A10: Long term drinking water plans

WONDERFUL ON TAP

Appendix 10: long term drinking water plans

Copy of a statement submission to the Drinking Water Inspectorate

September 2018

In this appendix we've redacted information that relates to the location of some of our water sites.

WONDERFUL ON TAP

This statement is in response to the long term planning guidance and provides assurance that our risk assessments include a long term view, highlighting our consideration of any significant new future risk mitigation measures relating to the quality of drinking water supplies. It builds on the meetings we had in November 2017, and March/May 2018, where we shared our AMP7 plans (summary provided in the appendix).

1.0 Overview

We recognise that our performance on water quality in the recent past has not been acceptable and we have had too many events. We are totally committed to resolving this situation and over the last two years we have invested significantly in our assets, processes and our people. We are confident that the work we are currently doing will enable us to have strong water quality performance well in advance of the start of AMP7.

At the heart of our approach to assessing and managing risk are the Drinking Water Safety Plans (DWSPs). These coupled with a developing progressive long term asset strategy, and innovation, will underpin a sustainable performance in the long term.

For our DWSPs we consider the complete 'source to tap' water cycle and seek to understand how risks identified at each point can have implications for each subsequent stage. Ultimately the DWSP approach will be fully embedded throughout the business and identify risks in real time, and we aim to have the process accredited and externally assured.

Much of the thinking on this is either in place now or soon to be implemented and will then evolve over the next 25 to 40 years. For example:

- Catchment Management and partnership working where we aim to prevent pollution occurring rather than simply mitigating its effects. We are also alert to our groundwaters where 'travel times' for pollutants can be 50 years in some of the aquifers.
- Water Resource Management Plans (WRMP) are cognisant of both availability and quality where some options reviewed for meeting future demand will necessitate movement of water between currently assigned zones
- Water treatment works further improved using innovation to optimise operation and to respond immediately and automatically when upstream processes indicate variation from normal limits
- Strategic network is maintained, managed and optimised to ensure the excellent quality produced at WTWs is protected through to the customer network
- Customers protected by ensuring the water they receive is conditioned such that it does not pick up plumbing metals. This supplemented by education, intervention and regulation.

Alongside this, we are adopting holistic water cycle and system planning. This is throughout the water value chain and incorporates, for example, ensuring our wastewater assets are managed to continually enhance the quality of the receiving waters to reduce risk to raw water abstraction points and the environment generally. Also opportunities to maximize benefits for the customer by linking investment plans such as lead pipe replacement, metering and leakage.

We will utilize real time data to oversee and intervene before events occur and have a resilient and adaptive network that enables us to maintain a consistent quality of water through to our customers.

Our long term strategic asset planning will be alert to the challenges that may be expected in the coming decades. This will include phenomenon like the changing climate and the consequential changes to the natural environment and therefore water availability and quality, as well as regulatory changes where ever tighter standards are sought.

We will have a more proactive focus on asset deterioration (and this will support assessments in the DWSPs) and plan interventions before risks escalate. This is coupled with a strong attention to resilience such that alternative systems and supplies can be relied upon should primary supplies be compromised.

Over a period of 20 to 30 years we expect we will have some significant expenditure in replacing aging assets and most likely some reconfiguration of our water treatment works and strategic network system. As many WTWs get to an age where continual maintenance is no longer economic or appropriate for future quality challenges, we will plan strategic investment to replace them on a managed basis, whilst improving our resilience. This will be planned to avoid 'lumpy' expenditure that could adversely impact customer bills, although the strong likelihood is that the expenditure necessary over the period will be greater than currently invested.

Whilst our assets and the use of innovation and 'smart' systems will be essential to ensure water quality is constantly improving, it is our people that will continue to be key to our success. We have an ambition to have the most technically competent and expert organisation in the industry, our commitment to building a technical training academy will be a huge step towards this ambition.. Recognising the critical importance of science and engineering as the foundations of excellence in managing the water system will enable us to be at the forefront of industry thinking and best practice. We will aim to lead and support industry groups and be obsessive about water quality and have this founded on a collective culture, embodied by a 'food factory mentality'.

In combination, we believe this strategy will greatly avoid the number of events that occur that could cause a quality impact, and any that do happen will be limited and contained and not become incidents where control is lost.

2.0 Structure

The report sets out the physical and regulatory context against which we plan to meet all water quality challenges now and in the long term.

It discusses the overlapping business drivers such as water availability and resilience and refers to our approach to capital maintenance and how this is developing to underpin our determination to have a sustainable long term investment plan.

We include a matrix of the strategic assessment of the known risks and their potential impact on each asset category and how they may influence future plans, and describe approaches to specific parameters such as lead.

3.0 Context

3.1 Statutory requirements and policy ambition

We have assessed our position against the EU proposals for revising the Drinking Water Directive and we are supportive of the objective and ambition of the Directive to focus on health protection. However, some of the proposed changes go significantly further than purely health-based standards and would have major implications for investment over the next decade.

A change in lead standard from 10ug/l to 5 ug/l is supported in principle and our AMP7 approach will position us well to progress the aim for full compliance. However, ultimately it will need enabling legislation and public expenditure to underpin our drive to ultimately remove all lead from customers' taps. Our estimate is that it will cost ~£65m to replace our communication pipes in around 30 zones. This will also need customer support to replace their pipes to allow compliance with the standard.

A change in the chlorate standard poses significant risks at sites where OSEC or hypochlorite is used. A high level estimate is more than £20m to overcome chlorate resulting from the on-site chlorine generation we recently installed to strategically phase out the need for chlorine gas storage. This could lead to a potential change in direction back to chlorine gas with increased risks associated with security of supply and safety. This would be a major driver of investment to either comply with existing equipment or return to conventional chlorine disinfection methods.

A tighter turbidity standard would be challenging to achieve 100% compliance, for limited customer benefit, and would pose a significant risk to CRI and require investment at a number of WTWs.

There is a risk that a metaldehyde ban is not effectively enforced resulting in continued regulatory failures and any consequential requirement for treatment solutions would lead to totally unsustainable outcomes.

After leaving the EU, changes made to the agricultural payments system no longer incentivise behaviour to protect the environment which could lead to increased catchment risks. However, the Government’s 25 year Environment Plan aspires to address this risk and support sustainable farming practices.

3.2 Climate Change and Population Growth

Whilst uncertainties remain around the changing climate, it is highly likely to put increasing pressures on limited resources, both from an availability and quality perspective. Coupled with an increased population, we must plan to make even better use of the water available and our operational systems designed and operated to minimise waste and ensure quality.

