected to remain at a higher level in the 2018-based projections, the dampened growth outcomes suggest a lower housing requirement over the WRMP horizon.

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<sup>17</sup> Whilst using a similar approach, the GLA has applied borough-specific rules to the control of occupancy in its housing-led scenario and has constrained the overall population growth total in this scenario to its Central trend outcome for London

- 4.20 To aid consideration of the accelerated housing growth that is planned to 2030, a separate analysis has provided supplementary information on housing growth outlook, using a combination of (Consilium) Local Plan sources to produce a 'Delivery Performance Indicator' (DPI) for each local authority<sup>18</sup>. This DPI is designed to indicate those areas where current housing plans are more or less likely to be delivered, based upon: (i) historical delivery rates; (ii) planned completions; and (iii) available capacity. This DPI is of most use in the consideration of the higher housing growth evident in Local Plans to 2030 and its likelihood for delivery during this, short-term, WRMP horizon.
- 4.21 The development of employment-led forecasts is particularly challenging within the current political and social environment. And even within 'normal' conditions, economic forecasts typically have a much shorter, 1–5-year outlook horizon, compared to demographic scenarios. Nevertheless, two employment-led scenarios have been formulated, not as a definitive indication of likely economic trajectories, but to benchmark other demographic and housing-led scenarios against a higher and lower employment growth outcome.
- 4.22 The VICUS framework is able to configure employment-led scenarios, but it does so from a demographic perspective, balancing the relationship between employment growth and the size of the resident labour force using higher or lower migration. The methodology incorporates important projections of age-specific labour force participation rates, especially important for modelling higher female participation and the effects of state pension age (SPA) adjustments. However, it combines these with static measures of unemployment and commuting ratios, a necessary simplification of a complex modelling process.

## Outcomes 2020–2050

- 4.23 Despite the methodological and data challenges detailed above, the VICUS framework provides a rigorous and robust basis for the configuration and comparison of a suite of WRSE growth scenarios. Given the challenges of presenting a single, definitive outcome on future population and housing growth, the transparency of the VICUS approach is designed to encourage consideration of a 'range' of outcomes to support water resource planning.
- 4.24 A summary illustration of the suite of 2020–2050 growth scenarios is presented, for WRSE in aggregate (Figure 8) and for each water company (Figure 9 – Figure 14).
- 4.25 The accompanying VICUS-BI dashboard provides further detail for individual WRZs, plus scenario output for the extended 2020–2100 forecast period. An additional Microsoft Excel workbook provides full detail on the data outputs from each scenario.
- 4.26 The range of 2020–2050 growth outcomes for the WRSE, in total, suggests population growth in the range of 402,000 to 5.1 million, with accompanying dwelling growth of 31,700–99,500 dwellings per annum (dpa). This gives an average of approximately 3.3 million population growth (c. 17%) and 73,000 dpa over the 30-year plan period.

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<sup>18</sup> The DPI analysis has been provided to WRSE members as an accompaniment to the main population and property forecast outputs.

- 4.27 This is a wide range of outcomes but at the lower end of the spectrum, the ONS-18-Low scenario presents an unrealistic growth projection. The ONS-18 *principal* projection presents an uncertain outcome itself, given the methodological differences in its approach to measuring internal migration. For this reason, a low variant on the principal outcome, which assumes a +90k per year international migration impact, should be disregarded.
- 4.28 In contrast, the ONS-14, Housing-Need and Housing-Plan scenarios present higher growth outcomes. The three are relatively consistent to 2030, deviating thereafter, with the Housing-Plan aligning more closely with ONS-14. The Housing-Need scenario with its continuation of an LPA's need assessment, albeit with a return to a trend value by 2050 and no modifications to account for higher household growth in young adults, produces a high growth outcome that is also likely to be unrealistic.
- 4.29 The inclusion of scenarios which consider future housing growth linked to past completion rates, provides a useful benchmark against the housing growth derived in the Housing-Plan trajectory. For the combined WRSE geography, the Housing-Plan dwelling growth total is approximately 23% higher than that associated with a continuation of the completion rate from the last five years of evidence and 45% higher than a continuation of the completion rate averaged over the extended 2001–2019 period.
- 4.30 The Housing-Plan scenario suggests high growth to 2030 (typically the limit of robust Local Plan evidence), reducing thereafter as the annual housing growth returns to a level derived from trend projections. The reduction in the household representative rates of young adults over the plan period (Housing-Plan-r), enforces a lower occupancy to the housing stock, reducing the population growth associated with the same level of housing growth. The requirement for higher housing growth in Local Plans is underpinned by a drive to make new homes more affordable and accessible to young adults, so the modification to household representative rates provides a legitimate dampening of the population growth, reducing housing stock average occupancies in the process.
- 4.31 The GLA scenarios project higher growth than the ONS-16 and ONS-18 outcomes, due to higher natural change and international migration, combined with a lower net outflow through internal migration. The Housing-Plan-r population growth aligns more closely with the GLA outcomes, albeit with a higher average dpa across the plan period, with the GLA assuming higher occupancies for the housing stock.
- 4.32 The employment-led scenarios estimate population growth of 8.4%–16.6%, with the higher growth of the Employment-1 scenario relatively consistent with the average over all scenarios. Dwelling growth associated with these scenarios is 48k–72k dpa to 2050, with a potential 20% uplift on the dpa if higher rates of household formation amongst young adults is considered.
- 4.33 The trends evident in the WRSE aggregate outcomes and the relationship between the different scenario outcomes, is generally replicated in the growth profiles presented for each of the water companies, with the Housing-Need and ONS-18-Low scenario sitting at the extremes of the growth spectrum.
- 4.34 For Affinity Water, an average population growth of approximately 605,000 (c. 17%) is estimated to 2050, coupled with a housing growth of 13,351 dpa. The Housing-Plan-r scenario aligns quite closely

to the GLA population outcomes, albeit with a higher annual average housing growth estimated from the Local Plan evidence.

- 4.35 For Portsmouth Water an average population growth of approximately 110,000 (c. 15%) is combined with a 2,370 dpa housing growth to 2050. The short-term (2020–2030) impact of higher housing growth in the Local Plan evidence is noticeable, particularly when compared to the scenarios based upon past housing completion rates.
- 4.36 Of a similar size to Portsmouth Water, SES Water has an average population growth outcome of approximately 111,000 (c. 16%) to 2050, with a housing growth of 2,525 dpa. ONS-14 and Housing-Need scenarios are associated with particularly high population growth when compared to past completion rates and to the Housing-Plan growth trajectory.
- 4.37 For South East Water, an average 2020–2050 population growth of approximately 389,000 (18%) is associated with an average annual housing growth figure of 7,925 dpa. Large scale housing growth detailed in Local Plans is reflected in the Housing-Plan trajectories for the 2020–2030 plan period.
- 4.38 It is a similar case for Southern Water, with high Local Plan housing totals fuelling the 2020–2030 population growth of the Housing-Plan scenarios. Across all scenarios, an average population growth of approximately 413,000 (c. 16%) is estimated, coupled with an average annual housing growth of 8,602 dpa.
- 4.39 Thames Water covers the largest and most diverse geography, with the low growth trajectory of the Completions-18Y scenario being particularly noticeable reflecting a history of under-supply of homes relative to population growth. Across all scenarios, an average population growth of 1.63 million (c. 17%) to 2050 is estimated, in combination with an annual average housing growth of 38,011 dpa.



Figure 8: VICUS-BI – Scenario Summary – WRSE



Figure 9: VICUS-BI – Scenario Summary – Affinity Water

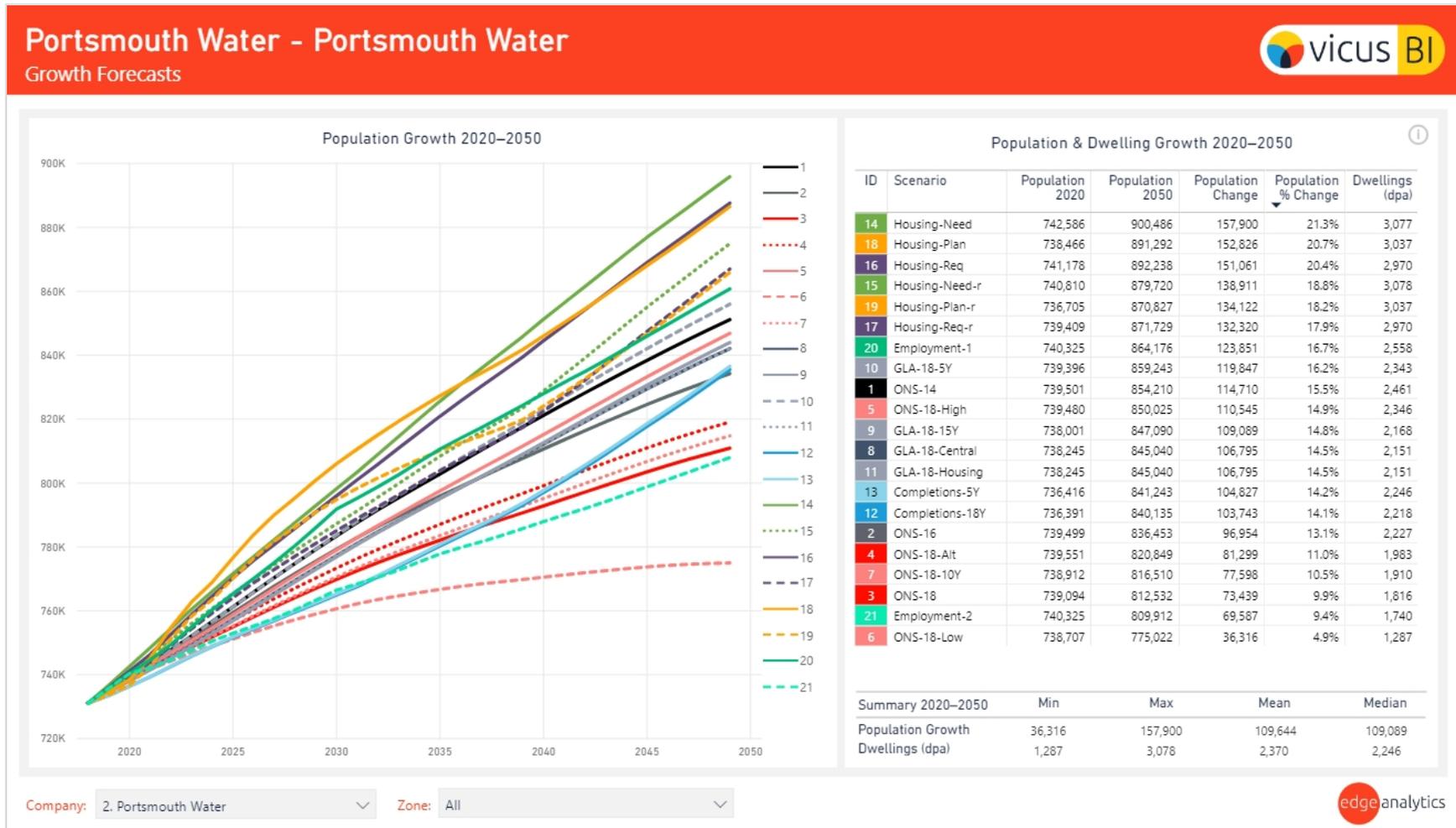


Figure 10: VICUS-BI – Scenario Summary – Portsmouth Water

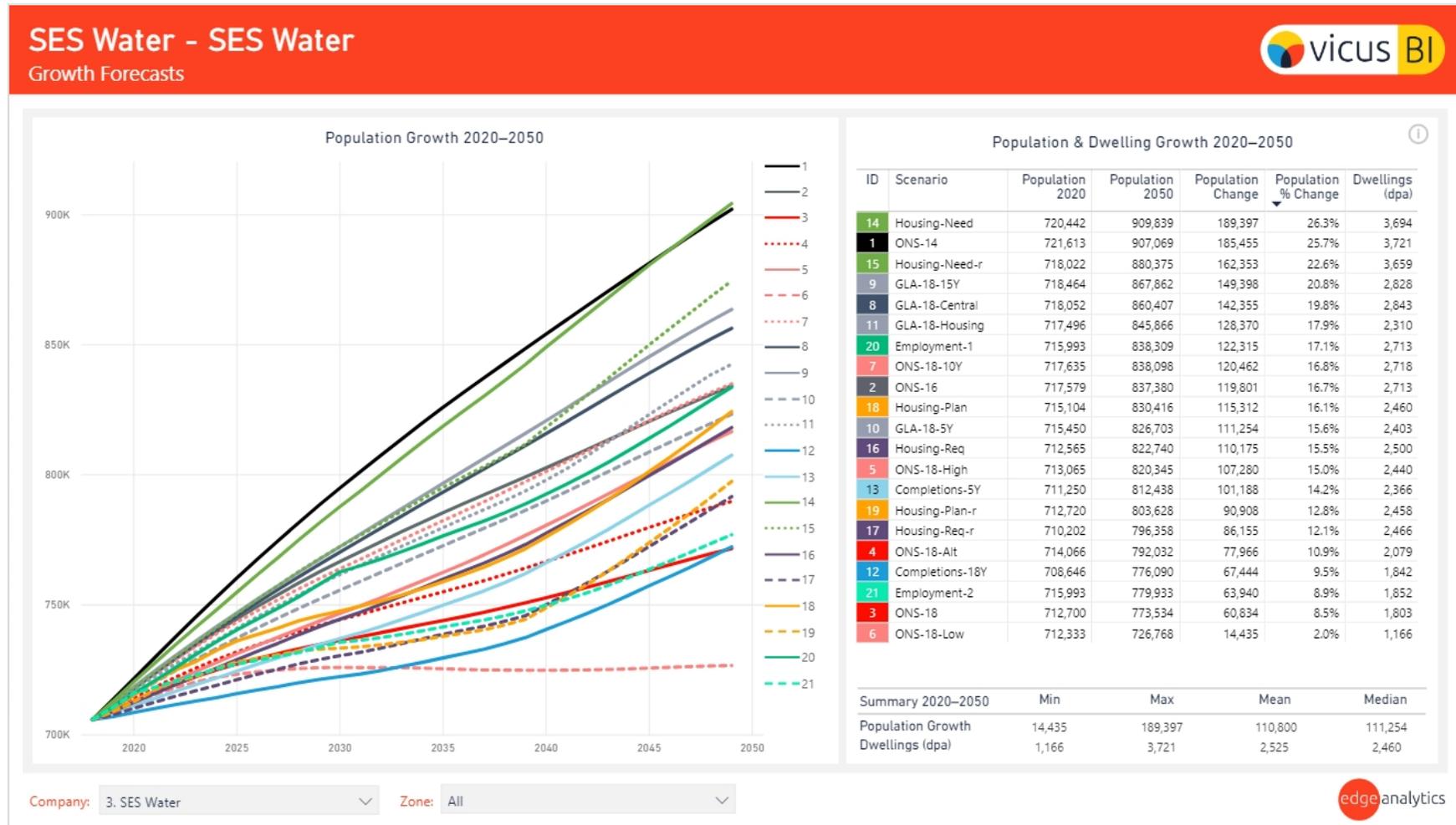


Figure 11: VICUS-BI – Scenario Summary – SES Water



Figure 12: VICUS-BI – Scenario Summary – South East Water



Figure 13: VICUS-BI – Scenario Summary – Southern Water



Figure 14: VICUS-BI – Scenario Summary – Thames Water

## Outcomes 2020–2100

- 4.40 To support the requirement for a long-term outlook for water resource planning across the WRSE region, the WRMP scenario horizon stretches to 2100. The accompanying VICUS-BI dashboard and Microsoft Excel workbook provide a full illustration and data detail on the range of growth outcomes for this extended outlook.
- 4.41 Inevitably, as the process of population change is cumulative, the reliability of growth scenarios will reduce over time. The long-term horizon, stretching from 2050–2100 is the period with greatest uncertainty. It is a period during which the large birth cohorts of the 1950s and 1960s will leave the population. Without a significant and continuing input from international migration, the UK's population and that of its local communities would quickly decline.
- 4.42 However, the 2020–2100 scenarios have been configured to first take account of the range of outcomes for the 2020–2050 plan period and then to consider longer-term growth aligned to ONS national population projections. For each of the scenarios presented for 2020–2050, a long-term growth outlook is considered, extending the scenario horizon to 2100, in alignment with the ONS 2018-based national population projection for the UK.
- 4.43 Three long-term trajectories are presented for each of the 2020–2050 scenarios: a principal, low and high growth outcome. The high and low variants of the long-term scenarios illustrate the potential extremes of growth under different assumptions of fertility, mortality and international migration.
- 4.44 In each of the three long-term outcomes, fertility and mortality rates trends are consistent with the NPP principal scenario. For international migration, the principal scenario assumes a +190k annual net growth through international migration, with the High and Low variants assuming +290k and +90k per year respectively. Whilst the robust prediction of likely growth through international migration post-2050 presents a significant challenge, the principal scenario is presented as the most prudent outlook for consideration in the long-term water resource planning process.
- 4.45 For the WRSE region in total, the 17% average growth in population 2020–2050, is accompanied by a 13% average growth for 2050–2100 under the principal long-term outcome. This is equivalent to an average population growth of approximately 32% over the 2020–2100 plan period, an additional 6.2 million people on the base year total. The Low and High population growth averages for the full 2020–2100 horizon, range from 21–42%.
- 4.46 In terms of estimated housing growth, the average annual growth under the suite of Principal scenarios for the long-term horizon is approximately 51,432 dpa, ranging from 38,194 dpa to 63,403 dpa under the Low and High scenarios respectively.
- 4.47 Similar long-term outcomes for each water company and each WRZ are contained within the accompanying VICUS-BI and Microsoft Excel output.

## Appendix A Glossary of Terms

APS	Annual Population Survey
ASFR	Age-specific fertility rate
ASMR	Age-specific mortality rate
BRES	Business Register & Employment survey
Defra	Department for Environment, Food and Rural Affairs
DWMP	Drainage and Wastewater Management Plan
DWP	Department for Works and Pensions
EA	Environment Agency
EFO	Economic and Fiscal Outlook
EU	European Union
GDP	Gross Domestic Product
GLA	Greater London Authority
H&T	Hidden and transient
LHN	Local Housing Need
LPA	Local Planning Authority
MHCLG	Ministry for Housing, Communities and Local Government
MYE	Mid-year population estimate
NPP	National Population Projection
NPPF	National Planning Policy Framework
OAN	Objective Assessment of Need
OBR	Office for Budget Responsibility
ONS	Office for National Statistics
OxCam	Oxford Cambridge Arc
PAF	Postcode Address File
PAS	Planning Advisory Service
PPG	Planning Policy Guidance
SHLAA	Strategic Housing Land Availability Assessment
SNPP	Sub-national Population Projection
SPA	State Pension Age
SRRP	Statement of Regional Resource Position
UK	United Kingdom
WG	Welsh Government
WRE	Water Resources East
WRMP	Water Resources Management Plan
WRN	Water Resources North
WRSE	Water Resources South East
WRSW	Water Resources South West
WRW	Water Resources West
WRZ	Water Resource Zone

## Appendix B Local Authority Status Log

B.1 The activity log indicates the date at which Local Plan evidence was last accessed from each LPA and added to the Consilium database.

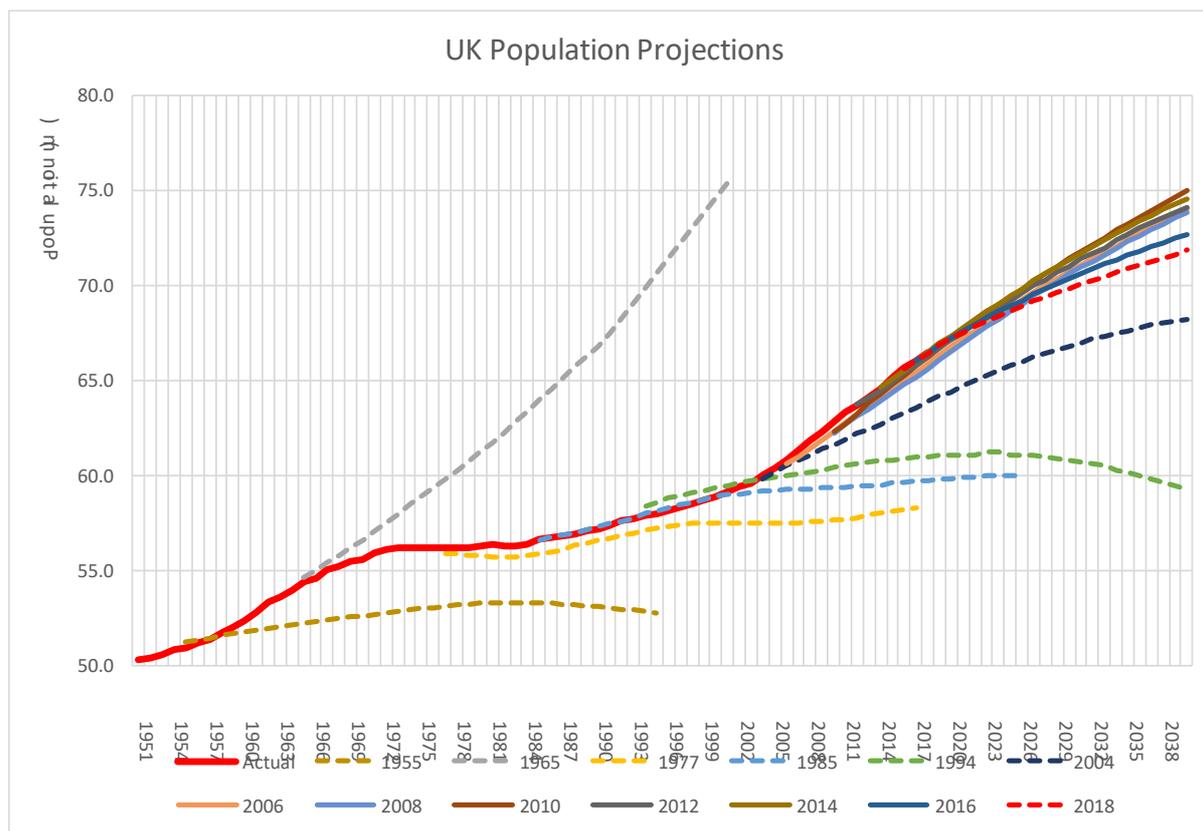
Area Name	Area Code	Region	WRSE	OxCam	Last Updated
Adur	E07000223	South East	WRSE		02/04/2020
Arun	E07000224	South East	WRSE		02/04/2020
Ashford	E07000105	South East	WRSE		17/03/2020
Aylesbury Vale	E07000004	South East	WRSE	OxCam	17/03/2020
Barnet	E09000003	London	WRSE		30/03/2020
Basingstoke and Deane	E07000084	South East	WRSE		02/04/2020
Bedford	E06000055	East of England		OxCam	26/03/2020
Bexley	E09000004	London	WRSE		31/03/2020
Bracknell Forest	E06000036	South East	WRSE		02/04/2020
Brent	E09000005	London	WRSE		31/03/2020
Brentwood	E07000068	East of England	WRSE		25/03/2020
Brighton and Hove	E06000043	South East	WRSE		02/04/2020
Bromley	E09000006	London	WRSE		30/03/2020
Broxbourne	E07000095	East of England	WRSE		27/03/2020
Cambridge	E07000008	East of England		OxCam	27/03/2020
Camden	E09000007	London	WRSE		30/03/2020
Canterbury	E07000106	South East	WRSE		17/03/2020
Central Bedfordshire	E06000056	East of England	WRSE	OxCam	27/03/2020
Cherwell	E07000177	South East	WRSE	OxCam	16/03/2020
Chichester	E07000225	South East	WRSE		16/03/2020
Chiltern	E07000005	South East	WRSE	OxCam	18/03/2020
City of London	E09000001	London	WRSE		30/03/2020
Corby	E07000150	East Midlands		OxCam	29/03/2020
Cotswold	E07000079	South West	WRSE		18/03/2020
Crawley	E07000226	South East	WRSE		02/04/2020
Croydon	E09000008	London	WRSE		30/03/2020
Dacorum	E07000096	East of England	WRSE		27/03/2020
Dartford	E07000107	South East	WRSE		17/03/2020
Daventry	E07000151	East Midlands		OxCam	29/03/2020
Dover	E07000108	South East	WRSE		18/03/2020
Ealing	E09000009	London	WRSE		31/03/2020
East Cambridgeshire	E07000009	East of England		OxCam	27/03/2020
East Hampshire	E07000085	South East	WRSE		18/03/2020
East Hertfordshire	E07000242	East of England	WRSE		27/03/2020
East Northamptonshire	E07000152	East Midlands		OxCam	30/03/2020
Eastbourne	E07000061	South East	WRSE		18/03/2020
Eastleigh	E07000086	South East	WRSE		18/03/2020
Elmbridge	E07000207	South East	WRSE		18/03/2020
Enfield	E09000010	London	WRSE		31/03/2020
Epping Forest	E07000072	East of England	WRSE		29/03/2020
Epsom and Ewell	E07000208	South East	WRSE		18/03/2020
Fareham	E07000087	South East	WRSE		02/04/2020
Fenland	E07000010	East of England		OxCam	26/03/2020
Folkestone and Hythe	E07000112	South East	WRSE		19/03/2020

Area Name	Area Code	Region	WRSE	OxCam	Last Updated
Gosport	E07000088	South East	WRSE		29/03/2020
Gravesham	E07000109	South East	WRSE		17/03/2020
Greenwich	E09000011	London	WRSE		31/03/2020
Guildford	E07000209	South East	WRSE		20/03/2020
Hackney	E09000012	London	WRSE		30/03/2020
Hammersmith and Fulham	E09000013	London	WRSE		30/03/2020
Haringey	E09000014	London	WRSE		31/03/2020
Harlow	E07000073	East of England	WRSE		27/03/2020
Harrow	E09000015	London	WRSE		31/03/2020
Hart	E07000089	South East	WRSE		20/03/2020
Hastings	E07000062	South East	WRSE		20/03/2020
Havant	E07000090	South East	WRSE		20/03/2020
Hertsmere	E07000098	East of England	WRSE		27/03/2020
Hillingdon	E09000017	London	WRSE		31/03/2020
Horsham	E07000227	South East	WRSE		20/03/2020
Hounslow	E09000018	London	WRSE		31/03/2020
Huntingdonshire	E07000011	East of England		OxCam	27/03/2020
Isle of Wight	E06000046	South East	WRSE		23/03/2020
Islington	E09000019	London	WRSE		30/03/2020
Kensington and Chelsea	E09000020	London	WRSE		30/03/2020
Kettering	E07000153	East Midlands		OxCam	30/03/2020
Kingston upon Thames	E09000021	London	WRSE		30/03/2020
Lambeth	E09000022	London	WRSE		30/03/2020
Lewes	E07000063	South East	WRSE		23/03/2020
Lewisham	E09000023	London	WRSE		29/03/2020
Luton	E06000032	East of England	WRSE	OxCam	26/03/2020
Maidstone	E07000110	South East	WRSE		23/03/2020
Medway	E06000035	South East	WRSE		23/03/2020
Merton	E09000024	London	WRSE		28/03/2020
Mid Sussex	E07000228	South East	WRSE		23/03/2020
Milton Keynes	E06000042	South East		OxCam	23/03/2020
Mole Valley	E07000210	South East	WRSE		18/03/2020
New Forest	E07000091	South East	WRSE		23/03/2020
New Forest National Park	E26000009	National Park	WRSE		30/03/2020
Newham	E09000025	London	WRSE		28/03/2020
North Hertfordshire	E07000099	East of England	WRSE		29/03/2020
Northampton	E07000154	East Midlands		OxCam	18/03/2020
Oxford	E07000178	South East	WRSE	OxCam	16/03/2020
Peterborough	E06000031	East of England		OxCam	29/03/2020
Portsmouth	E06000044	South East	WRSE		23/03/2020
Reading	E06000038	South East	WRSE		23/03/2020
Redbridge	E09000026	London	WRSE		27/03/2020
Reigate and Banstead	E07000211	South East	WRSE		23/03/2020
Richmond upon Thames	E09000027	London	WRSE		27/03/2020
Rother	E07000064	South East	WRSE		25/03/2020
Runnymede	E07000212	South East	WRSE		25/03/2020
Rushmoor	E07000092	South East	WRSE		25/03/2020
Sevenoaks	E07000111	South East	WRSE		25/03/2020

Area Name	Area Code	Region	WRSE	OxCam	Last Updated
Slough	E06000039	South East	WRSE		25/03/2020
South Bucks	E07000006	South East	WRSE	OxCam	25/03/2020
South Cambridgeshire	E07000012	East of England		OxCam	27/03/2020
South Downs National Park	E26000010	National Park	WRSE		02/04/2020
South Northamptonshire	E07000155	East Midlands	WRSE	OxCam	18/03/2020
South Oxfordshire	E07000179	South East	WRSE	OxCam	29/03/2020
Southampton	E06000045	South East	WRSE		25/03/2020
Southwark	E09000028	London	WRSE		27/03/2020
Spelthorne	E07000213	South East	WRSE		26/03/2020
St Albans	E07000240	East of England	WRSE		27/03/2020
Stevenage	E07000243	East of England	WRSE		23/03/2020
Stratford-on-Avon	E07000221	West Midlands	WRSE		12/03/2020
Surrey Heath	E07000214	South East	WRSE		27/03/2020
Sutton	E09000029	London	WRSE		24/03/2020
Swale	E07000113	South East	WRSE		27/03/2020
Swindon	E06000030	South West	WRSE		18/03/2020
Tandridge	E07000215	South East	WRSE		27/03/2020
Test Valley	E07000093	South East	WRSE		27/03/2020
Tewkesbury	E07000083	South West	WRSE		18/03/2020
Thanet	E07000114	South East	WRSE		27/03/2020
Three Rivers	E07000102	East of England	WRSE		23/03/2020
Tonbridge and Malling	E07000115	South East	WRSE		27/03/2020
Tower Hamlets	E09000030	London	WRSE		24/03/2020
Tunbridge Wells	E07000116	South East	WRSE		27/03/2020
Uttlesford	E07000077	East of England	WRSE		23/03/2020
Vale of White Horse	E07000180	South East	WRSE	OxCam	16/03/2020
Waltham Forest	E09000031	London	WRSE		23/03/2020
Wandsworth	E09000032	London	WRSE		23/03/2020
Watford	E07000103	East of England	WRSE		23/03/2020
Waverley	E07000216	South East	WRSE		27/03/2020
Wealden	E07000065	South East	WRSE		27/03/2020
Wellingborough	E07000156	East Midlands		OxCam	18/03/2020
Welwyn Hatfield	E07000241	East of England	WRSE		20/03/2020
West Berkshire	E06000037	South East	WRSE		28/03/2020
West Oxfordshire	E07000181	South East	WRSE	OxCam	16/03/2020
Westminster	E09000033	London	WRSE		23/03/2020
Wiltshire	E06000054	South West	WRSE		18/03/2020
Winchester	E07000094	South East	WRSE		28/03/2020
Windsor and Maidenhead	E06000040	South East	WRSE		29/03/2020
Woking	E07000217	South East	WRSE		29/03/2020
Wokingham	E06000041	South East	WRSE		29/03/2020
Worthing	E07000229	South East	WRSE		16/03/2020
Wychavon	E07000238	West Midlands	WRSE		12/03/2020
Wycombe	E07000007	South East	WRSE	OxCam	29/03/2020

## Appendix C Projection Accuracy

- C.1 The illustration below provides a summary of official UK population projections and their relationship to the actual trajectory of population change.



Source: ONS, OBR

- C.2 Historically, the UK population has risen more than projected, with one exception. The 1965-based population growth trajectory was based upon the continuation of the high fertility rates experienced in the early 1960s, which peaked in 1964, falling to a record low in 1977.
- C.3 In subsequent years, projections have typically under-estimated future population growth due to one or more of three factors: (i) the allocation of insufficient growth through international migration; (ii) a failure to anticipate a return to higher fertility rates; and (iii) a failure to anticipate the continued improvements in life expectancy (longevity).
- C.4 More recently, projections have demonstrated greater convergence, with lower international migration, plus reduced assumptions on long-term fertility rates and improvements in life expectancy, having a dampening effect upon population growth outcomes.

# Appendix D ONS & GLA Projections

## (i) ONS National Projections

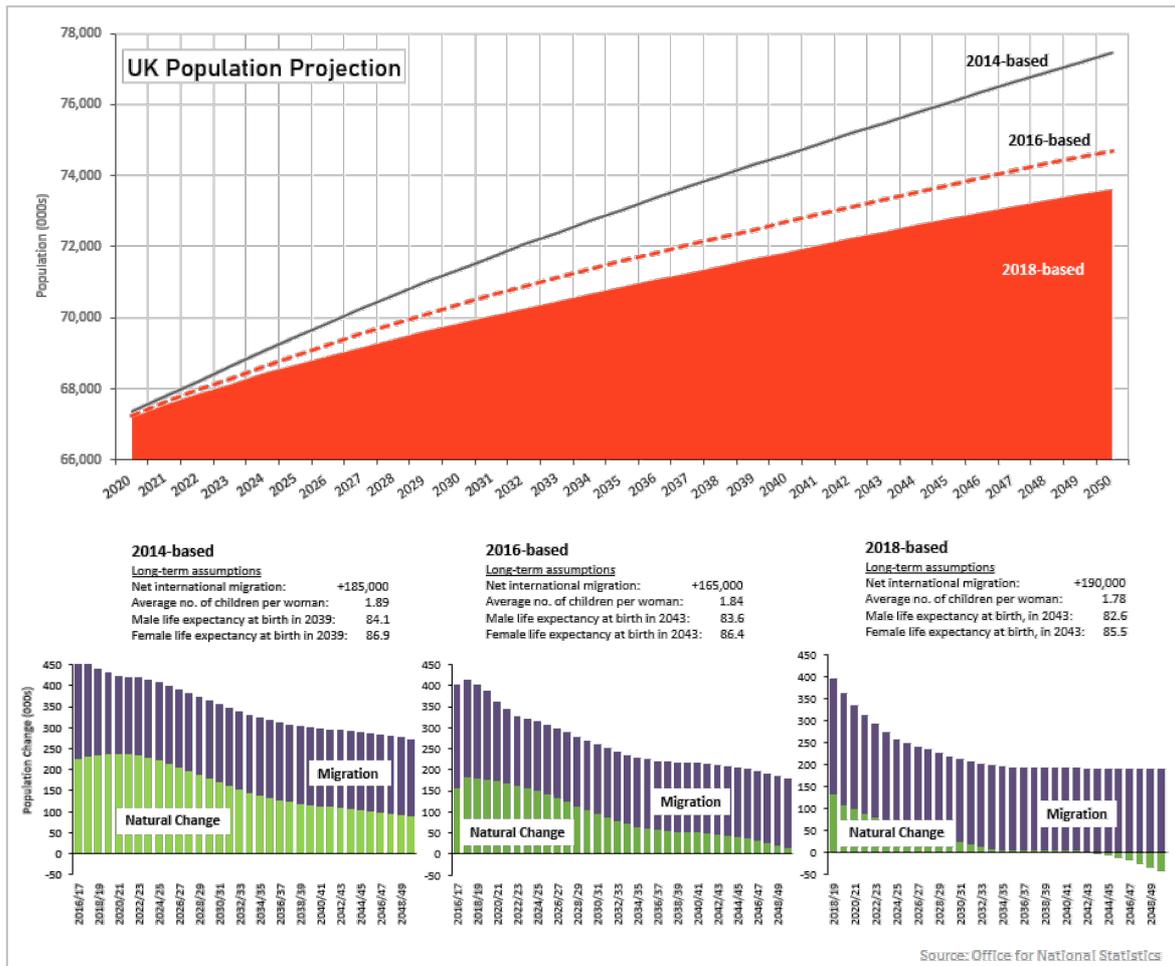
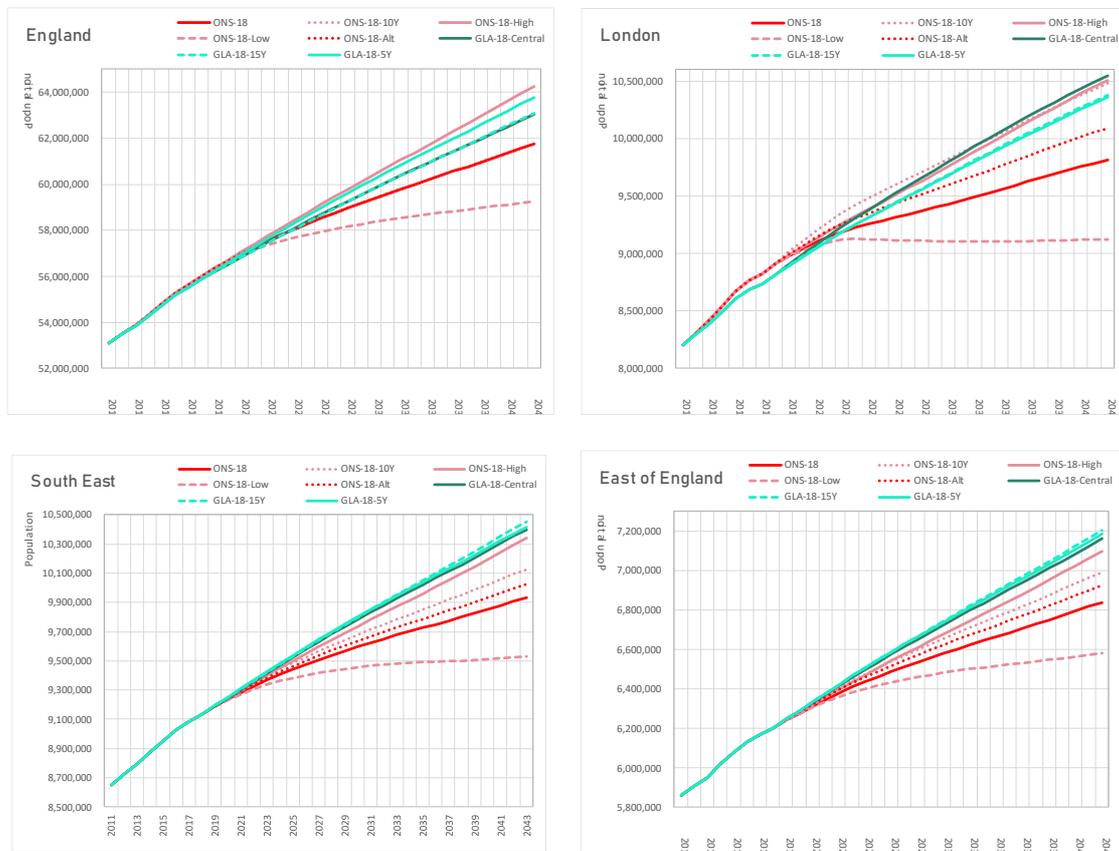


Figure 15: UK Population Projections

## (ii) ONS vs GLA Projections Compared



Source: ONS, GLA

Figure 16: ONS & GLA 2018-based Projections Compared

# Appendix E OxCam Geography

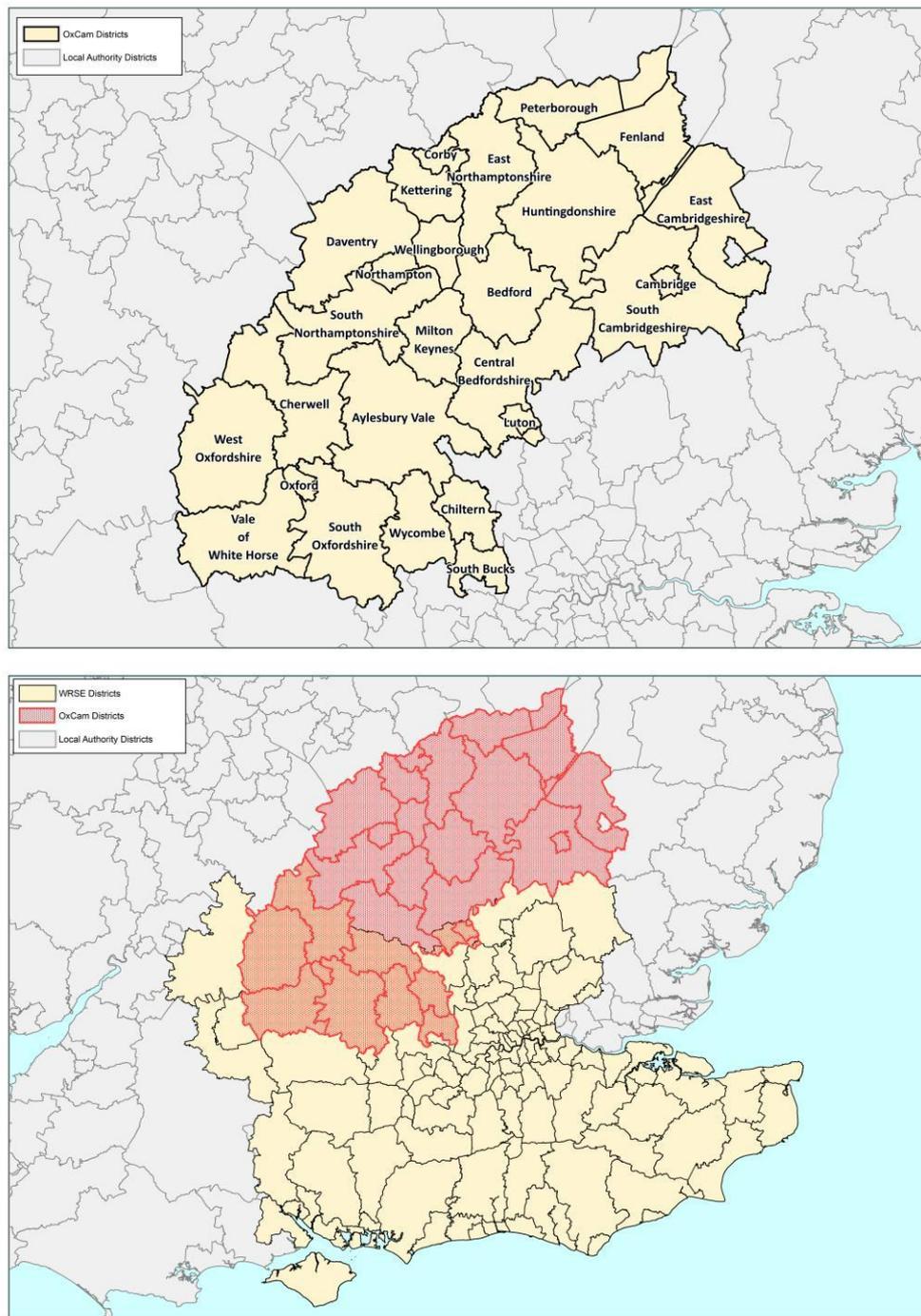
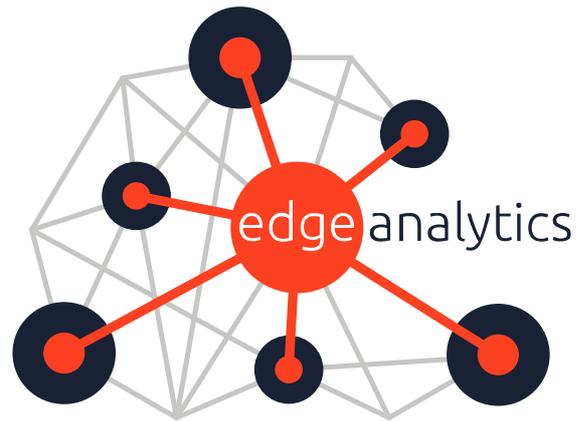


Figure 17: OxCam Area Definition



Edge Analytics Ltd

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# WRSE

## FORECAST COMPARISON

June 2023



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## ACKNOWLEDGEMENTS

Demographic statistics used in this report have been derived from data from the Office for National Statistics licensed under the Open Government Licence v.3.0.

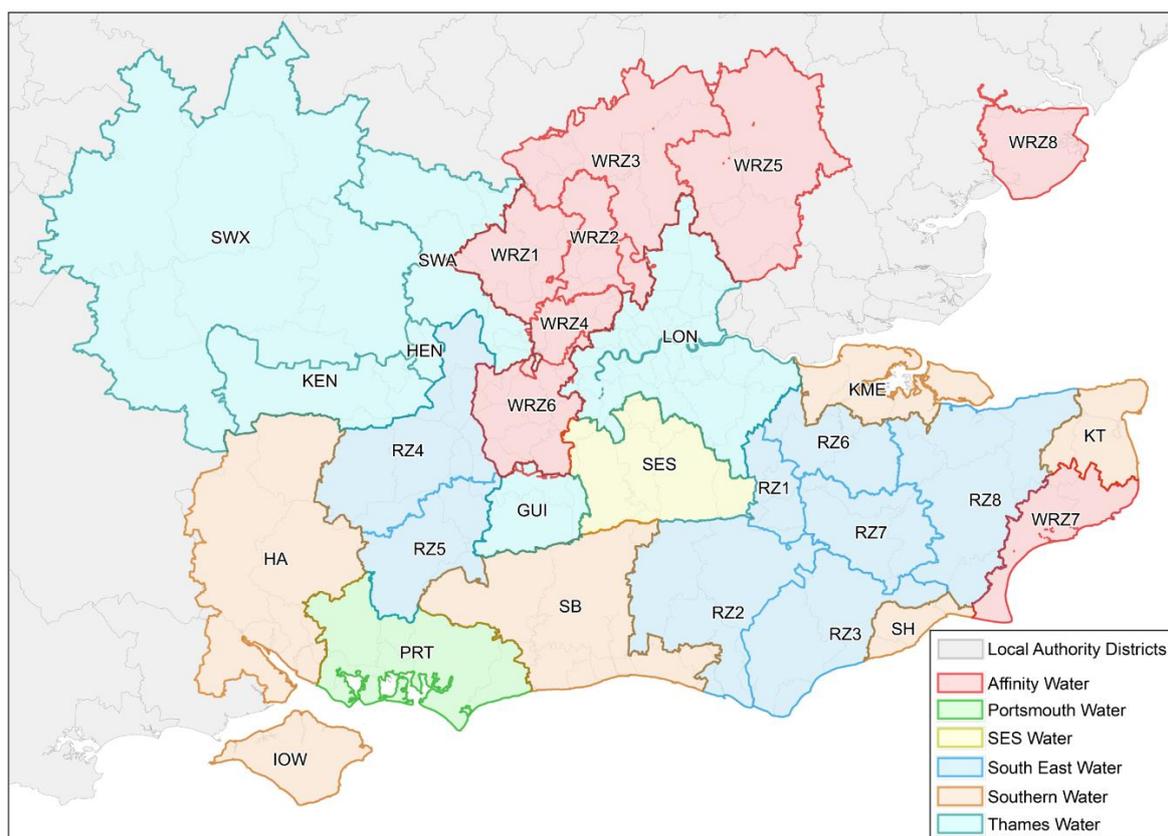
*The authors of this report do not accept liability for any costs or consequential loss involved following the use of the data and analysis referred to here; this is entirely the responsibility of the users of the information presented in this report.*

# CONTENTS

Acknowledgements.....	i
Contents .....	ii
<b>1</b> Introduction.....	1
<b>2</b> Methods, Data Inputs & Assumptions.....	3
Base Year.....	3
Local Plan Housing Growth Data .....	3
Other Changes.....	4
<b>3</b> Scenario Outcomes.....	5
WRSE.....	6
Affinity Water (WRZ 1–7) .....	7
Portsmouth Water .....	8
SES Water .....	9
South East Water .....	10
Southern Water .....	11
Thames Water.....	12
<b>4</b> Future Data Releases .....	13
Appendix A Scenario Definition 2020 .....	14

# 1 INTRODUCTION

- 1.1 The Water Resources South East (WRSE) group is an alliance of the six water companies that cover the South East region of England: Affinity Water, Portsmouth Water, SES Water, South East Water, Southern Water, and Thames Water.



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Figure 1: WRSE Area Definition

- 1.2 In spring and summer 2020, Edge Analytics delivered a suite of demographic and housing evidence to WRSE to inform the development of their Water Resource Management Plans (WRMP). The deliverables included (amongst other items):

- Local Plan Housing Growth information, from the Edge Analytics Consilium database
- Population and housing forecasts generated using Edge Analytics' VICUS forecasting technology (for a forecast period **2020–2100** and a range of trend-based, housing-led and employment-led scenarios)<sup>1</sup>.

<sup>1</sup> For the full list of scenarios refer to Appendix A.

- 1.3 Since the 2020 delivery, there have been a number of important data releases (e.g., Census 2021 results, more up-to-date Local Plan Housing Growth information), which highlighted the need to revisit the forecasts and update them in light of this new information.
- 1.4 In February 2023, WRSE commissioned Edge Analytics to produce updated population and property forecasts, taking account of the latest demographic and housing statistics<sup>2</sup>. The outputs were produced for a **2021–2101** forecast period and for a sub-set of the 2020 scenarios, including:
- ONS-18-Rebased-P
  - ONS-18-Rebased-L
  - Housing-Plan-P
  - Housing-Need-H
  - OxCam-1a-r-P.
- 1.5 An additional scenario was also produced, which was not included in the 2020 forecasts:
- OxCam-1a-P.
- 1.6 A detailed description of each of the scenarios is provided in Section 3 of this document.
- 1.7 This concise report aims to help in understanding how the 2023 forecasts compare to those produced in 2020, summarising the key differences in terms of methods, data inputs and assumptions (Section 2). A side-by-side comparison of the forecast outcomes is also presented at regional and company level in Section 3. Section 4 of the document provides a timeline of expected future data releases which will provide additional intelligence which can feed into future updated population and housing forecasts.

---

<sup>2</sup> Note that the latest Local Plan Housing Growth data was used to inform the scenario forecast development in February 2023, but it did not form part of the 2023 deliverable to WRSE.

## 2 METHODS, DATA INPUTS & ASSUMPTIONS

- 2.1 The overall approach for the development of the 2023 forecasts remains the same as in 2020. A detailed description of the forecasting framework can be found in the earlier Edge Analytics' report: **VICUS - Methodology - Final - 31.07.2020**.
- 2.2 This section focuses on the key changes to the methods, data inputs and assumptions that were required for the 2023 update.
- 2.3 The main drivers of the differences between the 2020 and 2023 forecasts are different **base years** and changes to the **housing growth evidence** informing the Housing-Need and Housing-Plan scenarios. Other methodological/data changes have also had an impact on the forecast outcomes but to a lesser extent. All are discussed in more detail below.

### Base Year

- 2.4 In the 2020 forecasts, the **2018** mid-year population estimates (MYE) provided the forecast base year. In the 2023 forecasts, the base year was updated to the **2021** MYEs, which were published by the Office for National Statistics (ONS) in December 2022. Importantly, the 2021 MYEs are the first MYEs to be underpinned by the Census 2021.
- 2.5 In the years in between the decennial Census, the population is estimated via an annual ONS MYE. This estimate takes account of registered births and deaths and estimates of domestic and international migration.
- 2.6 The output from the Census 2021 and the subsequent 2021 MYEs derived from it have shown differences in both the *population total* and the underlying *structure of the population* (its composition by age and sex) when compared to the MYEs that preceded it.

### Local Plan Housing Growth Data

- 2.7 Local Plan Housing Growth data provides the housing growth trajectories that drive population growth under the Housing-Need and Housing-Plan scenarios. In addition, it is the source of the housing development site information that further enhances the Housing-Plan scenario, ensuring that the growth forecasts are distributed in line with the location and phasing of future housing developments.
- 2.8 In both sets of the forecasts (2020 and 2023), the 'Need' and 'Plan' housing trajectories were drawn from the Edge Analytics Consilium Local Plan Housing Growth database. However, the information used in the 2020 forecasts was last updated in **March–April 2020**, whereas in the 2023 forecasts this data was last updated in **January–February 2023**.

## Other Changes

2.9 A number of other methodological/data changes were required for the 2023 update, including:

- Coercion of historical demographic inputs (population, households, population not-in-households, etc.) to a Census 2021 Output Area (OA21) geography.
- Alignment of the Census 2021 population, households and population not-in-households at district and small area level.
- Use of the Census/2021 MYE data to devise population by single year of age and sex constraints at OA21 level (not available from official releases).
- Modelling of population not-in-households data by age groups and sex from available partial Census 2021 data, aligning it with 2021 MYE.
- Updating/estimating other model inputs, such as household, vacancy, and properties to an OA21 basis, utilising Census 2021 where available.
- Rescaling Sub-National Population Projection (SNPP) trajectories to a 2021 MYE starting point and extending them to 2050.
- Rescaling of household headship rates to a rebased Census 2021 value.
- Reformulation of all models to accept the new Census/2021 MYE data.

## 3 SCENARIO OUTCOMES

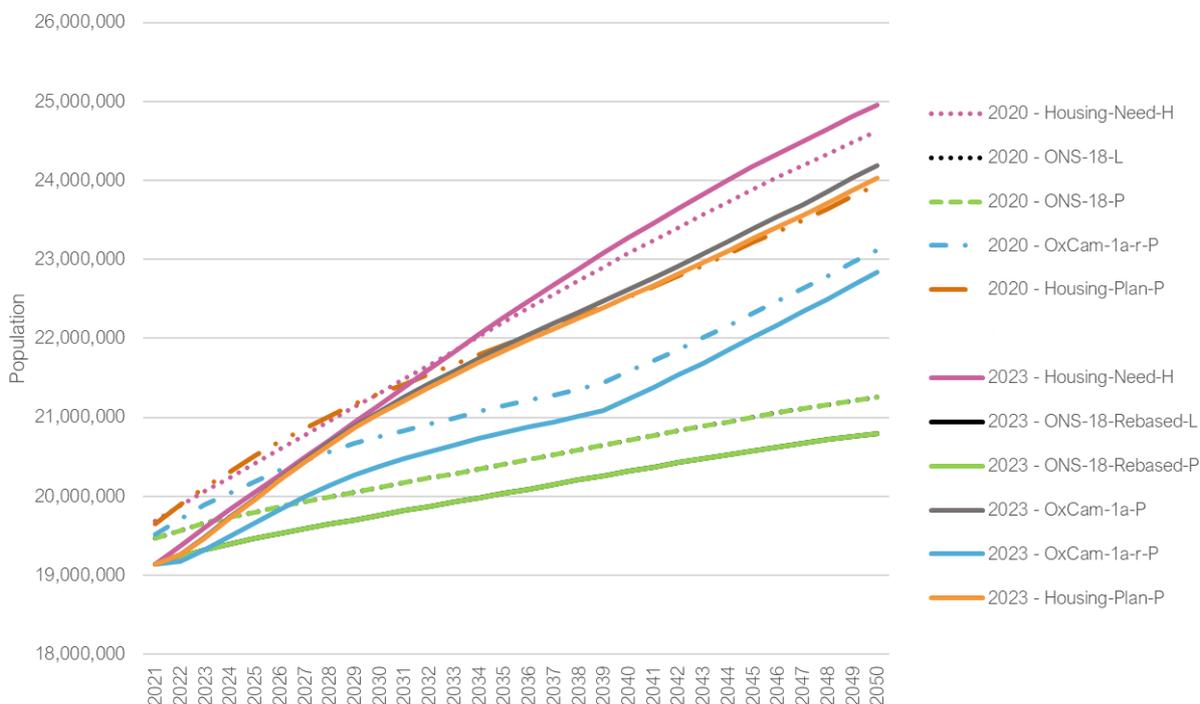
3.1 The 2023 forecasts were produced for the following scenarios:

ID	SCENARIO	DESCRIPTION
1a	ONS-18-Rebased-P	<p>ONS 2018-based <i>Principal</i> sub-national population projection (SNPP), using a five-year history (2013–2018) to derive local fertility &amp; mortality assumptions and a long-term UK net international migration assumption of +190k. Unlike earlier rounds of SNPP, the 2018-based <i>Principal</i> projection uses a two-year history (2016–2018) of internal migration assumptions, following recent changes to the methodology used for its estimation, which have only covered the latest 2 years. <b>This scenario has been rebased to the 2021 MYE.</b></p> <p>From 2050 to 2101, growth under this scenario is trended in line with the <i>Principal</i> (-P) 2018-based national population projection (NPP) from ONS.</p>
1b	ONS-18-Rebased-L	<p>ONS 2018-based <i>Principal</i> SNPP using a five-year history (2013–2018) to derive local fertility &amp; mortality assumptions and a long-term UK net international migration assumption of +190k. Unlike earlier rounds of SNPP, the 2018-based <i>Principal</i> projection uses a two-year history (2016–2018) of internal migration assumptions, following recent changes to the methodology used for its estimation, which have only covered the latest 2 years. <b>This scenario has been rebased to the 2021 MYE.</b></p> <p>From 2050 to 2101, growth under this scenario is trended in line with the <i>Low migration</i> (-L) variant of the ONS 2018-based NPP.</p>
2	Housing-Need-H	<p>A Housing-led scenario, with population growth underpinned by the trajectory of housing growth associated with each local authority's Local Housing Need (LHN) or Objectively Assessed Housing Need (OAHN). Following the final year of data, projected housing growth in non-London areas returns to the average of ONS-14 &amp; ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.</p> <p>From 2050 to 2101, growth under this scenario is trended in line with the <i>High migration</i> (-H) variant of the ONS 2018-based NPP.</p>
3	Housing-Plan-P	<p>A Housing-led scenario, with population growth underpinned by each local authority's Local Plan housing growth trajectory. Following the final year of data, projected housing growth in non-London areas returns to the average of ONS-14 &amp; ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.</p> <p>From 2050 to 2101, growth under this scenario is trended in line with the <i>Principal</i> (-P) 2018-based NPP from ONS.</p>
4	OxCam-1a-P	<p>'New Settlement' 23k dpa scenario, with c.3.8k dpa above Housing-Plan distributed between Cherwell (20%), Aylesbury Vale (20%), Central Bedfordshire (40%), South Cambridgeshire (20%).</p> <p>From 2050 to 2101, growth under this scenario is trended in line with the <i>Principal</i> (-P) 2018-based NPP from ONS.</p>
5	OxCam-1a-r-P	<p>A Housing-led scenario, consistent with the OxCam-1a scenario, but with household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.</p> <p>From 2050 to 2101, growth under this scenario is trended in line with the <i>Principal</i> (-P) 2018-based NPP from ONS.</p>

3.2 Scenario outcomes for these scenarios, compared to the equivalent scenarios from the 2020 forecasts, are presented below. Note that an additional OxCam scenario was included in the 2023 projections (OxCam-1a-P) that was not delivered as part of the 2020 scenarios.

3.3 For WRSE in total and each constituent water company, the summaries include a chart showing population growth between 2021 and 2050 and two tables contrasting population change and average dwellings per annum for the medium- (2021–2050) and long-term (2021–2100) forecast periods.

