Final Draft Water Resources Management Plan 2024

Appendix 4A – Baseline Demand Forecast

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OVERVIEW

The purpose of this document is to outline the technical details and assumptions that underpin the Portsmouth Water (PRT) WRMP24 baseline demand forecast, starting from the outturn base year 2021/22, extending up to 2074/75. The baseline demand forecast is subsequently used as an input into the WRSE investment modelling.

DOCUMENT LOG

Document History

Version Name	Edited by	Date Edited	Description of Edits	Further Comments
PRT_BaselineDemandDocumentation_v1.1	MS	09/12/2020	Document creation	
PRT_BaselineDemandDocumentation_v1.2	MS	15/12/2020	Updated BL leakage and climate change approach.	
PRT_BaselineDemandDocumentation_v1.3	MS	16/12/2020	Updated baseline options approach	
PRT_BaselineDemandDocumentation_v1.4	MS	23/02/2021	Minor update to population and demand normalisation.	
PRT_BaselineDemandDocumentation_v1.5	MS	23/03/2021	Added section on uncertainty	
PRT_BaselineDemandDocumentation_v1.6	SC	28/8/2023	Updates since draft WRMP24	
PRT_BaselineDemandDocumentation_v1.7	SC	30/9/2024	Updates for final WRMP24	

Review History

Version Name	Internal/External	Reviewed by	Date Reviewed	Comments
PRT_BaselineDemandDocumentation_v1.1	External	Jacobs	11/12/2020	Shared with Jacobs
PRT_BaselineDemandDocumentation_v1.5	Internal	Portsmouth Water	28/5/2023	Internal review
PRT_BaselineDemandDocumentation_v1.7	External	Jacobs	01/10/2024	Shared with Jacobs

CONTENTS

TECHNICAL DOCUMENTATION

1. PRT DEMAND MODEL

The Water Resources Planning Guideline (WRPG) requires demand forecasts to be produced for the three planning scenarios defined below:

- Normal Year Annual Average Demand (NYAA): The annual average daily value of demand under 'normal' weather conditions. The base year must be assessed as to whether it is a normal year, and if it is found not to be, its demand must be normalised to take account of factors such as weather.

- Dry Year Annual Average Demand (DYAA): The annual average value of demand under dry conditions without any drought demand restrictions in place. This demand is presented against the Average Demand Deployable Output (ADO) supply forecast.

- Dry Year Critical Period Demand (DYCP): The rolling 7-day average peak week that occurs during the dry year. This demand scenario is presented against the Peak Deployable Output (PDO) supply forecast.

The Normal Year Critical Period (NYCP), the 7-day average peak week that occurs during 'normal' weather conditions has also been reported for completeness. The agreed Portsmouth Water Dry Year definition is that "dry year" scenarios are classed as 1-in-20 year events.

We have developed a new WRMP24 demand model for calculating forecasts linked to each of the planning scenarios described above. All the separate components of the demand model are controlled in a single spreadsheet.

The spreadsheet model has been improved over time, incorporating feedback from internal reviews and external assurance processes associated with the submission of datasets towards the development of the Water Resources South East (WRSE) emerging, draft and revised draft regional plans. Model version '217' was used for the emerging plan, '222' for the draft plan and '230' for the revised draft and final plan.

The spreadsheet model is used to determine the base year component outputs for a given scenario, returning the forecasted components out to 2074/75. Fiscal year 2021/22, has been chosen as the base year for the WRMP24 to provide the most up-to-date view of demand possible (at the time of the demand forecast). Moreover, 2021/22 has been selected as the base year since 2020/21 was impacted by both Covid-19 and a hot dry summer.

Further detail of the methodologies followed are referred to within subsequent sections of this document.

The spreadsheet model consists of the core tabs in Table 1.