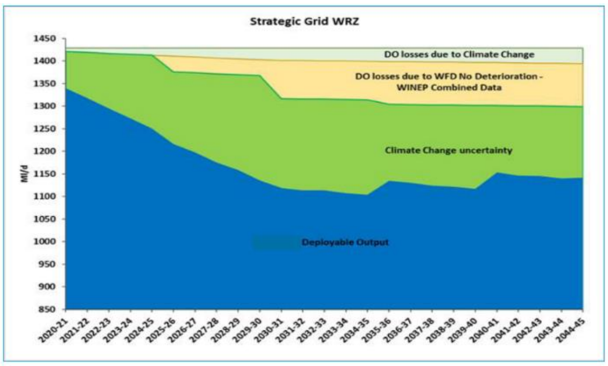
There is a risk we will be relying more heavily on sources with quality impacts; making our catchment approaches, for example, of critical importance.

Extreme weather events lead to rapidly deteriorating quality on our surface derived supplies and we need to ensure that we are resilient to such challenge, as well as the risk of inundation from flooding events.

3.3 Water Resource – supply demand

We have long term plans in place to accommodate the impacts of population growth, drought, our environmental obligations and climate change uncertainty in order to balance supply and demand. Through this we will ensure our product continues to be compliant and good to drink.

Our water resources modelling forecasts supply/demand balance over a 25 year period, using population forecasts and modelling of climate change, environmental impact of abstraction and raw water quality deterioration. We are faced with an unprecedented supply/demand shortfall of 164Ml/d in AMP7, growing to 320Ml/d by the end AMP8.



Our strategy is to use leakage, metering and demand management to reduce the total amount of water we need to put into supply. We will also increase our supply capability by investing in expanding our treatment and strategic distribution capacity and prioritising solutions that maximise use of existing water supply assets whilst improving our resilience.

Our draft Water Resources Management Plan (WRMP) considers scheme options at a high level and is the filter through which we assess which schemes should go forward for more detailed design.

These will be worked up in more detail for the final WRMP with more robust design, cost, benefit and environmental impact which will include drinking water quality risk assessment and mitigation. The feasibility and design of final solutions ensures that our customers’ drinking water quality is compliant and avoids changes in appearance, taste, odour and hardness.

Our WRMP is adaptable over the 25 years; if certain triggers are reached, we will be able to implement solutions that we have already designed and prepared for. We need to adapt to the uncertainty of climate change and refine our plan as evidence and projections are updated. We expect to publish our final WRMP in the autumn of 2018, and we are seeking investment as a special cost factor as part of our submission to Ofwat in September 2018.

4.0 Discussion

The following section covers the current and future approaches to the challenges of the natural environment, resilience and asset health.

4.1 Environment – changing raw water conditions

We consider current raw water quality constraints in our modelling of surface water and groundwater output, and we take a view of how they might change in the future. For surface water, where current raw water quality has the potential to effect the abstraction at a source, we have tested incorporating this into our model. The starting point for identifying groundwater sources at risk of deteriorating water quality are our Drinking Water Safety Plan (DWSP) risk assessments. We review 202 nitrate trends, 40 modelled nitrate trends, 68 non-nitrate trends and 36 water quality blends (nitrate and non-nitrate) to determine what impact, if any, the deteriorating water quality has on our ability to supply wholesome water in the future and on the source output over a 25 year period.

In our target headroom assessment, we make an allowance for the risk of gradual pollution, where worsening water quality will affect the ability of the source to maintain the current deployable output. Investigations include an assessment as to whether the cause of any water quality deterioration is anthropogenic in origin or inherent to the aquifer. We then determine if additional or new mitigation measures would be needed in the future, including catchment management investigations where appropriate and this gives us the ability to recognise and mitigate deterioration before it impacts on our customers.

Several blends and individual groundwater sources could be severely impacted by rising nitrate concentrations before 2045 and we have these covered in the AMP7 plans we have shared.

A key part of mitigating raw water deterioration is proactive management of the catchment. We shared our AMP6 and AMP7 catchment management programmes in November 2017, March/May 2018 meetings, and established our leading position in this area.

Catchment management represents an alternative to conventional, capital-intensive treatment solutions by focusing instead on working with land owners and other stakeholders to tackle problems at source, rather than just treating the symptoms. Our strategy is to, where possible, use catchment management incentivisation and advice to reduce the number of drinking water failures and minimise or delay future water treatment expenditure on raw water quality deterioration. To avoid the problem at source is clearly the right thing to do and this is further underpinned by our obligations under Article 7 of the Water Framework Directive (WFD) which states that as a water company:

- We should ensure there is no deterioration in the quality of water we abstract from the environment
- We should no longer put in new treatment processes to deal with anthropogenic causes
- In the long term we should reduce the amount of treatment necessary at each of our treatment works.

We are achieving this through working in collaboration with the Environment Agency (EA), Drinking Water Inspectorate (DWI) and OFWAT along with CaBA partnerships and other key stakeholders, and we fully support regulators in influencing the manufacturing and control of harmful agricultural products. All of this supports our catchment risk assessments and mitigation and ensures we deliver our obligations under the WFD, as well as reducing carbon usage.

Overall, we will have around 34 catchment schemes in AMP7 aimed at tackling pesticides, nitrate, colour and bacteriological risks over the next 5 to 25 years, to safeguard drinking water sources and to avoid the need for expensive treatment.

Catchment management schemes often have a significant ‘lead in’ phase, during which detailed management plans are drawn up and agreed with land owners and other stakeholders. Persuading farmers to change their behaviour and adopt new practices can also be challenging and time-consuming. It can take up to 18 months to establish a working relationship from scratch such that farmers are willing to work with the company to take action. Once measures are in place there is often a lag before positive responses are seen.

The shortest timescale for a positive response anticipated is 1 year, while the longest is in excess of 20 years, due to uncertainty over natural processes in the environment. In general, nitrate and colour trends in surface water and groundwater are the elements that will take the longest to improve following catchment management (on average, over 10 years). By contrast, pesticides, phosphates and peaks in nitrates in surface water are expected to take less time to respond to catchment management (on average, less than 5 years).