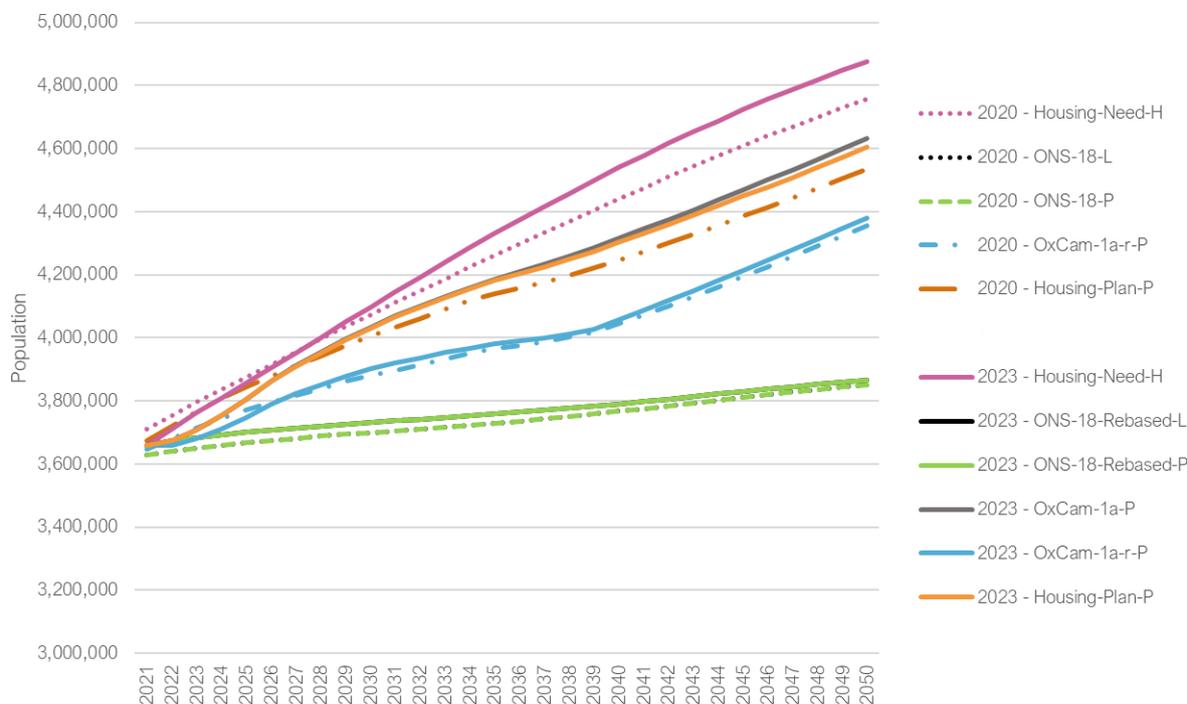
# WRSE



2020 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	19,692,433	24,628,751	4,936,318	25.1%	99,131	19,692,433	29,805,795	10,113,361	51.4%	75,819
Housing-Plan-P	19,648,395	23,945,684	4,297,290	21.9%	89,688	19,648,395	27,011,856	7,363,461	37.5%	58,558
ONS-18-L	19,473,684	21,251,483	1,777,798	9.1%	51,770	19,473,684	22,074,570	2,600,886	13.4%	29,409
ONS-18-P	19,473,684	21,251,483	1,777,798	9.1%	51,770	19,473,684	24,031,005	4,557,320	23.4%	42,021
OxCam-1a-r-P	19,514,665	23,117,138	3,602,473	18.5%	91,761	19,514,665	26,092,542	6,577,877	33.7%	59,484

2023 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	19,136,248	24,959,131	5,822,883	30.4%	105,433	19,136,248	29,243,867	10,107,619	52.8%	69,438
Housing-Plan-P	19,136,298	24,028,276	4,891,978	25.6%	91,840	19,136,298	25,884,596	6,748,298	35.3%	49,432
ONS-18-Rebased-L	19,136,248	20,799,731	1,663,482	8.7%	46,074	19,136,248	20,231,861	1,095,613	5.7%	17,364
ONS-18-Rebased-P	19,136,248	20,799,731	1,663,482	8.7%	46,074	19,136,248	22,442,699	3,306,451	17.3%	30,832
OxCam-1a-P	19,136,248	24,193,687	5,057,439	26.4%	94,542	19,136,248	26,060,611	6,924,363	36.2%	50,562
OxCam-1a-r-P	19,136,248	22,842,472	3,706,224	19.4%	94,469	19,136,248	24,629,081	5,492,833	28.7%	50,533

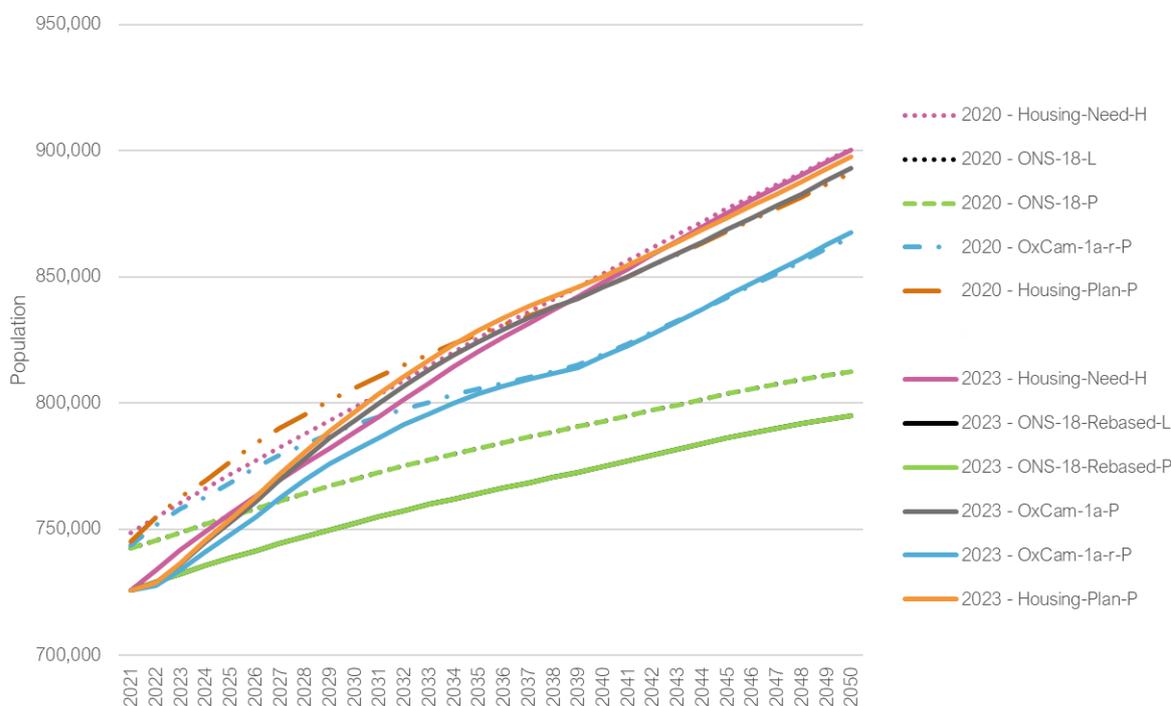
## Affinity Water (WRZ 1–7)



2020 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	3,712,322	4,756,450	1,044,128	28.1%	20,185	3,712,322	5,757,125	2,044,803	55.1%	14,996
Housing-Plan-P	3,675,735	4,534,814	859,079	23.4%	21,776	3,675,735	5,108,527	1,432,793	39.0%	13,576
ONS-18-L	3,627,846	3,851,581	223,735	6.2%	7,979	3,627,846	3,988,751	360,905	9.9%	4,814
ONS-18-P	3,627,846	3,851,581	223,735	6.2%	7,979	3,627,846	4,352,547	724,701	20.0%	7,087
OxCam-1a-r-P	3,645,711	4,356,258	710,547	19.5%	17,418	3,645,711	4,912,389	1,266,677	34.7%	11,232

2023 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	3,659,990	4,876,354	1,216,364	33.2%	21,484	3,659,990	5,675,305	2,015,315	55.1%	13,517
Housing-Plan-P	3,659,509	4,603,991	944,483	25.8%	17,540	3,659,509	4,923,200	1,263,692	34.5%	9,113
ONS-18-Rebased-L	3,659,990	3,867,145	207,156	5.7%	7,115	3,659,990	3,730,791	70,801	1.9%	2,478
ONS-18-Rebased-P	3,659,990	3,867,145	207,156	5.7%	7,115	3,659,990	4,140,910	480,920	13.1%	4,914
OxCam-1a-P	3,659,990	4,633,982	973,992	26.6%	18,169	3,659,990	4,955,098	1,295,109	35.4%	9,389
OxCam-1a-r-P	3,659,990	4,381,606	721,617	19.7%	18,108	3,659,990	4,689,747	1,029,757	28.1%	9,365

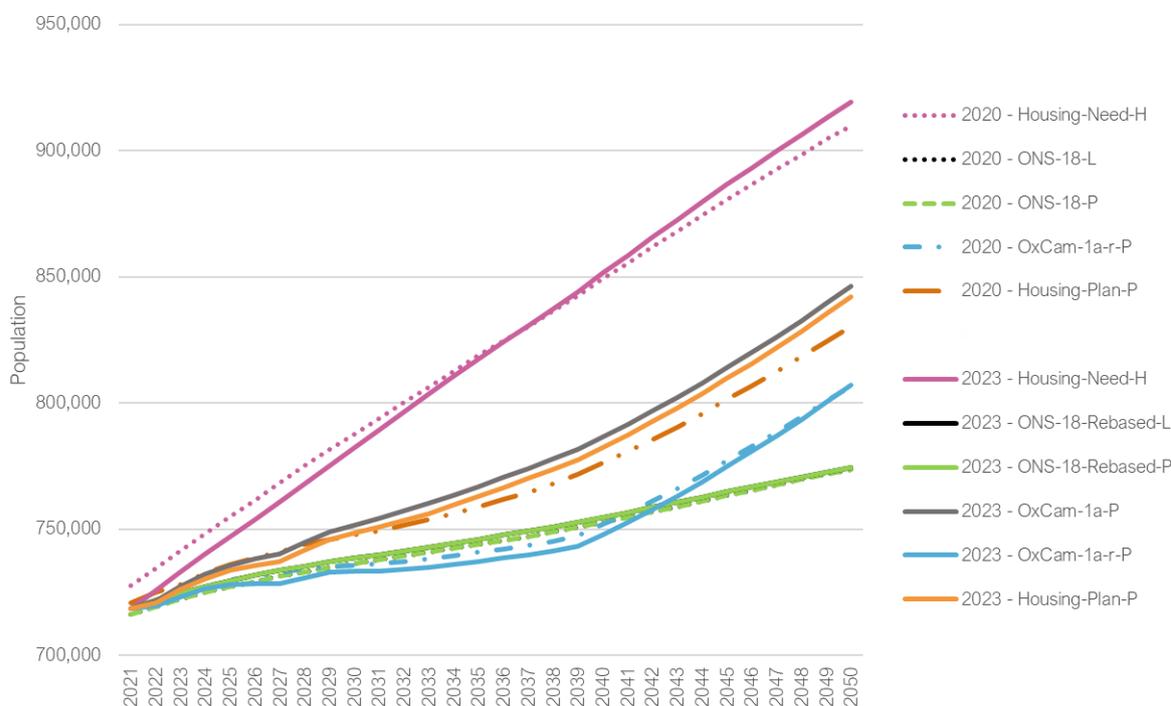
## Portsmouth Water



2020 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	748,387	900,486	152,099	20.3%	3,066	748,387	1,085,645	337,258	45.1%	2,532
Housing-Plan-P	745,237	891,292	146,055	19.6%	3,880	745,237	1,008,361	263,124	35.3%	2,721
ONS-18-L	742,427	812,532	70,105	9.4%	1,794	742,427	853,492	111,065	15.0%	1,111
ONS-18-P	742,427	812,532	70,105	9.4%	1,794	742,427	920,393	177,966	24.0%	1,542
OxCam-1a-r-P	743,456	865,817	122,361	16.5%	2,881	743,456	979,714	236,258	31.8%	2,014

2023 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	725,553	900,343	174,789	24.1%	3,127	725,553	1,075,251	349,698	48.2%	2,406
Housing-Plan-P	725,539	897,778	172,239	23.7%	3,140	725,539	985,527	259,988	35.8%	1,872
ONS-18-Rebased-L	725,553	795,045	69,492	9.6%	1,704	725,553	790,037	64,484	8.9%	752
ONS-18-Rebased-P	725,553	795,045	69,492	9.6%	1,704	725,553	874,172	148,619	20.5%	1,276
OxCam-1a-P	725,553	892,887	167,333	23.1%	3,022	725,553	980,087	254,533	35.1%	1,824
OxCam-1a-r-P	725,553	867,562	142,009	19.6%	3,023	725,553	952,748	227,194	31.3%	1,825

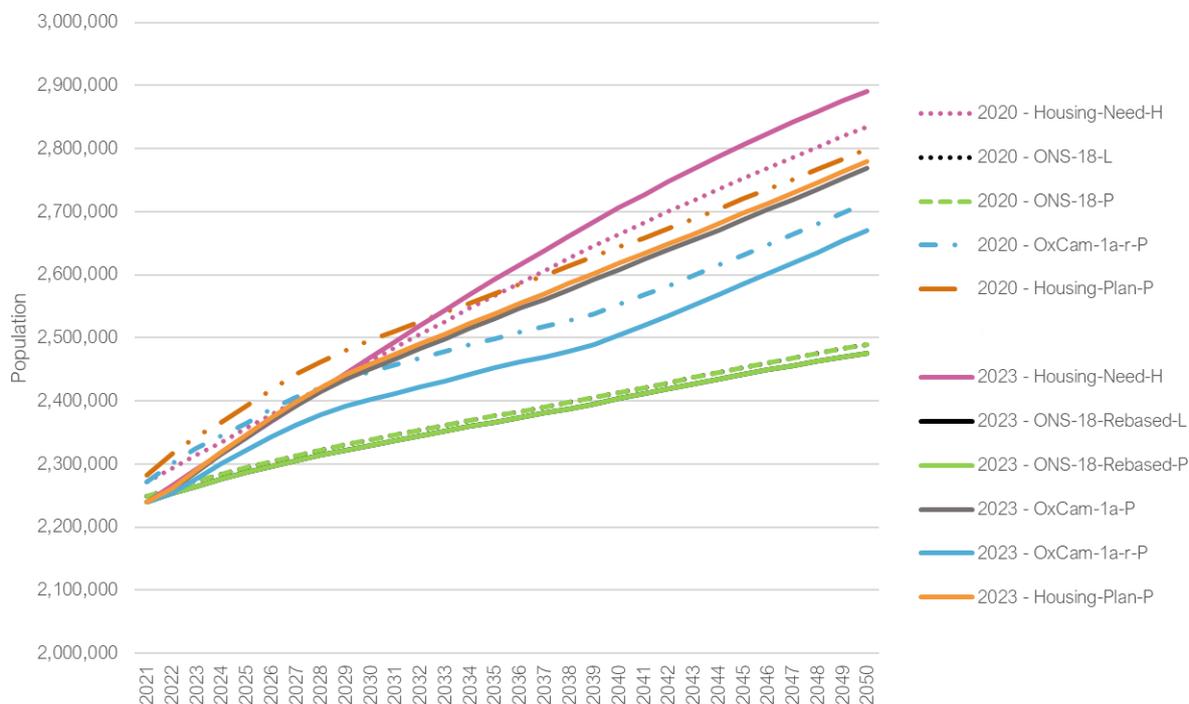
## SES Water



2020 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	727,523	909,839	182,316	25.1%	3,682	727,523	1,113,103	385,581	53.0%	2,872
Housing-Plan-P	720,607	830,416	109,809	15.2%	2,432	720,607	943,989	223,382	31.0%	1,797
ONS-18-L	716,189	773,534	57,344	8.0%	1,772	716,189	805,858	89,669	12.5%	1,052
ONS-18-P	716,189	773,534	57,344	8.0%	1,772	716,189	880,331	164,142	22.9%	1,520
OxCam-1a-r-P	718,493	806,816	88,323	12.3%	2,564	718,493	917,366	198,873	27.7%	1,875

2023 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	718,414	919,290	200,876	28.0%	3,822	718,414	1,082,268	363,854	50.6%	2,569
Housing-Plan-P	718,411	841,948	123,537	17.2%	2,561	718,411	908,215	189,804	26.4%	1,490
ONS-18-Rebased-L	718,414	774,239	55,825	7.8%	1,647	718,414	750,752	32,338	4.5%	615
ONS-18-Rebased-P	718,414	774,239	55,825	7.8%	1,647	718,414	835,422	117,008	16.3%	1,122
OxCam-1a-P	718,414	846,313	127,899	17.8%	2,766	718,414	912,751	194,337	27.1%	1,582
OxCam-1a-r-P	718,414	807,012	88,598	12.3%	2,726	718,414	870,926	152,512	21.2%	1,566

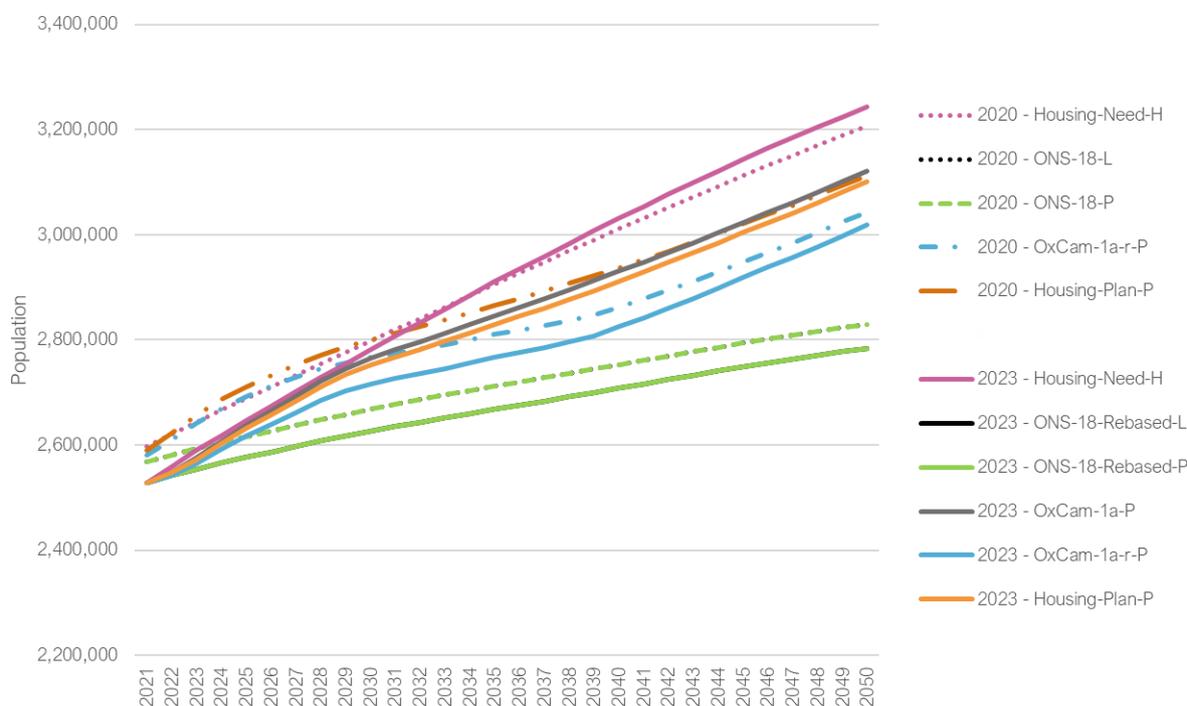
## South East Water



2020 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	2,271,042	2,834,703	563,661	24.8%	10,703	2,271,042	3,456,943	1,185,901	52.2%	8,592
Housing-Plan-P	2,282,131	2,799,709	517,578	22.7%	9,479	2,282,131	3,192,214	910,083	39.9%	6,473
ONS-18-L	2,248,224	2,489,172	240,948	10.7%	5,863	2,248,224	2,629,952	381,728	17.0%	3,730
ONS-18-P	2,248,224	2,489,172	240,948	10.7%	5,863	2,248,224	2,845,650	597,426	26.6%	5,064
OxCam-1a-r-P	2,271,558	2,714,652	443,094	19.5%	10,041	2,271,558	3,097,239	825,681	36.3%	6,915

2023 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	2,239,920	2,891,603	651,683	29.1%	11,689	2,239,920	3,436,782	1,196,862	53.4%	8,237
Housing-Plan-P	2,239,978	2,779,534	539,556	24.1%	10,040	2,239,978	3,034,274	794,296	35.5%	5,846
ONS-18-Rebased-L	2,239,920	2,475,501	235,580	10.5%	5,573	2,239,920	2,444,097	204,177	9.1%	2,429
ONS-18-Rebased-P	2,239,920	2,475,501	235,580	10.5%	5,573	2,239,920	2,706,523	466,603	20.8%	4,002
OxCam-1a-P	2,239,920	2,769,517	529,597	23.6%	9,852	2,239,920	3,023,315	783,394	35.0%	5,771
OxCam-1a-r-P	2,239,920	2,670,687	430,767	19.2%	9,858	2,239,920	2,917,194	677,274	30.2%	5,773

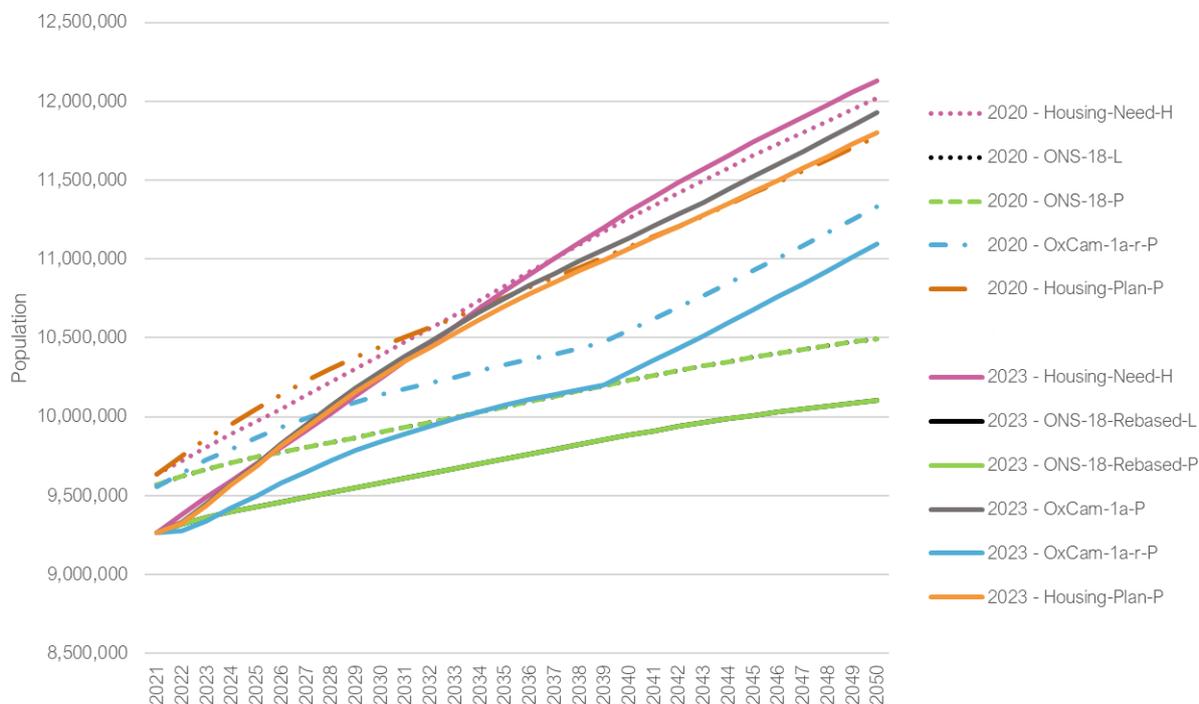
## Southern Water



2020 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	2,596,809	3,207,317	610,509	23.5%	11,837	2,596,809	3,934,210	1,337,401	51.5%	9,825
Housing-Plan-P	2,589,291	3,112,693	523,402	20.2%	10,330	2,589,291	3,578,632	989,341	38.2%	7,477
ONS-18-L	2,568,914	2,829,776	260,862	10.2%	6,459	2,568,914	3,014,022	445,108	17.3%	4,265
ONS-18-P	2,568,914	2,829,776	260,862	10.2%	6,459	2,568,914	3,256,305	687,392	26.8%	5,817
OxCam-1a-r-P	2,580,275	3,043,213	462,938	17.9%	10,648	2,580,275	3,499,841	919,565	35.6%	7,699

2023 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	2,528,359	3,243,223	714,864	28.3%	12,541	2,528,359	3,851,253	1,322,894	52.3%	8,952
Housing-Plan-P	2,528,327	3,100,327	572,000	22.6%	10,358	2,528,327	3,385,798	857,471	33.9%	6,147
ONS-18-Rebased-L	2,528,359	2,783,869	255,511	10.1%	6,170	2,528,359	2,748,969	220,610	8.7%	2,588
ONS-18-Rebased-P	2,528,359	2,783,869	255,511	10.1%	6,170	2,528,359	3,044,246	515,888	20.4%	4,411
OxCam-1a-P	2,528,359	3,120,341	591,983	23.4%	10,746	2,528,359	3,407,774	879,416	34.8%	6,306
OxCam-1a-r-P	2,528,359	3,018,091	489,732	19.4%	10,741	2,528,359	3,298,060	769,701	30.4%	6,305

## Thames Water



2020 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	9,636,351	12,019,956	2,383,605	24.7%	49,658	9,636,351	14,458,769	4,822,417	50.0%	37,003
Housing-Plan-P	9,635,394	11,776,760	2,141,366	22.2%	41,790	9,635,394	13,180,132	3,544,738	36.8%	26,513
ONS-18-L	9,570,084	10,494,887	924,804	9.7%	27,903	9,570,084	10,782,495	1,212,411	12.7%	14,437
ONS-18-P	9,570,084	10,494,887	924,804	9.7%	27,903	9,570,084	11,775,778	2,205,694	23.0%	20,991
OxCam-1a-r-P	9,555,172	11,330,382	1,775,210	18.6%	48,209	9,555,172	12,685,994	3,130,822	32.8%	29,749

2023 Scenarios	Population		Population Change	Population Change %	Dwellings p.a.	Population		Population Change	Population Change %	Dwellings p.a.
	2021	2050				2021	2100			
Housing-Need-H	9,264,012	12,128,318	2,864,306	30.9%	52,770	9,264,012	14,123,008	4,858,996	52.5%	33,757
Housing-Plan-P	9,264,534	11,804,698	2,540,164	27.4%	48,201	9,264,534	12,647,581	3,383,048	36.5%	24,964
ONS-18-Rebased-L	9,264,012	10,103,932	839,920	9.1%	23,865	9,264,012	9,767,215	503,203	5.4%	8,502
ONS-18-Rebased-P	9,264,012	10,103,932	839,920	9.1%	23,865	9,264,012	10,841,426	1,577,414	17.0%	15,107
OxCam-1a-P	9,264,012	11,930,647	2,666,635	28.8%	49,987	9,264,012	12,781,586	3,517,574	38.0%	25,689
OxCam-1a-r-P	9,264,012	11,097,513	1,833,500	19.8%	50,012	9,264,012	11,900,407	2,636,395	28.5%	25,699

## 4 FUTURE DATA RELEASES

- 4.1 All forecasts are dependent on the data inputs and assumptions used in their configuration, so it is important to monitor future data releases to understand when it may be needed to revisit and update the forecasts in the light of more up-to-date evidence.
- 4.2 The following table details the key forthcoming data from ONS which will provide additional intelligence to inform future forecasts:

Data release	Release date
Revised official 2021 MYE for the UK, its constituent countries and local authority districts.	<a href="#">September 2023 (provisional)</a>
Rebasing of MYEs following Census 2021, England and Wales This release contains the rebased MYEs for the period 2012 to 2020 to align with Census 2021 results.	<a href="#">September 2023 (provisional)</a>
Population estimates for England and Wales: mid-2022 National and sub-national mid-year population estimates for England and Wales by administrative area, age and sex.	<a href="#">September 2023 (provisional)</a>
National population projections: 2021-based	<a href="#">December 2023 (provisional)</a>
Sub-national population projections: 2021-based	Will follow on from 2021-based national population projections in 2024, but release timescale unknown
Household projections: 2021-based	Unknown

- 4.3 Due to uncertainty around the 2021 Census estimates and the intercensal MYEs, it is recommended that, once the updated MYEs are released in September 2023, a refresh of the scenario evidence is considered.

# Appendix A

## SCENARIO DEFINITION 2020

A.1 The table below provides a list of all 2020–2050 scenarios that were delivered to WRSE in 2020:

ID	SCENARIO	DESCRIPTION
1	ONS-14	ONS 2014-based sub-national population projection (SNPP), using a six-year history (2008–2014) to derive local fertility, mortality and internal migration assumptions, with a long-term UK net international migration assumption of +185k p.a.
2	ONS-16	ONS 2016-based Principal sub-national population projection (SNPP), using a five-year history (2011–2016) to derive local fertility, mortality and internal migration assumptions, and a long-term UK net international migration assumption of +165k. In line with the ONS 2016-based national population projection (NPP), this round of projections includes a reduced UK fertility outlook compared to ONS-14 and a dampened rate of improvement in life expectancy compared to ONS-14.
3	ONS-18	ONS 2018-based Principal sub-national population projection (SNPP), using a five-year history (2013–2018) to derive local fertility & mortality assumptions and a long-term UK net international migration assumption of +190k. Unlike earlier rounds of SNPP, the 2018-based Principal projection uses a two-year history (2016–2018) of internal migration assumptions, following recent changes to the methodology used for its estimation, which have only covered the latest 2 years. In line with the ONS 2018-based national population projection (NPP), this round of projections includes a reduced UK fertility outlook compared to ONS-16 and a dampened rate of improvement in life expectancy compared to ONS-16.
4	ONS-18-Alt	ONS 2018-based Alternative Internal Migration sub-national population projection (SNPP), produced by ONS as a comparison with the Principal projection. It uses a five-year average of internal migration (2013–2018), combining 3 years of data based on the old methodology and 2 years based on the new methodology. All other assumptions are consistent with ONS-18.
5	ONS-18-High	ONS 2018-based High International Migration sub-national population projection (SNPP), incorporating a High long-term UK net international migration assumption of +290k p.a., with all other assumptions consistent with ONS-18.
6	ONS-18-Low	ONS 2018-based Low International Migration sub-national population projection (SNPP), incorporating a Low long-term UK net international migration assumption of +90k p.a., with all other assumptions consistent with ONS-18.
7	ONS-18-10Y	ONS 2016-based 10yr Migration (all types) sub-national population projection, using a ten-year history (2008–2018) to derive internal migration assumptions, with all other assumptions consistent with ONS-18.
8	GLA-18-Central	Greater London Authority (GLA) 2018-based Central population projection, incorporating: GLA's own adjustments to the mid-year population estimates of London Boroughs; local fertility and mortality assumptions, trended in line with the ONS 2018-based NPP assumptions; internal and international migration assumptions derived from a 10-year history (2008–2018). This scenario includes projections for London Boroughs and for all other local authority areas.
9	GLA-18-15Y	GLA 2018-based long-term trend projection, incorporating internal and international migration assumptions derived from a 15-year history (2003–2018), with all other assumptions consistent with the Central scenario. This scenario includes projections for London Boroughs and for all other local authority areas.
10	GLA-18-5Y	GLA 2018-based short-term trend projection, incorporating internal and international migration assumptions derived from a 5-year history (2013–2018), with all other assumptions consistent with the Central scenario. This scenario includes projections for London Boroughs and for all other local authority areas.

ID	SCENARIO	DESCRIPTION
11	GLA-Housing	GLA 2018-based Housing-led projection, based on data from the 2016 Strategic Housing Land Availability Assessment (SHLAA). Beyond 2041, housing growth is aligned to the 2035–2041 average. Whilst the housing-led approach is applied to each London Borough, the population projection for Greater London, in total, remains consistent with the Central scenario. This scenario includes projections for London Boroughs only and is combined with the Central scenario for all other local authority areas when aggregated to WRZ geographies.
12	Completions-18Y	A Housing-led scenario, with population growth underpinned by a continuation of the rate of housing growth recorded in each local authority's 18-year completions history (2001–2019).
13	Completions-5Y	A Housing-led scenario, with population growth underpinned by a continuation of the rate of housing growth recorded in each local authority's 5-year completions history (2014–2019).
14	Housing-Need	A Housing-led scenario, with population growth underpinned by the trajectory of housing growth associated with each local authority's Local Housing Need (LHN) or Objectively Assessed Housing Need (OAHN). Following the final year of data, projected housing growth in non-London areas returns to the ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.
15	Housing-Need-r	A Housing-led scenario, consistent with the Housing-Need scenario, but with household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.
16	Housing-Req	A Housing-led scenario, with population growth underpinned by the trajectory of housing growth associated with each local authority's housing Requirement. Following the final year of data, projected housing growth in non-London areas returns to the ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.
17	Housing-Req-r	A Housing-led scenario, consistent with the Housing-Req scenario, but with household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.
18	Housing-Plan	A Housing-led scenario, with population growth underpinned by each local authority's Local Plan housing growth trajectory. Following the final year of data, projected housing growth in non-London areas returns to the ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.
19	Housing-Plan-r	A Housing-led scenario, consistent with the Housing-Plan scenario, but with household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.
20	Employment-1	An Employment-led scenario with 1.0% pa growth in London to 2030 and 0.5% pa thereafter; 0.8% pa growth in the South East and East of England to 2030, 0.4% thereafter.
21	Employment-2	An Employment-led scenario with 0.5% pa growth in London to 2030 and 0.25% pa thereafter; 0.4% pa growth in the South East and East of England to 2030, 0.2% thereafter.
22	OxCam-1a-r	'New Settlement' 23k dpa scenario, with c.4.2k dpa above Housing Plan distributed between Cherwell (20%), Aylesbury Vale (20%), Central Bedfordshire (40%), South Cambridgeshire (20%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.
23	OxCam-1b-r	'Expansion' 23k dpa scenario, with c 4.2k dpa distributed between: Milton Keynes: (30%) Luton (15%), Bedford (15%), Oxford (10%), Cambridge (10%), Northampton (10%), and Peterborough (10%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.
24	OxCam-2a-r	'New Settlement' 30k dpa scenario, with c.11.2k dpa above Housing Plan distributed between Cherwell (20%), Aylesbury Vale (20%), Central Bedfordshire (40%), South Cambridgeshire (20%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.

ID	SCENARIO	DESCRIPTION
25	OxCam-2b-r	'Expansion' 30k dpa scenario, with c 11.2k dpa distributed between: Milton Keynes: (30%) Luton (15%), Bedford (15%), Oxford (10%), Cambridge (10%), Northampton (10%), and Peterborough (10%). Household representative rates for young adults returning to (higher) 2001 levels by 2039, remaining fixed thereafter.



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# Level 2 Appendix B. Non-household demand forecasts 2020 to 2100

Water Resources South East – SES  
Water

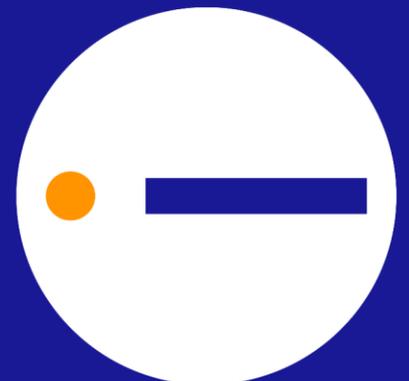
Non-household demand forecasts 2020  
to 2100

Company report - Final

Project reference: 2467

Report number: AR1393

2020-12-14



Report title: Non-household demand forecasts 2020 to 2100

Project reference: 2467

Report number: AR1393

Date: 2020-12-14

Client: Water Resources South East – SES Water

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Collaborators: Affinity Water, Portsmouth Water, SES Water, South East Water, Southern Water, Thames Water

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2	Dene Marshallsay	Kayleigh Powell	Final draft	27/11/2020
3	Dene Marshallsay, Francesca Cecinati	Kayleigh Powell, Sarah Rogerson	Final	11/12/2020

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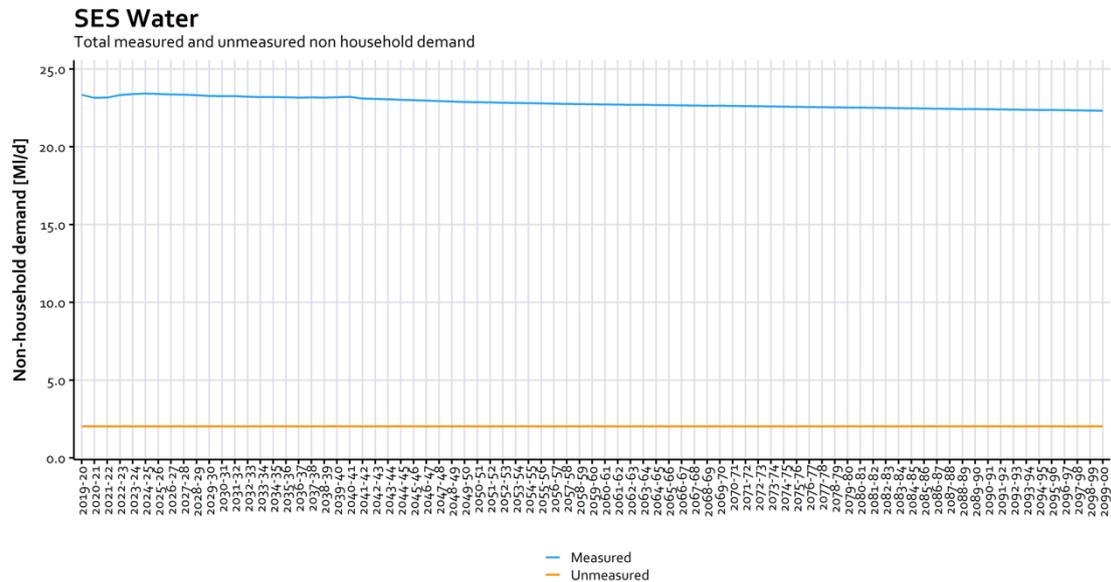
Website: [www.artesia-consulting.co.uk](http://www.artesia-consulting.co.uk)

## Executive summary

Water companies in England and Wales are required to develop a Water Resource Management Plan (WRMP) under the Water Industry Act 1991 where they set out their plans to ensure that they will have sufficient resources to meet demand under different climate conditions over a minimum of 25 years. Forecasting future demand for water is a key part of the process and consumption by the non-household sector is a major component of demand. This report describes the initial development of the demand forecasts for non-households in the Water Resources South East (WRSE) region.

We have produced a set of non-household demand forecasts for all 37 water resource zones in the WRSE region from 2019-2020 out to 2099-2100. These are presented for metered and unmetered properties at company level, water resource zone level and dis-aggregated by industrial sector. The approach used follows existing industry best practice, taking into account the recommendations from a review of non-household demand forecasting methods carried out by WRSE in early 2020. Robust multiple linear models have been produced for 4 cohorts of industrial sectors for each company in WRSE, using explanatory factors that include population, gross value-added metrics, employment rates, population density and other factors. This report provides an overview of the WRSE results and detailed results for SES Water.

The overall conclusion is that non-household demand in the SES Water region at the start of the planning period (2025), is predicted to be 25 MI/d within an overall range of 17 to 30 MI/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL. By the end of the planning period the non-household demand is predicted to be 24 MI/d (a decrease of 1 MI/d) within a range of 16 MI/d to 38 MI/d.



We have also made a prediction of the amount of non-public water supply (non-PWS) demand in the Portsmouth Water region and how this might change over the planning period. For Portsmouth Water, the current estimate of non-PWS non-household demand of 3.67 MI/d in 2019-20 is predicted to increase to 5.0 MI/d by 2050.

The first year of the forecast (2020) has seen an unprecedented change in non-household demand due to the policies introduced to combat the COVID-19 pandemic. This creates added uncertainty going forward as we still do not fully understand what the enduring impacts will be from changes in working practices, such as increased working from home. The sector also faces a number of future unknowns in demand from non-households, such as population change, Brexit, climate change and how water efficiency will be delivered in the non-household sector. Since the last set of non-household forecasts were completed for WRMP19, the non-household retail sector has undergone a transformation with the introduction of retail competition. We have observed a change in data quality and consistency since the change in 2017, which has complicated the modelling and has increased the uncertainty around the demand forecasts. Therefore, we have included all these factors in the scenario and uncertainty modelling.

We have presented the forecasts from a base year of 2019-20. The intermediate years 2020-21 through to 2024-25 are presented for information prior to the start of the planning period in 2025-26. These intermediate years are potentially volatile with a number of unknowns around the impact of the COVID-19 pandemic and the impact from Brexit on non-household consumption. Therefore, we recommend that the baseline and scenario forecasts are updated prior to the submission of the final water resource management plans.

During the course of the work, we have identified a number of improvements that could be implemented for future forecasts. These are included in the recommendations section of the report and cover: improving data quality, investigating different industrial sectors, looking at modelling WRZ groups by the way they behave as opposed to by company, and producing forecasts more frequently to reduce the step change transitions between forecasts every 5 years.

## Glossary

Term	Description
A classification of residential neighbourhoods (ACORN)	This is a socio-demographic classification of neighbourhoods published by CACI Ltd. The system is based on the assumption that people who live in similar neighbourhoods are likely to have similar behavioural and consumption habits.
Abstraction	The removal of water from any source, either permanently or temporarily.
Active leakage control (ALC)	Management policies and processes used to locate and repair unreported leaks from the water company supply system and customer supply pipes.
Annual average demand	The total demand in a year, normally measured as the amount of treated water entering the distribution system at the point of production, divided by the number of days in the year.
Annual return	An annual report made to Ofwat by water companies to advise on progress within that Asset Management Period.
Asset management period (AMP)	Five-year period for which water companies are funded by Ofwat according to their Business Plans.
Base year	The first year of the planning period/horizon, forming the basis for the water demand and supply forecasting of subsequent years.
Baseline forecast	A demand forecast of customer consumption without any further water company intervention during the planning period. A baseline customer demand forecast should take account of: customer demand without any further water efficiency or metering intervention, forecast population growth, change in household size, changes in property numbers and the impact of climate change on customers' behaviour. Leakage in the baseline forecast should remain static from the start of the plan to the end of the planning period.
Business plan	Business Plans are produced by the water companies for Ofwat and set out the investment programme for the water industry. These plans are drawn up through consultation with the Environment Agency and other bodies to cover a five-year period. Ofwat accept the Business Plan following detailed scrutiny and review.
Capital expenditure (Capex)	Spending on capital equipment. This includes spending on machinery, equipment and buildings. Capital expenditure is also termed investment.
Central market operating system (CMOS)	This is the computer system that manages all the electronic transactions involved in switching customers and provides usage and settlement data which is used in the billing process.
Consumption monitor	A sample of properties whose consumption is monitored in order to provide information on the consumption and behaviour of households served by the company.

Demand management	The implementation of policies or measures which serve to control or influence the consumption or waste of water (this definition can be applied at any point along the chain of supply).
Department for Environment, Food and Rural Affairs (Defra)	UK Government department with responsibility for water resources in England.
Deployable output (DO)	A measure of the available water resource during a drought year for a given level of service.
Distribution input (DI)	The amount of water entering the distribution system at the point of production.
Dry year annual average (DYAA)	The dry year annual average represents a period of low rainfall and unrestricted demand and is used as the basis of a water company's WRMP.
Dry year critical period (DYCP)	The generic term for the planning scenario which drives investment, i.e. at what point during the dry year (1 in 10 years severity of conditions) is the water supply most at risk of failing to meet planned levels of service.
Environment Agency	UK government agency whose principal aim is to protect and enhance the environment in England and Wales.
Final planning demand forecast	A demand forecast which reflects a company's preferred policy for managing demand and resources through the planning period, after taking account of all options through full economic analysis.
Mega litres per day (Ml/d)	One mega litre = one million litres (1,000 cubic metres) per day.
Meter optants	Properties in which a meter is voluntarily installed at the request of its occupants.
Micro-component analysis (MCA)	Detailed analysis of individual components of a customer's water use.
Non-households (NHH)	Properties receiving potable supplies that are not occupied as domestic premises, for example, factories, offices and commercial premises.
Normal year annual average (NYAA)	The total demand in a year with normal or average weather patterns, divided by the number of days in the year.
Operating expenditure (Opex)	Operating expenditure comprises day-to-day (planned and unplanned) routine expenses, which have no effect on the decline in service potential.
Optant metering	Customer led metering programme.
Peak demand	The highest demand that occurs, measured, either hourly, daily, weekly, monthly or yearly over a specified period of observation.
Per capita consumption (PCC)	The average annual consumption expressed in litres per person per day. Per capita consumption in an area is defined as the sum of measured household consumption and unmeasured household consumption divided by the total household population.
Per household consumption (PHC)	The average annual consumption expressed in litres per household per day. Per household consumption in an area is defined as the sum of measured household consumption and

	unmeasured household consumption divided by the total number of households.
Planning period	An agreed look ahead period for which the WRMP is prepared.
Social tariff	Tariff where the customer charge takes into account factors such as household size, medical needs, income levels or if certain state benefits are claimed.
Statement of response	A document that is produced at the end of the public consultation period for the draft WRMP. The document outlines the comments received from customers and the changes that will be made to the draft WRMP as a result of these comments.
Supply pipe losses	The sum of underground supply pipe losses and above ground supply pipe losses.
Target headroom	Headroom is a margin of safety which serves as a buffer between supply and demand. Target headroom is the threshold of minimum acceptable headroom which would trigger the need for water management options to either increase water available for use or decrease demand.
Underground supply pipe losses	Losses between the point of delivery and the point of consumption.
Void property	A property connected to the distribution network but not charged because it has no occupants.
Water available for use (WAFU)	Deployable output – less any sustainability reductions – plus any bulk supply imports – less any bulk supply exports – less any reductions made for outage allowance.
Water resource zone (WRZ)	The largest possible zone in which all resources including external transfers can be shared, and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall.
Water resources management plan (WRMP)	A water company's plan for supplying water to meet demand over a 25-year period.
Water resource planning guidelines (WRPG)	Guidance produced by the Environment Agency for developing water resource plans.

## Contents

1	Introduction.....	1
1.1	Background .....	1
1.2	Regulatory requirements.....	2
1.3	Best practice for developing non-household demand forecasts.....	2
1.4	WRSE requirements for the non-household demand forecast .....	4
1.4.1	Review of methods used in previous forecasts .....	4
1.4.2	WRSE specific requirements .....	5
2	Methodology .....	8
2.1	Data collection and formatting .....	8
2.2	Exploratory analysis and data preparation .....	9
2.2.1	Consumption data.....	9
2.2.2	Population data .....	10
2.2.3	Industry sector mapping .....	10
2.2.4	Weather data .....	12
2.2.5	Econometric data.....	12
2.2.6	Data collation .....	12
2.3	Model build, testing and refinement for baseline forecasts.....	13
2.3.1	Non-household forecast modelling .....	13
2.3.2	MLR modelling.....	13
2.3.3	Calibration .....	14
2.3.4	Baseline forecasts .....	14
2.4	Scenarios and uncertainty .....	15
2.4.1	Introduction.....	15
2.4.2	Modelling scenarios.....	16
2.4.3	Combining scenarios .....	24
2.4.4	Modelling uncertainty .....	25
2.4.5	Application of uncertainty .....	26
2.5	Potential non-PWS demand .....	27
2.5.1	Data .....	27
2.5.2	Analysis .....	27
3	Results.....	30
3.1	Baseline forecast for non-household public water supply demand .....	30
3.1.1	WRSE regional results .....	31
3.1.2	Affinity Water results .....	32

3.1.3	Portsmouth Water results.....	34
3.1.4	SES Water results.....	36
3.1.5	South East Water results .....	37
3.1.6	Southern Water results.....	39
3.1.7	Thames Water results.....	41
3.2	Potential non-public water supply demand.....	42
4	Discussion of findings .....	47
4.1	Modelling approach .....	47
4.2	Uncertainty in predictions .....	50
4.3	Data issues.....	50
4.3.1	MOSL data .....	51
4.3.2	Matching pre and post MOSL data.....	53
4.3.3	Property level consumption data .....	53
4.4	Industrial sector segments.....	53
4.5	Weather .....	55
4.6	Other improvements.....	55
5	Conclusions .....	56
6	Recommendations .....	57
	Appendix A: SES Water modelling results .....	58
	Overview of WRZ results .....	59
	WRZ industry sector results .....	61
	MLR modelling.....	62
	Calibration .....	64

## Figures

Figure 1	WRSE region showing the 37 water resource zones .....	1
Figure 2	Non-household demand forecasting best practice overview.....	3
Figure 3	Three population scenarios are chosen from the 72 Edge Analytic scenarios .....	16
Figure 4	Reduction in NHH water consumption during summer 2020 months compared to previous months. ....	18
Figure 5	Example (SEW-Maidstone) step change in property level consumption data post 2016 .....	20
Figure 6	Example (SWS-Hampshire Andover) step change in property level consumption data post 2016.....	21
Figure 7:	A plot showing the trend of peak daily temperatures since 1959. ....	22
Figure 8:	A plot showing the trend of average daily rainfall over since 1959. ....	23

Figure 9 Example of 81 of the 729 scenarios for Affinity Water .....	24
Figure 10 Example derivation of the Upper, Central, and Lower thresholds from the total scenario variability for Affinity Water .....	25
Figure 11 WRSE region measured and unmeasured non-houshold demand forecasts .....	31
Figure 12 WRSE region non-houshold consumption central, lower and upper scenarios .....	31
Figure 13 WRSE region non-houshold demand forecasts by industry sector .....	32
Figure 14 Affinity Water measured and unmeasured non-housheold consumption.....	33
Figure 15 Affinity Water region non-houshold consumption central, lower and upper scenarios .....	33
Figure 16 Affinity Water non-housheold consumption by industry sector.....	34
Figure 17 Portsmouth Water measured and unmeasured non-housheold consumption .....	34
Figure 18 Portsmouth Water region non-houshold consumption central, lower and upper scenarios .....	35
Figure 19 Portsmouth Water non-housheold consumption by industry sector.....	35
Figure 20 SES Water measured and unmeasured non-housheold consumption.....	36
Figure 21 SES Water region non-houshold consumption central, lower and upper scenarios .....	36
Figure 22 SES Water non-housheold consumption by industry sector.....	37
Figure 23 South East Water measured and unmeasured non-housheold consumption .....	38
Figure 24 South East Water region non-houshold consumption central, lower and upper scenarios .....	38
Figure 25 South East Water non-housheold consumption by industry sector.....	39
Figure 26 Southern Water measured and unmeasured non-housheold consumption.....	39
Figure 27 Southern Water region non-houshold consumption central, lower and upper scenarios .....	40
Figure 28 Southern Water non-housheold consumption by industry sector.....	40
Figure 29 Thames Water measured and unmeasured non-housheold consumption.....	41
Figure 30 Thames Water region non-houshold consumption central, lower and upper scenarios .....	41
Figure 31 Thames Water non-housheold consumption by industry sector .....	42
Figure 32 Base year existng abstractions by sector for the WRSE region .....	43
Figure 33 Best estimate of exisitng abstractions growth to 2050 by sector for WRSE region .....	44
Figure 34 Base year new abstractions by sector for WRSE region.....	44
Figure 35 Best estimate of new abstractions growth to 2050 by sector for WRSE region .....	45
Figure 36 Non PWS in base year and 2050 at WRSE region split out by best and 75 <sup>th</sup> percentile estimate and new abstractions .....	45
Figure 37 Non PWS in base year and 2050 by company split out by best and 75 <sup>th</sup> percentile estimate and new abstractions .....	46

Figure 38 Example (Thames-SWOX) step change in reported non-household consumption post 2016 .....	51
Figure 39 Example (SES Water) step change in reported non-household consumption post 2016 .....	52
Figure 40 Example (SEW-Maidstone) step change in reported non-household consumption post 2016 .....	52
Figure 41 Exploring alternative industry groupings for each company .....	54
Figure 42 Exploring alternative industry groupings for the region .....	54

## Tables

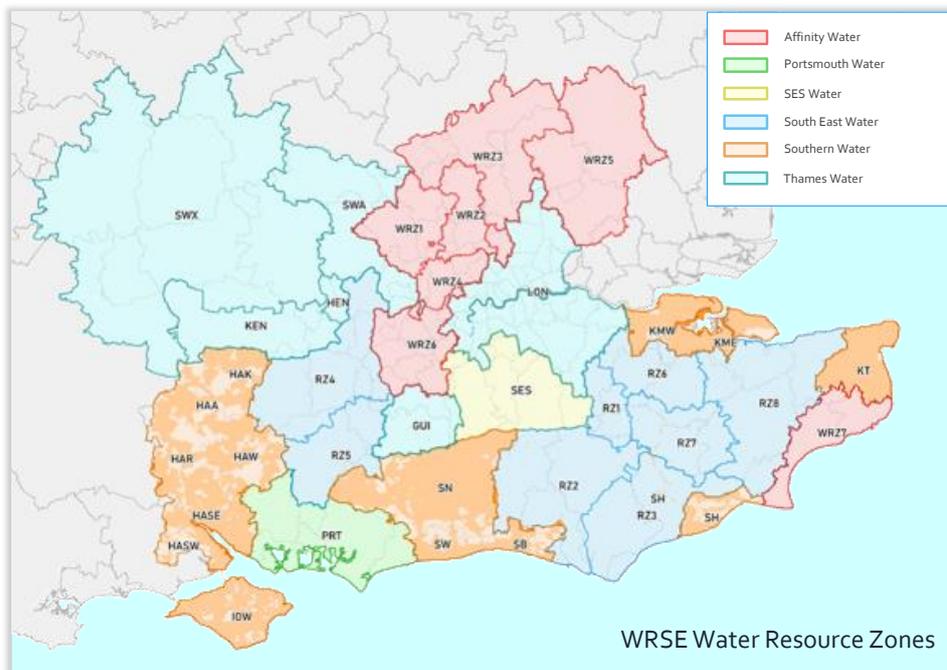
Table 1 Consumption data granularity .....	9
Table 2 Inclusion of voids and large users .....	10
Table 3 Industry groupings .....	11
Table 4 Proportion of properties and consumption in each industry group by company (2019-20) .....	11
Table 5 Brexit scenarios and their impact .....	17
Table 6 COVID-19 scenarios and their impact .....	19
Table 7 Sector segmentation – existing abstractions .....	27
Table 8 Sector segmentation – new authorisations .....	28
Table 9 Industry sector groupings and drivers from the initial WRSE review .....	47
Table 10 Significant explanatory variables in each sector model .....	48

# 1 Introduction

## 1.1 Background

Water companies in England and Wales are required to develop a Water Resource Management Plan (WRMP) under the Water Industry Act 1991 where they set out their plans to ensure that they will have sufficient resources to meet demand under different climate conditions over a minimum of 25 years. The plans are updated every 5 years. Forecasting future demand for water is a key part of the process and consumption by the non-household sector is a major component of demand. Robust assessment of future demand is a prerequisite for developing credible and resilient plans. This report describes the initial development of the demand forecasts for non-households in the Water Resources South East (WRSE) region (Figure 1).

Figure 1 WRSE region showing the 37 water resource zones



WRSE is one of the five regional groups looking to provide strategic oversight and co-ordination of water resources within the context of the new National Water Resources Framework<sup>1</sup>. The aim of the regional groups is to build resilience to drought and other pressures in a cost-effective way, taking account of regional and inter-regional solutions.

WRSE will be producing a sustainable regional resilience plan later in 2020. This plan will inform the Water Resource Management Plans of each member water company within the WRSE alliance. It will set out the schemes, investments and other actions which companies and other stakeholders will need to take to deliver our shared objective. It will also link with

<sup>1</sup> Meeting our future water needs: a national framework for water resources. Environment Agency. 2020.

the other regional plans across England to form the national picture for water resources management.

## 1.2 Regulatory requirements

The Environment Agency sets out its expectations and guidance for non-household demand forecasts in the Water Resource Management Plan (WRMP<sub>24</sub>) Guidelines (WRPG, currently draft)<sup>2</sup>. Water companies are required to forecast the demand for water being used by non-household premises (such as businesses and industrial processes) and for the population living in communal establishments (for instance hospitals, prisons and educational establishments).

Since the last non-household demand forecasts were developed, the non-household market has been opened for competition. The definition of non-households should be in line with Ofwat's guidance on whether non-household customers in England and Wales are eligible to switch their retailer<sup>3</sup> <sup>4</sup>. For WRMP<sub>24</sub>, water companies are also expected to work with non-household customers to improve water efficiency where you believe there are savings to be made.

The broad needs of the regulators are:

- A plan that contains an estimated demand forecast for non-households.
- To work with retailers and through regional groups (where applicable) to share information, data and expertise to ensure the forecasts and solutions are robust.
- A description of how figures and assumptions in the forecast have been derived.
- The plan makes use of the Market Operator Services Ltd (MOSL) system that stores retail company data as needed.
- The plan describes the makeup of non-household demand in different sectors either by using the service and non-service split (identifying the main sectors), or by using Standard Industrial Classification (SIC) categories published by the Office for National Statistics.
- We explain the existing water efficiency initiatives planned by both the wholesaler and retailer. The baseline forecast should reflect non-household demand without any further intervention.
- The final plan should include any forecast savings from water efficiency programmes.
- Consideration of non-household water efficiency as an option to manage the supply-demand balance.
- To consider any uncertainty associated with reducing demand and show how you will monitor the water efficiency programme and how the plan can be adapted if required
- That the plan considers the potential demand for other sources such as: agriculture and those on private water supply in a significant drought.

## 1.3 Best practice for developing non-household demand forecasts

There are a series of best practice documents in addition to the regulatory requirements, and an overview of these is presented in Figure 2.

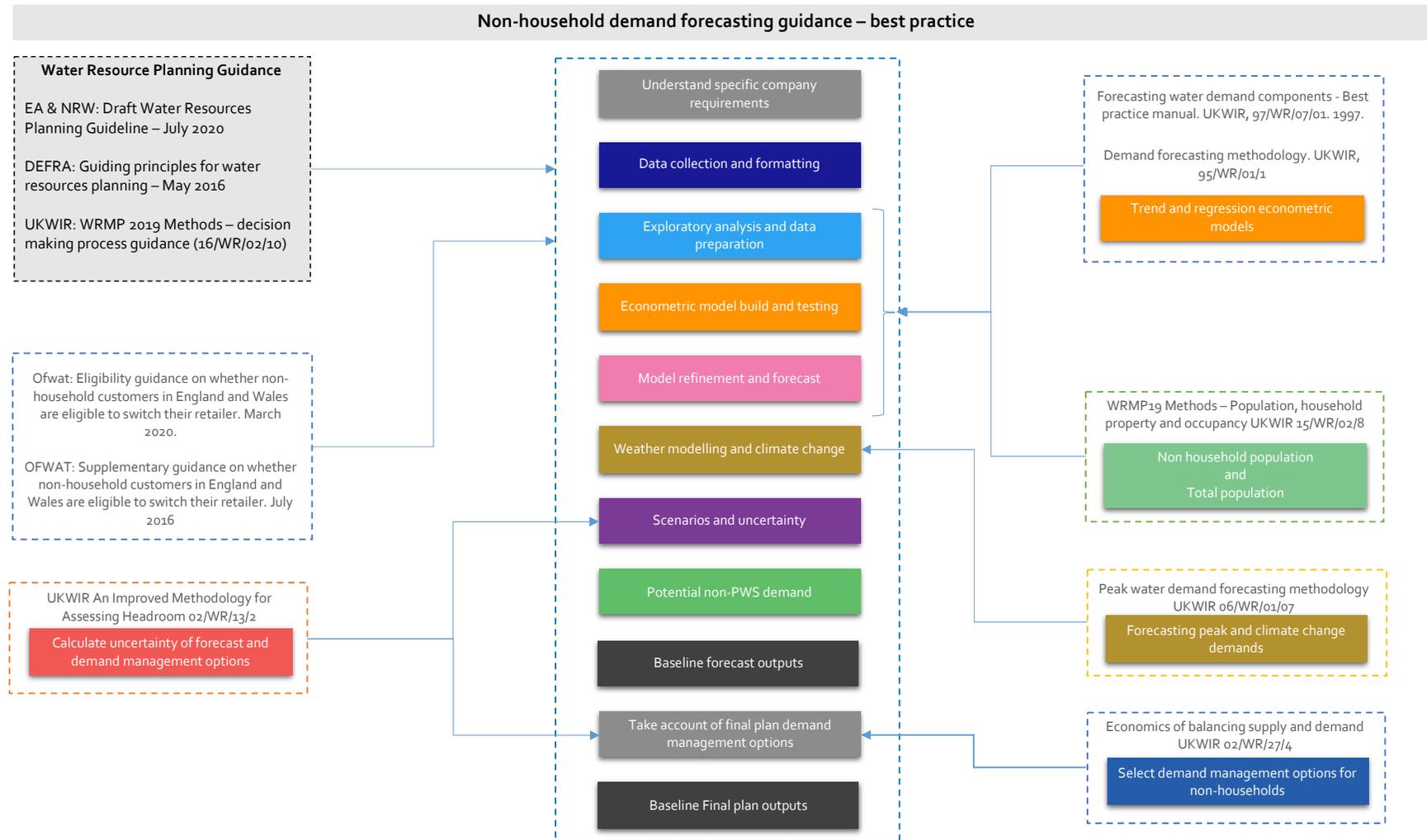
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<sup>2</sup> Water Resource Planning Guideline, draft for consultation July 2020. Environment Agency.

<sup>3</sup> <https://www.ofwat.gov.uk/wp-content/uploads/2016/07/Eligibility-Guidance.pdf>

<sup>4</sup> [https://www.ofwat.gov.uk/wp-content/uploads/2016/03/pap\\_gud201607suppretaileligibility.pdf](https://www.ofwat.gov.uk/wp-content/uploads/2016/03/pap_gud201607suppretaileligibility.pdf)

Figure 2 Non-household demand forecasting best practice overview



## 1.4 WRSE requirements for the non-household demand forecast

### 1.4.1 *Review of methods used in previous forecasts*

Prior to updating the non-household demand forecasts, WRSE commissioned a study<sup>5</sup> to review the current methods used by water companies for non-household demand forecasts and compare them to the water resources planning guidance.

This study developed a number of conclusions and recommendations. The key ones in relation to the non-household forecasts for regional and WRMP24 planning are:

- The use of data derived from Central Market Operating System (CMOS); information from the previous billing systems is increasingly outdated and by 2024 the last year of non-MOSL consumption data will be 8 years old.
- Accounting for the potential impacts of water efficiency improvements due to the retail market, beyond long term trends are already present within the model.
- Any influences of the Covid-19 pandemic on long-term trends in non-household consumption should be included in the forecasts.
- All WRMP stakeholders need to recognise that the quality of CMOS data is an issue for non-household demand forecasting.
- There is a general risk associated with models developed from poor quality data producing inaccurate or misleading outputs. This is exacerbated when there are changes in data quality over time as the models may reflect changes in data quality, rather than trends in the underlying data.
- The following set of industry groupings would form a reasonable stratification that balances data limitations with separating out those industries likely to have different underlying drivers for non-household consumption:
  - Agriculture (and other weather dependent industries)
  - Non-service industries (excluding Agriculture)
  - Service industries – population driven
  - Service industries – economy driven
  - Unclassified
- An alternative stratification could be used if this is shown to provide a better model.
- Due to COVID-19 and an unusually hot spring/summer, it is clear that reporting year 2020-21 will be unusual in terms of both the macro-economic climate and non-household consumption. The important aspects to consider for non-household demand forecasting to support WRMPs and regional planning are any long-term impacts of the current recession and the growth trajectory thereafter.
- Climate change scenarios need to be included for Agriculture and any other industries where weather is shown to be a significant explanatory factor for consumption, to identify their impact on consumption.
- The national framework report also considers a low demand scenario with a 4% reduction in non-household consumption by 2050 compared to the base case. In the absence of further evidence, this would represent a reasonable assumption for a water efficiency scenario driven by Government policy to reduce water demand.

<sup>5</sup> [https://www.wrse.org.uk/media/h1nhiuyg/wrse\\_file\\_1345\\_wrse-non-household-demand-forecast-methodology.pdf](https://www.wrse.org.uk/media/h1nhiuyg/wrse_file_1345_wrse-non-household-demand-forecast-methodology.pdf)

- WRSE member companies should in general adopt a standard set of scenarios and assumptions regarding economic growth, except where there are specific issues to a particular area of supply that need to be accounted for.
- WRSE member companies should use the information within the UK Climate Projections (UKCP18) datasets to develop scenarios of climate change for incorporation where weather is shown to be a significant influence on consumption.
- WRSE member companies should identify whether there are any major customers that should be treated separately because they have a significant impact on the supply-demand balance for a Water Resource Zone (WRZ). It may be appropriate to model scenarios related to these customers if they are likely to impact on the preferred option selection.

### **1.4.2 WRSE specific requirements**

Following the recommendations from the review of current non-household demand forecasts (section 1.4.1), WRSE developed a specification for the initial non-household demand forecast. The scope of this work was to develop a non-household demand forecasting model and produce a non-household demand forecast for the period 2025-2100 that is fully compliant with the WRP. The key tasks carried out against this requirement are described below.

#### ***Segmentation of customers and base year demand***

The WRP requires segmentation of non-household customers into appropriate industrial sectors and forecasting demand separately for each sector, taking account of the factors that affect demand in the sector. The review commissioned by WRSE (see section 1.4.1) has recommended the following five segments for this purpose.

- Agriculture and other weather dependent sectors
- Non-service industries (excluding agriculture and other weather dependent sectors)
- Service industries – population driven
- Service industries – economy driven
- Unclassified.

The source data for this work comes from the Central Market Operating System (CMOS) operated by Market Operator Services Ltd (MOSL) for the period 2017 to 2020. MOSL has regulated the non-household sector since the separation of household and non-household water retail services on 1 April 2017. Additional data from the pre-MOSL period has also been used to develop longer term trends in historic non-household consumption data.

Standard Industrial Classification (SIC) codes are a convenient way of the sub-dividing customers into sectors, especially when the nature of the business cannot be directly inferred from the business name. However, the SIC code data within CMOS dataset is neither complete nor entirely accurate. Several companies have datasets which use AddressBase Classifications for industry sectors, and these have been used to augment or cross check the SIC classifications.

In the process of segmenting the non-household consumption into the industrial sectors described above, we have attempted to keep the number of customers in the 'unclassified' segment as low as possible, ideally not exceeding 20% in any WRZ. In some instances, this

has not been possible due to the nature of the data provided and we have described these cases in the following sections.

Non-household demand in certain WRZs may primarily be driven by a single customer. Examples include airports, universities and large manufacturing units. We have attempted to identify these and exclude them from the modelling. This is not always possible due to water companies' different policies on data protection, and also where consumption data is provided already aggregated into sectors. In these cases, we have developed alternative means for excluding large customers, and these are described in subsequent sections.

The base year for this initial forecast is 2019-20 and all companies have calculated non-household demand in each WRZ for annual regulatory reporting. Once segmentation of the customers and modelling was completed, we rebased the base-year consumption to the annual reported volume for 2019-20.

### ***Identify explanatory factors for each customer segment***

We have identified the key factors that influence demand in the sector and derived historic and predicted values for these factors from:

- Oxford Economics (region specific gross value added and employment)
- Edge Analytics (Population predictions)
- Water companies (historic population data and property data).
- Office of National Statistics (Population density).

### ***Assess the impact of climate change***

We have assessed the impact of climate change on the demand by various sectors and developed scenarios that include climate change impacts on demand.

### ***Assess the impact of water efficiency***

A key objective behind creation of a separate retail market for non-household customers was to promote water efficiency. There is limited evidence to suggest water efficiency in the non-household sector has improved beyond historical trends since market separation (see section 1.4.1). We have therefore included the recommended 4% reduction in demand by 2050 (in line with the National Framework<sup>6</sup>), and also included a range of other glidepaths in alternative scenarios.

### ***Assess demand by other sectors***

Going forward, water companies are expected to take account of demand by sectors that do not currently take water from public water supplies (PWS) but may be required to do so in case of severe droughts and/or climate change. Wood plc have recently completed a study<sup>7</sup> on behalf of the Environment Agency that has looked at demand by other sectors.

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<sup>6</sup> [www.gov.uk/government/publications/meeting-our-future-water-needs-a-national-framework-for-water-resources](http://www.gov.uk/government/publications/meeting-our-future-water-needs-a-national-framework-for-water-resources)

<sup>7</sup> Understanding future water demand outside of the water industry, Defra, 28/02/2020

There are however gaps in the Wood report and we have carried out additional analysis to supplement the report with additional information and provided estimates of demand by other sectors at the WRZ level.

### ***Develop a demand forecasting model***

We have then developed a demand forecasting model that brings together outputs from the tasks above and allows demand for each sector to be forecast over the planning period. The model:

- Has been developed at the company and WRZ level and aggregated regional level for each sector.
- Includes multiple scenarios that have been generated to take account of uncertainties in various assessments.
- Has been developed to be fully transparent and able to withstand scrutiny at a public inquiry.
- The outputs have been incorporated into a commonly used tool that allows companies to select the various outputs and scenarios at different levels. We are in discussion with WRSE about how best to make the model available in an open way to the WRSE group.

### ***Recommend improvements***

As we have gone through the tasks above and analysed the data, we have identified a number of areas where the modelling, forecasting and outputs can be improved going forward. These are explained and in the recommendations section.

## 2 Methodology

This section provides additional details on the methodology we implemented to meet the requirements detailed in section 1.4.2.

### 2.1 Data collection and formatting

A consistent data requirement specification was provided to each of the companies is WRSE.

Ref	General data requirements	Data type
1	Data transfer preferences (e.g. email, SharePoint, DropBox, etc.)	Information
2	Key data contact	Information
3	Forecast granularity	Information
4	Number of areas	Number
5	Base year	Year
6	Population (total) forecasts by WRZ (from Base Year)	Population
7	Non-HH property forecasts by WRZ (from Base year) - Split measured and unmeasured	Property
8	Historic annual return: non-HH property numbers split by measured and unmeasured by WRZ	Property
9	Historic annual return: total population numbers by WRZ	Population
10	Pre 2017 annual non-HH consumption data (per property or per segment or industry code)	Consumption
11	2017 to 2020 annual non-HH consumption data (per property or per segment or industry code)	Consumption
12	Data to link non-HH consumption to industry code (SIC, ABP or Land Registry)	Data link
13	Data to link non-HH consumption to WRZ	Data link
14	Weather data for each WRZ: Monthly (or finer) mean temperature and mean rainfall	Weather
15	GVA and employment data by WRZ and industry segment (historic and forecast)	Economic Activity
16	Historic annual return consumption data up to and including base year	Consumption
17	Base year consumption data for each property linked to WRZ and Segment (may be included in Ref. 11)	Consumption
18	Climate change scenario predictions for temperature and rainfall	Climate
19	Scenario trend data	Trend
20	Non-PWS demand predictions	non-PWS
21	WRMP19 non-household consumption forecast outputs	Information

Each of the water companies provided data against these requirements. This data was assessed and formatted consistently for each company and water resource zone. Some companies had missing data, or different levels of granularity/length of time series. These differences were captured and discussed with relevant persons from the water companies. Additional data was collected where possible if gaps were identified. In some cases, full data was not available, and in these cases amendments to the process were agreed.