Table 1 Spreadsheet Model Tab Descriptions

Tab name	Description
controlLog	History of edits and reviews for each model version
modelParameters	Used for scenario selection according to defined WRSE outputs. The tab also contains the key assumptions and parameters for the model.
baseYearCalc	Converts the 2021/22 base year demand component actuals according to the selected scenario. This includes and adjustment to leakage and matches household demand to the climatic scenario.

optionsModel_AMP7	Applies assumptions of the AMP7 demand reduction strategy from 2019/20 to 2024/25.
nhhModel	Takes the raw Artesia non-household demand forecasts as inputs and converts them to net differences to apply to the base year. The tab is also used to produce the non-household property and population forecast
hhModel	The model controls the flow of properties and population between the three customer segments; Unmeasured, Meter Optants and New Properties. The tab also applies the PRT Variable Flow (VF) methodology, driving volume changes in the household customer base.
usplModel	Produces a forecast of Supply-Pipe Leakage given the expected growth in household properties.
demandForecast	Takes the model outputs from the preceding model tabs and applies the differences to the base year. The model also provides supporting metrics for a given scenario.
wrseTemplate	Applies relevant formatting to the demand forecast, outputting the data in in the format requested by WRSE.
demandDashboard	Provides summary plots of the outputs for a given scenario, comparing the results to those produced for WRMP19.

2. BASE YEAR CALCULATION

As described above, the base year for the demand forecast is 2021/22. Accordingly, the output components from the 2021/22 Water Balance 'Maximum Likelihood Estimation' (MLE) are used as a starting point within our WRMP24 demand model. Notably, the base year uses the updated methodologies for calculating PCC and leakage. This differs from the WRMP19 submission, which uses only 'new' methodology leakage. These methodology changes can impact the calculated total leakage and household consumption by up to 1 Ml/d.

The level of demand for water is not fully controlled by factors under the influence of a water company. Whilst demand does vary year to year because of ongoing trends, leakage reduction, water efficiency, metering and changes to properties and population, it is also dominated by the weather, with hot dry weather causing the demand for water to rise significantly.

Demand normalisation seeks to separate the effects of our ongoing interventions on leakage from the effects of weather, so that an estimate can be made of the demand that would have occurred in the base year had 'normal' or 'dry' conditions been experienced.

In order to achieve this, a weather demand model (Dynamic Demand Modelling for WRSE, Water Research Centre Limited, 2020), consistent with WRMP19 Methods – Household Consumption Forecasting (UKWIR, 2016) guidance, was developed. It allows historical and stochastically generated weather data to be run through the base year to determine how base year demand (both annual average and critical period) would change if the weather in year 'X' occurred again in 2021/22. Historical data is used to produce an estimate of the normal year, which is well understood, as this type of year occurs most frequently.

To get a best view of NYAA and NYCP demand in 2021/22, Distribution Input (DI) was de-trended using a Seasonal and Trend Loss decomposition. The data was then annualised and ranked, and the 50th percentile used to represent the Normal Year. Figure 1 shows the normalised result from the weather demand model. The blue line represents historic outturn DI, whilst the orange line represents the normalised DI data simulated by the regression model. The simulated DI data provides an estimate of what DI would be if that year's weather happened again with the current customer base and behaviours.

The weekly distribution data used in this analysis is the best available data set. Over the years, reporting methodologies for the components of distribution input have changed. Furthermore, the availability of data and our understanding of the water balance has improved over time. For example, during AMP4, Portsmouth Water completed the installation of 'Strategic Meter Areas' (SMAs). These strategic meter areas are permanently set up and data is logged and transferred by telemetry for analysis centrally.

The lower distribution input between 2012 and 2016 is believed to, in part, reflect increased expenditure in leakage reduction as a mitigation measure for drought risk and to meet Ofwat related targets. The decrease is also attributed to a fall in commercial demand since 2010, in addition to pressure management and improvements in household water efficiency. Outside of the 2012 to 2016 period, the detrended data is similar to the observed data. The increase in the observed distribution input between 2019/20 and 2020/21 is largely attributed to the impacts of the Covid-19 pandemic.