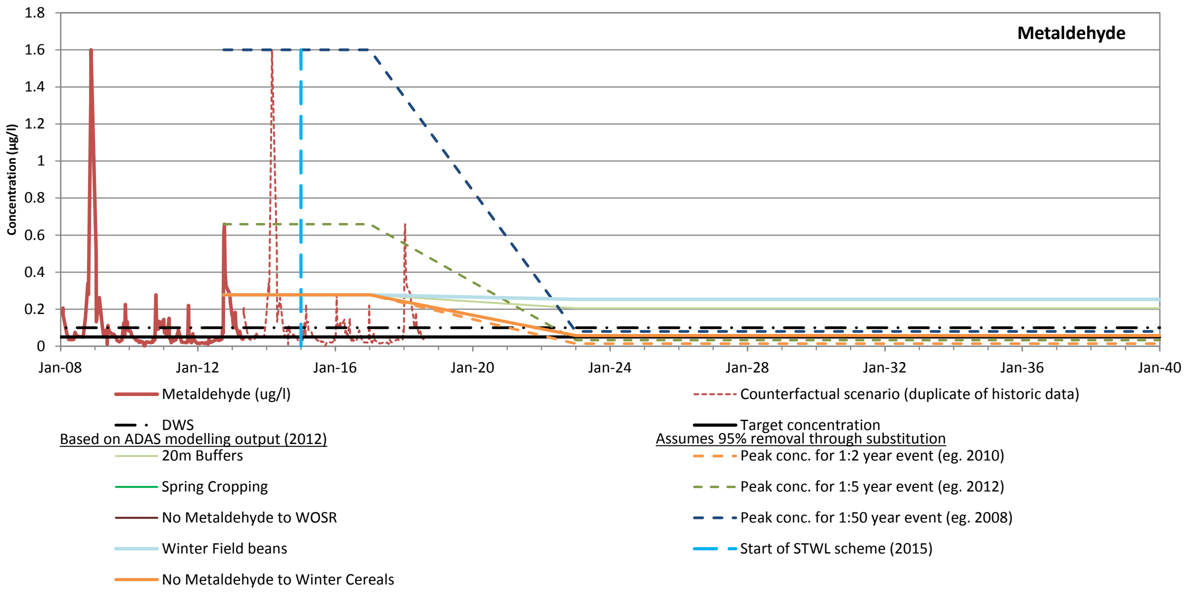


Figure 1. Conceptual plot of metaldehyde reductions as a result of catchment scheme

Due to the lag time between action on the ground and catchment response we are evaluating our catchment schemes using indicator metrics. This will enable our catchment schemes to be adaptive, identifying what is working well in practice (or not), and why, and refining our approach accordingly.

Sustaining our catchment outcomes is likely to require continuing effort over numerous AMPs. Within our catchment investigation work and cost benefit analysis we have considered the resource, time and risk to achieve desired outcomes. Following our extensive catchment investigations over the last two AMPs our catchment schemes have therefore been designed and costed as a 25 year programme of work. This is to ensure that:

- farming practices will not revert back to those prevailing prior to the scheme and as a consequence reverse any water quality improvements
- different land management, fertiliser and pesticide regimes can be proactively risk assessed when cropping patterns may be altered due to economic conditions over longer timescales.

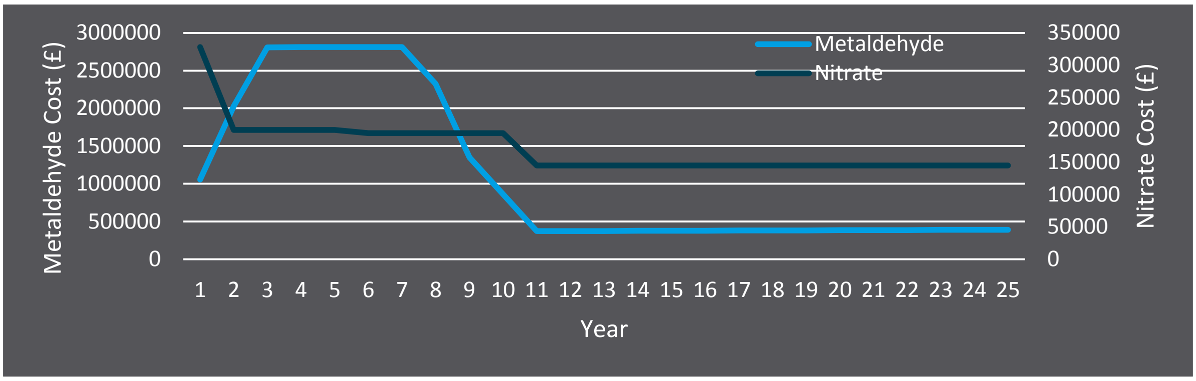


Figure 2. Example of 25 year cost profile for metaldehyde and nitrate catchment schemes

Successful implementation of our catchment schemes will mean avoiding the need for new conventional treatment solutions at 15 - 20 water treatment works. It is also considered that due to word of mouth between farmers and the implementation of farm management plans, benefits associated with good farm practice would extend to 40 years.

We are also adopting holistic systems thinking to ensure our catchment management strategy incorporates a range of synergistic opportunities such as flooding mitigation, wastewater discharge management and biodiversity enhancement.

4.2 Resilience – being prepared for future shocks

We have developed a good understanding of the risks to service at a system level since AMP5 and through delivering our AMP6 Birmingham Resilience scheme. Our approach enables us to improve our understanding of the wide range of shocks and stresses that could prevent us from providing the services our customers expect now and in the future. It improves our ability to predict how these may change over time so we can identify the most cost beneficial way of responding.

A schematic of our approach to resilience and asset health is included as appendix 1.

We have identified some assets that are so intrinsic to our ability to respond to significant events that the most cost beneficial solution is to enhance those assets.

Our Strategic Grid includes such critical assets; an integrated system of aqueducts, pipelines, reservoirs, resources, water treatment works and control systems spanning the length from Derbyshire in the north, down the eastern side of our region and across into Gloucestershire in the south. We are planning significant investment on our grid in AMP7/8 to strengthen further its resilience.

Our plans for the Strategic Grid are described in appendix 2.

We have reflected the Cabinet Office's four components of resilience (resistance, reliability, redundancy, and response and recovery) in our planning. We are also considering how we can achieve dual benefits through the schemes we are considering for our water resource management plan and the resilience benefits they may bring. This includes how we can integrate grid enhancements to improve operational flexibility while also meeting the future supply/demand balance challenge.

4.3 Protecting our production assets from extreme flooding

In early 2016 following a series of significant flood events around the country (Carlisle being a precipitative event) the UK Government initiated the National Flood Resilience Review (NFRR) to look at the UK's ability to maintain essential services during extreme flooding and extreme weather events. As part of the NFRR work we have re-assessed our vulnerability at all of our sites and assets against the Environment Agency (EA) Extreme Flood Outline Maps that are based on up to 1 in 1000 year events. We can foresee the impact loss of service from flooding can have and the risk across our entire asset base. We have considered potential solutions and developed a cost estimate for a programme of work for AMP7 and beyond for flood protection against a 1 in 1000 year event, prioritised based on site/asset level criticality. We have collaborated with our stakeholders (including city and district councils, flood & coastal committee, EA, National Flood Forum, Cabinet Office, Defra) to commence partnership approaches to this resilience challenge. There are a number of examples where we have installed flood protection schemes, for example on groundwaters, and learned from previous events such as at Mythe WTWs.