## 2.2 Exploratory analysis and data preparation

The outputs from the exploratory analysis and data preparation, were a set of consistent data frames. These consisted of:

- Segmented consumption
- Explanatory variables
- Annual return data

### 2.2.1 Consumption data

#### Data granularity

Consumption data was provided by companies at either individual property level or aggregated to industry classification (normally SIC<sup>8</sup> or AddressBase<sup>9</sup>). Table 1 shows the breakdown of how the data was provided by company.

Table 1 Consumption data granularity

Company	Consumption data granularity
Affinity Water	Property level
Portsmouth Water	Aggregated to SIC level
SES Water	Property level
South East Water	Property level
Southern Water	Property level
Thames Water	Property level

#### Voids and large users

If consumption data was provided at property level, and if we received data on which properties were void, we could exclude void data from the modelling stage. Having consumption data at property level also allows us to also identify and exclude large users, which may have a significant impact on consumption at WRZ level. Some companies provided us with data on specific large users. We were able to use this to determine a consumption threshold value above which we could classify users as a large user. We determined that this threshold should be set at 2%, i.e. if a single user consumes greater than

<sup>8</sup> <https://www.gov.uk/government/publications/standard-industrial-classification-of-economic-activities-sic>

<sup>9</sup> <https://www.ordnancesurvey.co.uk/business-government/products/addressbase-premium>

2% of the WRZ non-household consumption then we would flag this property as a large user. Table 2 highlights which companies could have voids and large users excluded.

**Table 2 Inclusion of voids and large users**

Company	Voids		Large users	
	Include	Exclude	Include	Exclude
Affinity Water		x		x
Portsmouth Water	x		x	
SES Water	x		x	
South East Water		x		x
Southern Water	x			x
Thames Water	x			x

### **Data checks**

Data quality checks were performed, looking at the following:

- Proportion of properties that were unclassified or unmatched to a SIC group, split by year.
- Percentage of reported (annual return) volume that is contained within either the classified or unclassified consumption data.

#### **2.2.2 Population data**

Population forecast data and annual return by year and WRZ are imported and combined to create a joint population dataset. Populations for overlapping years (2019-20) for both historical and forecast data are compared to check data accuracy.

For the baseline population we use Housing Plan - P.

#### **2.2.3 Industry sector mapping**

SIC groups or AddressBase classifications are mapped to industry grouping using various mapping files, we developed mapping files for SIC\_1980, SIC\_1992, SIC\_2003, SIC\_2007 and

AddressBase. These were then used to group the properties' consumption into the industrial sectors shown in Table 3.

**Table 3 Industry groupings**

Industry grouping	SIC_2007 sections	Reference
Agriculture (and other weather dependent industries)	A	1
Non-service industries (excluding Agriculture)	B, C, D, E, F	2
Service industries – population driven	O, P, Q, R, S, T	3
Service industries – economy driven	G, H, I, J, K, L, M, N	4
Unclassified		5

Table 4 shows the proportion of properties and the proportion of consumption for each company that falls into each of the industry groupings identified in Table 3.

**Table 4 Proportion of properties and consumption in each industry group by company (2019-20)**

Company	Industry grouping	Proportion of properties in group	Proportion of consumption in group
<b>Affinity Water</b>	Agriculture	1%	1%
	Non-service	4%	4%
	Service – population	10%	17%
	Service – economy	46%	28%
	Unclassified	39%	50%
<b>Portsmouth Water</b>	Agriculture	NA	12%
	Non-service	NA	22%
	Service – population	NA	27%
	Service – economy	NA	37%
	Unclassified	NA	2%
<b>SES Water</b>	Agriculture	2%	2%
	Non-service	14%	14%
	Service – population	26%	26%

	Service - economy	55%	55%
	Unclassified	3%	3%
<b>South East Water</b>	Agriculture	13%	13%
	Non-service	15%	15%
	Service – population	65%	66%
	Service – economy	N/A	N/A
	Unclassified	8%	6%
<b>Southern Water</b>	Agriculture	3%	3%
	Non-service	9%	10%
	Service – population	34%	35%
	Service – economy	45%	39%
	Unclassified	9%	13%
<b>Thames Water</b>	Agriculture	2%	3%
	Non-service	5%	7%
	Service – population	18%	27%
	Service – economy	29%	31%
	Unclassified	46%	34%

#### 2.2.4 Weather data

Compiled weather data is loaded with average daily rainfall and average maximum temperature by year.

#### 2.2.5 Econometric data

Econometric data was provided by Oxford Economics (OE). This data is formatted into employment and gross value added (GVA) by SIC group and region. All WRSE companies currently use the “South East” region, with the only exception being Thames Water where the London WRZ uses the “London” OE region. Historic data was provided from 1991, and forecast data was provided to 2040.

#### 2.2.6 Data collation

A maximal theoretical dataset was created by creating all combinations of year (from OE, weather, consumption, and population datasets), WRZ (weather, consumption, and population) and SIC/industry groups (consumption), with all variables joined to these where available.

This is then aggregated to industry grouping level, with group-specific numerical variables summed (consumption, employment, GVA) and other numerical variables re-joined at aggregated level (weather and population).

Both the SIC and industry grouping aggregation datasets are output for use in subsequent modules.

## 2.3 Model build, testing and refinement for baseline forecasts

### 2.3.1 *Non-household forecast modelling*

The non-household forecast modelling is carried out in line with best practice<sup>10</sup> and takes into account the findings of the WRSE review of non-household demand forecasts (section 1.4.1).

Choosing the right modelling process is a complex task that needs to take into consideration statistical model performances, but also many other variables that require the modeller's expert judgement (availability of variables, reliability of data, overfitting problems, and more). Therefore, the modelling process is based on offering all the statistical tools to the modeller, who then takes a decision based on all considered aspects.

The non-household (NHH) forecast modelling process is divided in the following steps:

1. Build the MLR model based on past aggregated consumption data, considering Oxford Economic variables and potentially other factors.
2. Calibrate the model for the base year, in this case 2019-20, first by industry sector using the property consumption data, then by WRZ using the Annual Return (AR) consumption.
3. Apply the MLR model and the calibration to future explanatory variables to estimate future NHH consumption.

The MLR modelling is done at company level, but considering industry groups independently. Calibration is instead performed at WRZ level.

At each stage adjustments and improvements can be made specifically for each company, depending on the specifics of the data. Therefore, in Appendix A there is a complete modelling report for SES Water which identifies all the specific modelling details.

### 2.3.2 *MLR modelling*

Multi linear regression (MLR) modelling aims at finding a linear relationship between the observed consumption and explanatory variables. At first, all available explanatory variables are considered. Subsequently, the model is refined choosing only the significant variables. The choice is based on:

- model performances excluding the variables one by one
- interaction between variables

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<sup>10</sup> Forecasting water demand components - Best practice manual. UKWIR, 97/WR/07/01. 1997.

- logical inclusions/exclusions based on the relationship between the expected effect of each variable on consumption, and the estimated coefficients
- exclusion of outliers
- other modellers' considerations.

SES Water specific results for each MLR model for each industry sector are included in Appendix A and include the following:

- model term
- estimate
- standard error
- p value.

### 2.3.3 Calibration

The MLR model is based on MOSL data in the base year, which may not represent the total annual reported NHH Measured consumption. For this reason, the results of the model need to be calibrated against the Annual Report data for the base year, in this case 2019-20. This also helps account for differences between WRZ, not accounted for building the model at company level.

To ensure the proportion between different sectors is maintained, the calibration has been further refined:

- First, modelled consumption is calibrated against property consumption for each industry group and WRZ, deriving an additive factor,
- Then the total measured consumption is calibrated against AR data at WRZ, deriving a multiplicative factor.

Appendix A includes the calibration factors for SES Water and each WRZ for each industry sector.

### 2.3.4 Baseline forecasts

Final NHH baseline forecasts are obtained separately for the measured and the unmeasured component.

For the measured component, NHH is forecast with the following steps:

- apply the MLR model separately for each industry group and WRZ,
- apply the two-step calibration,
- forecasts are then extended from 2040-41 to 2099-00 using a combination of the trend along with modelling using the population, depending on the presence of population in the baseline model, as follows:
  - where population is not present in the baseline model, then the forecast is kept constant after 2040-41

- where population is used, either alone or in combination with other variables in the baseline model, then a new simpler linear model is used to find a relationship between the consumption forecasted between 2025-26 and 2040-41 and the population forecast for the same years. The linear model is then used to forecast consumption between 2040-41 and 2099-00.
- minimum consumption is set to 10% of the observed years' average, with exclusion of 2020-21 that is allowed to go to zero considering the COVID crisis.

A simpler approach is followed for unmeasured non-household demand, as this is a minor component of the total non-household consumption. Unmeasured forecasts are obtained extending the base year unmeasured consumption as reported in the AR up to 2040. Then the extension from 2040-41 to 2099-00 is achieved using the same total company trend used for all other components.

The forecast outputs are presented and discussed in Appendix A, and a summary of the WRSE high level company outputs are presented in section 3.1.

## 2.4 Scenarios and uncertainty

### 2.4.1 *Introduction*

The concepts of uncertainty and scenarios are often used interchangeably and partially overlap in terms of meaning. Both represent unknowns that may affect water consumption forecasts. For the purpose of the WRMP24 non-household demand forecasts we need to separate the concepts through definitions:

- **Uncertainty** refers primarily to the variability we have in forecasts due to data uncertainty and unexplainable variability uncertainty. Uncertainty is non-zero even in the present figures and grows with time in a gradual way, due to uncertainty propagation. Uncertainty can be described by probability distributions and derived statistics, like mean, standard deviation, or quantiles.
- **Scenarios** refer to the variability in future projections due to foreseeable (at least in terms of happening) events. Scenarios' variability is only applicable to future figures, not to the present, and can grow or decrease in time according to the specific events we are considering. Scenarios are usually represented by a discrete number of alternative forecasts.

As the WRMP24 non-household (NHH) forecasts are derived through a complex process, the sources of uncertainty can be many and very little is known about the quantification of uncertainty. Similarly, the number of factors that can affect NHH water consumption can be large and unexpected events and technologies may alter the way we will consume water; therefore, it is very difficult to consider all plausible scenarios.

In this work, we introduce some approximations to overcome the unknown quantification and the technical limitations involved in modelling both the uncertainty and the scenarios. We first proceed in delineating a large number of foreseeable scenarios, from which we derive plausible central, lower and upper thresholds. Then we proceed in applying uncertainty estimations for quantifiable factors on the three selected thresholds.

Details on the scenarios' definition and the uncertainty quantification are reported in following sections.

### 2.4.2 Modelling scenarios

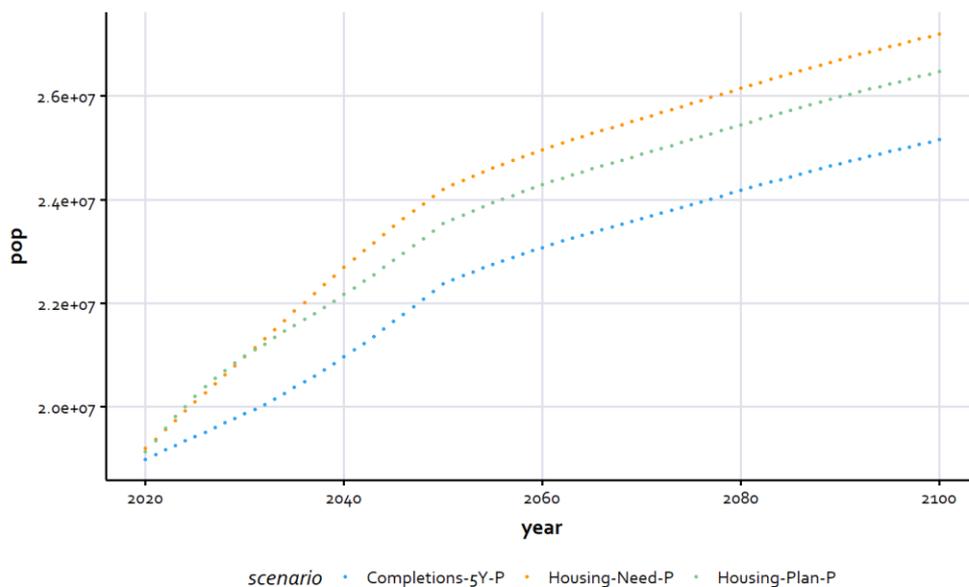
The scenarios represented in the WRMP24 NHH forecasts are chosen based on scenarios that are likely to happen in the short and long term and considering how these may quantitatively affect the NHH water consumption forecasts. We consider six factors, each represented by an upper, central and lower scenario. All combinations are tested, resulting in  $3^6$  scenarios, i.e. 729 individual scenarios.

#### Population scenarios

Population scenarios are chosen from the 72 Edge Analytic population forecasts. The scenario used for the baseline, Housing-Plan-P, is already on the upper range of Edge Analytic population scenarios. To maintain it the central scenario, to keep a balanced forecast, and to keep the risk-averse approach, three scenarios on the upper spectrum are selected and these are shown in Figure 3:

- Population upper scenario: Housing-Need-P
- Population central scenario: Housing-Plan-P
- Population lower scenario: Completions-5Y-P

Figure 3 Three population scenarios are chosen from the 72 Edge Analytic scenarios



#### Brexit

At the moment of writing this report, the United Kingdom has left the European Union and is in the transition period for which the majority of EU regulations are maintained, while the government negotiates an exit deal. The outcome of such negotiations is expected to impact the economy and the immigration scenarios for both the short and the long term. However, the short-term forecasts consider both Brexit and Covid-19 impacts on the economy, and

these two factors are difficult to separate. So, we decided to apply only the long-term impacts for the Brexit scenarios, as the short-term effects are already represented in the three COVID-19 scenarios.

NHH water consumption is modelled considering GVA, employment and population among other factors, and these factors are the ones impacted by Brexit.

The impact on population is estimated from Lomax, 2019<sup>11</sup>, considering the percentage variation between the three reported Brexit scenarios: EU-membership, soft Brexit and hard Brexit. Considering our baseline as the middle scenario, we can consider a change in population of +2.6% by 2040 under the upper Brexit scenario, and a decrease of -2.6% under the lower Brexit scenario.

For employment estimates, we considered the HM Government report *HM Treasury analysis: the long-term economic impact of EU membership and the alternatives*<sup>12</sup>, which states that “unemployment would reach 7% to 8% in 2020, compared with a projected rate of 5% if the UK remained in the EU”. Assuming our estimates correspond to the central, we can consider a variability around 3%, so +/- 1.5% for the upper and lower scenarios. Not having further temporal information, we keep this steady in time.

In terms of GVA (proportional to GDP if fixed taxation is assumed), the report proposes wider ranges, going between 1.2% and 2.8%, considering the uncertainty. For consistency we consider 1.5% like for the employment estimates. The summary of Brexit impacts is presented in Table 5.

**Table 5 Brexit scenarios and their impact**

	Population	GVA	Employment
<b>Upper Brexit scenario</b>	+2.6% by 2040	+1.5% fixed	+1.5% fixed
<b>Central Brexit Scenario</b>	baseline	baseline	baseline
<b>Lower Brexit Scenario</b>	-2.6% by 2040	-1.5% fixed	-1.5% fixed

## COVID-19

COVID-19 has had a strong negative impact on the economy and on NHH water consumption, due to lockdown measurements and economic recession, as well as due to remote-working measurements. At the time of writing this report, a vaccine is estimated to be available in 2021, and the impact of the pandemic is expected to gradually reduce after. The impact of COVID-19 is modelled in three different ways:

<sup>11</sup> Lomax, N., Wohland, P., Rees, P. & Norman, P. The impacts of international migration on the UK’s ethnic populations. *J. Ethn. Migr. Stud.* 46, 177–199 (2019).

<sup>12</sup> HM Government. *HM Treasury analysis: the long-term economic impact of EU membership and the alternatives*, 2016, Cm 9250, Web ISBN 9781474130905

1. GVA and Employment are modified on the short term, according to the expected impact on the economy.
2. Water consumption is reduced across all sectors.
3. Water consumption is shifted between sectors.

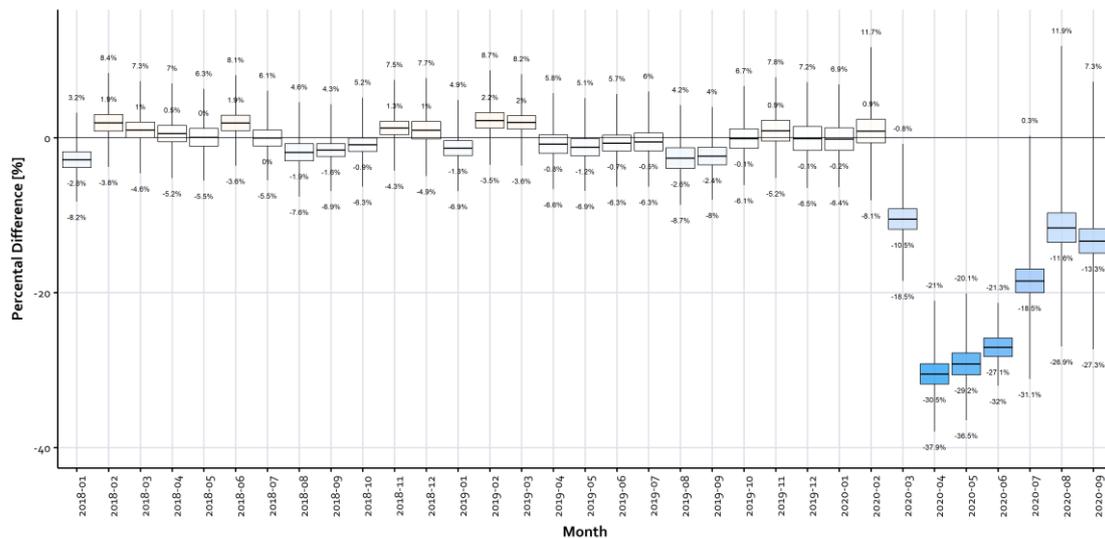
### COVID-19 impact on GVA and Employment

The impact of COVID-19 on GVA and Employment is estimated from the *Forecasts for the UK economy 2020* by the HM Treasury<sup>13</sup>. The report compares independent forecasts. The baseline was estimated using the Oxford Economic (OE) forecasts for GVA and Employment. From the report the upper and the lower thresholds are estimated for GVA (derived from GDP, Table M1 of the report, with the assumption of proportionality) and for employment (derived from unemployment forecasts, table M5 of the report), using the upper and the lower independent estimate. For GVA, OE is a central forecast, therefore is used as the central scenario, while for employment OE is already the upper forecast, so it is used as the upper scenario. The result is a set of percentage changes to apply to the baseline for years 2019-2024. These estimates also include the short-term impact of Brexit.

### NHH water consumption reduction due to COVID-19

Beyond the effects on the economy, COVID-19 has an effect on water consumed by businesses and non-household properties due to different operations and remote working. Artesia has conducted an independent study on the impact of COVID-19 on the NHH sector. Figure 4 shows the reduction in water consumption during summer 2020 months, compared to the previous year, considering weather, holidays, and other influencing factors.

Figure 4 Reduction in NHH water consumption during summer 2020 months compared to previous months.



The three scenarios are considered as follows:

- Upper COVID-19 scenario: no variation on the baseline.

<sup>13</sup> HM Treasury, *Forecasts for the UK economy: a comparison of independent forecasts, 2020*, No. 397, ISBN 978-1-913635-61-9

- Central COVID-19 scenario: -12% in 2020-21 and -6% in 2021-22, then baseline.
- Lower COVID-19 scenario: -20% in 2020-21 and -10% in 2021-22, then -3% on the baseline (long term effects due to permanent home-working adjustments and business closing).

### **Shift between sectors due to COVID-19**

The COVID-19 impact on water consumption is due to its impact on the economy and the change of operations due to a mass remote-working approach. However, both these factors, quantified above as a total effect, affect differently the different economic sectors. Therefore, a final step of the modelling is to shift water consumption across sectors.

To do so, we use data from the ONS Business Impact of COVID-19 Survey (BICS) from September 2020<sup>14</sup> (assumed to be the best representation to date to the post-lockdown COVID-19 scenario). The dataset reports both the changes in turnover and the percentage of workers working remotely, by sector. Combining the two factors we could derive that under the September 2020 conditions, NHH water consumption is likely to have shifted:

- Agriculture +0.4%
- Non-service +9.1%
- Service-economy -4.1%
- Service-population -5.8%
- Unclassified +0.4%

The shift is only considered in the lower COVID-19 scenario, where long term impact of remote-working is considered. Note that the figures above only report a shift (they sum up to zero) because the reductions per sectors are accounted at the previous step.

### **Summary of COVID-19 scenarios**

Table 6 lists the summary of the COVID-19 scenarios and their impact.

**Table 6 COVID-19 scenarios and their impact**

	<b>GVA</b>	<b>Employment</b>	<b>Consumption reduction</b>	<b>Sector shift</b>
<b>Upper COVID-19 scenario</b>	Upper independent forecast	OE forecast	baseline	baseline
<b>Central COVID-19 Scenario</b>	OE forecast	Central independent forecast	-12% in 2020-21 -6% in 2021-22 then baseline	baseline
<b>Lower COVID-19 Scenario</b>	Lower independent forecast	Lower independent forecast	-20% in 2020-21 -10% in 2021-22	Agric: +0.4% Non-serv: +9.1%

<sup>14</sup> ONS, BICS Wave 14 edition of this dataset 7 September to 20 September 2020.

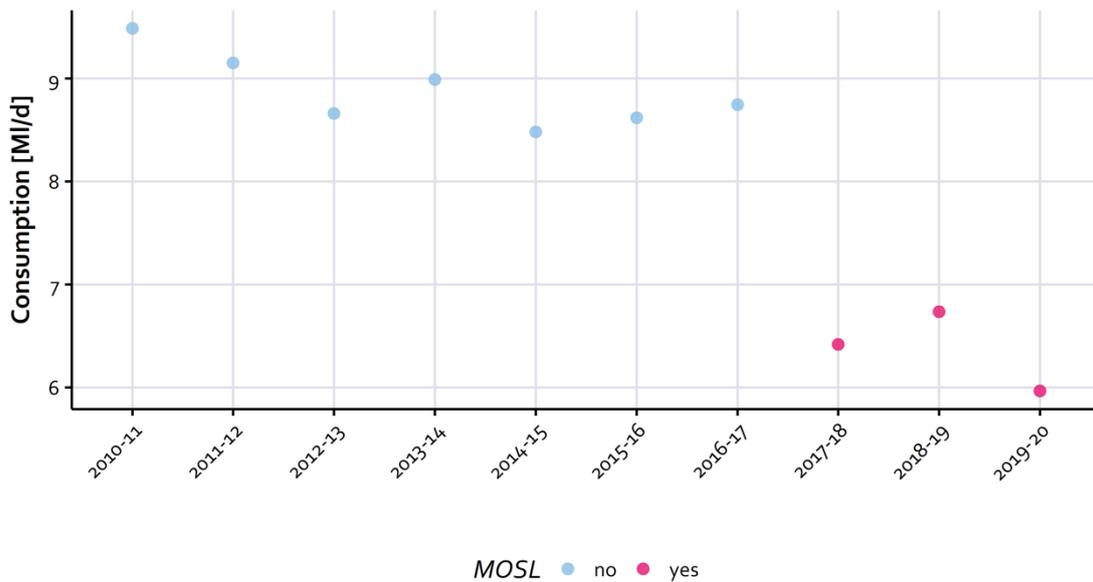
			then -3%	Serv-eco: -4.1%
				Serv-pop: -5.8%
				Unclass: +0.4%

### MOSL

The liberalisation of the water market for the commercial sector has had an impact on the water consumption reporting, operated by MOSL, the market operator for the water retail market in England. During this time, MOSL has failed to deliver some of its targets for improving data quality (notably in the “Long term unread meter category” and the “level of properties flagged as vacant” areas)<sup>15</sup>. The MOSL annual market performance report identifies that 1 in 6 premises is now flagged as vacant, and meters unread for more than a year have increased from 7% at 2017 to 15% at March 2019, with one-third of these not being read since market opening.

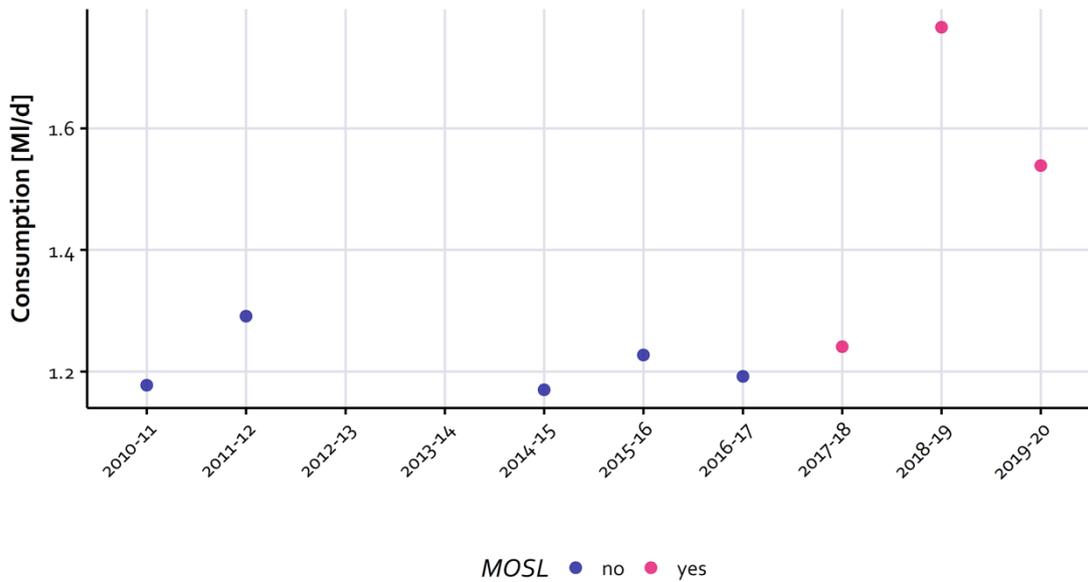
The effects are observable as the difference between the reporting before 2017 and after 2017. Step changes can be seen in the property level data that is used for the modelling, and if these step changes are not taken into consideration, they will impact the robustness of the models. Examples of this can be seen in Figure 5 and Figure 6. To account for this in the modelling a flag is used, which is set to zero before 2017 and set to 1 after.

Figure 5 Example (SEW-Maidstone) step change in property level consumption data post 2016



<sup>15</sup> Annual Market Performance Report 2019/20. MOSL.

Figure 6 Example (SWS-Hampshire Andover) step change in property level consumption data post 2016



However, there are commitments from MOSL to improve in this area and signs in 2019 that progress is being made. We are unsure how these improvements will impact reporting in the future, depending on how the water retail market evolves. Therefore, the following three scenarios are considered, quantifying the impact that the shift to MOSL reporting has had on each water resource zone and industry group separately:

- Upper MOSL scenario: the MOSL effect doubles in 2030, then remains at that level (data quality deteriorates).
- Central MOSL scenario: the MOSL effect remains constant in the future (data quality remains the same).
- Lower MOSL scenario: the MOSL effect gradually declines to zero in 2030 and remains at that level (data quality improves to pre-2017 levels).

## Climate change

### Modelling residuals

To consider weather effects on water consumption, a residual model is used, i.e. the difference between the actual consumption and the one that the MLR model estimates (residuals) are further modelled as a function of weather variables like temperature and rainfall.

Building the residual models for each WRZ independently is correct theoretically, but due to the low number of points in time it can result in unstable models. Therefore, we changed the approach to consider all residuals from all WRZs and all companies in one model. To make the residuals comparable, we standardised them, dividing them by the consumption itself:

$$residuals = \frac{(consumption - prediction)}{consumption}$$

Using this method, the resulting model predicts standardised residuals in the future as a function of weather variables (*average rainfall* and *average maximum temperature*). The residuals can then be adapted to each WRZ by multiplying them by the mean consumption of past years.

**Modelling historic weather trends**

The first step in the analysis is to establish the change in weather patterns that are occurring due to climate change. The weather variables under examination are *average maximum temperature* and *average rainfall*. Figure 7 and Figure 8 show that the trends of these variables over the years can be well represented with linear regressive models.

Figure 7: A plot showing the trend of peak daily temperatures since 1959.

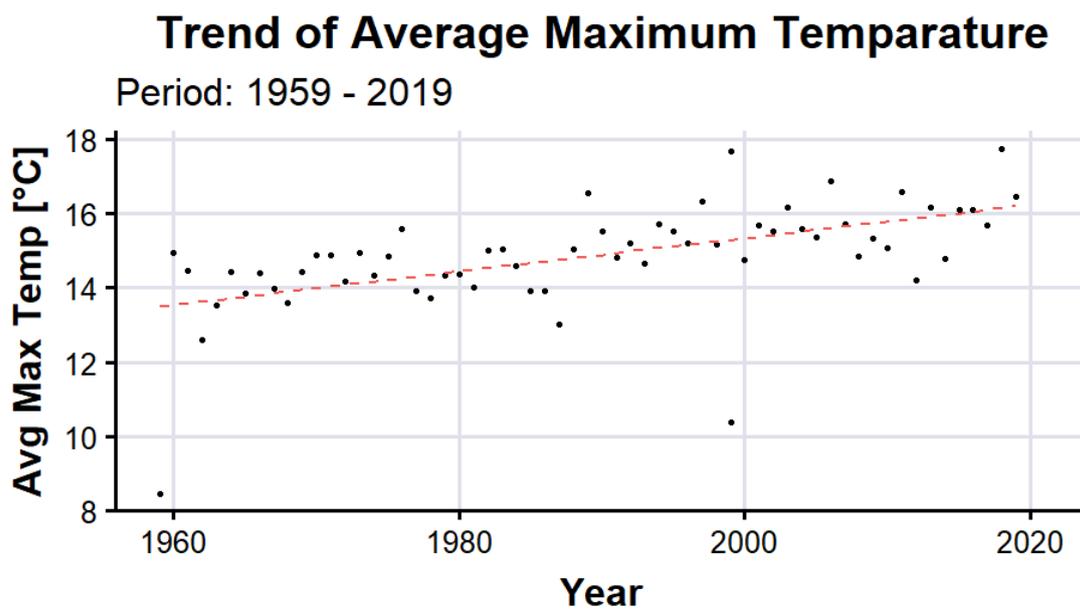
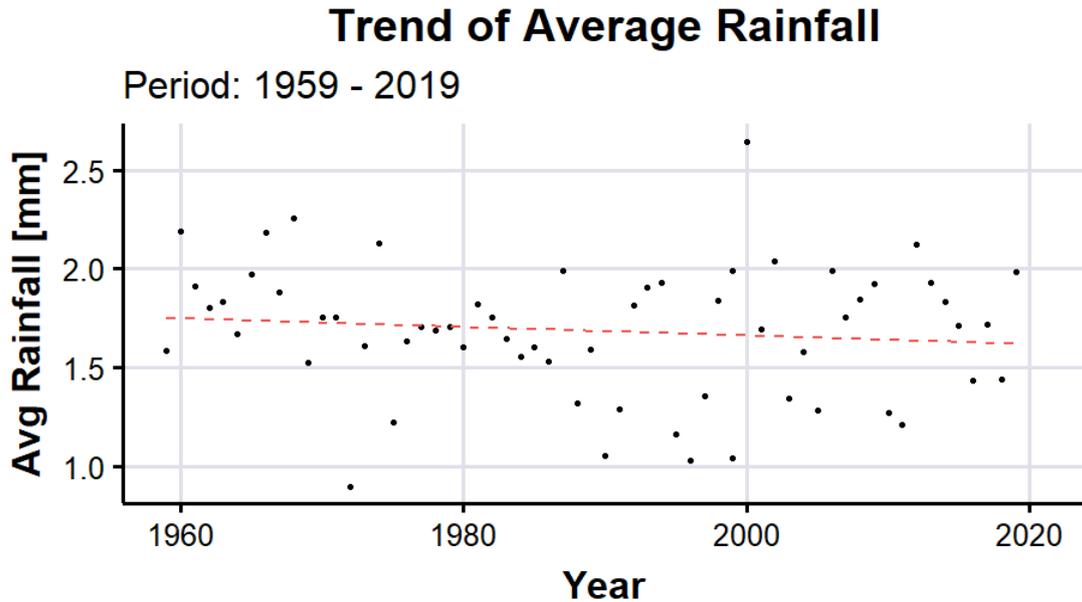


Figure 8: A plot showing the trend of average daily rainfall over since 1959.



### Forecasting Weather and Climate Change Residuals

The weather models developed in Figure 7 and Figure 8 are used to forecast *average maximum temperature* and *average rainfall* through the forecast period.

We used additive climate change models in conjunction with the weather forecasts. These models provide 12 scenarios of potential temperature and rainfall patterns.

The forecasts of the weather variables are each summed with the 12 relevant climate change scenarios to produce 12 forecasts for *average maximum temperature* and *average rainfall*. The 12 scenarios for each are then fed into the residual model to obtain residual forecasts.

However, all 12 scenarios are not required for this analysis, only a *low*, *central*, and *high* scenario. To extract three scenarios from the 12, the 10<sup>th</sup>, 50<sup>th</sup>, and 90<sup>th</sup> quantile of the scenarios are taken for each financial year.

The climate change scenarios only go up to the year 2080, whereas we need forecasts up to the year 2100. The forecasts must therefore be extended to meet client needs. To perform this extension, a linear regressive model is fitted to each of the *low*, *central*, and *high* scenarios and used to predict the final 20 years to the desired end year, 2100.

### Water efficiency

The evolution of technology and regulations is expected to contribute reducing NHH water consumption, by improving water efficiency.

The three water efficiency scenarios below were selected in consultation with the WRSE steering group:

- Upper water efficiency scenario: water consumption is reduced by 2% by 2050-51.
- Central water efficiency scenario: water consumption is reduced by 7.5% by 2050-51.
- Lower water efficiency scenario: water consumption is reduced by 16% by 2050-51.

### 2.4.3 Combining scenarios

All the scenarios described above result in a total of 729 scenarios for each Company/WRZ. This is a large number to report, so they are summarised as a central, upper, and lower thresholds. The thresholds have been derived as:

- Upper threshold: 90<sup>th</sup> percentile of all the scenarios each year.
- Central threshold: 50<sup>th</sup> percentile of all the scenarios each year.
- Lower threshold: 10<sup>th</sup> percentile of all the scenarios each year.

An example of 81 of the 729 scenarios is shown in Figure 9. A derivation of the Upper, Central and Lower thresholds from all 729 scenarios is illustrated in Figure 10 for Affinity Water as an example.

Figure 9 Example of 81 of the 729 scenarios for Affinity Water

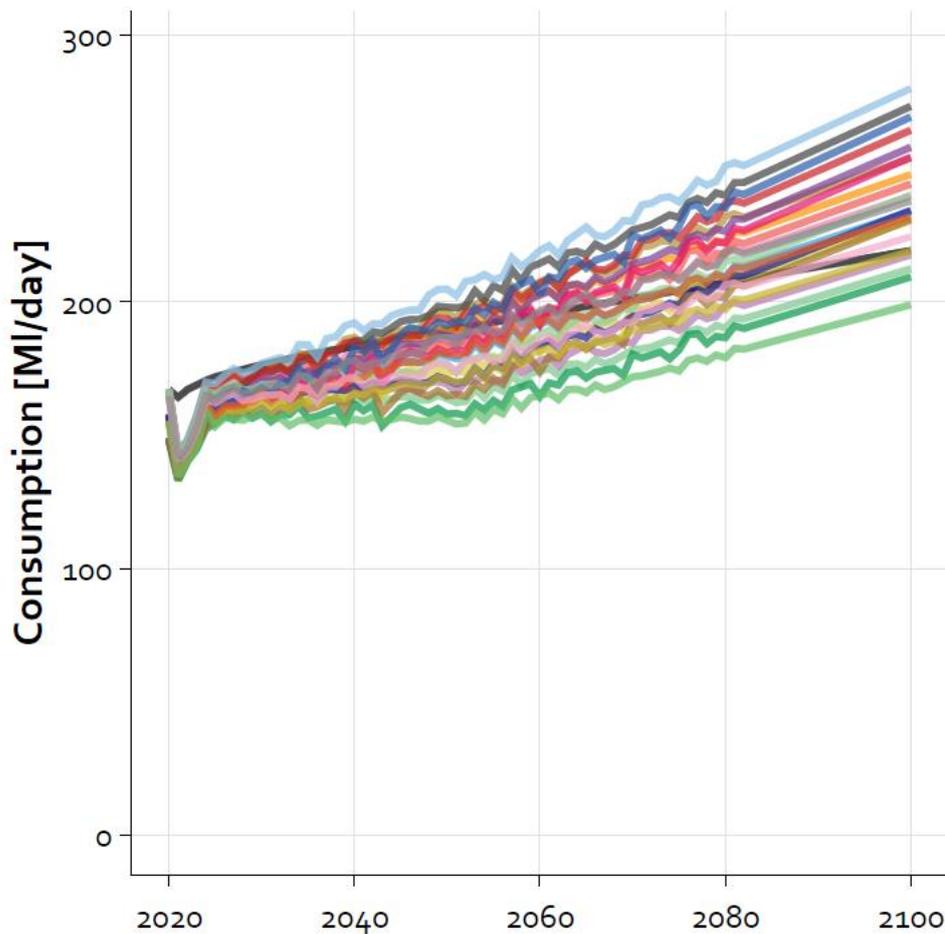
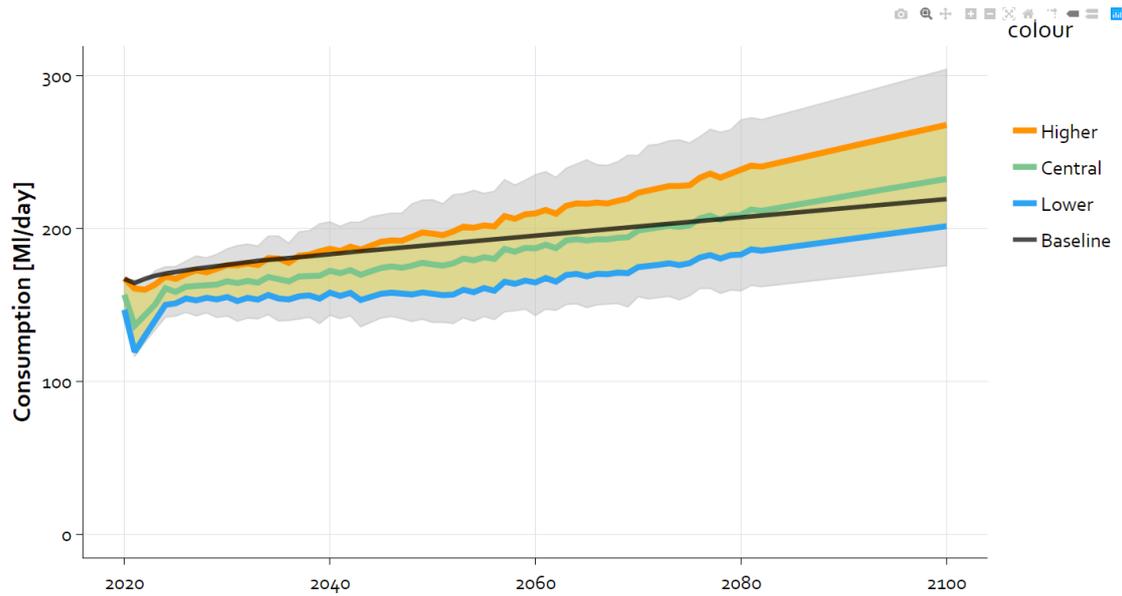


Figure 10 Example derivation of the Upper, Central, and Lower thresholds from the total scenario variability for Affinity Water



#### 2.4.4 Modelling uncertainty

Every single element of the complex WRMP24 NHH forecasts is affected by a certain degree of uncertainty, but the quantification is difficult. Therefore, we decided to focus on the elements that have the biggest impact on the forecasts:

- the explanatory variables used in the model
- the model
- climate change.

The quantification of uncertainty for each component is described in the following sections.

#### Explanatory variable uncertainty

Each explanatory variable is affected by a different degree of uncertainty. It is not easy to separate the uncertainties and to evaluate the effects of each on the resulting water consumption. However, thanks to the linear nature of the model, if we consider the explanatory variables to have the same uncertainty, e.g.  $\pm 10\%$ , we can derive that the same uncertainty will affect water consumption. The following explanatory variables are considered for uncertainty:

- GVA
- Employment
- Population

Other minor explanatory variables are expected to have a lower uncertainty and to affect the water consumption estimations to a smaller degree.

Observing the population scenarios from Edge Analytics, we can observe that their uncertainty is very small in the present and grows steadily in the future, reaching a value of  $\pm 6\%$  to  $\pm 12\%$  depending on what scenarios we consider.

In terms of GVA and employment we can observe in the *Forecasts for the UK economy 2020* by the HM Treasury, the larger uncertainty is actually in the short term and varies between  $\pm 30\%$  to  $\pm 50\%$  for GVA to  $\pm 1.5\%$  to  $\pm 3\%$  for Employment.

Considering the uncertainties estimated above, the general uncertainty for the explanatory variables is estimated as:

- $\pm 8\%$  of the water consumption in 2019-20.
- Growing to  $\pm 12\%$  of the water consumption in 2025-26.
- Growing to  $\pm 18\%$  of the water consumption in 2099-00.

### Model uncertainty

Model uncertainty is estimated separately for the considered industry groups and companies, as different models are used. A model's  $R^2$  value represents the variability in the data that the model is able to explain. We estimate the model uncertainty as  $1 - R^2$ , i.e. the variability in the data that the model is not able to explain. This is a simplification, as effects such as overfitting can increase the  $R^2$  value beyond what the real capabilities of the model are, but overall it is a good proxy for the model uncertainty.

### Climate change uncertainty

Climate change uncertainty has been estimated from the UKCP18 Climate Change Over Land infographic<sup>16</sup>, that estimates the following:

- Rainfall is expected to show a variability up to  $\pm 25-30\%$  in summer and  $\pm 12-19\%$  in winter by 2060-79. It can be approximated as a  $\pm 20\%$  on a yearly basis by 2060-79.
- Temperature is expected to show a total variability between  $2.5-3.5\text{ }^\circ\text{C}$  in winter and  $3.3-4.7\text{ }^\circ\text{C}$  in the summer, so about  $4\text{ }^\circ\text{C}$  on a yearly basis by 2060-79. Assuming an average yearly temperature around  $15\text{ }^\circ\text{C}$ , that is about  $15\text{ }^\circ\text{C} \pm 2\text{ }^\circ\text{C}$ , i.e.  $\pm 13\%$ . by 2060-79.

Combining the two estimates, we can consider a climate variability of about  $16\%$  by 2070, so we assume  $18\%$  by 2099.

### 2.4.5 Application of uncertainty

Once the uncertainty of the single components is defined, as stated in the previous sections, they are then combined in a quadratic way:

$$u = \sqrt{u_{EV}^2 + u_{model}^2 + u_{climate}^2}$$

<sup>16</sup> Met Office, 2018, UKCP18 Science Overview Report – November 2018 (Updated March 2019) – Infographic Headline Findings

The resulting uncertainty, estimated for each Company, WRZ, industry group and year, is applied on the three derived scenario thresholds.

## 2.5 Potential non-PWS demand

### 2.5.1 Data

For the calculation and forecast of non-PWS demand we used the output created for the Wood plc study for Defra and the Environment Agency, specifically the spreadsheet:

- Existing and new authorisations in SouthEast.xlsx

From this spreadsheet we mainly used data from the following TABS:

- **Existing\_Abstactions\_All** which contains combined surface water abstractions (SWABS) and groundwater abstractions (GWABS) point-purpose licence (extracted from WRGIS database February 2019) including multiple GWABS entries where impacts are apportioned to multiple surface water bodies.
- **New authorisations data** which contains any new abstraction licences since February 2019.

### 2.5.2 Analysis

#### *Existing abstractions*

Firstly, we removed all the public water supply abstractions by filtering them out using the “PWS” flag in the “secondary code” column. We then need to segment the non-PWS observations into industrial sectors. This was done using the codes shown in Table 7.

The data is then checked for duplicates and any duplicates removed.

**Table 7 Sector segmentation – existing abstractions**

Ref	Sector	How to reference
E1	Spray irrigation	Use the following Tertiary codes: 380 390 400 410 420
E2	Paper and pulp	Use secondary code: PAP
E3	Chemicals	Use secondary code: CHE
E4	Food and Drink	Use secondary code: FAD
E5	Power	Use primary code: P

E6	Agriculture (non-spray irrigation)	All remaining agriculture after E1 is removed.
E7	Navigation	Use secondary code: NAV
E8	Minerals and extraction	Use secondary codes: EXT and MIN
E9	Other	Anything that is left

The abstractions are then grouped by industry code and WRZ. We then for each WRZ, sum the following:

- Recent actual point purpose annual quantity in m<sup>3</sup>/year, consumptive quantities only (RAPTPANQM<sub>3</sub>).
- Consumptive only - Best Estimate Growth Factor Applied to RAPTPANQM<sub>3</sub>
- Consumptive only - 75<sup>th</sup> Percentile Growth Factor Applied to RAPTPANQM<sub>3</sub>.

The derivation of the “Best estimate growth” and the “75<sup>th</sup> percentile growth” factors are described in the Wood plc report<sup>7</sup>.

Annual predicted non-PWS needs projecting from 2025 to 2100. For 2025 to 2050 use a linear interpolation between baseline and growth to 2050. For 2051 to 2100 we keep the non-PWS flat for this first iteration (alternative scenarios for post 2050 growth could be applied later).

### ***New authorisations***

The new authorisations sheet does not include WRZ information. So, for the purpose of this analysis, the field “NA\_Catchment” was matched to water company through visual inspection. This results in sometimes allocating more than one water company to a catchment. In these cases, the volumes were split equally across the companies. This could be improved in the future.

The data is then checked for duplicates and any duplicates removed. We then need to select which industry sectors should be included, along with the best estimate growth factors. These are shown in Table 8.

**Table 8 Sector segmentation – new authorisations**

Ref	Sector	How to reference	Best estimate growth
N1	Horticultural watering	abpAbsPurposeDesc	2.01
N2	Make up or top up water	abpAbsPurposeDesc	1.00
N3	Spray irrigation -direct	abpAbsPurposeDesc	1.44
N4	Spray irrigation – storage	abpAbsPurposeDesc	1.44
N5	Trickle irrigation – direct	abpAbsPurposeDesc	1.44

<b>N6</b>	Trickle irrigation - storage	abpAbsPurposeDesc	1.44
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For new abstractions we only have the licenced volume, and therefore will assume that is an approximation to actual consumptive volume. The industry groups we have selected are the ones likely to have consumptive demand. After grouping by industry code, we then sum the following:

- Abstraction quantity per year ('apnAbsQtyYear').
- Compute the best estimate of growth to 2050 using the growth rate in Table 8.

The derivation of the "Best estimate growth" is based on similar sectors in the Wood plc report.

Annual predicted non-PWS needs projecting from 2025 to 2100. For 2025 to 2050 use a linear interpolation between baseline and growth to 2050. For 2051 to 2100 we keep the non-PWS flat for this first iteration (alternative scenarios for post 2050 growth could be applied later).

## 3 Results

### 3.1 Baseline forecast for non-household public water supply demand

Baseline forecast outputs are provided in the following attached file “01\_Artesia-WRSE\_NonHousehold-Demand-Forecasts\_Phase1-final-results\_20201008.xlsx”. This file includes the following breakdown of baseline non-household consumption forecasts from 2019-2020 through to 2099-2100:

- 01: Forecasts of measured non household demand for each industry sector in each water resource zone.
- 02: Forecasts of unmeasured non household demand for each WRZ (currently flat forecasts).
- 03: Aggregates of measured non household demand forecasts for each WRZ.
- 04: WRZ total forecasts (measured plus unmeasured).
- 05: Company total forecasts (measured plus unmeasured).
- 06: WRSE region total forecasts (measured plus unmeasured).

It is important to consider the baseline forecasts in the context of the uncertainty in the data and modelling, as well as future uncertainties (described in section 2.4). Therefore, we have produced scenarios for non-household demand forecast outputs are provided in the following attached files for the central, lower and upper scenarios:

- “01\_Artesia-WRSE\_NonHousehold-Demand-Forecasts\_central\_Scenario\_preliminary\_result\_20201016.xlsx”.
- “01\_Artesia-WRSE\_NonHousehold-Demand-Forecasts\_lower\_Scenario\_preliminary\_result\_20201016.xlsx”
- “01\_Artesia-WRSE\_NonHousehold-Demand-Forecasts\_upper\_Scenario\_preliminary\_result\_20201016.xlsx”

These files includes the following breakdown of scenario non-household demand forecasts from 2019-2020 through to 2099-2100:

- 1\_PWS\_WRZ\_measured\_scenario
- 2\_PWS\_WRZ\_unmeasured\_scenario
- 3\_PWS\_WRZ\_total\_scenario
- 4\_PWS\_Company\_measured\_scenario
- 5\_PWS\_Company\_unmeasured\_scenario
- 6\_PWS\_Company\_total\_scenario
- 7\_PWS\_Region\_measured\_scenario
- 8\_PWS\_Region\_unmeasured\_scenario
- 9\_PWS\_Region\_total\_scenario

WRSE level graphs of non-household baseline demand and scenarios are presented in Figure 11, Figure 12 and Figure 13. Company graphs for non-household demand scenarios are then shown in Figure 14 through to Figure 31.

### 3.1.1 WRSE regional results

At start of the planning period (2025), the WRSE region total non-household demand is predicted to be 921 Ml/d within an overall range of 594 to 1121 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 1032 Ml/d (an increase of 111 Ml/d) within a range of 630 Ml/d to 1637 Ml/d.

Figure 11 WRSE region measured and unmeasured non-household demand forecasts

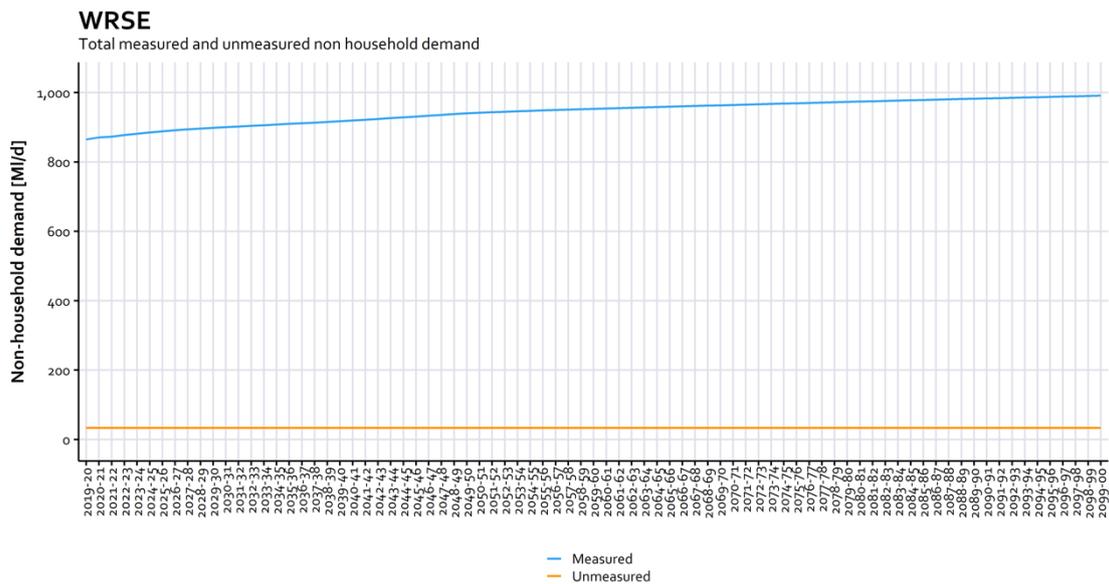


Figure 12 WRSE region non-household consumption central, lower and upper scenarios

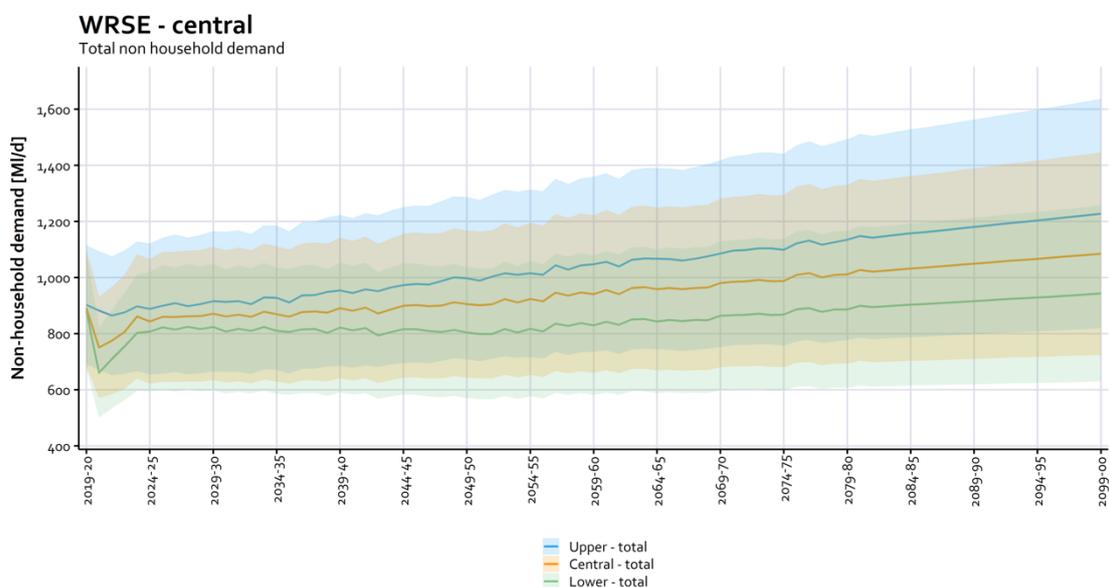
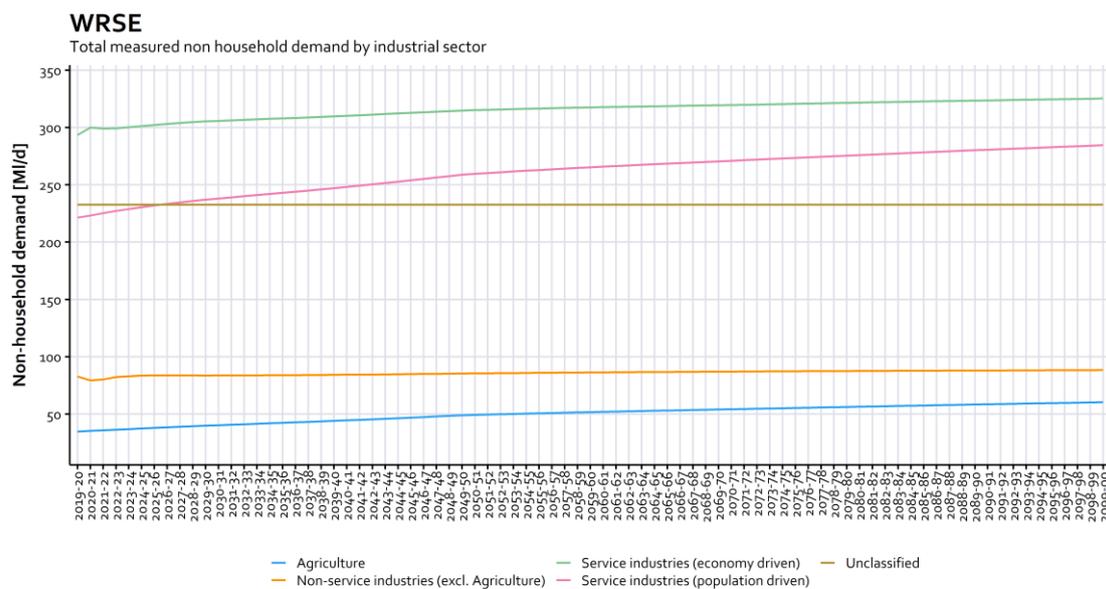


Figure 13 shows how the non-household demand is broken down into the standard industry sectors. There is limited growth in the ‘non-service industries’ i.e. manufacturing etc. Most of the growth is in the service sectors, which are driven by population and economy.

Approximately one quarter of the non-household demand in the WRSE region falls into the ‘unclassified’ category. These are properties that could not be allocated into an industry sector because either the property has no industry code assigned to it or the industry code is incorrectly recorded and cannot be matched to a sector. We did attempt to model this unclassified sector, but because of the inconsistency in the data it was not possible to derive meaningful relationships or models, therefore we held the forecast for the unclassified sector flat across the planning period.

Figure 13 WRSE region non-household demand forecasts by industry sector



### 3.1.2 Affinity Water results

The results for Affinity Water are shown in Figure 14 to Figure 16. At start of the planning period (2025), the Affinity region total non-household demand is predicted to be 174 ML/d within an overall range of 87 to 242 ML/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 208 ML/d (an increase of 34 ML/d) within a range of 100 ML/d to 371 ML/d.

Figure 14 Affinity Water measured and unmeasured non-household consumption

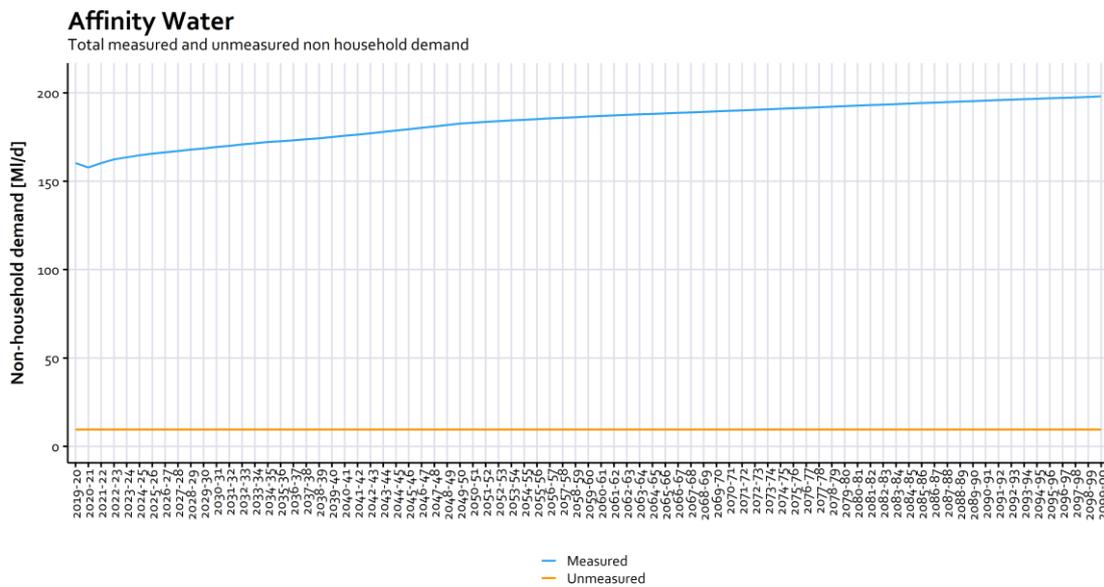
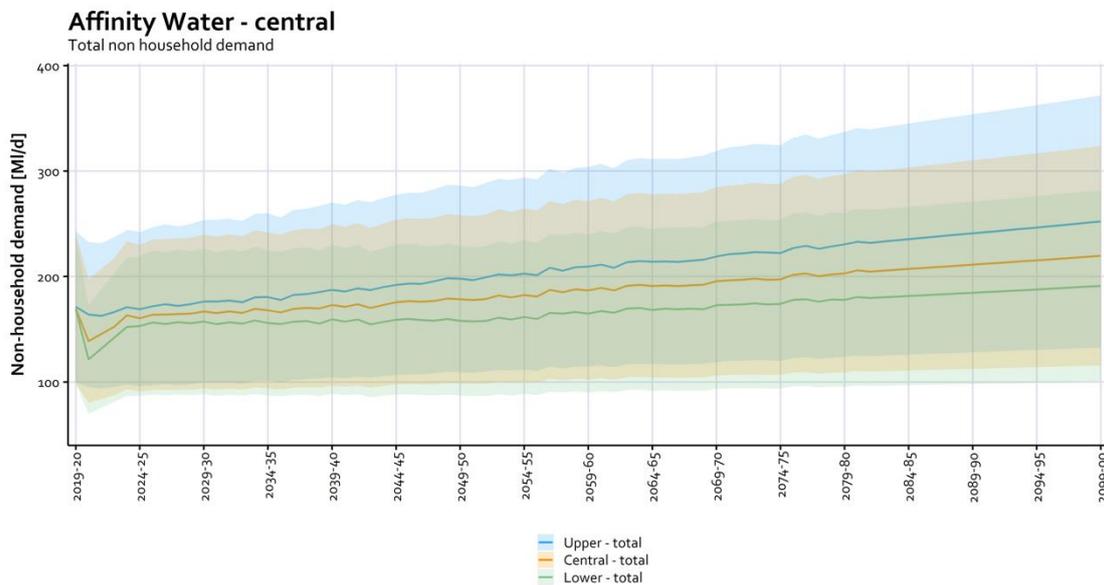
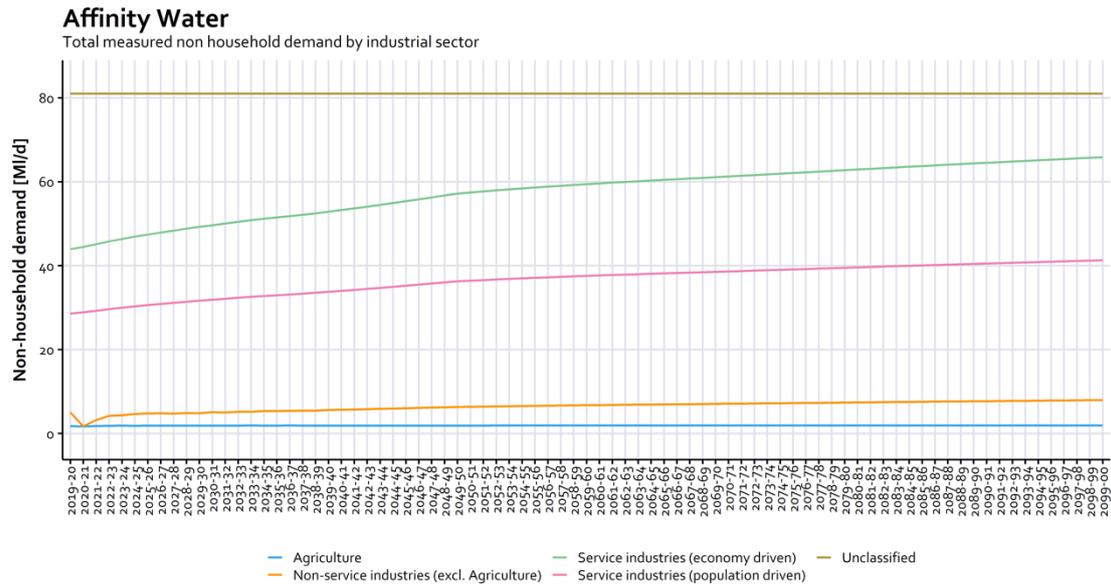


Figure 15 Affinity Water region non-household consumption central, lower and upper scenarios



Most of the growth in the Affinity region comes from the service sectors, with the non-service sector and agriculture remaining approximately flat across the planning period. Approximately one third of the demand in the Affinity region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 16 Affinity Water non-household consumption by industry sector



### 3.1.3 Portsmouth Water results

The results for Portsmouth Water are shown in Figure 17 to Figure 19. At start of the planning period (2025), the Portsmouth region total non-household demand is predicted to be 35 Ml/d within an overall range of 23 to 41 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 40 Ml/d (an increase of 5 Ml/d) within a range of 20 Ml/d to 69 Ml/d.