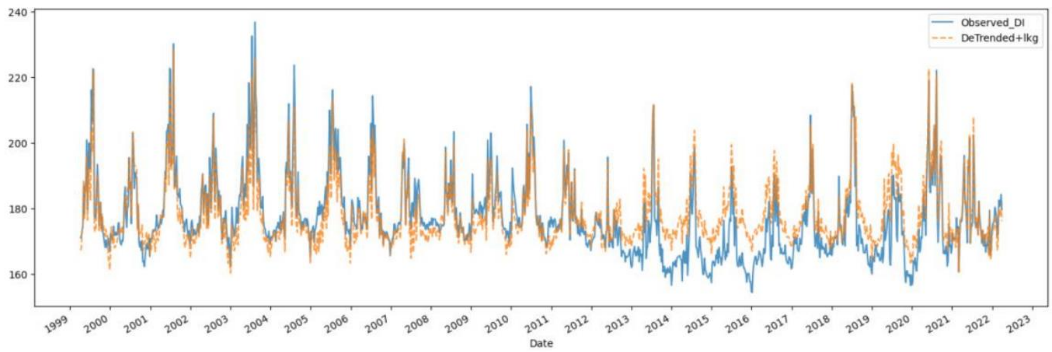

Figure 1 Calculating the NYAA by detrending the historic series. The NYAA is the medial annual average and annual maximum week

Following the calculation of the NYAA and NYCP DI, stochastic DI data is then used to explore rarer events, which are limited in the historic 20 year record. Raw simulated DI is first normalised to the median DI across all years and stochastic runs converted to factors. These factors can then be used as multipliers to the already derived NYAA and NYCP to generate DI annual averages (AA) and annual weekly maximums (CP) for different return periods, including the 1-in-20 year DYAA and DYCP.

WRc with Artesia have produced two sets of output stochastic DI reflecting two types 'Series 2' and 'Series 3'. For Portsmouth Water, both models perform well against the historical series though Series 3 is both recommended by Artesia, and, closely fits the historic series to within about 1 Ml/d as can be seen in Figure 2. Therefore, we have used Series 3.

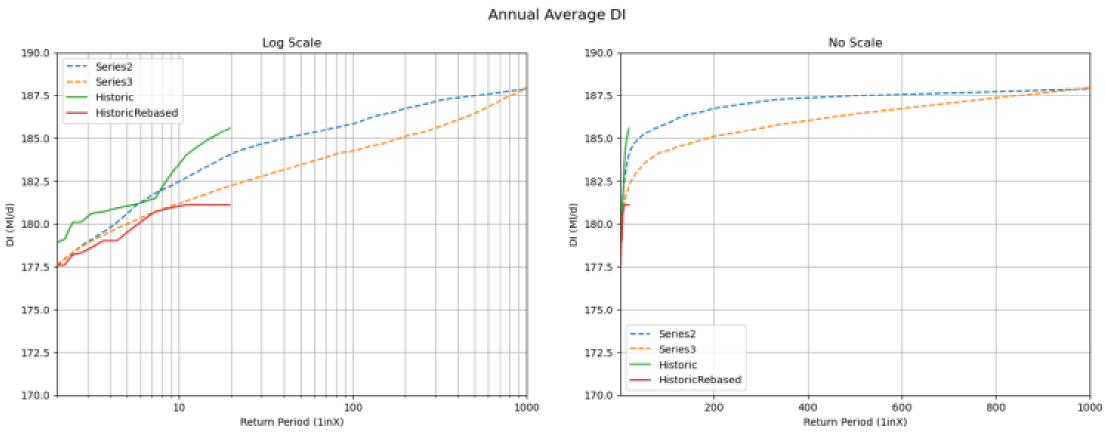

Figure 2 Stochastic DI against the historic record. Note that the 'HistoricRebased' is the de-trended DI series

To adjust the outturn (observed) base year DI to the 'target' DI for a specific climatic scenario, factors are applied to household consumption (a component of DI). The difference between the target and outturn DI, referred to as the ‘residual’ DI in the model, is allocated using an MLE type process using (Volume * Uplift).

Weather factors of 0.2 (20 %) and 0.3 (30 %) are used for the metered and unmetered household groups, respectively. These factors are based on outputs of the ‘Water demand insights from summer 2018’ club project, delivered by Artesia (see Figure 3).

