Water Resources Management Plan 2019
Annex 4: Environmental Forecast

December 2019

Version 1

Contents

1. Executive summary

In considering the scale of future potential environmental change and its implications for long term water resource planning, we have developed a set of future environmental scenarios which have been used to explore a range of potential future environmental conditions as part of the decision-making process and sensitivity testing for the Water Resources Management Plan 2019. Future environmental scenario testing will help to establish the robustness and resilience of the Plan to potential longer-term environmental change and, as far as is possible, to reduce the risk of abortive, redundant or inappropriate water resource investment.

Establishing the potential changes in the natural environment over extended planning horizons of over 50 years clearly requires consideration of uncertainty. This is often addressed through the development of future scenarios, for example as used widely by central UK government and its agencies for long-term policy development. Scenario-based analysis has become a well-accepted means of considering alternative future outcomes involving the construction of a potential sequence of events for the purpose of focusing attention on causal processes and decision points. It is important to emphasise that scenarios are not projections, forecasts or predictions; instead, they set out alternative future changes with a logical narrative governing the manner in which events could unfold.

A key step in scenario development is the identification of the major driving forces that represent the key factors, trends or processes that are likely to influence or alter the current “central” forecast, focal issue or decisions. Five main drivers were established during a workshop undertaken within Southern Water with support from consultancy staff in February 2017:

- Climate change
- Environmental regulation
- Technology
- Environmental values and perceptions
- Demographic/population change and distributions

Using these five drivers, three future scenarios were developed for the period planning horizons of 2050 and 2080:

1. ‘Conventional world’ scenario – based on what could be expected according to conventional expectations about the future.
2. “Sustainable world” scenario – based on a future where sustainability underpins policy and decision-making.
3. “Consumptive world” scenario – based on a future where market forces and consumption drive policy and decision-making.

For each driver, a series of pressures were identified and the critical dimensions of change in relation to the impact on water resource availability was assessed according to a ranking scale from 1. (positive to low impact) to 4 (significant impact).

A summary of these scenarios and the critical dimensions of change associated with each driver and pressure is provided in Figure 1 below. It is evident that, for both the 2050 and 2080 planning horizon, the dominant drivers are climate change effects on catchment processes and water quality and the environmental impacts on catchments related to population growth. Social changes (such as environmental awareness and attitudes to environmental protection) could also impact on future water resource availability.

Figure 1 Critical dimensions of change for key drivers for each scenario at 2050 and 2080

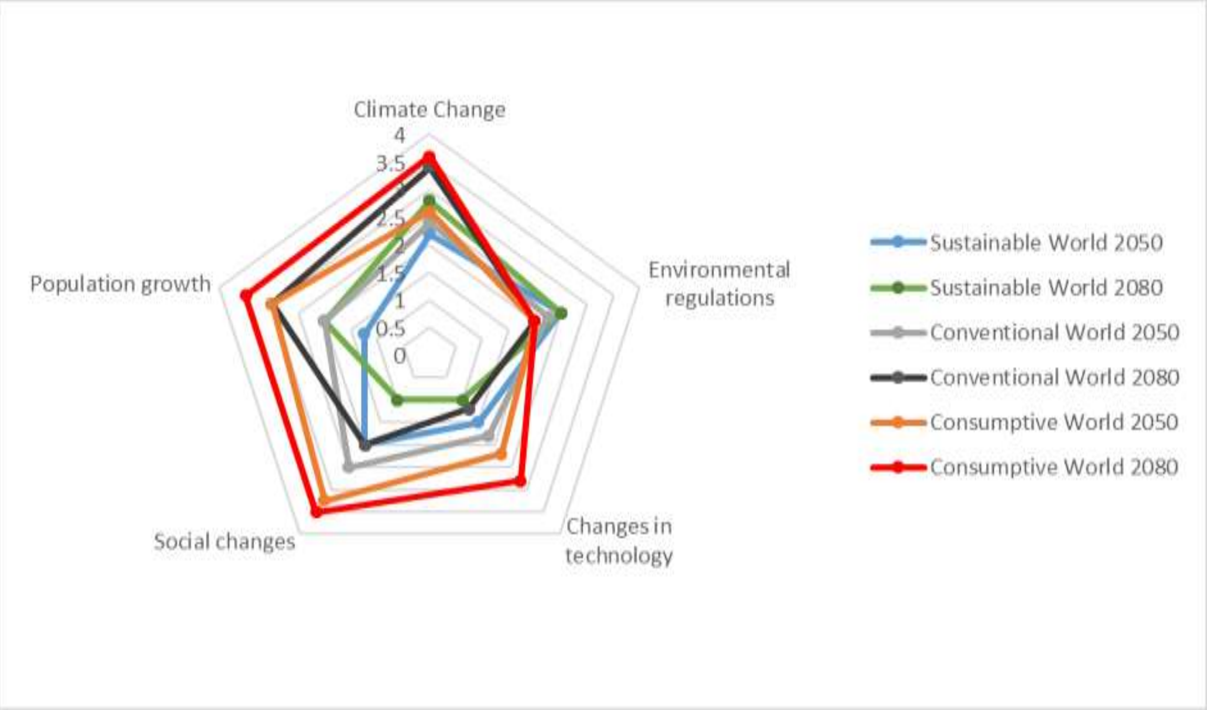


Figure 1 shows that the consumptive world scenario generally has the greatest impact on water resource availability in our operational area with the exception of environmental regulation where market forces and de-regulation would lead to a lower level of water environmental protection and therefore increased water resource availability. The conventional world shows a general progression from the current baseline conditions, whereas the sustainable world tends to work with the environment and leads to increased water resource availability except in respect of environmental regulations which has the greatest negative effect of all of the scenarios.

It is evident that, for both the 2050 and 2080 period, the conventional world and consumptive world scenarios would result in an adverse effect on water resources availability compared to the central forecast for deployable output set out in the draft version of this plan. For the sustainable world scenario, the effects at 2050 are low to positive, but by 2080 there is a negative effect, albeit lower than under the other two scenarios. These are considered plausible outcomes given the nature and scale of the key drivers and pressures identified for inclusion in the scenario development.

1.1 Risk of double counting impacts between central forecasts and environmental scenarios for this plan

Of the five drivers, only three have the potential for double counting impacts. This includes climate change, environmental regulations, and population growth*.*

1.1.1 Climate change

The deployable output forecast for this plan already takes account of the effects of climate change on water source hydrological runoff/hydrogeological recharge characteristics but not the effects of climate change on catchment land use or the water environment more widely which have been considered in the environmental scenarios. Consequently, there is no “double counting” of climate change impacts between the central forecast for this plan and the environmental scenarios.

1.1.2 Environmental regulations

The deployable output forecast for this plan includes known, ‘confirmed’ sustainability reductions arising from current environmental regulations (notably the Water Framework Directive and the Habitats Directive) as set out in Annex 3. The environmental scenarios consider whether future environmental regulations would be more or less stringent than existing regulations and postulate whether there would be a greater level of sustainability reductions in the future compared with those included in the central forecast of deployable output.

1.1.3 Population growth

The demand forecast for this plan includes projections of future population growth, but the environmental forecasts do not include any effects of population growth on demand for public water supplies (although demand for water abstraction by agriculture and industry is considered). Consequently, there is no double counting of the effects of population growth on public water supply demand.

1.2 Translating pressures and impacts into a deployable output response

In order to apply the three environmental scenarios to sensitivity testing of this plan, several steps are necessary to convert the pressures and impacts summarised in Figure 1 into a potential numerical effect on the central deployable output forecast for each water resource zone that can be used to “stress test” this plan.

The first step is to assess how each scenario driver may affect key indicators of change that influence water availability. This is set out for the Southern Water operational area in Table 1**,** demonstrating the linkage to the summary impact rankings for each driver identified in Figure 12.

The second step is to assess how each scenario driver may affect key indicators of change to habitats and species, taking account of the relationships between physical environmental change and consequent effects on flora and fauna. Climate change is the key driver of effects on flora and fauna: there is a 50% probability of an increase in temperature under all three future scenarios, ranging from 2.5^{o}C during summer to up to 8^{o}C with significant implications for aquatic species. It is estimated that a 1.5-2.5°C could result in a 20-30% loss of species. This, together with the effects of sea-level rise along the south coast, could result in significant changes in the distribution of species and habitats that currently drive water abstraction regulation in the Southern Water operational area. Under such a scenario, current sustainable abstraction decisions and Hands-off Flow (HoF) targets may no longer be appropriate, particularly where there are significant changes in the distribution of the species that drive these flow objectives. Other drivers have a lower effect on habitats and species as summarised in Table 2. Table 2 also assesses the likely consequential effects of these habitat and species changes on abstraction licence conditions under each of the three scenarios (***over and above any changes already identified under the environmental regulation driver).***

By considering the summary impact rankings and the key indicators in Table 1 and Table 2, it is possible to postulate a percentage change to the central forecast of deployable output for each of the three scenarios as set out in Table 3 for each main water source type (i.e. groundwater, river, reservoir, water reuse and desalination). These percentages changes can then be applied to each water resource zone source deployable output values. Further Tables are provided in Appendix B which indicate the potential changes to source deployable outputs for each water resource zone linked to the combined environmental scenario by 2050 and 2080 and changes in species and habitats at 2050 and 2080.

1.2.1 Rivers

With regards to climate change impact on rivers, we have already assessed the effect of climate change on runoff/recharge impacts on existing water sources (see Annex 3). As such, the direct impacts of climate change on water availability has been assessed as zero (0) to avoid double counting of climate change impacts.

Climate change impacts may have wider impacts on river abstraction sources. This will be mostly related to water quality and particularly the impact of sea level rise and the associated saline intrusion. Many of the Southern Water river abstraction points are situated near the tidal limit; changes in salinity resulting from rising sea level and an upstream shift in the salt mixing zone could therefore reduce freshwater availability and lead to a reduction in the deployable output of river sources near the tidal limit. This would be of particular concern during spring high tides should there be an extensive rise in sea levels (>40cm). Similarly, river source deployable output could be impacted by changes in nutrient and pesticide runoff. With a large decrease in summer rainfall expected for all future scenarios, there would be a decrease in the dilution capacity of rivers. The potential risk of changes in water quality would be a major concern during summer, coinciding with the expected decrease in precipitation. The decreased dilution factor and changes in water quality could be further exacerbated as a result of urbanisation which would increase the proportion of impermeable surfaces within river catchments. The extent to which these climate and population growth related impacts on water quality would impact on deployable output would be different for each scenario.

While social and technology changes would have little impact on the deployable output from river sources, some decreases in deployable output may be offset under the conventional world and consumptive world scenarios by relaxations to current HoF targets. This would be expected towards the latter part of the century when climate driven changes in species and habitats has resulted in a change in biodiversity within the operational area and a decrease in concern for the environment from a social perspective under these two scenarios.

The deployable output for river sources is expected to decrease regardless of the scenario. Both the conventional world scenario and the sustainable world scenario could see a reduction in deployable output from river sources by up to 21%. The conventional world scenario may result in a reduction in deployable output in the medium term, largely as a result of water quality changes between now and 2050.

1.2.2 Reservoirs

We have already assessed the effect of climate change on runoff/recharge impacts on our existing reservoir sources (see Annex 3). As such, the direct impacts of climate change on water availability has been assessed as zero (0) to avoid double counting of climate change impacts on reservoir sources.

The impact of water quality and surface runoff changes on reservoirs will likely be lower than for river sources. The impacts of changes in runoff on reservoir deployable output as a result of population growth will be lower as higher winter/peak runoff can be captured and stored and reservoir refill is already very limited during most summers due to negligible effective rainfall. The impact on water quality during the winter refill of reservoirs would also be lower as nutrient and pesticide concentrations would be lower during the winter period and dilution capacity of the rivers (for pumped refill reservoirs) and inflows (for impounding reservoirs) will be higher. The reservoir intakes for Southern Water's reservoirs tend to be further inland when compared to the key river source abstraction points and would therefore be less susceptible to impacts related to salinity changes.

While social and technology changes would have little impact on the deployable output from reservoir sources, some of the decreases in deployable output could be offset by relaxations of current HoF targets and/or river regulation release requirements (e.g. for River Medway Scheme). Compared to the impact on river source deployable output, there is less variation in the potential changes to deployable output between the different scenarios. By 2080, the deployable output could decrease by 10% under a sustainable world and 7% under the conventional world scenario. A small increase in deployable output from reservoirs could occur towards 2080 under a consumptive world scenario, mainly due to relaxations in environmental protection requirements. Overall, reservoir sources are likely to be more robust to potential future environmental change than the river sources. This is to be expected given the benefits afforded by the water storage capacity of reservoirs.

1.2.3 Groundwater

We have already assessed the effect of climate change on recharge impacts on existing groundwater sources (see Annex 3). As such, the direct impacts of climate change on water availability from groundwater sources has been assessed as zero to avoid double counting of climate change impacts.

The wider climate change impacts on groundwater sources are mostly related to population growth and the associated increase in urbanisation which would impact on groundwater recharge mechanisms during the winter periods due to an increase in impermeable surfaces within groundwater source catchment areas, thereby reducing infiltration capacity. Urbanisation will also reduce soil moisture storage within the catchment area, leading to a greater soil moisture deficit to be overcome before groundwater recharge can commence. Water quality within the aquifers could also be impacted as a result of increased population growth due to increased concentration of agricultural activity over a smaller area of land, leading to increased pesticide and nutrient concentrations during summer.

Climate change, exacerbated by reduced recharge due to urbanisation pressures, is likely to increase the risk of saline intrusion to groundwater sources in coastal areas: Southern Water has already been adversely affected by saline intrusion to some borehole sources in coastal areas. There would therefore be an increased pressure on groundwater sources, particularly in respect of treating higher salinity water and meeting drinking water quality standards.

While social and technology changes would likely have little impact on the deployable output from groundwater sources, some of the decreases in deployable output referenced above might be partially offset by relaxations of current abstraction licence conditions under the consumptive world scenario towards the 2080 planning horizon (for example, removing any river flow-related constraints or hands-off groundwater level conditions). Groundwater source deployable output values are however less constrained by abstraction licence conditions than river sources and therefore any partial offset will be small.

Overall there would likely be a decrease in deployable output from groundwater sources, varying in extent dependent on the selected scenario. Regardless of the scenario, groundwater deployable output could potentially decrease by more than 10% by 2080.

1.2.4 Water reuse

Southern Water currently has limited water reuse schemes as part of its water resource system. Southern Water currently recycle approximately 30% of the effluent upstream of abstraction points. The impacts of climate change on potential future water reuse options under consideration for this plan have not been explicitly assessed by the company but are flagged as a potential risk. In developing the environmental scenarios, consideration has been given to the potential effects of the various future environmental drivers on the assessed deployable output of water reuse schemes.

The impacts of reduced runoff as a result of climate change effects on precipitation and temperature are not expected to be significant on water reuse schemes; although there may be less flow in the river systems for dilution of the treated effluent upstream of the re-abstraction intake, this can be addressed through more intensive treatment of the effluent to meet water quality standards (at additional cost). Climate change changes in salinity are also considered unlikely to impact on reuse schemes, with dilution of treated effluent discharges taking place some distance upstream of existing abstraction intakes and so further upstream from saline intrusion threats.

There is likely to be an increase in dry weather flow to the wastewater treatment works as a result of population growth under all scenarios and so there would be no adverse effect on availability of effluent.

Water quality changes could impact on reuse schemes: increased nutrient and pesticide concentrations in rivers could potentially reduce the dilution capacity for treated effluent, reducing the volumes of treated effluent that can be discharged for re-abstraction.

Compared to other source types, social and technology changes are likely to benefit water reuse schemes. This could include changes in societal perception of indirect treated effluent as a water source and improvements in technology that result in lower cost treatment processes and a lower carbon footprint. These changes would be most notable under the sustainable world scenario where the emphasis is on protecting the environment and so there would be a greater focus on reuse schemes and finding lower cost, lower carbon treatment solutions.

There may be some benefits to developing reuse schemes in relation to changes in the environmental permitting regime, notably where these regulatory constraints might be relaxed under the consumptive world scenario. Such benefits are not expected under the Conventional or sustainable world scenarios.

Overall there could be some benefit to deployable output of water reuse schemes under a sustainable world scenario. Under the other scenarios, a decrease in deployable output may arise over time, mostly as a result of future adverse water quality changes occurring in these scenarios which reduce the dilution capability which cannot be overcome economically by more intensive treatment processes.

1.2.5 Desalination

Southern Water currently has no desalination schemes as part of its water resource system. The impacts of climate change on potential future desalination options under consideration for this plan have not been explicitly assessed by the company, but are flagged as a potential risk. In developing the environmental scenarios, consideration has been given to the potential effects of the various future environmental drivers on the assessed deployable output of desalination schemes.

Changes in summer precipitation and temperature (and consequently runoff) due to climate change could result in increased estuarine salinity due to reduced freshwater flows to estuaries. This could be further exacerbated by an increase in salinity in estuaries as a result of sea level rise and a change in the location of the salt mixing zone. Any changes would be seasonal in nature but will more acute in dry summers when desalination is most likely to be required. This increase in salinity would likely reduce the output from a desalination plant, with increased brine production and a lower proportion of drinking water produced. This could be overcome in time by adding increased process units to cope with the higher salinity (at additional cost).

There could be minor implications as a result of water quality changes (excluding salinity) in freshwater flows to estuaries and estuarine wastewater discharges in some scenarios due to increased population growth and urbanisation under the conventional and consumptive world scenarios. Increased nutrient and pesticides runoff will potentially reduce desalination treatment work output to ensure drinking water quality standards are met.

Desalination sources of water will likely be less constrained by changes in environmental regulations and permitting. The major driver of change would be changes in the social perception of desalination and changes in technology. Under a sustainable world scenario, consumers may be more willing to accept alternative water sources and there is likely to be a greater focus on improving desalination technology to reduce costs and increase energy and carbon efficiency. This emphasis could result in an overall slight net increase in deployable output from desalination under the sustainable world scenario.

Climate change and population growth drivers would likely lead to reductions to desalination deployable output under the conventional world and consumptive world scenarios.

1.3 Scenario testing

We used the results of the analysis from the environmental forecasting to run a sensitivity test in the plan for each area to understand the potential implications that the future environmental changes could have on the plan over the longer term. This sensitivity run assumes that there could be additional sustainability reductions in future, over and above those assumed in our baseline supply-demand balances in the late 2020's.

This is a critical additional uncertainty to consider; as whilst we have, as part of our decision making approach, already taken account of a range of plausible but uncertain futures, the Water Resources Management Plan (WRMP) process does not, at present, adequately account for future environmental uncertainties which may cause as yet unidentified sustainability reductions. The focus is primarily on short term sustainability reductions, but there is then an implicit assumption that there will be no further sustainability reductions in the mid- to long-term, which is not intuitive – as the environment comes under increasing stress there are various drivers which suggest that environmental regulation could become more stringent.

The aim of the sensitivity runs was therefore to identify how the strategy would change and whether it would trigger significantly different options if there were further reductions to water available for abstraction due to future environmental changes or policies. Alternatively, it could highlight that there would not be sufficient options available (based on the current list of feasible options) to solve additional possible sustainability reductions later in the planning period.

From our analysis for the draft WRMP, we identified that there were additional investments needed and / or unsolvable deficits later in the planning period. Options included additional desalination options (or larger desalination options), additional bulk imports, new reservoirs, additional water reuse options, and continued use of drought intervention options across the planning period.

There were no objections raised to our approach to including environmental forecasting uncertainties from respondents to the draft WRMP consultation. We therefore intend to pursue this further in our next WRMP in 2024, to ensure that in addition to forecasting supply and demand, WRMPs also take account of potential future changes to the environment which can and will impact on the availability for water resource purposes, and on the investment needed to ensure a secure supply of water in the future.