4.4 Water treatment works flexibility

In 25 years' time we want to be operating water treatment works that have full flexibility to respond if there's an issue with our upstream processes. We will get supplies back on quicker in the event of a problem whilst ensuring the product that our customers receive is not compromised in any way.

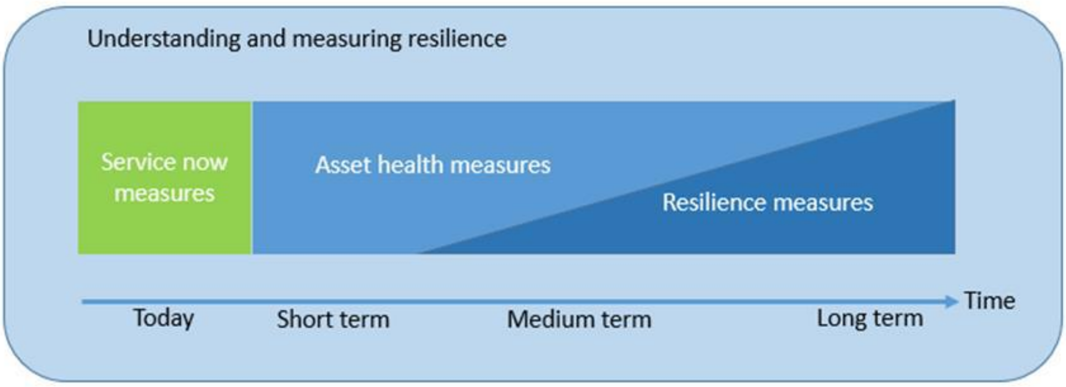
Our AMP7 plan shows how we are setting out to review and re-design run-to-waste/flow diversion capability across all of our water production sites. We will be addressing those that are most critical to supply by 2025 so we will have significantly fewer events. The review will inform our longer term plan for the rest of the asset base.

At PR14 we committed to providing shut-down capability at Frankley WTW in AMP6 as part of Birmingham Resilience scheme, and at Bamford in AMP7, which we shall include in our resilience plan. We'll continue to look at intra-stage works capability in conjunction with fail-safes and operational procedures, and this will inform our longer term plan and prioritisation.

4.5 Asset Health – ensuring our assets are operated and maintained effectively for the long term

Given the long life nature of our assets, a major component of our risk assessment is asset health. We use this term to describe the overall understanding of the performance and condition of our assets and systems, and we have developed a basket of measures and targets to support this being visible.

This chart shows the conceptual interaction between asset health and resilience.



Our current measures provide a solid basis for understanding asset health and support us to:

- Predict and avoid future service failures
- Target investment (and resources) on the most critical assets, which would result in more effective risk management;
- Improve the robustness and efficiency in our long term plan by identifying interventions based on high quality data and rooted in a robust assessment of the long-term capability of our asset base; and
- Deliver cost efficiency

A description of some of the tools we use is included as appendix 3.

We'll be continuing our systematic approach that we set out on at PR14 using DWSP "Effectiveness of Control" assessment to drive maintenance on key treatment processes and assets.

It is likely that we will have a number of major investments over the next 25 years to replace old assets and enable them to meet the increasing challenges facing them from a drinking water quality perspective.

The following provides a summary of our capital maintenance approach for key asset types:

Asset base	25 year view
Groundwater	In AMP6 we stepped up our borehole monitoring and surveys e.g. cctv (following UKWIR best practice) to ensure we check a 1/3 of our asset base per AMP, and we are continuing this commitment to grow our asset data. We plan to continue with the approach we set out at PR14 to deliver a 25 year programme of structural improvements to manage the risk of permanently losing some of our older and more critical borehole sources; maintaining an average age of c50 years vs. generic asset life of 80. Major borehole projects take typically 5-10 years and require specialist contractors.
Surface water treatment	We are continuing what we set out at PR14; using DWSP "Effectiveness of Control" methodology, as a measure of Asset Health, and Water Resource criticality to target and prioritise modelled capital investment within a 5 year period. We have had great success this AMP with our Rapid Gravity Filter and Coagulation & Clarification refurbishment programmes. We can now focus more on processes further downstream such as disinfection control, sludge/wastewater, tanks, chemical dosing and pumps. Each AMP we review the effectiveness of our processes, and will target investment appropriately.
Water Storage	We have one of the largest asset bases of DSRs in the industry with 542 sites and 810 cells. We have stepped up our enabling and remedial works investment significantly to improve our inspection frequency and to recover our DSR coliform performance. We plan to continue this level of investment into AMP7 as well as planning to continue a refurbish/rebuild programme. For longer term planning we are commissioning civils asset deterioration modelling with OXAND - which draws on global best practice from other industries including nuclear, to improve our ability to predict the remaining asset life of our concrete and masonry DSRs. We are also using flow cytometry to understand impending risks and target inspections and testing.
Trunk mains	Integral to both our short and long term planning is the development of our Dynamic Trunk Main Risk Model, which will improve our understanding of holistic risk and cost beneficial investment opportunities. The delivery of our future Strategic Grid Resilience work will be a significant maintenance enabler for trunk mains over next 25 years as it will allow us to resolve some of the highest discolouration/water quality risk elements of our system, allowing them to operate in a resilience scenario reducing the risk of discolouration, poor pressure or long duration supply interruptions. In AMP7 we are looking to use innovative dynamic flow control valves to allow flow conditioning at key trunk mains in our Central/Birmingham area which accounts for almost 40% of our discoloration complaints. This will be our main focus for discoloration along with optimising WTWs for iron and manganese removal and DMA flushing,
Distribution mains	Unlined Cast Iron Mains: In AMP6 we have doubled our original PR14 programme investment in relining/replacing these and this has played a major role in solving a number of long standing water quality issues and delivered secondary benefits for leakage and burst reduction. We plan to continue this approach in AMP7 targeting those areas which pose the highest risk to drinking water quality. Epoxy lined mains: less than 2% of our mains network is resin lined; a limited number and these are aging well and are not generating issues currently for our customers. We will continue to monitor the performance of these linings and only intervene if we start to see a degradation in performance. Going forward, whilst we will maintain lining as an approach to resolving water quality issues generated from cast iron mains which are still structurally sound, we will monitor the products on the market to ensure robust supply and a quality product prior to using linings as a solution. Renewal will be the chosen technique if we are unable to guarantee the quality and supply of the lining products.