Figure 17 Portsmouth Water measured and unmeasured non-household consumption

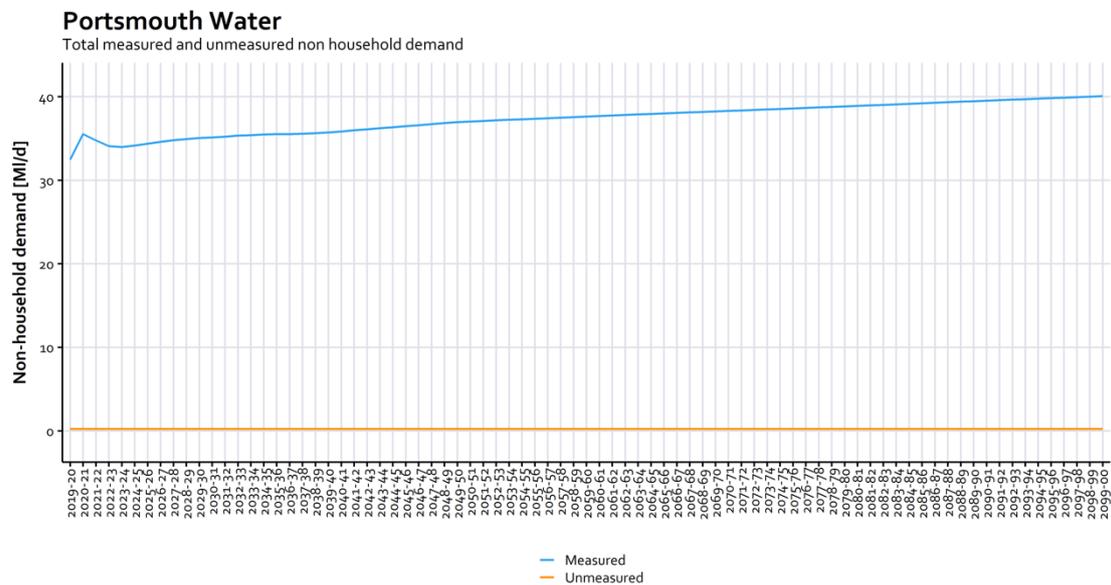
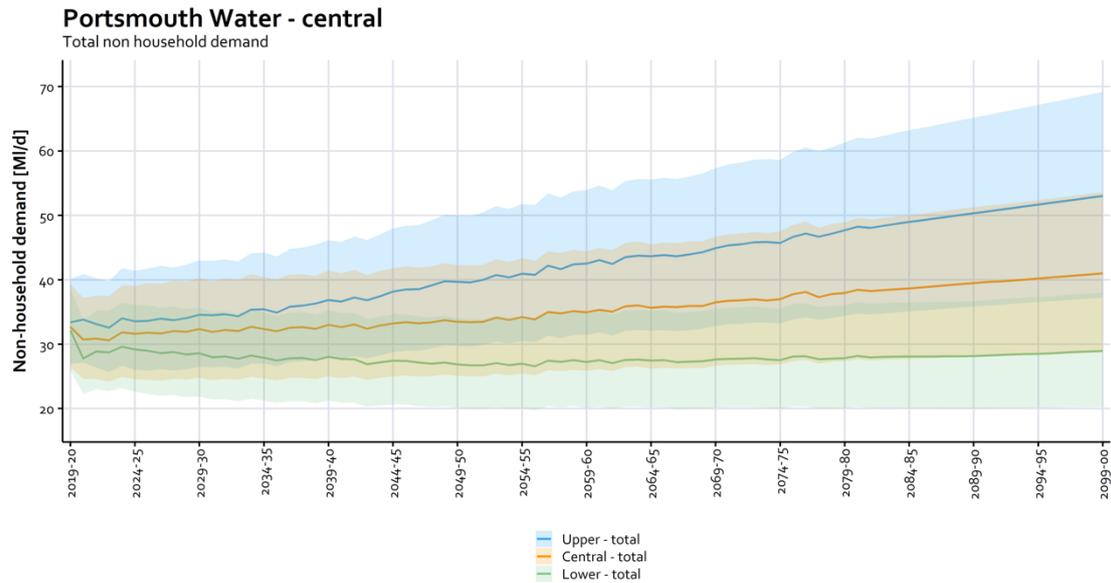
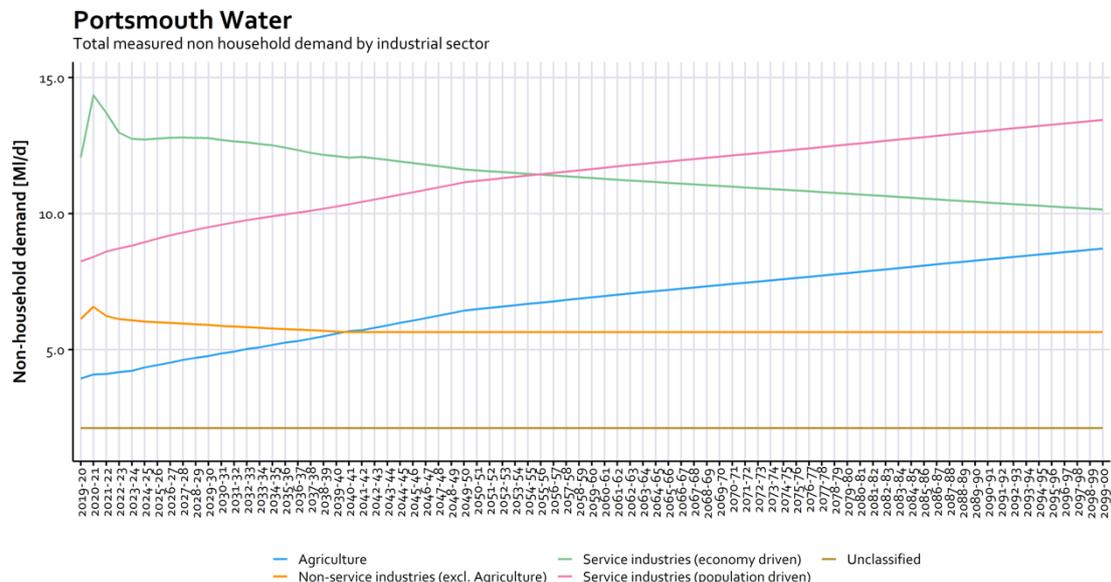


Figure 18 Portsmouth Water region non-household consumption central, lower and upper scenarios



Most of the growth in the Portsmouth region comes from the service-population driven and agriculture sectors, with the service-economy and non-service sector reducing across the planning period. Less than 1% of the demand in the Portsmouth region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 19 Portsmouth Water non-household consumption by industry sector



### 3.1.4 SES Water results

The results for SES Water are shown in Figure 20 to Figure 22. At start of the planning period (2025), the SES region total non-household demand is predicted to be 25 MI/d within an overall range of 17 to 30 MI/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 24 MI/d (a decrease of 1 MI/d) within a range of 16 MI/d to 38 MI/d.

Figure 20 SES Water measured and unmeasured non-housheold consumption

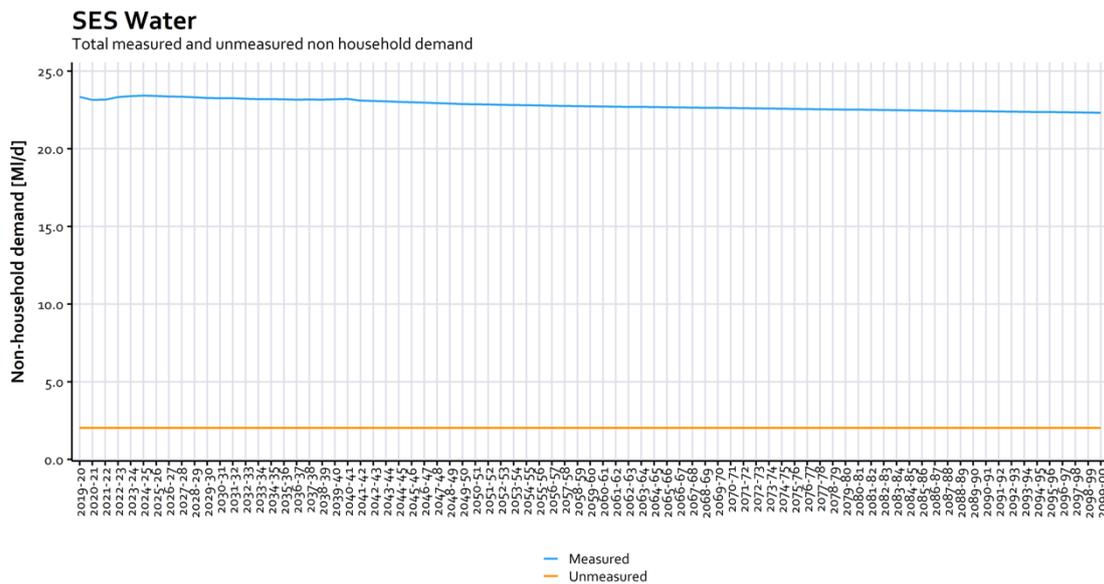
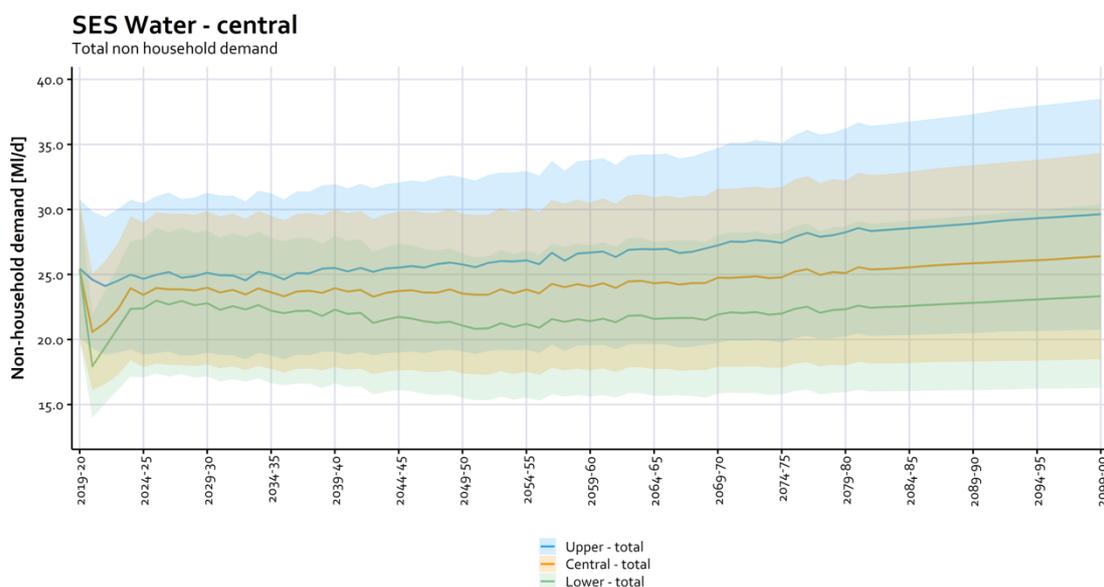
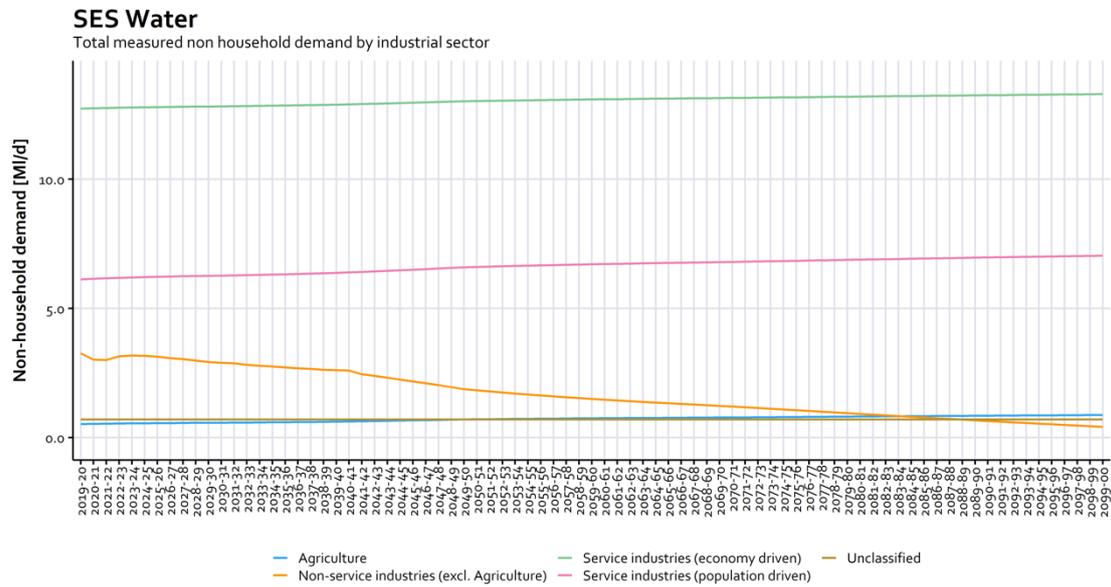


Figure 21 SES Water region non-household consumption central, lower and upper scenarios



There is slight growth in the SES region from the service sectors, with the non-service sector reducing across the planning period. About 3% of the demand in the SES region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 22 SES Water non-household consumption by industry sector



### 3.1.5 South East Water results

The results for South East Water are shown in Figure 23 to Figure 25. At start of the planning period (2025), the South East Water total non-household demand is predicted to be 98 ML/d within an overall range of 63 to 120 ML/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 113 ML/d (an increase of 15 ML/d) within a range of 72 ML/d to 180 ML/d.

Figure 23 South East Water measured and unmeasured non-household consumption

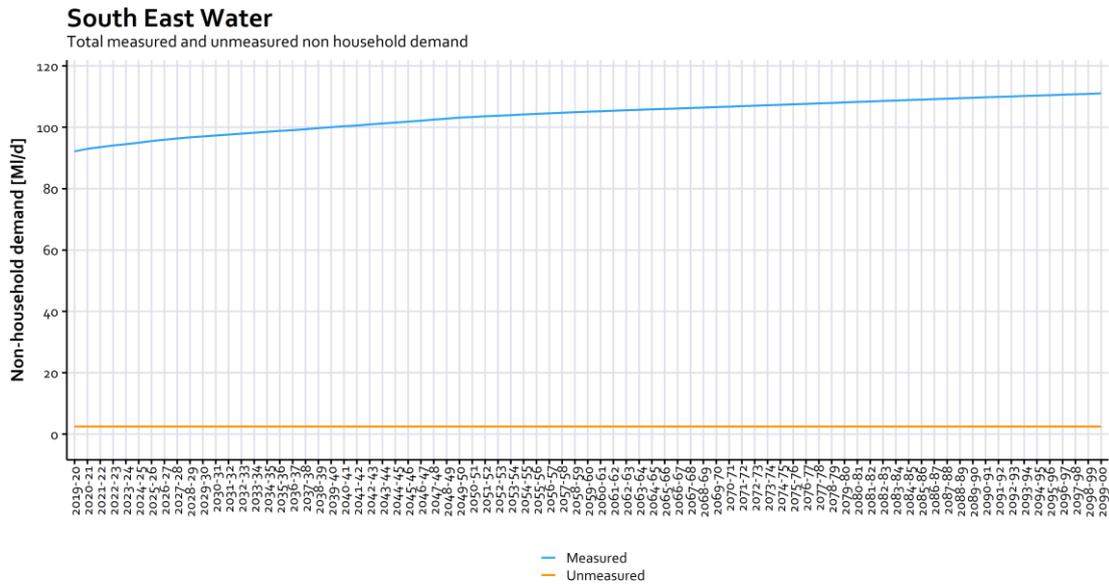
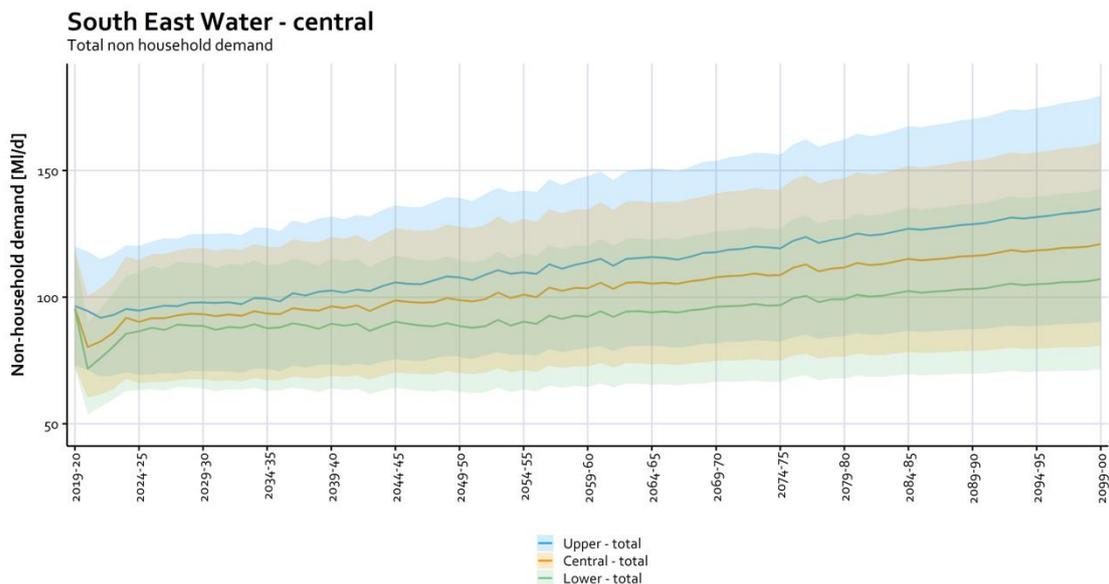
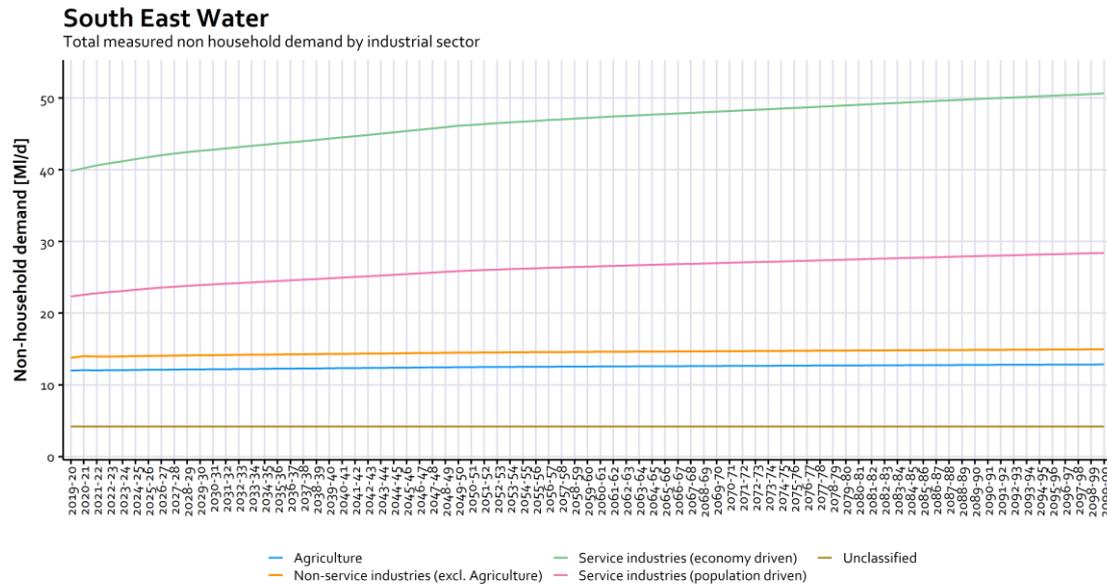


Figure 24 South East Water region non-household consumption central, lower and upper scenarios



There is growth in the South East region from the service sectors, with the non-service sector and agriculture sectors remaining flat across the planning period. About 4% of the demand in the South East Water region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 25 South East Water non-household consumption by industry sector



### 3.1.6 Southern Water results

The results for Southern Water are shown in Figure 26 to. Figure 28. At start of the planning period (2025), the Southern Water region total non-household demand is predicted to be 115 ML/d within an overall range of 71 to 142 ML/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 122 ML/d (an increase of 7 ML/d) within a range of 107 ML/d to 207 ML/d.

Figure 26 Southern Water measured and unmeasured non-household consumption

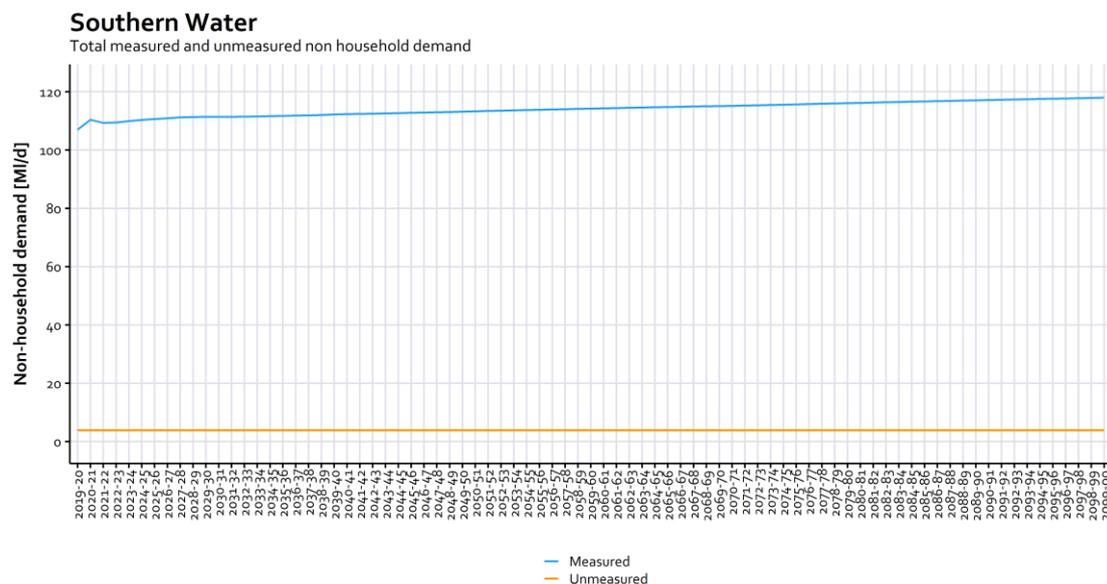
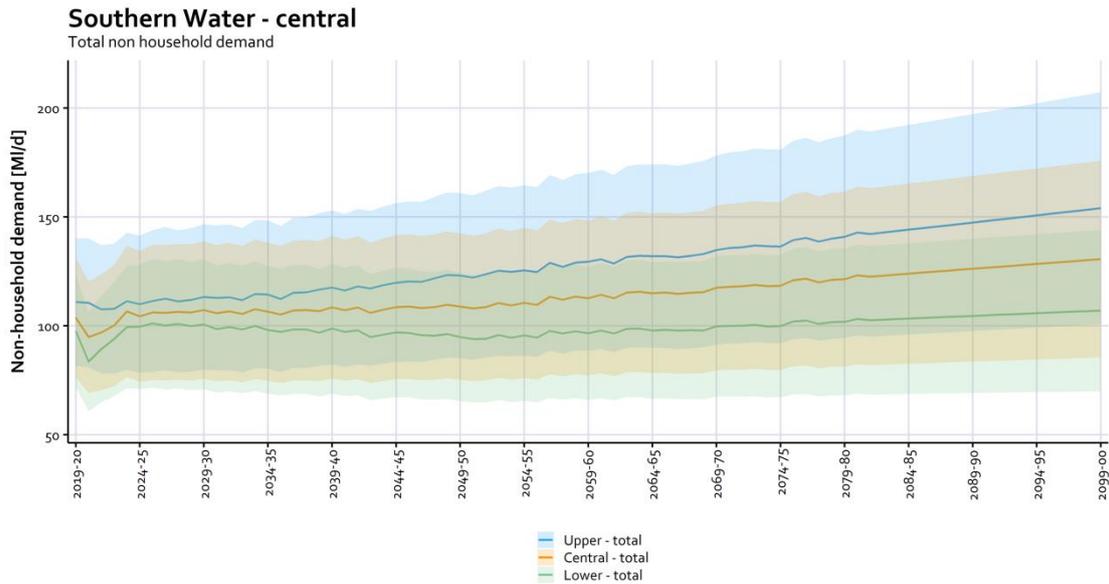
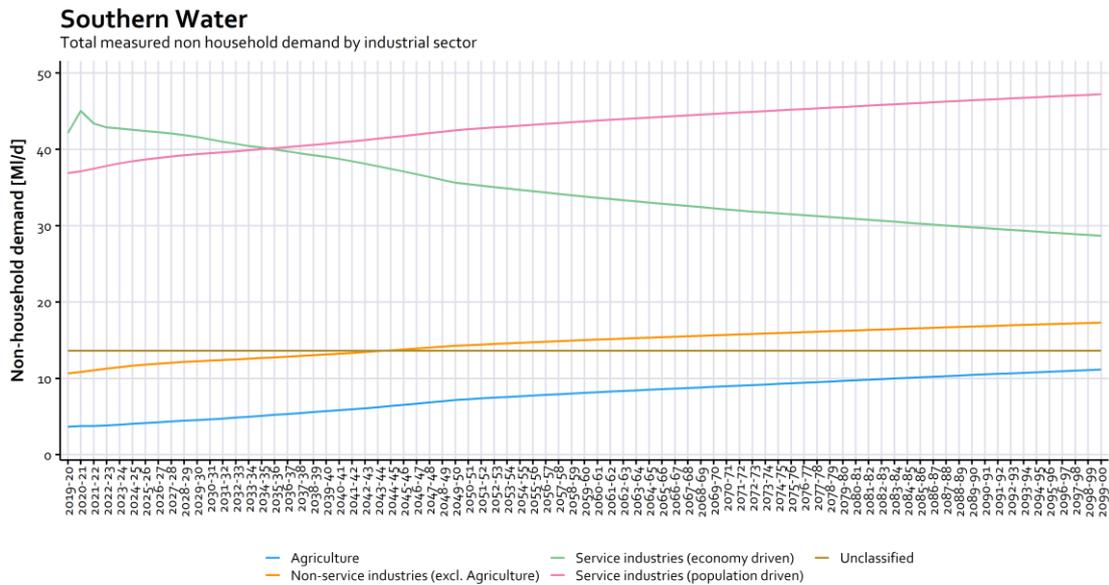


Figure 27 Southern Water region non-household consumption central, lower and upper scenarios



There is growth in the Southern Water region from the population service, non-service and agriculture sectors, with economy service sector reducing across the planning period. About 12% of the demand in the Southern Water region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 28 Southern Water non-household consumption by industry sector



### 3.1.7 Thames Water results

The results for Thames Water are shown in Figure 29 to Figure 31. At start of the planning period (2025), the Thames Water region total non-household demand is predicted to be 471 MI/d within an overall range of 334 to 546 MI/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 516 MI/d (an increase of 45 MI/d) within a range of 351 MI/d to 771 MI/d.

Figure 29 Thames Water measured and unmeasured non-housheold consumption

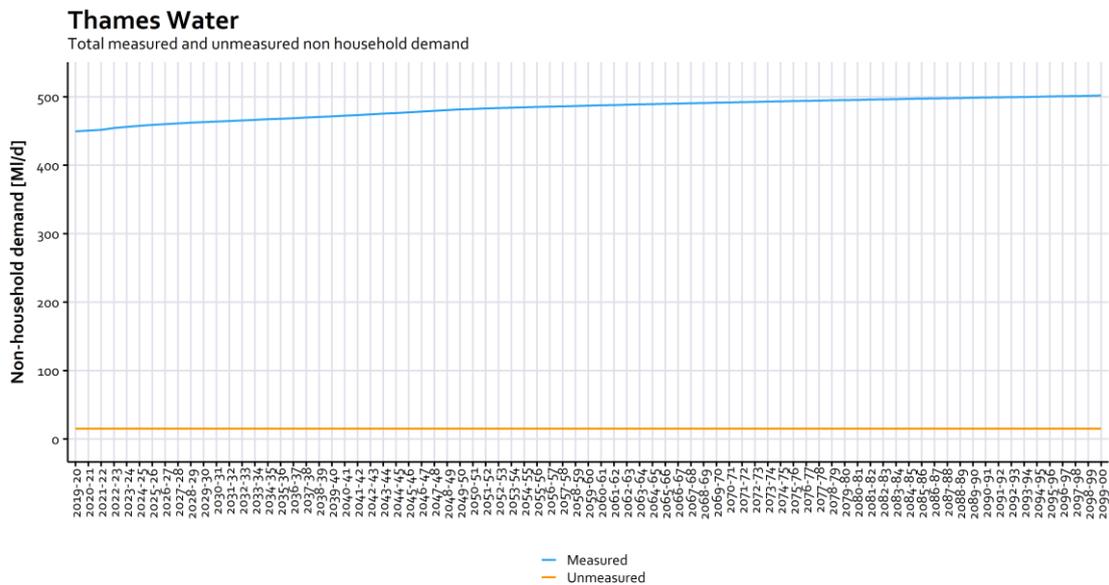
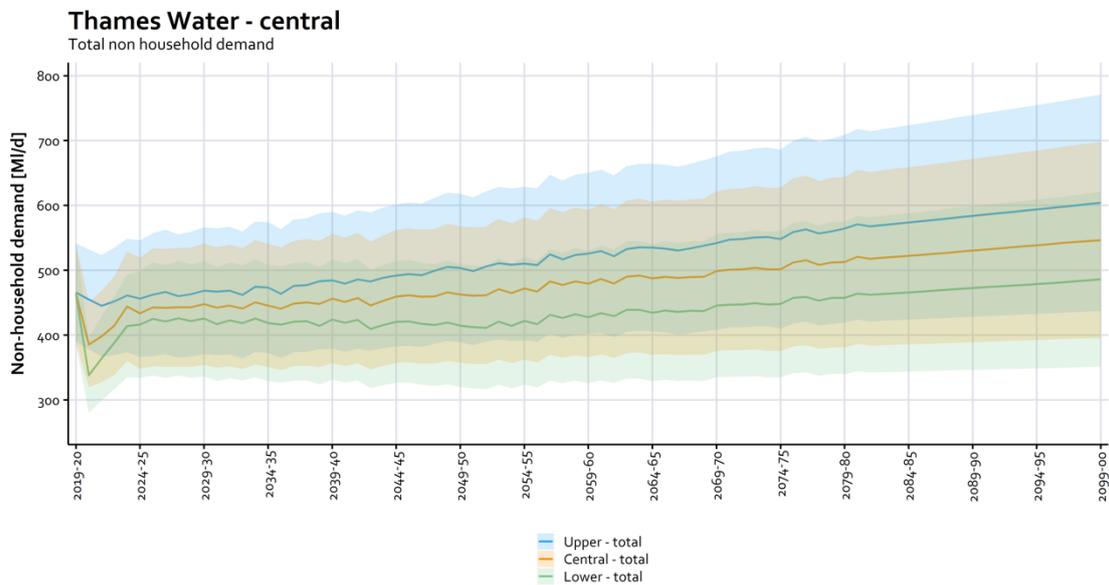


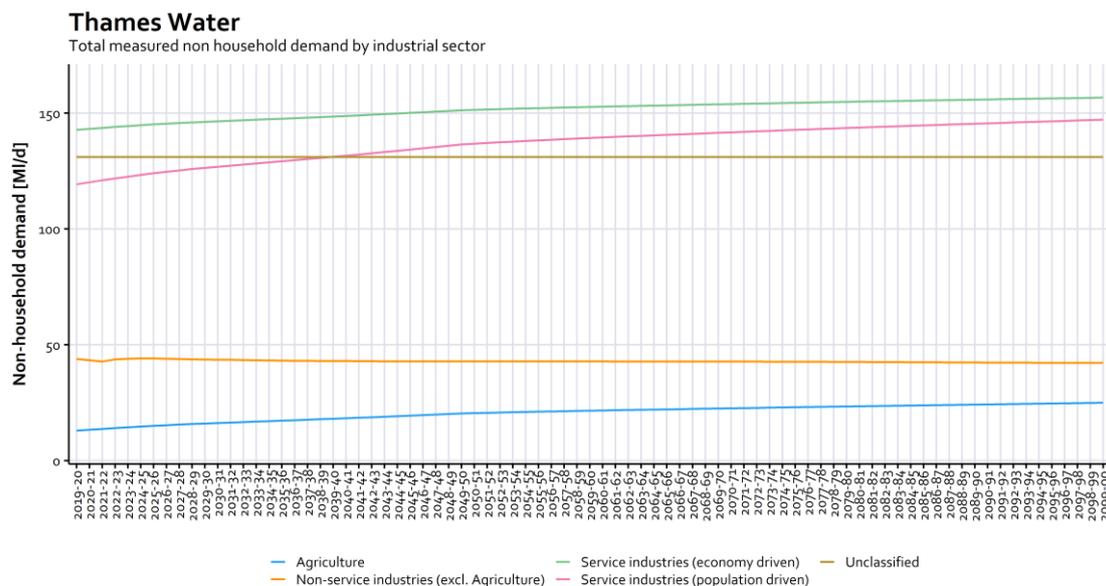
Figure 30 Thames Water region non-household consumption central, lower and upper scenarios



There is growth in the Thames Water region from the service sectors, with a small increase in agriculture, the non-service sector remains flat across the planning period.

About 27% of the demand in the Thames Water region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period. These are properties that could not be allocated into an industry sector because either the property has no industry code assigned to it or the industry code is incorrectly recorded and cannot be matched to a sector. We did attempt to model this unclassified sector, but because of the inconsistency in the data it was not possible to derive meaningful relationships or models, therefore we held the forecast for the unclassified sector flat across the planning period.

Figure 31 Thames Water non-household consumption by industry sector



### 3.2 Potential non-public water supply demand

Projections for non-PWS non-household demand are provided in the following file "01\_Artesia-WRSE\_NonHousehold-Demand-Forecasts\_non-PWS\_Phase1-final-results\_20201008.xlsx".

These files includes the following breakdown of scenario non-household demand forecasts from 2019-2020 through to 2099-2100:

- 1 Existing abstraction, Best estimate, Recent actual consumptive volume with growth to 2050, By WRZ and sector
- 2 Existing abstraction, 75th percentile, Recent actual consumptive volume with growth to 2050, By WRZ and sector
- 3 New licence, New licenced volume with growth to 2050, By WRZ and sector
- 4 Existing abstraction, Best estimate, Recent actual consumptive volume with growth to 2050, Summed to WRZ
- 5 Existing abstraction 75th percentile Recent actual consumptive volume with growth to 2050 Summed to WRZ
- 6 New licence, New licenced volume with growth to 2050, Summed to WRZ

- 7 Total non\_PWS, Best estimate, Recent actual consumptive volume plus new abstractions with growth to 2050, At WRZ
- 8 Total non\_PWS, 75th percentile, Recent actual consumptive volume plus new abstractions with growth to 2050, At WRZ
- 9 Total non\_PWS, Best estimate, Recent actual consumptive volume plus new abstractions with growth to 2050, At company
- 10 Total non\_PWS, 75th percentile, Recent actual consumptive volume plus new abstractions with growth to 2050, At company
- 11 Total non\_PWS, Best estimate, Recent actual consumptive volume plus new abstractions with growth to 2050, At region
- 12 Total non\_PWS, 75th percentile, Recent actual consumptive volume plus new abstractions with growth to 2050, At region

The base year abstraction by sector is shown in Figure 32, with the best estimate of growth to 2050 shown in Figure 33. The estimated new abstractions by sector are shown for the base year in Figure 34, with the projected growth to 2050 shown in Figure 35.

These have been aggregated to regional level in Figure 36. The figures are then segregated to water company level and are shown in Figure 37, split out by water company with the best estimate, 75<sup>th</sup> percentile estimate and new abstractions for the base year (2019-20) and for 2049-50.

Figure 32 Base year existing abstractions by sector for the WRSE region

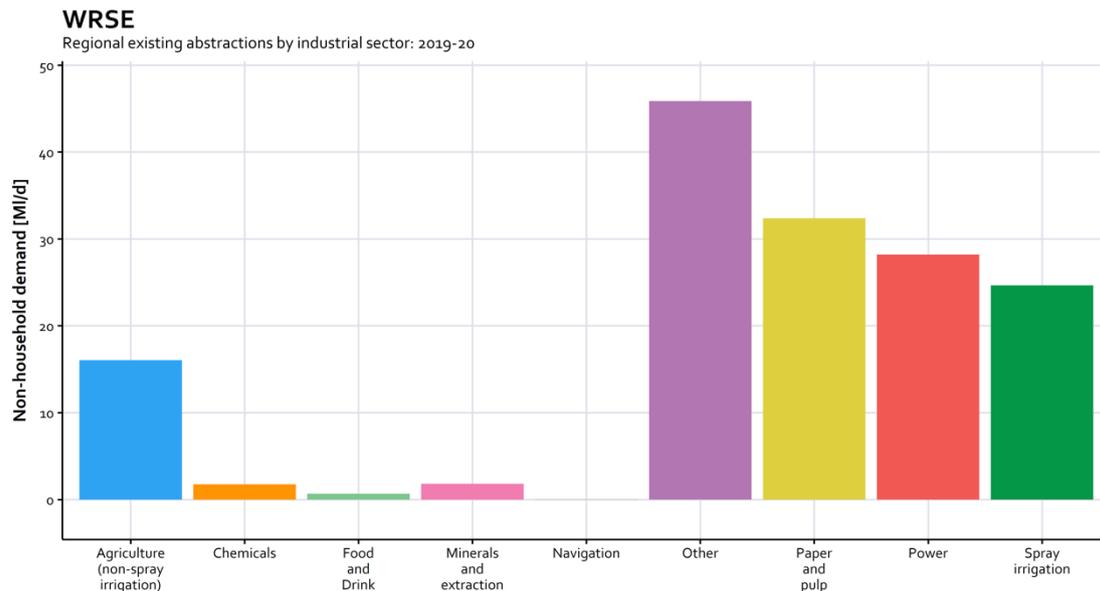


Figure 33 Best estimate of existing abstractions growth to 2050 by sector for WRSE region

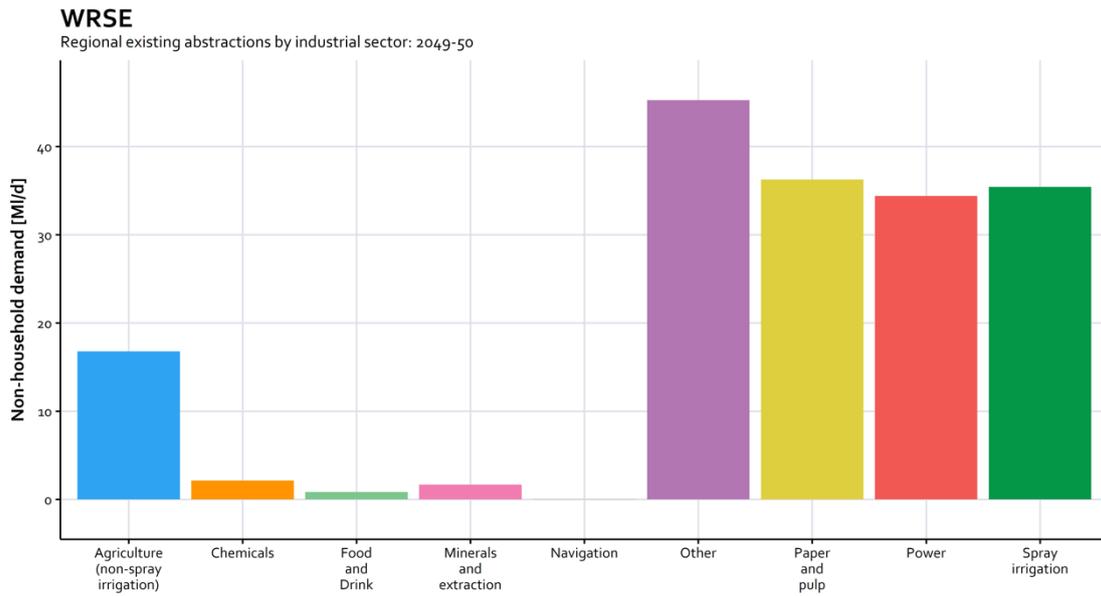


Figure 34 Base year new abstractions by sector for WRSE region

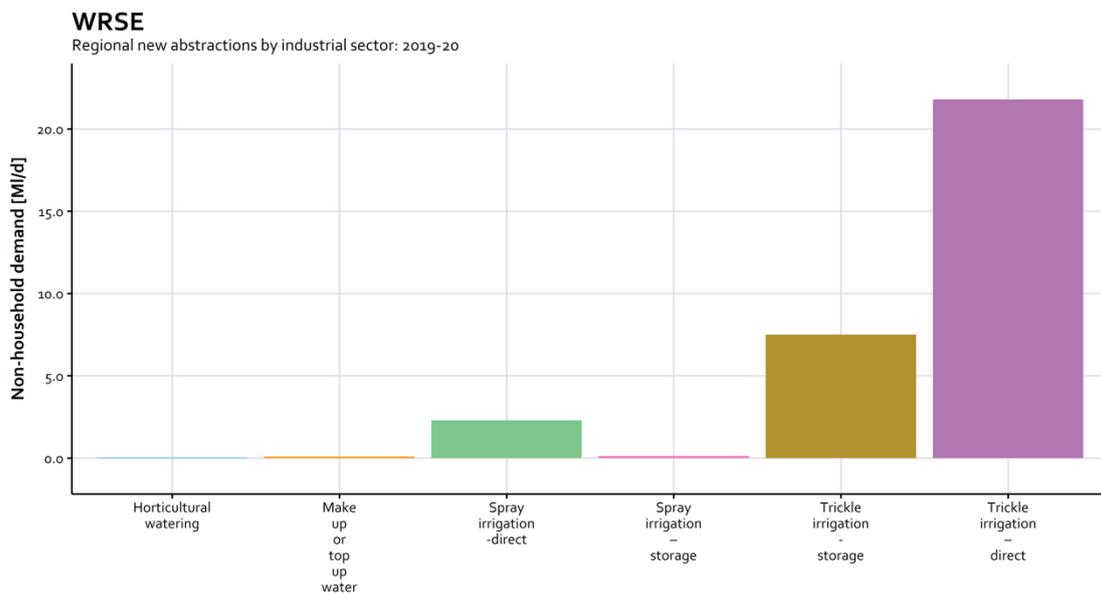


Figure 35 Best estimate of new abstractions growth to 2050 by sector for WRSE region

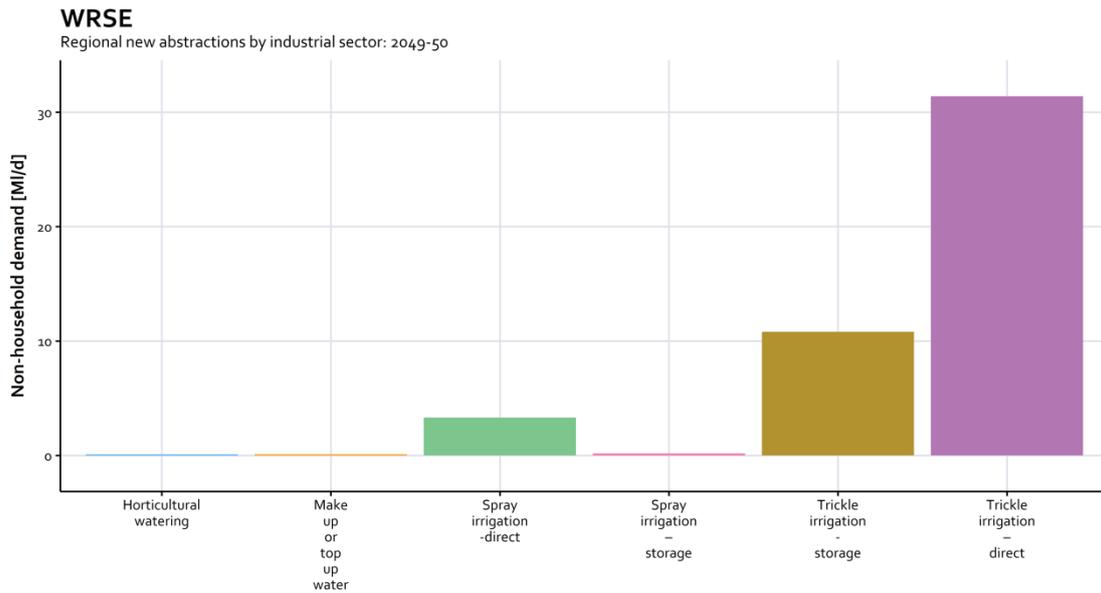


Figure 36 Non PWS in base year and 2050 at WRSE region split out by best and 75<sup>th</sup> percentile estimate and new abstractions

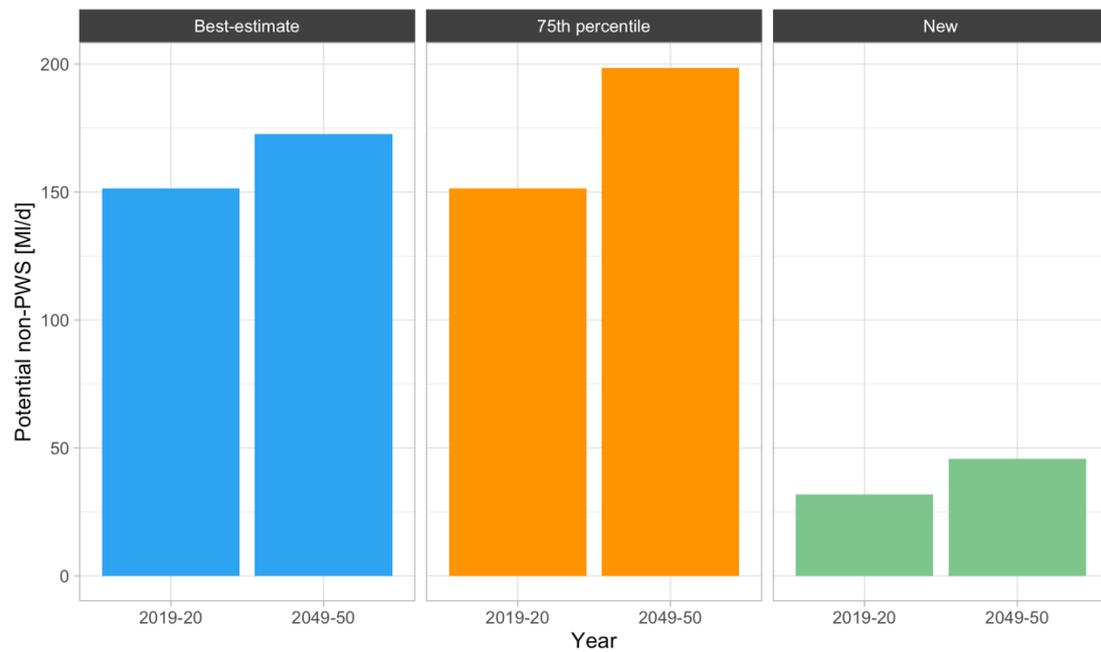
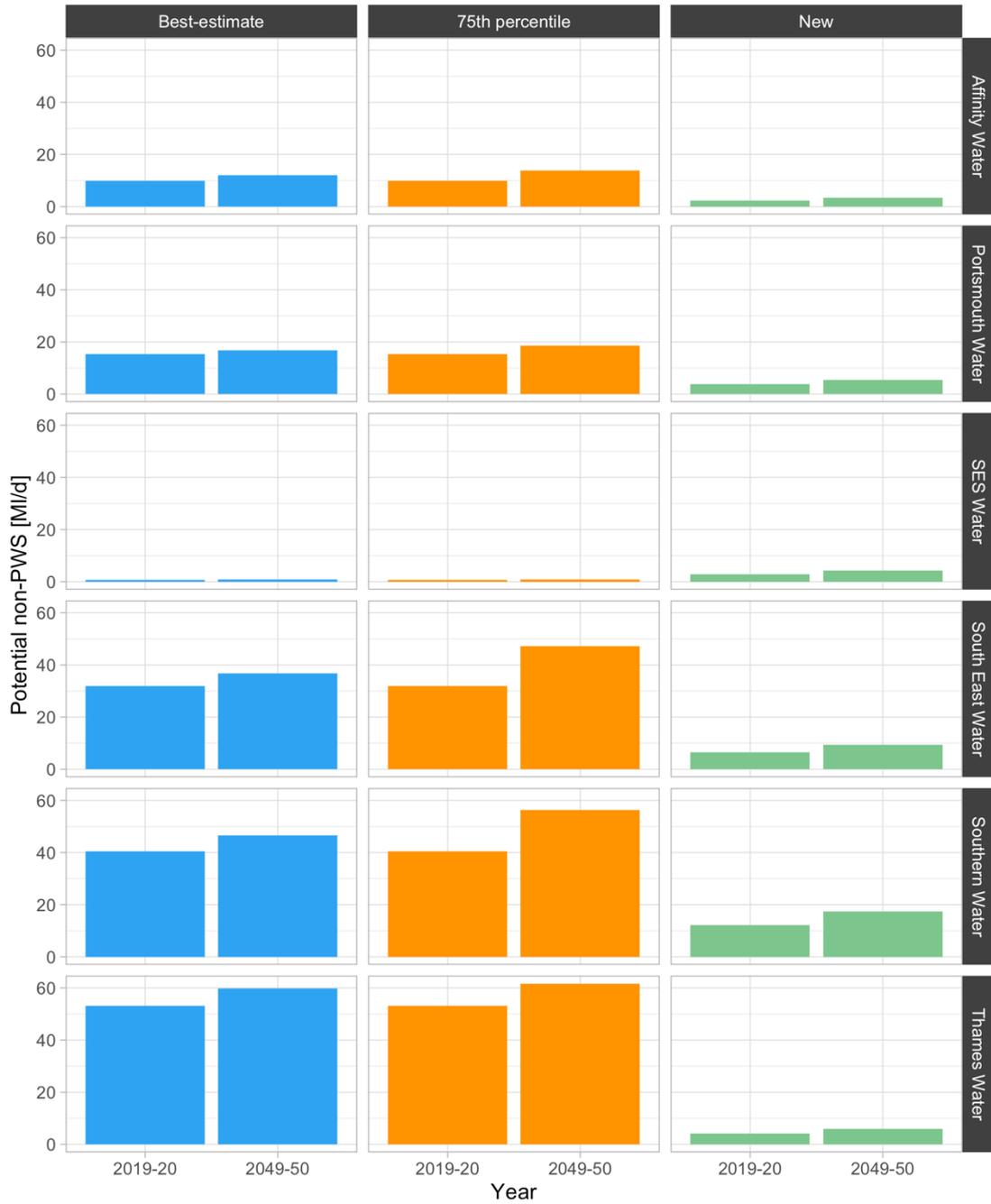


Figure 37 Non PWS in base year and 2050 by company split out by best and 75<sup>th</sup> percentile estimate and new abstractions



## 4 Discussion of findings

This section discusses the overall results and findings that are consistent across WRSE, any company specific findings are discussed in Appendix A. The discussion is broken down into the following sections:

- The modelling approach used for this study.
- Uncertainty in the predictions.
- Data issues.
- Potential alternative industry segments.
- Weather impacts.
- Other potential improvements.

### 4.1 Modelling approach

As explained in sections 1.4.1 and 1.4.2, this project followed well prescribed approach, based on an initial review of best practice and previous WRMP company models carried out by WRSE. This has ensured that a consistent approach has been applied to modelling non-household consumption across all 37 WRZs in the WRSE region. As part of this approach, the industry sector grouping, along with expected drivers for each group, were prescribed in Table 3 of the WRSE review<sup>5</sup> described in section 1.4.1. The groups and drivers are set out in Table 9. This grouping seems sensible based on the review of previous non-household models, and therefore was used for this study.

**Table 9 Industry sector groupings and drivers from the initial WRSE review**

Sector_Name	Sector_Description
<b>Agriculture</b>	Agriculture clearly has a stronger relationship to weather than other sectors, and therefore if it is significant it warrants separate treatment, particularly in the context of climate change scenarios. There may be other weather-dependent industries that behave similarly.
<b>Non-service industries (excl. Agriculture)</b>	These are again more likely to show trends related to the economy, but are likely to contain different trends in patterns of water use and efficiency.
<b>Service industries (economy driven)</b>	Other areas of the service sector, such as retail and entertainment, are more likely to show trends related to the size of the economy or employment.
<b>Service industries (population driven)</b>	Certain areas of the service sector, such as education and health, are more likely to be driven by population size rather than measures of economic output, and therefore it is worth including these as a separate grouping.

<b>Unclassified</b>	Some non-households may not readily be assigned to any of the other categories. It is also unlikely to be able to assign industry sectors to every property, and a significant volume of consumption will not be assigned to one of the previous sectors. Care needs to be taken that strong trends in this sector are not simply reflecting changes in data quality over time.
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In the process of developing the non-household consumption models we started with the different drivers for each sector group. However, some models were weak, and therefore we allowed the data for each sector's model to guide us in the selection of the explanatory variables, i.e. all explanatory variables were applied to each sector model and the models refined through a process of variable reduction until the strongest models remained. The resulting significant variables for each company model across WRSE are shown in Table 10.

**Table 10 Significant explanatory variables in each sector model**

Company	Sector model	Population	GVA	Employment	MOSL flag	Other
Affinity	Agriculture	X	X	X	X	
	Non-service	X	X	X	X	
	Service-economy	X			X	
	Service-population	X			X	
Portsmouth	Agriculture	X	X	X	X	
	Non-service		X		X	
	Service-economy	X	X	X	X	X
	Service-population	X		X	X	X
SES Water	Agriculture	X				X
	Non-service	X		X		X
	Service-economy	X				X
	Service-population	X				X
South East	Agriculture	X	X		X	X
	Non-service	X	X		X	X

Company	Sector model	Population	GVA	Employment	MOSL flag	Other
	Service-economy	X			X	
	Service-population	X			X	
Southern	Agriculture	X		X	X	X
	Non-service	X			X	X
	Service-economy	X	X		X	
	Service-population	X		X	X	X
Thames	Agriculture	X			X	X
	Non-service	X		X		X
	Service-economy	X			X	X
	Service-population	X			X	X

What we see is quite a mix of explanatory factors, with population having a strong influence in nearly all models. Economy (GVA) is a factor in some of the non-service and service-economy models. Employment is a factor in some of the models across all four sector groupings. The MOSL flag (discussed in sections 2.4.2 and 4.3.1) is significant in nearly all models. Some models contain an additional factor which would typically be added following an analysis of residuals were relationships in the residuals are observed, for example population density. Note, that for the unclassified sector there was too much variation in the data to establish any robust models, therefore these were held flat across the planning period.

Overall, the picture is a lot more varied than the anticipated factors from the initial review (Table 9). For some of the segments the resulting models using the explanatory factors described above were very weak, so we expanded the modelling to allow all the explanatory factors to be used for each segment to develop stronger models. Where some of the models remained weak, we looked for other explanatory factors such as population density. We also did some additional exploratory work on why the segments as defined, didn't always result in strong models. This identified that within some of the segments we were seeing different SIC divisions showing a positive relationship with the explanatory variables whilst others showed a negative relationship which were cancelling each other out.

There are some opportunities to improve the industry groupings and explore some initial analysis on this in section 4.4 below.

However, all the models developed and used in this report are robust, but some will have wider uncertainty bands. In addition, the consistency of the approach across the WRZs within

WRSE brings additional benefits in comparing the results between zones and applying them in a consistent way to the planning solution.

## 4.2 Uncertainty in predictions

We have estimated unknowns that may affect water consumption forecasts through applying uncertainties and scenarios around the baseline forecasts. We have estimated uncertainties due to the data uncertainty and unexplained variability, and applied these across the forecasts such that they grow in a gradual way over time. For unknowns in future projections we have used scenarios to estimate the future variability. We created scenarios that include future variations in population, Brexit impacts, COVID-19 impacts, MOSL data quality, climate change and water efficiency. These are all explained in section 2.4.

The result is some significant uncertainty around the future projections of non-household consumption. For example, at WRSE level, the results show an uncertainty (including the scenarios) in the starting point of the forecast of approximately +22% and -35%, with these increasing to approximately +58% and -39% by 2100.

The forecasts start from a base year of 2019-20 and some of the early uncertainty will be due to Covid-19 impacts. Within the baseline models Covid-19 causes a decline in the GVA forecast from Oxford Economics in 2020/21, then a return to normal, however we have shown in section 2.4.2 that the effect on Covid-19 on demand is likely to be larger than this and so a larger adjustment for Covid-19 is made in the scenario forecasts.

The scenarios are produced independently to the baseline forecast. The baseline just takes into account the future trend in the explanatory factors. The scenarios allow us to that include future variations in population, Brexit impacts, COVID-19 impacts, MOSL data quality, climate change and water efficiency (these are all explained in detail in section 2.4).

The central scenario is not intended to be the same as the baseline, but should be similar, generally the baseline is slightly below central, and above the lower scenario. The baseline forecast is the outcome of the timeseries linear modelling as described in best practice and section 2, it is a prediction based just on the relationship between economic variables and the historic consumption. The central, and the upper and lower scenarios have additional data and assumptions behind them. Central is the 50th percentile of all of the 729 different combinations of assumptions around Covid-19, Brexit, water efficiency, climate change, population change and impact of MOSL data. The upper scenario is the 90th percentile and the lower is the 10th percentile. Uncertainties have been provided around each of the scenarios which have been based on modelling and data errors that are propagated through the forecasts and scenarios.

Therefore, companies may consider selecting a forecast which differs slightly from the baseline, but within the scenario ranges, depending on their own local knowledge and approach to risk.

## 4.3 Data issues

As anticipated in the review stage (section 1.4.1) we found a range of data issues whilst carrying out the work. These are discussed below.

### 4.3.1 MOSL data

The quality of the MOSL data had a direct impact on the quality of the forecasts. We found some significant step changes in consumption in the years since 2017, in the aggregate consumption data and in annual reported data. Most of these step changes are downward, although for some WRZs they are in the other direction.

Figure 38 to Figure 40 show examples of big swings in reported non-household consumption following 2016 for 3 WRZs from 3 different companies. In all cases the step changes in a single year are greater than observed in the historic company reported data. MOSL reported data is in pink. In the first example the change is about 28% in one year, in the second two the change is about 11%. As the forecasts are rebased to the annual reported consumption in the based year (2019-20), the accuracy of this data is important.

Figure 38 Example (Thames-SWOX) step change in reported non-household consumption post 2016

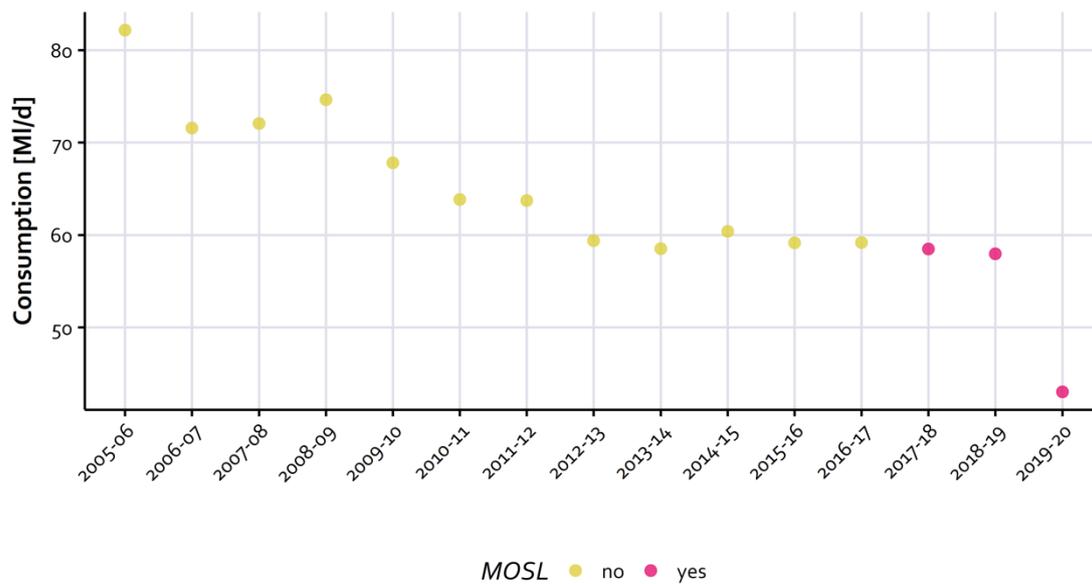


Figure 39 Example (SES Water) step change in reported non-household consumption post 2016

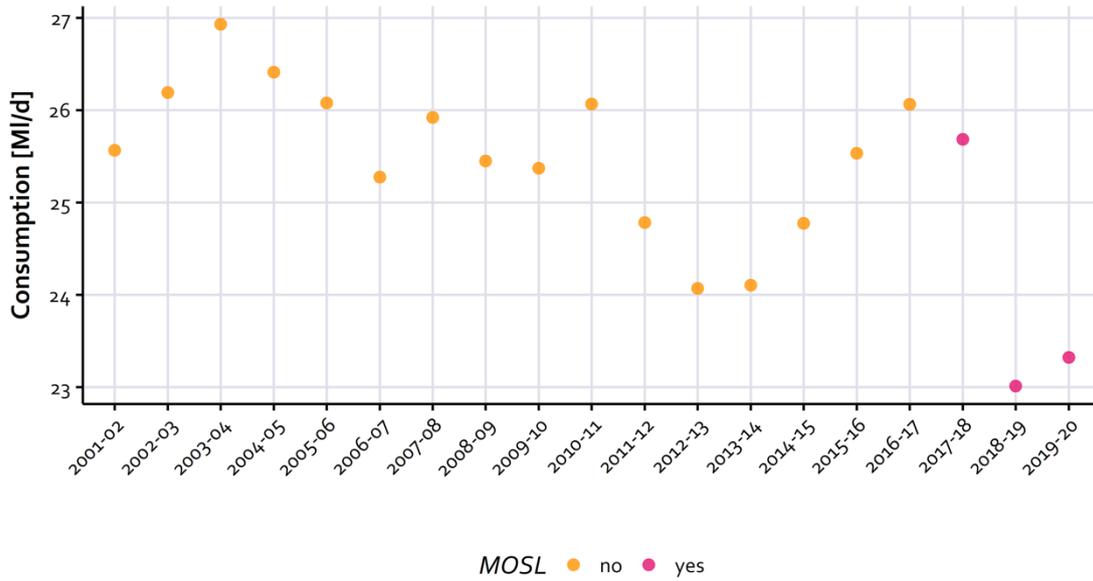
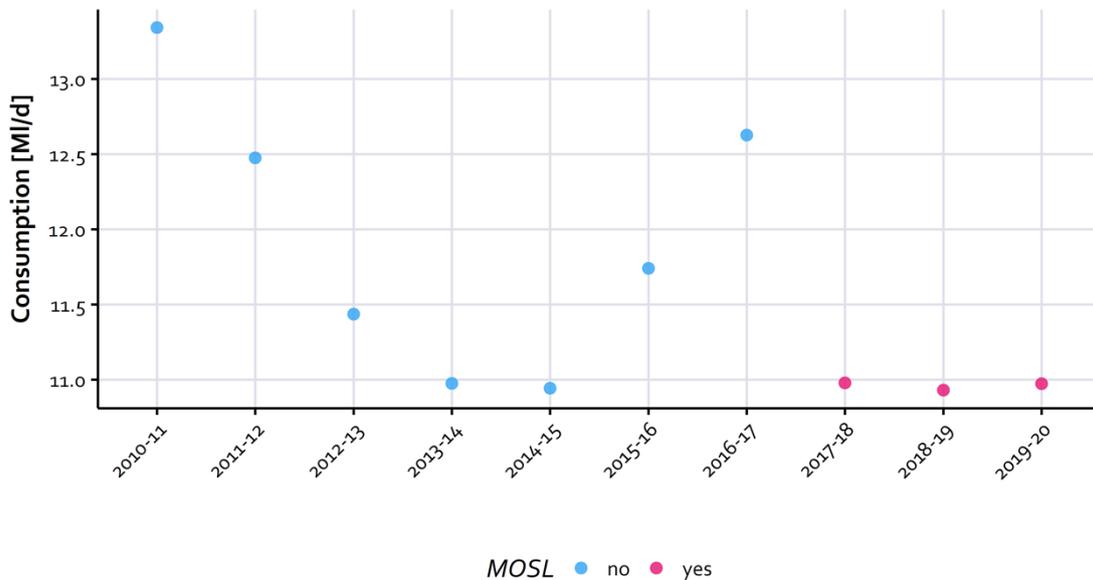


Figure 40 Example (SEW-Maidstone) step change in reported non-household consumption post 2016



We have dealt with the uncertainty about the data since 2017 in two ways. Firstly, we added a flag to the model to indicate the MOSL data, which allows the models to take into account any step changes resulting from the transition of retail separation.