Table 1 Key indicators of physical changes associated with each of the drivers for each scenario

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
		2050	2080	2050	2080	2050	2080
Population growth	Pressure-Impact Ranking Summary	1.3	2.0	2.0	3.0	3.0	3.7
	Risk of reduced runoff and recharge within water source catchments	**Very Low**	**Low**	**Low**	**Moderate**	**Moderate**	**High**
Climate change	Pressure-Impact Ranking Summary	2.2	2.8	2.4	3.4	2.6	3.6
	Percentage change in summer precipitation	-37 to +9	- 39 to +13	-39 to +13	-48 to +7	-48 to +7	-55 to +5
	Summer temperature increase (°C)	1.4 – 4.3	1.4 – 5.1	1.3 – 4.6	2 – 6.5	1.4 – 5.2	2.6 – 8.1
	Sea level rise (cm)	15-20	20-25	20-25	30-35	20-25	>40
	Risk of saline intrusion to water sources	Low	Low	Low	Moderate	Low	High
	Risk of impact on water sources from other water quality changes	Low	Low	Moderate	High	Moderate	High
Environmental regulation	Pressure-Impact Ranking Summary	2.5	2.5	2.25	2.0	2.0	2.0
	Benefit to water resource availability	Low	Low	Low	Moderate	Moderate	Moderate
Technology changes	Pressure-Impact Ranking Summary	1.5	1.0	1.8	1.2	2.2	2.8
	Benefit to water resource availability	Moderate	High	Moderate	Moderate	Low	Low
Social changes	Pressure-Impact Ranking Summary	2.0	1.0	2.5	2	3.3	3.5
	Benefit to water resource availability	Low	Moderate	Low	Low	Very Low	Very Low

Table 2 Key indicators of habitat and species change associated with each of the drivers for each scenario

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
		2050	2080	2050	2080	2050	2080
Population growth	Habitat and species adverse impact due to changes in runoff and recharge regimes	Very low	Low	Low	Moderate	Moderate	High
Climate change	Habitat and species adverse impact due to climate change effects	Moderate	Moderate	Moderate	High	Moderate	High
Environmental regulation	Habitat and species adverse impact arising from the environmental regulation regime	Low	Low	Low	Moderate	Moderate	High
Technology changes	Habitat and species adverse impact arising from technology changes	Low	Low	Low	Moderate	Moderate	High
Social changes	Habitat and species adverse impact arising from social changes	Low	Low	Low	Moderate	High	High
Changes to abstraction licence conditions to address identified impacts on habitats and species		Additional constraint	Significant additional constraint	No action taken	Additional constraint	No action taken	Constraint relaxed

Table 3 Potential percentage change to deployable output by source type for Southern Water region

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
		2050	2080	2050	2080	2050	2080
Population growth	**Risk of reduced runoff and recharge within water source catchments**	**Very Low**	**Low**	**Low**	**Moderate**	**Moderate**	**High**
River		0	-1	-1	-3	-3	-5
Reservoir		0	0	0	-1	-1	-2
Groundwater		0	-2	-2	-5	-5	-7
Reuse scheme		0	0	0	-2	-2	-3
Desalination		0	0	0	-1	-1	-2
Climate change	**Percentage change in summer precipitation**	**-37 to +9**	**- 39 to +13**	**-39 to +13**	**-48 to +7**	**-48 to +7**	**-55 to +5**
	Summer temperature increase (°C)	**1.4 – 4.3**	**1.4 – 5.1**	**1.3 – 4.6**	**2 – 6.5**	**1.4 – 5.2**	**2.6 – 8.1**
River		0	0	0	0	0	0
Reservoir		0	0	0	0	0	0
Groundwater		0	0	0	0	0	0
Reuse scheme		0	0	0	0	0	0
Desalination		0	0	0	0	0	0
Climate change	**Sea level rise (cm)**	**15-20**	**20-25**	**20-25**	**30-35**	**20-25**	**>40**
	Risk of saline intrusion to water sources	**Low**	**Low**	**Low**	**Moderate**	**Low**	**High**
River		-1	-1	-1	-3	-1	-5
Reservoir		0	0	0	0	0	0
Groundwater		-3	-3	-3	-5	-3	-7
Reuse scheme		0	0	0	0	0	0
Desalination		0	-1	-1	-3	-3	-5

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
Climate change	**Risk of impact on water sources from other water quality changes**	**Low**	**Low**	**Moderate**	**High**	**Moderate**	**High**
River		-1	-1	-3	-5	-3	-5
Reservoir		0	0	0	-1	0	-1
Groundwater		-1	-1	-3	-5	-3	-5
Reuse scheme		-2	-2	-5	-7	-5	-7
Desalination		0	0	-2	-4	-2	-4
Environmental regulation	**Benefit to water resource availability**	**Low**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**
River		0	0	0	10	10	10
Reservoir		0	0	0	5	5	5
Groundwater		0	0	0	3	3	3
Reuse scheme		0	0	0	5	5	5
Desalination		0	0	0	0	0	0
Technology changes	**Benefit to water resource availability**	**Moderate**	**High**	**Moderate**	**Moderate**	**Low**	**Low**
River		1	2	1	1	0	0
Reservoir		0	0	0	0	0	0
Groundwater		1	3	1	1	0	0
Reuse scheme		3	5	3	3	1	1
Desalination		3	5	3	3	1	1
Social changes	**Benefit to water resource availability**	**Low**	**Moderate**	**Low**	**Low**	**Very Low**	**Very Low**
River		0	0	0	0	0	0
Reservoir		0	0	0	0	0	0
Groundwater		0	0	0	0	0	0
Reuse scheme		0	2	0	0	0	0
Desalination		0	2	0	0	0	0

Driver Indicator	Sustainable World		Conventional World		Consumptive World	
Changes to abstraction licence conditions to address identified impacts on habitats and species	**Additional constraint**	**Significant additional constraint**	**No action taken**	**Additional constraint**	**No action taken**	**Constraint relaxed**
River	-10	-20	0	-10	0	10
Reservoir	-5	-10	0	-5	0	5
Groundwater	-5	-10	0	-5	0	5
Reuse scheme	-2	-4	0	-2	0	2
Desalination	-1	-3	0	-1	0	1
Total Change for all drivers (%)						
River	-11	-21	-4	-20	-7	-5
Reservoir	-5	-10	0	-7	-1	2
Groundwater	-8	-13	-7	-19	-11	-14
Reuse scheme	-1	1	-2	-8	-6	-7
Desalination	2	3	0	-6	-5	-9

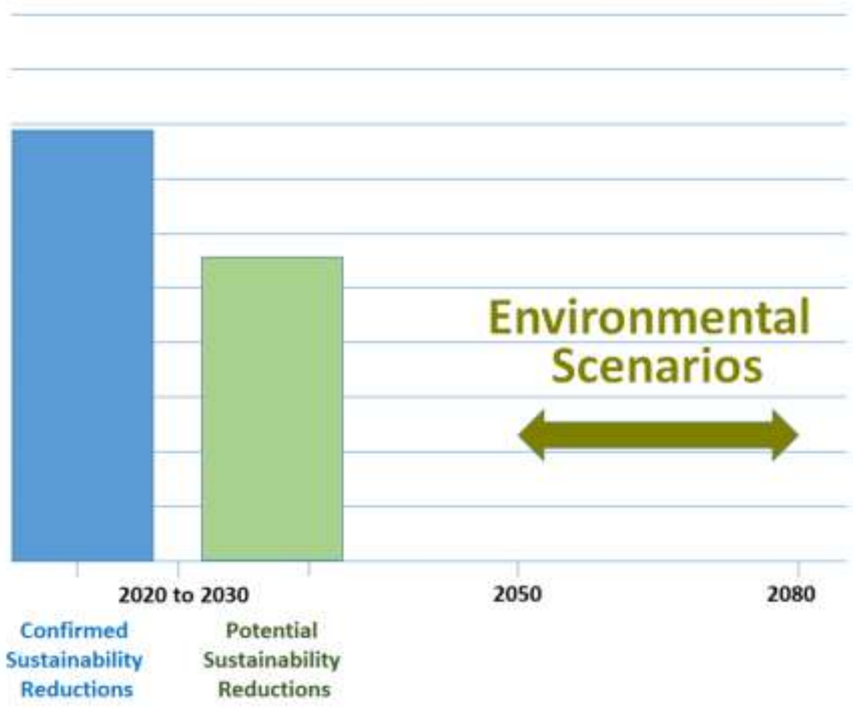
2. Framework assessment

2.1 Introduction

We supply water to customers in three operational areas within south east England (parts of Hampshire and the whole of the Isle of Wight; parts of Sussex; parts of Kent) and also provide bulk supplies to neighbouring water companies. It has a mixture of groundwater, reservoir and river sources, which react differently to hydrological and environmental conditions.

As part of the development of our Water Resources Management Plan (WRMP), we have tested the sensitivity and robustness of our plan over the longer-term by using a set of future environmental change scenarios for 2050 and 2080 to explore some of the uncertainties surrounding the potential impacts of environmental change on water resources provision in the future. Understanding these potential futures will help inform decision-making on the overall strategy for our operational area. Figure 2 shows how future environmental scenarios build on the confirmed and potential sustainability reductions included in our plan.

Figure 2 Diagram to show how future environmental change scenarios correspond with confirmed and potential sustainability reductions included in this plan



2.1.1 Scope and structure of this report

The purpose of this report is to describe a set of future environmental change scenarios that can be used for testing the consequences for water resources planning and help test the robustness of this plan. The approach adopted in this report allows for description of the potential future impacts of the company’s abstractions on the environment, as well as the effects of future environmental change on our water resource activities through explicit consideration of future environmental uncertainties.

The structure of the report is summarised below:

- Background to the Southern Water operational area, including the main environmental features of concern

- A background to managing uncertainty within the water resource management environment
- The approach to assessing the potential implications of different future scenarios
- A description of the current state of water availability within the operational area
- A description of the potential future drivers, the establishment and assessment of critical dimensions of each pressure for each of the future scenarios and the likely impact on water resource availability
- The response to the identified pressures and impacts on water resource deployable output is discussed, concluding with a percentage change to the central deployable output forecast for each scenario for use in sensitivity testing of this plan

2.2 Managing uncertainty

The long-term planning of water resources is a vital part of delivering the government's objectives to deliver secure, reliable, sustainable and affordable supplies of water, to value nature in decision making and connect people with the environment (Defra, 2015). The main aim of the WRMP process is the development of plans to provide a high quality, reliable and affordable water supply service to customers that is resilient to future uncertainties. Given the long-term nature of water resource assets and the lead time for their provision, it is important to test the risks to the WRMP over the long-term horizon (at least 50 years ahead or greater). Risk and uncertainty characterises much of long-term water resource planning and decision-making processes are therefore complex, requiring multidisciplinary information to evaluate their effects at a social, economic and environmental level.

In view of these challenges, more advanced water resources planning approaches have been developed, both at conceptual and practical levels, while modelling methods have become more powerful as reflected in the recent UKWIR project: WRMP 2019 Methods – Risk Based Planning Methods (UKWIR, 2016b). This UKWIR guidance provides a framework aimed at managing risks, uncertainty and alternative approaches to WRMP decision-making.

Understanding the potential changes in supply and demand over long periods inevitably involves dealing with uncertainty. Scenario analysis has increasingly been adopted across a wide range of long-term planning applications to help assess and manage uncertainty: scenario analysis has also been the subject of methodological elaboration since its emergence as a strategic planning tool in the 1970s and has become an accepted means of considering the future through the understanding of the nature and importance of the driving forces that may affect it (Manoli et al., 2005).

A useful definition of the term 'scenario' is: 'a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points' (Kahn & Wiener, 1967). It is important to emphasise that scenarios are **not** projections, forecasts or predictions. Rather, they are stories about the future with a logical plot and narrative governing the manner in which events unfold (Schwartz, 1991).

Scenarios usually include images of the future – snapshots of the major features of interest at various points in time – and an account of the causal flow of events leading from the present (or the base situation) to such future conditions. A key step in manging uncertainties through scenario based approaches is the identification of the major driving forces that represent the key factors, trends or processes that may influence and/or alter the current base forecast, focal issue or decisions. Some of these forces are invariant (e.g. they apply to all scenarios) and to a large extent may be predetermined. Some of the driving forces may represent critical uncertainties, the resolution of which can fundamentally alter the course of events. These driving forces (or drivers, for short) influence, but do not completely determine, the future.

With regards to the water sector, a number of driving forces were identified as part of the third edition of the World Water Development Report (World Water Assessment Programme, 2009) as well as by the scenario panel that defined the scenarios of the World Water Vision (Cosgrove & Rijsberman, 2000). These driving forces covered a range of considerations including:

- Demographics
- Economic
- Technological
- Water infrastructure
- Global climate change
- Environmental (including agriculture)
- Social
- Cultural and ethical
- Institutional/governance
- Political considerations

These driving forces consist of a subset of trends, processes or developments that influence the overall future. The economic driver, for example, is influenced by a demand for food, energy and other natural resources, global trade (including water trading) and economic globalisation (increasing interdependency among nations).

Scenarios are assessed according to previously selected critical dimensions which jointly define the most important attributes of the alternative futures (Gallopín & Rjsberman, 2000). The critical dimensions do not necessarily imply causal assumptions; rather, they are defined in terms of their salience as descriptors of the most important attributes of the images of the future: they are the fundamental indicators used to evaluate the desirability and sustainability of the alternative futures. Figure 3 includes a range of critical dimensions that may be applicable to future water resources planning scenarios.

During the scenario development process, the fundamental traits of each of these critical dimensions can be ranked, with the difference in rankings providing a picture of a potential future. In the example provided in Figure 4, a water stressed world scenario is characterised by intense water stress, high population growth, extreme climate change and poor ecosystem health. Although scenarios are definitely not predictions, they can provide knowledge on potential futures and events that, unlike forecasts, can present alternative images of these futures, without providing probabilistic estimates and analyses. Each scenario has critical effects and stimulates a range of pressures on the environment which may then influence water resource availability. For example, climate change may affect rainfall and temperature which will have direct impacts on water availability, and secondary effects on ecological communities, water quality and the environmental protection measures required to help maintain their ecosystem service functions.

Figure 3 Critical dimensions of scenarios potentially associated with water resource management (Gallopín, 2012)

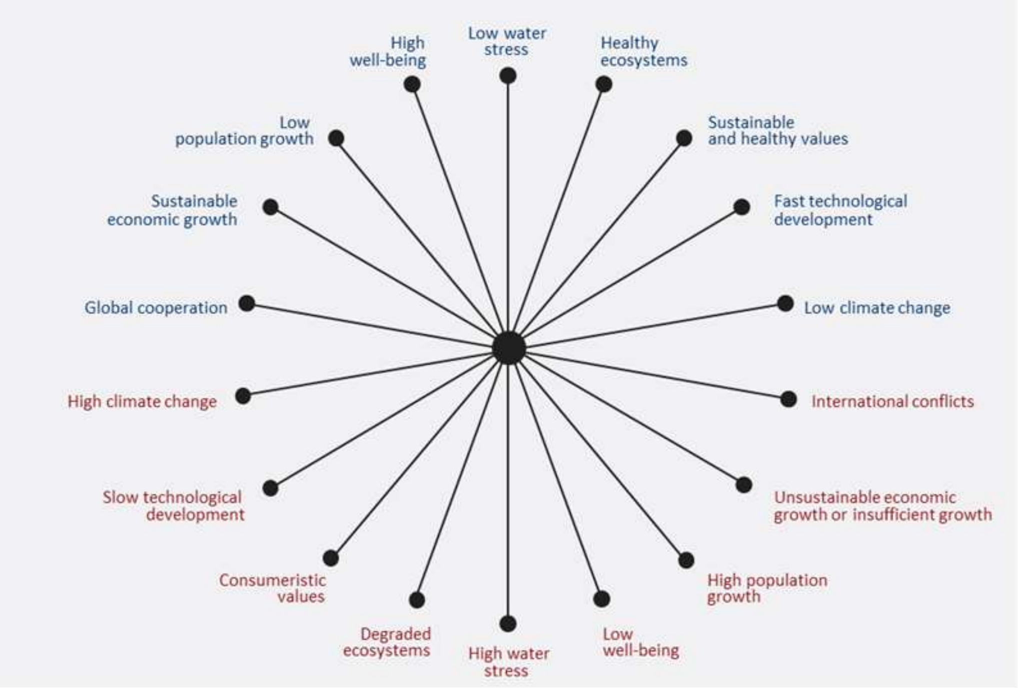
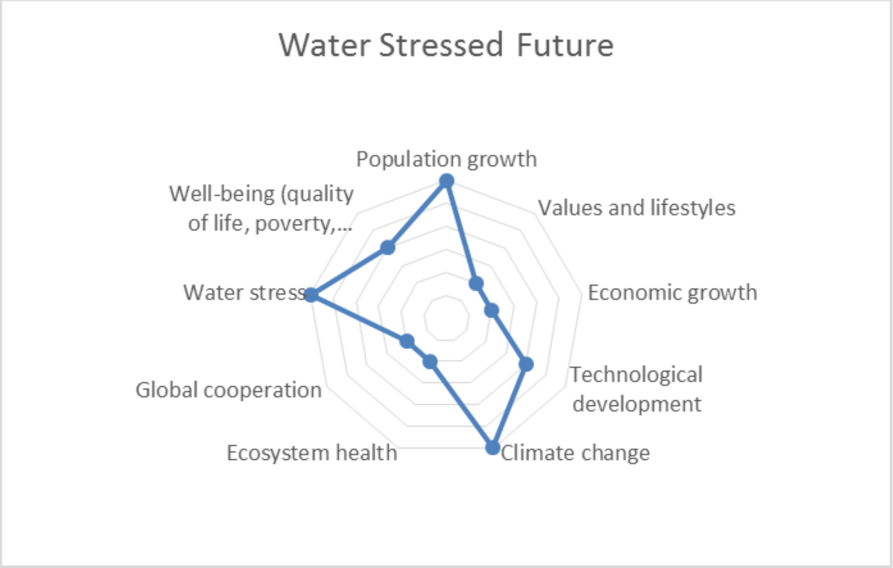


Figure 4 Graphical representation of the main drivers in an example of a water stressed future



3. Scenario approach for this plan

For the purpose of this plan, the potential impacts of each environmental scenario developed are considered over the medium to long-term and includes the potential impact of each scenario by 2050 and 2080.

In developing the environmental scenarios for this plan, reference has been made to the Department of Food and Rural Affairs (Defra) and Environment Agency (EA) recent use of scenarios. The Henley Centre Headlight Vision was commissioned in 2005 by the EA and the Defra to develop a set of scenarios that explored the possible changes in the pressures on water in the UK. In addition to different climate change scenarios, future scenarios were also developed to improve the understanding of water availability by considering a range of potential future scenarios based on different types of society (conservationist through to consumerist) and governance (growth-focused through to sustainability focused).

Future changes in demand for water were assessed by the EA based on four scenarios of the future based on the assumed changes in prioritised drivers (Environment Agency, 2011b). Analysis was also undertaken to assess the importance and level of uncertainty of each driver in relation to their overall impacts on the nature of future pressures on the environment. This resulted in a matrix (see **Error! Reference source not found.**) that represents the relative importance and uncertainty of the key drivers used in the EA study, based on the dominance and dependency scores derived from the analysis above. This analysis allowed for the categorisation of drivers into four groups:

- The first group of drivers (in the orange zone, left-hand column) contained those that were very important, but not that uncertain (for example, demographic change). These drivers act as a background context and were fed as inputs into all the scenarios
- The second set of drivers (in the blue zone, bottom right) contained those that have low ‘importance’ scores but have relatively high scores for uncertainty. The outcome of these drivers varied as a result of other drivers that shape the scenarios. They were not key driving forces in terms of future change, but could be considered as outputs or outcomes that may differ in each of the scenarios
- The third group of drivers (in white, bottom left) consists of those with low scores for both importance and uncertainty. This means they were usually not major influences on the overall future, but were still worth keeping in mind
- The fourth group of drivers (in the red zone, top right) contains those that have fairly significant levels of importance and uncertainty. It is these important and uncertain drivers that were the key focus of most attention in 2005, as they represent the key uncertainties that could lead to the most divergent views about the future

Those drivers that emerged from the above process as both important and uncertain were clustered to identify two ‘axes of uncertainty’. These axes capture the critical uncertainties in relation to the major forces that drive future pressures on the environment and thereby help to define the range of possible outcomes to be captured by the scenarios. Four scenarios were included to understand the potential changes in drivers and pressures by 2030 and subsequently 2050. These scenarios can be summarised as follows:

- **Innovation**: This is a world where society expects government and scientists to solve the problems of climate change and resource shortfalls so they can carry on living their lives as they wish. Although sustainable development is at the core of the scenario, this is delivered through means other than a shift in societal values. Regulation is strong and compliance high. The speed with which innovation is moving means the risk of new chemicals being released into the environment is greater, however, this world has the technology to cope with these risks

- **Uncontrolled Demand:** This is a largely selfish world driven by a desire for economic growth about both a national and individual scale. This however results in a significant divide between the very rich and the very poor with the remainder of society in the fragile middle ground. The environment is low on the agenda expect for the very rich who can afford to pay for access to ‘nice’ areas. As a result, regulation is minimal and regulatory standards low
- **Local Resilience:** This is a world recovering from a massive economic shock earlier in the 21st century. The result is that growth, whilst important, is no longer about money. There is a massive rise in subsistence type living and a ‘make-do and mend’ culture. As a result, society and its governance has a much greater regional focus and this extends to both regulations of the environment and operation of water systems
- **Sustainable behaviour:** The focus of this world is on achieving sustainable development and living within our environmental means. However, it is important to recognise that this does not mean the environment wins every time – economy and society are important too. The focus of the early part of the century was on reducing carbon and now both low carbon technologies and green energy are common place

Table 4 Matrix of drivers used in the Environment Agency future scenarios for 2030

High dominance/ importance		Globalisation	Resource constraints Climate change and societal response Increasing environmental awareness
Medium dominance/ importance	GRIN technologies Future of Europe Rise in global population	Uncertain international governance Rise of personal mobility Increased focus on wellbeing Role of self-interest in responding to environmental change	Consumption culture Changing nature of environmental legislation Developing environmental technologies Increasingly stressed infrastructure
Low dominance/ importance	Changing household set up Increased scientific understanding of environmental systems	Increased pressure on public spending Changing land-use patterns	
	Low dependency/ uncertainty	Medium dependency/ uncertainty	High dependency/ uncertainty

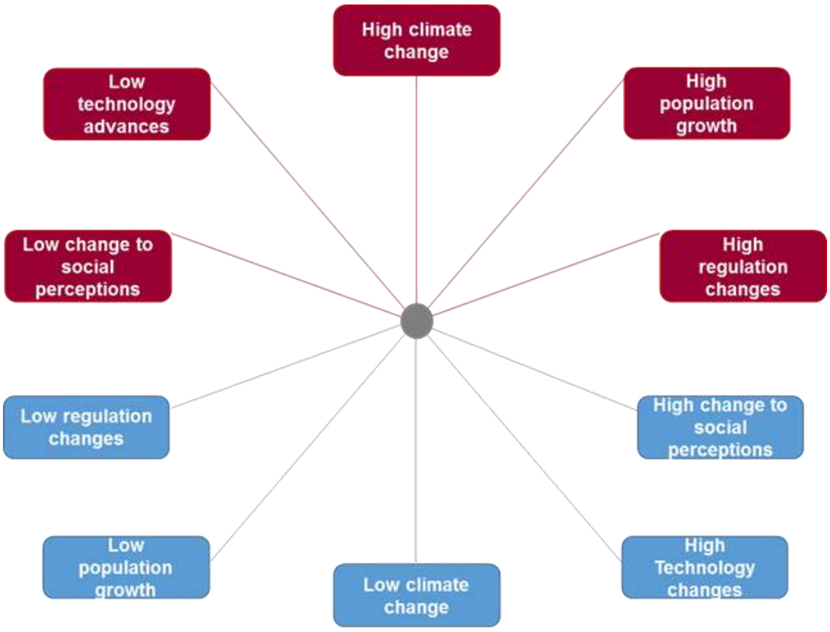
Based on these scenarios, the EA published a briefing note in 2009 on ‘Demand for water in the 2050s’. The note outlined the processes and outcomes of the water demand scenarios for the 2050s and was subsequently updated and replaced in 2011 (Environment Agency, 2011b). The scenarios used in this EA report considers assumptions about how people will live and work, systems of government, the technology that will be available, how people will use their leisure time and how they value the environment.

For this plan, three different future environmental scenarios have been developed to assess the impacts of future changes specific to the company’s operational area on water availability. These scenarios are not meant to replace scenarios that have been developed by the EA for assessing water demand and availability across the UK and nor do they replace the climate change scenarios developed through the 2009 UK Climate Projections (UKCP09) projects. Each of the drivers that have been included within the Southern Water future scenarios are linked to several pressures. We have included five (5) main drivers for consideration within the development of the scenarios - these drivers were identified as being of key concern through discussion with Southern Water during a workshop held on 9th February 2017, as set out below:

- Climate change
- Changes in environmental regulation
- Changes in technology
- Social changes in environmental values and perception
- Population growth

The critical dimension for each of these are indicated in Figure 5.