4.6 Building a Resilient Workforce for the future

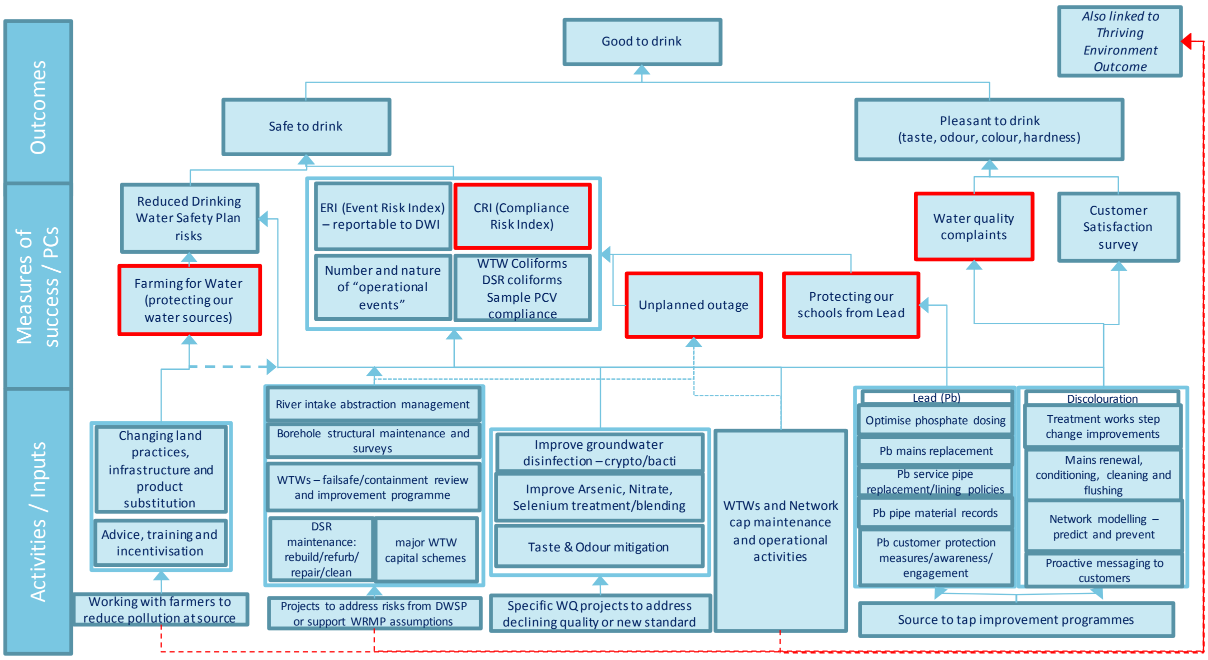
In 25 years' time our network will continue to be run by a competent motivated workforce, who will have skills and knowledge to enable them to get things done right first time, the confidence in the decisions they make and actions they take, and can adapt to the emerging challenges that will shape their work.

To achieve this, we need to retain highly skilled and experienced people. Like many other organisations, we have an ageing workforce, and in our operational teams we will feel the effect of this in the coming years. The lead time for building new capability here is significant and we are investing heavily in creating new apprenticeships and finding new ways to develop and attract skills so we are prepared for the future.

Appendix 4 describes some of the things we are doing.

5 Good to Drink

We have included here a schematic of our AMP7 plan for "Good to Drink", which encapsulates how the various components fit together.



5.1 Lead – looking for a holistic approach with multiple benefits

In 25 years' time we will know where all lead pipes are, both ours and those that are privately owned. Society will be better prepared for this multi-sector challenge, and we will be prepared for Supply Pipe Ownership, if that becomes a reality. To get there, we will need to improve asset data records on communication and supply pipe material and location. We have started to do this and have created GIS based risk mapping which uses data gathered when we have replaced/separated common supply pipes, also using housing age, postcodes and water quality failures. This provides broad areas where lead is most likely to be so we can target investment and communications.

Over the next three AMP periods, as part of our WRMP, we will be installing boundary boxes and meters at all properties. This will be an important opportunity to record and map where lead pipes are, and we will be designing this data capture into our enhanced metering strategy.

We will look at any opportunities and innovation for lead pipe replacement while we install meters. This synergy is currently limited as meter/boundary box installations do not require the costly and disruptive traffic management practices that lead pipe replacement schemes do. We will be looking for innovative ways to overcome this cost and practicality challenge to leverage the multiple benefits of metering, leakage and lead pipe replacement.

By 2045 we will have already replaced a significant proportion of our lead pipes, having protected all of our highest risk/vulnerable customers, and have created some carefully managed zones where we don't need to dose costly phosphate for controlling plumbosolvency. This will be informed by the learning from the Welsh part of our business where we are identifying a long term plan for enabling removal of phosphate dosing, as part of working towards a lead free Wales.

Our plan in AMP7 to target schools for lead pipe replacement will help to inform the practicalities of large scale pipe replacement programmes.

We are currently improving our understanding for prioritising pipe replacement that would enable phosphate dosing to be withdrawn. Plemstall WTW in England and Pendinas WTW in Wales have the potential for trialling this approach, as they both supply a population less than 7,000.

The trial will:

- Identify location of lead pipes to allow a cost estimate for replacement or lining
- Investigate the general corrosion inhibition benefits from the phosphate dosing to understand if alternative treatments would be required
- Understand the implications to water supply resilience if phosphate dosing ceased in target areas

These outputs could then inform the cost/risk decision on whether an alternative to phosphate dosing could be deployed in these areas.

