Appendix:
Resilience: Clean water

YKY-PR24-DDR-37-CE-Resilience-clean-water-appendix

YorkshireWater

Contents

1. Enhancement Case: Resilience (clean water)

1.1 Introduction

This appendix sets out the case for £12.7m of investment to build resilience to climate-related risks across our clean water asset base, specifically focusing on enhancing resilience to power outages and the increasing impact due to climate induced storm events and decarbonisation of the grid. We also set out a case for investment in a specific water supply resilience priority. This case has been created in response to the enhancement uplift (based on 0.7% of base allowances) allowed by Ofwat in the draft determination for companies to prioritise their biggest climate related risks. Due to the time available to create this case, we have used best available data, and we have highlighted the robust governance that will be put in place to ensure best value solutions are delivered.

For the purposes of this submission, a power disturbance/outage constitutes either short and/or long-duration disruptions (including a significant voltage dip) on one or more electrical phases to the normal sinusoidal current and voltage waveforms measured at the incoming power supply to a treatment or pumping asset.

A summary of the key points is set out below:

- The majority of our proposal is based on improving the resilience of our sites against both short and long duration power disturbances caused as a result of climate change.
- Due to the nature of our business, our dependency on grid electricity exposes us to risks of power outages, which are beyond our management control.
- The power supply resilience risks we wish to protect the assets against are attributed not only to the direct impacts of extreme weather events (e.g. high wind, flooding and higher temperature) but also to the secondary effects resulting from an increased reliance on electrical distribution systems by society to enable technology to be introduced to off-set the effects of global warming via reduced CO_2 emissions.

Climate change is already impacting Yorkshire and further impacts are expected in future. In particular, climate-induced severe weather and the transition to a decarbonised energy system poses risks to the stability of future power supplies.

To resolve power supply resilience resulting from climate related risks, a number of schemes have been proposed to provide more resilience in the event of an unplanned power outage e.g. due to a storm. These include installing:

- Enhanced power outage reset systems capable of detecting and responding to millisecond power events.
- Uninterruptible Power Supply (UPS) equipment to insulate key assets against short duration outages.
- Enhanced, high integrity ICA systems that are more immune to short duration outages.
- Short-term power disturbance/outage resilience equipment (usually called voltage correction or conditioning units) to allow sites to automatically reset themselves to allow an automatic restart.

Our proposal also comprises of a scheme to enhance the resilience of the Worth Valley area of West Yorkshire (within Keighley Water Supply System (WSS)). This area was identified as the highest risk area as a result of the drought in 2022, where emergency measures via an overland pipeline were put in place to temporarily transfer raw water from the Walshaw Dean Upper reservoir, over the moors, to Ponden reservoir in the Worth Valley. A distance of approximately 2.1km of overland pipework. Based upon this event, a permanent solution is required to connect Keighley WSS with another treated water system, to allow more flexibility within the network due to the risks of climate change impacting raw water availability and long-term power outages at Sladen Valley and Oldfield WTW.

Our proposal comprises £3.8m capex to lay a new water main from Thornton Moor SRE to Haworth to enhance climate change resilience and £8.9m totex for priority investment schemes to improve power resilience at our higher-risk sites.

The reliability and quality of our services is essential to the people, economy and environment of Yorkshire. We have invested to create a resilient business, successfully maintaining services through many extreme events over recent years, as well as responding to long-term trends. However, there are always limits to levels of resilience, particularly given the growing climate-related risks facing our business.

Ofwat expects us to incorporate some aspects of climate change into base allowances, but it has also retained a resilience category under enhancement. This is for additional investment to manage increasing risks, or changing acceptance/acceptability of risk, from hazards that are beyond our control. It is for investment not covered by other enhancement areas.

In its draft determination, Ofwat proposed a sector wide enhancement uplift (based on 0.7% of base allowances) for companies to prioritise their biggest climate related risks. This document sets out what we will deliver for the additional funding to build resilience across our clean asset base to climate-related risk as part of our response to the draft determination, with a particular focus on addressing additional power resilience risks posed by climate change.

Our proposals meet Ofwat's criteria for resilience funding and are not covered by other enhancement areas.

1.2 Drivers: Resilience

Requested Investment

Table 1.1: AMP8 Expenditure

	BP submission (£m)	Ofwat DD (£m)	DDR (£m)	Variance (£m)
Enhancement Expenditure Capex	0	10.8	10.8	0
Enhancement Expenditure Opex	0	1.9	1.9	0
Total	**0**	12.7	12.7	0

Associated Reporting lines in Data Table

Table 1.2: Reporting Lines

Line Number	Line Description
CW3.118	Resilience; enhancement water capex
CW3.119	Resilience; enhancement water opex
CW3.120	Resilience; enhancement water totex

1.3 High level driver description:

The reliability and quality of our services is essential to the people, economy and environment of Yorkshire. We have invested to create a resilient business, successfully maintaining services through many extreme events over recent years as well as responding to long term trends. However, there are always limits to levels of resilience, particularly given the growing climate-related risks facing our business and the wider region.