The base year rebasing calculations can be seen in Figure 4. The weather factors in column H are applied to the outturn volumes to calculate the volume uplift in column I. Then the ‘weather allocation %’ in column J compares this uplift with the total volume uplift (e.g. 6.4 / (6.4 + 25.7) = 20%. Finally, the ‘weather allocation %’ is applied to the ‘residual’ DI to calculate the ‘Weather Allocation #’ in column K, which is then added to the outturn value to provide a rebased value in column L.

The ‘Uplift Factor’ in column M reflects the rebased value in column L divided by the outturn value in column E.

The total rebased DI in Cell L12 is calculated by summing the rebased component values in column L and it can be seen that this matches the ‘target DI’ in cell B5. It is the rebased component values for a selected climate scenario for 2021-22 that are subsequently used to develop the forecasts to 2074-75 (not the observed / outturn data).

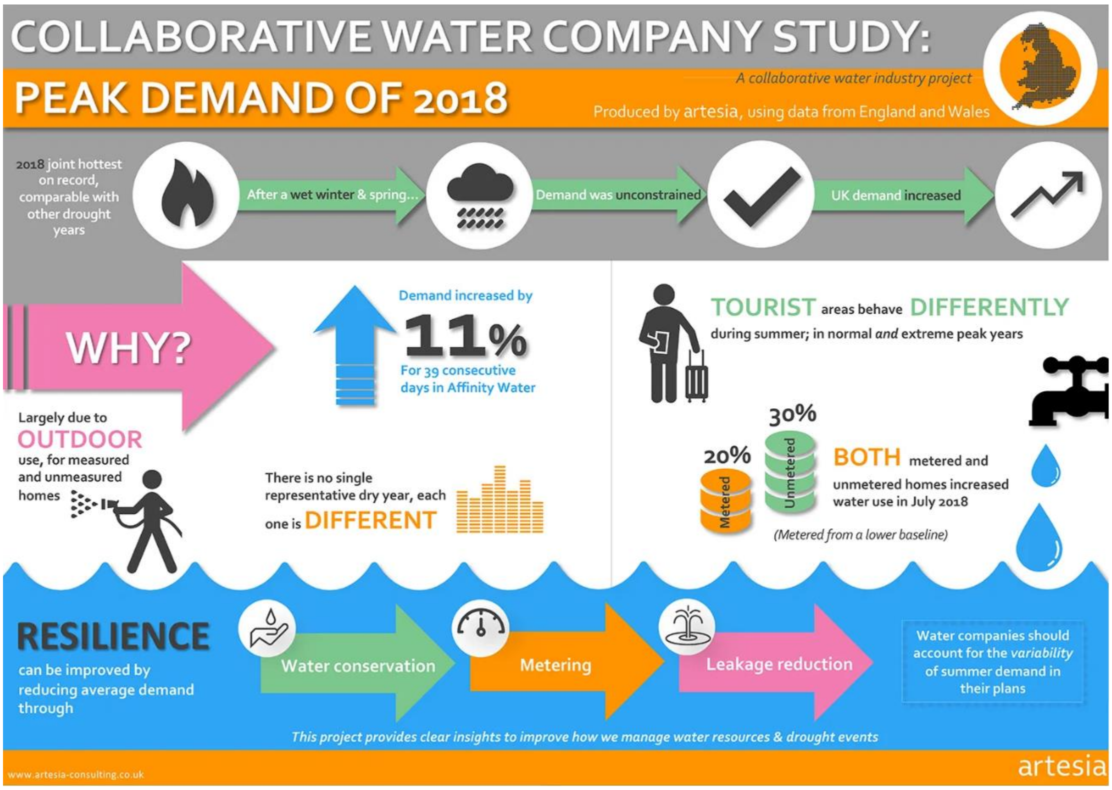

Figure 3 Peak demand of summer 2018 infographic (reproduced from Artesia)