Secondly, it would be useful to understand better whether the changes in the annual return aggregated property level data from MOSL are a long-term change or a short-term result of data issues during retail separation. MOSL’s report for 2019-20 identifies that there are specific problems with long term un-read meters and high numbers of vacant properties (some with high consumption values)<sup>15</sup>. Therefore, we have included three future scenarios,

one where the data improves, one where it deteriorates and one where it stays as it is currently.

For future forecasts, we need to consider further whether can we make better adjustments for the effects from retail separation, and consider if this is the new normal (e.g. due to the redefinition of NHHs to HHs) or is it due to erroneous data, that will eventually be resolved. It might be useful to flag to MOSL, Ofwat and the Environment Agency the significance of these data errors.

### **4.3.2 Matching pre and post MOSL data**

Another factor that impacts the modelling in data post MOSL is the standard industry classification data. Data is often presented as a mix of SIC\_1980, SIC\_1992, SIC\_2003 and SIC\_2007 and often the SIC codes presented cannot be matched accurately to the correct SIC classification. Improvements in this area of data quality would help modelling.

Some companies have better matching of properties and industry classifications pre and post MOSL. This definitely helps build better models as there is a more consistent set of time series data for modelling.

### **4.3.3 Property level consumption data**

Not all companies were able to provide property level consumption data (sometimes it was provided already aggregated to industry code level).

Having property level consumption data improves the identification of large users and voids, it improves consistency of data and allows for better quality checks on the data; all of which will improve the model results. It would be better to have a consistent smaller set of properties that are representative of an area, than try and reduce the overall size of the unclassified group.

For example, the Affinity Water data set had lower coverage than some, but the data was very consistent and tidy over time and provides a good coverage of industry types. This means that the variation that we observe is genuine and can be modelled better.

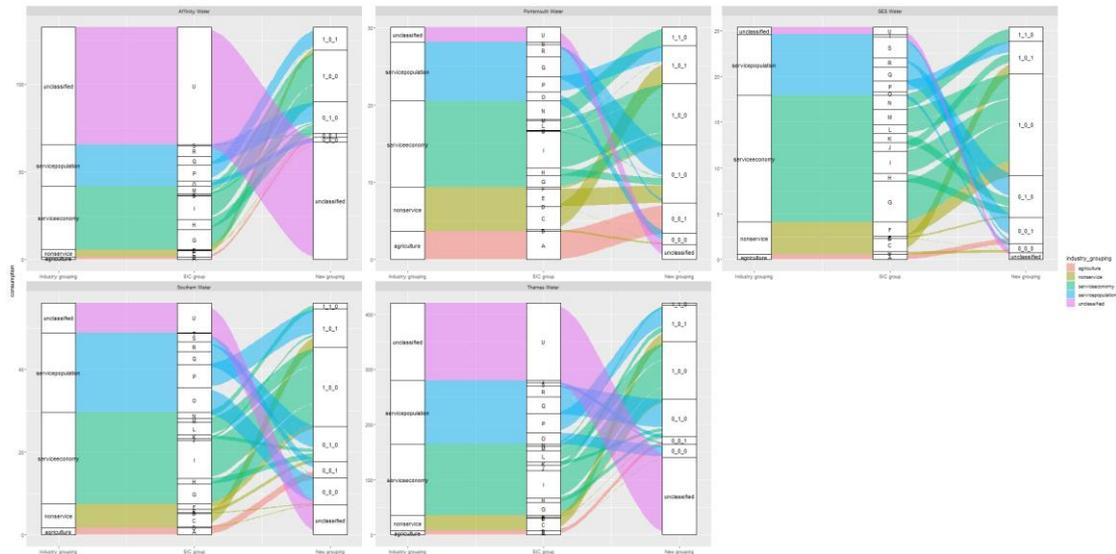
## **4.4 Industrial sector segments**

Through analysing all the non-household data in the WRSE region we found that the industry grouping recommended in the earlier review (section 1.4.1), whilst logical, is probably too coarse and is masking some of the genuine relationships. This is based on what the data is telling us.

When we examined the 19 SIC divisions and how they mapped onto the 5 industry groupings we find that in some groupings there are competing trends, i.e. some are increasing and some decreasing. This is also true for some of the explanatory factor data (GVA and employment) which was also provided at the 19 SIC division level.

We did some analysis starting with the 19 SIC divisions and looked at grouping these together so that explanatory factors have coefficients that are in the intended direction and are significant in the modelling. Preliminary results of this are shown in Figure 41.

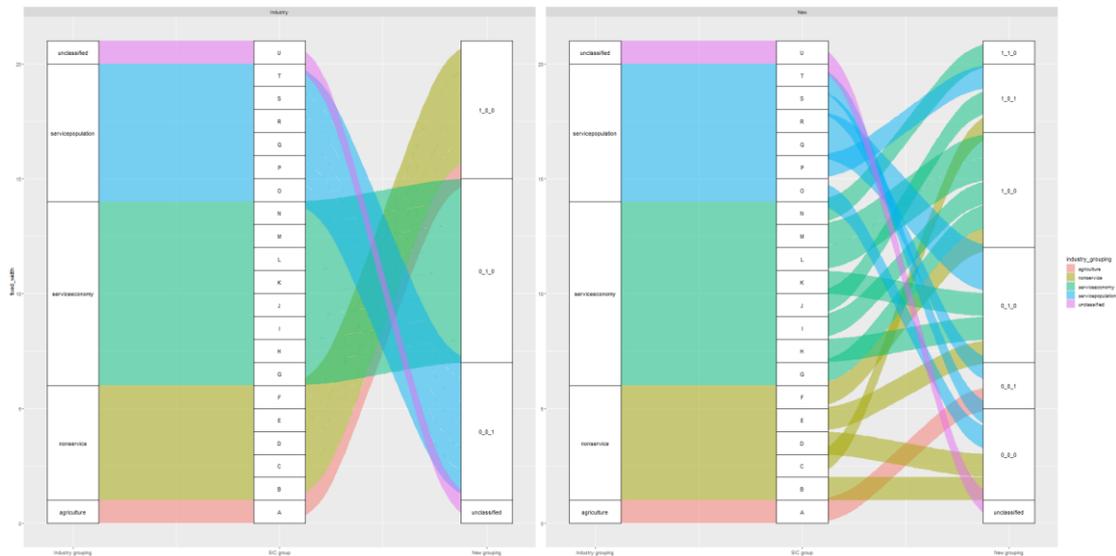
Figure 41 Exploring alternative industry groupings for each company



In Figure 41 we show the impact of grouping the SIC divisions so that the explanatory factor coefficients are in the correct direction and significant (new groupings on the right hand side of each figure), and then show this against the original industry grouping on the left side of the figure.

The groupings vary across the companies, but there is some consistency, and a version of this process for the whole region is shown in Figure 42, with the existing grouping on the left and the alternate grouping on the right.

Figure 42 Exploring alternative industry groupings for the region



This may be worth exploring further by taking the best and most consistent quality data from across the region to provide a single data set.

We also found that there were other significant explanatory factors, in addition to the econometric GVA and employment factors. We introduced a population density factor in the

Southern Water model (which had a positive impact), and it is likely that there are other factors that would improve models further.

#### 4.5 Weather

The outputs from this modelling are raw un-normalised forecasts of non-household demand, calibrated to the reported values for AR 2019/20. This is in line with the scope of the project. The Water Resource Planning guidance does not specifically require companies to apply weather factors to non-household demand. The preliminary review of non-household forecasting carried out by WRSE states that "Companies should include weather variables for those industries and/or areas where this can be shown to be a significant factor in modelling non-household consumption".

Companies wishing to derive and apply NY (normal year) or DY (dry year) factors to the non-household demand forecasts derived in this project should consider the relative size of the weather driven non-household demand (i.e. from the agricultural sector) in their region and individual WRZs, compared to other non-household and total demand. They should also take into account the quality of the data for deriving these factors.

#### 4.6 Other improvements

There is clearly an impact on the forecasts from the quality of the data. There should be further work to help water companies improve the quality the data they use for forecasts. It might be more cost effective to do this as a regional group, rather than individually.

The current best practice (developed in 1997) suggests the econometric approach and this has been applied quite consistently by individual companies over the past few WRMPs. However, looking at the data from the WRSE companies across the region shows that some of these relationships are quite weak and there might be alternative forecasting techniques that might be better given the quality constraints on some of the data. WRSE (or all the regions) should consider whether it is worth carrying out some wider industry research to evaluate alternate methods for modelling and forecasting.

Another option worth considering is a greater level of aggregation within the WRSE region. In this study we have modelled each company consistently, but independently. We have seen that there are limitations in the data, and it might be possible to look at all the WRZs across the region and group together WRZs based on how their non-household consumption behaves (as opposed to a company geographical boundary). This may allow more data to be pooled, and when combined with a more sophisticated approach to grouping industrial sectors (section 4.4), this may result in stronger models being developed.

## 5 Conclusions

We have produced a set of non-household demand forecasts for all 37 water resource zones in the WRSE region from 2019-2020 out to 2099-2100. These are presented for metered and unmetered properties at company level, water resource zone level and dis-aggregated by industrial sector.

The approach used follows existing industry best practice, taking into account the recommendations from a review of non-household demand forecasting methods carried out by WRSE in early 2020. Robust multiple linear models have been produced for 4 cohorts of industrial sectors for each company in WRSE, using explanatory factors that include population, gross value-added metrics, employment rates, population density and other factors.

Since the last set of non-household forecasts were completed for WRMP19, the non-household retail sector has undergone a transformation with the introduction of retail competition. A significant impact from this is that metered non-household consumption data is now the responsibility new retailers, managed by the new Market Operator Services Ltd (MOSL). We have observed a change in data quality and consistency since the change in 2017. This has complicated the modelling (which relies on a consistent set of time series data) and has increased the uncertainty around the demand forecasts. This has been taken into account in the models, uncertainty and scenario estimates.

The first year of the forecast (2020) has seen an unprecedented change in non-household demand due to the policies introduced to combat the COVID-19 pandemic. This increases uncertainty going forward as we still do not fully understand what the enduring impacts will be from changes in working practices, such as increased working from home. Therefore, we have included the COVID-19 impact in the scenarios and uncertainty estimates.

The sector also faces a number of future unknowns in demand from non-households, such as population change, Brexit, climate change and how water efficiency will be delivered in the non-household sector. Therefore, these have also been included in the scenario and uncertainty modelling.

The overall conclusion is that non-household demand in the WRSE region at the start of the planning period (2025), is predicted to be 921 MI/d within an overall range of 594 to 1121 MI/d. This is predicted to increase by the end of the planning period (2100) to 1032 MI/d (an increase of 111 MI/d) within a range of 630 MI/d to 1637 MI/d.

We have also made a prediction of the amount of non-public water supply (non-PWS) demand in the WRSE region and how this might change over the planning period. The non-PWS demand includes all existing abstractions used for non-household demand plus any new authorisations since February 2019. This is broken down by sector and water resource zone. Overall for the WRSE region, the current estimate of non-PWS non-household demand of 183 MI/d in 2019-20 is predicted to increase to 218 MI/d by 2050. Due to the uncertainty in the data we have held the forecast flat for the remainder of the planning period.

We have identified a number of improvements that could be implemented for future forecasts, and these are included in the recommendations.

## 6 Recommendations

Companies in WRSE should use the baseline and scenario forecasts presented in this report to select an initial WRMP baseline forecast for the metered and unmetered non-household demand forecast lines in the Environment Agency's water resource planning tables.

We have presented the forecasts from a base year of 2019-20. The intermediate years 2020-21 through to 2024-25 are presented for information prior to the start of the planning period in 2025-26. These intermediate years are potentially volatile with a number of unknowns around the impact of the COVID-19 pandemic and the impact from Brexit on non-household consumption. Therefore we recommend that the baseline and scenario forecasts are updated prior to the submission of the final water resource management plans.

For the first time we have presented an initial view of non-PWS forecasts. We suggest these should be used as an upper limit for the amount of non-PWS demand that could switch to PWS under drought conditions.

During the course of the work to develop the non-household demand forecasts we have identified a number of potential improvements to achieve more accurate forecasts. These are set out below.

WRSE should inform MOSL of the importance of getting consistent good quality data on non-household consumption for forecasts. MOSL's report for 2019-20 identifies that there are specific problems with long term un-read meters and high numbers of vacant properties. These have caused some volatility in the consumption data since the introduction of market reform, which have impact on the robustness of future forecasts.

The ability to allocate non-households to specific industry sectors through tools such as SIC or AddressBase Premium also aids the robustness of forecasts. Across the WRSE there is quite a bit of variability in the proportion of properties that need to be placed in the "unclassified" sector due to the quality, quantity or availability of non-household sector classifications. Companies in WRSE should investigate the most efficient way of improving this information for future forecasts. Note, it is important that there is good quality and consistency of data over time for a good coverage of industry types, which in turn means that the variation that we observe is genuine and can be modelled better.

WRSE should consider investigating different industrial sector groupings than those selected for use in this study. We have done some preliminary analysis that shows there are potentially better sector groupings that could improve the quality of the model outputs.

The consistency of approach and method across the WRZ's in WRSE is beneficial. As well as looking at improved sector groupings, we recommend investigating the grouping of WRZs based on how their non-household consumption behaves (as opposed to a company geographical boundary). This may help to overcome some of the data limitations.

The forecast modelling in this study has been carried out using a functional programming approach that allows forecasts to be run and evaluated more efficiently. This approach allows forecasts to be produced more frequently, potentially sub-annually, as data is updated. A more continuous forecasting approach would remove the step-like transitions between AMP forecasts and could improve the robustness of the forecasts. The functional approach would also allow for different sectors grouping or WRZ grouping to be applied quickly and efficiently.

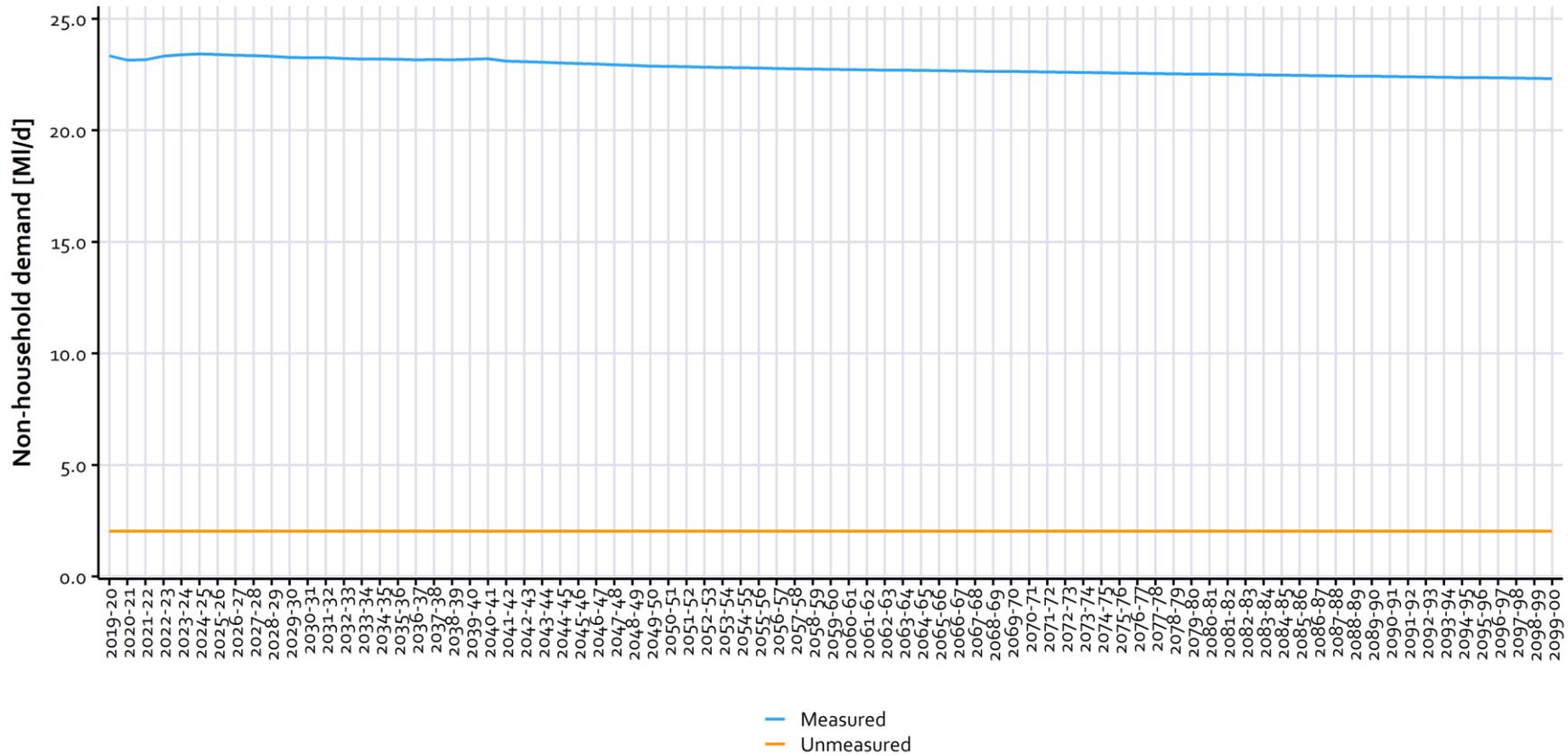
## Appendix A: SES Water modelling results

Note this appendix is presented in landscape format to improve the presentation of the graphs. Firstly we present the WRZ graphs for metered and unmetered NHH consumption, along with the scenario graphs. Then we present the sector graphs for each WRZ. Then we present the MLR (multi linear regression model metrics for each section to identify the drivers for the forecast in each zone. Then we present the calibration factors for each WRZ and sector. A full set of graphs and tabulated sets of yearly forecasts for PWS and non-PWS demand are hosted on the WRSE SharePoint site.

## Overview of WRZ results

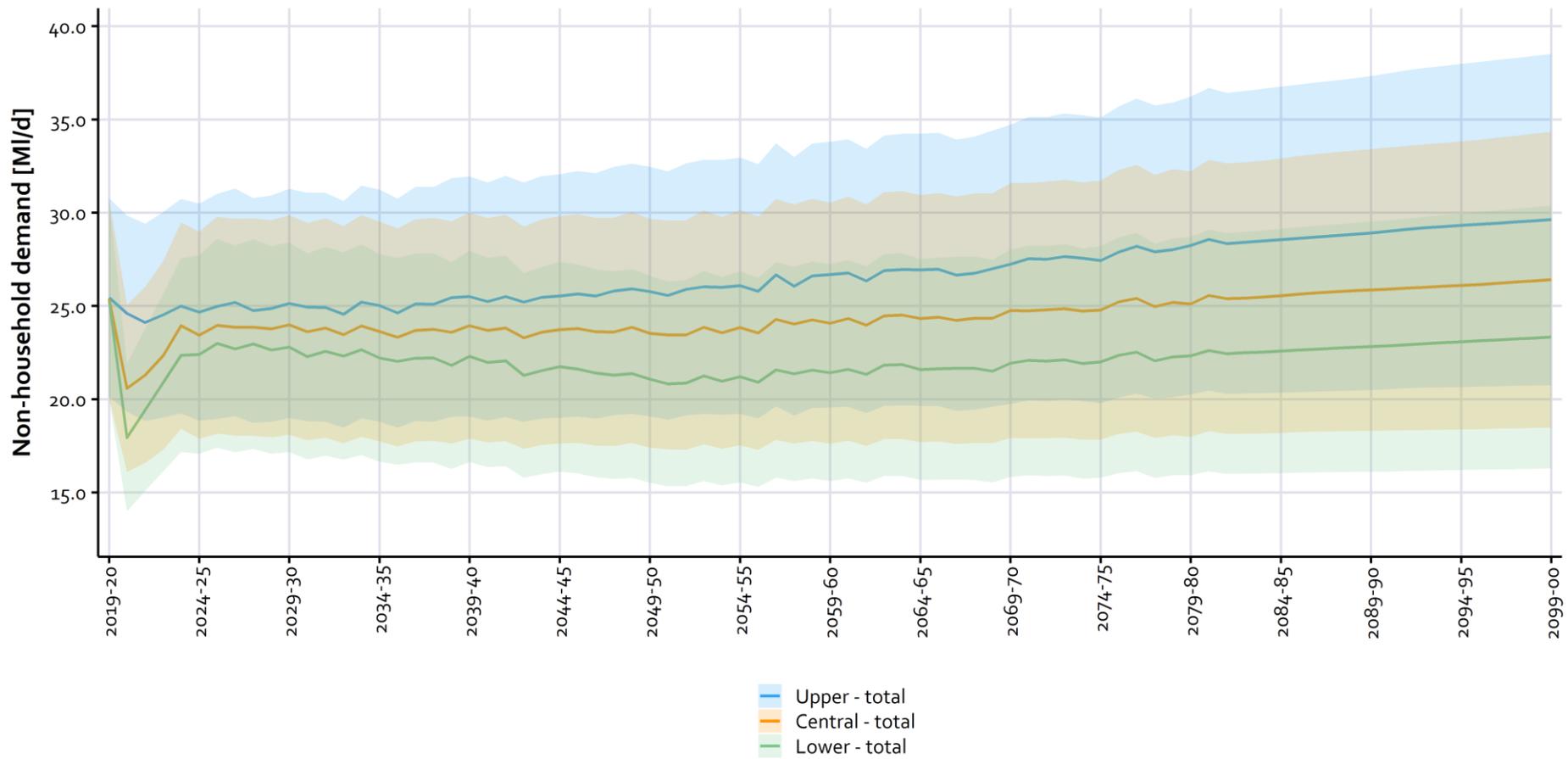
### SES Water

SES Water: Measured and unmeasured non household demand



### SES Water - central

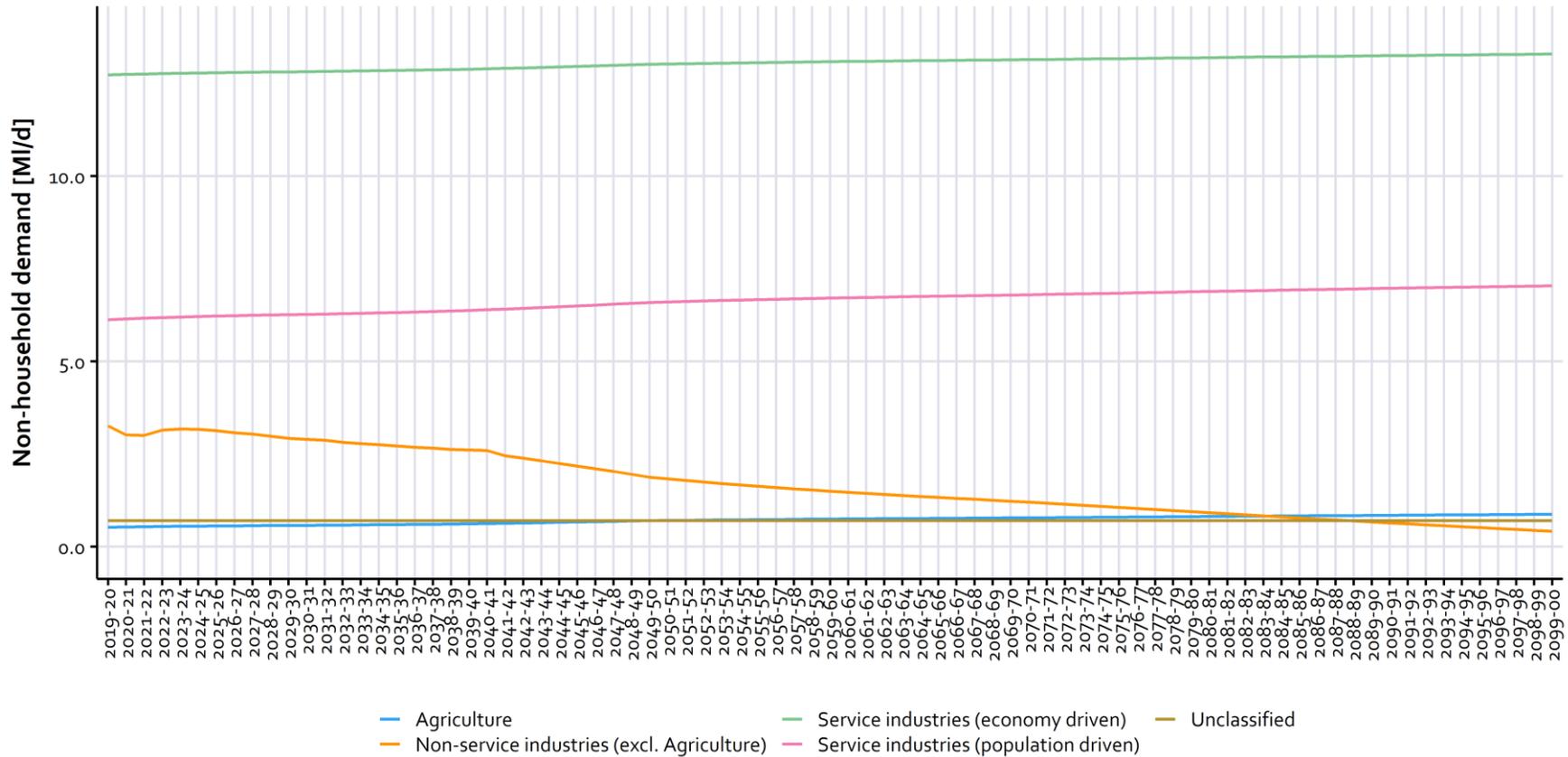
SES Water: Total non household demand



## WRZ industry sector results

### SES Water

SES Water: Measured non household demand by industrial sector



## MLR modelling

Note:

- Years 2018-19 and 2019-20 in AR are significantly lower than previous years. This impacted the forecasts.
- The Unclassified sector has been forecasted as constant, keeping the base year value steady.
- There is slight growth in the SES region from the service sectors, with the non-service sector reducing across the planning period. About 3% of the demand in the SES region falls into the unclassified group

The result in the case of SES Water NHH consumption MLR model is reported in the following tables.

### MLR model summary for the industry group "agriculture"

term	estimate	std.error	p.value
(Intercept)	-0.039	0.11	0.7199
population	0.0000017	0.00000018	0
london	-10.717	1.24	0

### MLR model summary for the industry group "nonservice"

term	estimate	std.error	p.value
(Intercept)	-9.61	7.8	0.2221
employment	0.015	0.012	0.2107
population	0.0000047	0.0000011	0
london	-12.816	8.65	0.1429

MLR model summary for the industry group "serviceeconomy"

term	estimate	std.error	p.value
(Intercept)	2.24	0.82	0.0076
population	0.0000026	0.0000014	0.0621
london	78.902	9.49	0

MLR model summary for the industry group "servicepopulation"

term	estimate	std.error	p.value
(Intercept)	2.72	0.75	0.0005
population	0.0000043	0.0000013	0.0011
london	51.368	8.67	0

## Calibration

The calibration factors for SES Water are reported below.

Calibration factors for the considered WRZs.

wrz	industry_grouping	factor1	factor2
Company	agriculture	-0.580	0.920
Company	nonservice	-1.062	0.920
Company	serviceeconomy	9.709	0.920
Company	servicepopulation	0.860	0.920
Company	unclassified	-5.648	0.920

# Level 2 Appendix C. WRMP19 Household Consumption Forecast: Baseline Forecast

SES Water

**WRMP19 Household consumption forecast:  
Baseline forecast**

**Final**

AR1176

September 2017

**Report title:** WRMP19 Household consumption forecast: Baseline forecast  
**Report number:** AR1176  
**Date:** September 2017  
**Client:** SES Water  
**Author(s):** Sarah Rogerson, Dene Marshallsay, Rob Lawson

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## Executive Summary

The current Water Resources Planning Guideline identifies the need for water companies to use methods for supply and demand analysis that are appropriate to the level of planning concern in their water resources zones (WRZs).

The company-level supply-demand balance in the 2014 Water Resources Management Plan (WRMP14) had a surplus in available water resources until 2033/34. This was based on the transfer of surplus water from the East Surrey water resources zone (WRZ) to Sutton WRZ. In WRMP14 SES Water used a micro-component model to forecast household consumption.

SES Water has determined that problem characterisation for the company (now a single WRZ) should be 'low'.

A baseline household consumption forecast has been produced for the SES Water Resource Zone using micro-component modelling and forecasting, which is suitable for a zone with a low level of water resource planning concern.

The micro-component model has been developed using best available data from local and national datasets. The model is segmented by property type using unmetered, new build metered and optant metered households. The model is based on per household consumption (PHC), and includes linear modelling of key micro-components against occupancy to reflect the variation of PHC by occupancy within each household type. The model forecasts are developed from historic industry and UKWIR micro-component datasets and Market Transformation Programme predictions (these are explained in the report).

The property and population forecasts used in this model are taken from estimates provided by Experian as part of a separate project. We have checked the validity of these property and population forecasts and ensured their compliance with regulatory guidance.

The results of the micro-component forecast give a 36.96 MI/day increase in household consumption for Dry Year Annual Average consumption, this is a 33.8% increase over the planning period to 2079/80. This is largely driven by a 69.6% increase in the property forecast. Average PHC and PCC decrease throughout the forecast period, this is partly due to decreases in component demand due to market transformation, but mostly due to the shift from unmeasured to measured, properties. Average household PCC (mean of all household types) reduces from 160 to 147 l/person/day.

The model contains forecasts for Normal Year Annual Average, Dry Year Annual Average and Critical Period; with a breakdown of micro-components for each year of the forecast.

## Contents

1	Context.....	1
2	Method selection.....	3
2.1	Approach .....	3
2.2	RAG matrix and comments .....	3
3	Review data availability .....	6
3.1	Base year data .....	6
3.2	Other data .....	6
3.3	Measured micro-component data .....	7
3.4	Market transformation data .....	9
4	Property segmentation.....	10
5	Household consumption forecasts.....	14
5.1	Approach to micro-component forecasting.....	14
5.2	Basic inputs required.....	14
5.3	Selection of the basic unit of consumption.....	15
5.4	Micro-component occupancy model .....	15
5.5	Micro-component trend model – baseline scenario.....	23
5.6	Micro-component trend model – alternative scenarios .....	33
5.7	Base Year Calibration .....	34
5.8	Climate change.....	34
5.9	Trends, scenarios and uncertainty .....	35
6	Consumption uplifts for normal, dry year and critical period .....	37
7	Household consumption outputs .....	40
8	Conclusions & Recommendations .....	46

## Tables

Table 1	Justification for RAG Matrix scoring.....	5
Table 2	Micro-component summary data from 2015/16 metered billed households... 9	9
Table 3	Micro-component summary for 2015/16 RV billed households.....	9
Table 4	Micro-component summary for 2002/04 RV billed households.....	9
Table 5	Change of occupier and optant forecasts total by AMP.....	11
Table 6	Micro-component variables that change with meter status .....	20
Table 7	Micro-component occupancy model parameters.....	21
Table 8	Micro-component occupancy model parameters – Base year (adjusted to NYAA) .....	22
Table 9	Micro-component occupancy model parameters – Final year (NYAA).....	23
Table 10	Micro-component rate of change by property type.....	32
Table 11	Summary of factors applied in the household forecast.....	39
Table 12	Redistribution of Artesia Micro-component to EA Micro-component.....	44
Table 13	DYAA household consumption forecast – central property forecast .....	45

## Figures

Figure 1	Best practice guidelines for household demand forecasting.....	2
Figure 2	SES Water RAG Matrix for household consumption forecast method selection.....	4

Figure 3	Siloette logger installed in a boundary box.....	8
Figure 4	Illustration of Siloette logger output.....	8
Figure 5	Illustration of property breakdown within the company, forecast from base year to the point of 100% meter penetration.....	12
Figure 7	Illustration of the change in occupancy as meter penetration tends towards 100% .....	13
Figure 8	Each micro-component daily use plotted against occupancy.....	16
Figure 9	Variation of WC flushing frequency (uses per day) with occupancy.....	17
Figure 10	Variation of shower volume used per day with occupancy .....	18
Figure 11	Variation of bath volume used per day with occupancy.....	19
Figure 12	Variation of tap volume used per day with occupancy.....	19
Figure 13	Variation of washing machine (frequency of use per day) with occupancy ....	20
Figure 14	Histogram of WC flush volumes from 2002/04 and 2015/16 .....	24
Figure 15	Regulatory changes in flush volumes .....	24
Figure 16	Historic, current and future flush volumes .....	25
Figure 17	Trends for WC flush volumes .....	26
Figure 18	Trend of daily volume of water used for showering.....	27
Figure 19	Future trend for daily volume of water used for showering (unique trend for all house types).....	27
Figure 20	Trend of daily volume of water used for bath use.....	28
Figure 21	Predicted trends of daily volume of water used for bath use (unique trend for all house types).....	29
Figure 22	Historic trend in washing machine volume per use.....	30
Figure 23	Future trend of washing machine volume per use .....	30
Figure 24	Historic trend in dish washer volume per use.....	31
Figure 25	Future trends of dish washer volume per use .....	32
Figure 26	Variation in base line (DY) PCC trends.....	34
Figure 27	Company level measured HH consumption Monte Carlo error distribution...	36
Figure 28	Company level unmeasured HH consumption Monte Carlo error distribution	36
Figure 29:	Quadrant plot for determining the dry year .....	37
Figure 30	Reported PCC trend - measured properties (dry year indicated in red, base year indicated in yellow) .....	38
Figure 31	Reported PCC trend - unmeasured properties (base year in yellow) .....	38
Figure 32	Total number of households, split by household segment.....	40
Figure 33	Total household consumption (Ml/d), split by household segment.....	40
Figure 34	Company level PHC, split by household segment .....	41
Figure 35	Company level PCC, split by household segment .....	42
Figure 36	Company level occupancy, split by household segment.....	43

## 1 Context

SES Water used a micro-component forecast to predict household consumption in WRMP14. This predicted a relatively flat profile over the planning period, with an average decline of 0.097% per annum for measured households and an average decline of 0.151% per annum for unmeasured households, excluding climate change impacts. For both measured and unmeasured households there was a long-term reduction in consumption for toilet flushing, clothes washing, dish washing and external use, and a long-term increase in consumption for personal washing, mainly driven by an increase in the ownership and frequency of shower use.

The WRMP14 plan was for two water resources zones (WRZs). The company is now using a single WRZ.

The problem characterisation for the company's single water resource zone has been confirmed as 'low' for WRMP19. An assessment of suitable household consumption forecasting methods was carried out based on a low medium level of concern. This took account of known data availability for the SES WRZ, and indicated that micro-component modelling would be the preferred forecasting approach for this level of concern. A suitable alternative would be regression modelling, however, SES Water does not have sufficient data and information on individual household consumption and property characteristics to enable regression modelling.

Therefore it has been decided to develop an updated micro-component forecast for WRMP19.

Micro-component models have been used for water demand forecasting in England and Wales from the late 1990s. They quantify the water used for specific activities (e.g. showering, bathing, toilet flushing, dishwashing, garden watering, etc.) by combining values for ownership (O), volume per use (V) and frequency of use (F). This study makes use of a national micro-component survey of 62 properties, alongside survey data which was collected at property level for the monitoring period. The study also uses micro-component survey data for about 8500 households collected from the company's on-line water efficiency calculator.

The micro-component model is combined with property, population and occupancy forecasts in a unique way in that the micro-components vary with occupancy. Certain components have a valid relationship with occupancy, and others don't. This method is used to calculate base year OVF PHC (OVF: ownership, volume, frequency, PHC: per household consumption) values, which are then calibrated to the zonal normal year PHC values.

Forecasts of the property, population and occupancy are established by household segment via a model to allow for various assumptions and mathematical calculations as the company tends towards 100% meter penetration. Each household segment has a different base year OVF table / calculation, these are based on both measured differences between measured and unmeasured households, as well as assumptions made about devices within new properties, change of occupier and optant properties.

Micro-components are then forecast using a combination of longitudinal micro-component data and future market transformation programme derived micro-component values. These trends are applied to the normal year micro-component values. An additional occupancy specific trend is also added, to ensure that the varying occupancy within each of the household segments is captured.

Data from national studies was used to update previous micro-component estimates (from surveys, the Market Transformation (MTP) scenarios and other, older sources), and to consider upper and lower consumption forecasts.

Relevant data, existing survey results, and consumption data from metered customer billing records were all analysed and investigated, along with data collected in the 2016 UKWIR behaviour integration study, to estimate base year micro-component estimates.

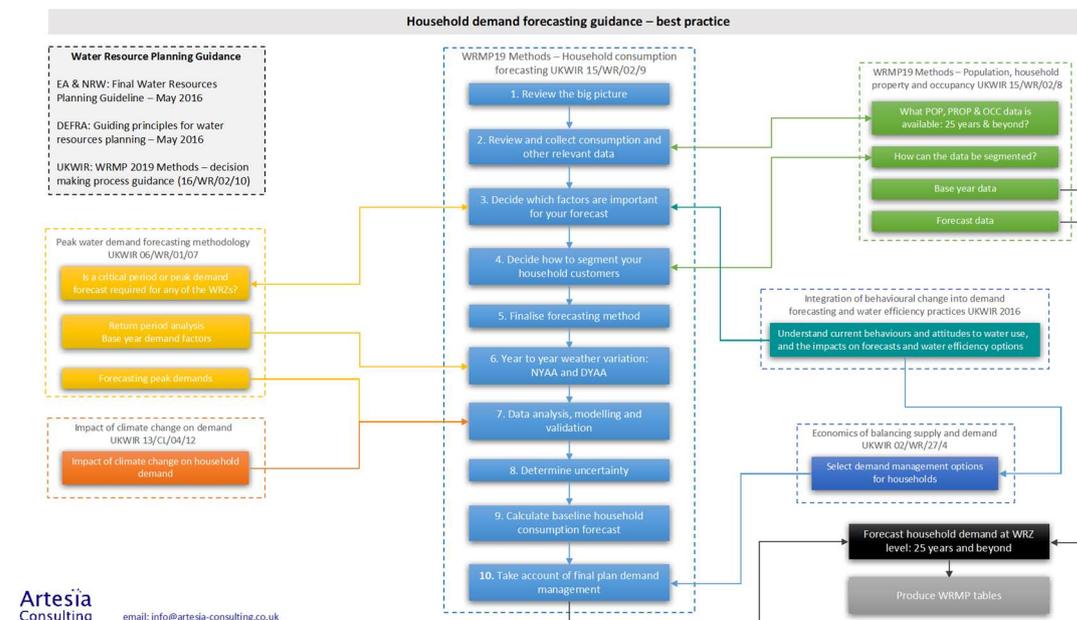
Household customers were segmented based on meter status (measured/unmeasured), with sub-divisions for meter type (existing metered, meter optants, new property, change of occupier). Data was used to determine how to account for differences in consumption between segments and also the effect of meter switching.

Normal year and dry year adjustments were made to the base year consumption and the consumption forecast.

A scenario approach to modelling uncertainty was used, to reflect the various uncertainties in consumption forecasts.

Best practice guidelines (detailed in Figure 1) have been followed in deriving the baseline household demand forecast.

**Figure 1 Best practice guidelines for household demand forecasting**



## 2 Method selection

The current Water Resources Planning Guideline<sup>1</sup> identifies the need for water companies to use methods for supply and demand analysis that are appropriate to the level of planning concern in their water resources zones (WRZs).

A separate detailed problem characterisation exercise was undertaken by the Company, and has confirmed an overall level of concern of 'low'. This will be a factor in the choice of method for forecasting household consumption, as described below.

### 2.1 Approach

Guidance on the selection of appropriate household consumption forecasting methods were developed by UKWIR (UKWIR, 2016), along with guidance on the application of these methods.

The UKWIR guidance identifies nine criteria and a weighting and scoring framework, set out in a 'RAG Matrix'<sup>2</sup>. The guidance recommends that practitioners adapt the weightings and scores in this matrix to reflect their own situation, in order to identify the most appropriate methods for forecasting household consumption. In particular, the matrix should be amended to reflect the level of planning concern in a particular WRZ.

SES Water has used the RAG matrix, with amendments to reflect the status of its single WRZ to shortlist preferred methods for household consumption forecasting. The assessment that has been undertaken is presented in the following sections.

### 2.2 RAG matrix and comments

#### Introduction

Figure 2 illustrates the results of the RAG matrix.

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<sup>1</sup> Water Resources Planning Guideline: Interim Update April 2017

<sup>2</sup> Red Amber Green Matrix, used to highlight which methods score best to worst

Figure 2 SES Water RAG Matrix for household consumption forecast method selection

Low concern zone	Weighting	Regression models	Micro-component models	Macro-components	Variable flow methods	Trend based models	Per capita methods	Use existing study data
Acceptance by stakeholders	10	7	6	8	6	6	4	2
Explicit treatment of uncertainty	5	8	6	6	5	4	2	2
Underpinned by valid data	6	5	6	6	4	4	2	2
Transparency and clarity	5	6	6	7	6	5	4	2
Appropriate to level of risk	7	6	8	8	7	6	3	2
Logical and theoretical approach	5	6	7	7	6	5	4	2
Empirical validation	2	7	6	7	4	4	2	2
Explicit treatment of factors that explain HH consumption	5	6	6	7	6	4	2	2
Flexibility to cope with new scenarios	5	7	6	8	5	4	4	2
Weighted score		321	319	361	281	244	157	100
Ranked		2	3	1	4	5	6	7

Table 1 provides comments on the justification for the scores presented in Figure 2.

**Table 1** Justification for RAG Matrix scoring

Criteria	Comment
Acceptance by stakeholders	Based on existing micro-component model, the micro and macro component approaches should score more highly. The next highest alternate should be the Variable flow method, as this can use the BY PCC/PHC with a trend developed from the macro-component data. In effect, the macro-component approach is a micro-model of demand, with a trends developed through a macro-component approach.
Explicit treatment of uncertainty	Regression models do this best, so should score more highly.
Underpinned by valid data	The quality of data available from the control areas for PCC/PHC is probably not sufficient for regression models - so this is marked down. National micro-component data are available, there are no company-specific data. Given the low level of concern national data is appropriate. Trend data is probably stronger at the macro level. These should score more highly.
Transparency and clarity	The macro-component model for forecasting which is built on the existing micro BY demand model should satisfy this criterion.
Appropriate to level of risk	Low level of concern, so do not need to develop a completely new method. Micro-component model of demand should suffice with the data available, but to forecast each individual component may be difficult with the data available. Trends in micro-components are more readily available at the macro-component level, therefore this should score higher for the forecast.
Logical and theoretical approach	Given the level of concern and the data available, then the micro/macro approach is logical.
Empirical validation	Whilst the regression model should be better at this, the data won't allow it. The micro-component BY demand model can be calibrated against the BY reported PHC values; these also feed into the start of the macro forecast. The same approach can be tested on the model 5 years ago to see how it would turn out against the current PHC values to validate the forecast.
Explicit treatment of factors that explain HH consumption	Same comment re data availability and the regression - so marked down. The macro model picks up the main technological trends and personal bathing trends without the unnecessary complexity of the micro-component model.
Flexibility to cope with new scenarios	The macro-model for forecasting is most appropriate for this.

The weightings used in the matrix are based on industry standards, amended where appropriate to reflect the SES Water position.

The scoring reflects the relevance of the methods to the SES Water situation – particularly with regard to the level of planning concern in the WRZ and the availability of company-specific data, particularly for regression modelling.

Based on this, there are two viable candidate options – micro-components and/or macro-components, as there are insufficient company-specific data to proceed with regression modelling.

A micro-component forecast has been selected for this project. The available data makes this possible and is effectively more advanced than the macro-component method identified in the RAG matrix. This will be based on recent national micro-component data to establish a base year model of consumption.

## 3 Review data availability

### 3.1 Base year data

The base year selected for the Draft model is 2015/16.

Base year figures have been extracted from Table 10 of the Annual Report data. SES Water has one water resource zone (WRZ). The base year per capita consumption excluding supply pipe leakage (PCC) for measured and unmeasured properties, post MLE (maximum likelihood estimation), are 140.65 litres/head/day and 157.11 litres/head/day respectively.

Measured and unmeasured property and population figures are also extracted from the June returns. In the base year SES Water has 128,020 measured properties and 135,431 unmeasured properties. Population within the measured households is 308,259, with a resulting occupancy of 2.41 the population of unmeasured properties is 366,032 with a resulting occupancy of 2.70. For the purpose of forecasting household consumption, the reported figures are adjusted to align with Experian figures to account for properties not captured in the customer numbers. Consequently, the population for measured household are set to 312,907 and unmeasured are set to 371,550, total population is 684,456 which has come from the econometric population forecast from Experian, this has been deemed to be the most likely forecast and sits between the plan and trend forecast. A most likely forecast was chosen over the plan forecast due to plan being quite low in comparison. The resulting measured occupancy is 2.44 and unmeasured occupancy is 2.74.

Note: For this forecast the property, population and occupancy analysis has been carried out as described above and in section 4. In the reporting year 2017/18, SES Water are planning to move about 2000 'shared flats' properties from the non-household cohort into the household cohort (currently consumption from these flats is included in the non-household forecast). When these properties are moved from non-household to household, both the household and non-household forecasts will need to be updated, but this cannot be done until the precise nature of these properties (in terms of meter type and occupancy) is determined.

The calculated per household consumption (PHC) values post MLE for measured households is 338.68 litres/property/day, unmeasured PHC is 424.61. This is calculated from the reported PCC figures combined with the reported occupancy figures.

### 3.2 Other data

SES Water supplied Artesia with some other data sources which are either used in the forecast, or for validation of the model. This data includes historic trends from the June Returns, the WRMP14 forecast, Experian forecast for population and properties, historic

weather data, historic distribution input (DI) data, also micro-component survey data for about 8500 households from the company's on-line water efficiency calculator.

In addition to the data provided by SES Water several national datasets are used to increase the understanding of historic, present and future micro-component consumption. Historic micro-components are extracted from the WRc CP187 report, current micro-components are extracted from UKWIR 16/WR/01/15 Integration of Behaviour Change and future projections are extracted from the Market Transformation Programme (MTP).

### **3.3 Measured micro-component data**

By 'measured' we mean micro-component data that has been collected by measuring the different micro-components used within the household (as opposed from survey questions and assumptions). This allows ownership (O), volume per use (V) and frequency of use (F), to be calculated for each micro-component. There are two main sources of data for this:

- 2015-16 data collected using the Siloette system:
  - a sample of measured billed households, which has associated occupancies and demographic information on the households, collated during an UKWIR Study<sup>3</sup> (this contains 62 households from around England and Wales),
  - a sample of RV billed households, which does not have associated demographics (collated from other anonymous Siloette studies carried out by Artesia Consulting, from England and Wales).
- 2002 – 2004 O, V, and F data collected using the Identiflow system (a sample of RV billed households, reporting in WRc Report CP187<sup>4</sup>).

Both the Siloette and Identiflow systems measure the flow into a property and compute the individual micro-components through pattern recognition (although the detailed methodology of the two systems is different).

The Siloette system uses a Siloette logger that is connected to the pulsed output from a meter via a pulse unit, as illustrated in Figure 3.

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<sup>3</sup> Integration of behavioural change into demand forecasting and water efficiency practices, UKWIR 16/WR/01/15, 2016

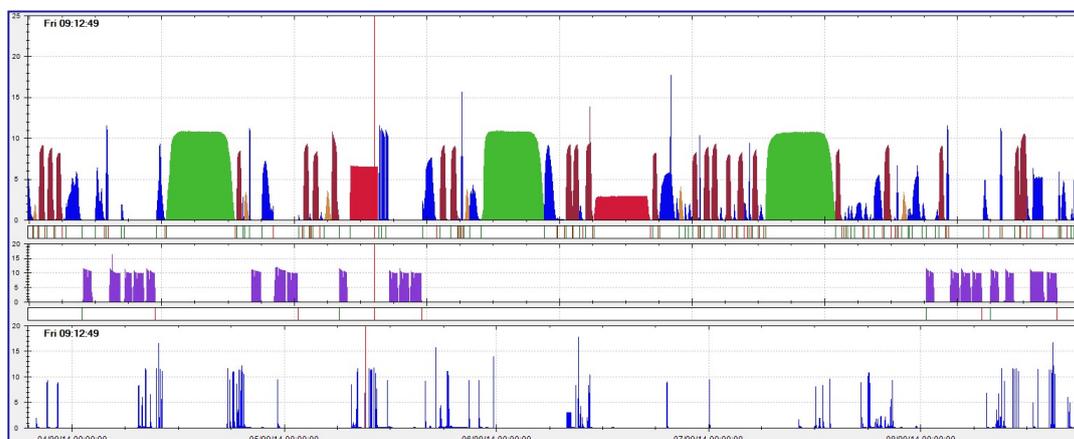
<sup>4</sup> Increasing the Value of Domestic Water use Data for Demand Management, WRc, March 2005

**Figure 3 Siloette logger installed in a boundary box**



The logger records the flow through the meter at sub 1-second resolution. Once downloaded an algorithm is applied to the data to create a high-resolution flow trace of the flow into the property, as illustrated in Figure 4.

**Figure 4 Illustration of Siloette logger output**



Each water-using event in the house has a flow-rate profile characterised by the time, duration and volume of water per use. Siloette takes the data from the logger and uses pattern-recognition software to disaggregate and quantify the individual micro-component events and provide information on time of event, flow rates and volumes. In Figure 4 the bottom trace shows the time-series of the flow profile, and the top row shows the resulting events that have been characterised, with each event type shown in a different colour (for example, baths are coloured green in Figure 4.)

The three sources of data described above are shown in Table 2 to Table 4.

**Table 2 Micro-component summary data from 2015/16 metered billed households**

2015/16 Metered billed households					
Micro-component	" Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.26	7.83	56.83	23.92
Shower	0.92	62.36	0.86	49.54	20.85
Bath	0.43	104.60	0.24	10.61	4.47
Tap	1.00	5.66	11.61	65.72	27.66
Dish Washer	0.42	16.70	0.50	3.53	1.48
Washing Machine	0.95	54.19	0.55	28.44	11.97
Water Softener	0.02	52.06	0.97	0.98	0.41
External use	0.18	285.18	0.07	3.34	1.40
Plumbing Losses	0.22	37.20	1.55	12.86	5.41
Miscellaneous	0.95	1.63	3.74	5.78	2.43

**Table 3 Micro-component summary for 2015/16 RV billed households**

2015/16 RV billed households					
Micro-component	" Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.58	8.86	67.15	22.53
Shower	0.94	54.82	0.94	48.69	16.34
Bath	0.54	113.65	0.36	22.35	7.50
Tap	1.00	4.56	17.91	81.62	27.39
Dish Washer	0.37	19.68	0.28	2.02	0.68
Washing Machine	0.94	56.36	0.66	34.59	11.60
Water Softener	0.09	112.02	0.24	2.41	0.81
External use	0.51	183.03	0.19	17.58	5.90
Plumbing Losses	0.30	75.84	0.65	14.76	4.95
Miscellaneous	0.93	1.56	4.75	6.85	2.30

**Table 4 Micro-component summary for 2002/04 RV billed households**

2002-2004 (from WRc CP187)					
Micro-component	" Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	9.40	11.52	108.29	29.19
Shower	0.85	25.70	1.46	31.97	8.62
Bath	0.88	73.30	0.95	61.35	16.54
Tap	1.00	2.30	37.90	87.17	23.50
Dish Washer	0.37	21.30	0.71	5.60	1.51
Washing Machine	0.94	61.00	0.81	46.30	12.48
Water Softener	0.02	182.50	0.39	1.14	0.31
External use	0.65	46.70	0.89	27.10	7.30
Plumbing Losses					0.00
Miscellaneous	0.19	20.40	0.53	2.08	0.56

### 3.4 Market transformation data

Defra's Market Transformation Programme produced product summaries for various water using appliances in 2011<sup>5</sup>. These provide predictions of water use for appliances and devices in 2030 for three scenarios:

- Reference scenario (equivalent to baseline forecast)
- Policy scenario (assuming more effective implementation and accelerated take-up of more sustainable products)
- EBP or early best practice (which assumes a more positive impact than the policy scenario and an early take up of innovative water efficient products).

<sup>5</sup> <http://efficient-products.ghkint.eu/cms/product-strategies/subsector/domestic-water-using-products.html#viewlist>

## 4 Property segmentation

Most companies report consumption figures for measured and unmeasured properties. To fully explore the complexity of different household segments and the difference in their consumption, behaviour and future trends, Artesia calculates the forecast with the measured households split into: existing properties, new properties, optants, as well as 'compulsory', 'selective', 'change of occupier', and 'other' metering programmes. 'Existing' metered households are in fact a combination of these different metered types, but will be termed 'existing' and remain as a constant segment throughout the forecast from the base year value. An illustration of the breakdown of the measured and unmeasured households are shown in Figure 5.

A forecast produced by Experian as part of a separate project<sup>6</sup> details the increase in number of properties. We have chosen to use the 'econometric' forecast from Experian, following consultation with SES Water. Guidance suggests the use of plan based properties and population. We deviate slightly from the guidance here due to the comparison of plan verses trend, here we see a lower projection for plan than trend, which is unusual. We in fact select the econometric trend as it sits between the plan and trend which we feel gives the most likely estimate. Using the lower plan based projections might leave the company at risk for water balance if the properties and population were in fact to follow either of the other trends provided by Experian. We have checked the validity of these property and population forecasts and ensured their compliance with regulatory guidance.

The Experian forecast only provides total property numbers. Therefore, as part of this work we have determined the switch from unmeasured to optant, which depends on the forecast optant rate. The optant forecast rate is calculated using a combination of the WRMP14 forecast and the historic reported optant numbers. Additionally the number of change of occupier metered properties are forecast, and are forecast in a similar way to optants, using historic reported figure and the WRMP14 forecasts. The change of occupier figures forecasted in WRMP14 forecast showed a steep decline likely due to the planned policy at the time. This has been discussed with SES, and it was decided to leave this in place as the current number of optants are following the WRMP14 forecasts. This will need to be revisited in the next WRMP. The figures used for the forecasts for free optants and change of occupier are shown in Table 5.

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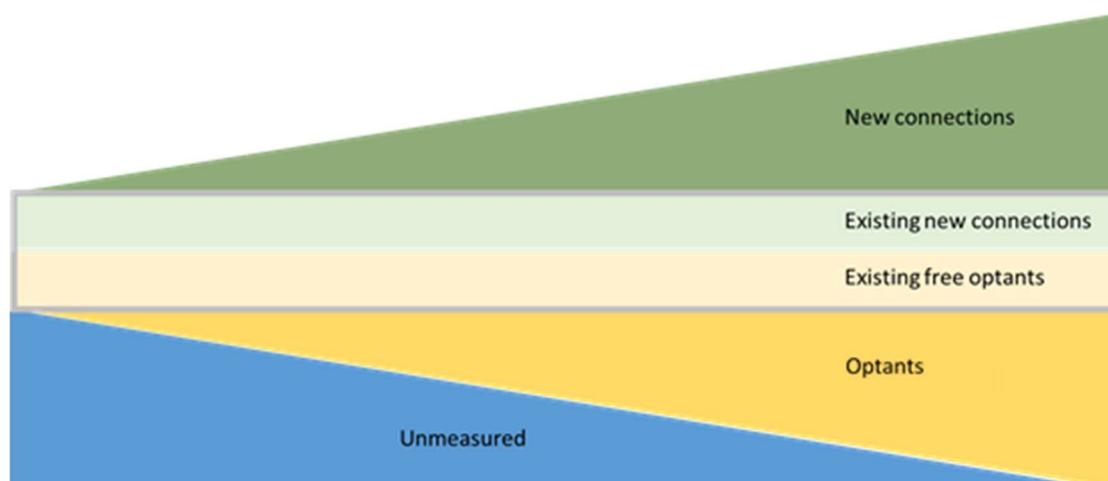
<sup>6</sup> Experian (2017) Population, Household, Property and Occupancy Forecasts for WRMP19. January 2017

Table 5 Change of occupier and optant forecasts total by AMP

	AMP5	AMP6	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP13	AMP14	AMP15	AMP16	AMP17	AMP18
<b>Optants (total per AMP '000)</b>	11.802	19.729	18.087	13.391	9.914	7.341	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<b>Change of occupier (total per AMP '000)</b>	18.724	12.346	10.391	7.693	5.696	4.217	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<b>New connections (total per AMP '000)</b>	7.394	9.804	12.628	13.894	14.734	15.845	16.270	14.805	14.388	14.388	14.388	14.388	14.388	14.388
<b>Meter penetration (at end of AMP)</b>	45.8%	59.7%	71.5%	79.9%	85.8%	90.0%	90.5%	90.9%	91.2%	91.5%	91.8%	92.1%	92.4%	92.6%

Property, optant and change of occupier forecasts are each inputs into the segmentation model.

**Figure 5** Illustration of property breakdown within the company, forecast from base year to the point of 100% meter penetration

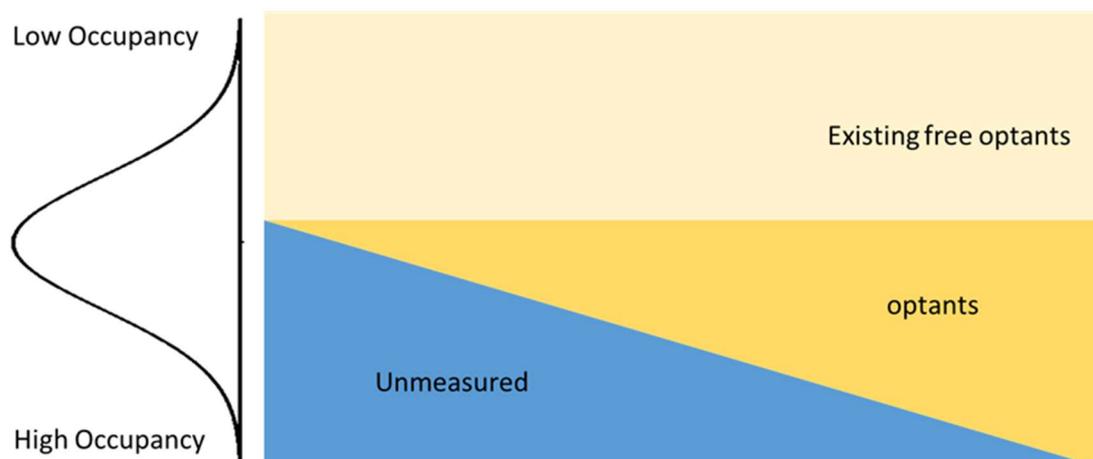


Some key assumptions made in the segmentation model:

- New households will always be metered.
- Optants and change of occupiers move directly out of the unmeasured property segment.
- Voids are forecast to remain constant throughout the forecast period, in that there are no further voids added beyond the base year. Consumption in void properties is included in the demand category 'minor components' in 'water unbilled' (i.e. not in the household consumption component).
- The point at which 100% meter penetration occurs is based on the meter optant and change of occupier forecasts.
- Despite 100% penetration being unlikely in practice, the year in which this point is reached is needed for mathematical calculations in order to balance the population figures. In practice, this point is beyond the forecast period. The subtleties of final meter penetration rate may need further work in future forecasts.

Further to mapping properties into each of these segments, population must also be distributed.

Figure 6 Illustration of the change in occupancy as meter penetration tends towards 100%



In order to successfully distribute the population between the segments, certain assumptions and knowledge of the segments must be assessed. Occupancy is only reported for measured and unmeasured. For SES the population figures are calibrated up to meet the Experian population, this occurs in the base year and throughout the forecast. Measured households generally have lower occupancy than unmeasured households. New properties are assumed to have company average occupancy (this assumes that occupants are moving into new properties from a range of existing properties, measured or unmeasured, either within or from outside the region, and hence have a company average occupancy). Occupancy of new properties and optant properties are inter-dependent, in that the sum of new and optant population within the existing measured households must equal the total for measured household population. Optants have a low occupancy, however this is highly dependent on meter penetration. Figure 6 demonstrates that as meter penetration increases, the occupancy of the unmeasured and optants increase until 100% meter penetration. Throughout the forecast the sum population for the optants plus unmeasured remains the same (this assumes that each year optants come from the unmeasured pool). Change of occupier metering is not shown in Figure 6; the occupancy of change of occupier is assumed to be the same as the unmeasured properties, due to this process being random with respect to occupancy, with properties switched to being metered.

Meanwhile the average occupancy of all the segments must follow the change in occupancy from the Experian property and population forecasts. These assumptions provide an estimate of the change in occupancy within the household segments over time; in reality, there will be a complex movement of population within these segments, reflecting births, deaths, people moving into the region, people moving out of the region, and people moving within the region. Each year the segments are calibrated to take into account the company level occupancy changes throughout the forecast period. There is a slight decrease in company occupancy over the next 25 years, and this is attributed equally across all household segments.

To ensure the segmented households and populations sum to the company forecast various calibration steps and data validation checks are also included in the calculations.

## 5 Household consumption forecasts

### 5.1 Approach to micro-component forecasting

Micro-component models have been used for water demand forecasting in England and Wales from the late 1990s. They quantify the water used for specific activities (e.g. showering, bathing, toilet flushing, dishwashing, garden watering, etc.) by combining values for ownership (O), volume per use (V) and frequency of use (F). For example, per-capita (PCC) or per household consumption (PHC) can be modelled as:

$$\text{PCC or PHC} = \sum_i (O_i \times V_i \times F_i) + \text{pcr}$$

Where:

‘O’ is the proportion of household occupants or households using the appliance or activity for micro-component ‘i’,

‘V’ is the volume per use for ‘i’,

‘F’ is the frequency per use by household occupants or households for ‘i’,

pcr is per capita residual demand.

By applying this together with the population or property data, a water demand model can be formed. By forecasting changes in each of the variables (O, V, F or daily water use for each micro-component) over time, a water demand forecast can be created. Hence the micro-component forecast model requires estimates of changes in these variables, to reflect future changes in technology, policy, regulation, and behaviour.

This report describes how the inputs have been generated for:

- Base year micro-components from a micro-component occupancy model.
- Final planning year micro-components from an occupancy model. This allows a rate of change of micro-component daily water use to be derived due to the change in occupancy over the planning period.
- Technology, policy and behaviour trend values for micro-components (based on historic analysis of trends and future predictions from the Market Transformation Programme).

### 5.2 Basic inputs required

To build the micro-component forecast model, we need the following inputs:

- Base year household consumption broken down into micro-components.

- Reported base year household consumption (from water company annual return data).
- Rates of change in micro-components across the planning period.

### **5.3 Selection of the basic unit of consumption**

Two commonly used methods of consumption forecasts are based on Per Capita Consumption (PCC) and Per Household Consumption (PHC). Linear modelling can use either approach.

In the case of PHC modelling, occupancy needs to be included as an explanatory variable, and PHC is composed of a consumption allotted to the house on the basis of its characteristics, and an additional consumption assigned to each occupant.

PCC modelling assigns a different consumption value per person on the basis of the characteristics of the property they inhabit.

In the former case, the model is property driven, which aligns with the data collection based on household meter reads.

The latter case introduces all the error associated with the household occupancy figure into the model at the very first step. If the model is based on PCC, the PCC is calculated from estimated occupancy (for which there is an error), so there is no part of the consumption modelling that is independent of occupancy error; all the error in population forecasting is propagated through the zonal forecast if it is based on PCC.

Modelling by PHC makes occupancy-driven household consumption components implicit in the model whereas PCC-driven modelling would need to incorporate a correction for changing occupancy rates in PCC forecasting.

For these reasons PHC is used as the basis for aggregating up to a zonal consumption forecast.

The Environment Agency require that the micro-components are reported in the WRMP tables in units of occupancy, i.e. per capita consumption; and the model converts the PHC micro-component values at the zonal level to PCC by dividing by occupancy.

### **5.4 Micro-component occupancy model**

Whilst we carry out the forecast model at household level, there is an influence on a selection of the micro-components from occupancy. Therefore, in calculating the base year and final year PHC values, we use a set of linear models that relate either daily use or frequency of use to occupancy in each year. The model is also used to provide the base and final year values for different metered property types: existing metered, optant metered, new property metered, selective metered and change of occupier metered.

The UKWIR 2015/16 micro-component data for measured billed households was used for the modelling because this dataset had a complete set of occupancy data for each

household over the logging period. The total number of households in the sample was 62. In addition to this we use the SES Water micro-component survey data to tailor the occupancy models and OVF outputs for the update these figures to closer match the reported figures. The measured data is used as the primary source, with the survey data being used to validate and amend where necessary.