Figure 5 Critical dimensions of the future Southern Water environmental scenarios



The three scenarios proposed are set out below:

- **'Conventional world' scenario** – this is not a projection (linear or otherwise) of current trends but a scenario based on what could be expected according to conventional expectations about the future. This includes an exacerbation of current trends and the assumption that the behaviour of decision-makers in governments and societies in the next few decades will not be substantively different from that exhibited in the last 50 years (i.e. more focused on finding solutions to short-term problems with less consideration for the longer view), all operating within the constraints of the current environment.

- **'Sustainable world' scenario** – this describes a future in which policy follows an integrated approach to economic, social and environmental goals, and major institutional change occurs, with the overall goal of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". This scenario will consider the impacts of climate change to be mitigated over the medium term with extensive advances in technologies and suitably rigorous and timely societal change.

- **'Consumptive world' scenario** – this describes a future where one of the main drivers is the intensification of climate change and environmental degradation due to insufficient political will and a decrease in sustainability considerations. This could have serious consequences for the environment with rising temperature, sea level and changes in precipitation resulting in material changes to existing habitats, increased human development pressures on species and the spread of invasive species. Technology advances are inadequate to providing sustainable solutions to the mounting environmental changes. In this scenario, significant changes in land use are prevalent in order to meet population and economic growth.

Consultation with regulators and stakeholders is key in the development of a WRMP and stakeholder feedback on the environmental scenarios adopted will be sought as part of the draft WRMP consultation process.

3.1 Development of the three future scenario critical dimensions

Development of each of the three scenarios was informed by published evidence where available and plausible to fit the particular scenario. As an example, the potential future scenarios for climate change were based around the envelope of potential future forecasts available through the UK Climate Projections (Sexton et al., 2010). Other drivers, such as the potential change in social perception were based as far as possible on published research. However, for some drivers, professional judgment was required to construct the relevant boundaries and narrative of future change. Where possible, these scenarios were also informed by the scenarios used for the EA water demand 2050 study (Environment Agency, 2011b).

In determining the critical dimensions for each driver, the potential changes that could arise were established in the form of “pressures” and the critical dimension of each pressure were numerically ranked, ranging from 1 (low) to 4 (high) as shown in **Error! Reference source not found.** according to how that pressure may impact on water resources availability. The numerical average of the ranking was used to provide an overall assessment of the likely impact of the driver and its associated pressures on water resource availability. Finally, the aggregated impacts were used to assess the response of the water resources systems to these impacts – both direct impacts (e.g. change in runoff and baseflow) and indirectly (e.g. changes in habitat and species composition leading indirectly to changes to water resource availability, dependent on the particular chosen scenario).

A narrative description has been provided for each driver to inform the assessment of impacts on the current state/baseline of the water availability within our operational area. Ultimately, this approach has provided a ‘story’ and more detailed descriptors of potential change (quantified where possible) for each driver that has been used to determine the impact on water resources availability within our operational area.

The various future scenarios would result in different impacts on water resources availability. To better understand these impacts, a framework was necessary to establish the various drivers, impacts and the response pathways of relevance to future water resource planning that allows systematic consideration of the multi-faceted and inter-related effects of future scenarios on the environment and consequently this plan. The framework for the analysis is described below.

Table 5 Example of setting future scenarios for a particular set of pressures for a given driver using a ranking from 1 (low -to-positive change) to 4 (high-negative change)

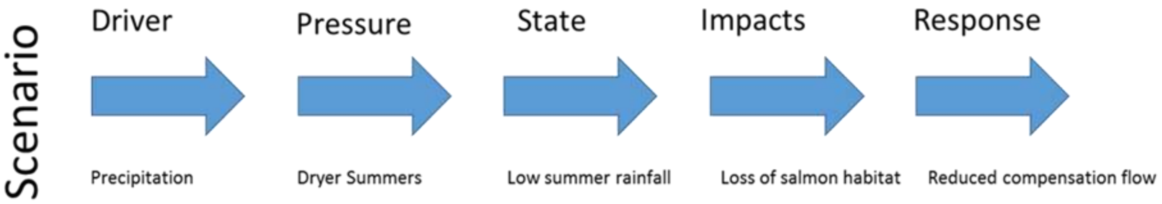
	Scenario					
Pressure	Sustainable World		Conventional World		Consumptive World	
	2050	2080	2050	2080	2050	2080
Pressure A	2	1	3	2	3	4
Pressure B	2	1	3	2	3	3
Pressure C	2	1	3	2	4	4
Pressure D	2	1	2	1	3	3
Pressure E	2	1	3	2	4	4
Pressure F	2	1	2	1	3	3
Average	**2**	**1**	**2.7**	**1.7**	**3.3**	**3.5**

4. DPSIR Framework

For the purpose of the scenario application, a modified Driver, Pressure, State, Impacts and Response (DPSIR) framework approach has been adopted to determine the response to each future scenario. The Global International Water assessment study developed ‘causal chain analyses’ to explore the perceived problems caused by societal root factors. A Pressure-State-Response (PSR) model was utilised by the Organisation for Economic Cooperation and Development (OECD) State of the Environment group and the United Nations Commission on Sustainable Development during their work on sustainable development. It considered the pressure of human activities on the quality and quantity of natural resource, and the societal response. Although the model is limited in that it only acknowledges that relationships exist and does not comment on the positive/negative nature of the relationship, it is also versatile as it is relatively simple. This model has been extended to distinguish DPSIR. Through identifying the progressive chain of events leading to state change, impact, and response, the DPSIR framework and derivatives can potentially be applied to nearly all types of environmental problems.

The DPSIR framework allows consideration of the chain of causal links (see Figure 6), starting with the identification of the major drivers followed by identification of the potential trends in the pressures applied. For example, climate change (driver) may influence precipitation and temperatures (pressures) which would then act on the natural environment (state). There may be consequences for habitats and species (impacts) that require a modification to abstraction (response).

Figure 6 DPSIR Framework for Scenario Analysis: Example



To assess the possible impact of future scenarios on this plan, a DPSIR framework was adapted to determine the extent to which changes in various drivers will impact on a number of different types of water resource plan intervention options (e.g. water reuse, reservoirs, groundwater abstractions) considered in this plan. Each step within the DPSIR framework has been described in more detail hereafter.

4.1 Drivers

Many different meanings have been attached to the concept of a Driving Force or driver, depending on “where” the cause of an environmental problem is identified (either in the human or in the natural systems, or in both) and on the level of the chosen system at which it is assumed to arise. Within a water resources context, drivers are the changes in the social, economic and institutional systems that directly or indirectly trigger pressures on the environmental state. The European Environmental Agency (EEA) defines such drives as ‘the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns (European Environmental Agency, 2007).

For the purpose of this study, the drivers are considered those forces which could potentially alter the current state of the environment in which we operate. This includes:

- Human activities (such as population growth) which are often driven by societal, technological and regulatory forces.

- Climate change - while it has often been considered a pressure rather than a driver (Millennium Ecosystem Assessment, 2005), in the context of the current study, climate change has also been considered a driver of change.

Each driver will have a varying degree of influence on the environment which is intrinsically linked to a range of pressures.

4.2 Pressures

Pressures are anthropogenic factors inducing environmental change. Usually these changes are unwanted and seen as negative (damage, degradation, etc.). According to EEA, pressures are “developments in release of substances (emissions), physical and biological agents, the use of resources and the use of land by human activities”. The definition of pressure and its usage in the literature differs in at least four aspects: the objective of change, the relationship between the pressure and the changes induced, the character of the pressure and finally the specification level of the pressure (Maxim et al., 2009).

A description of each key driver has been undertaken for each of the future scenarios. This is then used to determine the response of the environment within the constraints of the critical dimensions. Only those pressures which will ultimately influence water resources within the Southern Water operational area have been considered to assess impacts on the current state (baseline)

4.3 State

The current state is also known as the baseline. The EEA indicates that the state is “the quantity and quality of physical phenomena (such as temperature), biological phenomena (such as fish stocks) and chemical phenomena (such as atmospheric CO_2 concentrations) in a certain area.

In the context of the WRMP environmental scenarios, the state is mainly related to the current and ‘central’ future forecast of water demand and availability of water within the Southern Water operational area, as well as the baseline environmental conditions which are mainly assumed to remain static in the supply-demand balance forecasts (with the notable exception of climate change effects on hydrological conditions only). For the purpose of this report, a brief description of the current environmental status of associated waterbodies, a description of the main habitat features within the study area currently associated with abstractions (including designated sites) and a description of the current main biological features (including protected species) has been included.

Understanding the baseline state is necessary to establish the potential impacts associated with each scenario. Based on each future scenario, each pressure will result in certain changes (within the critical dimensions) in the base environmental conditions and/or distribution of important species and habitats. Understanding these effects is a fundamental basis for assessment of the pressures, the pathways of impact and knowledge of the locations and sensitivities of receptor habitats and communities.

4.4 Impacts

The extent of any impact is dependent on the particular environmental and/or ecological pathways and receptors associated with both the current state and the particular driver and pressure.

The DPSIR framework does not include a detailed assessment of these pathways or receptors, and this additional step has been adopted for the current study. Identifying these pathways and receptors is not only important for determining the extent of any impacts, but also assists in determining which pressures should be considered. For example, one of the pressures associated with the climate change driver is a change in summer rainfall: whilst this pressure can alter the current state of surface water availability, groundwater quality changes are likely to be impacted to a lesser extent due to the buffering afforded by natural infiltration processes.

An evidence-based understanding of the potential impact of each driver and pressure has be adopted. The result of changes to receptors can then ultimately be expressed as changes in features and/or regulations that are considered to be important with regards to the management of abstraction and water availability within the Southern Water area. Impacts may, for example, include changes in water quality, water quantity, Water Framework Directive (WFD) status or habitat extent. Each of these impacts will, in turn, result in a particular response.

4.5 Response

The extent of the identified impacts will result in a certain response. In the context of this report, the report assesses the response of the water resources system to the impacts identified, i.e. the change in deployable output either directly (e.g. due to the impact on river flow) or indirectly through policy response/action (e.g. changing hands-off flow conditions). Indirect responses may seek to control drivers or pressures (prevention, mitigation), to maintain or restore the state of the environment, to help accommodate impacts (adaptation) or even deliberate “do nothing” strategies (Perrings, 2005).

5. Application of DPSIR to the Southern Water region environmental scenarios

5.1 Drivers

In respect of the environmental scenarios for the Southern Water region, the following drivers have been identified:

- Climate change
- Changes in environmental regulation
- Changes in technology
- Social changes in environmental values and perception
- Population growth

5.2 Pressures, state and impacts

The following sections discuss each of the above drivers in turn, exploring the pressures, state (baseline conditions) and potential impacts under each of the three different scenarios.

5.2.1 Climate change

The first UK-wide Climate Change Risk Assessment (CCRA1) was published by the UK Government in January 2012 and updated in January 2017 (CCRA2) (Committee on Climate Change, 2017). The CCRA analysis has been split into 11 sectors to mirror the general sectoral split of climate impacts research: Agriculture, Biodiversity and Ecosystem Services, Built Environment, Business, Industry and Services, Energy, Floods and Coastal Erosion, Forestry, Health, Marine and Fisheries, Transport and Water.

The CCRA2 indicates that the most up-to-date land and marine climate change scenarios available for the UK remain the UKCP09 projections. Since UKCP09 was launched, a newer set of climate models has been developed to inform the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. A comparison between UKCP09 and the newer CMIP5 multi-model simulations conducted as part of preparing CCRA2 concluded that the results are generally consistent (Sexton et al., 2016). UKCP09 therefore continues to provide a valid assessment of the 21st century UK climate change risks and, in general, its outputs remain appropriate for strategic planning.

UKCP09 projections are produced for three different carbon emissions scenarios: Low, Medium and High (IPCC, 2000). Emissions scenarios were developed by the IPCC and reflect changes in the way economies are structured, population grows, technology develops, as well as energy intensity and land use changes. Importantly, all scenarios should be assumed to be equally plausible. They are all "non-intervention" scenarios that do not assume specific policy measures to mitigate the effects of climate change. The scenarios are referred to as the “A1 storyline” (which consists of three sub-groups (families) known as the A1F1, A1T and A1B storylines) and the “B1 storyline”.

The A1 storyline describes a future world of very rapid economic growth, and a global population that increases from 5.3 billion in 1990 to peak in 2050 at 8.7 billion and then declines to 7.1 billion in 2100. Rapid introduction of new and efficient technologies is assumed, as is convergence among regions, including large reductions in regional differences in Gross Domestic Product (GDP). Within the A1 family are three subgroups, referring to high use of fossil fuels (A1F1), high use of non-fossil energy sources (A1T) or an intermediate case (A1B) (Murphy et al., 2009). The A1F1 and A1B sub-family scenarios have been considered relevant for the UKCP09 medium and high emissions scenarios respectively.

The B1 storyline also describes a convergent, more equitable world, and has the same global population scenario as the A1 storyline. However, rapid changes in economic structures towards a service and information economy are assumed, with reductions in material intensity, and the introduction of clean and resource efficient technologies. Global solutions are found to economic, social and environmental sustainability.

UKCP09 treats these scenarios as equally plausible and it is considered best practice to present findings for a range of scenarios to show the range of possible outcomes when presenting UKCP09 projections.

5.2.2 Future climate changes

Projected change in temperature and precipitation for the 2050s and 2080s in the South East region of England, covering most of our operational area, are given as probabilities in the UKCP09. The probabilities given in UKCP09 represent the relative degree to which each climate outcome is supported by the evidence currently available, taking into account our understanding of climate science and observations, and using expert judgement (Murphy et al., 2009). For example, if a projected temperature change of +4.5°C is associated with the 90% probability at a particular location in the 2080s for the UKCP09 medium emission scenario, this should be interpreted as there is a 90% likelihood that temperatures at that location will be equal to or less than 4.5°C warmer than temperatures in the 1961-1990 baseline period. Conversely, there is a 10% likelihood that those temperatures will be greater than 4.5°C warmer than the baseline period.

From **Error! Reference source not found.,** it is evident that there is a large variation in the potential changes that could be observed under a medium emission scenario. By 2050, mean annual temperature is likely (50% probability) to have increased by ~2.8˚C. Seasonal variation in the magnitude of temperature increases is relatively small at 50% probability, though the effect is exacerbated in summer and autumn. Though unlikely, extreme high (90% probability) temperatures in summer are notably higher than temperatures in other seasons, especially compared with spring. The trend of temperature increases continues to the 2080s, with similar inter-seasonal variation seen. Mean annual temperature is most likely to have increased by ~3.6˚C.

Precipitation changes are more complex than temperature. Mean annual percentage change is minimal, being 0.2% by the 2050s and 0.7% by the 2080s at 50% probability. However, mean annual change masks significant seasonal variation. Percentage change in precipitation at 50% probability for both spring and autumn is low, being <5% even in 2080, though these seasons are projected to see increased precipitation in all cases. Winter precipitation is projected to increase in all cases, with a most likely increase of 16.6% by the 2050s and a 22.2% increase by the 2080s. Extreme high winter precipitation increases of 37.1% and 52.7% in the 2050s and 2080s, respectively, would signal massive shifts in the region’s winter precipitation regime. Summer precipitation is most likely to decrease by similar magnitudes, with reductions of -19% and -23% by the 2050s and 2080s, respectively. **Error! Reference source not found.** indicates that the extreme lows that may be observed in this scenario would result in extensive changes to hydrological regimes during summer months in the South East.

Error! Reference source not found. and **Error! Reference source not found.** present potential changes to sea level (in cm) relative to 1990 levels, indicating a positive rise is anticipated and increasing with time. These are derived from UKCP09 (for London) and recent work (Sayers at al., 2015) for the UK Committee on Climate Change CCRA2 (2017) on future flood risk (for Dungeness). There is a notably large difference between the low and high scenarios reflecting the complexity of the inter-dependent processes that influence eustatic and isostatic changes in sea level at the local level.

Table 6 Baseline temperature and precipitation change from the UKCP09 emissions scenario (Probabilities express percentage chance the deviation from the UKCP09 1990 climate baseline will be less than the value stated)

Variable	Time period	Emissions scenario	Change at 10% probability	Change at 50% probability	Change at 90% probability
Mean winter temperature (ºC)	2050s	Low	0.9	2	3.1
	2080s	Low	2	2.6	4
	2050s	Medium	1.1	2.2	3.4
	2080s	Medium	1.6	3	4.7
	2050s	High	1.4	2.5	3.8
	2080s	High	2	3.7	5.7
Mean summer temperature (ºC)	2050s	Low	1.4	2.6	4.3
	2080s	Low	1.4	3	5.1
	2050s	Medium	1.3	2.8	4.6
	2080s	Medium	2	3.9	6.5
	2050s	High	1.4	3.1	5.2
	2080s	High	2.6	4.9	8.1
Percentage change in mean winter precipitation (mm)	2050s	Low	1	13	30
	2080s	Low	4	18	40
	2050s	Medium	2	16	36
	2080s	Medium	4	22	51
	2050s	High	3	19	40
	2080s	High	7	30	67
Percentage change in mean summer precipitation (mm)	2050s	Low	–37	–14	9
	2080s	Low	–39	–15	13
	2050s	Medium	–41	–19	7
	2080s	Medium	–48	–23	7
	2050s	High	–43	–19	9
	2080s	High	–57	–29	5

Table 7 Relative change in sea level for each decade (in cm) with respect to 1990 levels for London (UKCP09)

Year	London		
	High	Med	Low
2000	4	3	3
2010	7	6	5
2020	12	10	8
2030	16	14	12
2040	21	18	15
2050	26	22	18
2060	31	26	22
2070	37	31	26
2080	43	36	31
2090	50	42	35
2095	53	44	37

Table 8 Relative change in sea level for each decade (in cm) with respect to 1990 levels for Dungeness (CCRA2, 2017)

	Dungeness		
Year	**High (Environment Agency, 2011a)**	**Medium (IPCC/UKCP09 Hybrid with 4°C temperature rise)**	**Low (UKCP09 with 2°C temperature rise)**
2020	14	14	3
2050	60	37	14
2080	143	64	26

5.2.3 Climate change: critical dimensions

The main pressures associated with climate change include changes in mean winter temperature (ºC), changes in mean summer temperature (ºC), changes in mean winter precipitation (mm and %) and changes in mean summer precipitation (mm and change %), along with sea level rise (cm). There is a range (or envelope) of change that may be observed for each of the pressures associated with climate change which is different for each time period (i.e. 2050 and 2080).

As UKCP09 treats all scenarios as equally plausible, each climate change scenarios have been considered in the context of the three scenarios considered for this report as follows:

- The medium emission scenario has been considered to be representative of a median scenario or the ‘conventional world’ scenario
- The low emission scenario has been considered to be representative of the sustainable world scenario
- The high emission scenario has been considered representative of the consumptive world scenario

The predicted changes in pressures have been assigned a rating based on the 50% probability for each forecast. The ranking system (from 1 to 4) used for the dimensions of changes associated with climate change is set out in Table 9**.** Application of this ranking system to the dimensions of change associated with climate change is set out in Table 10.

Table 9 Ranking system used for the dimensions of changes associated with climate change

Pressure	1	2	3	4
Temperature (°C)	0-1	1.2 – 2	2.1-3	>3
Rainfall (% change)	0-10	11-20	21-30	>30
Sea level rise (cm)	0-10	11-20	20-30	>30

Table 10 Critical dimensions for each pressure associated with climate change

Pressure	Sustainable World		Conventional World		Consumptive World	
	2050	2080	2050	2080	2050	2080
Mean winter temperature	2	3	3	3	2	4
Mean summer temperature	3	3	3	4	4	4
Changes in mean winter precipitation	2	2	2	3	2	3
Changes in mean summer precipitation	2	2	2	3	2	3
Sea level rise	2	4	2	4	3	4
Average	**2.2**	**2.8**	**2.4**	**3.4**	**2.6**	**3.6**

5.2.4 Climate change summary

Based on the potential future climate change scenarios, the potential envelope of change for each environmental scenario can be summarised as follows:

Conventional world scenario

- For the conventional world scenario, the median temperature increase during winter is expected to be around 2.2°C by 2050 with a range of 1.1°C – 3.4°C. The median increase for this medium emission scenario by 2080 is higher and predicted to be around 3°C. Summer temperatures are also expected to increase by 2.8°C and is unlikely to be less than 1.3°C for both winter and summer and is highly likely to increase by as much as 4.6°C and 6.5°C by 2050 and 2080 respectively
- Winter precipitation is expected to increase by a median of 16% and 22% by 2050 and 2080 respectively. Summer rainfall is expected to decrease by around 19% by 2050 and 23% by 2080
- Changes driven by climate change are therefore expected to be very similar to the sustainable world scenario up to 2050, and milder and wetter winters and hotter and drier summers could be expected
- Sea level is expected to rise by between 22cm to 37cm by 2050 and by between 36cm to 64cm by 2080

Sustainable world scenario

- For the sustainable world scenario, the median temperature increase during winter is expected to be around 2°C by 2050 with a range of 0.9°C – 3.1°C. The median increase for this low emission scenario by 2080 is not much higher and predicted to be around 2.6°C. Summer temperatures are also expected to increase by 2.6°C and is unlikely to be less than

1.4°C for both scenarios and is highly likely to increase by as much as 4.3°C and 5.1°C by 2050 and 2080 respectively

- Winter precipitation is expected to increase by a median of 13% and 18% by 2050 and 2080 respectively. Summer rainfall (in mm) is expected to decrease by around 14% by 2050 and 15% by 2080
- Climate change will therefore lead to milder and wetter winters and hotter and drier summers.
- Sea level is expected to rise by 14cm to 18cm by 2050 and 26cm to 30cm by 2080

Consumptive world scenario

- Median temperature increase during winter is expected to be around 2.5°C by 2050 with a range of 1.4°C – 3.8°C. The median increase for this high emission scenario by 2080 is higher and predicted to be around 3.7°C. Summer temperatures are also expected to increase by 3.1°C and is unlikely to be less than 1.4°C for both winter and summer and is highly likely to increase by as much as 5.2°C and 8.1°C by 2050 and 2080 respectively
- Winter precipitation is expected to increase by a median of 19% and 30% by 2050 and 2080 respectively. Summer rainfall is expected to decrease by around 19% by 2050 and 29% by 2080
- Changes driven by climate change is therefore expected to be similar to both the sustainable world and conventional world scenario up to 2050, and milder and wetter winters and hotter and drier summers could be expected
- Sea level is expected to rise by between 26cm to 60cm by 2050 and 43cm to 143cm by 2080.