6.0 Long term impacts and priorities

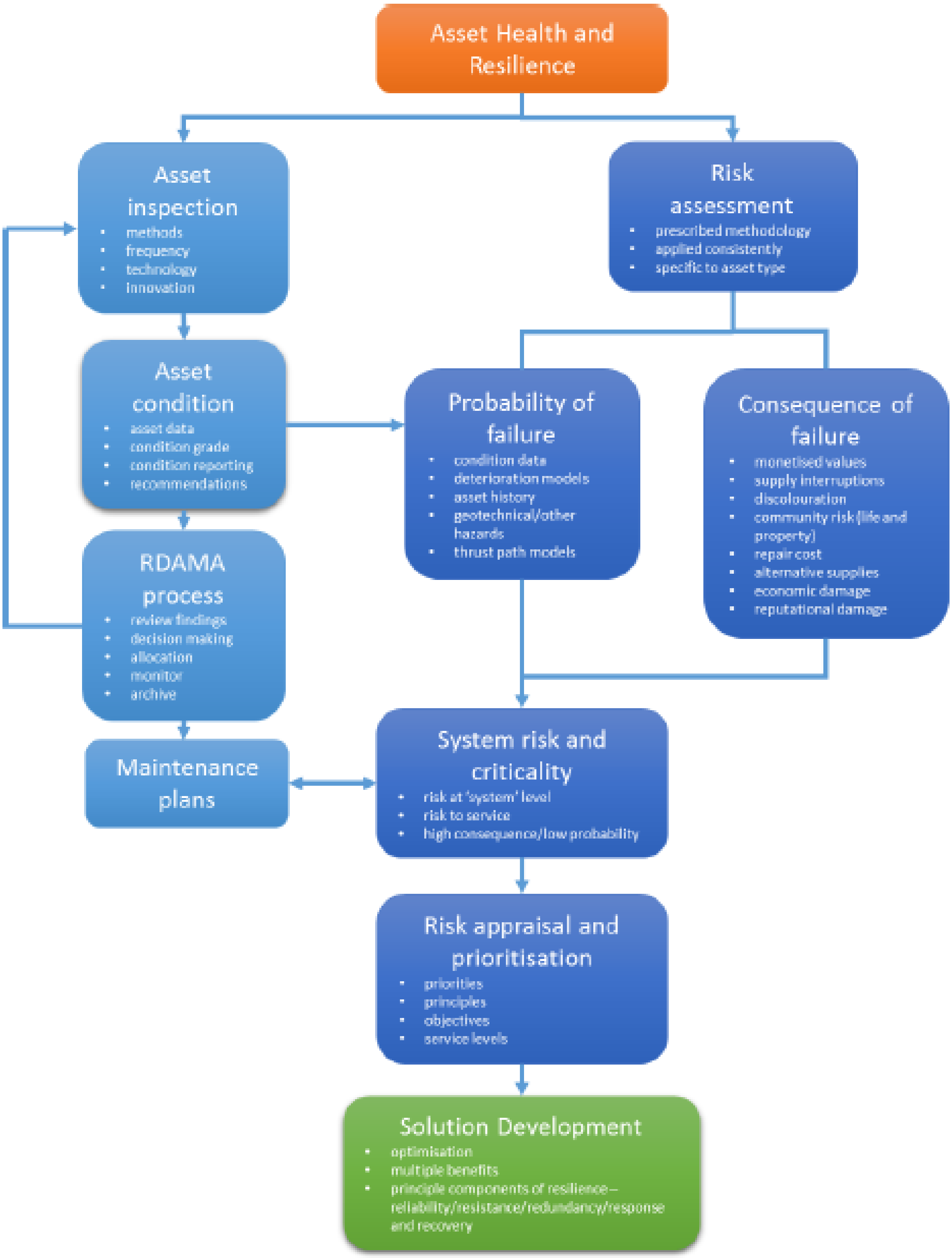
We have made an assessment of the main drivers facing the industry over the coming decades and their potential impacts on various asset categories.

This assessment is included as appendix 5.

Whilst there is a fair degree of subjectivity in the assessments, we consider this will be a useful tool to help us shape our long term plans and to prioritise those areas where we will gather more information to develop appropriate strategies.

Appendix 1

Approach to Asset Health and Resilience



Appendix 2

Resilience for our Strategic Grid

i) Strategic sections of assets - tunnel and conduit sections

We have assessed these assets in terms of likelihood and consequence of failure and they are complex in their operation and unique in their construction. They present a single point of failure, as well as providing REDACTED. Given the strategic role of these assets, solutions to reduce risk are complicated and require an holistic system view due to the many interactions with our operating network. The inability to isolate the sections means we are unable to carry out any detailed physical inspections and condition assessments or carry out any remedial maintenance works should they be required. Our investment plans aim to change this to provide more flexibility and which will have benefits for both a resilient water supply and drinking water quality.

ii) Large surface water treatment works

We completed a study in June 2016 to improve our understanding of the capability, capacity and constraints of the Strategic Grid and other assets for then and at the end of AMP6. This involved stress testing our water treatment works' production capability under a range of scenarios.

The outputs from our model identified REDACTED water treatment works as carrying the greatest risk in terms of consequence of failure and the number of customers impacted.

We also carried out a 'structured what if technique' (SWIFT) analysis on our major water treatment works which are at risk of causing a future supply deficit. The technique analysed process type operations and gave us a greater understanding of the level of risk in the event of a catastrophic failure. This analysis has:

- confirmed the plausible failure modes – i.e. the events that could result in a water treatment works outage
- confirmed the operational mitigation that is available to limit the consequence and impact of a failure event;
- confirmed the duration of an outage for each failure event; and
- estimated the likelihood / probability of each failure event.

The analysis considered the entire end-to-end treatment process from river intake/raw water reservoir storage through to treatment and final water treatment works' output. The outputs of the study have helped us to prioritise long term investment options and informed the type and scale of resilience solutions recommended for a given level of risk. The solutions identified for our highest risk works include dual streaming (removal of single points of failure) at REDACTED and REDACTED; and connections between REDACTED to deploy spare capacity. We are fostering closer links with South Staffordshire water on REDACTED and recognise we need to share innovation/ideas to improve drinking water quality in general.

iii) Network assets

We have undertaken a review of our network assets to understand the likelihood and impact of failure, including detailed mass flow balance analysis using Aquator modelling. Our investigation has assessed the condition and status of all assets that would need to be operated under a 'resilience scenario' across our network e.g. in the event of a failure at a major water treatment works.

The study outputs showed that significant flow direction and rate changes would be required across our network in order to deploy our existing second source capability. Multiple water treatment works would also need to increase production to replace the deficit in the event of failure of a customer's primary source of treated water.

We have identified solutions setting out the extent of investment required to improve the performance of these network assets in a resilience scenario - to improve our capability of moving water around to maintain supply in the event of a larger treatment works failing and to reduce the risk of discoloured supplies for 1,346,990 customers.

In summary, for the strategic grid as a whole, we have identified a range of options / costs (£85m to 120m) that include solutions for dual streaming of WTWs, removal of single points of failures, new mains (connections), imports, new water treatment works and grid solutions; all of which reduce risk of water quality/discoloration.