**Figure 7** Each micro-component daily use plotted against occupancy

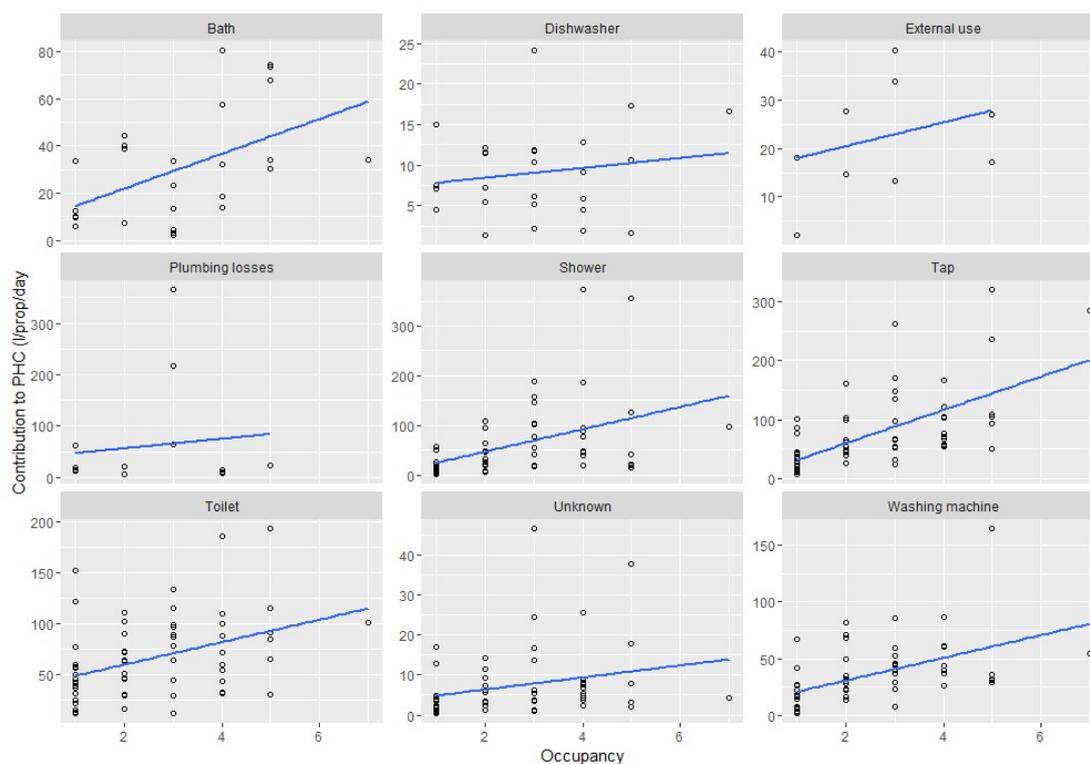


Figure 7 shows the average daily use (or contribution to per household consumption) for each of the following micro-components:

- WC flushing,
- Shower use,
- Bath use,
- Tap use,
- Dish washer use,
- Washing machine use,
- Water softener use,
- External use, and
- Miscellaneous use (including internal plumbing losses).

Each of the micro-components were investigated to determine whether the daily volume per use, frequency of use or ownership varied significantly with occupancy. The following micro-components showed relationships where occupancy was a significant factor:

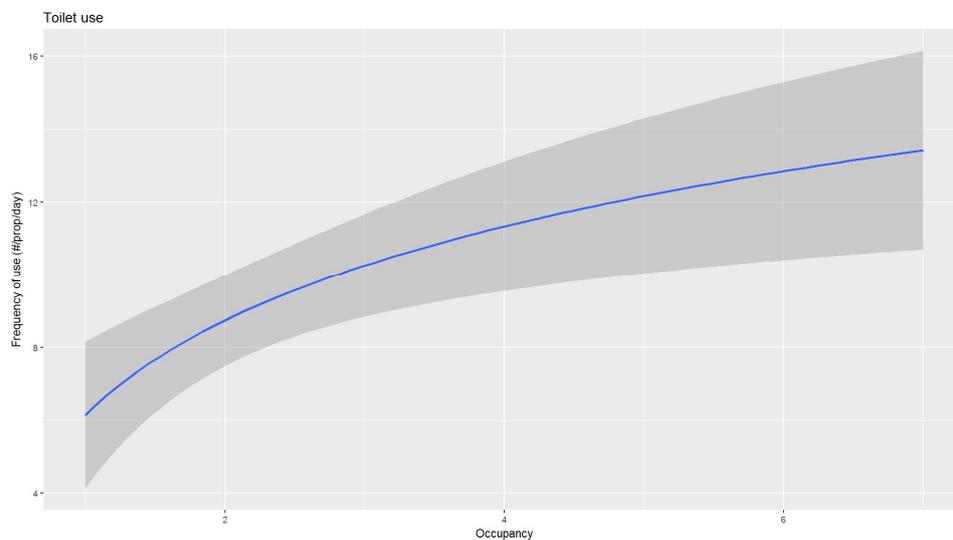
- WC flushing,
- Shower use,
- Bath use,
- Tap use,
- Washing machine use.

For each of these micro-components (WC, Shower, Bath, WM and Taps) we developed a linear model using occupancy as the predictive factor.

Figure 8 shows the variation of WC flushing frequency per day with occupancy, with the mean frequency of use per day plotted against occupancy. The model is a log relationship of frequency of use against occupancy with the following equation:

$$\text{Frequency of use (uses/day)} = 6.143 + 3.744 * \ln(\text{occupancy}) \quad \text{Equation 1}$$

**Figure 8** Variation of WC flushing frequency (uses per day) with occupancy



Specifically for SES Water the first update using the survey data was to incorporate the measured vs unmeasured split in the survey data. Due to the nature of the questions asked, only total PHC for toilets could be modelled, rather than frequency per use.

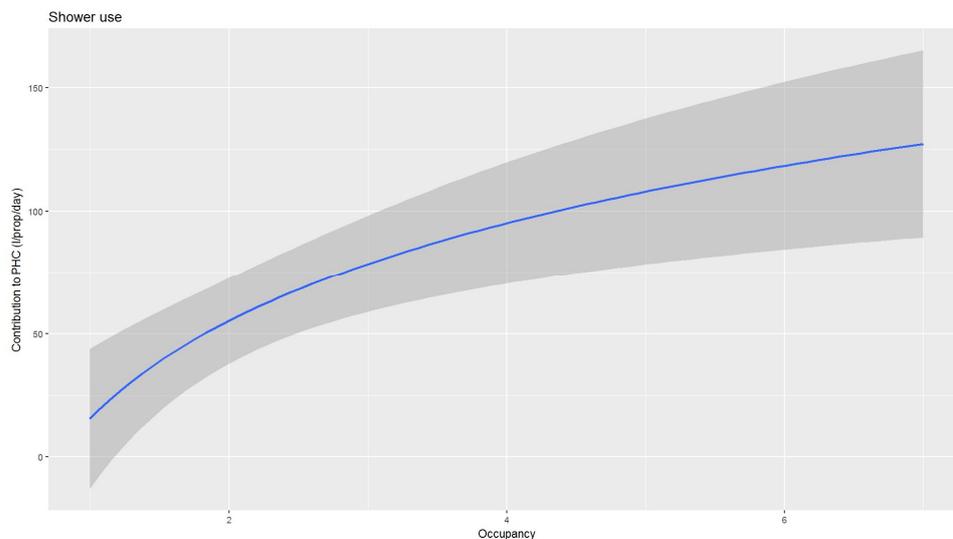
$$\text{SES Contribution to umPHC (l/prop/day)} = 10.071 + 80.214 * \ln(\text{occupancy}) \quad \text{Equation 1a}$$

$$\text{SES Contribution to mPHC (l/prop/day)} = 19.305 + 67.269 * \ln(\text{occupancy}) \quad \text{Equation 1b}$$

Figure 9 shows the variation of the water used for showering each day with occupancy, with the mean water use per day plotted against occupancy. Shower use was also explored in terms of frequency of use per day, but a more robust model could be built with volume used per day. This is probably because with increased occupancy there is increased variation in length of showering. The model is a log relationship of volume used per day against occupancy with the following equation:

$$\text{Shower volume used per day} = 15.47 + 57.47 * \ln(\text{occupancy}) \quad \text{Equation 2}$$

**Figure 9** Variation of shower volume used per day with occupancy



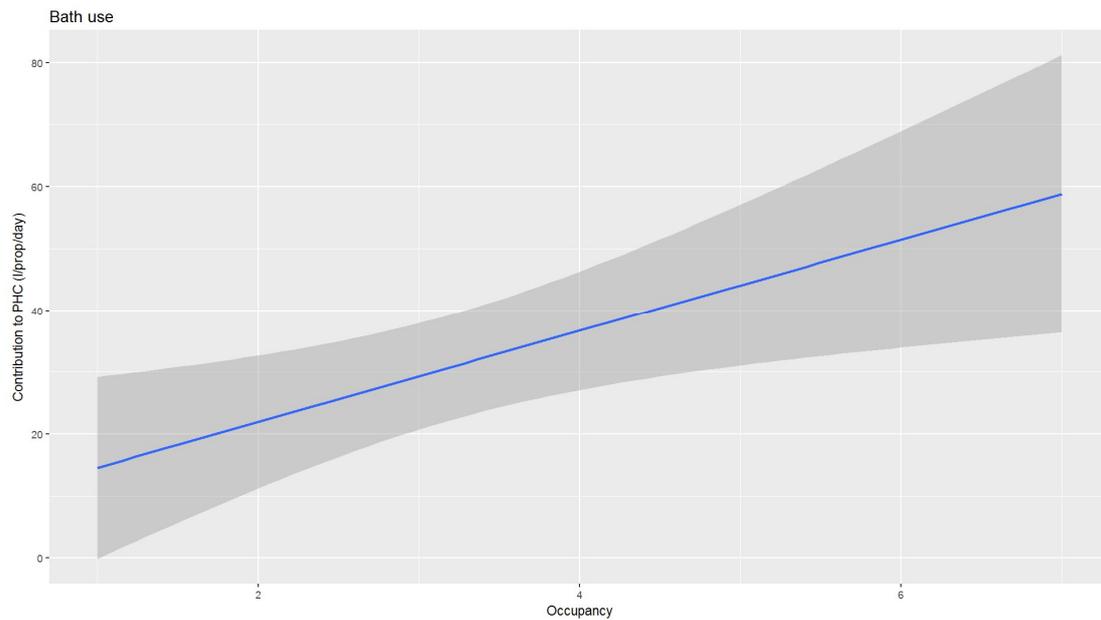
$$\text{SES Unmeasured Shower volume used per day} = 29.93 + 92.69 * \ln(\text{occupancy}) \quad \text{Equation 2a}$$

$$\text{SES Measured Shower volume used per day} = 29.10 + 86.99 * \ln(\text{occupancy}) \quad \text{Equation 2b}$$

Figure 10 shows the variation of the water used for bath use each day with occupancy, with the mean water use per day plotted against occupancy. The model is a linear relationship of volume used per day against occupancy with the following equation:

$$\text{Bath volume used per day} = 7.181 + 7.378 * \text{occupancy} \quad \text{Equation 3}$$

**Figure 10** Variation of bath volume used per day with occupancy



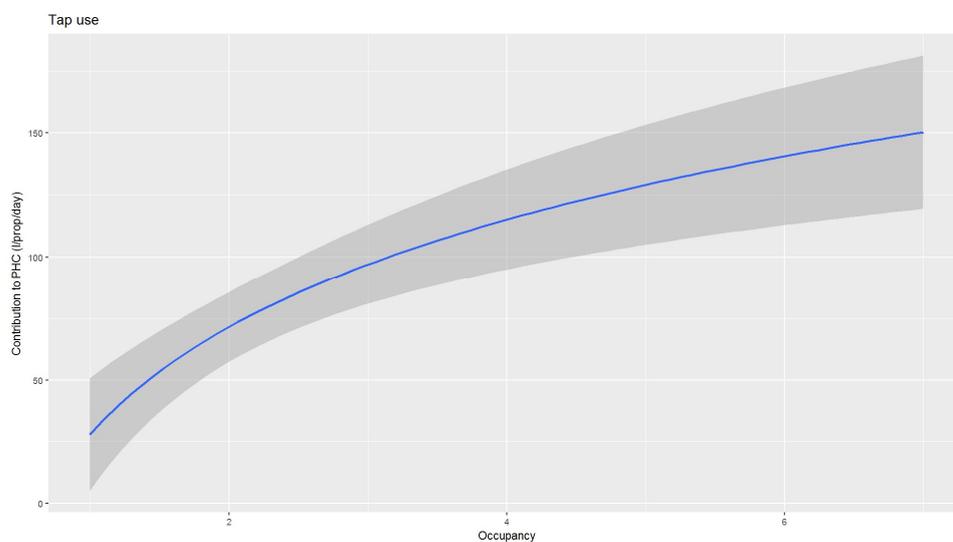
*SES unmeasured Bath volume used per day = 7.293 + 7.089 \* occupancy* **Equation 3a**

*SES measured Bath volume used per day = 6.077 + 9.185 \* occupancy* **Equation 3b**

Figure 11 shows the variation of the water used for tap use each day with occupancy, with the mean water use per day plotted against occupancy. The model is a log relationship of volume used per day against occupancy with the following equation:

*Tap volume used per day = 27.92 + 62.89 \* ln(occupancy)* **Equation 4**

**Figure 11** Variation of tap volume used per day with occupancy



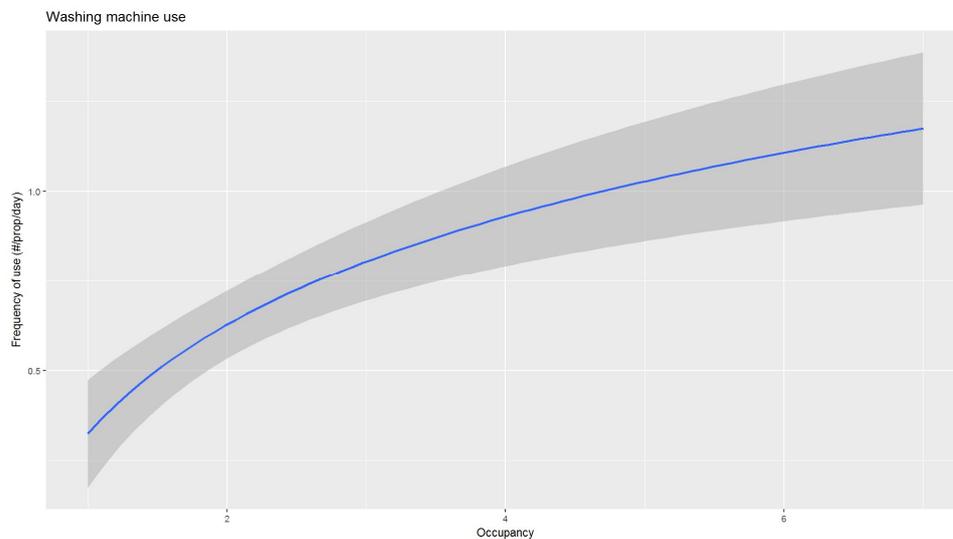
*SES unmeasured Tap volume used per day = 14.561 + 106.557 \* ln(occupancy) Equation 4a*

*SES measured Tap volume used per day = 25.525 + 87.764 \* ln(occupancy) Equation 4b*

Figure 12 shows the variation of the water used for washing machine use each day with occupancy, with the mean frequency of use per day plotted against occupancy. The model is a log relationship of frequency of use per day against occupancy with the following equation:

*Frequency of use (uses/day) = 0.3242+ 0.43705 \* ln(occupancy) Equation 5*

**Figure 12** Variation of washing machine (frequency of use per day) with occupancy



*SES Contribution to umPHC (l/prop/day) = 11.555 + 16.517 \* ln(occupancy) Equation 5a*

*SES Contribution to mPHC (l/prop/day) = 14.949 + 5.179 \* ln(occupancy) Equation 5b*

For each property type the model variables shown in Table 6 are also changed depending on the meter status of the property.

Wastage/plumbing losses frequency of occurrence value of 1.55 is taken from the UKWIR report<sup>7</sup>. The multiplying factors have been assumed considering the impact of metering on plumbing losses across property type.

**Table 6** Micro-component variables that change with meter status

Property type	WC flush volume (mean l/flush)	Washing machine volume/use (mean l/use)	Dish washer volume/use (mean l/use)	Wastage / plumbing losses (frequency of
---------------	--------------------------------	---	-------------------------------------	---

<sup>7</sup> UKWIR (2014) Understanding Customer Behaviour for Water Demand Forecasting

				<b>occurrence)</b>
RV billed household (HH)	7.58	54.19	16.7	1.5*1.55
Existing measured HH	7.26	54.19	16.7	1.55
Optant measured HH	6.0	54.19	16.7	0.5*1.55
New build measured HH	5.5	50.0	15.0	0.5*1.55
Change of Occupier	7.58	54.19	16.7	0.5*1.55

Combining all the relationships and variables, the micro-component occupancy model is defined in Table 7.

**Table 7 Micro-component occupancy model parameters**

Micro-component	Weighted Ownership 'O'	Volume per use 'V' (l/use)	Frequency of use 'F' (uses/day)	Daily use (l/prop/day)
WC flushing	1	See Table 6	See Equation 1	If New/opt $O*V*F$ , if umHH see Eq1a, if existHH average Eq 1b and $O*V*F$
Shower use				If New/opt See Equation 2, if umHH see Eq2a, if existHH average Eq 2b and Eq2.
Bath use				If New/opt See Equation 3, if umHH see Eq3a, if existHH average Eq 3b and Eq3.
Tap use				If New/opt See Equation 4, if umHH see Eq4a, if existHH average Eq 4b and Eq4.
Dish washer	0.42	See Table 6	0.5	$O*V*F$
Washing machine	0.95	See Table 6	See Equation 5	If New/opt $O*V*F$ , if umHH see Eq5a, if existHH average Eq 5b and $O*V*F$
Water softener	0.02	52.06	0.97	$O*V*F$

SES Water

External use	0.18	285.18	0.07	O*V*F
Plumbing losses	0.22	37.2	See Table 6	O*V*F
Miscellaneous	0.95	1.63	3.74	O*V*F

The model can then be used to calculate the micro-component daily use (and hence the per household consumption 'PHC') for the following property types based on the occupancy assigned to each property type, in the base year and in the final year of the forecast:

- RV billed households
- Existing metered billed households
- Optant metered billed households
- New build metered households
- Change of occupier metered billed households.

Application of the occupancy model in the base year and final year are shown in Table 8 and Table 9 respectively. The base year in Table 8, which shows the occupancy, PHC derived from the micro-component occupancy model, and the calculated PCC. Also shown is the PHC and PCC calibrated to base year (normalised to NYAA).

**Table 8 Micro-component occupancy model parameters – Base year (adjusted to NYAA)**

Household types	Occupancy	PHC (modelled)	PCC (modelled)	Base year (NYAA) calibrated PHC	Base year calibrated PCC
RV billed HH	2.74	424.46	154.72	432.37	157.60
Existing metered billed HH	2.45	338.23	138.24	332.62	135.94
New build metered HH	2.60	291.90	112.24	316.07	121.53
Optant metered HH	2.04	255.89	125.50	277.08	135.89
Change of occupier metered HH	2.75	411.94	149.99	356.84	129.93

Table 9 shows the modelled PHC and PCC figures based on the final year occupancies. These figures are without the forecast trends applied so is to demonstrate the impact of the changing occupancy over time of each of the household segments. RV billed occupancy

increases with a resulting increase in PHC and decrease in PCC. The measured properties have a decreasing occupancy over the forecast period with a resulting reduction in PHC and small increase in PCC.

**Table 9 Micro-component occupancy model parameters – Final year (NYAA)**

Household types	Occupancy	PHC (OVF calculated)	PCC (OVF calculated)
RV billed HH	2.99	451.65	151.07
Existing metered billed HH	2.21	315.04	142.31
New build metered HH	2.01	246.38	122.38
Optant metered HH	1.91	244.18	127.85
Change of occupier metered HH	3.13	453.06	144.88

Using the base year and final year PHC values, a rate of change in PHC due to occupancy change can be calculated for each household metered status. This is in addition to the technology and behaviour trends described in the following section.

## 5.5 Micro-component trend model – baseline scenario

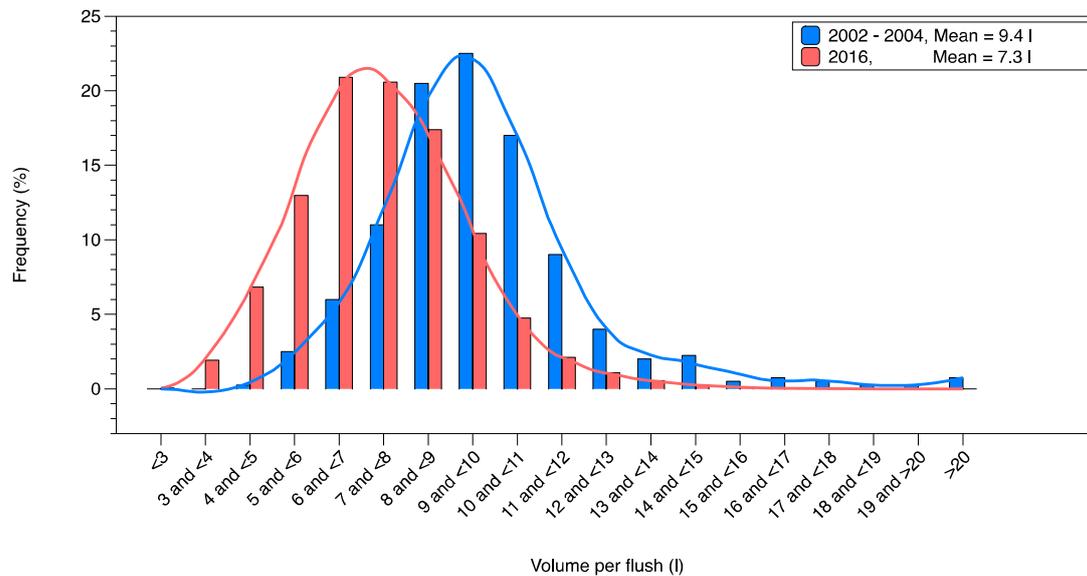
To investigate trends in individual micro-components due to technology change, policies and regulation, and behaviour change, we have used the data set from 2002/04 (Table 4) and the 2015/16 datasets (Table 2 and Table 3). For future projections of trends we have generally used the forecast water use values from Defra’s Market Transformation Programme.

### 5.5.1 *WC flushing*

For the trend we assume that ownership and frequency of use for WC flushing remains constant, with the volume per use changing due to market transformation.

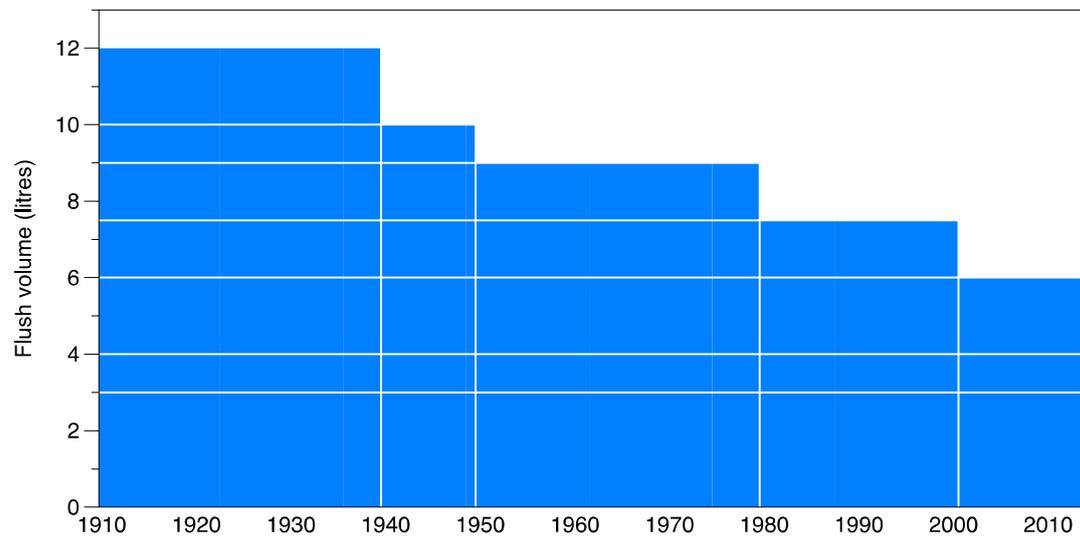
Using data from the WRc micro-component report CP187 and data from the UKWIR 2016 study, we can create a histogram of the volumes per flush from 2002/04 and 2015/16. These are shown in Figure 13. This shows that for 2002/04 the mean flush volume was 9.4 l/flush, with a range of flush volumes from 5 litres to > 15 litres. In 2015/16 the mean flush volume had reduced to around 7.3 litres with a range from 3 litres to about 13 litres per flush.

**Figure 13** Histogram of WC flush volumes from 2002/04 and 2015/16



The reason for the reduction in flush volumes from 2002/04 to 2015/16 is due to the replacement of larger volume WC cisterns with smaller volume cisterns, due to market transformation based on regulatory policies. The schematic in Figure 14 shows the change in maximum flush volumes over time due to changes in regulation. From 12 litres in 1910 to 6 litre single flush or 6/4 or 6/3 litre dual flush in 2000 to date. The reason why we see larger flush volumes in the histogram is due to incorrect setting up of the fill height or over filling during the flush period.

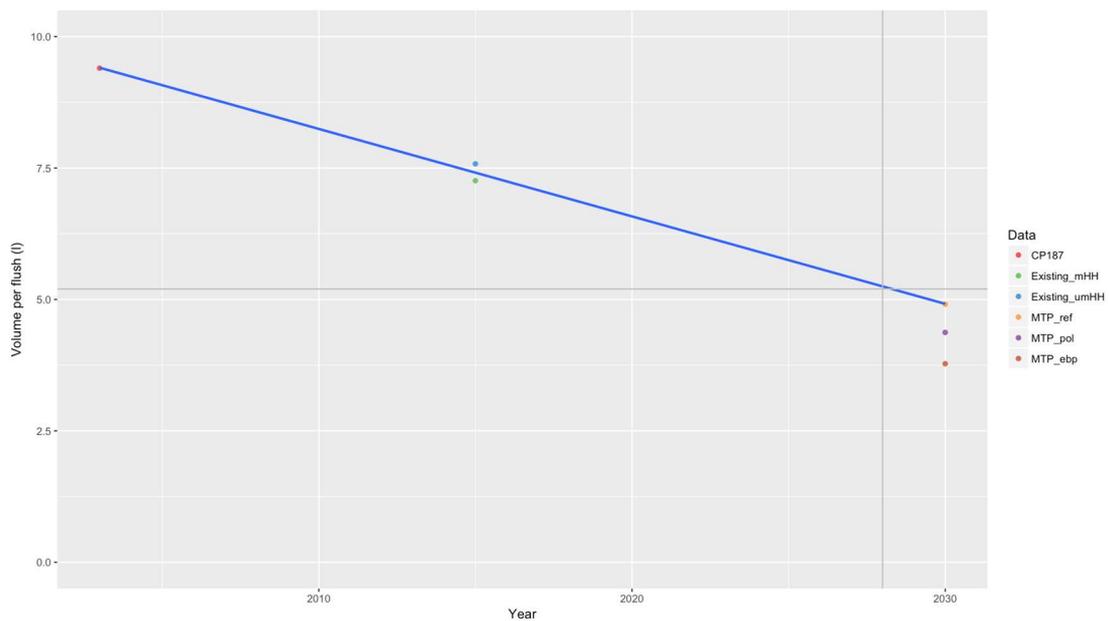
**Figure 14** Regulatory changes in flush volumes



The latest MTP projections for WC flushing volumes<sup>8</sup> in 2030 for the reference scenario is 4.8 litres/flush. Figure 15 shows the mean 2002/04 (CP187), the 2015/16 flush volumes (Existing\_mHH and Existing\_umHH), and the flush volume from the MTP scenarios in 2030. The blue line shows the linear fit from the 2002/04, 2015/16 and MTP Reference scenarios.

If we assume that the market transformation continues at the current rate (a reasonable assumption for baseline forecasts, as there are no planned regulatory changes in WC flush volumes), then the flush volume in 2028 will be approximately 5.1 litres (shown by the intersect of the grey lines in Figure 15). This provides some confidence in the MTP Reference scenario for WC flush volumes.

**Figure 15** Historic, current and future flush volumes

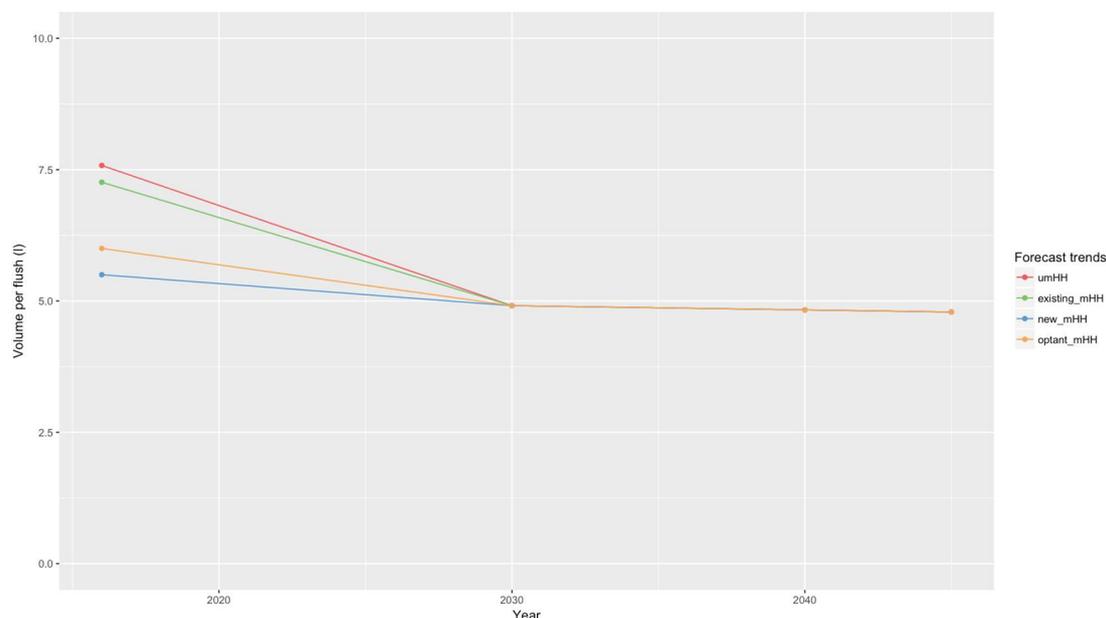


We have created future trends for WC volume per flush (see Figure 16) using:

- the base year volumes per flush in Table 6 for different property types,
- the 2030 projection for WC flush volume from the MTP reference scenario,
- an assumption that all property types will have achieved the MTP Reference scenario between the forecast base year and 2030 (for the baseline forecast assuming no change to current WC flush regulations)<sup>9</sup>,
- and an assumption that the volume per use will then remain relatively constant until 2045.

<sup>8</sup> Source: <http://efficient-products.ghkint.eu/spm/download/document/id/954.pdf>

<sup>9</sup> This is a reasonable assumption given the rate of change in actual data presented in Figure 14 and discussed elsewhere in this section.

**Figure 16** Trends for WC flush volumes

From these trends, annual rates of change have been produced for each of the property types. The rates of change are then incorporated into the model.

### 5.5.2 Showering

To investigate showering trends, we have used the overall daily water use (per household) from shower data. This is because shower use is a complex mix of behaviour (showering time), technology (shower flows), as well as frequency of use and occupancy.

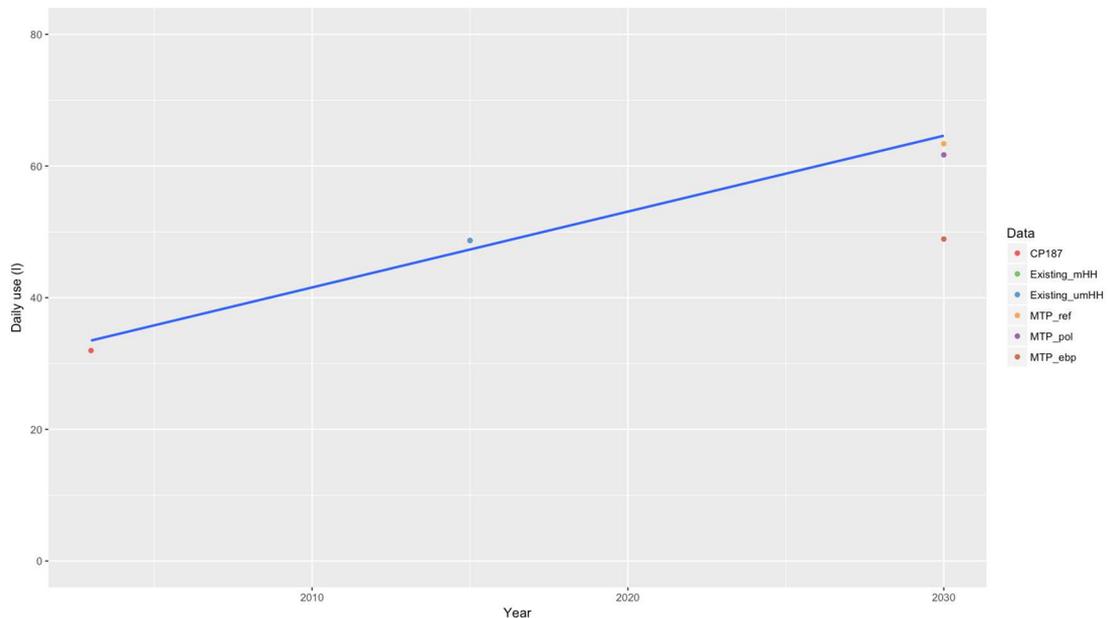
Figure 17 shows the following data points on daily shower volumes (l/day):

- 2003 from WRc CP187 report,
- 2016 from Table 2 (Existing\_mHH) and Table 3 (Existing\_umHH), both are approximately 49 l/day,
- 2030 from the MTP reference, policy and early best practice scenarios.

These data points assume an average occupancy for households in their specific years. The blue line shows a linear fit from the 2003, 2015/16 and MTP reference scenario. This shows a rising trend, which is consistent with the observations that shower use is increasing (in terms of ownership, frequency and flow rate).

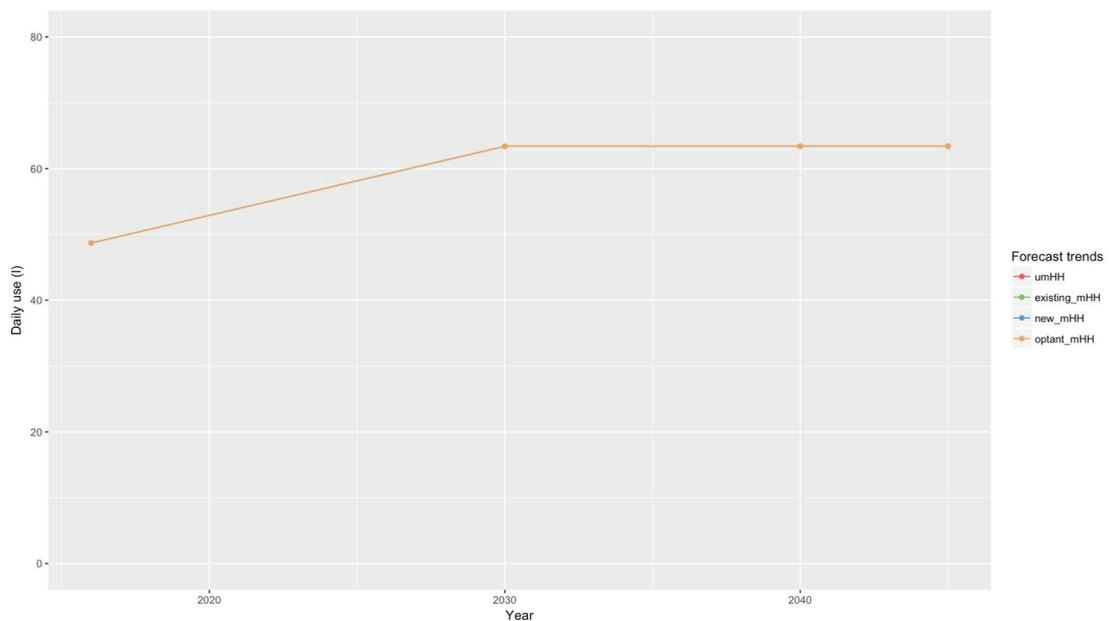
We have chosen not to fit trend line through the MTP Early Best Practice point as this assumes a very high proportion of water efficient showers being installed in new and existing households (which is not evident in current practice). This is used in the development of the lower PCC trend discussed in the alternative scenarios in Section 5.6.

**Figure 17** Trend of daily volume of water used for showering



Using the trend line from Figure 17 and assuming that shower volumes per day plateau at the MTP reference scenario in 2030 and remain flat over the rest of the planning period, we have produced a predicted trend for shower use as shown in Figure 18. There is no evidence for different house types having different trends, so the same trend is used for all house types. This is shown in the following figure.

**Figure 18** Future trend for daily volume of water used for showering (unique trend for all house types)



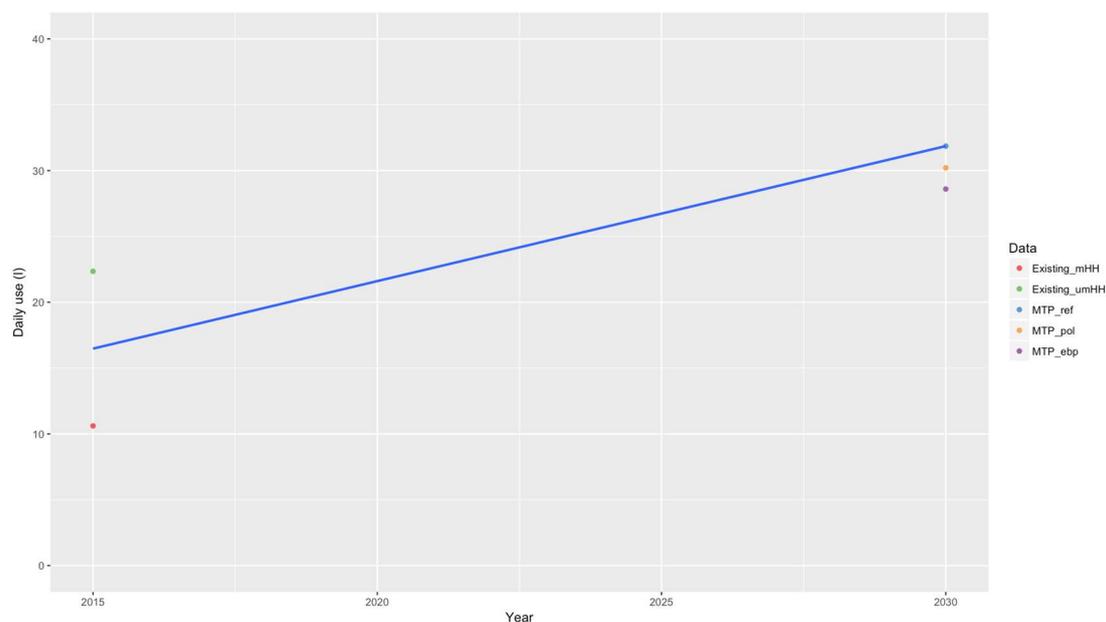
From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

### 5.5.3 Bath use

For bath use trends, we have used the overall household daily water use from baths. Like showering, bath use is mix of behaviour, frequency of use and volume per use. Figure 19 shows the evidence for daily volume of bath use from the following data points (l/day):

- 2016 from the bath use in Table 2 and Table 3,
- 2030 from the MTP reference, policy and early best practice scenarios.

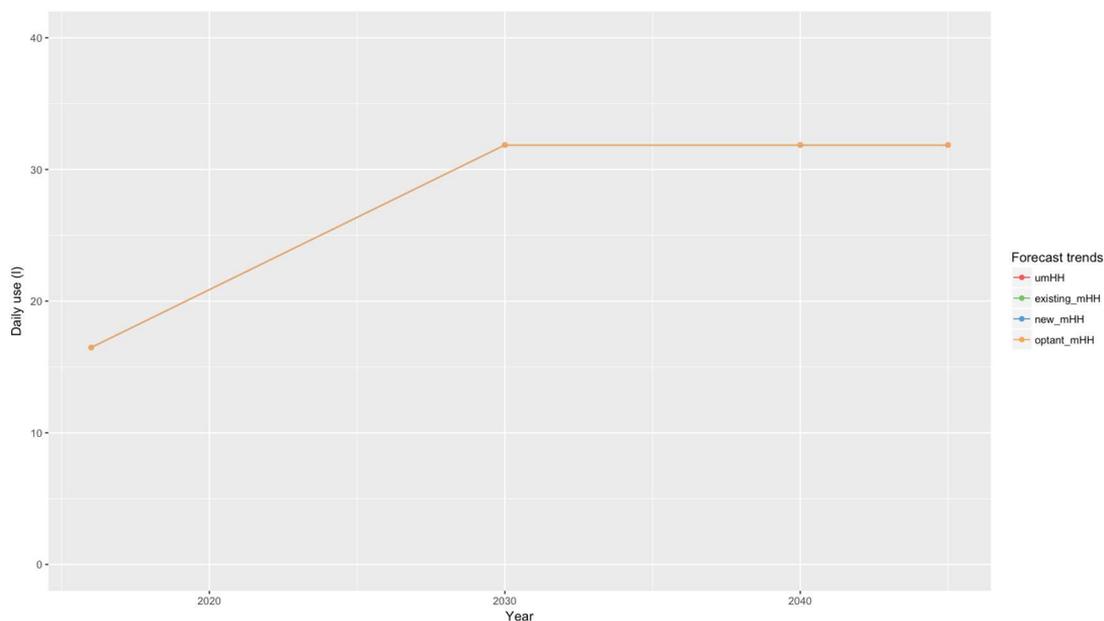
**Figure 19** Trend of daily volume of water used for bath use



The blue line in Figure 19 is a linear fit of the 2016 and 2030 data. Using this trend, and assuming that bath use then levels off at 2030 to the end of the planning period, we have created the future trend shown in Figure 20. We have assumed that all household types show the same trend.

From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

**Figure 20** Predicted trends of daily volume of water used for bath use (unique trend for all house types)



### 5.5.4 Washing machine use

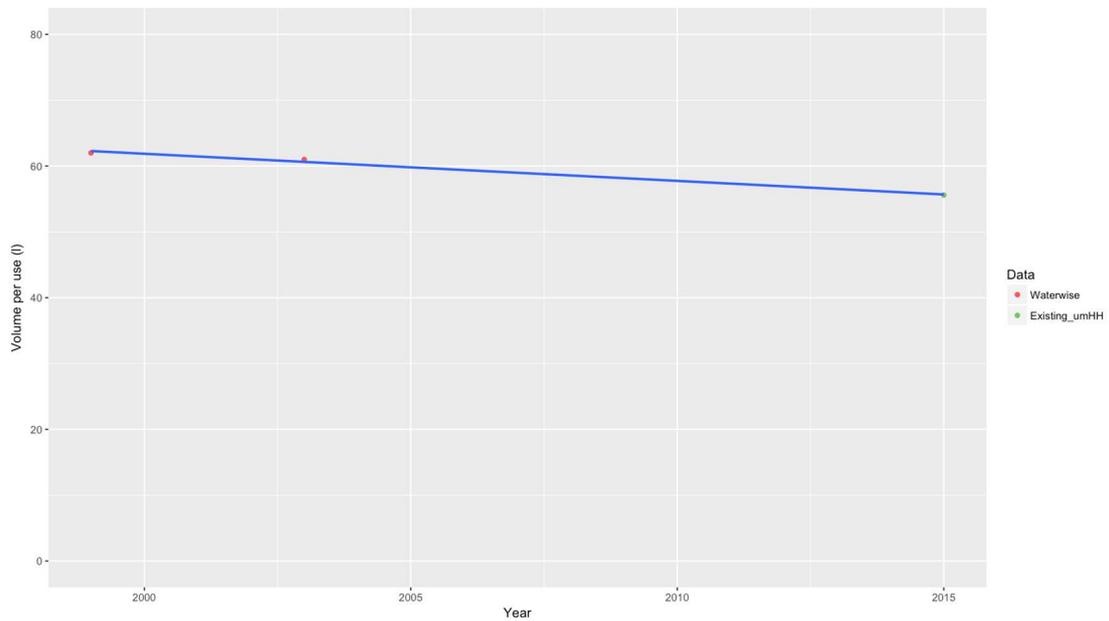
For washing machine use, the following evidence has been used to derive an historic trend in volume per use:

- Waterwise data on washing machine volume per use from 1999 and 2003,
- Washing machine volume per use in 2016 from Table 3.

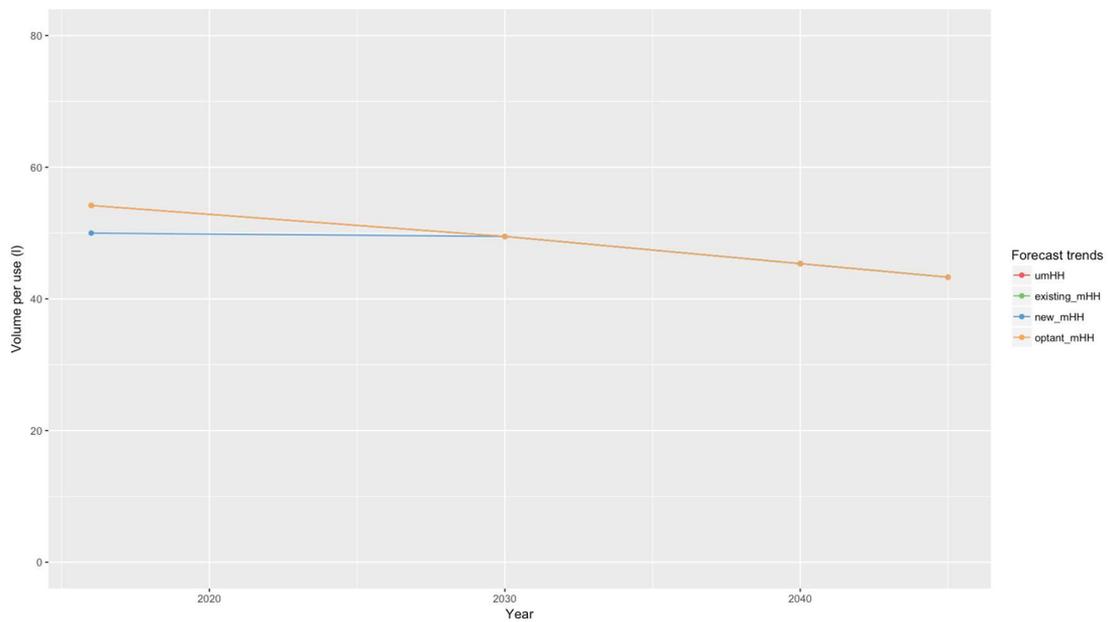
This data was used to produce a linear trend over time shown in Figure 21 (blue line). The volume per use has a trend over time to reflect the improvement in technologies to reduce energy and water use.

For the future trend in washing machine volume per use, we have extrapolated this trend to the end of the planning period (assuming continuous developments in technology). This trend is applied to all household types except new properties. These are assumed to have a starting point of 50 l/use in 2016. The resulting future trends are shown in Figure 22. Rates of change are then computed from these trends and incorporated in the model.

**Figure 21** Historic trend in washing machine volume per use



**Figure 22** Future trend of washing machine volume per use



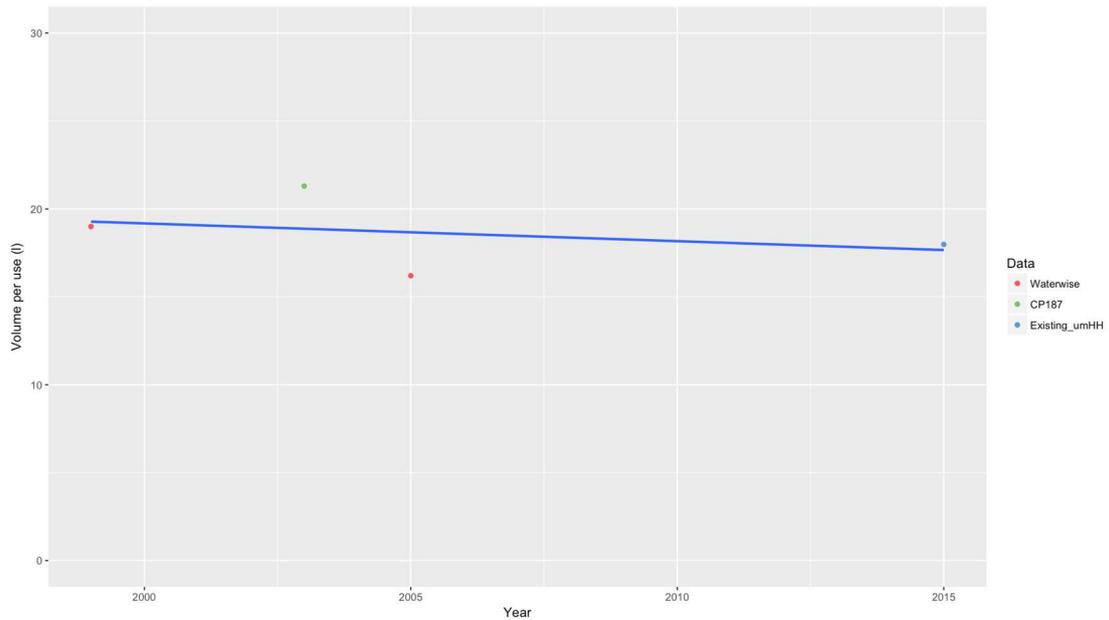
### 5.5.5 Dish washer use

For dishwasher use, the following evidence has been used to derive an historic trend in volume per use:

- Waterwise data on washing machine volume per use from 1999 and 2003,
- Washing machine volume per use in 2016 from Table 3.

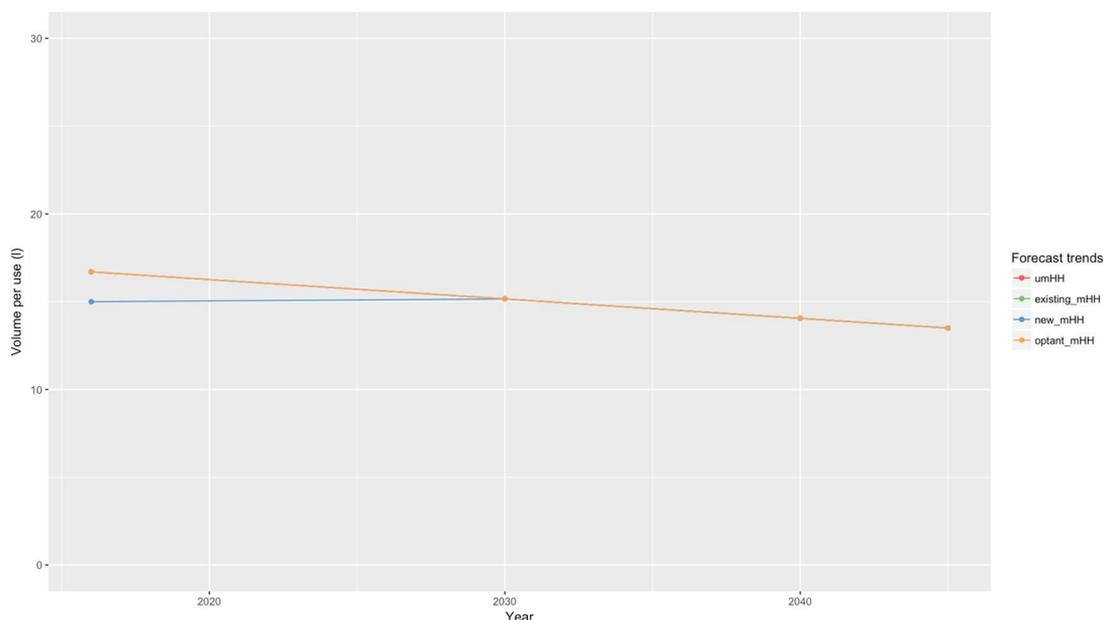
This data was used to produce a linear fit over time shown in Figure 23 (blue line). The volume per use has a trend over time to reflect the improvement in technologies to reduce energy and water use.

**Figure 23** Historic trend in dish washer volume per use



For the future trend in dish washer machine volume per use, we have extrapolated this trend to the end of the planning period (assuming continuous developments in technology). This trend is applied to all household types except new properties. These are assumed to have a starting point of 15 l/use in 2016. The resulting future trends are shown in Figure 24. Rates of change are then computed from these trends and incorporated in the model.

**Figure 24** Future trends of dish washer volume per use



### 5.5.6 Micro-component rate of change by house type

Based on the analysis detailed in the previous section, a series of trend have been developed by micro-component. These are summarised in the following table:

**Table 10** Micro-component rate of change by property type

micro-component	property type	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12
		start	start	start	start	start	start
		2020/21	2025/26	2030/31	2035/36	2040/41	2045/46
WC flushing	Unmeasured (umHH)	-0.126	-0.144	-0.136	-0.008	-0.008	-0.008
	Existing measured (existing mHH)	-0.116	-0.131	-0.122	-0.008	-0.008	-0.008
	New measured (new mHH)	-0.038	-0.040	-0.035	-0.008	-0.008	-0.008
	Optant measured (optant mHH)	-0.065	-0.069	-0.061	-0.008	-0.008	-0.008
	Change of occupier measured (selective mHH)	-0.126	-0.144	-0.136	-0.008	-0.008	-0.008
Shower	Unmeasured (umHH)	0.077	0.071	0.053	0.000	0.000	0.000
	Existing measured (existing mHH)	0.090	0.083	0.061	0.000	0.000	0.000
	New measured (new mHH)	0.082	0.076	0.056	0.000	0.000	0.000
	Optant measured (optant mHH)	0.098	0.089	0.066	0.000	0.000	0.000

	Change of occupier measured (selective mHH)	0.077	0.071	0.053	0.000	0.000	0.000
<b>Bath</b>	Unmeasured (umHH)	0.190	0.160	0.110	0.000	0.000	0.000
	Existing measured (existing mHH)	0.216	0.178	0.121	0.000	0.000	0.000
	New measured (new mHH)	0.201	0.167	0.115	0.000	0.000	0.000
	Optant measured (optant mHH)	0.228	0.186	0.125	0.000	0.000	0.000
	Change of occupier measured (selective mHH)	0.190	0.160	0.110	0.000	0.000	0.000
<b>Dish Washer</b>	Unmeasured (umHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
	Existing measured (existing mHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
	New measured (new mHH)	0.004	0.004	-0.004	-0.037	-0.038	-0.040
	Optant measured (optant mHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
	Change of occupier measured (selective mHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
<b>Washing machine</b>	Unmeasured (umHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046
	Existing measured (existing mHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046
	New measured (new mHH)	-0.004	-0.004	-0.011	-0.042	-0.044	-0.046
	Optant measured (optant mHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046
	Change of occupier measured (selective mHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046

After 45/46 rate of change is assumed to be zero for each micro-component.

## 5.6 Micro-component trend model – alternative scenarios

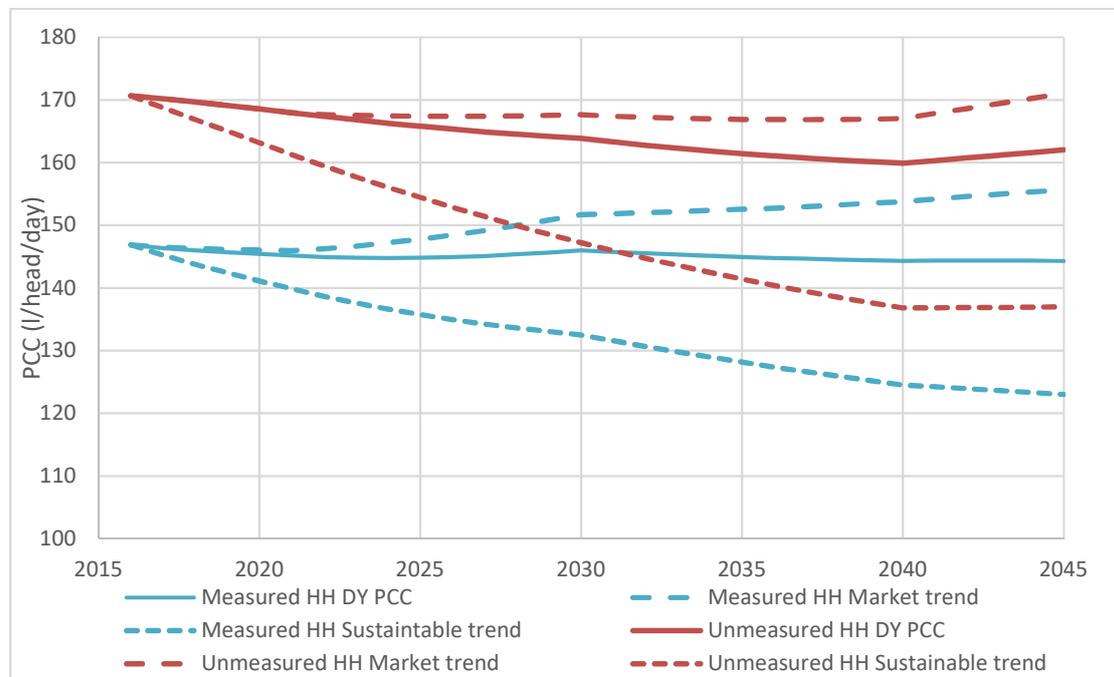
Two scenarios based on micro-component trends are added to account for variations within the future predicted rate of change in consumption.

Firstly, sustainable development, in this most extreme efficiency scenario, we have assumed that water saving is driven by both technological advancements and attitudinal changes. Sophisticated filtration technology would allow recirculation of shower water saving both energy and water. Waste water and washing functions are fulfilled by greywater recycling, aided by hydrophobic frictionless surfaces. Bathing is pretty much obsolete.

Secondly, market trend, this scenario assumes that the projected trend in micro-components does not continue beyond 2022. This would require a situation such as Brexit where UK building regulations may be decoupled from current standards and the logical decline in flush volumes is curtailed. The observed upward trend in showering continues to increase.

The variation in the trends is shown in Figure 25 for measured and unmeasured household PCC. These upper and lower scenarios may be used in the demand forecast uncertainty component of headroom.

**Figure 25** Variation in base line (DY) PCC trends



## 5.7 Base Year Calibration

For each of the household segments, the OVF models are applied using the base year occupancy values. The OVF calculated PHC is then calibrated to the normal year annual average (NYAA) value. Further details of the NY calculations are described in section 6, however it is important to note that the NY factor is applied within the base year (BY) calibration to ensure that the rate of change over time for each component is not affected by annual variation that might be contained within the BY. The zonal reported measured and unmeasured BYAA are factored to NYAA. The zonal PHC values for the non-reported figures; existing measured, new properties measured, optant measured, selective/compulsory measured and change of occupier measured are calculated proportionally based on the NYAA measured value using the OVF calculated PHC in each segment.

## 5.8 Climate change

Climate change impacts on consumption have been calculated in accordance to UKWIR 13/CL/04/12 Impact of Climate Change on water demand. Median percentage climate change impacts on household demand at 2040, relative to 2012 are published for each river basin within the UK. SES Water sits entirely within the Thames basin. Therefore, the dry year annual average forecasts have a 0.88% increase in consumption over that period. As the base year is now 2015/16 and the final forecast year is 2079/80 the percentage change is shifted along and projected to the 2079/80 planning year as there has been no further evidence since this report. Therefore, as the forecast period is longer, the final percentage is

larger than the figure printed in the guidance with a predicted impact in 2079/80 of 2.0 % for DYAA. If the forecast were to be run under a critical period scenario the percentage affected by climate increases to 5.5%. When critical period is selected the appropriate climate change factor is applied in a linear fashion across the forecast period.

The model includes functionality to output forecasts with and without climate change factors. The additional demand from climate change is added to the external use micro-component only. The volume attributed to climate change is displayed in a separate row in the top section of the outputs.

## 5.9 Trends, scenarios and uncertainty

Further work was carried out using a Monte Carlo approach, which has been applied at company (MI/d) and at property level (PHC) split by measured and unmeasured to give an idea of the statistical variance and error calculations throughout the modelling procedure, these are shown in Figure 26 and Figure 27.

Population and property errors; for the population and properties we apply the UKWIR guideline<sup>10</sup> errors to a normal distribution (which we note is truncated at zero for the unmetered figures). The groups within the overall population and property figures are varied (where the figure is not fixed) and then normalised to sum to an overall population and property figure varied with the UKWIR errors. Note that the precise implementation requires a re-normalisation process at each time-step; as this process is somewhat complex we merely summarise the process here.

Modelling error has been derived from the standard statistical outputs from the micro-component linear modelling. It combines error within the predictor variables, modelling error and errors in the trends.

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<sup>10</sup> UKWIR 15/WR/02/8 WRMP19 methods – population, household property and occupancy forecasting

Figure 26 Company level measured HH consumption Monte Carlo error distribution

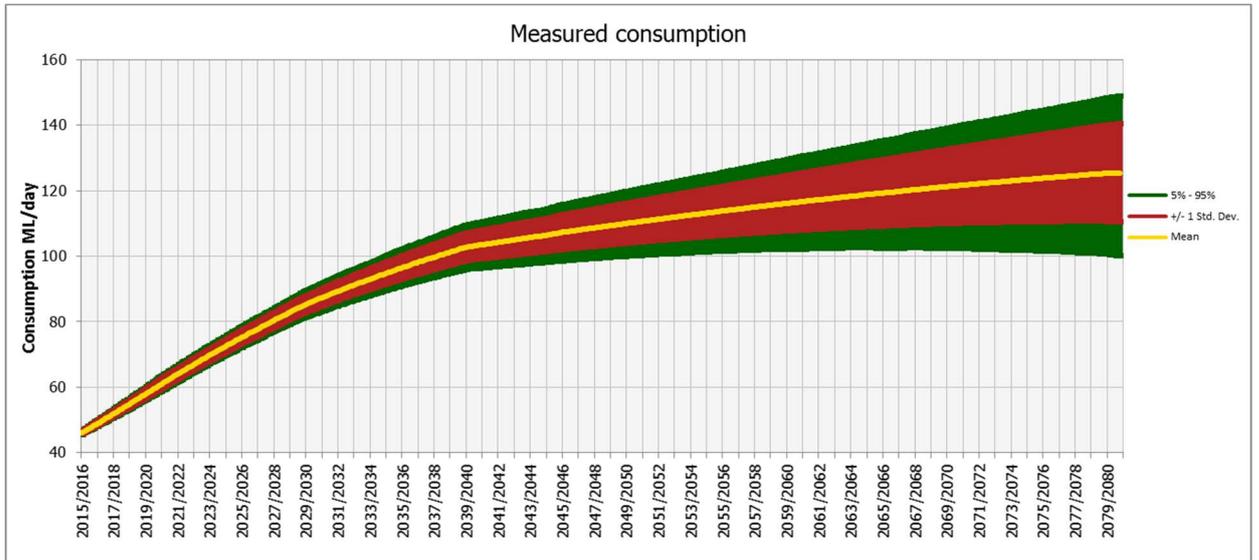
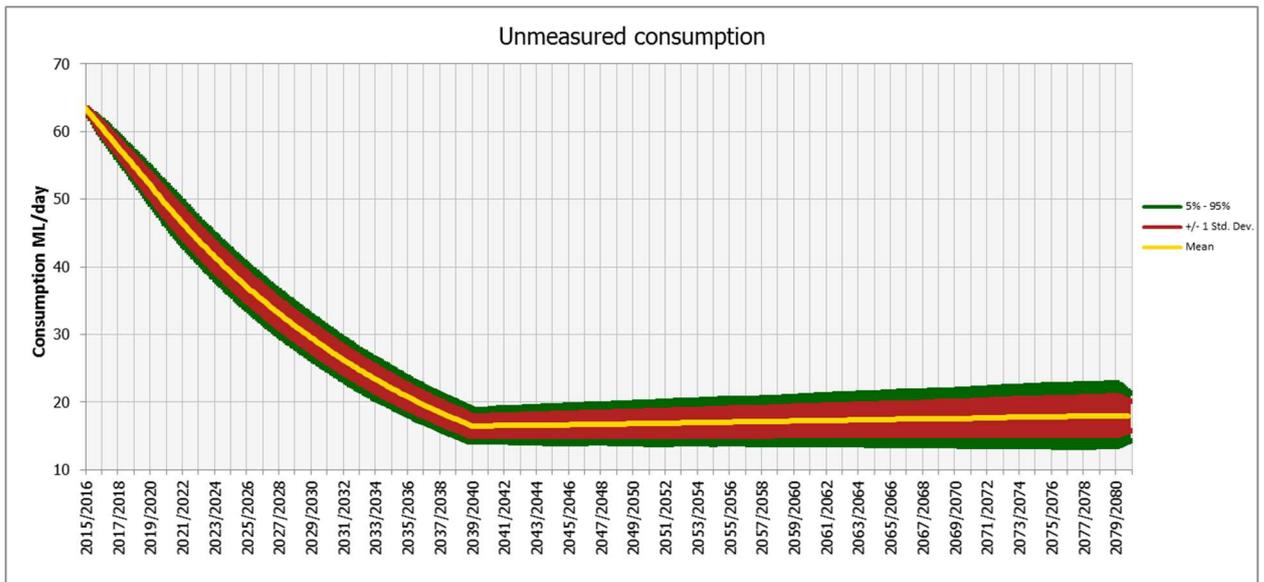


Figure 27 Company level unmeasured HH consumption Monte Carlo error distribution



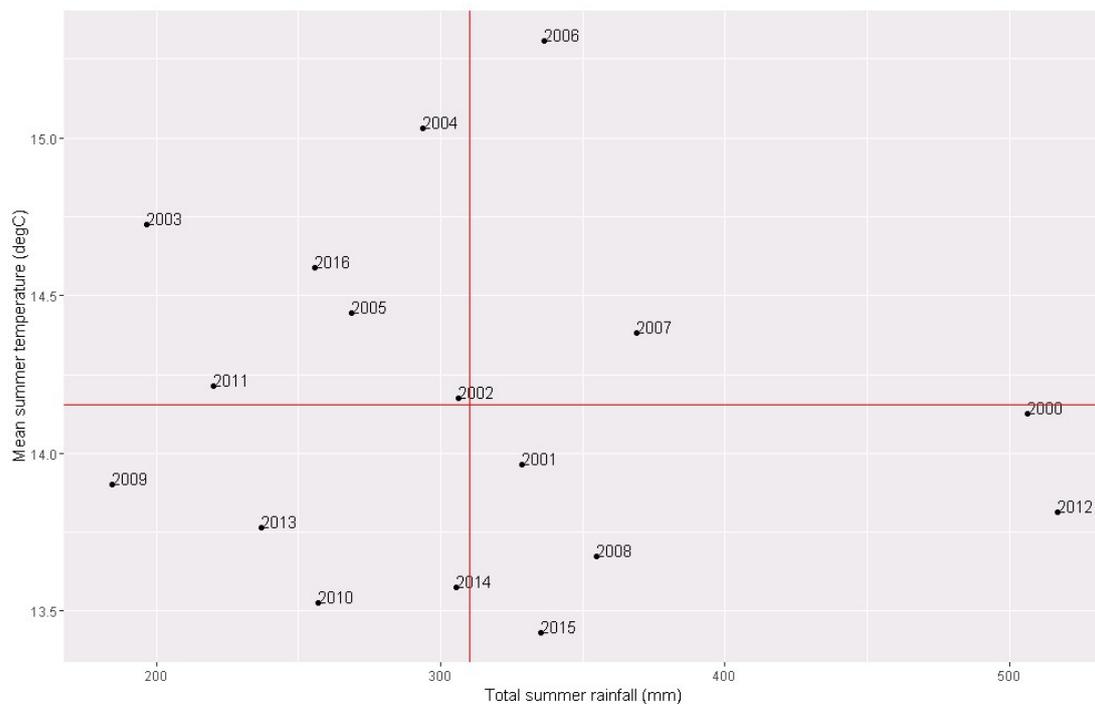
The results of this section are not used within the forecasting process, but are input into the headroom assessments. The graphs in Figure 26 and Figure 27 provide a graphical representation of the uncertainty surrounding the household consumption forecast.