5.2.5 Environmental regulation

Within our operating area, a raft of environmental protection legislation is in place for a wide range of sensitive species and habitats, with a significant number of international designated freshwater, estuarine and coastal waters (Ramsar sites, Special Areas of Conservation and Special Protection Areas) as well as national designations (Sites of Special Scientific Interest, Marine Conservation Zones, two National Parks, various Areas of Outstanding Natural Beauty and National Nature Reserves) and NERC Act Section 41 Priority Habitats and Species

Sensitive aquatic species within our operating area include:

- Atlantic salmon (Salmo salar)
- Brown/sea trout (Salmo trutta)
- Bullhead (Cottus gobio)
- European eel Anguilla (anguilla)
- River lamprey (Lampetra fluviatilis)
- Sea lamprey (Petromyzon marinus), white-clawed crayfish (Austropotamobius pallipes),
- Smelt (Osmerus eperlanus)
- Depressed river mussel (Pseudanodonta complanata)
- Tentacled lagoon worm (Alkmaria romijni)
- Otter (Lutra lutra)
- Water vole (Arvicola amphibius)
- European beaver (Castor fiber)

Priority habitats include: rivers and streams (headwaters and middle and lower reaches), standing open water (lakes and ponds), lowland fens, estuary, saltmarsh and mudflats.

Appendix A sets out potential effects on key species due to environmental changes.

In addition to the Water Resources Act 1991 (as amended) legislative controls and the associated abstraction licensing regulatory regime, water availability is also constrained by environmental protection regulatory requirements of various national and international legislation and associated regulatory guidance:

- Water Framework Directive – primarily requiring measures to achieve Good Ecological Status (or Potential) for all WFD water bodies (surface water, groundwater and transitional and coastal water)
- NERC Act (protection of designated Priority Habitats and Species)
- Habitats Directive and Regulations (protection of European designated conservation sites)
- CRoW Act (including protection of Sites of Special Interest)
- Other environmental legislation covering Marine Conservation Zones, National Parks and Areas of Outstanding Natural Beauty

Key controls on water abstraction to meet the environmental protection requirements set out in the above legislation are predominately set out in abstraction licence conditions, including Hands-off Flow or Hands-off groundwater level requirements, Minimum Residual Flows, compensation flow releases from reservoir and volumetric constraints on abstraction (from hourly to multi-year constraints).

5.2.6 Future changes in environmental regulation

Changes to environmental legislation and regulations in the future, including changes that could arise post-Brexit, may lead to changes to the water environment, either in a beneficial or adverse direction, with consequent implications for water availability. Given the vast array of regulatory drivers, the following key pressure areas have been identified as particularly pertinent to future water availability (noting that regulatory changes relating to planning policies and population growth are addressed under that driver separately):

- ***Effects of regulatory or policy changes on catchment (drinking) water quality*** - including changes to legislation to control the use and application of nutrients (e.g. nitrate-based fertilisers) and pesticides, changes to management and control of other diffuse pollution and soil erosion, changes to agricultural policies and subsidies, and drinking water quality regulatory changes (which may affect practices such as indirect and direct effluent reuse)
- ***Effects of regulatory or policy changes on runoff management*** – including changes to flood risk management approaches (for example, natural flood risk management or more ‘hard’ engineering solutions), land drainage activities and urban runoff management (including in new urban areas)
- ***Effects of regulatory water market reforms*** – including changes to the water resources wholesale market (greater or less competition), water trading and water resource allocation between public water supply and agriculture/industry
- ***Effects of water environmental regulatory changes on water resources and abstraction management*** – including changes to water environmental legislation and targets, environmental protection requirements, the future role of international laws, effluent treatment and discharge controls, abstraction controls and changes to water resources planning national best practice guidance

5.2.7 Environmental regulations: critical dimensions

Based on analysis of potential future changes to the various regulations and policies that may impact on water resources availability, each of the pressures have been assessed and ranked under the three future scenarios (Table 11), from 1 = low adverse pressure on water resources availability, to 4 = high adverse pressure. The rationale behind these rankings is provided below.

Table 11 Critical dimensions for each pressure associated with changes to UK water regulations

Pressure	Sustainable World		Conventional World		Consumptive World	
	2050	2080	2050	2080	2050	2080
Drinking water quality	2	2	1	1	2	2
Land drainage and flood management	1	1	2	2	3	4
Water market reforms	3	3	2	2	1	1
Water environmental regulation	4	4	4	3	2	1
Average	**2.5**	**2.5**	**2.25**	**2.0**	**2.0**	**2.0**

5.2.8 Environmental regulations: summary

The potential changes under each of the three scenarios are summarised as follows.

Under the ***conventional world*** scenario:

- Drinking water quality protection measures will continue, aiming for better agricultural and land-use management practices and increasing use of catchment management measures to avoid deterioration of water quality for abstraction. Regulations will remain largely unchanged in relation to the parameters and standards that water companies must achieve in drinking water supplies
- Land drainage and flood management will become more pressing with increased housing growth in the Southern Water area, with an increased uptake of natural flood risk management and sustainable drainage measures, but also increased land drainage activities to provide for housing growth, with the net effect of less water being retained in catchments for baseflow protection, reducing water resource availability
- Water market regulatory reform will include wholesale water resources competition but water trading and inter-basin will continue to be constrained by environmental considerations limiting provision of additional water availability
- Water environmental regulations continue to 2050 along a similar trajectory to the baseline position, with regulations driving more stringent environmental protection and the UK continuing to enshrine the principles of WFD and Habitats Directives in national law in a post-Brexit setting, reducing water availability in dry weather. By 2080, some relaxation will be made to regulatory requirements as a pragmatic solution to a need to increase water availability

Under the ***sustainable world*** scenario:

- Drinking water quality protection measures will be much more enhanced, with tighter controls on agricultural and land-use management practices and mandatory catchment management schemes in place to improve water quality for abstraction and the environment. Regulations in respect of the parameters and standards that water companies must achieve in drinking water supplies will be strengthened to address issues such as pharmaceuticals and a wider range of disinfection bi-product parameters, which may restrict the use of some water sources and reduce the scope for reuse of treated effluent
- Land drainage and flood management will be managed in line with a sustainable growth in housing in the Southern Water area through natural flood risk management being highly prevalent and sustainable drainage measures mandatory for all new development, and land drainage activities minimised to protect natural flood plain storage and natural wetlands. The net effect will be that there will be a little less water available for water resources in order to maintain a balance between water abstraction and restoring / sustaining wetland environments

- Water market regulatory reform will be positioned to balance water resource needs with environmental protection, with constraints on water trading and inter-basin transfers and actions to address potential adverse effects of existing water transfers. This will act to reduce water availability in the Southern Water area
- Water environmental regulations by 2050 have driven more stringent environmental protection and the UK further enhancing the principles of WFD and Habitats Directives in national law in a post-Brexit setting, reducing water availability in dry weather. By 2080, these measures have been retained despite an increasing need for additional water resources

Under the ***consumptive world*** scenario:

- Drinking water quality protection measures will reduce in scope to facilitate greater agricultural production in a more intensive manner so as to free agricultural land up for development to meet population growth, placing greater pressure on drinking water catchments. Regulations will remain largely unchanged in relation to the parameters and standards that water companies must achieve in drinking water supplies. Regulations around effluent reuse will be introduced to make it easier to develop reuse schemes to meet growing demand for water. Overall, the effects of these changes are assessed as moderately adverse in relation to water resources availability compared to the baseline case
- Land drainage and flood management will become pressing issues with significant housing growth in the Southern Water area. This will be addressed by extensive land drainage activities and ‘hard’ engineering urban drainage solutions to provide for housing growth rather than use of Natural Flood Management and Sustainable Drainage approaches, leading to a speeding up of the passage of water through catchments. The effect will be that much less water is retained in catchments for baseflow protection, reducing water resource availability over time as housing growth and urbanisation intensify
- Water market regulatory reform will be positioned to maximise the movement of water around the country and to make water trading as easy as possible to meet the needs of population and housing growth. Environmental constraints will be relaxed where necessary to facilitate inter-basin transfers so as to free up water resource availability
- Water environmental regulations have been relaxed by 2050 to allow for greater abstraction of water to meet population and housing growth, even if this causes a detrimental effect on the water environment. By 2080, as the need for additional water resources intensifies, further de-regulation takes place to help address the water resource availability challenge.

5.2.9 Changes in technology

The UK water industry continues to become more effective and efficient from improving technologies, although the scope for innovation is considered to be significant given the relatively low investment in research and development compared to some other industries. For the purpose of this report, the outcomes of future technology changes are considered in the context of decreasing/increasing water resource availability.

5.2.10 Future changes in technology

Relevant future changes in technology that may influence water resource availability have been identified in relation to the following key areas:

- Cost-effective leakage control – advances in pipes and joints manufacture/installation; enhanced detection methods; advances in pipe resilience, changes to pipe repair and replacement techniques
- Agricultural water use technology advances – this may include use of genetically-modified and/or more drought resistant arable crops, more efficient irrigation techniques and regimes, alternative washing-down methods / water recycling for the dairy industry and new regimes for fruit and vegetable washing

- Industrial water use technology advances – this may include further enhancements in water reuse/recycling and reduced use of water in product manufacturing techniques
- Improvements to water company assets, maintenance and outage response times – this might include self-maintaining assets, more advanced power supply resilience, increased efficiency of pumping stations, new treatment techniques to reduce treatment works losses and enhanced monitoring of asset health and performance
- Improvements to abstraction control systems and infrastructure – including more efficient fish screens and borehole screens, enhanced controls on water regulation releases and abstraction optimisation techniques to maximise deployable output
- Improvement in water reuse and desalination techniques – technological advances to help reduce the cost and efficiency of reuse and desalination so as to reduce pressures on freshwater resources

5.2.11 Future changes in technology: critical dimensions

In applying these pressures within each of the three scenarios (Table 12), a ranking system has applied based on the impact on water resource availability, ranging from 1 (low-to-positive) to 4 (high-negative).

Table 12 Critical dimensions for each pressure associated with changes in technology

Pressure	**Sustainable World**		**Conventional World**		**Consumptive World**	
	2050	2080	2050	2080	2050	2080
Cost-effective leakage control advances	2	1	2	2	2	3
Agricultural water use technology advances	2	1	2	1	3	4
Industry water use technology advances	2	1	2	1	2	3
Improved water company asset resilience	1	1	2	1	2	3
Improved abstraction controls and infrastructure	1	1	2	1	2	2
Improvement in water reuse and desalination treatment techniques	1	1	1	1	2	2
Average	**1.5**	**1.0**	**1.8**	**1.2**	**2.2**	**2.8**

5.2.12 Future changes in technology summary

The potential changes under each of the three scenarios are summarised as follows.

Under the conventional world scenario:

- Cost-effective leakage control advances are driven by regulatory pressures to further reduce leakage levels and continuing constraints on water availability.
- Agricultural water use technology advances are driven by continuing constraints on water availability and efforts to maximise yields in face of growing international competition in agriculture.
- Industry water use technology advances are driven by economic pressures to maximise production such that volumes of water used per unit reduce but overall output intensifies, leading to an overall increase in water use.
- Improved water company asset resilience and improved abstraction controls and infrastructure are driven by the continuing constraints on water availability and the need to optimise existing water resources.

- Improvement in water reuse and desalination treatment techniques is driven by the continuing constraints on water availability and the recognition that reuse and desalination will be needed to help maintain reliability of water supplies.

Under the sustainable world scenario:

- Cost-effective leakage control advances are driven by mandatory regulatory requirements to drive down leakage levels to maximise water resource availability whilst meeting environmental requirements.
- Agricultural water use technology advances are driven by mandatory regulatory requirements to reduce water usage and more stringent abstraction licence conditions, combined with measures to prevent further intensification of agriculture and actively move more agricultural land back to natural land use to increase natural catchment processes.
- Industry water use technology advances are driven by mandatory regulatory requirements for water efficiency and more stringent abstraction licence conditions.
- Improved water company asset resilience as well as improved abstraction controls and infrastructure are driven by a proactive regulatory regime to maximise use of existing water resources to reduce the need for the development of new freshwater resources.
- Improvement in water reuse and desalination treatment techniques is proactively driven by government through innovation incentives and support to the treatment industries to develop low energy, high efficiency treatment solutions to maximise reuse of water (within environmental and drinking water regulatory constraints) and desalination.

Under the consumptive world scenario:

- Cost-effective leakage control advances are related to the continued use of economic level of leakage principles with less innovation than under the other scenarios, with innovation funding focused elsewhere.
- Agricultural water use technology advances are driven by intensification of farming to release agriculture land for housing growth, with the focus on more genetically-modified crops plus more sophisticated irrigation methods to maximise crop yields – the innovation focus is on the latter rather than water efficiency.

- Industry water use technology advances are driven by economic pressures in the face of growing international competition to keep unit costs of production as low as possible.
- Improved water company asset resilience and improved abstraction controls and infrastructure are driven by the continuing constraints on water availability and the need to optimise existing water resources.
- Improvement in water reuse and desalination treatment techniques is driven by the need to meet population growth, but with reduced concerns about the environmental effects of existing abstraction, there is a less intensive focus on reuse and desalination techniques.

5.2.13 Social changes in environmental values and perception

Pressures relating to **attitudes to sustainable water use** include consideration of:

- Individual behaviours and expectations for sustainable water use
- Importance/value of the water environment to individuals and society
- Community-based influencing of individuals and society on sustainable water use (e.g. strength of influence by water environmental NGOs)
- Consumer influencing of sustainable water use (e.g. price of water through metering, water company / EA education campaigns, etc.)

How societal attitudes may change in the future in respect of sustainable water use will influence government, regulatory and water company decisions and may have a bearing on future water resource availability.

Attitudes towards the environment have evolved and changed over the last century and can be tracked through questionnaires and survey. Recent modelling has suggested that increased environmental awareness at the household level may not significantly affect the consumption of polluting goods (Iosifidi, 2016). Higher levels of education are generally associated with more environmentally friendly behaviour, but people across different socio-economic and educational backgrounds are currently quite unlikely to curtail certain behaviours despite the environmental impact of their activities (Macdiarmid et al., 2016).

Research into environmental attitudes suggests that they are influenced by a wide range of external factors, including mainstream media representation of environmental issues, promotion of environmentally-friendly products and associated environmental awareness campaigns, nature of the school curriculum in relation to the environment, impacts of environmental incidents on society (e.g. floods, pollution, drought), political debate and discourse in relation to the environment, and the 'belief structures' prevalent within society in respect of the environment. All of these factors can change with time and may have an influence on future water availability. The EA's water demand scenarios (Environment Agency, 2011b) considered society and environmental awareness in a similar manner to this study, with the prevailing state of the environment assessed as being one of the main factors driving behaviour at all levels (internationally and nationally, and among governments and private citizens).

5.2.14 Social changes in environmental values and perception: critical dimensions

Based on potential future attitudes of society towards sustainable water use and the environment, critical dimensions for each of the three future scenarios are summarised in Table 13. The pressures included for social perceptions of the environment as a driver have been summarised as:

- Individual behaviour change in relation to sustainable water use
- Societal willingness to apply sustainable water use solutions
- Adoption of community-based action in relation to sustainable water use
- Effectiveness of consumer influencing strategies for sustainable water use
- Changes in societal environmental awareness
- Willingness of society to adopt environmentally-friendly policies and strategies

Applying these pressures within each of our scenarios, a ranking of the dimensions of change for each pressure in relation to water resource availability has been adopted from a scale of 1 (low-to-positive) to 4 (high-negative). Rankings have considered both the likely magnitude of change of each pressure and the approximate magnitude in change to water resource availability for each scenario, e.g. a strong willingness to adopt environmental-friendly policies could likely lead to reductions in water availability with more stringent abstraction licence conditions than assumed in the baseline forecast.

Table 13 Critical dimensions for each pressure associated with changes in social attitudes

Pressure	Sustainable World		Conventional World		Consumptive World	
	2050	2080	2050	2080	2050	2080
Individual behaviour change	1	2	2	3	3	4
Apply sustainable water use solutions	2	2	2	3	3	4

Community-based action	1	2	2	3	3	3
Consumer influencing	1	2	2	3	3	3
Average	**1.25**	**2**	**2**	**3**	**3**	**3.5**

5.2.15 Social changes in environmental values and perception: summary

The potential changes under each of the three scenarios are summarised as follows.

Under the conventional world scenario:

- Attitudes to sustainable water use and use of sustainable water use solutions continue to improve compared to the current position with continued education and promotion by government, regulators, water companies and NGOs, thereby freeing up some water resources to meet growth in demand. This is supported by greater use of price signals in metered water tariffs. Community-based actions take longer to have a positive effect on water availability as people have not become more community-minded in terms of dealing with water resource shortages, but as the adverse effects of growth and climate change increase, uptake increases by 2080.

Under the sustainable world scenario:

- Attitudes to sustainable water use and use of sustainable water use solutions are very positive with much greater awareness of the need to use water wisely, thereby freeing up water resources to meet growth in demand. This is supported by strong incentive and reward metered water tariff structures as well as for surface water drainage to encourage sustainable drainage activities. Community-based actions are increasingly prevalent and have a positive effect on water availability as people become more community-minded in terms of dealing with water resource shortages, which strengthen with time as the adverse effects of growth and climate change increase by 2080.

Under the consumptive world scenario:

- Attitudes to sustainable water use and use of sustainable water use solutions harden with consumers expecting the water companies and market forces to secure a supply-demand balance to meet increasing water consumption needs rather than seeking to constrain them, thereby acting to reduce water resource availability. Increased retail and wholesale competition has led to companies introducing low metered tariffs to retain customers. Community-based actions are not seen as necessary in dealing with water resource shortages, with the onus on the market to resolve the problems and invest in technologies to provide more water to meet the growth in demand. Society is passive and the environment is allowed to adapt to the pressures applied to it, with little proactive intervention or protection measures – levels of protection for the aquatic environment are relaxed to increase water resource availability.

5.2.16 Population growth

The population in the company area is set to continue to increase putting additional strain on water resources, both through an increase in the number of households and a commercial growth in water consumption to service the expanded population.

Together with neighbouring water companies (Affinity Water, Portsmouth Water, South East Water and Sutton and East Surrey Water), Southern Water commissioned a study in 2016 to provide forecasts for:

- Total population
- Household population
- Communal population
- Households
- Household occupancy
- Residential properties

The study was completed at the start of 2017 (Experian, 2017). Forecasts up to the year 2044-45 were developed in line with the guidance issued by the EA (Environment Agency & Natural Resources Wales, 2017) and UK Water Industry Research (UKWIR, 2016a).

Accordingly, the following four sets of forecasts were produced with outputs provided at Census 2011 output area (OA) and water resource zone level:

- Trend-based (i.e. based on official statistics)
- Plan-based (i.e. based on Local Plans)
- Econometric forecasts (i.e. taking account of economic factors)
- Hybrid forecasts

It should be noted that Southern Water billing system shows the number of connections or accounts rather than properties. This is because multiple properties can have a single connection, or a single property may have more than one water connection. The property figures provided by Experian have therefore been translated into connections.

5.2.17 Population growth: future changes

The future demand within each water resource zone has been discussed in detail in Annex 2. In terms of net growth over the planning period from 2020-21 to 2044-45, all four forecasts are very similar. For total population, plan-based and trend-based forecasts predict a 17% net increase in whereas hybrid and econometric forecasts predict a 16% increase. For total connections, plan-based forecast predicts a 22% increase, trend-based forecast a 21% increase whereas the other forecasts predict a 20% increase.

The guidance (Environment Agency & Natural Resources Wales, 2017) requires water companies in England to base their growth forecasts on local plans published by the local council or unitary authority. For the plan-based projection, the Eastern area shows the highest growth in total population (24%) followed by the Western area (16%). The Central area shows the lowest increase (12%). Total population numbers by area are shown in Figure 7. The projected growth in total connections is much higher than total population and the differences between the three areas are much more pronounced. The Eastern area shows 29% increase over the planning period, followed by Western area at 20% and the Central area at 16%. The actual numbers by area are shown in Figure 8.

For plan-based projections, the trend in household population growth differs from total population growth. Household population is forecast to grow by 17% overall. The Eastern area still shows the highest growth (24%) but the growth is more than twice as high as the Central area (11%) and significantly higher than the Western area (16%). The picture is very similar for household connections. Overall, household connections are forecast to grow by 23%. The Eastern area has the highest projected growth (31%), followed by the Western area (22%) and the Central area (17%).