baseYearCalc

Takes the base year sub-components of demand and converts these values

Selected Scenario	DYAA (1 in 20)
Target DI	182.24
Outturn DI	177.2
Residual	5.1

<- Adjust using modelParameter Sheet

Base Year 2021-22

	DEMAND			Outturn	Leakage Adj	Lkg Adj Outturn	Weather Factors	Weather Factor Adj	Weather Allocation %	Weather Allocation #	Rebased Balance	Uplift Factor
11AR	Distribution input (in reporting year)	Ml/d	2dp	177.18		177.18					182.24	
	Consumption											
23AR	Measured non household - consumption	Ml/d	2dp	29.05		29.05	0	0.0	0%	0	29.05	
24AR	Unmeasured non household - consumption	Ml/d	2dp	0.61		0.61	0	0.0	0%	0	0.61	
25AR	Measured household - consumption	Ml/d	2dp	31.95		31.95	0.2	6.4	20%	1.01	32.96	**1.032**
26AR	Unmeasured household - consumption	Ml/d	2dp	85.50		85.50	0.3	25.7	80%	4.05	89.55	**1.047**
29AR	Measured household - pcc	l/h/d	0dp	144.61		144.61					149.20	
30AR	Unmeasured household - pcc	l/h/d	0dp	167.02		167.02					174.92	
31AR	Average household - pcc	l/h/d	0dp	160.30		160.30					167.17	
32AR	Water taken unbilled	Ml/d	2dp	2.62		2.62	0	0.0	0%	0	2.62	
33AR	Distribution system operational use	Ml/d	2dp	0.52		0.52	0	0.0	0%	0	0.52	
	Leakage											
34AR	Measured non household - uspl	Ml/d	2dp	0.60		0.60	0	0.0	0%	0	0.60	
35AR	Unmeasured non-household - uspl	Ml/d	2dp	0.05		0.05	0	0.0	0%	0	0.05	
36AR	Measured household - uspl	Ml/d	2dp	5.07		5.07	0	0.0	0%	0	5.07	
37AR	Unmeasured household - uspl	Ml/d	2dp	7.11		7.11	0	0.0	0%	0	7.11	
38AR	Void properties - uspl	Ml/d	2dp	0.40		0.40	0	0.0	0%	0	0.40	
39AR	Distribution Losses	Ml/d	2dp	13.70		13.70	0	0.0	0%	0	13.70	
40AR	Total leakage	Ml/d	2dp	26.93		26.93	0	0.0	0%	0	26.93	

Figure 4 Screenshot demonstrating the calculation of rebased demand for use in the WRMP24 forecast

3. PROPERTIES & POPULATION

Eight properties and population scenarios were uploaded to the WRSE model: BL_H_Plan, Compl_5Y, H_Need, Max, Median, Min_10%, ONS18, Oxcam1a. PRT has used the 'WRSE VICUS Forecasts - February 2023' source data provided by Edge.

All forecasts are derived using the Edge Analytics Bottom-Up (BU) forecasts which allocate local plan growth according to potential housing development sites – rather than Top-Down, which allocated growth according to existing levels of growth.

The Max, Median, Min_10% are specific to each company. As the PRT household demand model volume growth is driven by both population and property growth, these scenarios are selected based on an analysis of ML/d impact in 2099/00.

WRSE Scenario	Edge Forecast
Max	Housing-Need-H
Median	Completions-5Y-P
Min	ONS-18-Low-L

Figure 5 Selected forecasts for Max, Median, Min scenarios

As the Edge base year estimates vary between scenarios and the PRT outturn reported figures, all forecasts are adjusted to outturn reported base year. This is achieved by taking the growth associated with each forecast and applying the net increase in each year.

All household property growth occurs in the measured group, as all new properties are measured.

Household population growth is not directly allocated to the measured customer base as this type of growth can occur across the unmeasured and measured population. Instead, the population is assigned according to a controlled logic in the PRT population and property model. Each new property is always assumed to be occupied with the estimated new property occupancy for a given year in the forecast. Suppose in any year the new properties cannot be filled with the new population as there is an excess of housing. In that case, the population is taken from the unmeasured and existing measured groups proportionally. Likewise, if there is an excess of the population beyond that met by new housing, then the surplus population is allocated proportionally.