## 6 Consumption uplifts for normal, dry year and critical period

The application of NYAA was touched on in section 5.7. In this section the full methodology and application is explained. The methodology for the NYAA and DYAA factors comes from the UKWIR guidance report number 15/WR/02/9 – household consumption forecasting.

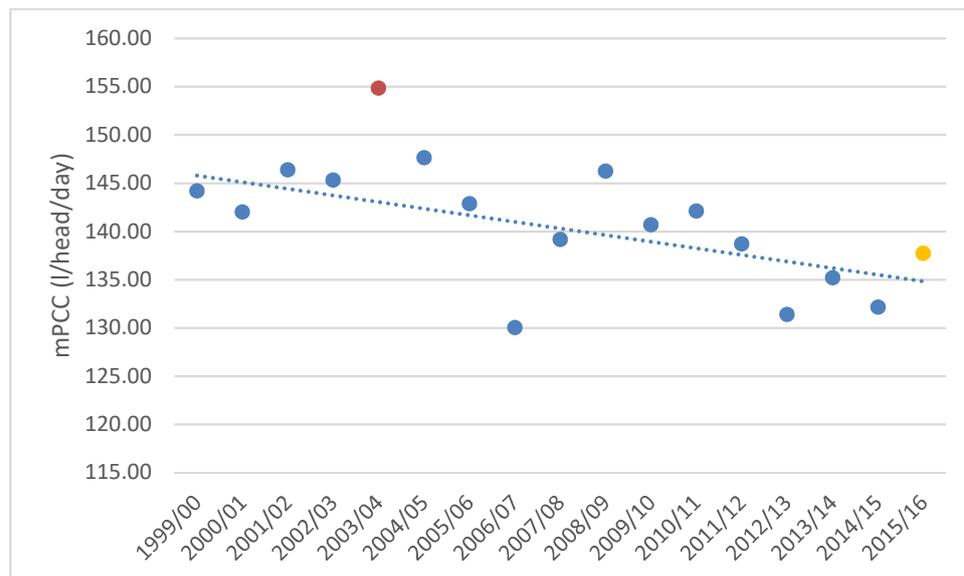
Stage one is to assess the weather data, more specifically summer temperature and rainfall. Each factor is summarised for the summer months for each year. Total summer rainfall is plotted against mean summer temperature, with the mean of all years for the two factors plotted as ablines on the graph. This graph is shown in Figure 28. A judgement is made as to which is the hottest and driest year; 2003/04, 2004/05 and 2011/12 appear the strongest dry years in within the top left quadrant.

**Figure 28: Quadrant plot for determining the dry year**

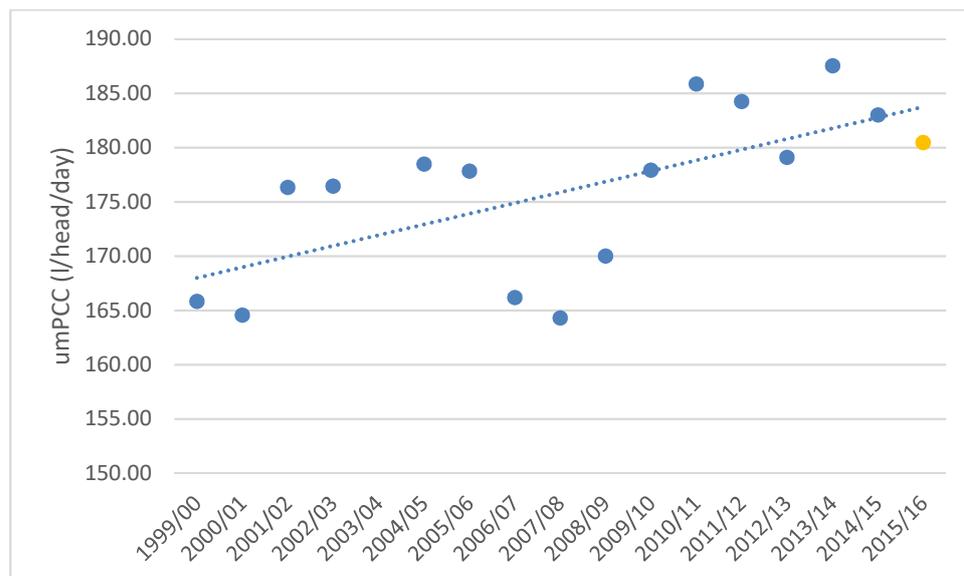


Stage two is to analyse the PCC trends for measured and unmeasured, these are done separately to account for the difference in trend and also the potential difference in impact of the dry year.

**Figure 29** Reported PCC trend - measured properties (dry year indicated in red, base year indicated in yellow)



**Figure 30** Reported PCC trend - unmeasured properties (base year in yellow)



The selection of the DY is done using the measured PCC values, shown in Figure 29. The reason for this is that measured values are deemed to be more accurate and less variable due to better quality data and fewer adjustments made with relation to supply pipe leakage. When assessing Figure 29, 2003/04 stands out as the year that responds the strongest out of the three possible dry year selections. In 2006/07 several companies enforced hosepipe bans especially in the South East of the UK. Whether or not SES Water enforced the ban, media coverage of the ban has been shown to decrease consumption across many of the water companies, in fact 2006/07 does not appear strong in the quadrant plot either. The dry year factor is calculated by removing the dry year, then calculating a trend line through the remaining points. The dry year factor is the reported figure divided by the modelled figure.

Normal year factor calculations are calculated in a similar way, using the same trend line which excludes the dry year point. The normal year factor is the modelled figure divided by the reported figure (yellow dot in Figure 29 and Figure 30). As stated previously, this is done separately for measured and unmeasured.

The dry year factor is calculated to be 1.0827, measured normal year factor is 0.9790 and the unmeasured normal year factor is 1.0183. The WRMP14 forecast used a 1.10 dry year factor, which was using 03/04, no normal year adjustment factor was applied.

Critical period calculations are done in accordance to the methodology stated in UKWIR 06/WR/01/7. Distribution input (DI) is used due to the methodology requiring daily consumption figures. Despite DI including leakage it is the best source of data available. From the daily data a weekly rolling mean is calculated. For each (financial) year, the peak week and the annual average are calculated. A long term annual average is then calculated from all of the years in the time series, and the critical period peak week factor is the maximum peak week within one of the dry years (top left quadrant). The peak week was selected from 2003/04, with a result of 1.4949. WRMP14 used a 1.50 critical period adjustment, the methodology was assessed and deemed out of line with the UKWIR peak week guidance, the updated figure is therefore a reflection of a minor change in methodology to use a long term annual average rather than a single annual average in the dry year.

Application of the NY factor is different to the DY and CP factors. The base year to normal year is applied before the calibration of the OVF calculated PHC, the reported figures are adjusted prior to this step so that the forecast is run from the normal year. Once the normal year forecasts are calculated the DY and CP factors are applied. These factors are independent of each other in that they are both applied to the NY forecast. Either option can be selected within the model. The baseline forecast for SES is as a DYAA. CP can be selected as an alternative scenario.

A summary of the NYAA, DYAA and CP factors are summarised in Table 11.

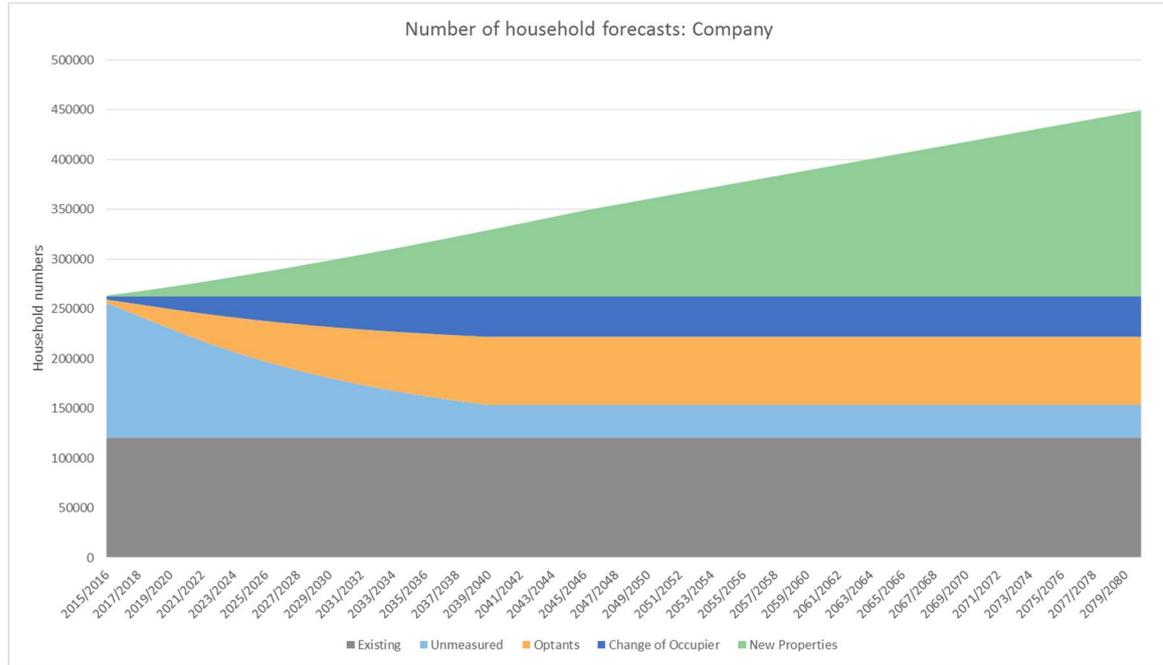
**Table 11 Summary of factors applied in the household forecast**

<b>Factor</b>	<b>WRMP19</b>	<b>WRMP14</b>
Normal to Dry year factor (all households)	8.3%	10%
Base to Normal year factor (measured households)	-2.1%	0
Base to Normal year factor (unmeasured households)	1.8%	0
Normal to Critical period factor (all households)	49.2%	50%

## 7 Household consumption outputs

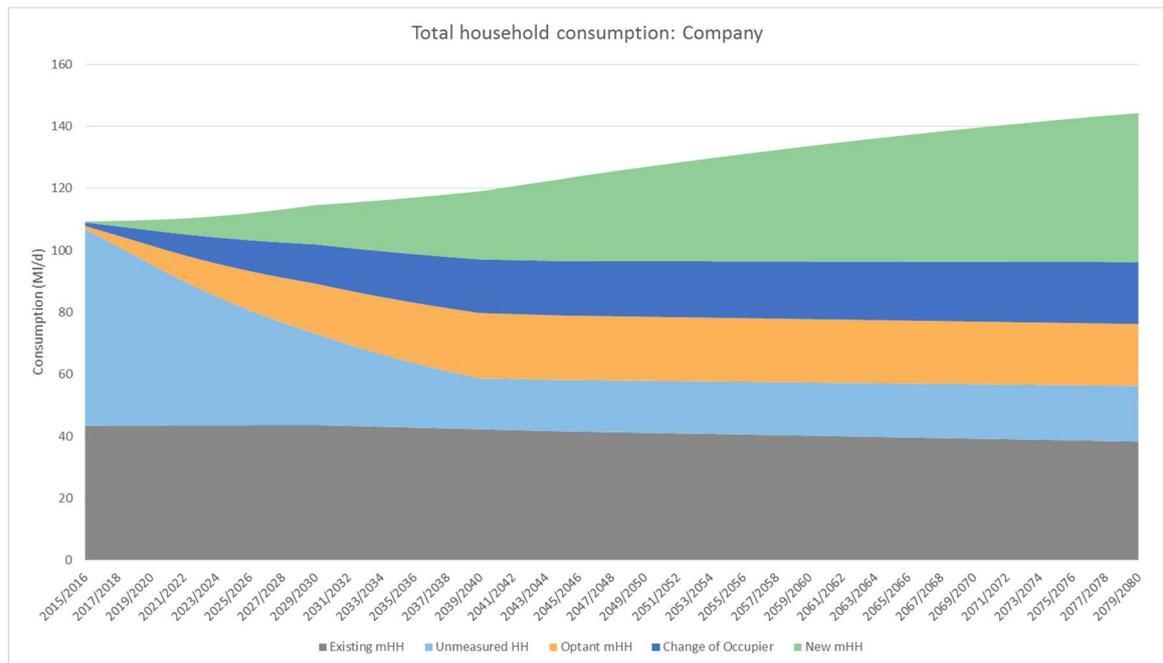
Graphical outputs for the central property forecast only (DYAA) are shown in figures 32 and 33. The central data is provided in tabular form in Table 13.

**Figure 31 Total number of households, split by household segment**



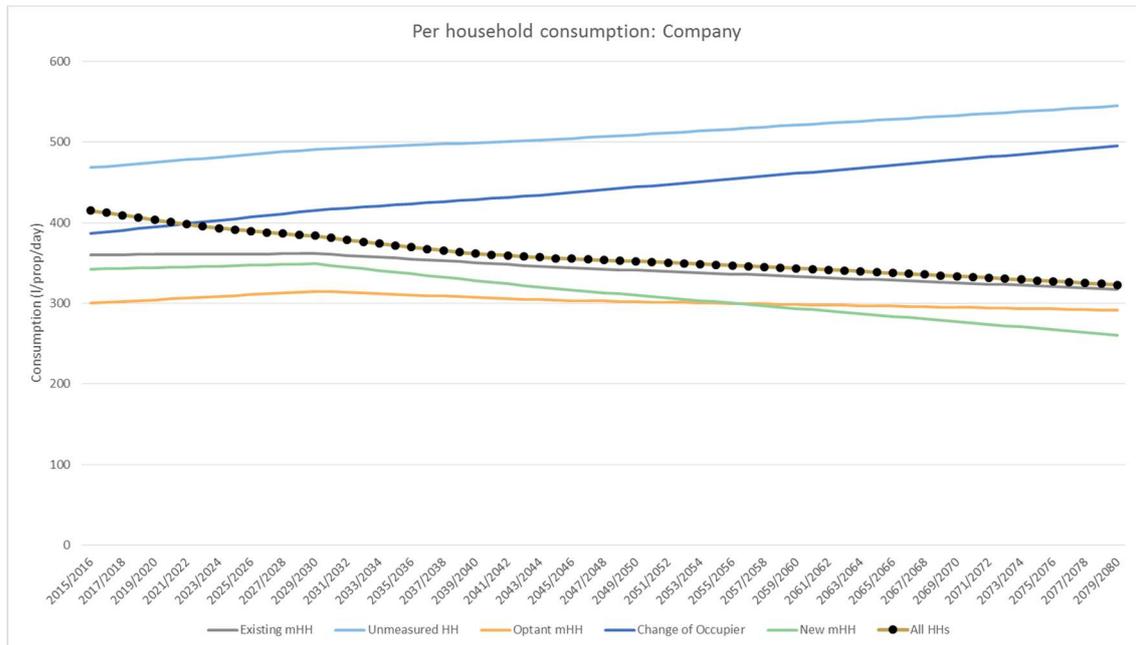
The total number of households, shown in Figure 31, increases from 263,451 to 446,691, so a 69.6% increase over the forecasting period.

**Figure 32 Total household consumption (MI/d), split by household segment**



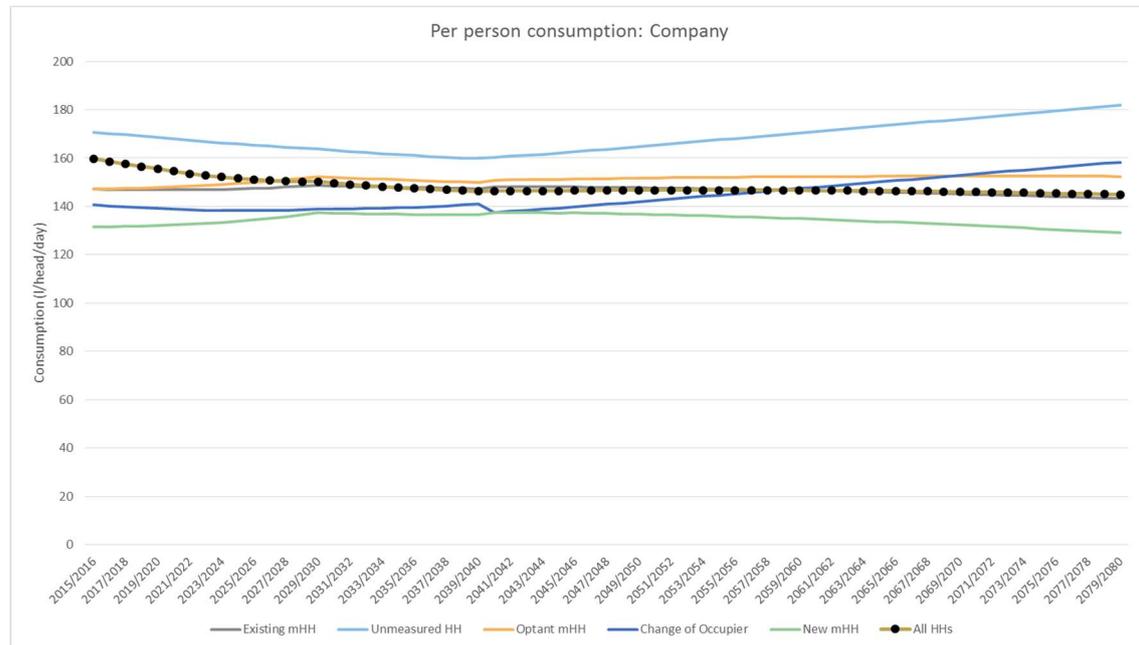
Total company household consumption increases from 109.36 MI/day to 144.26 MI/day, which is a 31.9% increase in demand over the forecast period, shown in Figure 32.

**Figure 33** Company level PHC, split by household segment



Therefore, the PHC must decrease over the forecasting period, this is shown in Figure 33. The total average PHC decreases from 415.10 l/property/day to 322.95 l/property/day. Each of the household segments have different trends, with the unmeasured households increasing from 468.13 l/property/day to 544.76 l/property/day. Each of the measured segments remain quite stable, with a slight rise and then fall dependent on the rate of change developed from measured and MTP figures. The overall decrease in PHC is a function of the unmeasured households converting to optant properties with a lower PHC.

Figure 34 Company level PCC, split by household segment



Company level PCC has a similar trend to PHC, with a slight decrease from 159.77 to 144.93 l/head/day. Unmeasured PCC shows an increasing trend which is different compared to the PHC trend, this is due to the increase in occupancy within this segment, shown in Figure 35. The lower occupancy properties convert to optants, while the higher occupancy properties remain in the unmeasured segment. The measured segments show a rise until 2030, this is based on predicted increase in personal washing and then levels off. There is a small ‘kink in change of occupier PCC around 2029/30: this is due to small change in assumed occupancy, as illustrated in Figure 35.

The unmeasured properties have a similar trend in personal washing, but they have increased reductions due to higher white goods and WC flush volumes at the start of the planning period.

Figure 35 Company level occupancy, split by household segment

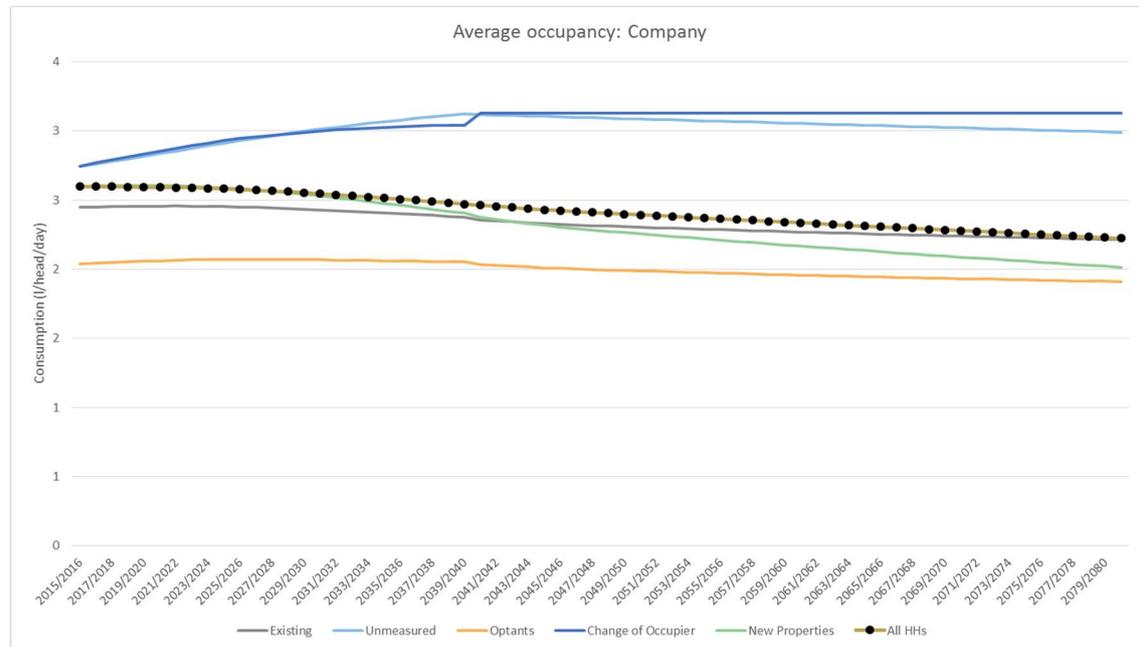


Figure 35 shows the trends in occupancy, the unmeasured rise is most notable, and as described before this is the impact of optant properties coming from the lower end of the occupancy distribution within the unmeasured households.

The Environment Agency (EA) requires micro-component models to report results following a particular classification, which is detailed below:

- WC (toilet) flushing
- Personal washing
- Clothes washing
- Dishwashing
- Miscellaneous (internal) use
- External use

In order to reconcile micro-component analysed by Artesia with the ones required by the EA WRMP tables, Artesia micro-components are redistributed. This is explicated by the following table.

Table 12 Redistribution of Artesia Micro-component to EA Micro-component

EA WRPG Micro-components		Micro-components	Multiplier	Tap use
WC (toilet) flushing	=	WC (Toilet flushing)	1	
Clothes washing	=	Washing Machine	1	
	+	Washer Drier	N/A	
	+	Internal Tap	0.02	Clothes washing
Personal washing	=	Showers	1	
	+	Power Showers	N/A	
	+	Baths	1	
	+	Internal Tap	0.03	Washing hands
	+	Internal Tap	0.45	Bathroom
Dishwashing	=	DISHWASHER	1	
	+	Hand Dishes	N/A	
	+	Internal Tap	0.32	Dishwashing
External use	=	Garden Hose	1	
	+	Garden Sprinkler	1	
	+	Watering Can	1	
Miscellaneous (internal) use	=	Internal Tap	0.08	Cleaning
	+	Internal Tap	0.07	Cooking
	+	Internal Tap	0.04	Drinking
	+	Wastage	1	

An overview of the final forecast for DYAA is shown in Table 13.

**Table 13** DYAA household consumption forecast – central property forecast

	AMP6					AMP7					AMP8	AMP9	AMP10	AMP11	AMP15	AMP18
Company Consumption (Ml/d)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
Total company	109.36	109.39	109.49	109.63	109.80	109.99	110.25	110.59	111.00	111.45	114.58	116.54	119.03	122.98	136.63	144.26
Measured	45.96	48.84	51.75	54.71	57.74	60.80	63.77	66.67	69.50	72.24	85.06	94.50	102.58	106.40	119.27	126.30
Unmeasured	63.40	60.55	57.74	54.91	52.06	49.19	46.48	43.92	41.50	39.21	29.52	22.04	16.45	16.58	17.36	17.96
Company PHC (l/prop/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
Company average	415.10	412.10	409.18	406.28	403.40	400.56	397.95	395.54	393.32	391.30	383.58	371.80	361.48	355.90	338.60	322.95
Measured	358.99	357.67	356.66	355.88	355.31	354.91	354.69	354.62	354.66	354.81	356.51	351.41	346.18	340.38	321.86	305.28
Unmeasured	468.13	469.76	471.38	473.01	474.64	476.27	477.90	479.53	481.16	482.80	490.98	494.99	499.01	503.04	526.79	544.76
Company PCC (l/head/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
Company average	159.77	158.64	157.58	156.56	155.55	154.54	153.61	152.81	152.15	151.57	150.21	147.80	146.28	146.45	146.43	144.93
Measured	146.88	146.36	145.98	145.68	145.42	145.16	144.92	144.81	144.80	144.83	145.99	144.95	144.30	144.29	143.20	140.85
Unmeasured	170.64	170.16	169.67	169.14	168.57	167.95	167.36	166.80	166.28	165.79	163.85	161.42	159.89	162.02	173.23	182.02
Measured PCC (l/head/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
WC (toilet) flushing	32.08	31.07	30.09	29.19	28.32	27.48	26.67	25.91	25.19	24.49	21.35	21.16	21.02	20.95	20.75	20.38
Personal washing	68.91	69.64	70.44	71.23	72.02	72.79	73.56	74.37	75.22	76.08	80.75	80.29	80.08	80.26	78.88	77.13
Clothes washing	13.90	13.87	13.85	13.82	13.78	13.74	13.68	13.63	13.58	13.53	13.33	12.95	12.57	12.21	12.45	12.42
Dishwashing	14.53	14.47	14.42	14.37	14.32	14.27	14.22	14.17	14.13	14.09	13.98	13.91	13.88	13.89	13.75	13.50
Miscellaneous (internal) use	16.00	15.81	15.64	15.48	15.34	15.20	15.07	14.96	14.87	14.78	14.50	14.34	14.26	14.27	13.99	13.65
External use	1.46	1.50	1.55	1.59	1.64	1.68	1.72	1.77	1.81	1.85	2.08	2.29	2.50	2.70	3.39	3.76
SUM	146.88	146.36	145.98	145.68	145.42	145.16	144.92	144.81	144.80	144.83	145.99	144.95	144.30	144.29	143.20	140.85
Unmeasured PCC (l/head/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
WC (toilet) flushing	36.59	35.53	34.46	33.40	32.34	31.28	30.24	29.20	28.19	27.18	22.35	21.89	21.55	21.70	23.03	24.06
Personal washing	83.91	84.73	85.54	86.31	87.06	87.77	88.48	89.21	89.94	90.68	94.54	93.35	92.67	94.11	99.90	104.36
Clothes washing	12.15	12.03	11.91	11.79	11.67	11.54	11.42	11.30	11.18	11.06	10.53	9.99	9.52	9.27	9.84	10.27
Dishwashing	17.02	16.95	16.87	16.78	16.69	16.60	16.51	16.43	16.35	16.27	15.93	15.68	15.53	15.72	16.69	17.43
Miscellaneous (internal) use	19.61	19.53	19.45	19.37	19.28	19.18	19.09	19.00	18.92	18.83	18.49	18.26	18.13	18.41	19.54	20.41
External use	1.34	1.39	1.44	1.49	1.53	1.58	1.63	1.67	1.72	1.77	2.00	2.25	2.50	2.81	4.24	5.47
SUM	170.64	170.16	169.67	169.14	168.57	167.95	167.36	166.80	166.28	165.79	163.85	161.42	159.89	162.02	173.23	182.02

The increase in company level household demand is largely due to the increase in the number of properties throughout the forecast period. PHC and PCC decline slightly which is largely based on the impact of increasing meter penetration. The PCC in the final year of this forecast is 144.93, with a total company household consumption of 144.26 MI/day.

## 8 Conclusions & Recommendations

A baseline household consumption forecast has been produced for the SES Water Resource Zone using micro-component modelling and forecasting, which is suitable for a zone with a low level of water resource planning concern.

The micro-component model has been developed using best available data from local and national datasets. The model is segmented by property type using unmetered, new build metered, change of occupier metered and optant metered households. The model is based on per household consumption (PHC), and includes linear modelling of key micro-components against occupancy to reflect the variation of PHC by occupancy within each household type. The model forecasts are developed from historic micro-component datasets and Market Transformation Programme predictions.

The results of the micro-component forecast give a 36.67 MI/day increase in household consumption for Dry Year Annual Average consumption, this is a 31.9% increase. This is largely driven by a 70% increase in the property forecast. Average PHC and PCC decrease throughout the forecast period, this is partly due to decreases in component demand due to market transformation, but mostly due to the shift from unmeasured to measured, properties. Average household PCC (mean of all household types) reduces from 160 to 145 l/person/day.

The model contains forecasts for Normal Year Annual Average, Dry Year Annual Average and Critical Period; with a breakdown of micro-components for each year of the forecast.

# Level 2 Appendix D. Demand Forecast Updates for the WRSE Regional Plan Report

# SES Water - Water Resources Support

Demand Forecast Updates for the WRSE Regional  
Plan

Level 2 Appendix D of Water Resource Management  
Plan Level 1 Appendix C

SES Water

October 2022

5197934/DG/070



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# Contents

Chapter	Page
<b>1. Introduction</b>	<b>5</b>
<b>2. Background to SES Water’s household consumption model</b>	<b>6</b>
<b>3. Review of model</b>	<b>6</b>
<b>4. Household population and properties</b>	<b>6</b>
4.1. Annual Review data	7
4.2. Edge Analytics data	7
4.3. Hidden and transient population	8
4.4. Property types	8
<b>5. Household occupancy rates</b>	<b>10</b>
5.1. Base year occupancy rates	10
5.2. Baseline forecast occupancy rates	11
<b>6. Household consumption</b>	<b>12</b>
6.1. Micro-component modelling and forecasting	12
6.2. Base year household consumption calibration	24
6.3. Outcome Delivery Incentive	25
<b>7. Non-household consumption</b>	<b>26</b>
<b>8. Non-household population and properties</b>	<b>26</b>
8.1. Property and population forecast	26
<b>9. Other demand components</b>	<b>28</b>
9.1. Leakage	28
9.2. Water taken unbilled	29
9.3. Distribution System Operational Use	29
9.4. Climate change	29
<b>10. Consumption uplifts factors</b>	<b>29</b>
10.1. Normal and dry year factors	29
10.2. Critical period factor	31
10.3. 1 in 200 and 1 in 500 drought event factors	32
<b>11. WRSE outputs</b>	<b>32</b>
<b>12. Summary</b>	<b>34</b>

## Tables

Table 4-1 - Population and property baseline forecast	6
Table 4-2 - Base year 2019/20 household population and property numbers data	7
Table 4-3 - Selected growth forecasts for SES Water	7
Table 4-4 - Hidden and transient populations	8
Table 4-5 - Property types	9
Table 4-6 - Baseline forecast metering data	10
Table 5-1 - Base year occupancy rates	11
Table 6-1 - External use OVF values	13
Table 6-2 - Percentage of water usage per micro-component for SES Water's WRMP19	14
Table 6-3 – Micro-component data sources presented in Appendix E2 of SES Water's Final WRMP19	17
Table 6-4 - Ownership and frequency values from the Get Water Fit data	18
Table 6-5 - Ownership values (represented as percentages) from Get Water Fit data	20
Table 6-6 - Average water use for showering	20
Table 6-7 - Base year 2019/20 household consumption	25
Table 6-8 - Metering savings	25
Table 8-1 - Base year non-household population and property data	26
Table 8-2 – Base year non-household PPC and PCC	26
Table 9-1 – Leakage values	28
Table 10-1 - Summary of factors applied in the household forecast	32
Table 10-2 – 1 in 200 and 1 in 500 drought event factors	32
Table 11-1 - Growth forecasts for DLP template	32
Table 11-2 - Model switches	33

## Figures

Figure 6-1 - Household water consumption	16
Figure 6-2 - WRMP19 micro-component data	17
Figure 6-3 - Measured micro-component consumption NYAA	22
Figure 6-4 - Unmeasured micro-component consumption NYAA	22
Figure 6-5 - Measured micro-component consumption DYAA	23
Figure 6-6 - Unmeasured micro-component consumption DYAA	23
Figure 6-7 - Measured micro-component consumption DYCP	24
Figure 6-8 - Unmeasured micro-component consumption DYCP	24
Figure 8-1 - Non-household property forecast	27
Figure 8-2 - Non-household population forecast	28
Figure 10-1 – Quadrant plot for determining the dry year	30
Figure 10-2 - Reported PCC trend - measured properties	30
Figure 10-3 – Reported PCC trend – unmeasured properties	31
Figure 11-1 - WRSE outputs worksheet	33

# 1. Introduction

For the 2019 Water Resources Management Plan (WRMP19) SES Water commissioned Artesia Consulting to develop a household consumption forecast. Artesia Consulting produced a household consumption forecast by using micro-component modelling and forecasting. Further details of this modelling and forecasting are provided in Section 2.

In April 2020 SES Water commissioned Atkins to update their household consumption forecast model (herein referred to as the model) developed by Artesia Consulting to enable SES Water to produce a demand forecast for the Water Resources South East (WRSE) regional plan.

To be able to produce a demand forecast for the WRSE regional plan the following tasks needed to be undertaken. These tasks were completed following the guidance provided in the demand forecast method statement which was produced by WRSE<sup>1</sup> and with reference to the then draft Water Resources Planning Guideline (WRPG)<sup>2</sup>. The WRPG has since been finalised<sup>3</sup>.

- Amend the model base year to 2019/20 and the baseline forecast to 2099/2100.
- Incorporate base year population and property data and incorporate population and property forecasts produced by Edge Analytics into the model.
- Incorporate company policy/funded metering (including the compulsory metering expected in Asset Management Plan (AMP) period 7) assumptions for AMP7 into the model (noting that from 2025/26 onwards, the WRPG states that baseline demand should not include any further water efficiency or metering interventions from companies).
- Review the approach to micro-components included in the model and update where necessary according to latest available guidance and evidence base.
- Incorporate SES Water's leakage estimates into the model, both for unmeasured supply pipe leakage and distribution losses (noting that from 2025/26 onwards, the WRPG states that leakage should remain static).
- Incorporate into the model SES Water's current estimates of Water Taken Unbilled and Distribution System Operational Use.
- Review the climate change factors included in the model and amend where necessary according to latest available guidance.
- Develop and incorporate Normal Year Annual Average (NYAA), Dry Year Annual Average (DYAA) and Dry Year Critical Period (DYCP) (including 1 in 200 and 1 in 500 drought events) uplifts into the model.
- Develop and incorporate a non-household forecast into the model.

This report describes how these tasks were undertaken, including documenting the data used.

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<sup>1</sup> Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4

<sup>2</sup> Environment Agency, 2020, Water Resources Planning Guideline, draft for consultation, version 6.8

<sup>3</sup> Environment Agency, February 2021, Water Resources Planning Guideline, for publishing, version 9

## 2. Background to SES Water’s household consumption model

The WRMP19 model developed for SES Water used micro-component modelling and forecasting, which is suitable for a Water Resource Zone (WRZ) with a low level of water resource planning concern.

The model was developed using best available data from local and national datasets. The model is segmented by property type using unmeasured and measured, with measured households split into existing properties, new builds, optants as well as compulsory, selective, change of occupier and other metering programmes. The model is based on per household consumption and includes linear modelling of key micro-components against occupancy to reflect the variation of per household consumption by occupancy within each household type. The model forecasts are developed from historic industry and UKWIR micro-component datasets and Market Transformation programme predictions.

The property and population forecasts used in the model are taken from estimates provided by Experian.

The model produces forecasts for NYAA, DYAA and DYCP; with a breakdown of micro-components for each year of the forecast.

Further details of how the model was developed can be found in Appendix E2 of SES Water’s Final WRMP19<sup>4</sup>.

## 3. Review of model

Atkins undertook a review of version 4.4 of the model which was provided to Atkins by SES Water on 19<sup>th</sup> May 2020. The aim of the review was to enable Atkins to understand how the model functioned and highlight the input data required for the model to be updated.

The following sections (sections 4 to 11) explain the model updates undertaken, including the data used.

## 4. Household population and properties

The model required revised population and property forecasts. This involved updating the base year and baseline forecast population and property data. The base year and baseline forecast population and property data came from two sources:

- SES Water 2019/20 Annual Review
- Edge Analytics.

Table 4-1 shows how these sources of data were used in the model. Section 4.1 and 4.2 describe these data sources in more detail.

**Table 4-1 - Population and property baseline forecast**

Category	Source
Base year population	Edge Analytics (Housing-Plan-P)
Base year property numbers	SES Water 2019/20 Annual Review
Baseline forecast population	Edge Analytics (Housing-Plan-P)
Baseline forecast property numbers	Edge Analytics data (Housing-Plan-P) calibrated to the SES Water 2019/20 Annual Review data

<sup>4</sup> SES Water, September 2017, WRMP19 Household consumption forecast: baseline forecast

As the model calibrates the Edge Analytic property data to SES Water’s 2019/20 Annual Review property data, the model therefore deviates from the occupancy rates provided by Edge Analytics, although the rate of change in properties and therefore occupancy rates over the planning period remains consistent with the Edge Analytics forecast. The calibration is required to ensure there is consistency between SES Water’s customer database and the Edge Analytics data.

## 4.1. Annual Review data

Base year 2019/20 population and property figures were extracted from SES Water’s 2019/20 Annual Review and are presented in Table 4-2.

**Table 4-2 - Base year 2019/20 household population and property numbers data**

	Properties	Population
Measured	162,355	419,998
Unmeasured	108,685	307,037
<b>Total</b>	<b>271,040</b>	<b>727,035</b>

## 4.2. Edge Analytics data

Property and population forecasts for SES Water were supplied by Edge Analytics. Edge Analytics used the latest available Local Plan and Office for National Statistics (ONS) trend-based data, as well as other sources including the Greater London Authority (GLA). Forecasts were produced for a wide range of scenarios, by using a combination of trend, housing-led (incorporating housing need, housing requirements and actual planned scenarios) and employment-led forecasts, to account for the considerable uncertainty in the projections.

From the range of scenarios, there was the need to adopt one as a baseline growth forecast, supported by a selected number of additional growth projections that allows SES Water to account for uncertainty.

WRSE agreed on consistent property and population growth scenarios for companies across the region to base their demand forecasts on and provided guidance in a WRSE Method Statement<sup>5</sup>. Using the guidance provided in the WRSE Method Statement the relevant property and population forecasts were extracted for use in SES Water’s demand forecast. Table 4-3 provides a list of the scenarios WRSE decided should be included in the model and the growth forecasts which match these scenarios.

For the baseline forecast the Housing-Plan-P scenario was selected. The Housing-Plan-P scenario was developed using two approaches: a ‘top-down’ approach and a ‘bottom-up’ approach. WRSE adopted the ‘bottom-up’ approach as it is considered to more accurately represent the locations of new growth across Water Resource Zones (WRZs).

**Table 4-3 - Selected growth forecasts for SES Water**

Scenario	Selected growth forecast for SES Water
Baseline	Housing-Plan-P (bottom-up)
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H

The household population estimates comprise both people living in households and people living in communal establishments (population ‘not in households’), e.g. care homes, long-stay hospitals, students in halls of residence. Even though the property types for these customers may be classed as non-household, the water use is largely domestic, so they are counted as household customers for the purposes of the demand forecast.

<sup>5</sup> Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4.

Year-on-year projections of household population were provided for the above scenarios.

To allow the desired growth forecast to be used in the model a switch was added to the model, which allows the user to select the desired population and property forecast. The switch works by the user manually typing in the name of the population and property scenario they wish to run through the model. This scenario is then selected by the model.

### 4.3. Hidden and transient population

Edge Analytics (again as part of the WRSE collaborative study on population) provided data on the hidden and transient population within the SES Water area. The data used in the demand forecast was the mid-level estimate for irregular migrants, short-term residents and second addresses (not visitors). The base year figures provided by SES Water are shown in Table 4-4. Year-on-year forecasts were not available for this segment of population so these figures remained constant throughout the baseline forecast.

**Table 4-4 - Hidden and transient populations**

Hidden and transient population types	Population
Irregular migrants	8,801
Short-term residents	1,453
Second addresses	726
Visitors	0
<b>Total</b>	<b>10,980</b>

### 4.4. Property types

Within the model household properties are split into those which are measured and those which are unmeasured. Measured households are further sub-divided into the following categories:

- Existing
- New properties
- Optants
- Change of occupier.

The data required to determine the number of properties in each category for the base year and baseline forecast are explained in Section 4.4.1 and 4.4.2.

#### 4.4.1. Base year 2019/20

Base year household properties are split between measured households and unmeasured households. This split was determined by the data extracted from SES Water's 2019/20 Annual Review (see Section 4.1).

For the base year the number of new properties, the number of properties opting for a meter in-year (optants) and the number of properties metered on change of occupancy is required. Table 4-5 presents the base year properties in each of these categories and a brief explanation of how they have been determined.

**Table 4-5 - Property types**

Property type	Explanation	Number of properties in the base year 2019/20
Unmeasured properties	The number of unmeasured properties has been extracted from SES Water's 2019/20 Annual Review.	108,685
Existing measured properties	The number of existing measured properties has been calculated by subtracting the number of new properties, optants and change of occupier properties (method for calculating these properties types is provided in the rows below) from the total number of measured properties which was extracted from SES Water's 2019/20 Annual Review.	153,335
New properties (or new connections)	The annual number of new connections for 2019/20 has been calculated from SES Water's 2019/20 Annual Review. The total number of measured and unmeasured properties in a given year is subtracted from the previous year's total number of measured and unmeasured household properties to give the difference which is the annual number new connections.	2,620
Optants	The number of optant properties has been calculated from data included SES Water's 2019 Water Resources Planning Tables (row 45.2). The number of optant properties in 2019/20 has been used.	4,065
Change of occupier	The number of change of occupier properties has been calculated from data included SES Water's 2019 Water Resources Planning Tables. The number of properties metered on change of occupier (row 45.4) and the number of compulsory metered properties (row 45.3) in 2019/20 have been added together.	2,335
<b>Total number of household properties</b>		<b>271,040</b>

#### 4.4.2. Baseline forecast

To determine the proportion of properties in the optants and change of occupier categories, metering data was taken from the SES Water's 2019 Water Resources Planning Tables.

For the baseline forecast after AMP7 (2025/26 onwards) there is no metering on change of occupancy. This assumption is based on the WRPG which states '*your baseline customer demand should take account of customer demand without any further water efficiency or metering intervention from yourselves...*':

The number of change of occupier properties for each year of the baseline forecast has been calculated by adding together the number of properties metered on change of occupier (row 45.4 from SES Water's 2019 Water Resources Planning Tables) and the number of properties compulsory metered (row 45.3 from SES Water's 2019 Water Resources Planning Tables).

For optant metering the baseline forecast only included optant metering beyond AMP7 (2024/25) which was not encouraged by SES Water. Optant metering data for the baseline has been taken from the SES Water's 2019 Water Resources Planning Tables (row 45.2) and includes optant metering until 2029/30.

Table 4-6 presents the metering data included in the baseline forecast.

**Table 4-6 - Baseline forecast metering data**

Year	Change of occupancy and compulsory metering	Optants
2020/21	12,881	4,065
2021/22	12,745	3,828
2022/23	12,617	3,604
2023/24	12,496	3,394
2024/25	12,382	3,196
2024/26	0	2,006
2026/27	0	1,889
2027/28	0	1,779
2028/29	0	1,675
2029/30	0	1,577

## 5. Household occupancy rates

Occupancy rates for each property type are calculated by dividing the population by the number of properties. As discussed in section 4.1 and 4.2 the population data is supplied by Edge Analytics. Property data is also supplied by Edge Analytics, but this is calibrated to the property data from SES Water's 2019/20 Annual Review. These occupancy rates are used in the model to convert per household consumption (PHC) to per person consumption (PCC).

### 5.1. Base year occupancy rates

Table 5-1 provides an explanation on how occupancy rate has been derived for the base year.

**Table 5-1 - Base year occupancy rates**

Property type	Explanation	Occupancy rate in the base year 2019/20
Measured	The population data provided by Edge Analytics is split between measured and unmeasured households based on the proportion of the population reported to be living in measured and unmeasured households in SES Water's 2019/20 Annual Review. The population is then divided by the number of properties, which has been calculated by calibrating the property data provided by Edge Analytics to the property data in SES Water's 2019/20 Annual Review, to give an occupancy rate.	2.58
Unmeasured		2.82
Existing measured	The occupancy rate of existing properties is calculated by dividing the final (following calibration) existing population by the number of existing properties.	2.59
New properties (or new connections)	The occupancy rate of the new connection properties is assumed to be the mean of measured and unmeasured occupancy.	2.68
Optants	Calculated by dividing the optant population by the number of optant properties. The number of optant properties is calculated by taking the total measured properties minus the new connections population, minus the change in occupier properties. Population is calculated by taking the total measured population minus the new connections population, minus the change in occupier population	2.32
Change of occupier	The occupancy rate for change of occupier is assumed to be the same as the unmeasured occupancy rate.	2.82

## 5.2. Baseline forecast occupancy rates

In the baseline forecast in order to successfully distribute the population between the property types, certain assumptions and knowledge of the property types must be assessed. As previously mentioned in Table 4-1 SES Water has used the Edge Analytics population data for the purposes of the WRMP24, which is considered to be the best available data on population and therefore superseding the company's Annual Review 2019/20 population numbers. This occurs in the base year and throughout the baseline forecast.

Measured households generally have lower occupancy than unmeasured households. New properties are assumed to have company average occupancy (this assumes that occupants are moving into new properties from a range of existing properties, measured or unmeasured, either within or from outside the region, and hence have a company average occupancy). Occupancy of new properties and optant properties are inter-dependent, in that the sum of new property population and optant population within the existing measured households must equal the total measured household population. Optants generally have a low occupancy, however this is highly dependent on meter penetration. As meter penetration increases, the occupancy rates of unmeasured and optant properties increase until 100% meter penetration is reached, because those lower occupancy households for whom opting to have a meter installed is more likely to be economically beneficial would likely have opted already.

Meanwhile the average occupancy of all the property types must follow the year-on-year trend in occupancy from the Edge Analytics property and population data. These assumptions provide an estimate of the change in occupancy within the household types over time; in reality, there will be a complex movement of population within these property types, reflecting births, deaths, people moving into the region, people moving out of the region, and people moving within the region.

In order to achieve the desired occupancy rate for each property type and for the average occupancy of all the property types to follow the year-on-year trend in occupancy from the Edge Analytics data the existing measured property type is used as a balancing item in the model.

## 6. Household consumption

The model generates household consumption through micro-component modelling. The model is based on PHC, which makes the occupancy-driven household consumption component implicit in the model. The PHC values for each property type are converted to a total consumption per property by multiplying by the total number of properties. The total consumption per property values are then converted to a PCC by dividing by the population for the property type.

The results from this modelling are calibrated to base year household consumption data extracted from SES Water's 2019/20 Pre-MLE Water Balance and Post-MLE Water Balance. The process involved in reviewing the micro-component modelling and any amendments to the data included in the model are described in Section 6.1. The input data required for calibrating the base year micro-component modelling results is presented in Section 6.2. SES Water's household consumption forecast also takes account of its PR19 Outcome Delivery Incentive (ODI) targets linked to household PCC. This target is explained in Section 6.3 and how the target is included in the model is documented.

### 6.1. Micro-component modelling and forecasting

In the model the relationship between some micro-components (WC flushing, shower use, bath use, tap use and washing machine use) and occupancy has been used to calculate base year ownership, volume per use and frequency of use (OVF) per household consumption values. According to Appendix E2 of SES Water's Final WRMP19, OVF values from an UKWIR study undertaken in 2016<sup>6</sup> formed the basis for this modelling. For those micro-components which did not have a relationship with occupancy, the OVF values from the UKWIR 2015/16 micro-component dataset were used for calculating base year water usage. This dataset was used because it had a complete set of occupancy data for each household over the monitoring period which was required for the linear modelling.

A review of the WRMP19 micro-component modelling and forecasting approach was undertaken which included:

- Reviewing the split of household water consumption between the various micro-components based on professional judgement and any relevant data collected during the literature review.
- A literature review to determine if any new data on micro-component water usage was available.
- Analysing micro-component data collected by SES Water's 'Get Water Fit' initiative.

The findings of the review are documented in Sections 6.1.1 to 6.1.3.

#### 6.1.1. Split of household consumption between micro-components

From an initial high-level review of the micro-component OVF values included in the model it was apparent external use was lower than expected. Table 6-1 shows the OVF values used to calculate household measured and unmeasured external use. Further analysis of the split between micro-components which was reported in SES Water's Final WRMP19 shows that external water use only makes up 1% of micro-component water usage (see

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<sup>6</sup> UKWIR, 2016, 16/WR/01/15, Integration of behavioural change into demand forecasting and water efficiency practices

Table 6-2).

**Table 6-1 - External use OVF values**

Micro-component	Ownership	Volume (litres)	Frequency of use per day	O*V*F
External use	0.18	285.18	0.07	3.34

**Table 6-2 - Percentage of water usage per micro-component for SES Water’s WRMP19**

Micro-component	WRMP19	
	Measured	Unmeasured
Toilet flushing	21.8%	21.4%
Personal washing	46.9%	49.2%
Clothes washing	9.5%	7.1%
Dish washing	9.9%	10.0%
Miscellaneous internal use	10.9%	11.5%
External use	1.0%	0.8%

Figure 6-1 which is taken from the Energy Saving Trust’s report ‘At home with water’<sup>7</sup> suggests that external water usage should be approximately 2% of household consumption. This has been determined by adding garden usage and car usage (assumed to be car washing) together. It was concluded that potentially the model underestimates the proportion of water used externally.

Figure 6-1 shows the percentage of water usage for dish washing (by hand and by a dishwasher) is 5%, which is 5% lower than SES Water’s WRMP19 data in

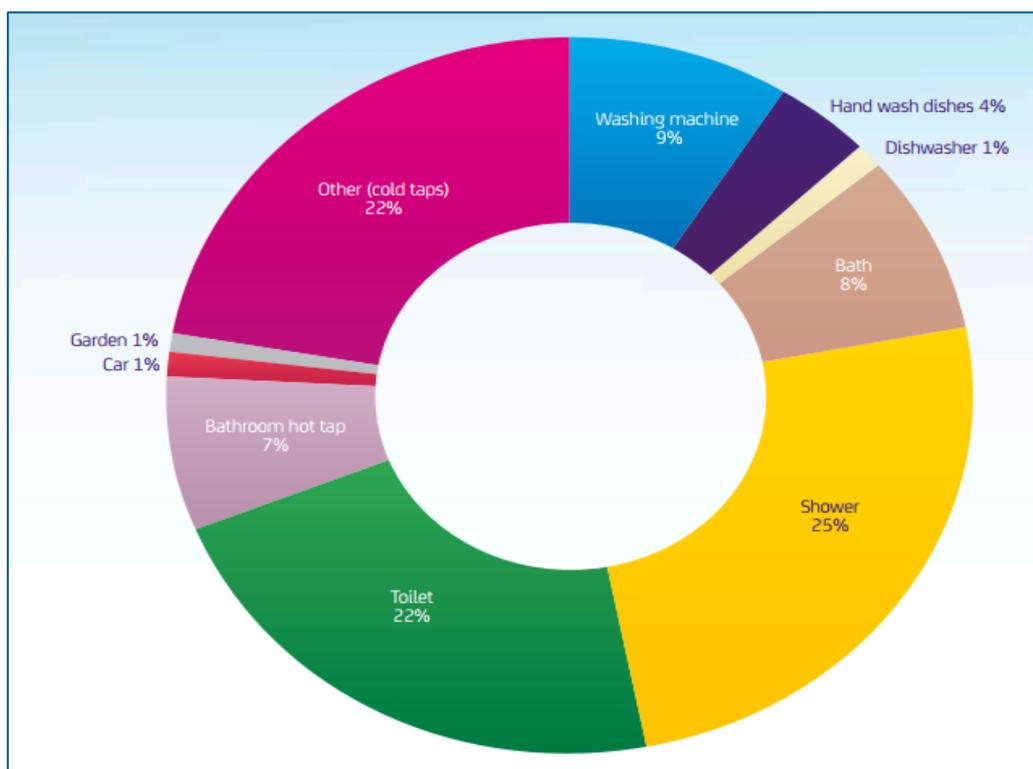
<sup>7</sup> Energy Saving Trust, July 2013, At home with water

Table 6-2. However, determining the activities that water from a kitchen tap is used for (e.g. washing dishes, hand washing, preparing food etc) can be hard to establish.

For the majority of the remaining micro-components listed in

Table 6-2 the percentages shown were considered reasonable and roughly correspond to the data presented by the Energy Saving Trust in Figure 6-1.

**Figure 6-1 - Household water consumption**



Source: Energy Saving Trust, At home with water, July 2013.

#### 6.1.1.1. External use adjustments

Temporary Use Bans (TUBs), one of the mechanisms by which companies can encourage customers to save water during a drought, target external uses of water. With external use representing such a low proportion of household water use in SES Water’s WRMP19 model, it was found that external use was not high enough to apply the assumed TUBs savings, which are assumed in the company’s Draft Drought Plan 2021<sup>8</sup> to equate to approximately 3.2 % of DYAA demand (Distribution Input (DI) minus leakage) and approximately 5.4% of DYCP demand (DI minus leakage).

Appendix E2 of SES Water’s Final WRMP19<sup>9</sup> presents three tables of micro-component data, including the data used in the model. A description of the data in each table is provided in Table 6-3. The actual data is provided in Figure 6-2, which was used when the model was developed. External use represents 1.4% of household water consumption. The percentage of external use in the other two tables is higher at 5.9% and 7.3% of per household consumption.

Sensitivity testing was undertaken using the external use values from Tables 3 and 4 from Figure 6-2 in turn. The external use OVF values in the model were replaced with the OVF values from Table 3 and Table 4 to see what impact they each had on external use. It should be noted that altering the external use OVF values will not impact the overall PCC because the model offsets the increase in the external use micro-component by applying an equal percentage decrease across all the other micro-components. The sensitivity analysis concluded that only the Table 4 external use micro-component OVF values ensure that TUBs savings could be purely attributed to reductions in external use, i.e. the savings are less than the external use values in both the base year and the final year of the planning period. The final year of the planning period would also work using Table 3 OVF values, but not the base year.

SES Water decided to adopt the Table 3 OVF values and the necessary updates were applied to the model. Even though the Table 3 external use micro-component OVF values means that TUBs savings cannot be

<sup>8</sup> SES Water, March 2021, Draft Drought Plan, for public consultation

<sup>9</sup> SES Water, September 2017, WRMP19 Household consumption forecast: baseline forecast

purely attributed to reductions in external use in the base year, SES Water decided to use this data because it is more recent than the Table 4 OVF values.

**Table 6-3 – Micro-component data sources presented in Appendix E2 of SES Water’s Final WRMP19**

Data source	Description
Table 2	Micro-component summary data from 2015/16 metered billed households. A sample of measured billed households, which has associated occupancies and demographic information on the households, collated during an UKWIR Study (this contains 62 households from around England and Wales).
Table 3	2015/16 RV billed households. A sample of RV billed households, which does not have associated demographics (collated from other anonymous Siloette studies carried out by Artesia Consulting, from England and Wales).
Table 4	Micro-component summary for 2002/04 RV billed households. 2002 – 2004 O, V, and F data collected using the Identiflow system (a sample of RV billed households, reporting in WRc Report CP187).

**Figure 6-2 - WRMP19 micro-component data**

**Table 2 Micro-component summary data from 2015/16 metered billed households**

2015/16 Metered billed households					
Micro-component	“ Weighted Ownership”	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.26	7.83	56.83	23.92
Shower	0.92	62.36	0.86	49.54	20.85
Bath	0.43	104.60	0.24	10.61	4.47
Tap	1.00	5.66	11.61	65.72	27.66
Dish Washer	0.42	16.70	0.50	3.53	1.48
Washing Machine	0.95	54.19	0.55	28.44	11.97
Water Softener	0.02	52.06	0.97	0.98	0.41
External use	0.18	285.18	0.07	3.34	1.40
Plumbing Losses	0.22	37.20	1.55	12.86	5.41
Miscellaneous	0.95	1.63	3.74	5.78	2.43

**Table 3 Micro-component summary for 2015/16 RV billed households**

2016/16 RV billed households					
Micro-component	“ Weighted Ownership”	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.58	8.86	67.15	22.53
Shower	0.94	54.82	0.94	48.69	16.34
Bath	0.54	113.65	0.36	22.35	7.50
Tap	1.00	4.56	17.91	81.62	27.39
Dish Washer	0.37	19.68	0.28	2.02	0.68
Washing Machine	0.94	56.36	0.66	34.59	11.60
Water Softener	0.09	112.02	0.24	2.41	0.81
External use	0.51	183.03	0.19	17.58	5.90
Plumbing Losses	0.30	75.84	0.65	14.76	4.95
Miscellaneous	0.93	1.56	4.75	6.85	2.30

**Table 4 Micro-component summary for 2002/04 RV billed households**

2002-2004 (from WRc CP187)					
Micro-component	“ Weighted Ownership”	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	9.40	11.52	108.29	29.19
Shower	0.85	25.70	1.46	31.97	8.62
Bath	0.88	73.30	0.95	61.35	16.54
Tap	1.00	2.30	37.90	87.17	23.50
Dish Washer	0.37	21.30	0.71	5.60	1.51
Washing Machine	0.94	61.00	0.81	46.30	12.48
Water Softener	0.02	182.50	0.39	1.14	0.31
External use	0.65	46.70	0.89	27.10	7.30
Plumbing Losses					0.00
Miscellaneous	0.19	20.40	0.53	2.08	0.56

## 6.1.2. Literature review

A literature review was undertaken to establish whether any new data on micro-component water usage was available, which could then potentially be used to update the model.

The review showed that no new data on micro-component water usage was available and the model used the latest data which was collated during an UKWIR study<sup>10</sup>. However, the review identified the potential impact the COVID-19 pandemic could be having on water demand. The 'lockdown' response to the pandemic has disrupted the normality of everyday lives which has had a knock-on effect on water use practices and therefore water use in the home. With working from home being part of lockdown, people have spent more time at home than normal and therefore used more water in the home. The frequency of use of certain indoor micro-component has increased according to a survey conducted in May 2020<sup>11</sup>. In addition, indoor micro-components in the home are generally less water efficient than those in offices. Therefore, the volume of water used per use may be greater than using the same micro-component in an office. During lockdown people spent more time than normal in their gardens. Water UK (2020) reported that UK water companies saw the highest ever demand for water. It is likely that the surge in demand was caused by a combination of increased external water use for watering gardens and filling up paddling pools due to the warm weather, and people spending more time at home than normal. Also, an increased ownership of hot tubs was seen during lockdown which will have contributed to external water use. Although regardless of the COVID-19 pandemic hot tub ownership was increasing prior to the pandemic beginning.

The potential impact the COVID-19 pandemic has had on demand for water has not been included in the model update as lockdown started at the end of March 2020 and therefore the majority of the impacts would have not occurred in the base year (2019/20).

## 6.1.3. 'Get Water Fit' initiative

SES Water are running an initiative to encourage their customers to use water wisely. This initiative is called 'Get Water Fit'. The data collected through this initiative included information such as whether the household has a dishwasher and washing machine and how many times it is used per week, the type of shower, how many times it is used per week and the duration of the shower. It also collected information on household occupancy. This type of information could potentially be used to inform the micro-component OVF values.

SES Water provided Atkins with the July 2020 and August 2020 'Get Water Fit' datasets. The combined datasets included approximately 100 measured households and 100 unmeasured households. Initial analysis of this data provided the ownership and frequency values for a range of micro-components for measured and unmeasured households (Table 6-4). Further ownership values for additional micro-components (represented as a percentage) are presented in Table 6-5.

**Table 6-4 - Ownership and frequency values from the Get Water Fit data**

Micro-component	Ownership		Frequency of use per day	
	Measured	Unmeasured	Measured	Unmeasured
Shower	1.53	1.35	2.11	2.07
Toilet	2.19	1.87	*	*
Basin	2.14	1.81	*	*
Bath	1.03	0.96	0.44	0.47
Kitchen utility tap	1.42	1.29	*	*
Kettle	*	*	3.38	3.18
Wash dishes by hand	See Table 6-5	See Table 6-5	2.05	1.72
Dishwasher	See Table 6-5	See Table 6-5	0.67	0.52

<sup>10</sup> UKWIR, 2016, UKWIR 16/WR/01/15 Integration of behavioural change into demand forecasting and water efficiency practices.

<sup>11</sup> FINISH, 2020, The Great British Rain Paradox

Washing machine	See Table 6-5	See Table 6-5	0.79	0.79
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\*No data available to calculate ownership or frequency of use per day values.

**Table 6-5 - Ownership values (represented as percentages) from Get Water Fit data**

Micro-component	Ownership %			
	Measured		Unmeasured	
	Yes	No	Yes	No
Wash dishes by hand	49	51	55	45
Dishwasher	75	25	64	36
Washing machine	98	2	98	2

Using assumptions on the volume of water used for showers from the Energy Saving Trust (13 litres per minute for a power shower and 5 litres per minute for an electric shower) the average volume of water used per person per day has been calculated (see Table 6-6). This calculation is based on the average duration of a shower for measured households being 7.9 minutes and for unmeasured households 8.26 minutes. The duration of a shower data has been collated from the 'Get Water Fit' datasets.

**Table 6-6 - Average water use for showering**

	Multi jet (Power)		Electric	
	Measured	Unmeasured	Measured	Unmeasured
Average water use (litres per person per day)	120.78	118.86	46.45	45.71

The data being collected by the 'Get Water Fit' initiative provides the ownership and frequency of use information required for calculating micro-component water usage. As demonstrated above it can be combined with appliance water usage data other studies to develop the volume per use values which is also required to calculate micro-component water usage.