Figure 7 Total population forecast by area (Plan-based scenario)

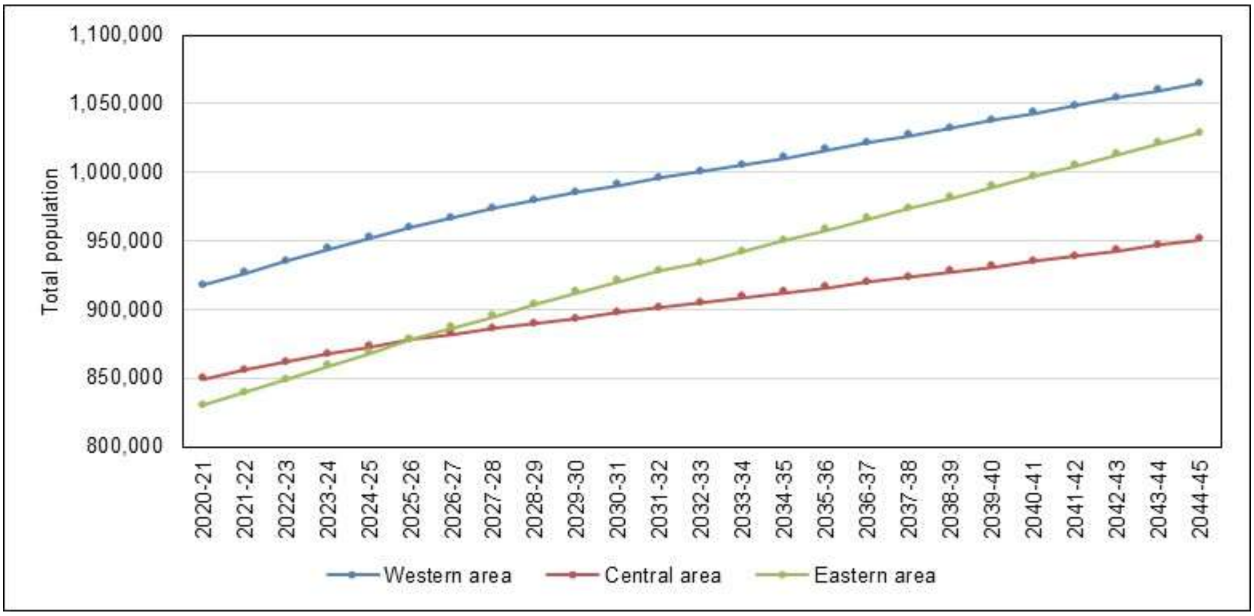
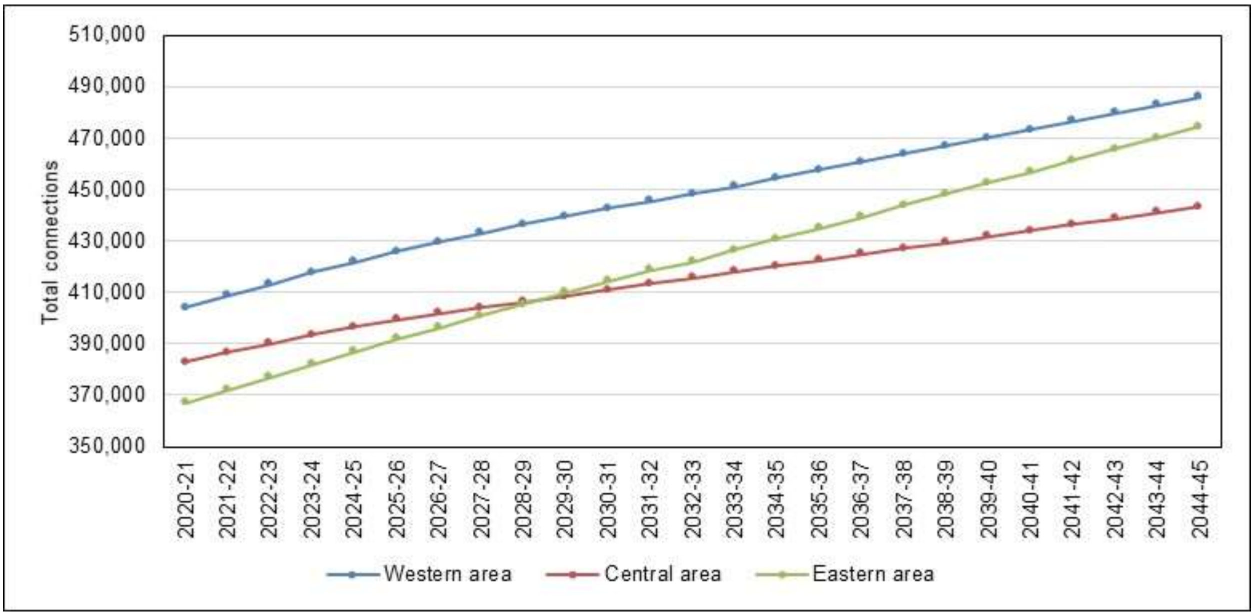


Figure 8 Total connections forecast (Plan-based scenario)



The study undertaken by Experian considered population growth within the planning period (up to 2045). To provide an extended forecast (beyond 2040) we have created a simplified estimated projection for administrative districts in the South East. We have extended the administrative district projections by reference to the 'National Population Projections for 100 years ahead' of ONS datasets growth rates and applied them to each administration district, assuming trends remain constant beyond 2039.

Three key population forecast variations are considered by the Office for National Statistics for the period to 2039:

- "High" Population – High fertility, high life expectancy and high net migration.
- "Low" population – Lower fertility, low life expectancy and low net migration.

- Zero net migration/natural change only – this is similar to the central population projection, but with zero net migration.

Results are shown in Table 14 but are likely to be understated as the South East projected population is expected to grow faster than the country as a whole but the approximation allows the differences between the ONS 'high fertility' and 'low fertility' variations to the principal projection to be illuminated so as to help inform the three future environmental scenarios for this plan.

The principal projections for population growth are very similar to the projected population growth as determined by the plan-based projection used in the Experian study. Based on the principal projection considered in the ONS projections, the population growth in the South East is estimated to be around 16%. For total population, plan-based projections predict a 17% net increase.

Table 14 Mid-year population estimates for south east England administrative districts under different ONS projections (starting from a 2017 estimated population of 10,549,689)

Low Fertility Variation		Principal		High Fertility Variation	
2040	2080	2040	2080	2040	2080
11,799,256	12,770,071	12,256,811	14,433,357	12,674,986	15,785,988

Table 14 shows an increase of 1.7 million people from 2017 to 2039 and an increase of 3.9 million people from 2017 to 2080 under the principal projection. The 'high' and 'low' population variations would increase or decrease population by 0.4-0.5 million people in 2040, and by 1.3-1.7 million people in 2080.

As with the study completed by Experian, for every ONS scenario, the population of the Southern Water operating area is likely to increase, adding to the existing pressures on water resources. Population growth, along with rising incomes, increases in water-using appliances, urbanisation and associated economic development, will increase demand for water (not the subject of the environmental scenarios) but will also increase environmental pressures, such as an increase in pollution incidents and changes in raw water quality, loss of natural catchment land and changes to catchment land use, and physical stress on the extent of habitats and the distribution of species. These potential changes are incorporated into the three environmental scenarios as discussed in the following sub-sections.

5.2.18 Population growth: critical dimensions

For the purpose of this environmental forecast, the 'low' ONS projection has been considered for the population growth under a sustainable world scenario while the 'high' projection has been considered for the consumptive world scenario. For the conventional world scenario, the principal projection has been assumed as the basis for establishing the key pressures on the water environment.

Increased population growth and further urbanisation in the Southern Water operational area will result in several pressures on the water environment and associated impact on water resources availability. Each of the key identified pressures have been assessed and ranked for each of the three future scenarios (Table 15) from 1 (= low pressure on water resources) to 4 (= high pressure). The rationale behind these rankings is provided in the summary section below.

Table 15 Critical dimensions for each pressure associated with population growth

Pressure	Sustainable World		Conventional World		Consumptive World	
	2050	2080	2050	2080	2050	2080
Increased demand for abstraction by agriculture and industry	1	2	2	3	3	4
Increased urbanisation impacts on catchment land	2	2	2	3	3	4
Water quality impacts from increased population pressures	1	2	2	3	3	3
Average	**1.3**	**2.0**	**2.0**	**3.0**	**3.0**	**3.7**

5.2.19 Population growth: summary

The potential changes under each of the three scenarios are summarised as follows.

Under the conventional world scenario:

- Population growth is significant and is likely to increase demand for freshwater resources by agriculture due to the need to meet increased consumer demand for food (noting that imports of food are also likely to increase to meet demand), as well as the likely intensification of agricultural production as farmland is sold for housing. With increased consumer demand, industrial demand for freshwater resources may also grow (although at a lower rate as most demand will be on water company supplies rather than direct abstraction). The effect will be to reduce water resource availability for the company.
- Increased urbanisation will place greater pressures on catchment land quality, with loss of natural catchment land and increased impermeable land cover. This will have adverse effects on runoff characteristics and water quality, reducing baseflows and groundwater recharge, and increasing the risks of outage and/or reduction in deployable output due to adverse water quality.

Under the sustainable world scenario:

- Population growth is lower but still significant and consequently there is some increase in demand for freshwater resources by agriculture due to the need to meet increased consumer demand for food (noting that imports of food are also likely to increase to meet demand), but sustainable farming methods are introduced to minimise this growth. Increased consumer demand is less significant and industrial demand for freshwater resources is held broadly static with assistance and incentives in place to recycle and reuse water. The effect will be to slightly reduce water resource availability for the company.
- Garden cities and suburbs will predominately cater for increased population growth to reduce pressures on catchment land quality. As much natural catchment land as possible will be retained and sustainable drainage approaches will be maximised to reduce the growth in impermeable land cover. This will have much lower adverse effects on runoff characteristics and water quality, with lower levels of impact on baseflows and groundwater recharge, and minimise the risks of outage and/or reduction in deployable output due to adverse water quality.

Under the consumptive world scenario:

- Population growth is greater and very significant; consequently there is sizable increase in demand for freshwater resources by agriculture due to the need to meet increased consumer demand for food (noting that imports of food are also likely to increase to meet demand), and this is achieved through very intensive farming practices. Increased consumer demand is a key factor in this scenario, driving increases in industrial demand for freshwater resources. The effect will be to materially reduce water resource availability for the company.
- Increased population growth will be accommodated through extensive new homes built on green belt land and the wider countryside, significantly increasing pressures on catchment land quality and leading to a much greater level of impermeable land cover. This will have significant adverse effects on runoff characteristics and water quality, with consequent material impact on base flows and groundwater recharge, and increased risks of outage and/or reduction in deployable output due to adverse water quality.

5.3 Summary critical dimensions of impacts for each future environmental scenario

A summary of the future scenarios based on the potential future changes and critical dimensions of change associated with each driver is provided in Figure 9.

Figure 9 Graphical representation of each driver for each future scenario by 2050 and 2080

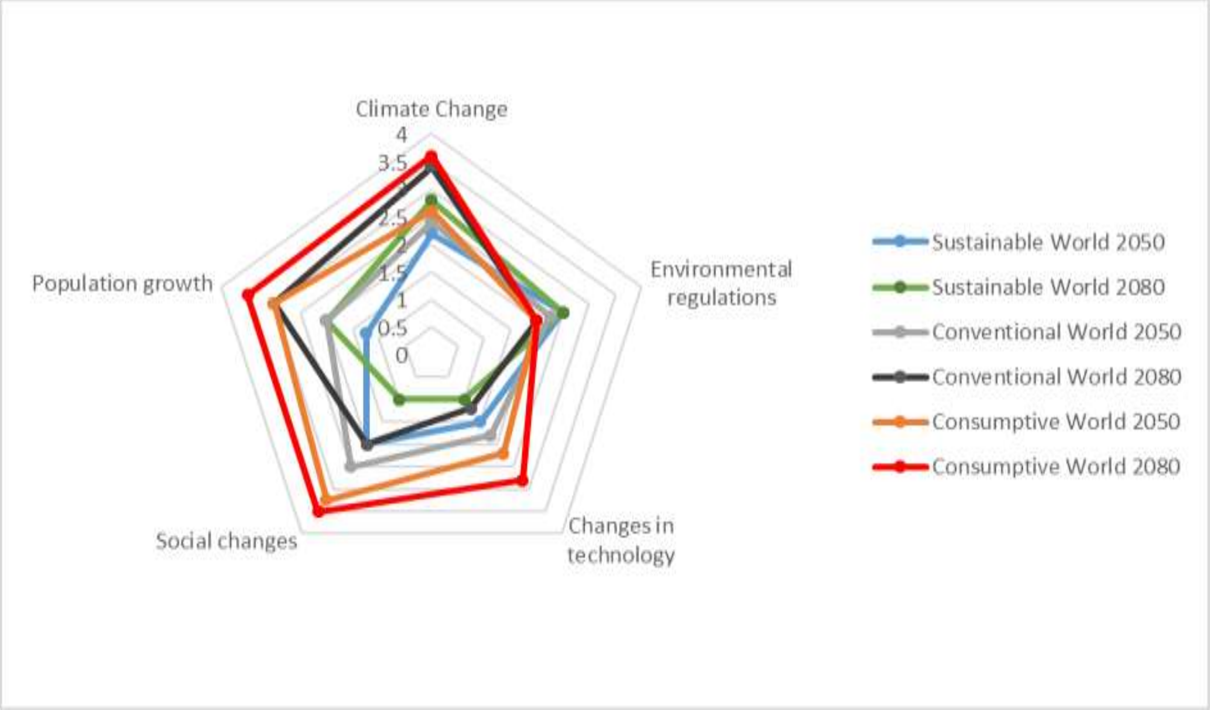


Figure 9 shows that the consumptive world scenario generally has the greatest impact on water resource availability in the Southern Water operational area with the exception of environmental regulation where market forces and de-regulation would lead to a lower level of water environmental protection and therefore increased water resource availability. The conventional world shows general progression from the current baseline conditions, whereas the sustainable world tends to work with the environment and leads to increased water resource availability except in respect of environmental regulations which has the greatest negative effect.

5.4 Response: implications for water source availability

A summary of the potential impacts of the drivers and pressures on the response of water source availability for each of the three scenarios is provided in Table 16, expressed as the average of the various rankings assigned to each pressure.

Table 16 Summary of the potential changes in drivers under different future scenarios based on the impact on water resources availability from 1 (low-to-positive) to 4 (high-negative)

	Sustainable World		Conventional World		Consumptive World	
	2050	2080	2050	2080	2050	2080
Climate change	2.2	2.8	2.4	3.4	2.6	3.6
Environmental regulations	2.5	2.5	2.25	2.0	2.0	2.0
Changes in technology	1.5	1.0	1.8	1.2	2.2	2.8
Social changes	2.3	1.8	2.5	2.2	2.8	2.7
Population growth	1.3	2.0	2.0	3.0	3.0	3.7

It is evident that, for both the 2050 and 2080 period, the conventional world and consumptive world scenarios will result in an adverse effect on water resources availability compared to the central forecast for deployable output set out in the draft version of this plan. For the sustainable world scenario, the effects at 2050 are low to positive, but by 2080 there is a negative effect, albeit lower than under the other two scenarios. This is considered a plausible outcome given the nature and scale of the key drivers and pressures identified for inclusion in the scenario building – it is difficult to create a plausible future scenario out to 2080 in which the environmental drivers and pressures on water resource availability would lead to an increase in water resource availability compared to the central forecast which largely excludes consideration of environmental changes.

Risk of double counting impacts between central forecasts and environmental scenarios for this plan.

- *Climate change:*
  The deployable output forecast for this plan takes account of the effects of climate change on water source hydrological runoff/hydrogeological recharge characteristics but not the effects of climate change on catchment land use or the water environment more widely (e.g. sea level rise impacts) as have been considered in the environmental scenarios. Consequently, there is no “double counting” of climate change impacts between the central forecast for this plan and the environmental scenarios.

- *Environmental regulations:*
  The deployable output forecast for this plan includes known, ‘confirmed’ sustainability reductions arising from current environmental regulations (notably WFD and Habitats regulations). The environmental scenarios consider whether future environmental regulations would be more or less stringent than existing regulations and postulate whether there would be a greater level of sustainability reductions in the future compared with those included in the central forecast of deployable output, irrespective of any further change to the environment which may necessitate additional changes to environmental regulations.

- *Population growth:*
  The demand forecast for this plan includes projections of future population growth but the environmental forecasts do not include any effects of population growth on demand for public water supplies (although demand for abstraction by agriculture and industry is considered). Consequently, there is no double counting of the effects of population growth on public water supply demand.

5.4.1 Translating pressures and impacts into a deployable output response

In order to apply the three environmental scenarios to sensitivity testing of this plan, several steps are necessary to convert the pressures and impacts summarised in Table 16 into a potential numerical effect on the central deployable output forecast that can be used to “stress test” this plan.

The first step is to assess how each scenario driver may affect key indicators of change that influence water availability. This is set out for the Southern Water operational area in demonstrating the linkage to the summary impact rankings for each driver identified and the changes set out in Table 16.

The second step is to assess how each scenario driver may affect key indicators of change to habitats and species, taking account of the relationships between physical environmental change and consequent effects on flora and fauna. Climate change is the key driver of effects on flora and fauna: there is a 50% probability of an increase in temperature under all three future scenarios, ranging from 2.5^{o}C during summer to up to 8^{o}C with significant implications for aquatic species: it is estimated that a 1.5-2.5°C could result in a 20-30% loss of species. This, together with the effects of sea-level rise along the south coast, could result in significant changes in the distribution of species and habitats that currently drive water abstraction regulation in the Southern Water operational area. Under such a scenario, current sustainable abstraction decisions and Hands of Flow (HoF) targets may no longer be appropriate, particularly where there are significant changes in the distribution of the species that drive these flow objectives.

Other drivers have a lower effect on habitats and species as summarised in **Error! Reference source not found.**, linking to the summary impact rankings and the key indicators of water availability in **Error! Reference source not found.**. **Error! Reference source not found.** also assesses the likely consequential effects of these habitat and species changes on abstraction licence conditions under each of the three scenarios (**over and above any changes already identified under the environmental regulation driver**).

By considering the summary impact rankings and the key indicators in **Error! Reference source not found.** and **Error! Reference source not found.**, it is possible to postulate a percentage change to the central forecast of deployable output for each of the three scenarios as set out in **Error! Reference source not found.**, Appendix B provides further tables for each main water source type (i.e. groundwater, river, reservoir, water reuse and desalination) for each planning horizon, respectively and which set out the impact on source deployable output based only the implications arising from changes to habitats and species for each scenario and planning horizon.

5.4.2 Impact on rivers

With regards to climate change impact on rivers, we have already assessed the effect of climate change on runoff/recharge impacts on existing water sources (see Annex 3). As such, the direct impacts of climate change on water availability has been assessed as zero (0) to avoid double counting of climate change impacts.

Climate change impacts may have wider impacts on river abstraction sources. This will be mostly related to water quality and particularly the impact of sea level rise and the associated saline intrusion. Many of the Southern Water river abstraction points are situated near the tidal limit; changes in salinity resulting from rising sea level and an upstream shift in the salt mixing zone could therefore reduce freshwater availability and lead to a reduction in the deployable output of river sources near the tidal limit. This would be of particular concern during spring high tides should there be an extensive rise in sea levels (>40cm). Similarly, river source deployable output could be impacted by changes in nutrient and pesticide runoff. With a large decrease in summer rainfall expected for all future scenarios, there would be a decrease in the dilution capacity of rivers. The potential risk of changes in water quality would be a major concern during summer, coinciding with the expected decrease in precipitation. The decreased dilution factor and changes in water quality could be further exacerbated as a result of urbanisation which would increase the proportion of impermeable surfaces within river catchments. The extent to which these climate and population growth related impacts on water quality would impact on deployable output would be different for each scenario.

While social and technology changes would have little impact on the deployable output from river sources, some decreases in deployable output may be offset under the conventional world and consumptive world scenarios by relaxations to current HoF targets. This would be expected towards the latter part of the century when climate driven changes in species and habitats has resulted in a change in biodiversity within the operational area and a decrease in concern for the environment from a social perspective under these two scenarios.

The deployable output for river sources is expected to decrease regardless of the scenario. Both the conventional world scenario and the sustainable world scenario could see a reduction in deployable output from river sources by up to 21%. The conventional world scenario may result in a reduction in deployable output in the medium term, largely as a result of water quality changes between now and 2050.

Impact on reservoirs

We have already assessed the effect of climate change on runoff/recharge impacts on our existing reservoir sources (see Annex 3). As such, the direct impacts of climate change on water availability has been assessed as zero (0) to avoid double counting of climate change impacts on reservoir sources.

The impact of water quality and surface runoff changes on reservoirs will likely be lower than for river sources. The impacts of changes in runoff on reservoir deployable output as a result of population growth will be lower as higher winter/peak runoff can be captured and stored and reservoir refill is already very limited during most summers due to negligible effective rainfall. The impact on water quality during the winter refill of reservoirs would also be lower as nutrient and pesticide concentrations would be lower during the winter period and dilution capacity of the rivers (for pumped refill reservoirs) and inflows (for impounding reservoirs) will be higher. The reservoir intakes for Southern Water’s reservoirs tend to be further inland when compared to the key river source abstraction points and would therefore be less susceptible to impacts related to salinity changes.

While social and technology changes would have little impact on the deployable output from reservoir sources, some of the decreases in deployable output could be offset by relaxations of current HoF targets and/or river regulation release requirements (e.g. for River Medway Scheme). Compared to the impact on river source deployable output, there is less variation in the potential changes to deployable output between the different scenarios. By 2080, the deployable output could decrease by 10% under a sustainable world and 7% under the conventional world scenario. A small increase in deployable output from reservoirs could occur towards 2080 under a consumptive world scenario, mainly due to relaxations in environmental protection requirements. Overall, reservoir sources are likely to be more robust to potential future environmental change than the river sources. This is to be expected given the benefits afforded by the water storage capacity of reservoirs.

Impact on groundwater

We have already assessed the effect of climate change on recharge impacts on existing groundwater sources (see Annex 3). As such, the direct impacts of climate change on water availability from groundwater sources has been assessed as zero to avoid double counting of climate change impacts.

The wider climate change impacts on groundwater sources are mostly related to population growth and the associated increase in urbanisation which would impact on groundwater recharge mechanisms during the winter periods due to an increase in impermeable surfaces within groundwater source catchment areas, thereby reducing infiltration capacity. Urbanisation will also reduce soil moisture storage within the catchment area, leading to a greater soil moisture deficit to be overcome before groundwater recharge can commence. Water quality within the aquifers could also be impacted as a result of increased population growth due to increased concentration of agricultural activity over a smaller area of land, leading to increased pesticide and nutrient concentrations during summer.

Climate change, exacerbated by reduced recharge due to urbanisation pressures, is likely to increase the risk of saline intrusion to groundwater sources in coastal areas: Southern Water has already been adversely affected by saline intrusion to some borehole sources in coastal areas. There would therefore be an increased pressure on groundwater sources, particularly in respect of treating higher salinity water and meeting drinking water quality standards.

While social and technology changes would likely have little impact on the deployable output from groundwater sources, some of the decreases in deployable output referenced above might be partially offset by relaxations of current abstraction licence conditions under the consumptive world scenario towards the 2080 planning horizon (for example, removing any river flow-related constraints or hands-off groundwater level conditions). Groundwater source deployable output values are however less constrained by abstraction licence conditions than river sources and therefore any partial offset will be small.

Overall there would likely be a decrease in deployable output from groundwater sources, varying in extent dependent on the selected scenario. Regardless of the scenario, groundwater deployable output could potentially decrease by more than 10% by 2080.

Impact on water reuse schemes

We currently have no water reuse schemes as part of our water resource system. The impacts of climate change on potential future water reuse options under consideration for this plan have not been explicitly assessed by Southern Water, but are flagged as a potential risk. In developing the environmental scenarios, consideration has been given to the potential effects of the various future environmental drivers on the assessed deployable output of water reuse schemes.

The impacts of reduced runoff as a result of climate change effects on precipitation and temperature are not expected to be significant on water reuse schemes; although there may be less flow in the river systems for dilution of the treated effluent upstream of the re-abstraction intake, this can be addressed through more intensive treatment of the effluent to meet water quality standards (at additional cost). Climate change changes in salinity are also considered unlikely to impact on reuse schemes, with dilution of treated effluent discharges taking place some distance upstream of existing abstraction intakes and so further upstream from saline intrusion threats.

There is likely to be an increase in dry weather flow to the wastewater treatment works as a result of population growth under all scenarios and so there would be no adverse effect on availability of effluent.
Water quality changes could impact on reuse schemes: increased nutrient and pesticide concentrations in rivers could potentially reduce the dilution capacity for treated effluent, reducing the volumes of treated effluent that can be discharged for re-abstraction.