All new Non-Household growth is assumed to occur to the measured Non-household group only. This approach is applied as the unmeasured Non-household group is small and remained stable for many years.

4. HOUSEHOLD DEMAND

The WRMP24 has used a 'Variable Flow' (VF) method proposed in the 'WRMP19 Methods – Household Consumption Forecasting' guidance. This was a new approach developed for the final WRMP19. The VF method involves explicit exploration of the factors impacting demand and the uncertainty surrounding the model assumptions. The variable flow method uses historical data to define variables, but also requires expert judgement and the application of assumptions. The term 'variable flow' refers to how factors modify fixed future assumptions on 'flows' of water into supply. For this WRMP24, the method has been applied again with updated assumptions.

The core drivers of volume in the VF model are population, properties and climate change. The model also includes impacts for baseline options implemented for metering, leakage and water efficiency for the period leading up to 2024–25. These are consistent with the medium scenario provided as part of regional planning for the WRSE options submission.

The household demand splits the household customer base into three groups: unmeasured properties, new properties and meter optants. New properties are those customers with properties built after 2006 while meter optants are properties that have voluntarily opted for a meter. Typically, in water resource planning, new volumes associated with growth are assigned to either new properties or new persons. One weakness of this approach is that it does not fully recognise the impact of occupancy on consumption, i.e. if average occupancy increases, then homes become more efficient and vice versa. The VF model attempts to capture occupancy impacts by assigning volumes to both properties and persons. Customer movements can then drive volume factors according to the outputs of the properties and population model.

In order to derive the volume factors, a linear regression model was developed using company-specific data. The model uses customer type and occupancy to predict Per Household Consumption (PHC) volumes. It uses per property meter reads for all household properties over two years, 2017/18 (Normal) and 2018/19 (Dry). The output of the model is provided in the Appendix, which indicates an R2 value of 0.53 and therefore a reasonable model fit.

The output is coefficients that split the PHC volume impacts for persons and households ('Intercept', 'c(buildStatus)[T.Property>2006]', 'c(buildStatus)[T.Property>2006]: Occupancy' and 'c(meterStatus)[T.Unmetered]: Occupancy') (see the Appendix). The aggregated coefficients are presented below in Figure 5. Note that only new properties have an aggregated property coefficient, as the measured and unmeasured properties already exist.

As an illustration for the PHC calculation, a single new property with an average occupancy of 2.2 would lead to an increased volume of 91.2 + (72.4 * 2.2) = 250.5 l/d. Likewise, the availability of new housing would cause a reduction in the unmeasured population and a relative increase in the New Property group. For each person, this would have an overall volume impact of (+72.4) +(-94.4) = -18.8 l/d.

Pop & Prop	Properties (l/prop/d)	Population (l/pers/d)
New Property	91.2	72.4
Measured (Meter Optant)	N/A	85.9
Unmeasured	N/A	94.4

Figure 6 Aggregated coefficients for population and property movements

The PRT climate change impact is based on the outputs of the UKWIR 'Impact of Climate Change on Water Demand Project' (2012), applying the look-up table of factors in Appendix 6. PRT has implemented the factors used for the South East using the 'Thames' outputs. The factors cover a range of scenarios from p10 to p90, the p50 figures are used as the central scenario. The raw factors extend to 2040, therefore the remaining years have been extrapolated using the Excel ETS forecast function, applied using Log(year) as inputs. The raw factors also use a 2012 base, to adjust to the WRMP24 base, the net difference is taken from 2021-22 onwards. The factors applied differ according to the climatic scenario i.e. Annual Average and Critical Period. An MDO set of forecasts are also produced, but are not utilised as a scenario for WRSE. In order to convert the factors to Ml/d impacts, the factors are multiplied by the base year total household consumption, which also varies according to the relevant climatic scenario. The total Ml/d impact of climate change in each year is then split between the Unmeasured and Measured groups proportionally, according to the split of households for a given year.