However, currently, with only 200 sample households, the dataset is small and therefore not considered sufficiently robust to base SES Water's micro-component demand forecast on.

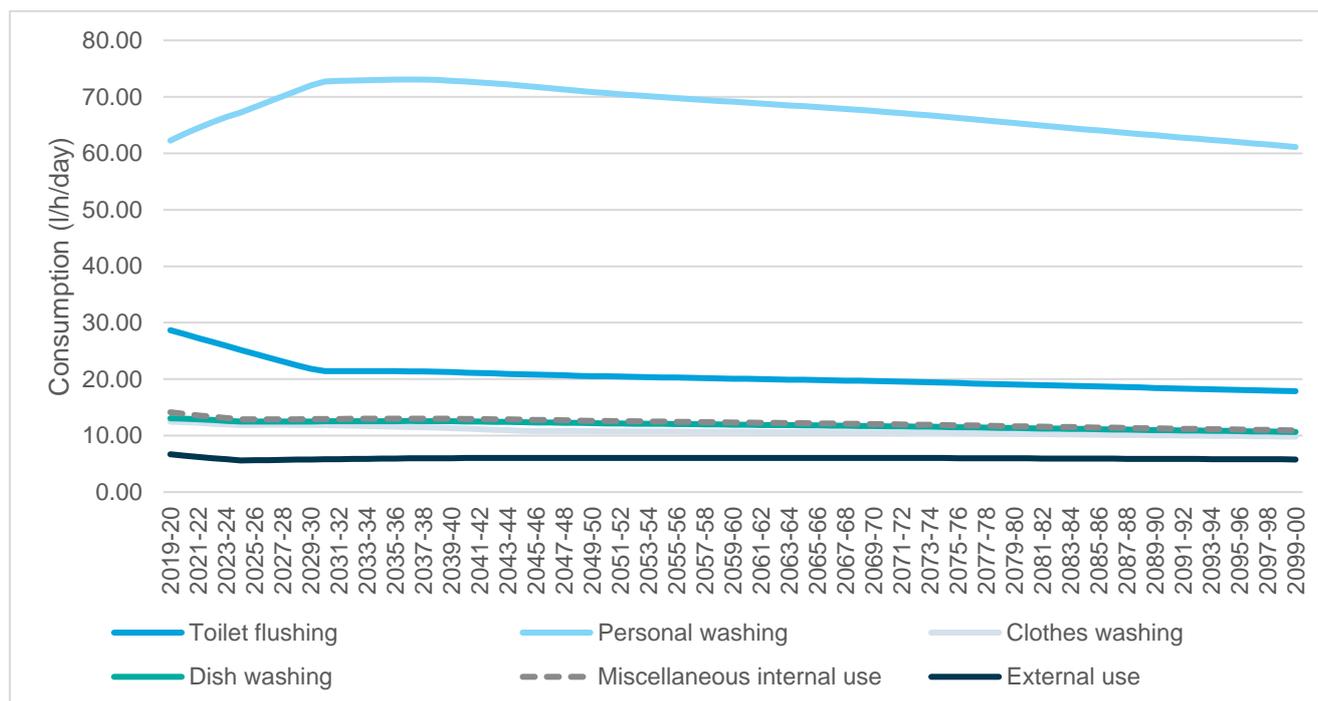
#### 6.1.4. Summary

It was concluded that even though potentially new trends in micro-component water usage were highlighted in the literature review, because the model includes linear modelling of micro-components against occupancy it would not be straight forward for Atkins to amend the micro-component trends as the exact calculations behind the linear modelling were not available in the model.

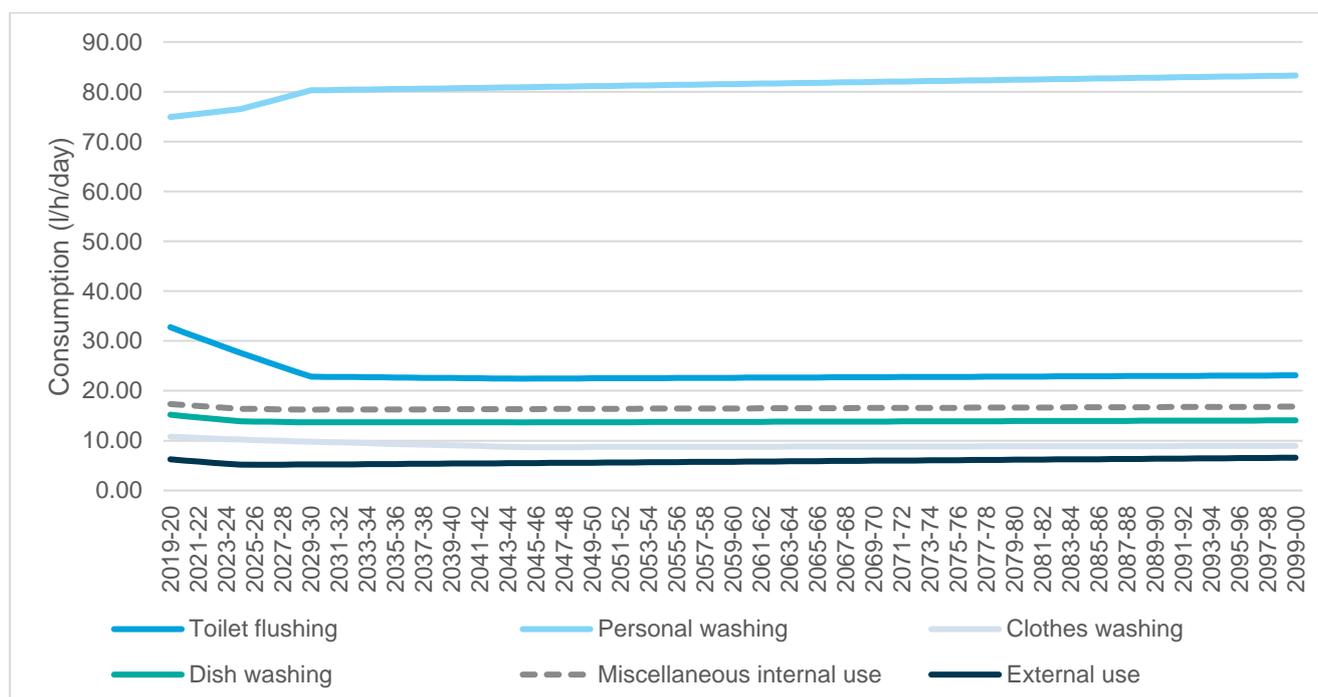
The review also highlighted that external use represented a very low proportion of household water consumption which would have implications if TUBs savings were applied. As external use did not have a relationship with occupancy the OVF values used to calculate base year external use water usage came directly from the UKWIR 2015/16 micro-component dataset. It was therefore decided to alter the OVF values for external use as documented in Section 6.1.1.1.

Figure 6-3 to Figure 6-8 present a summary of the micro-component PCC for the measured and unmeasured households for various consumption uplift factors.

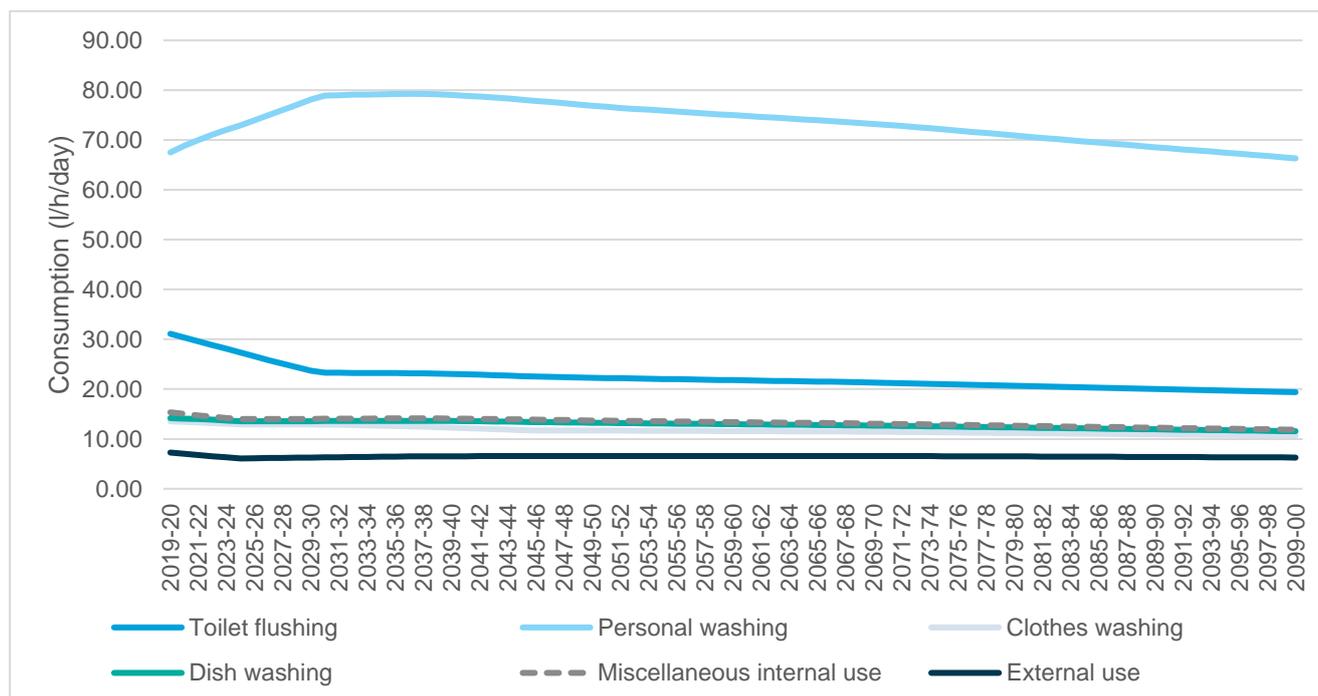
**Figure 6-3 - Measured micro-component consumption NYAA**



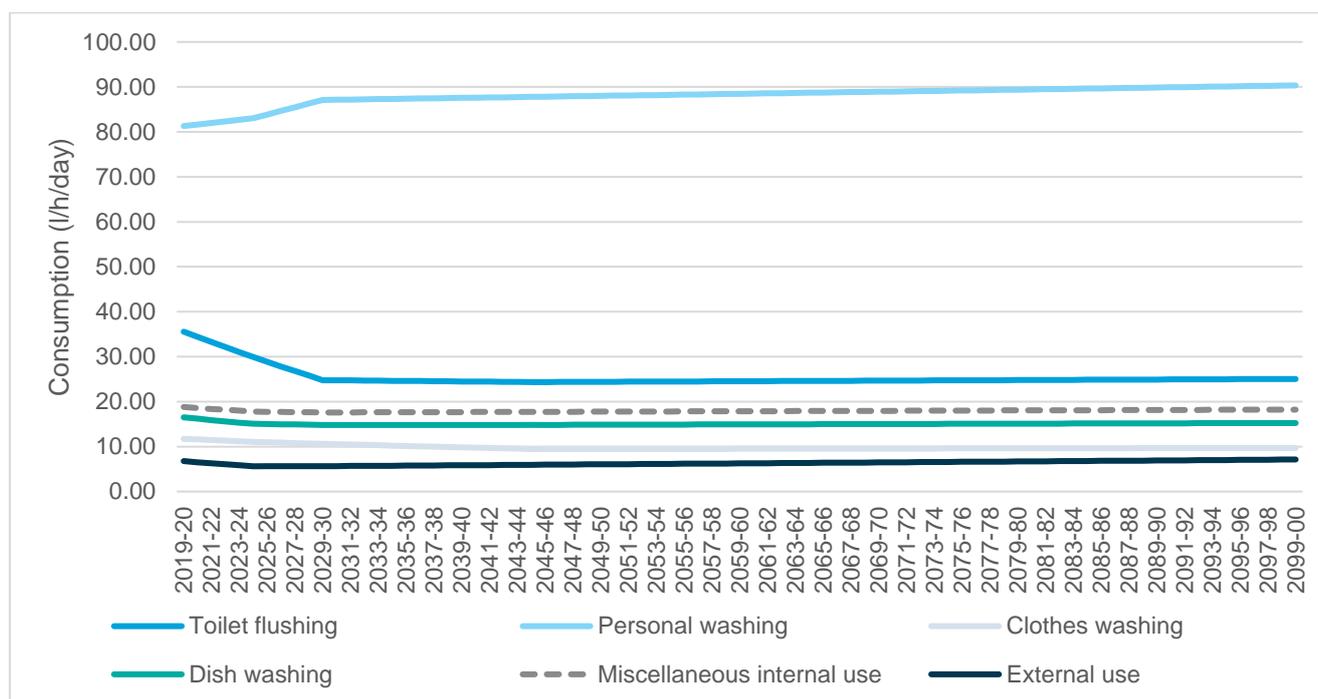
**Figure 6-4 - Unmeasured micro-component consumption NYAA**



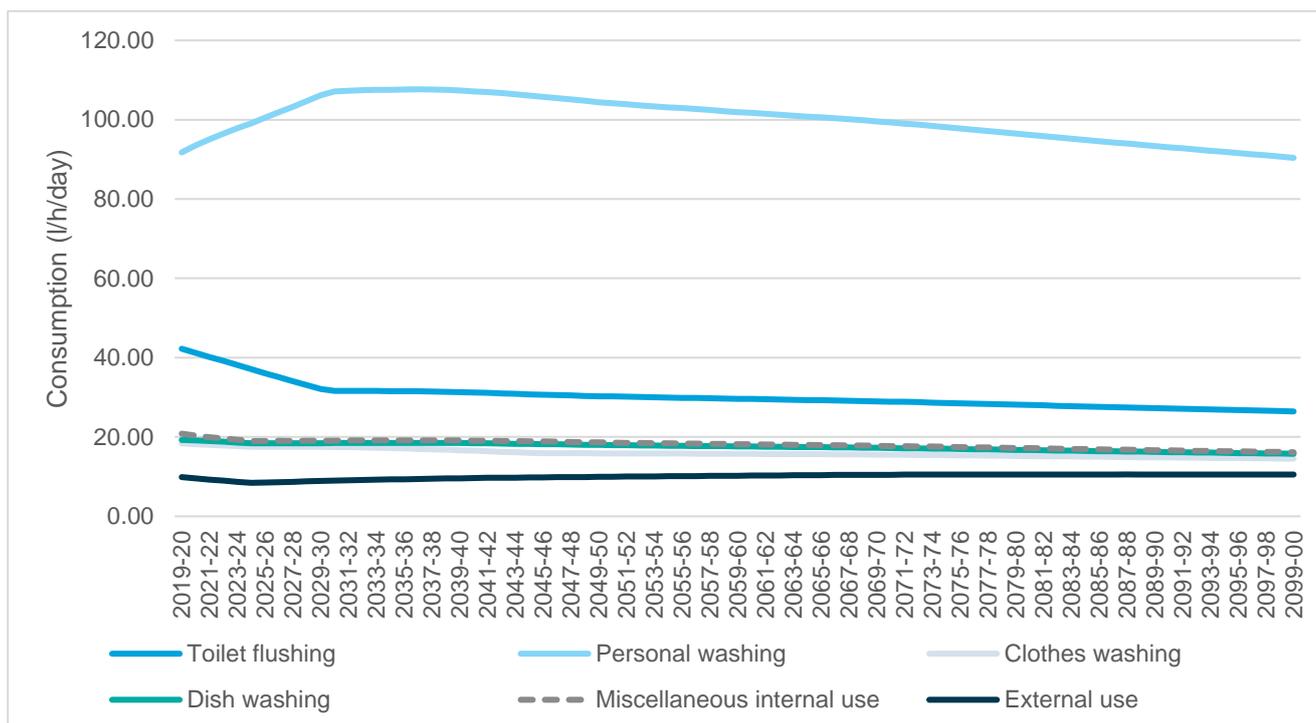
**Figure 6-5 - Measured micro-component consumption DYAA**



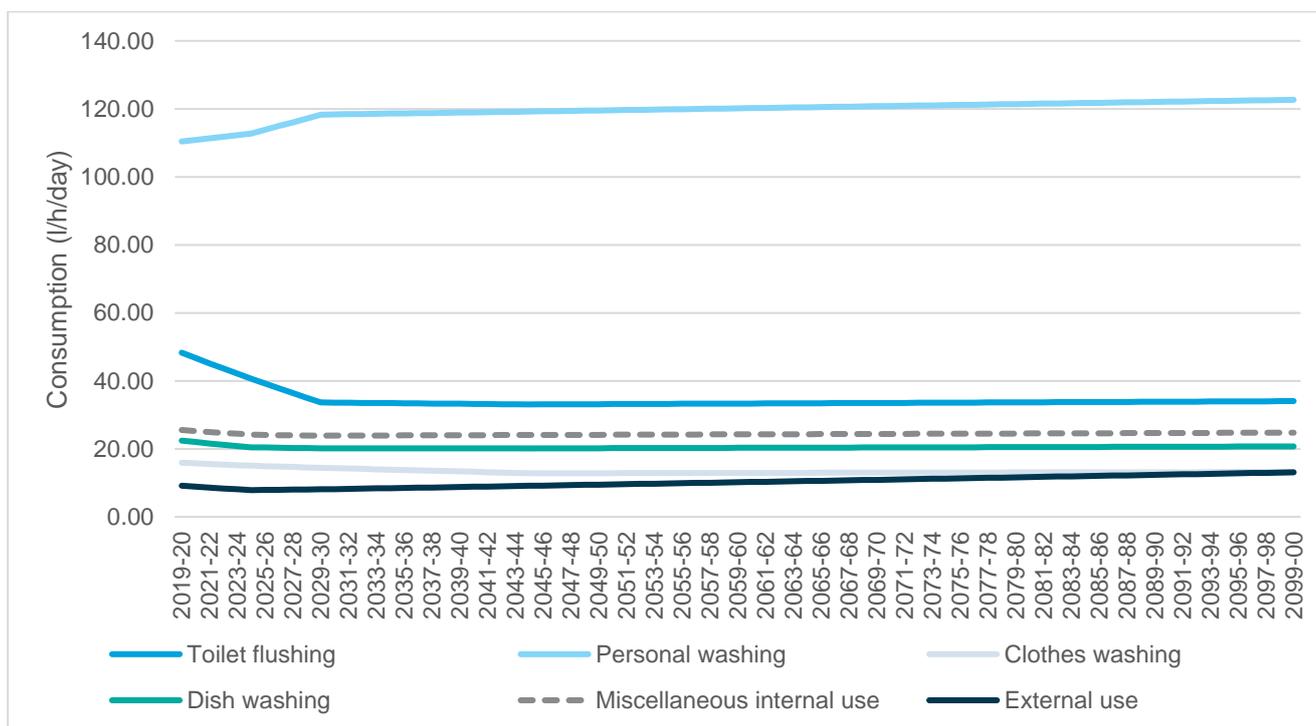
**Figure 6-6 - Unmeasured micro-component consumption DYAA**



**Figure 6-7 - Measured micro-component consumption DYCP**



**Figure 6-8 - Unmeasured micro-component consumption DYCP**



## 6.2. Base year household consumption calibration

Base year household consumption data (pre-Maximum Likelihood Estimation (MLE) and post-MLE) in MI/d has been extracted from SES Water’s 2019/20 Pre-MLE Water Balance and Post-MLE Water Balance data. Using the base year property and population data from the 2019/20 Annual Review the consumption data has been converted into a consumption per property per day both measured and unmeasured households. The Post MLE per property consumption data is then used to calibrate the consumption data generated by the model.

Table 6-7 presents the base year household consumption data from SES Water’s 2019/20 Pre-MLE Water Balance and Post-MLE Water Balance and the per property consumption calculated using this data and SES Water’s 2019/20 Annual Review property and population data.

**Table 6-7 - Base year 2019/20 household consumption**

	Pre-MLE	Post-MLE
Measured households (Ml/d)	57.25	57.92
Unmeasured household (Ml/d)	44.29	46.25
Measured household (Litres/property/day)	352.64	356.78
Unmeasured household (Litres/property/day)	407.50	425.51

### 6.3. Outcome Delivery Incentive

SES Water have an ODI linked to household PCC. By the end of AMP7 SES Water have a target PCC of 136.8 litres per head per day for NYAA and 148.5 litres per head per day for DYAA (derived from the overall PCC target of 138.0 litres per head per day, weighted for 1 dry year occurring every 10 years). This target is achieved through metering savings and water efficiency savings. The following sections describe the metering savings and water efficiency savings applied in the model to achieve this target.

#### 6.3.1. Metering savings

Metering savings included in the model were updated to match the assumptions stated in SES Water’s 2019 Business Plan. The metering savings assumed for WRMP19 and the WRSE regional plan submission in 2020/21 are presented in Table 6-8.

**Table 6-8 - Metering savings**

Type of metering	Saving assumed for WRMP19	Saving assumed for WRSE submission
Metering on change of occupier	20.0%	14.5%
Optant smart metering	n/a	2.5%

#### 6.3.2. Water efficiency savings

After updating the metering savings assumptions, the residual of the AMP7 target was achieved through applying water efficiency savings to the following micro-components:

- Taps
- External use.

These micro-components were selected because they are two areas where water efficiency savings can easily be made in the home. For example: turning the tap off whilst brushing your teeth and using collected rainwater or re-using paddling pool water to water the garden.

A saving of 1.45% was applied to taps and a saving of 3.5% was applied to external use. These savings were applied from 2020/21 to the end of AMP7 (2024/25). The savings are applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into per capita consumption by dividing by the total population.

With reference to section 6.1.1.1 (External use adjustments) it should be noted that the water efficiency savings outlined in this section had been applied to external use when the sensitivity testing was undertaken to determine if the TUBs savings could be purely attributed to reductions in external use.

## 7. Non-household consumption

WRSE commissioned Artesia to carry out a region-wide assessment of non-household and non-public water supply demand. The aim was to produce a Central (baseline) forecast for each WRZ, alongside an Upper and Lower forecast to account for uncertainty, using a methodology which is relatively consistent across the companies as well as adhering to the planning guidelines.

A forecast for measured and unmeasured non-households was produced. Three scenario forecasts (Lower, Central and Upper) as well as a baseline forecast were produced. A new worksheet called *Non HH forecast* was added to the model to incorporate this data. The new worksheet was linked to the existing outputs worksheet in the model (*Scenario selection & outputs*) and also includes a facility to select which non-household scenario forecast the user wants to include in the model.

Through discussions with SES Water it was decided to use the baseline forecast from 2019/20 to 2024/25 and from 2025/26 the central forecast was used. The reason for using the baseline forecast and the central forecast was because in the central forecast there was an unexplained dip in the measured non-household consumption after the base year, which corrects itself by 2025/26.

## 8. Non-household population and properties

### 8.1. Property and population forecast

The model required a revised population and property forecast for non-households. This involved updating the base year and baseline forecast non-household property and population data. The base year non-household population and property data was obtained from SES Water's 2019/20 Annual Review. The baseline non-household population and property forecasts were calculated using the base year data and the non-household consumption forecast supplied by Artesia. Further details of the base year values included in the model and how the baseline forecast was calculated is included in Sections 8.1.1 and 8.1.2.

#### 8.1.1. Base year

Base year population and property figures were extracted from SES Water's 2019/20 Annual Review. Table 8-1 presents the household population and property data from SES Water's 2019/20 Annual Review.

**Table 8-1 - Base year non-household population and property data**

	Properties (000s)	Population (000s)
Measured	7.75	7.69
Unmeasured	1.15	0.75
Total	8.91	8.42

#### 8.1.2. Baseline forecast

To calculate the population and property baseline forecast the non-household consumption data supplied by Artesia was used along with the base year population and property values to calculate a measured per property consumption (PPC) and PCC. The outputs of these calculations are presented in Table 8-2.

**Table 8-2 – Base year non-household PPC and PCC**

Component	Base year (M/d)
Non household measured PPC	3.01
Non household measured PCC	3.04
Non household unmeasured PPC	1.76
Non household unmeasured PCC	2.79

The PPC value was used to calculate the number of properties for each year of the forecast using the following formula:

$$\text{Previous year's number of properties} + (\text{consumption for given year} - \text{previous year's consumption}) / \text{base year PPC}$$

By using this approach, it was assumed that the increase in non-household consumption through the planning period is a result of more non-household properties and not the existing non-household properties using more water.

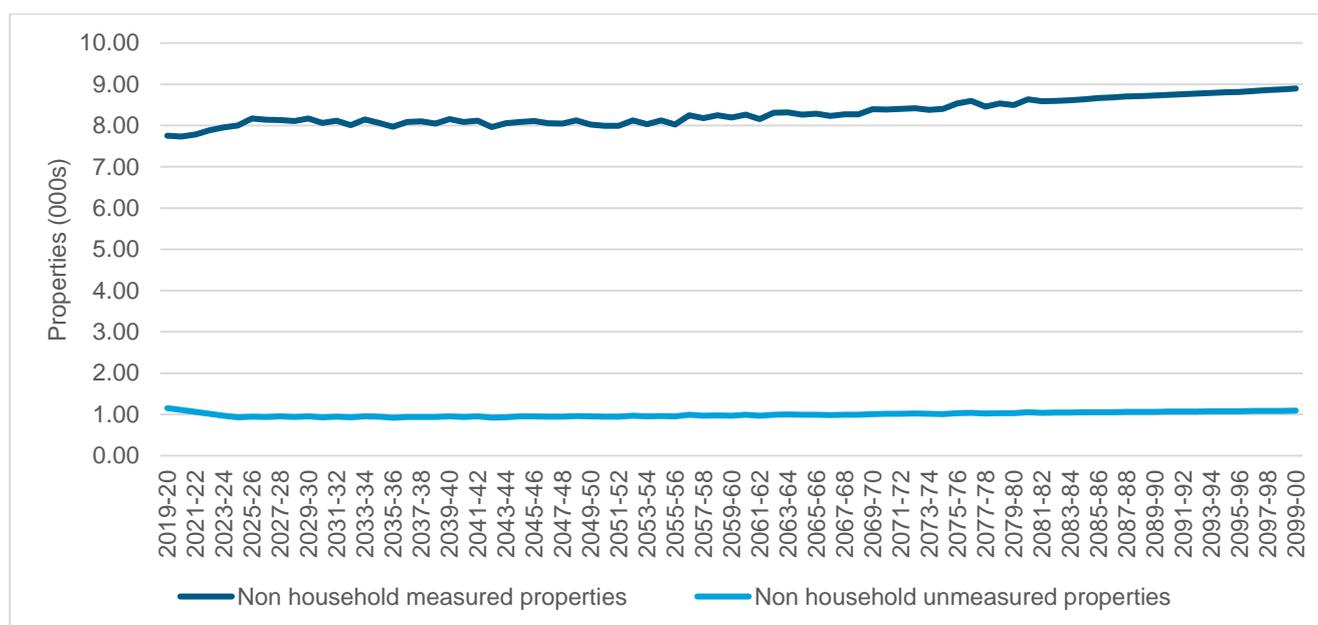
The PCC value was used to calculate the population for each year of the forecast using the following formula:

$$\text{Previous year's population} + (\text{consumption for given year} - \text{previous year's consumption}) / \text{base year PCC}$$

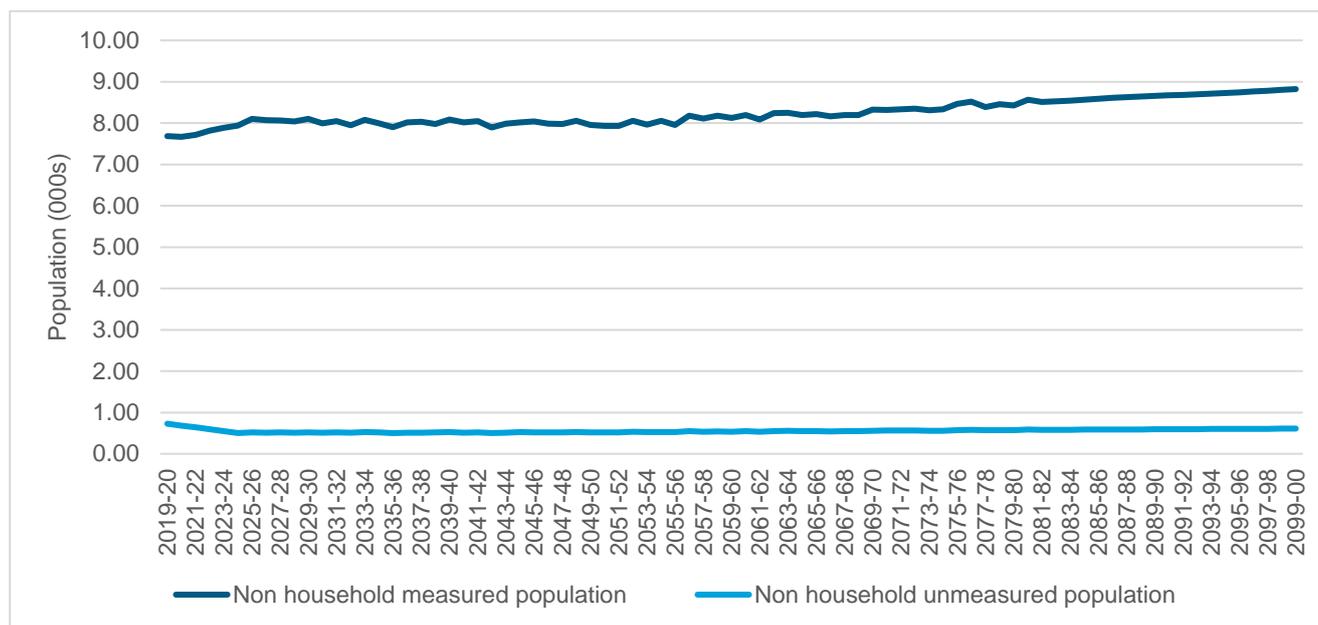
As mentioned in Section 7 the baseline and central consumptions forecasts were used in the model. When calculating PPC and PCC the baseline or central consumption forecast was used as stated in Section 6.1.

The assumption that 90% of non-household properties would be measured by the end of AMP7 (2024/25), as planned for in SES Water's PR19 Business Plan, was also applied to the model. The resultant property forecast is presented in Figure 8-1 and the population forecast in Figure 8-2.

**Figure 8-1 - Non-household property forecast**



**Figure 8-2 - Non-household population forecast**



## 9. Other demand components

### 9.1. Leakage

Base year leakage figures have been extracted from SES Water’s 2019/20 WRMP Annual Review. Table 9-1 presents the base year leakage data included in the model.

According to the WRPG, total leakage should remain constant “from 2025/26 [...] from the start of your plan to the end of the planning period”. In the model leakage remains constant from the first year of AMP8 (2025/26). Leakage values for the start of AMP8 were extracted from SES Water’s Final WRMP19 and these values remain constant through to 2099/00. Between the base year (2019/20) and the start of AMP8 (2025/26) SES Water’s 2019/20 Annual Review leakage values have been linearly interpolated as presented in Table 9-1.

**Table 9-1 – Leakage values**

Component	2019/20 (Base year)	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26
	Ml/d						
Measured Non-household - USPL	0.18	0.19	0.20	0.21	0.22	0.22	0.23
Unmeasured Non-household - USPL	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Measured household - USPL	3.41	3.60	3.78	3.97	4.15	4.34	4.52
Unmeasured household - USPL	4.35	3.77	3.18	2.60	2.01	1.43	0.84
Void Properties – USPL	0.41	0.36	0.32	0.27	0.22	0.18	0.13
Distribution Losses	15.52	15.27	15.01	14.76	14.51	14.25	14.00
Total leakage	23.94	23.25	22.56	21.86	21.17	20.48	19.79

## 9.2. Water taken unbilled

Water taken unbilled has been extracted from SES Water's 2019/20 WRMP Annual Review. A figure of 2.01MI/d has been used for the base year and this remains constant throughout the baseline forecast.

## 9.3. Distribution System Operational Use

Distribution System Operational Use has been extracted from SES Water's 2019/20 WRMP Annual Review. A figure of 2.73MI/d has been used for the base year and this remains constant throughout the baseline forecast.

## 9.4. Climate change

The climate change factors used in the model were reviewed with reference to the following guidance, which are referred to in the draft WRPG:

- UKWIR (2009) Assessment of the Significance to Water Resource Management Plans of the UK Climate Projections 2009,
- UKWIR (2013) Impact of Climate Change on Water Demand.

The review showed that no changes were required to the climate change factors used in the model.

When the model is run under the NYAA or DYAA scenarios the percentage of consumption driven by climate change is 0.6% by 2074/75 and 1.6% under the DYCP scenario.

# 10. Consumption uplifts factors

## 10.1. Normal and dry year factors

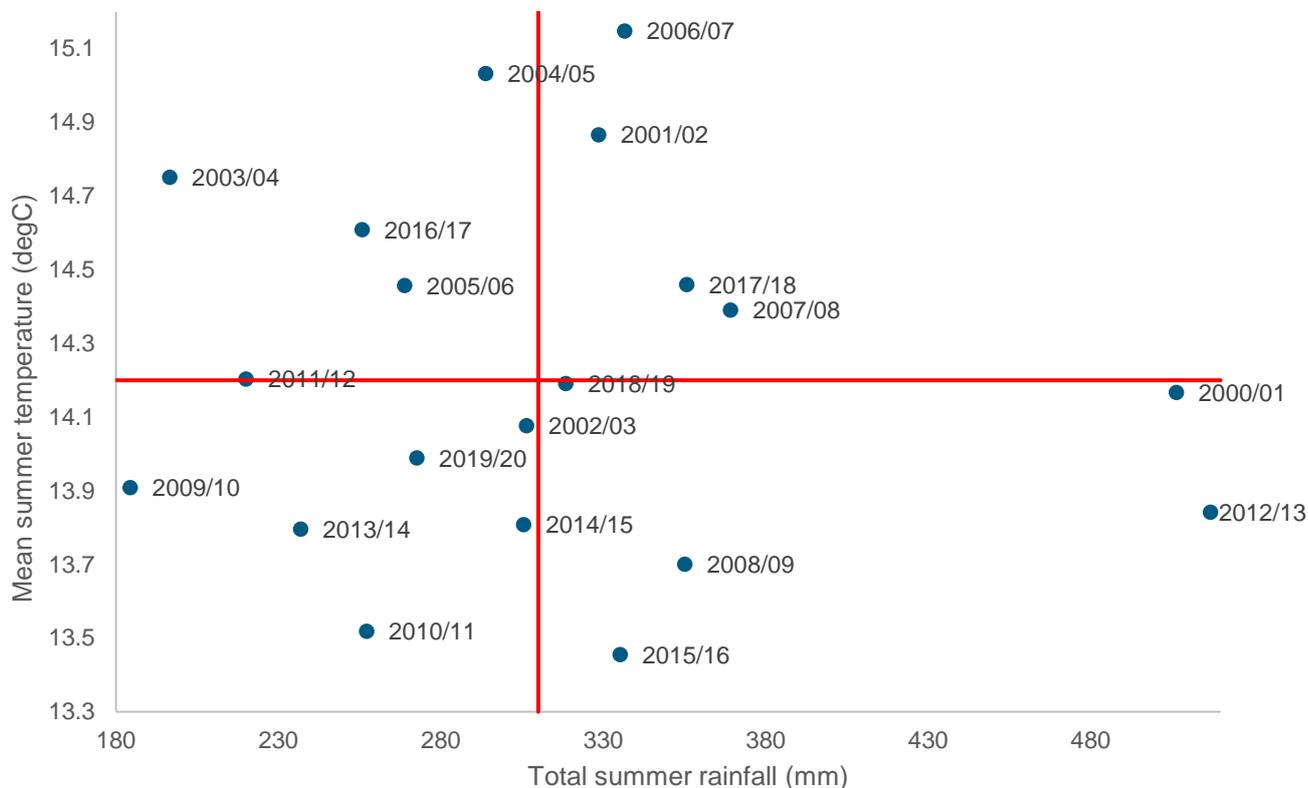
Consumption uplift factors for NYAA and DYAA have been re-calculated using the methodology from the UKWIR guidance report number 15/WR/02/9 – household consumption forecasting<sup>12</sup>. This is the same methodology used when the model was developed for WRMP19 and which is documented in Appendix E2 of SES Water's Final WRMP19<sup>13</sup>. The WRPG states this UKWIR guidance should be followed to develop consumption uplift factors for WRMP24.

The first stage is to assess the weather data, more specifically summer temperature and rainfall. Each factor was summarised for the summer months for each year (April, May, June, July, August and September). To help select the hottest and driest year a rainfall-temperature-quadrant plot was produced (Figure 10-1) with the axes representing long-term average weather. A judgement was made as to which is the hottest and driest year. 2003/04, 2004/05, 2005/06 2016/17, sit within the top left quadrant showing they are the strongest dry years.

<sup>12</sup> UKWIR, 2016, WRMP19 Methods – Household Consumption Forecasting

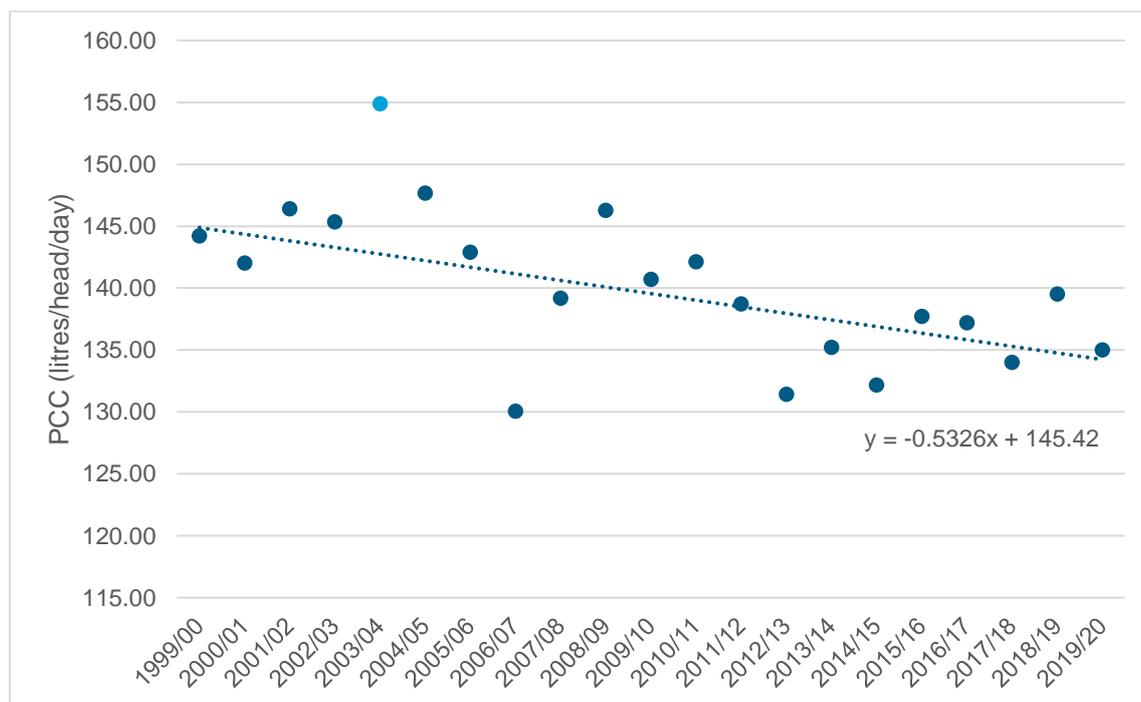
<sup>13</sup> SES Water, September 2017, WRMP19 Household consumption forecast: baseline forecast

**Figure 10-1 – Quadrant plot for determining the dry year**



The next stage was to analyse the PCC trends for measured and unmeasured. These were done separately to account for the difference in trends and the potential difference in impact of the dry year.

**Figure 10-2 - Reported PCC trend - measured properties**



**Figure 10-3 – Reported PCC trend – unmeasured properties**

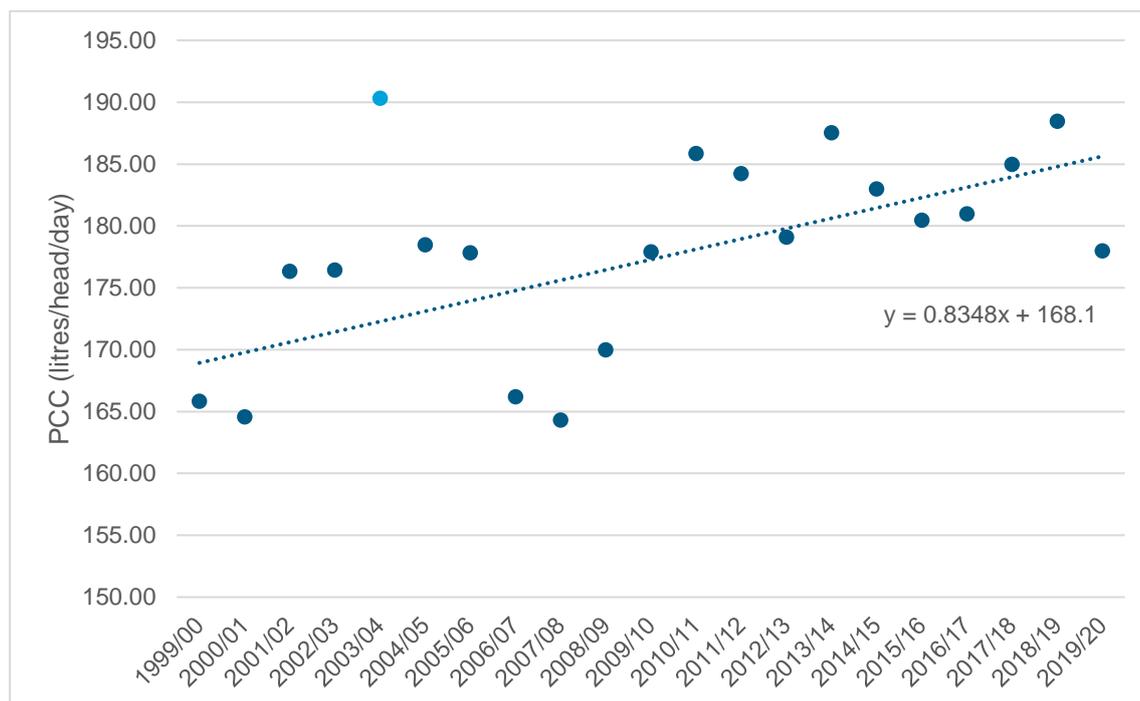


Figure 10-2 (measured reported PCC trend) was used to select the dry year. The reason for using the measured reported PCC values was because they were deemed to be more accurate and less variable due to better quality data and fewer adjustments made with the relation to supply pipe leakage. In Figure 10-2 2003/04 stands out as the year that responds the strongest out of the possible dry year selections.

The dry year factor is calculated by removing the dry year, then calculating a trend line through the remaining points. The dry year factor is the reported figure divided by the modelled figure.

The normal year factor is calculated in a similar way, using the same trend line which excludes the dry year point. The normal year factor is the modelled figure divided by the reported figure (2019/20 PCC value). This is done separately for measured and unmeasured.

The dry year factor is calculated to be 1.085, the measured normal year factor is 0.994 and the unmeasured normal year factor is 1.043. The normal year factors are applied to the per property consumption data, which has been generated using the post-MLE consumption and the property data from SES Water’s 2019/2020 Annual Review. These normalised per property consumption values are then used to calibrate the per property consumption values, generated for each property type, by the model.

## 10.2. Critical period factor

Critical period calculations have been done in accordance to the methodology stated in the UWKIR report Peak Water Demand Forecasting Methodology<sup>14</sup> which is the guidance the WRPG states should be followed. DI is used due to the methodology requiring daily consumption figures. Despite DI including leakage it is the best source of data available. From the daily data a weekly rolling mean was calculated. For each financial year, the peak week and the annual average are calculated. A long-term annual average is then calculated from all of the years in the time series, and the critical period peak week factor is the maximum peak week within one of the dry years (top left quadrant). The peak week was selected from 2003/04, with a result of 1.4735.

A summary of the NYAA, DYAA and DYCP factors are provided in Table 10-1.

<sup>14</sup> UKWIR, 2006, Peak Water Demand Forecasting Methodology

**Table 10-1 - Summary of factors applied in the household forecast**

Factor	WRSE submission
NYAA (measured)	0.9943
NYAA (unmeasured)	1.0429
DYAA	1.0849
DYCP	1.4735

### 10.3. 1 in 200 and 1 in 500 drought event factors

The peak week factors for 1 in 200 and 1 in 500 drought events were generated by Artesia and provided in the WRSE Dynamic demand analysis, Phase 2 report (reference: AR1408)<sup>15</sup>. These factors were incorporated into the household consumption forecast model in the same way as the DYAA and DYCP factors. These factors are applied to the NYAA forecast and can be selected within the model the same way as NYAA, DYAA or DYCP

**Table 10-2 – 1 in 200 and 1 in 500 drought event factors**

SES Water	Series 3	
	1 in 200	1 in 500
WRZ		
SES Water	1.26	1.29

## 11. WRSE outputs

WRSE provided SES Water with the Data Landing Platform (DLP) template. The model was used to populate the BL Demand worksheet in the DLP template. The BL Demand worksheet included a list of demand components. These components needed to be populated for a number of run scenarios and growth forecasts. Table 11-1 shows the growth forecasts which were required to populate the DLP template. For each of the six growth forecasts the following scenarios were required: NYAA, DYAA, DYCP, 1 in 200 annual average (A), 1 in 200 critical period (P), 1 in 500A and 1 in 500P. The same uplift factors (as shown in Table 10-2) were used to populate the A and P 1 in 200 and 1 in 500 run scenarios.

**Table 11-1 - Growth forecasts for DLP template**

Scenario	Selected growth forecast for SES Water
Baseline	Housing-Plan-P (bottom-up)
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H

To populate the demand components of the DLP template an additional worksheet was added to the model (called WRSE outputs). This worksheet included the 24 components from the *BL Demand* worksheet and covered the planning period (2019/20 to 2099/00). For every year of the planning period each component was linked to the corresponding output cell(s) of the model, which are in the *Scenario selection & outputs* worksheet of the model. The distribution input component included the percentage of consumption driven by climate change. The WRSE outputs worksheet automatically populated with the output data from the model.

<sup>15</sup> Artesia, February 2021, WRSE Dynamic demand analysis, Phase 2

Switches were included in the model to allow the user to select the required model run in order to populate the various run scenarios and growth forecasts required in the DLP template. Table 11-2 describes the switches included in the model.

**Table 11-2 - Model switches**

	Switch details
Household growth forecast	Switch added to the POPROC split worksheet. The user is required to manually type in the name of the population and property scenario they wish to run through the model.
Run Scenario	A drop-down menu in the Scenario selection & outputs worksheet allows the user to select the run scenario. The following options are available: NYAA, DYAA, DYCP, 1 in 200 and 1 in 500.
Non household forecast	A switch had been added to the Non HH forecast worksheet. The user is required to manually type in the number scenario they wish to run through the model. The scenarios have been numbered as follows: central = 1, lower = 2, upper = 3 and baseline = 4.

The WRSE outputs worksheet includes a summary of the selected parameters chosen for the model run. This allows the user to easily identify the parameters which have been used to run the model and populate the DLP template. An example of the *WRSE outputs* worksheet is shown in Figure 11-1.

For each run scenario and growth forecast the data in the *WRSE outputs* worksheet needed to be manually copied in the corresponding rows of the *BL Demand* worksheet in the DLP template which would be submitted.

**Figure 11-1 - WRSE outputs worksheet**

Forecast ID	DLP Stage	Company	Zone	Planning Scenario	Growth Forecast	Run Scenario	Row Ref	Component	Unit	Decimal places	2019-20	For info 2020-21	For info 2021-22	For info 2022-23	2023-24	2024-25	2025-26	2026-27
6	SES	SES		Housing-Plan-P	NYAA		11BL	Distribution Input	MWd	2	159.62	158.04	156.59	155.23	154.00	152.67	150.93	151.30
7	SES	SES		Housing-Plan-P	NYAA		23BL	Measured Non Household - Consumption	MWd	2	23.16	22.95	22.96	23.12	23.17	23.19	21.82	21.72
8	SES	SES		Housing-Plan-P	NYAA		24BL	Unmeasured Non Household - Consumption	MWd	2	1.97	1.97	1.97	1.97	1.97	1.97	1.84	1.83
9	SES	SES		Housing-Plan-P	NYAA		25BL	Measured Household - Consumption	MWd	2	57.60	64.64	71.35	77.77	84.20	90.37	91.67	92.96
10	SES	SES		Housing-Plan-P	NYAA		26BL	Unmeasured Household - Consumption	MWd	2	48.23	40.49	32.99	25.74	18.70	11.87	11.01	10.19
11	SES	SES		Housing-Plan-P	NYAA		32BL	Water Taken Unbilled	MWd	2	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01
12	SES	SES		Housing-Plan-P	NYAA		33BL	Distribution System Operational Use	MWd	2	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
13	SES	SES		Housing-Plan-P	NYAA		34BL	Measured Non Household - USPL	MWd	2	0.18	0.19	0.20	0.21	0.22	0.22	0.23	0.23
14	SES	SES		Housing-Plan-P	NYAA		35BL	Unmeasured Non Household - USPL	MWd	2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
15	SES	SES		Housing-Plan-P	NYAA		36BL	Measured Household - USPL	MWd	2	3.41	3.60	3.78	3.97	4.15	4.34	4.52	4.52
16	SES	SES		Housing-Plan-P	NYAA		37BL	Unmeasured Household - USPL	MWd	2	4.35	3.77	3.18	2.60	2.01	1.43	0.84	0.84
17	SES	SES		Housing-Plan-P	NYAA		38BL	Void Properties - USPL	MWd	2	0.41	0.36	0.32	0.27	0.22	0.18	0.13	0.13
18	SES	SES		Housing-Plan-P	NYAA		39BL	Distribution Losses	MWd	2	15.52	15.27	15.01	14.76	14.51	14.25	14.00	14.00
19	SES	SES		Housing-Plan-P	NYAA		42BL	Measured non-households - properties	000's	2	7.75	7.73	7.79	7.89	7.95	8.00	8.17	8.14
20	SES	SES		Housing-Plan-P	NYAA		43BL	Unmeasured non-households - properties	000's	2	1.15	1.11	1.06	1.02	0.97	0.93	0.95	0.94
21	SES	SES		Housing-Plan-P	NYAA		44BL	All void non-households - properties	000's	2	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
22	SES	SES		Housing-Plan-P	NYAA		45.7BL	Measured void households - properties	000's	2	6.88	6.54	6.19	5.85	5.50	5.16	5.16	5.16
23	SES	SES		Housing-Plan-P	NYAA		45BL	Total measured households - properties (excl void)	000's	2	162.36	182.57	202.01	220.72	239.65	257.95	262.27	266.50
24	SES	SES		Housing-Plan-P	NYAA		46BL	Unmeasured households - properties (excl void)	000's	2	108.69	91.74	75.17	58.95	43.06	27.48	25.47	23.58
25	SES	SES		Housing-Plan-P	NYAA		47BL	Unmeasured void households - properties	000's	2	3.20	2.67	2.14	1.61	1.08	0.55	0.55	0.55
26	SES	SES		Housing-Plan-P	NYAA		49BL	Measured Non Household - Population	000's	2	7.69	7.67	7.72	7.82	7.88	7.93	8.10	8.07
27	SES	SES		Housing-Plan-P	NYAA		50BL	Unmeasured Non Household - Population	000's	2	0.73	0.68	0.64	0.59	0.55	0.51	0.52	0.51
28	SES	SES		Housing-Plan-P	NYAA		51BL	Measured Household - Population	000's	2	419.45	471.55	521.85	570.54	619.80	667.87	675.97	683.70
29	SES	SES		Housing-Plan-P	NYAA		52BL	Unmeasured Household - Population	000's	2	306.64	260.04	214.04	168.60	123.69	79.27	73.68	68.38

## 12. Summary

SES Water commissioned Atkins to update their household consumption forecast model to allow them to produce a demand forecast for the WRSE regional plan.

The updates included:

- Incorporating new household population and property data, including SES Water's AMP7 metering and water efficiency strategies.
- Reviewing the micro-component modelling and forecasting approach, which resulted in external water usage OVF values being adjusted to ensure TUBs savings could be applied appropriately.
- Incorporating non-household consumption data into the model and developing a non-household property and population forecast which was also incorporated into the model.
- Calculating consumption uplift factors and incorporating these into the model.
- Updating other components of baseline demand within the model such as water taken unbilled and leakage.

Following these updates, the baseline demand components of the DLP template were populated and submitted for the WRSE regional plan.

For the WRMP24, SES Water will be incorporating the effects of COVID-19 in its assessment of baseline demand. This will be undertaken in a future iteration of the model. Also, as the 'Get Water fit' initiative continues and the dataset grows, the data should continue to be analysed and used to inform the micro-component modelling.

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# Level 2 Appendix E. Demand Forecast – 2021-22 Rebase for WRSE

# Technical Note

<b>Project:</b>	Water Resources Support		
<b>Subject:</b>	Demand Forecast - 2021-22 rebase update for WRSE		
<b>Author:</b>	Lauren Petch		
<b>Date:</b>	10/03/2023	<b>Project No.:</b>	5197934
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## Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1	First draft	LP	MS	MS	SW	10/03/2023

## 1. Introduction

This technical note outlines work carried out by Atkins in February and March 2023 to rebase SES Water's demand forecast to 2021-22 data and refers to v4.19 of the model<sup>1</sup>. This builds on previous work carried out by Atkins, Task WR-6, (see technical note: Summary of Water Resources and Drought Plan support services provided by Atkins to SES Water on 26 Jan 2023) to review and update the demand forecast model for the WRSE Regional Plan<sup>2</sup>.

Section 2 of this note details all the updates carried out to each part of the spreadsheet model. A more detailed explanation of what is included in the model and how it works can be found in our previous report<sup>2</sup>.

### 1.1. Data

For this work the following new or updated datasets were provided by SES Water and utilised as described in Table 2-1:

- SES Water dWRMP22 Tables final November 2022.xlsx
- 20230215\_MLE\_AR22Extract.xlsx
- 20230215\_Population\_properties\_AR22Extract.xlsx

<sup>1</sup> SES Water MC HHCP Model v4.19.xlsx

<sup>2</sup> Demand Forecast Updates for the WRSE Regional Plan, Atkins 2022, ref: 5197934/DG/070

- WRSE VICUS Forecasts – February 2023.xlsx
- 20230306\_AR21\_Extract\_Pop\_Prop.xlsx
- New Connections since 2008.xlsx

## 2. Demand model updates

Rebasing the demand model to 2021-22 required a full review of all model components to update year profiles, redirect relevant formulas and, where appropriate, insert updated data. Table 2-1 summarises changes made to each worksheet in the Excel model, while the following subsection identifies further items of note. A copy of the revised Excel model (v4.19) is provided alongside this technical note.

**Table 2-1 - Summary of updates to demand forecast model**

Worksheet	Description of sheet	Summary of changes
Front Sheet	List of worksheets in the model	<ul style="list-style-type: none"> <li>• Model version updated to 4.19</li> </ul>
Abbreviations	Abbreviations	N/A
Scenario selection & outputs	Water Resources Management Plan (WRMP) tables for baseline and final planning demand forecasts under various planning scenarios. Ability for the user to specify different aspects of the forecasts which plot in a series of micro-component graphs in rows 12 to 53.	<ul style="list-style-type: none"> <li>• Update WRMP Row ref's to align with latest WRMP table formats. Just relevant rows included and not full WRMP tables</li> <li>• Updated 36BL (Total Resource Zone Properties (incl voids)) to include 34.7BL</li> <li>• Copied in final plans option data for 12.2FP, 13.1FP, 14.1FP and 15.1FP to feed into final plan table outputs</li> </ul>
WRSE output calcs		N/A
WRSE outputs	Template for WRSE demand data	<ul style="list-style-type: none"> <li>• Update references to link with updated WRMP table inputs in Scenario selection &amp; outputs sheet</li> </ul>
POPROC split	Re-bases the population and property forecasts to SES Water reported households.	<ul style="list-style-type: none"> <li>• Total measured/unmeasured property and population figures automatically updated through links to POPROC inputs sheet.</li> <li>• Total new connections updated (C11) using 'New connections since 2008.xlsx' with data added to reflect addition of 2 years to base year</li> <li>• Updated linked cells from the Annual reported figures table (B17:H22) to show profile from 2016/17 up to 2021/22.</li> <li>• Updated Base year to 2021/22 in forecast and Outputs tables (Rows 27:70).</li> <li>• Updated linked formulas in the 'Method and calculations' section to point to new Base year</li> <li>• Update check formula in C49 to allow for up to 0.01% tolerance in totals</li> </ul>
POPROC inputs	Population and property data from Annual Returns and the WRMP	<ul style="list-style-type: none"> <li>• Updated the Pre- and Post-MLE totals in cells D14:E15 from '20230215_MLE_AR22Extract.xlsx'.</li> </ul>

Worksheet	Description of sheet	Summary of changes
		<ul style="list-style-type: none"> <li>Updated property and population totals in D20:D23 from '20230215_Population_Properties_AR22Extract.xlsx'.</li> <li>Extended Annual Return Water Balance components to include 2021-21 and 2021-22 (Note: value for 2020-21 interpolated from adjacent years).</li> <li>Updated Meter Optant and change of occupancy property values from dWRMP22 Tables (34.2FP, 34.3FP and 34.4FP)</li> <li>2020-21 measured and unmeasured properties figures taken from '20230306_AR21_Extract_Pop_Prop.xlsx'</li> <li>Updated Edge Analytics population and property forecasts in rows 76:94 from 'WRSE VICUS Forecasts – February 2023.xlsx'</li> </ul>
Non HH forecast	Non household central, lower and upper forecasts. Supplied from Artesia.	N/A
AMP7 targets and PC Tracker		N/A
Average Yr calcs	Normal Year Annual Average (NYAA) and Dry Year Annual average (DYAA) Distribution Input (DI) data (copied and pasted as values) for central growth forecast, with probability of occurrence percentages for dry years vs normal years. This data is used to generate overall average Distribution Input.	N/A
Charts tables	Data inputs to 'Scenario selection & outputs' worksheet micro-component graphs in row 12 to 53	<ul style="list-style-type: none"> <li>Updated all year columns headings to reflect new base year.</li> <li>Update index formulas to include all years up to 2100 for charts on 'Scenario selection &amp; outputs' worksheet.</li> <li>Updated baseline BL demand checks (rows 459:464) to work with updated WRMP tables</li> </ul>
Graph data	Worksheet collating the data inputs for graphs in the 'Charts tables' worksheet. Climate change factor input required. Currently includes the annual average and critical period climate change factors.	<ul style="list-style-type: none"> <li>Updated climate change uplift factors to reflect correction previously applied accounting for 2012-2040 profile of 0.88 and 2.4 climate change factors.</li> <li>Updated annual headings to reflect 2021/22 base year.</li> </ul>
Summary graphs	Various graphs summarising the trends in the subcomponents of the demand forecast such as	N/A

Worksheet	Description of sheet	Summary of changes
	the split of households (existing measured, unmeasured, optants, change of occupier and new properties).	
PCC variation	Calculates Dry Year (DY), market trend and sustainable trend measured household /unmeasured household PCC for each year of the planning period. Calculations based on PCC variation for each scenario which is a user input.	<ul style="list-style-type: none"> <li>Updated year column heading to reflect new base year.</li> <li>Market trend and sustainable trend figures shifted to reflect new base year but not updated.</li> </ul>
POPROC	Summarises the population and property forecasts calculated in the 'POPROC split' worksheet. Occupancy rates are calculated as Population divided by Properties.	<ul style="list-style-type: none"> <li>Updated year column heading to reflect new base year.</li> </ul>
Scenarios	Metering scenarios to determine the forecasts for optants and selective metering. Data linked from the 'POPROC split' worksheet. User input required to define scenarios.	<ul style="list-style-type: none"> <li>Formulas in 'New connections' (row 7) updated to reflect new base year.</li> </ul>
Base year	Collates base year per property consumption data from POPROC inputs worksheet and base year occupancy data from POPROC tab. Also collates final year occupancy data from POPROC worksheet. Percentage change in occupancy rate from base year to final year calculated. Contains NYAA and DYAA calculations. Contains critical period peak week calculations.	<ul style="list-style-type: none"> <li>Updated base year references to reflect updated base year and linked cells.</li> <li>NYAA/DYAA adjustment factors not updated.</li> </ul>
OVFs	Artesia micro-component OVF (ownership, volume and frequency) model intercept and slope. User can input 'Change of Occupier metering reduction' assumption.	<ul style="list-style-type: none"> <li>Updated headings to reflect base year and linked data.</li> </ul>

Worksheet	Description of sheet	Summary of changes
umHH PHC	Normal Year micro-component forecast for specified group (per household consumption). Calculations use linked data from 'POPROC'.	<ul style="list-style-type: none"> <li>Updated year column headings to reflect base year (includes shifting micro-component change factor forecasts but not updating).</li> <li>Updated water efficiency savings to achieve PCC targets from 3.5% for external, 0% for shower and 1.5% for tap to 10.5% for external, 3.5% for shower and 6.5% for taps.</li> </ul>
mHH PHC		
Existing PHC		
New prop PHC		
Optant PHC		
COO PHC		
mHH total	Micro-component forecast for specified group (total household consumption). Calculated from linked data in other worksheets.	<ul style="list-style-type: none"> <li>Updated year column headings to reflect base year.</li> </ul>
umHH total		
Existing total		
New prop total		
Optant total		
COO total		
umHH PCC	Micro-component forecast for specified group (per capita consumption). Calculated from linked data in other worksheets.	<ul style="list-style-type: none"> <li>Updated year column headings to reflect base year</li> </ul>
mHH PCC		
Existing PCC		
New prop PCC		
Optant PCC		

## 2.1. Items of note

As noted earlier a number of items of note have been identified as not being updated in this instance that SES Water may want to review.

### Metering Scenarios

The metering scenarios in the 'Scenarios' worksheet have not been updated. These were previously entered by SES Water and may need review to confirm they are still correct. The current scenarios include:

- Baseline 1 current model
- Baseline 2 – continue AMP5 percentage of unmeasured
- Scenario 3 – 80% metering by 2025
- Scenario 4 – 85% metering by 2025

### Water efficiency savings

As noted in Table 2-1 against the PHC worksheets, the water efficiency saving assumptions have been significantly increased so that the overall PCC estimate for 2024-25 continues to hit PCC target. The PCC targets are outlined on the AMP7 targets and PC Tracker sheet to be 138 l/h/d equating to approximately 148.5 l/h/d DYAA. It is noted that given the increase required to continue to meet these targets SES may want to review these changes.

### Hidden and transient population estimates

Hidden and transient population estimates are currently provided separately to the main population and property forecasts as static figures across the time horizon in the 'POPROC inputs' worksheet. These figures

came from '2020 Population Estimates - Edge Analytics.xlsx' but have not been updated in the current round of work.

### **Non HH forecast**

The non-household forecast is a static element within the model and has not been updated as part of this work.

### **Input data rows in 'Scenario selection and outputs' sheet**

There are a number of rows from the WRMP tables in this worksheet that are input cells and not linked to other elements of the model. These data points have all been check against SES Water's latest published WRMP tables however may need additional validation.

### **PHC Occupancy figure**

The PHC worksheets for umHH, existing, new prop, optant and COO contain a PHC Occ figure based

$$(FY(NY) - OVF(PHC))/29$$

This formula is consistent with the original spreadsheet model. However, we are not clear on the reasoning behind this specific calculation and have highlighted for further investigation in case an update may be needed.

### **Covid-19 adjustment**

With the demand forecast rebased to 2021-22 it is also necessary to update the approach to forecasting impacts associated with Covid-19. The previous base year was considered to pre-date the impacts of Covid-19 on demand and a percentage adjustment on household and non-household demand was therefore made and profiled within the WRSE headroom template. By rebasing to 2021-22, after the emergence of Covid-19, the baseline demand data incorporates its impacts such as those of more homeworking. This therefore necessitates that the previously applied Covid-19 headroom adjustment be removed so that Covid-19 impacts are not double counted. To align with the approach of other WRSE water companies, the Covid-19 of component of headroom has been removed completely rather than reprofiled to zero impact in 2040 as it was, or some other future date, on the assumption that the altered behaviours we now see that affect demand will endure.

To achieve this Atkins has updated the 'Covid impact calculation' worksheet within: WRMP19 headroom analysis for WRSE data request\_Apr20221\_V4 MS 2023.xlsx. This was done using outputs from the SES Water MC HHCF Model v4.19.xls (from the worksheet titled 'WRSE outputs') to update the following rows:

- Measured Non Household - Consumption (Ml/d)
- Unmeasured Non Household - Consumption (Ml/d)
- Measured Household - Consumption (Ml/d)
- Unmeasured Household - Consumption (Ml/d)

No other data within the headroom analysis spreadsheet have been updated.