Compared to other source types, social and technology changes are likely to benefit water reuse schemes. This could include changes in societal perception of indirect treated effluent as a water source and improvements in technology that result in lower cost treatment processes and a lower carbon footprint. These changes would be most notable under the sustainable world scenario where the emphasis is on protecting the environment and so there would be a greater focus on reuse schemes and finding lower cost, lower carbon treatment solutions.

There may be some benefits to developing reuse schemes in relation to changes in the environmental permitting regime, notably where these regulatory constraints might be relaxed under the consumptive world scenario. Such benefits are not expected under the Conventional or sustainable world scenarios.

Overall there could be some benefit to deployable output of water reuse schemes under a sustainable world scenario. Under the other scenarios, a decrease in deployable output may arise over time, mostly as a result of future adverse water quality changes occurring in these scenarios which reduce the dilution capability which cannot be overcome economically by more intensive treatment processes.

Impact on desalination

We currently have no desalination schemes as part of our water resource system. The impacts of climate change on potential future desalination options under consideration for this plan have not been explicitly assessed by Southern Water, but are flagged as a potential risk. In developing the environmental scenarios, consideration has been given to the potential effects of the various future environmental drivers on the assessed deployable output of desalination schemes.

Changes in summer precipitation and temperature (and consequently runoff) due to climate change could result in increased estuarine salinity due to reduced freshwater flows to estuaries. This could be further exacerbated by an increase in salinity in estuaries as a result of sea level rise and a change in the location of the salt mixing zone. Any changes would be seasonal in nature but will more acute in dry summers when desalination is most likely to be required. This increase in salinity would likely reduce the output from a desalination plant, with increased brine production and a lower proportion of drinking water produced. This could be overcome in time by adding increased process units to cope with the higher salinity (at additional cost).

There could be minor implications as a result of water quality changes (excluding salinity) in freshwater flows to estuaries and estuarine wastewater discharges in some scenarios due to increased population growth and urbanisation under the Conventional and consumptive world scenarios. Increased nutrient and pesticides runoff will potentially reduce desalination treatment work output to ensure drinking water quality standards are met.

Desalination sources of water will likely be less constrained by changes in environmental regulations and permitting. The major driver of change would be changes in the social perception of desalination and changes in technology. Under a sustainable world scenario, consumers may be more willing to accept alternative water sources and there is likely to be a greater focus on improving desalination technology to reduce costs and increase energy and carbon efficiency. This emphasis could result in an overall slight net increase in deployable output from desalination under the sustainable world scenario.

Climate change and population growth drivers would likely lead to reductions to desalination deployable output under the conventional world and consumptive world scenarios.

Table 17 Key indicators of physical changes associated with each of the drivers for each scenario

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
		2050	2080	2050	2080	2050	2080
	Pressure-Impact Ranking Summary	1.3	2.0	2.0	3.0	3.0	3.7
Population growth	Risk of reduced runoff and recharge within water source catchments	Very Low	Low	Low	Moderate	Moderate	High
Climate change	Pressure-Impact Ranking Summary	2.2	2.8	2.4	3.4	2.6	3.6
	Percentage change in summer precipitation (mm)	-37 to +9	- 39 to +13	-39 to +13	-48 to +7	-48 to +7	-55 to +5
	Summer temperature increase (^{o}C)	1.4 – 4.3	1.4 – 5.1	1.3 – 4.6	2 – 6.5	1.4 – 5.2	2.6 – 8.1
	Sea level rise (cm)	15-20	20-25	20-25	30-35	20-25	>40
	Risk of saline intrusion to water sources	Low	Low	Low	Moderate	Low	High
	Risk of impact on water sources from other water quality changes	Low	Low	Moderate	High	Moderate	High
Environmental regulation	Pressure-Impact Ranking Summary	2.5	2.5	2.25	2.0	2.0	2.0
	Benefit to water resource availability	Low	Low	Low	Moderate	Moderate	Moderate
Technology changes	Pressure-Impact Ranking Summary	1.5	1.0	1.8	1.2	2.2	2.8
	Benefit to water resource availability	Moderate	High	Moderate	Moderate	Low	Low
Social changes	Pressure-Impact Ranking Summary	2.3	1.8	2.5	2.2	2.8	2.7
	Benefit to water resource availability	Low	Moderate	Low	Low	Very Low	Very Low

Table 18 Key indicators of habitat and species change associated with each of the drivers for each scenario

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
		2050	2080	2050	2080	2050	2080
Population growth	Habitat and species adverse impact due to changes in runoff and recharge regimes	Very low	Low	Low	Moderate	Moderate	High
Climate change	Habitat and species adverse impact due to climate change effects	Moderate	Moderate	Moderate	High	Moderate	High
Environmental regulation	Habitat and species adverse impact arising from the environmental regulation regime	Low	Low	Low	Moderate	Moderate	High
Technology changes	Habitat and species adverse impact arising from technology changes	Low	Low	Low	Moderate	Moderate	High
Social changes	Habitat and species adverse impact arising from social changes	Low	Low	Low	Moderate	High	High
Changes to abstraction licence conditions to address identified impacts on habitats and species		Additional constraint	Significant additional constraint	No action taken	Additional constraint	No action taken	Constraint relaxed

Table 19 Potential percentage change to deployable output by driver and source type for the Southern Water region

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
		2050	2080	2050	2080	2050	2080
Population growth	**Risk of reduced runoff and recharge within water source catchments**	**Very Low**	**Low**	**Low**	**Moderate**	**Moderate**	**High**
River		0	-1	-1	-3	-3	-5
Reservoir		0	0	0	-1	-1	-2
Groundwater		0	-2	-2	-5	-5	-7
Reuse scheme		0	0	0	-2	-2	-3
Desalination		0	0	0	-1	-1	-2
Climate change	**Percentage change in summer precipitation**	**-37 to +9**	**- 39 to +13**	**-39 to +13**	**-48 to +7**	**-48 to +7**	**-55 to +5**
	Summer temperature increase (°C)	**1.4 – 4.3**	**1.4 – 5.1**	**1.3 – 4.6**	**2 – 6.5**	**1.4 – 5.2**	**2.6 – 8.1**
River		0	0	0	0	0	0
Reservoir		0	0	0	0	0	0
Groundwater		0	0	0	0	0	0
Reuse scheme		0	0	0	0	0	0
Desalination		0	0	0	0	0	0
Climate change	**Sea level rise (cm)**	**15-20**	**20-25**	**20-25**	**30-35**	**20-25**	**>40**
	Risk of saline intrusion to water sources	**Low**	**Low**	**Low**	**Moderate**	**Low**	**High**
River		-1	-1	-1	-3	-1	-5
Reservoir		0	0	0	0	0	0
Groundwater		-3	-3	-3	-5	-3	-7
Reuse scheme		0	0	0	0	0	0
Desalination		0	-1	-1	-3	-3	-5

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
Climate change	**Risk of impact on water sources from other water quality changes**	**Low**	**Low**	**Moderate**	**High**	**Moderate**	**High**
River		-1	-1	-3	-5	-3	-5
Reservoir		0	0	0	-1	0	-1
Groundwater		-1	-1	-3	-5	-3	-5
Reuse scheme		-2	-2	-5	-7	-5	-7
Desalination		0	0	-2	-4	-2	-4
Environmental regulation	**Benefit to water resource availability**	**Low**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**
River		0	0	0	10	10	10
Reservoir		0	0	0	5	5	5
Groundwater		0	0	0	3	3	3
Reuse scheme		0	0	0	5	5	5
Desalination		0	0	0	0	0	0
Technology changes	**Benefit to water resource availability**	**Moderate**	**High**	**Moderate**	**Moderate**	**Low**	**Low**
River		1	2	1	1	0	0
Reservoir		0	0	0	0	0	0
Groundwater		1	3	1	1	0	0
Reuse scheme		3	5	3	3	1	1
Desalination		3	5	3	3	1	1
Social changes	**Benefit to water resource availability**	**Low**	**Moderate**	**Low**	**Low**	**Very Low**	**Very Low**
River		0	0	0	0	0	0
Reservoir		0	0	0	0	0	0
Groundwater		0	0	0	0	0	0
Reuse scheme		0	2	0	0	0	0
Desalination		0	2	0	0	0	0

Driver	Indicator	Sustainable World		Conventional World		Consumptive World	
Changes to abstraction licence conditions to address identified impacts on habitats and species		**Additional constraint**	**Significant additional constraint**	**No action taken**	**Additional constraint**	**No action taken**	**Constraint relaxed**
River		-10	-20	0	-10	0	10
Reservoir		-5	-10	0	-5	0	5
Groundwater		-5	-10	0	-5	0	5
Reuse scheme		-2	-4	0	-2	0	2
Desalination		-1	-3	0	-1	0	1
Total Change							
River		-11	-21	-4	-20	-7	-5
Reservoir		-5	-10	0	-7	-1	2
Groundwater		-8	-13	-7	-19	-11	-14
Reuse scheme		-1	1	-2	-8	-6	-7
Desalination		2	3	0	-6	-5	-9

6. Conclusions

Three environmental scenarios have been developed covering a range of potential future changes to the environment within the Southern Water operational area for 2050 and 2080. For each scenario, assessment has been carried out to consider how different drivers and pressures might affect water source availability compared to the baseline central deployable output forecast included in the draft version of this plan. Impacts have been assessed using a semi-quantitative scoring process which have then been converted into a potential percentage change (positive or negative) to deployable output values for each water source type (river, groundwater, reservoir, reuse schemes and desalination). Finally, these percentage changes have been applied for each scenario to the deployable output values for each water resource zone by source type to postulate potential change to deployable output for each of the three scenarios and the two planning horizons.

The assessment has indicated that the net impact on deployable output may be positive for some source types (reuse schemes and desalination) under the sustainable world scenario and for reservoir sources under the consumptive world scenario. For all other source types and scenarios, the net effect is assessed as a negative impact on deployable output, although the potential scale of percentage change varies between source type and scenario. For Southern Water's existing water sources, the adverse impacts are lowest for reservoir sources and greatest for 'run-of-river' sources where there is no storage to buffer the effect of environmental changes.

6.1 Scenario testing

We used the results of the analysis from the environmental forecasting to run a sensitivity test for each area to understand the potential implications future environmental changes could have on the plan over the longer term. This sensitivity run assumes that there could be additional sustainability reductions in future, over and above those assumed in our baseline supply-demand balances in the late 2020's.

This is a critical additional uncertainty to consider; as whilst we have as part of our decision making approach already taken account of a range of plausible but uncertain futures, the WRMP process does not at present, adequately account for future environmental uncertainties which may cause as yet unidentified sustainability reductions. The focus is primarily on short term sustainability reductions, but there is then an implicit assumption that there will be no further sustainability reductions in the mid- to long-term, which is not intuitive – as the environment comes under increasing stress there are various drivers which suggest that environmental regulation could become more stringent.

The aim of the sensitivity runs was therefore to identify how the strategy would change and whether it would trigger significantly different options if there were further reductions to water available for abstraction due to future environmental changes or policies. Alternatively, it could highlight that there would not be sufficient options available (based on the current list of feasible options) to solve additional possible sustainability reductions later in the planning period.

From our analysis which we consulted on in the draft WRMP, we identified that there were additional investments needed and / or unsolvable deficits later in the planning period. Options included additional desalination options (or larger desalination options), additional bulk imports, new reservoirs, additional water reuse options, and continued use of drought intervention options across the planning period.

There were no objections raised to our approach to including environmental forecasting uncertainties from respondents to the draft WRMP consultation. We therefore intend to pursue this further in our next WRMP in 2023-242024, to ensure that in addition to forecasting supply and demand, WRMPs also take account of potential future changes to the environment which can and will impact on the availability for water resource purposes, and on the investment needed to ensure a secure supply of water in the future

7. References

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Annex 4: Environmental Forecast

Appendix A: Impacts of Environmental Changes on Species

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Contents

1. Impacts of environmental changes on species

All the pressures and drivers assessed in the scenario development could potentially impact on species and habitats.

1.1 Population growth

Population increases under both a conventional world and consumptive world could result in adverse water quality changes due to a range of factors, including:

- Further development of urban areas to accommodate new housing and employment facilities, leading to increased surface runoff that may be contaminated with metals, hydrocarbons and suspended solids
- Population growth could further increase loading to wastewater treatment plants in the water source catchments which could causes further pressures on water quality for river sources.
- Increased abstraction to meet greater demand for water could modify dilution effects within waterbodies
- A transfer to urban land use from agricultural uses could reduce some nutrient loadings to rivers and groundwater, though these are likely to be offset by increased concentrations of hydrocarbon and metals
- Increased pressure to provide more food for the growing population in a smaller agricultural land area could lead to intensification of agricultural land use, reducing the sustainability of the soil, adding increased agricultural pollutant loadings to rivers and groundwater

While some of these changes could be offset by improved technologies in water treatment and changes in social behaviour and attitudes to the environment, most of the impacts associated with population growth would exacerbate any climate change impacts. Water quality changes driven by population growth could result in extensive changes in the types of chemical changes that require consideration in the future from a regulatory perspective. Climate change, however, is perhaps the greatest concern with regards to future water quality within the Southern Water operational area.

Of particular concern is the impact on aquatic ecosystems with changing temperature and potential changes to salinity and nutrient loading. Cold-water aquatic species are especially sensitive to temperature changes and could have implications for environmental regulation within the operational area as discussed further below.

Temperature is a major trait of the ecological niche of poikilotherm species (Angilletta, 2009) and a key factor in fish energy balance, affecting the rate of food intake, metabolic rate and growth performance (Elliott J.M. & Allonby J.D., 2013). It is also involved in many other physiological functions such as blood and reproductive maturation, reproductive timing, gametogenesis, cardiac function, gene expression, ecological relationships and fish behaviour (Santiago et al., 2017). In general, the thermal regime of rivers is highly influenced by meteorological and river conditions as well as by their geographical setting. Studies have shown the water temperature is strongly correlated with air temperature (especially in shallow rivers) although there is usually a time lag that can range from hours to days (Stefan H.G. & Preud'homme E.B., 1993). Stream temperature increases have been documented for the last decades throughout the globe, including Europe (Orr et al., 2015). This alteration may especially affect cold-water fish, which have been shown to be very sensitive to climate warming (Santiago et al., 2017).

The water temperature in rivers are controlled by a number of factors. Bogan (Bogan et al., 2003) showed that water temperatures were uniquely controlled by climate in only 26% of 596 studied stream reaches. Groundwater, wastewater and reservoir releases influenced water temperature in the remaining 74% of the cases. Where rivers are groundwater fed, the impact of increased air temperatures would thus be of less concern, especially in the upper reaches. With respect to biogeochemical conditions and water quality in general, most climate change impacts can be attributed to changes in stream water temperature. When water temperature increases, dissolved oxygen decreases, and biological activities are enhanced. These changes have potential consequences on nutrients, organic matter and biomass in general.

Ultimately, higher water temperatures, increased precipitation intensity, and longer periods of low flows are projected to exacerbate many forms of water pollution, including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution. This will promote algal blooms (Environment Canada, 2001) and increase the bacterial and fungal content (Kumagai et al., 2003) in surface water. The quality of groundwater may also deteriorate.

These water quality changes will have implications for the WFD status of waterbodies and could potentially impact on abstraction quantity and quality within the Southern Water operational area.

1.2 Climate change: sea level rise

In coastal areas, rising sea levels may have negative effects on storm-water drainage and sewage disposal and increase the potential for the intrusion of saline water into coastal aquifers, thus adversely affecting groundwater resources. Any decrease in groundwater recharge will exacerbate the effect of sea-level rise. In inland aquifers, a decrease in groundwater recharge can lead to saltwater intrusion from neighbouring saline aquifers (Chen et al., 2004). Changes in temperature and precipitation may have potential impacts on the distribution of coastal habitats: much of the coastal area associated with the Southern Water operational area has been designated as sites of European importance and national importance (such as Special Areas of Conservation, Special Protection Areas and Marine Conservation Zones). This includes habitats such as estuaries, mudflats and sandflats not covered by seawater at low tide, coastal lagoons, annual vegetation of drift lines, vegetated sea cliffs of the Atlantic and Baltic Coasts. Sea level rise poses a direct physical threat to these habitats.

Under a conventional world scenario, latest UKCP09 projections indicate that sea levels around the south of the UK might rise by 22cm by 2050 and 36cm by 2080. The immediate effect of such sea level rises will be increased duration and spatial extent of habitat submergence and increased risk of flooding of coastal land, along with saline intrusion to both rivers and coastal aquifers. Longer-term effects will also occur as the coastline adjusts to the new sea level conditions, including increased erosion risks on sensitive coastal and estuarine habitats, such as salt marsh. Coastal wetlands (including saltmarsh) will also decline unless they have a sufficient sediment supply to keep pace with sea level rise. The physical loss of these features may alter the extent of coastal and estuarine designated sites within the Southern Water operational area.

1.3 Potential impacts on species

Future changes in climate, population growth, social behaviour and the perception of the environment, as well as changes in technology (especially water and wastewater treatment) could have direct impacts and indirect impacts on species.

Under both conventional world and sustainable world scenarios, environmental protecting would likely continue to drive abstraction licensing regimes that employ tools such as Environmental Flow Indicators (EFI) and Hands-off Flow (HoF) conditions to restrict abstraction at times of low river flows. Under a sustainable world scenario in particular, social awareness of the environment would particularly drive the protection of the environment which could impact on water supply availability through more stringent abstraction licence conditions. As indicated above, climate change would be a main driver of change in species and habitats, regardless of any social or regulatory changes.

Climate change could have a variety of effects on species which includes changes in metabolic rates, changing ecosystem productivity and biodiversity, species distributions, fish migration patterns and dispersal corridors, increase in nutrients and therefore eutrophication, and changes in aquatic species in designated areas.

Based on a sample of species distributions models, Thomas (Thomas et al. 2004) estimated that 20-30% of species face extinction if temperature increases by 1.5-2.5°C. The 50% probability increase in temperature under all future scenarios considered in this report would see an increase of more than 2.5ºC during summer. This will have a negative effect on species, with vulnerability varying across the different taxa (**Error! Reference source not found.**) associated with the Southern Water operational area.

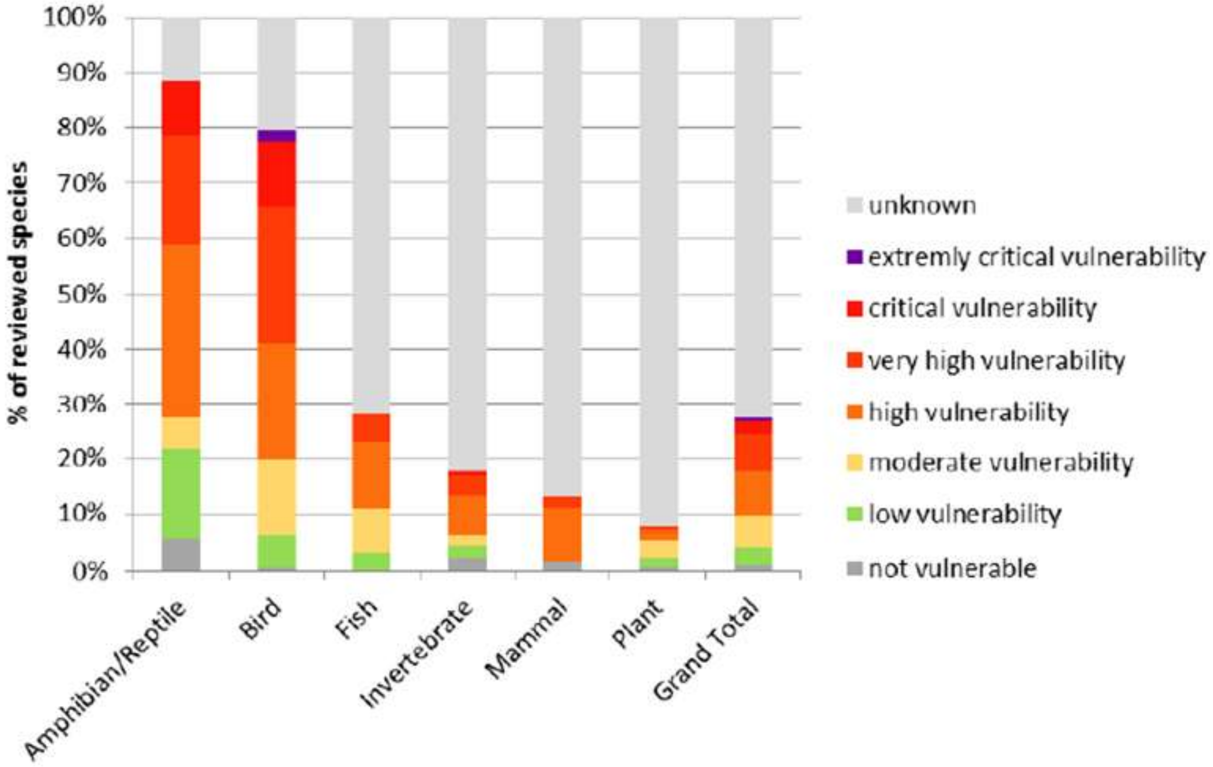
Error! Reference source not found. shows that a proportion of bird species have ‘extremely critical vulnerability’ and have the largest proportion of species at ‘critical vulnerability’ and ‘very high vulnerability’. The amphibian and reptile group have the highest proportion of ‘high vulnerability’, with the highest overall % of reviewed species. This is of particular concern in the Southern Water operational area due to a number of Special Protection Areas and Ramsar sites associated with the surface water abstractions.

1.3.1 Invasive non-native species (INNS)

The dual threat from climate change and INNS to native fauna could have a devastating effect on biodiversity. The distribution of INNS could increase due to increased sources, pathways and receptors. A study conducted by Gallardo and Aldridge (Gallardo B. & Aldridge D.C., 2013) predicted the impact of climate change scenarios for 2050 on the range of four species which included the invasive zebra mussel and signal crayfish and native depressed river mussel. Regional species distribution models (SDMs) to predict the impact and four contrasting future climate scenarios were used to account for the high uncertainty associated with such predictions. The 2050 scenarios suggested that the invasive zebra mussel could strongly benefit from climate change’s effects, with an increase of 15-20% in their range size, invading new areas in northeast Europe. In contrast, the native depressed river mussel was predicted to experience considerable loss of 14-36%. Furthermore, populations could decline even further as a result of a predicted increase in range overlap (up to 24%) with the faster growing zebra mussel population.