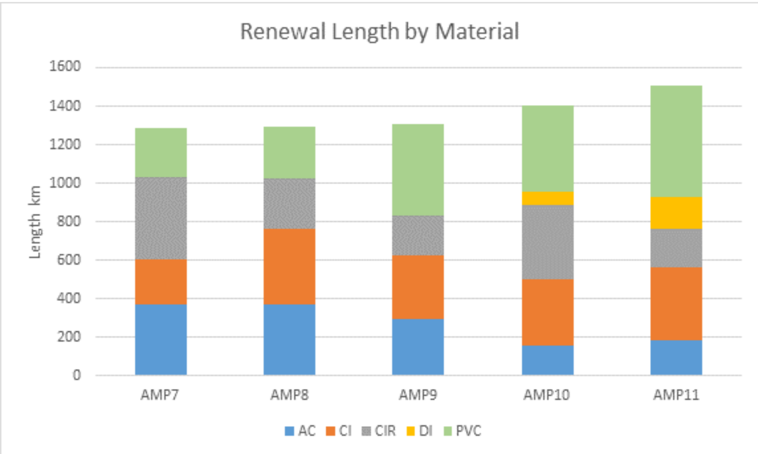
Appendix 3

Approaches to Asset Health

We have mature systems that enable us to combine asset health with other information such as failure history and age to assess the likelihood of an asset failing.   We combine it with consequence of failure to give us an understanding of risk over time, and use it to ensure we are delivering services to our customers at a broadly stable level of risk, thereby meeting our long term obligations and licence conditions. These are our suite of asset modelling tools that we have been developing for several AMPs, and they give us the longer term view of asset health and interventions required. They predict interventions to give strategic levels of investment to maximise asset life and ensure we have optimal and appropriate investment levels over multiple AMP periods. We have developed two approaches: one for below ground (infrastructure) assets and service, and one for above ground (non-infrastructure) assets.

Infrastructure asset models
Our 'infra' models determine the deterioration rate of our pipes by calculating the relationship between pipe attributes and failure. The attributes include pipe material, age, and soil characteristics. We combine these asset/system attributes with historical failure data. For water assets this includes bursts, interruptions, leakage, supply demand balance, pressure and discolouration. The models create cohorts of similarly behaving pipes to then calculate the least cost intervention plan for delivering the specified service levels.

This graph shows the forecast renewal lengths by material:

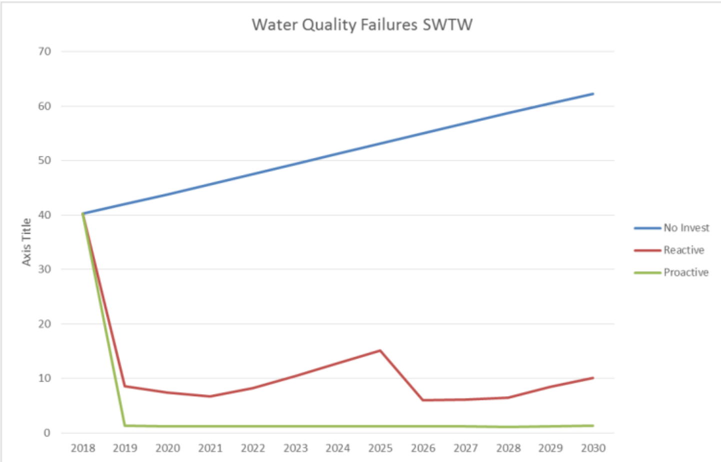


Non Infrastructure asset models
Our non-infrastructure models look at mechanical and electrical equipment, and are predominantly planning tools used to understand the overall investment needed to maintain broadly stable risk. They are 'strategic' models and not typically intended to be used to target specific interventions. The modelling approach is most suited to high volume data (i.e. such as infra model, where we have a lot of similar assets that have frequent and regular observations about their performance).   Our non-infrastructure asset stock is diverse, generally has more inbuilt redundancy which means we have less service failure data. The basic premise of the model is:

Risk = The probability of asset failure **X** probability of that asset failure causing a service failure **X** consequence of that service failure

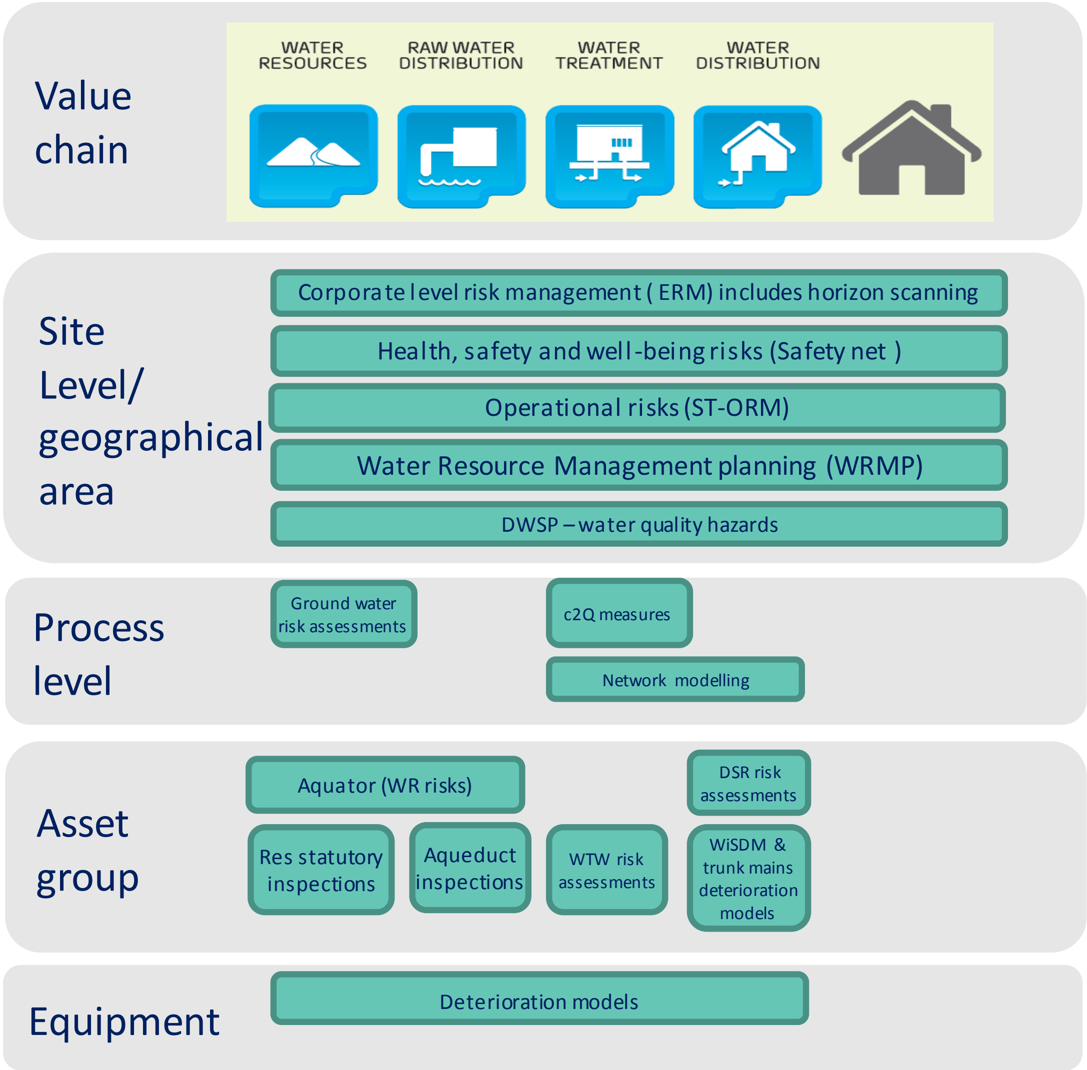
The modelled approach has the following key steps