In theory, some fall in per customer demand is expected without company intervention, driven by replacement of old, less efficient, water-using devices. In practice, PRT has seen a continual increase in PCC for several years. This may suggest that this impact is being offset by other factors, for example, changes in customer behaviour. As these impacts cannot be robustly estimated, no reduction for water efficiency is assumed for the central scenario. Instead, ranges will be explored as part of the uncertainty analysis.

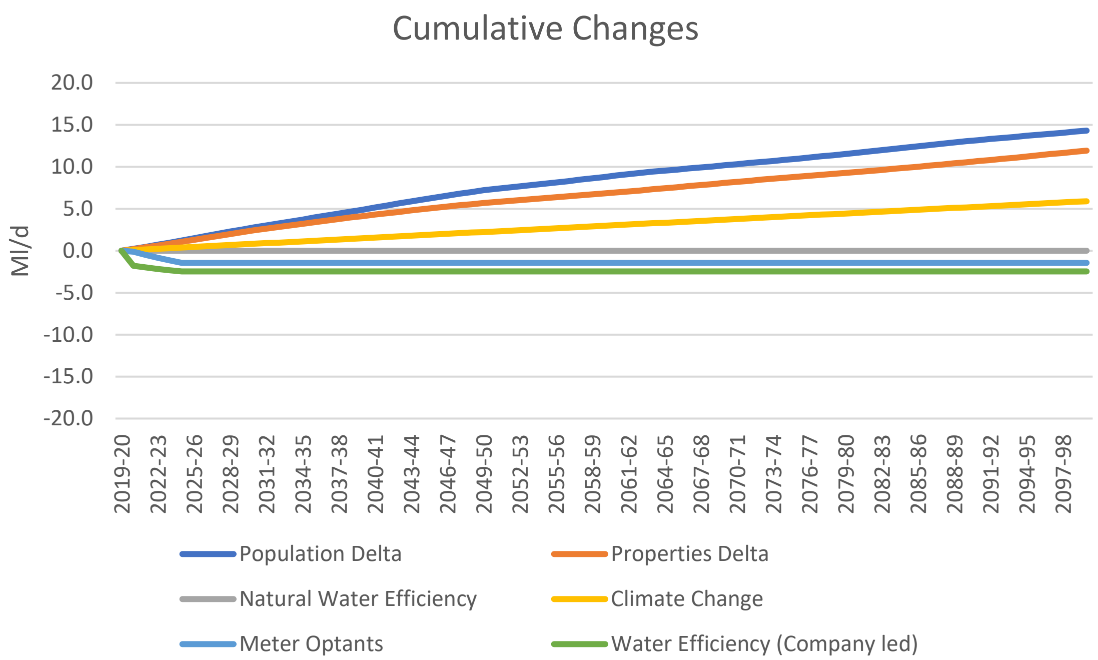

Figure 7 Example VF cumulative Ml/d impacts for NYAA

5. NON-HOUSEHOLD DEMAND

Artesia has created four core forecasts with associated uncertainty scenarios: Baseline, Low, Central, High. The Central scenario has been adopted for the main scenario.

As each of the scenarios has different starting points in the base year, all the forecasts have been adjusted to the 2021/22 outturn. This is achieved by taking the cumulative change from the base of each forecast, applying it to the 2021/22 actuals.