Conversely, negative effects of climatic changes for both species of crayfish were predicted, especially the invasive signal crayfish, which could suffer up to 32% decrease in range size. The overlap between the ranges of the two crayfishes was also expected to decrease by 13-16%.

Figure 1 Species vulnerability for climate change



1.3.2 Marine fish

Water temperatures could bring about more exotic species. Already over recent years, fish rarities are being recorded around the UK coast (Table 1), including triggerfish (*Balistes capriscus*), ocean sunfish (*Mola mola*) and some more exotic bream varieties have become increasingly more abundant in UK waters.

Rising sea temperatures could cause a shift in the fish community would impact on commercial fishing. A study by the Marine Climate Change Impacts Partnership (MCCIP, 2012) warned that if water temperatures rise by 1°C in Northern Ireland and Scotland, mussel production will fall by 50%, while predicted increases in violent ocean storms are likely to cause "considerable economic impacts" on salmon farming, by damaging fish cages and allowing millions of salmon to escape and breed with wild stocks.

Furthermore, the range of one southerly species, the bib, had extended north by 342 kilometres (212 miles) in two decades while common North Sea species such as cod, lemon sole and saithe were swimming at depths which were increasing by 5.5 metres a decade. Whilst a shift in distributions might be an opportunity for the fishing industry (more fleets are catching squid which was once deemed a Mediterranean species), boarfish (landing have increased around Ireland) and anchovies, the loss of others might not outweigh the benefit, with increased risk from INNS and associated exotic diseases.

Table 1 Fish rarities observed around the UK coast

Species	Location	Typically found	Year
Crocodile shark (*Pseudocarcharias kamoharai*)	Plymouth	Brazil and Australia	2017
Blue marlin (*Makaira nigricans*)	Pembrokeshire	Atlantic	2016
Bluefin tuna (*Thunnus thynnus*)	Cornwall	Western and eastern Atlantic and Mediterranean	2016
Deal fish (*Trachipterus arcticus*)	Yorkshire	North of Scotland	2014
Almaco jack (*Seriola rivoliana*)	Bristol Channel	Caribbean	2009
Oarfish (*Rehalecus glesne*)	North-east coast	Tropics	2009
Atlantic pomfret (*Brama brama*)	Northumberland	West Africa	2009
Louvar (*Luvarus imperialis*)	Newlyn	Mediterranean	1998
Comber (*Serranus cabrilla*)	Cornwall	Mediterranean (uncommon north of the Bay of Biscay)	1996
Opar (Lampris guttatus)	Orkneys	Tropical to temperate	1995

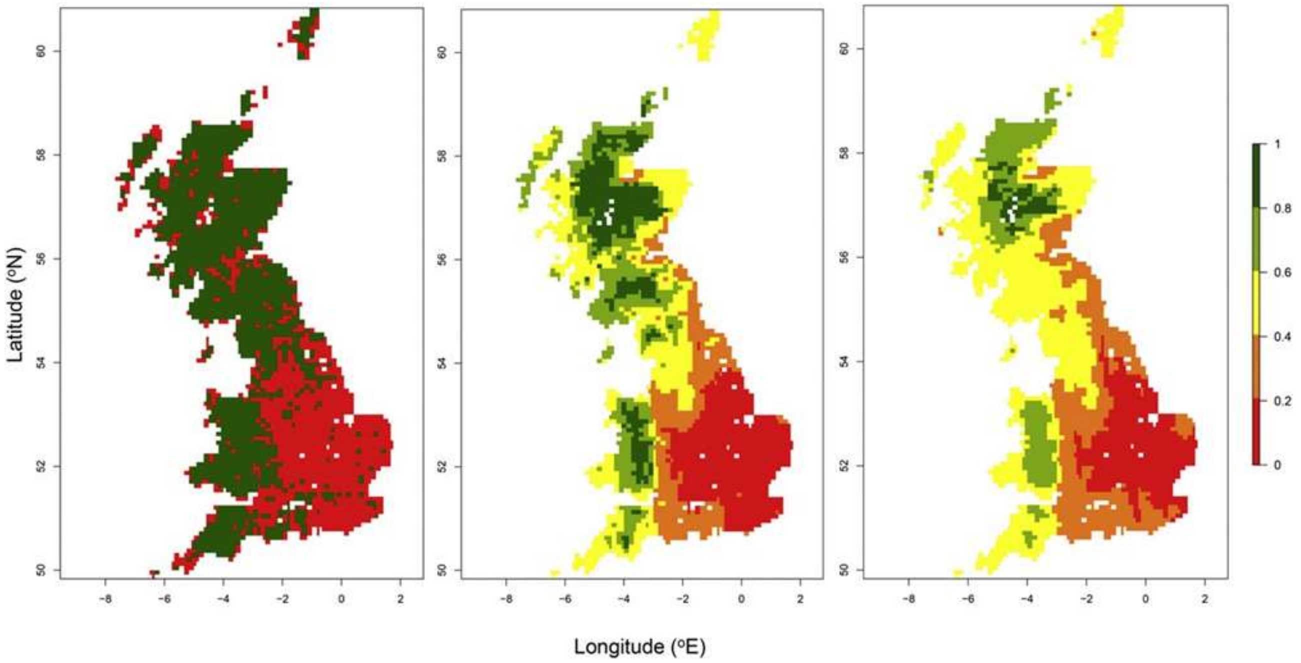
1.3.3 Freshwater fish

Salmonids

A study conducted by multiple authors (Santiago et al., 2017) concluded that temperature and streamflow changes will cause a shift in the species distribution of cold-water fish (brown trout) due to their sensitivity at the 'rear edge' of their distribution. Jonsson & Jonsson (2009) predicted that expected effects of climate change on water temperatures and streamflow will have implications for migration, ontogeny, growth and life-history traits of Atlantic salmon and brown trout. Brown trout is a sensitive species to changes in discharge patterns because high intensity floods during the incubation and emergence periods may limit recruitment (Junker et al., 2015 and Lobón-Cerviá & Mortensen, 2007 and). Significant flow reductions are expected during the summer in most of the studied rivers and streams at the end of the century, and this may mean, in turn, the reduction of available habitat for trout (Muñoz-Mas et al., 2016).

A recent UK study (Santiago et al., 2017) investigated climate change scenarios for 12 species of fish. Studies using species' current distributions and their relationships with current climatic variables predicted a 78% decrease in Atlantic salmon, with the major driver being temperature for salmonids (**Error! Reference source not found.**).

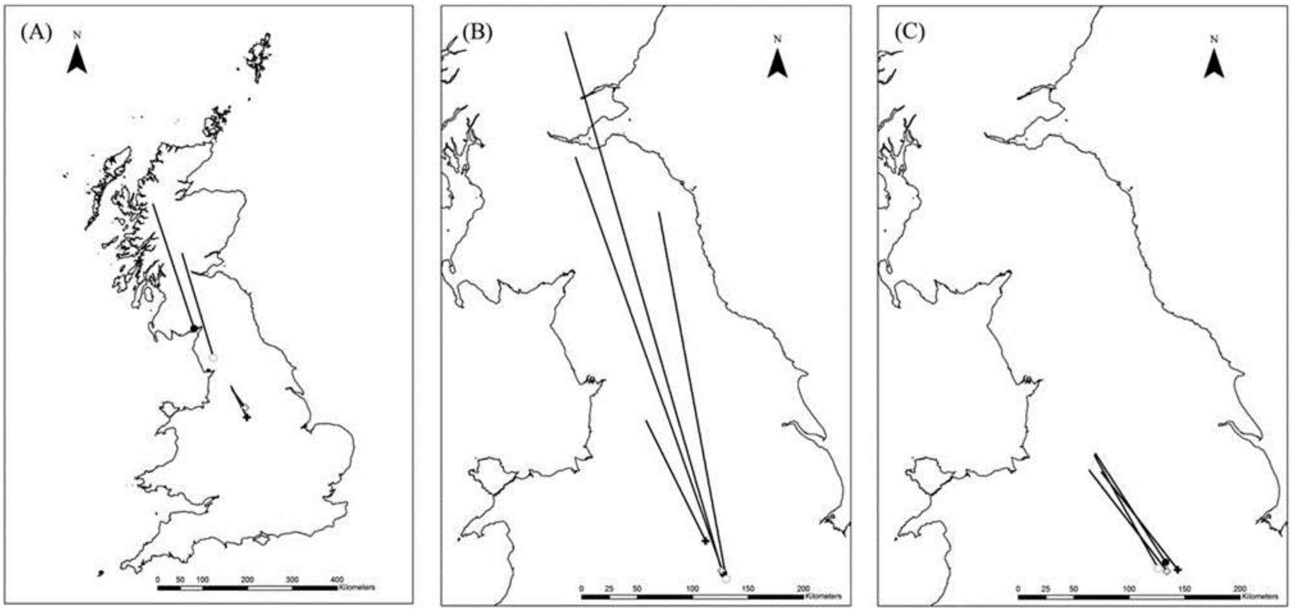
Figure 2 Current spatial distribution of Atlantic salmon (left) and their predicted low emission climate scenario in 2050 (middle) and high emission climate scenario in 2070 (right)



Non-salmonids

The same study indicated that the species shift for cyprinid fish would likely be reflected in an expansion rather than a decrease in population. Cyprinid species studied included common carp (*Cyprinus carpio*), crucian carp (*Carassius carassius*), rudd (*Scardinius erythrophthalmus*), roach (*Rutilus rutilus*), chub (*Squalius cephalus*), bream (*Abramis brama*), Dace (*Leuciscus leuciscus*) and bullhead (*Gobio* gobio). These species would expand into more northerly regions, with the key driver being a combination of temperature and mean annual precipitation (**Error! Reference source not found.**).

Figure 3 Extent of displacement for pike (left), perch, salmon and trout (left), bullhead, roach, chub and dace (middle) and rudd, crucian carp, bream and common carp (right)



Habitats might become increasingly unsuitable if extreme flooding events increase and crayfish in-river refuge areas are washed away, or increased siltation leads to habitat deterioration. Conditions might allow for an increased risk of crayfish plague if conditions are suitable. Furthermore, climate change could allow the introduction of new invasive non-native species and existing ones (signal crayfish) to thrive and outcompete native crayfish. However, it should be noted that those INNS that are already present might also experience a decrease in range.

1.3.5 Plant communities

A study conducted by Lemoine (Lemoine & Böhning-Gaese, 2007) highlighted a shift in earlier flowering times for European plant species. Aquatic plants would be impacted further due to habitat fragmentation and pressures from temperature increases, increased and prolonged drought periods.

Species such as stream water crowfoot (*Ranunculus penicillatus* subsp. *pseudofluitans*) and other *Ranunculus* species are at a real risk of decline due to habitat degradation of chalk rivers. Other threats include increased nutrients with phosphate being of particular concern and the smothering from algae, competition from other macrophytes variable flows from over-abstraction or fluctuations in precipitation and habitat loss and quality decline. Climate change as a driver can have an influence on velocity, discharge, substrate and siltation, with effects worsened when the impacted river is also being abstracted from. Overall, *Ranunculus* will be subjected to regional spatial changes, sediment loading and changes in precipitation patterns.

1.3.6 Migratory birds

Migratory birds are highly sensitive to climate change and the same study by Lemoine & Böhning-Gaese (2007) concluded that the species richness and composition of European bird communities had already been influenced by global climate change. Some species are migrating earlier as a result of climate change which illustrates their adaptability, whereas some move poleward and to higher elevations to stay within their preferred climate. However, not all species are able to adapt: in particular, those living on the edge of their range are more at risk as migration capacity can decrease. In relation to Natura 2000 sites, the European Environment and Sustainable Development Advisory Council (EEAC) has highlighted those habitats most vulnerable for birds, including mountain, arctic and coastal wetlands and the Mediterranean regions.

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Appendix B: Potential Changes to Deployable Output for each Water Resource Zone

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1. Potential changes to Deployable Output for each Water Resource Zone

The following abbreviations are used in Tables 1 – 4 presented in this Appendix.

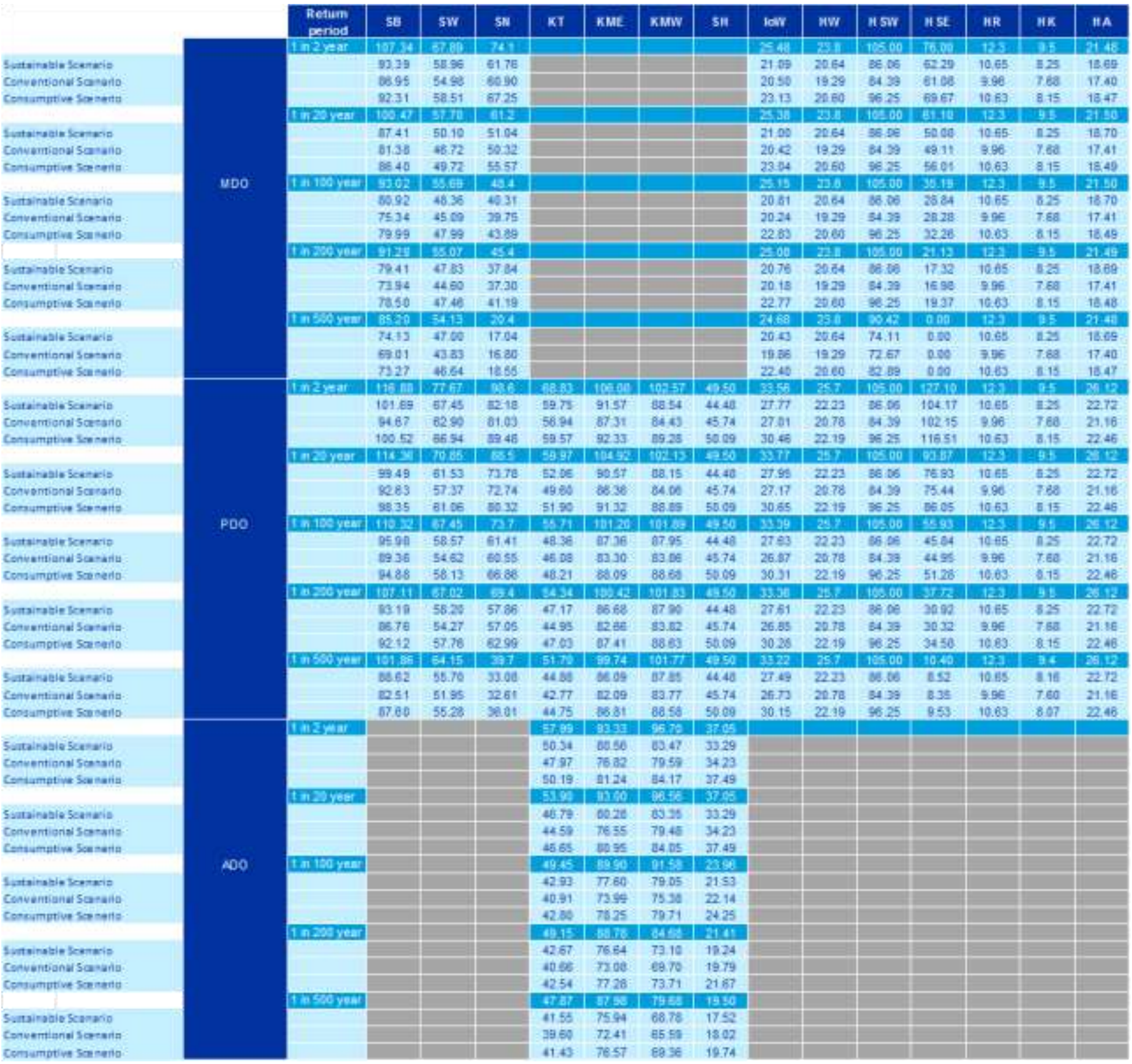
HK	Hampshire Kingsclere
HA	Hampshire Andover
IW	Isle of Wight
HR	Hampshire Rural
HW	Hampshire Winchester
HSE	Hampshire Southampton East
HSW	Hampshire Southampton West
SN	Sussex North
SW	Sussex Worthing
SB	Sussex Brighton
KME	Kent Medway East
KMW	Kent Medway West
KT	Kent Thanet
SH	Sussex Hastings
DO	Deployable Output
P	Peak
A	Average

1.1 Under the combined environmental scenario by 2050 and 2080

Table 1 Potential changes (Ml/d) to Deployable Output of existing sources for each Water Resource Zone under the combined environmental scenario by 2050

		Return period	SB	SW	SN	KT	KME	KMW	SH	IoW	HW	HSW	HSE	HR	HK	HA
	MDO	1 in 2 year	107.34	67.89	74.1					25.48	23.8	105.00	76.00	12.3	9.5	21.48
Sustainable Scenario			98.75	62.42	67.36					23.04	21.89	94.62	68.48	11.30	8.72	19.76
Conventional Scenario			99.83	63.18	70.78					24.10	22.20	99.63	72.12	11.46	8.82	19.98
Consumptive Scenerio			95.53	60.48	68.17					23.22	21.26	96.10	69.56	10.97	8.44	19.12
		1 in 20 year	100.47	57.70	61.2					25.38	23.8	105.00	61.10	12.3	9.5	21.50
Sustainable Scenario			92.43	53.05	55.66					22.95	21.89	94.62	55.06	11.30	8.72	19.78
Conventional Scenario			93.44	53.69	58.49					24.01	22.20	99.63	57.98	11.46	8.82	19.99
Consumptive Scenerio			89.42	51.40	56.33					23.13	21.26	96.10	55.92	10.97	8.44	19.13
		1 in 100 year	93.02	55.69	48.4					25.15	23.8	105.00	35.19	12.3	9.5	21.50
Sustainable Scenario			85.57	51.20	43.96					22.74	21.89	94.62	31.71	11.30	8.72	19.78
Conventional Scenario			86.51	51.82	46.20					23.79	22.20	99.63	33.39	11.46	8.82	19.99
Consumptive Scenerio			82.78	49.60	44.49					22.92	21.26	96.10	32.21	10.97	8.44	19.13
		1 in 200 year	91.28	55.07	45.4					25.08	23.8	105.00	21.13	12.3	9.5	21.49
Sustainable Scenario			83.98	50.63	41.26					22.67	21.89	94.62	19.04	11.30	8.72	19.77
Conventional Scenario			84.89	51.25	43.36					23.72	22.20	99.63	20.05	11.46	8.82	19.98
Consumptive Scenerio			81.24	49.06	41.76					22.85	21.26	96.10	19.34	10.97	8.44	19.12
		1 in 500 year	85.20	54.13	20.4					24.68	23.8	90.42	0.00	12.3	9.5	21.48
Sustainable Scenario			78.39	49.76	18.59					22.31	21.89	81.48	0.00	11.30	8.72	19.76
Conventional Scenario			79.24	50.37	19.53					23.34	22.20	85.80	0.00	11.46	8.82	19.97
Consumptive Scenerio			75.83	48.21	18.81					22.49	21.26	82.76	0.00	10.97	8.44	19.12
	PDO	1 in 2 year	116.88	77.67	98.6	68.83	106.08	102.57	49.50	33.56	25.7	105.00	127.10	12.3	9.5	26.12
Sustainable Scenario			107.53	71.41	89.63	63.47	97.56	94.33	46.95	30.34	23.58	94.62	114.53	11.30	8.72	24.03
Conventional Scenario			108.70	72.28	94.18	64.90	99.96	96.65	49.33	31.74	23.91	99.63	120.60	11.46	8.82	24.29
Consumptive Scenerio			104.02	69.19	90.70	61.95	95.56	92.40	48.76	30.58	22.90	96.10	116.32	10.97	8.44	23.25
		1 in 20 year	114.36	70.85	88.5	59.97	104.92	102.13	49.50	33.77	25.7	105.00	93.87	12.3	9.5	26.12
Sustainable Scenario			105.21	65.14	80.46	55.30	96.50	93.92	46.95	30.53	23.58	94.62	84.58	11.30	8.72	24.03
Conventional Scenario			106.36	65.93	84.55	56.54	98.87	96.23	49.33	31.94	23.91	99.63	89.07	11.46	8.82	24.29
Consumptive Scenerio			101.78	63.11	81.42	53.97	94.52	92.00	48.76	30.77	22.90	96.10	85.91	10.97	8.44	23.25
		1 in 100 year	110.32	67.45	73.7	55.71	101.20	101.89	49.50	33.39	25.7	105.00	55.93	12.3	9.5	26.12
Sustainable Scenario			101.50	62.01	66.97	51.37	93.07	93.70	46.95	30.19	23.58	94.62	50.40	11.30	8.72	24.03
Conventional Scenario			102.60	62.77	70.37	52.52	95.36	96.01	49.33	31.59	23.91	99.63	53.08	11.46	8.82	24.29
Consumptive Scenerio			98.19	60.08	67.77	50.14	91.17	91.79	48.76	30.43	22.90	96.10	51.19	10.97	8.44	23.25
		1 in 200 year	107.11	67.02	69.4	54.34	100.42	101.83	49.50	33.36	25.7	105.00	37.72	12.3	9.5	26.12
Sustainable Scenario			98.54	61.62	63.10	50.10	92.36	93.65	46.95	30.16	23.58	94.62	33.99	11.30	8.72	24.03
Conventional Scenario			99.62	62.37	66.31	51.23	94.63	95.95	49.33	31.56	23.91	99.63	35.79	11.46	8.82	24.29
Consumptive Scenerio			95.33	59.70	63.85	48.91	90.47	91.73	48.76	30.40	22.90	96.10	34.52	10.97	8.44	23.25
		1 in 500 year	101.86	64.15	39.7	51.70	99.74	101.77	49.50	33.22	25.7	105.00	10.40	12.3	9.4	26.12
Sustainable Scenario			93.71	58.98	36.07	47.68	91.73	93.60	46.95	30.03	23.58	94.62	9.37	11.30	8.63	24.03
Conventional Scenario			94.73	59.69	37.91	48.75	93.98	95.90	49.33	31.42	23.91	99.63	9.86	11.46	8.72	24.29
Consumptive Scenerio			90.65	57.14	36.51	46.54	89.85	91.68	48.76	30.27	22.90	96.10	9.51	10.97	8.35	23.25
	ADO	1 in 2 year				57.99	93.33	96.70	37.05							
Sustainable Scenario						53.47	85.84	88.93	35.14							
Conventional Scenario						54.68	87.95	91.12	36.92							
Consumptive Scenerio						52.19	84.08	87.11	36.49							
		1 in 20 year				53.90	93.00	96.56	37.05							
Sustainable Scenario						49.70	85.53	88.81	35.14							
Conventional Scenario						50.82	87.64	90.99	36.92							
Consumptive Scenerio						48.51	83.78	86.99	36.49							
		1 in 100 year				49.45	89.90	91.58	23.96							
Sustainable Scenario						45.60	82.68	84.23	22.73							
Conventional Scenario						46.63	84.71	86.30	23.88							
Consumptive Scenerio						44.51	80.98	82.50	23.60							
		1 in 200 year				49.15	88.78	84.68	21.41							
Sustainable Scenario						45.32	81.65	77.88	20.31							
Conventional Scenario						46.35	83.66	79.80	21.34							
Consumptive Scenerio						44.24	79.98	76.29	21.09							
		1 in 500 year				47.87	87.98	79.68	19.50							
Sustainable Scenario						44.14	80.91	73.28	18.50							
Conventional Scenario						45.13	82.90	75.08	19.44							
Consumptive Scenerio						43.08	79.26	71.78	19.21							