- We input historical data (e.g. age, maintenance frequency) into an asset deterioration model for a particular asset type to determine when they are predicted to fail.
- We then assess the probability and consequence of that failure for each asset at different locations, taking into account the designed redundancy and standby capacity available. Quantified costs of service failures are used for this calculation.
- We consider how individual assets perform using performance data (e.g. interruption events, water quality sample failures, DWSPs, opex costs and reactive jobs).
- We generate options for interventions (do nothing, allow to run to fail, reactive replacement, planned replacement).
- We then run the models to generate the lowest whole life cost options over 25 years.



The complexity of the non infra asset base and interaction/interdependency of interventions means that a simple relationship between individual asset health metrics and changes in specific levels of service that customers experience (and cost of delivery) does not exist. We recognise this and take a more holistic approach by tracking asset health, service delivery to customers and expenditure through the AMPs. As part of the longer term planning cycle, we review the risk exposure in each major asset group and develop intervention plans required to maintain a stable level of risk.

To target and prioritise the model outputs and to help us create 5 year delivery plans we utilise our key risk assessment tools that we have across the business:



Delivering Capital Maintenance

Our investment prioritisation approach has evolved over AMP6 to ensure we have a flexible approach to balancing investment needed to deliver against our Performance Commitments and investment needed to deliver our wider obligations and long term strategy.

Over the next 25 years, we will have benefitted from a risk-based and adaptive maintenance programme to drive up compliance, ensuring that our network and assets are effective, reliable and efficient. Due to the large and complex asset base we have, and the size of our capital maintenance programme, we will be able to adapt and reprioritise for asset health needs as they arise through the AMP periods. We have proved in AMP6 that we can do this by being able to allocate additional investment into areas such as DSR remedial works. We'll be continuously improving and growing our corporate systems and data so we can do this better; we will know the risks we are carrying and we have tools and strategies to manage them.

Appendix 4

Building a resilient workforce

There are a number things we are doing now to be prepared for the challenges in the labour market:

- we provide a wide variety of apprenticeships at different levels and in different disciplines
- we’ve rejuvenated our graduate entry schemes in recent years and now have 4 schemes on offer across our graduate programme – Business Leadership, Engineering, Digital/IS (Information Systems) and Finance.
- we have opened up entry to our apprenticeships and graduate schemes to all employees to provide growth opportunities to our existing workforce
- all our trainees go into real roles within the business and have hands-on experience across a wide variety of disciplines.
- engineering graduates can pursue Chartered status, whilst financial graduates will study for professional accounting qualifications. Our advanced apprentices are able to gain NVQ qualifications.
- our Water Process Technical Trailblazer programme was shortlisted for the Water Industry Achievements Award of ‘people initiative of the year’ and we are also proud to have been listed within the Top 100 apprentice employers
- this year, we have also announced our intention to build an Academy – a centre of technical excellence that will support high quality education in areas of core competency and ensure we have the skills in place for now and the future
- we are forming strong relationships with regional universities to develop a pipeline of graduates and post-graduates with the technical skills to match our operational needs for now and the future.

We know that this is working because:

- over the last 2 years we’ve retained 97% of our apprentices, and 93% of our graduates.
- with regard to upskilling our existing workforce, training modules have seen higher pass marks and their attendance levels have almost doubled.
- our new operational training program won the People Initiative of the Year at the Water Industry Achievement Awards in May 2017.
- having excellent apprenticeships and graduate schemes help affirm that Severn Trent is at the forefront of innovation. We want to do our best to raise awareness of the water industry as a whole and proactively take action to address areas of skills shortages in our region and our sector.

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Appendix 5

Matrix of investment drivers and our assessment of the relative impacts on various asset categories.

Asset category - in investment plans

Driver	Catchment		GW Boreholes		Raw water abstraction and WTW pumping		Water Treatment Works GW		Water Treatment Works Surface		Strategic Network (WTWs to DSRs)		Distribution Service Reservoirs		Distribution Pumping		Customer Network		ICA&Telemetry - source to tap		Our People	
	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050	2025	2050
Customer expectations	3	2	3	2	3	2	4	3	4	3	2	3	2	2	1	1	4	2	2	1	3	3
Asset Condition	3	2	3	2	3	3	4	3	4	3	2	4	4	3	2	1	3	4	2	4	3	3
Population Growth / Demand	2	3	3	2	3	3	2	2	3	3	4	2	1	1	1	1	2	2	2	3	3	3
Climate Change / extreme weather	2	3	3	3	3	3	3	2	3	3	4	2	1	1	1	1	3	3	2	3	3	3
Pollution (historic lag & future)	3	2	1	1	2	2	4	2	2	2	2	1	1	1	1	1	2	1	2	2	3	3
Environmental obligations e.g. WFD	3	2	4	3	3	2	2	2	3	1	2	2	1	1	1	1	2	1	2	2	3	3
Security inc. Defra's PSG 2020 & EU NIS directive	2	3	3	2	2	2	3	2	4	2	4	2	4	2	2	2	2	1	4	3	3	3
DWQ Regs: EU DWD Chlorate	1	1	1	1	1	1	4	3	4	3	1	1	2	2	1	1	4	3	2	1	1	1
DWQ Regs: EU DWD Lead	1	1	1	1	1	1	4	2	2	2	1	1	1	1	1	1	4	4	2	1	2	1
DWQ Regs: EU DWD Turbidity	2	1	3	2	2	2	3	2	3	2	1	1	1	1	1	1	2	1	3	1	2	1
Technology	2	4	2	3	2	2	3	2	2	4	2	3	3	3	2	2	3	3	3	3	4	3
People skills/availability	3	2	4	2	2	2	3	2	3	3	3	2	3	2	2	2	3	2	3	4	3	2

1 = low influence; 4 = v high influence By influence I mean what I can see in the Reg Plan constraints and what I think the delivery plan will be in AMP7 i.e. what we will have to do in later AMPS

nb.no drivers have a "very low" influence on investment

low	med	high	v high
1	2	3	4
green	yellow	amber	red

Assessment for current period through to 2025, and also for period from 2025 to 2050.

NB. Dams & Imp Reservoirs not considered yet

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