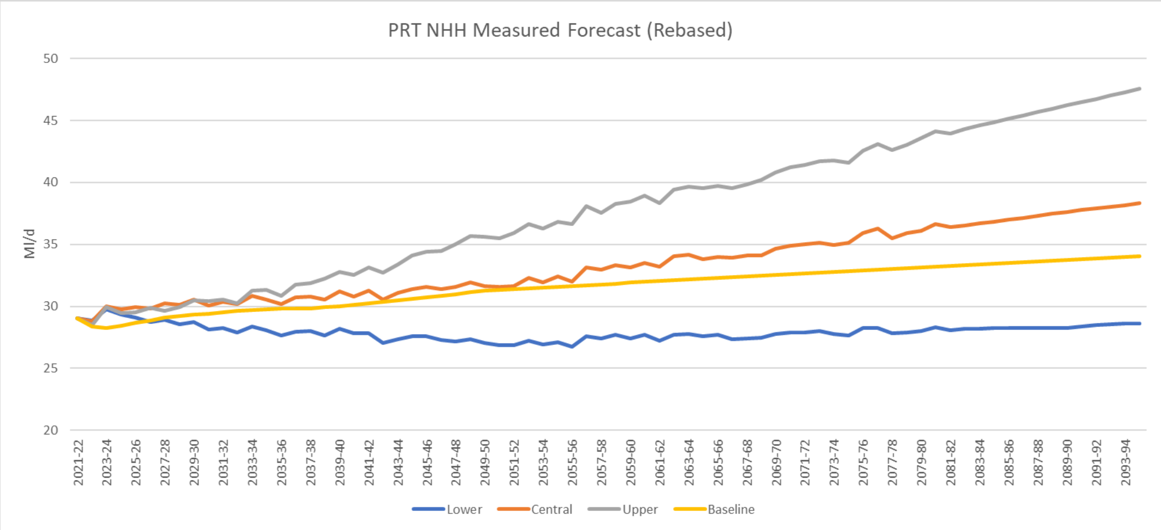

Figure 8 Non-household volume forecasts

6. LEAKAGE

The draft Environment Agency guidance suggests that leakage in the baseline forecast should be flat. Leakage in your baseline should remain static from the start of your plan to the end of the planning period. If there is significant growth planned in a resource zone you should discuss and agree your approach with regulators".

In practice, given no additional company effort, the baseline leakage might be expected to rise as the length of the network, and the number of supply pipe connections, increase with growth. In alignment with the guidance, however, all leakage is kept flat over the entirety of the period.

7. MINOR COMPONENTS

Water taken unbilled and Distribution system operational use are kept constant over the entirety of the planning period, held at 2021/22 levels.

8. BASELINE OPTIONS

Baseline options for metering, leakage and water efficiency are included in the period leading up to 2024/25. These are based on our most up-to-date view of the estimated outturn for AMP7.

The options applied in the period to 2024/25 are those intended during the AMP with lower reductions than the assumptions used in WRMP24.

Option impacts are scaled from the Normal Year NYAA scenario to the given climatic condition according to the relevant uplift in total household consumption.

APPENDIX

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    PHC   R-squared:                       0.532
Model:                            OLS   Adj. R-squared:                  0.532
Method:                 Least Squares   F-statistic:                 2.473e+04
Date:                Mon, 07 Sep 2020   Prob (F-statistic):               0.00
Time:                        14:25:42   Log-Likelihood:            -7.9225e+05
No. Observations:              130447   AIC:                         1.585e+06
Df Residuals:                  130440   BIC:                         1.585e+06
Df Model:                           6
Covariance Type:            nonrobust
=========================================================================================================
                                              coef    std err          t      P>|t|      [0.025      0.975]
---------------------------------------------------------------------------------------------------------
Intercept                                  63.1889      0.934     67.620      0.000      61.357      65.020
C(meterStatus)[T.Unmetered]                15.0782      6.567      2.296      0.022       2.207      27.949
C(buildStatus)[T.Property>2006]            28.0375      1.147     24.447      0.000      25.790      30.285
Occupancy                                  85.9360      0.399    215.513      0.000      85.154      86.718
C(meterStatus)[T.Unmetered]:Occupancy       8.4102      2.462      3.417      0.001       3.585      13.235
C(buildStatus)[T.Property>2006]:Occupancy -13.6761      0.492    -27.825      0.000     -14.639     -12.713
dryYear                                     3.1113      0.586      5.313      0.000       1.963       4.259
==============================================================================
Omnibus:                    12748.266   Durbin-Watson:                   1.231
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            20718.303
Skew:                           0.715   Prob(JB):                         0.00
Kurtosis:                       4.330   Cond. No.                         74.2
==============================================================================
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Figure 9 Measured Household PHC Regression Model