Table 2 Potential changes (Ml/d) to Deployable Output of existing sources for each Water Resource Zone under the combined environmental scenario by 2080



		Return period	SB	SW	SN	KT	KME	KMW	SH	IoW	HW	H SW	H SE	H R	H K	H A
	MDO	1 in 2 year	107.34	67.89	74.1					25.48	23.8	105.00	76.00	12.3	9.5	21.48
Sustainable Scenario			93.39	58.96	61.76					21.09	20.64	86.06	62.29	10.65	8.25	18.69
Conventional Scenario			86.95	54.98	60.90					20.50	19.29	84.39	61.08	9.96	7.68	17.40
Consumptive Scenario			92.31	58.51	67.25					23.13	20.60	96.25	69.67	10.63	8.15	18.47
		1 in 20 year	100.47	57.78	61.2					25.38	23.8	105.00	81.10	12.3	9.5	21.50
Sustainable Scenario			87.41	50.10	51.04					21.00	20.64	86.06	50.00	10.65	8.25	18.70
Conventional Scenario			81.38	46.72	50.32					20.42	19.29	84.39	49.11	9.96	7.68	17.41
Consumptive Scenario			86.40	49.72	55.57					23.04	20.60	96.25	56.01	10.63	8.15	18.49
		1 in 100 year	93.02	55.69	48.4					25.15	23.8	105.00	30.19	12.3	9.5	21.50
Sustainable Scenario			80.92	48.36	40.31					20.81	20.64	86.06	26.84	10.65	8.25	18.70
Conventional Scenario			75.34	45.09	39.75					20.24	19.29	84.39	28.28	9.96	7.68	17.41
Consumptive Scenario			79.99	47.99	43.89					22.83	20.60	96.25	32.26	10.63	8.15	18.49
		1 in 200 year	91.29	55.07	45.4					25.00	23.8	105.00	21.13	12.3	9.5	21.49
Sustainable Scenario			79.41	47.83	37.84					20.76	20.64	86.06	17.32	10.65	8.25	18.69
Conventional Scenario			73.94	44.60	37.30					20.18	19.29	84.39	16.98	9.96	7.68	17.41
Consumptive Scenario			78.50	47.46	41.19					22.77	20.60	96.25	19.37	10.63	8.15	18.48
		1 in 500 year	85.20	54.13	20.4					24.68	23.8	90.42	0.00	12.3	9.5	21.48
Sustainable Scenario			74.13	47.00	17.04					20.43	20.64	74.11	0.00	10.65	8.25	18.69
Conventional Scenario			69.01	43.83	16.80					19.86	19.29	72.67	0.00	9.96	7.68	17.40
Consumptive Scenario			73.27	46.64	18.55					22.40	20.60	82.89	0.00	10.63	8.15	18.47
	PDO	1 in 2 year	116.88	77.67	98.6	68.83	106.08	102.57	49.50	33.56	25.7	105.00	127.10	12.3	9.5	26.12
Sustainable Scenario			101.69	67.45	82.18	59.75	91.57	88.54	44.48	27.77	22.23	86.06	104.17	10.65	8.25	22.72
Conventional Scenario			94.67	62.90	81.03	58.94	87.31	84.43	45.74	27.81	20.78	84.39	102.15	9.96	7.68	21.16
Consumptive Scenario			100.52	66.94	89.46	59.57	92.33	89.28	50.09	30.46	22.19	96.25	116.51	10.63	8.15	22.46
		1 in 20 year	114.38	70.65	88.5	59.97	104.92	102.13	49.50	33.77	25.7	105.00	93.87	12.3	9.5	26.12
Sustainable Scenario			99.49	61.53	73.78	52.06	90.57	88.15	44.48	27.95	22.23	86.06	76.93	10.65	8.25	22.72
Conventional Scenario			92.83	57.37	72.74	49.60	86.38	84.06	45.74	27.17	20.78	84.39	75.44	9.96	7.68	21.16
Consumptive Scenario			98.35	61.06	80.32	51.90	91.32	88.89	50.09	30.65	22.19	96.25	86.05	10.63	8.15	22.46
		1 in 100 year	110.32	67.45	73.7	55.71	101.20	101.89	49.50	33.39	25.7	105.00	55.93	12.3	9.5	26.12
Sustainable Scenario			95.98	58.57	61.41	48.36	87.36	87.95	44.48	27.63	22.23	86.06	45.84	10.65	8.25	22.72
Conventional Scenario			89.36	54.62	60.55	46.08	83.30	83.86	45.74	26.87	20.78	84.39	44.95	9.96	7.68	21.16
Consumptive Scenario			94.88	58.13	66.88	48.21	88.09	88.68	50.09	30.31	22.19	96.25	51.28	10.63	8.15	22.46
		1 in 200 year	107.11	67.02	69.4	54.34	100.42	101.83	49.50	33.36	25.7	105.00	37.72	12.3	9.5	26.12
Sustainable Scenario			93.19	58.28	57.86	47.17	86.68	87.90	44.48	27.61	22.23	86.06	30.92	10.65	8.25	22.72
Conventional Scenario			86.76	54.27	57.05	44.95	82.66	83.82	45.74	26.85	20.78	84.39	30.32	9.96	7.68	21.16
Consumptive Scenario			92.12	57.76	62.99	47.03	87.41	88.63	50.09	30.26	22.19	96.25	34.58	10.63	8.15	22.46
		1 in 500 year	101.86	64.15	39.7	51.79	99.74	101.77	49.50	33.22	25.7	105.00	10.40	12.3	9.4	26.12
Sustainable Scenario			88.62	55.70	33.08	44.88	86.09	87.85	44.48	27.49	22.23	86.06	8.52	10.65	8.16	22.72
Conventional Scenario			82.51	51.95	32.61	42.77	82.09	83.77	45.74	26.73	20.78	84.39	8.35	9.96	7.60	21.16
Consumptive Scenario			87.60	55.28	38.01	44.75	86.81	88.58	50.09	30.15	22.19	96.25	9.53	10.63	8.07	22.46
	ADO	1 in 2 year				57.99	93.33	96.79	37.05							
Sustainable Scenario						50.34	80.56	83.47	33.29							
Conventional Scenario						47.97	76.82	79.59	34.23							
Consumptive Scenario						50.19	81.24	84.17	37.49							
		1 in 20 year				53.98	93.00	96.56	37.05							
Sustainable Scenario						46.79	80.28	83.35	33.29							
Conventional Scenario						44.59	76.55	79.48	34.23							
Consumptive Scenario						46.65	80.95	84.05	37.49							
		1 in 100 year				49.45	89.90	91.58	23.96							
Sustainable Scenario						42.93	77.60	79.05	21.53							
Conventional Scenario						40.91	73.99	75.38	22.14							
Consumptive Scenario						42.80	78.25	79.71	24.25							
		1 in 200 year				49.15	88.76	84.68	21.41							
Sustainable Scenario						42.67	76.64	73.10	19.24							
Conventional Scenario						40.66	73.08	69.70	19.79							
Consumptive Scenario						42.54	77.28	73.71	21.67							
		1 in 500 year				47.87	87.98	79.68	19.50							
Sustainable Scenario						41.55	75.94	68.78	17.52							
Conventional Scenario						39.60	72.41	65.59	18.02							
Consumptive Scenario						41.43	76.57	69.36	19.74							

1.2 Under the Habitats and Species Change scenario at 2050 and 2080

Table 3 Potential changes (Ml/d) to Deployable Output of existing sources for each Water Resource Zone under the Habitats and Species Change scenario only at 2050

		Return period	SB	SW	SN	KT	KME	KMW	SH	IoW	HW	HSW	HSE	HR	HK	HA
	MDO	1 in 2 year	107.34	67.89	74.1					25.48	23.8	105.00	76.00	12.3	9.5	21.48
Sustainable Scenario			101.97	64.43	68.52					23.53	22.58	96.44	69.81	11.65	9.01	20.41
Conventional Scenario			107.34	67.89	74.11					25.48	23.83	105.00	76.00	12.30	9.48	21.48
Consumptive Scenerio			107.34	67.89	74.11					25.48	23.83	105.00	76.00	12.30	9.48	21.48
		1 in 20 year	100.47	57.70	61.2					25.38	23.8	105.00	61.10	12.3	9.5	21.50
Sustainable Scenario			95.45	54.75	56.62					23.44	22.58	96.44	56.12	11.65	9.01	20.42
Conventional Scenario			100.47	57.70	61.24					25.38	23.83	105.00	61.10	12.30	9.48	21.50
Consumptive Scenerio			100.47	57.70	61.24					25.38	23.83	105.00	61.10	12.30	9.48	21.50
		1 in 100 year	93.02	55.69	48.4					25.15	23.8	105.00	35.19	12.3	9.5	21.50
Sustainable Scenario			88.37	52.85	44.72					23.23	22.58	96.44	32.32	11.65	9.01	20.42
Conventional Scenario			93.02	55.69	48.37					25.15	23.83	105.00	35.19	12.30	9.48	21.50
Consumptive Scenerio			93.02	55.69	48.37					25.15	23.83	105.00	35.19	12.30	9.48	21.50
		1 in 200 year	91.28	55.07	45.4					25.08	23.8	105.00	21.13	12.3	9.5	21.49
Sustainable Scenario			86.72	52.26	41.97					23.16	22.58	96.44	19.41	11.65	9.01	20.41
Conventional Scenario			91.28	55.07	45.40					25.08	23.83	105.00	21.13	12.30	9.48	21.49
Consumptive Scenerio			91.28	55.07	45.40					25.08	23.83	105.00	21.13	12.30	9.48	21.49
		1 in 500 year	85.20	54.13	20.4					24.68	23.8	90.42	0.00	12.3	9.5	21.48
Sustainable Scenario			80.94	51.36	18.90					22.79	22.58	83.05	0.00	11.65	9.01	20.40
Conventional Scenario			85.20	54.13	20.45					24.68	23.83	90.42	0.00	12.30	9.48	21.48
Consumptive Scenerio			85.20	54.13	20.45					24.68	23.83	90.42	0.00	12.30	9.48	21.48
	PDO	1 in 2 year	116.88	77.67	98.6	68.83	106.08	102.57	49.50	33.56	25.7	105.00	127.10	12.3	9.5	26.12
Sustainable Scenario			111.04	73.71	91.16	65.12	100.09	96.77	47.03	30.99	24.32	96.44	116.74	11.65	9.01	24.81
Conventional Scenario			116.88	77.67	98.61	68.83	106.08	102.57	49.50	33.56	25.67	105.00	127.10	12.30	9.48	26.12
Consumptive Scenerio			116.88	77.67	98.61	68.83	106.08	102.57	49.50	33.56	25.67	105.00	127.10	12.30	9.48	26.12
		1 in 20 year	114.36	70.85	88.5	59.97	104.92	102.13	49.50	33.77	25.7	105.00	93.87	12.3	9.5	26.12
Sustainable Scenario			108.64	67.24	81.84	56.73	98.99	96.36	47.03	31.18	24.32	96.44	86.22	11.65	9.01	24.81
Conventional Scenario			114.36	70.85	88.52	59.97	104.92	102.13	49.50	33.77	25.67	105.00	93.87	12.30	9.48	26.12
Consumptive Scenerio			114.36	70.85	88.52	59.97	104.92	102.13	49.50	33.77	25.67	105.00	93.87	12.30	9.48	26.12
		1 in 100 year	110.32	67.45	73.7	55.71	101.20	101.89	49.50	33.39	25.7	105.00	55.93	12.3	9.5	26.12
Sustainable Scenario			104.81	64.01	68.12	52.70	95.48	96.13	47.03	30.84	24.32	96.44	51.38	11.65	9.01	24.81
Conventional Scenario			110.32	67.45	73.68	55.71	101.20	101.89	49.50	33.39	25.67	105.00	55.93	12.30	9.48	26.12
Consumptive Scenerio			110.32	67.45	73.68	55.71	101.20	101.89	49.50	33.39	25.67	105.00	55.93	12.30	9.48	26.12
		1 in 200 year	107.11	67.02	69.4	54.34	100.42	101.83	49.50	33.36	25.7	105.00	37.72	12.3	9.5	26.12
Sustainable Scenario			101.76	63.60	64.18	51.40	94.75	96.08	47.03	30.81	24.32	96.44	34.65	11.65	9.01	24.81
Conventional Scenario			107.11	67.02	69.42	54.34	100.42	101.83	49.50	33.36	25.67	105.00	37.72	12.30	9.48	26.12
Consumptive Scenerio			107.11	67.02	69.42	54.34	100.42	101.83	49.50	33.36	25.67	105.00	37.72	12.30	9.48	26.12
		1 in 500 year	101.86	64.15	39.7	51.70	99.74	101.77	49.50	33.22	25.7	105.00	10.40	12.3	9.4	26.12
Sustainable Scenario			96.77	60.87	36.69	48.91	94.10	96.02	47.03	30.68	24.32	96.44	9.55	11.65	8.91	24.81
Conventional Scenario			101.86	64.15	39.69	51.70	99.74	101.77	49.50	33.22	25.67	105.00	10.40	12.30	9.38	26.12
Consumptive Scenerio			101.86	64.15	39.69	51.70	99.74	101.77	49.50	33.22	25.67	105.00	10.40	12.30	9.38	26.12
	ADO	1 in 2 year				57.99	93.33	96.70	37.05							
Sustainable Scenario						54.86	88.06	91.24	35.19							
Conventional Scenario						57.99	93.33	96.70	37.05							
Consumptive Scenerio						57.99	93.33	96.70	37.05							
		1 in 20 year				53.90	93.00	96.56	37.05							
Sustainable Scenario						50.99	87.75	91.11	35.19							
Conventional Scenario						53.90	93.00	96.56	37.05							
Consumptive Scenerio						53.90	93.00	96.56	37.05							
		1 in 100 year				49.45	89.90	91.58	23.96							
Sustainable Scenario						46.78	84.82	86.41	22.76							
Conventional Scenario						49.45	89.90	91.58	23.96							
Consumptive Scenerio						49.45	89.90	91.58	23.96							
		1 in 200 year				49.15	88.78	84.68	21.41							
Sustainable Scenario						46.50	83.77	79.90	20.34							
Conventional Scenario						49.15	88.78	84.68	21.41							
Consumptive Scenerio						49.15	88.78	84.68	21.41							
		1 in 500 year				47.87	87.98	79.68	19.50							
Sustainable Scenario						45.28	83.01	75.18	18.53							
Conventional Scenario						47.87	87.98	79.68	19.50							
Consumptive Scenerio						47.87	87.98	79.68	19.50							

Table 4 Potential changes (Ml/d) to Deployable Output of existing sources for each Water Resource Zone under the Habitats and Species Change scenario only at 2080

		Return period	SB	SW	SN	KT	KME	KMW	SH	IoW	HW	H SW	H SE	HR	H K	H A
	MDO	1 in 2 year	107.34	67.89	74.1					25.48	23.8	105.00	76.00	12.3	9.5	21.48
Sustainable Scenario			96.61	60.97	62.92					21.58	21.33	87.89	63.61	11.01	8.53	19.33
Conventional Scenario			101.97	64.43	68.52					23.53	22.58	96.44	69.81	11.65	9.01	20.41
Consumptive Scenerio			112.71	71.35	78.60					27.43	25.08	113.56	82.19	12.95	9.95	22.56
		1 in 20 year	100.47	57.70	61.2					25.38	23.8	105.00	61.10	12.3	9.5	21.50
Sustainable Scenario			90.42	51.81	51.99					21.50	21.33	87.89	51.14	11.01	8.53	19.35
Conventional Scenario			95.45	54.75	56.62					23.44	22.58	96.44	56.12	11.65	9.01	20.42
Consumptive Scenerio			105.49	60.64	64.95					27.32	25.08	113.56	66.08	12.95	9.95	22.57
		1 in 100 year	93.02	55.69	48.4					25.15	23.8	105.00	35.19	12.3	9.5	21.50
Sustainable Scenario			83.71	50.01	41.07					21.30	21.33	87.89	29.45	11.01	8.53	19.35
Conventional Scenario			88.37	52.85	44.72					23.23	22.58	96.44	32.32	11.65	9.01	20.42
Consumptive Scenerio			97.67	58.53	51.30					27.07	25.08	113.56	38.06	12.95	9.95	22.57
		1 in 200 year	91.28	55.07	45.4					25.08	23.8	105.00	21.13	12.3	9.5	21.49
Sustainable Scenario			82.15	49.46	38.54					21.24	21.33	87.89	17.69	11.01	8.53	19.34
Conventional Scenario			86.72	52.26	41.97					23.16	22.58	96.44	19.41	11.65	9.01	20.41
Consumptive Scenerio			95.85	57.88	48.15					27.00	25.08	113.56	22.85	12.95	9.95	22.56
		1 in 500 year	85.20	54.13	20.4					24.68	23.8	90.42	0.00	12.3	9.5	21.48
Sustainable Scenario			76.68	48.60	17.36					20.90	21.33	75.69	0.00	11.01	8.53	19.33
Conventional Scenario			80.94	51.36	18.90					22.79	22.58	83.05	0.00	11.65	9.01	20.40
Consumptive Scenerio			89.46	56.89	21.69					26.57	25.08	97.79	0.00	12.95	9.95	22.55
	PDO	1 in 2 year	116.88	77.67	98.6	68.83	106.08	102.57	49.50	33.56	25.7	105.00	127.10	12.3	9.5	26.12
Sustainable Scenario			105.19	69.75	83.72	61.40	94.09	90.98	44.55	28.43	22.97	87.89	106.38	11.01	8.53	23.51
Conventional Scenario			111.04	73.71	91.16	65.12	100.09	96.77	47.03	30.99	24.32	96.44	116.74	11.65	9.01	24.81
Consumptive Scenerio			122.72	81.63	104.58	71.93	111.24	107.56	51.98	36.13	27.02	113.56	137.46	12.95	9.95	27.42
		1 in 20 year	114.36	70.85	88.5	59.97	104.92	102.13	49.50	33.77	25.7	105.00	93.87	12.3	9.5	26.12
Sustainable Scenario			102.93	63.62	75.16	53.49	93.07	90.59	44.55	28.60	22.97	87.89	78.57	11.01	8.53	23.51
Conventional Scenario			108.64	67.24	81.84	56.73	98.99	96.36	47.03	31.18	24.32	96.44	86.22	11.65	9.01	24.81
Consumptive Scenerio			120.08	74.46	93.88	62.67	110.03	107.09	51.98	36.35	27.02	113.56	101.52	12.95	9.95	27.42
		1 in 100 year	110.32	67.45	73.7	55.71	101.20	101.89	49.50	33.39	25.7	105.00	55.93	12.3	9.5	26.12
Sustainable Scenario			99.29	60.57	62.56	49.69	89.77	90.37	44.55	28.28	22.97	87.89	46.82	11.01	8.53	23.51
Conventional Scenario			104.81	64.01	68.12	52.70	95.48	96.13	47.03	30.84	24.32	96.44	51.38	11.65	9.01	24.81
Consumptive Scenerio			115.84	70.89	78.14	58.22	106.12	106.84	51.98	35.95	27.02	113.56	60.49	12.95	9.95	27.42
		1 in 200 year	107.11	67.02	69.4	54.34	100.42	101.83	49.50	33.36	25.7	105.00	37.72	12.3	9.5	26.12
Sustainable Scenario			96.40	60.18	58.94	48.47	89.07	90.32	44.55	28.26	22.97	87.89	31.57	11.01	8.53	23.51
Conventional Scenario			101.76	63.60	64.18	51.40	94.75	96.08	47.03	30.81	24.32	96.44	34.65	11.65	9.01	24.81
Consumptive Scenerio			112.47	70.44	73.63	56.79	105.31	106.78	51.98	35.92	27.02	113.56	40.79	12.95	9.95	27.42
		1 in 500 year	101.86	64.15	39.7	51.70	99.74	101.77	49.50	33.22	25.7	105.00	10.40	12.3	9.4	26.12
Sustainable Scenario			91.67	57.60	33.70	46.12	88.47	90.27	44.55	28.14	22.97	87.89	8.70	11.01	8.44	23.51
Conventional Scenario			96.77	60.87	36.69	48.91	94.10	96.02	47.03	30.68	24.32	96.44	9.55	11.65	8.91	24.81
Consumptive Scenerio			106.95	67.42	42.09	54.03	104.59	106.72	51.98	35.76	27.02	113.56	11.24	12.95	9.85	27.42
	ADO	1 in 2 year				57.99	93.33	96.70	37.05							
Sustainable Scenario						51.73	82.78	85.77	33.34							
Conventional Scenario						54.86	88.06	91.24	35.19							
Consumptive Scenerio						60.60	97.87	101.40	38.90							
		1 in 20 year				53.90	93.00	96.56	37.05							
Sustainable Scenario						48.08	82.49	85.65	33.34							
Conventional Scenario						50.99	87.75	91.11	35.19							
Consumptive Scenerio						56.33	97.53	101.26	38.90							
		1 in 100 year				49.45	89.90	91.58	23.96							
Sustainable Scenario						44.11	79.74	81.23	21.57							
Conventional Scenario						46.78	84.82	86.41	22.76							
Consumptive Scenerio						51.68	94.27	96.04	25.16							
		1 in 200 year				49.15	88.78	84.68	21.41							
Sustainable Scenario						43.84	78.75	75.11	19.27							
Conventional Scenario						46.50	83.77	79.90	20.34							
Consumptive Scenerio						51.37	93.10	88.80	22.48							
		1 in 500 year				47.87	87.98	79.68	19.50							
Sustainable Scenario						42.70	78.04	70.68	17.55							
Conventional Scenario						45.28	83.01	75.18	18.53							
Consumptive Scenerio						50.02	92.26	83.56	20.48							