Ofwat expects us to incorporate some aspects of climate change into base allowances, but it has also retained a resilience category under enhancement. This is for additional investment to manage increasing risks, or changing acceptance/acceptability of risk, from hazards that are beyond our control. It is for investment not covered by other enhancement areas.

In its draft determination, Ofwat proposed a sector wide enhancement uplift (based on 0.7% of base allowances) for companies to prioritise their biggest climate related risks.

Yorkshire Water support this aspect of the draft determination and this document sets out what we will deliver for the additional funding to build resilience across our water assets to climate-related risk as part of our response to the draft determination, with a particular focus on addressing power resilience requirements from climate change.

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1.4 Need for investment

1.4.1 The Need for the Proposed Investment

Customers highlight resilience as a top priority, with the most important issue being able to receive reliable, uninterrupted services. However, our resilience is particularly stretched when hazards beyond our control impact on our activities, and risks to resilience are increasing in the face of climate change.

We are already seeing the impact of climate change on our natural environment, which in turn affects our customers, the communities we serve, and the way we operate our business. As well as the physical risks posed by climate change, we also face a number of risks related to the process of transitioning away from reliance on fossil fuels and toward a low-carbon economy. In particular, increasing demand for electricity and volatility in renewable energy generation and loads places strain on electricity transmission systems and increases the risk of unexpected outages (ref).

Our primary driver within this document is power supply resilience as a result of the impacts of climate change.

The likely outcome of forthcoming climate change will lead to excessive weather events (higher temperatures, winds, floods) and the higher global temperatures will lead to ice melt and rising sea levels. Whilst these events will have an impact on the power supply resilience and lead to power disturbances for the source of the supply to our sites, it is by no means the only power supply disturbance/outage impact that is driven by climate change. The global aims driven by the United Nations and ratified by the Paris Agreement to reduce global CO_2 emission to 45% in 2030 and reach net zero by 2050 has meant a shift to more sustainable energy sources being used, and this has also had an impact.

The drive to reduce CO_2 emissions in the UK has placed significant pressures on the electrical infrastructure, both by moving away from large scale fossil fuel power generating plants to many small scale distributed renewable energy plants, and by moving from fossil fuel-based heating and transportation systems to electric power-based systems. Both the direct impacts plus the secondary impacts of climate change have jointly contributed to the electrical systems becoming less resilient and there being more disturbances (i.e. power cuts, dips, surges, sag etc.) (Beyza and Yusta, 2021). This is acknowledged to reduce the “inertia” in the supply system thereby allowing increased short duration power outages/disturbances (Howard & Bengherbi, 2016 & Blackout Report Link). The impact of more frequent short duration power outages is at least as disruptive as infrequent long-term power outages and so there is a need to insulate assets against both.). The impact of more frequent short duration power outages is at least as disruptive as infrequent long-term power outages and so there is a need to insulate assets against both.

Ofgem acknowledge that extremely short duration disturbances are largely unavoidable and are byproducts of the electrical system responding to an electrical fault. Consequently, efforts to improve resilience is largely focused on longer duration blackouts (ie the loss of power for greater than three minutes). The electrical industry has therefore put in place interventions that automate electrical systems to return power to the customer within three minutes.

The conclusion is that climate change is resulting in UK electricity users experiencing more short duration disturbances and less long duration blackouts. This change in resilience and properties of the power being supplied to our sites necessitates further investments in our assets to achieve our customers expectation with respect to the abstraction, treatment and supply of water.

Data from Northern power grid with regard to outages of less than three minutes in duration could not be obtained. Capturing empirical evidence of power disturbances / outages that are less than three minutes in duration would require the long-term installation of expensive power quality monitoring devices across numerous assets, this has been unaffordable in AMP7 and is not seen as the best use of customers money.

However, later in this document evidence is provided of the increased number of outages directly attributed to all power outage disturbances. Taking into account the claimed reduced frequency of blackouts (>3min duration outages) this data evidences the increasing impact of short duration disturbances/outages.

As mentioned in the introduction, we have proposed a further scheme related to climate change resilience. We have chosen to include the business case in this section, as the underlying issue is climate change that requires the need for a new water main from Thornton Moor SRE to Haworth. Details and images as a result of the drought in 2022 help demonstrate this. If Ofwat feel that this business case is not relevant within this section (due to it being climate change related but not solely power or flooding) we have additional schemes, shown in Figure 3, that go over and above the modelled allowance that has been proposed.

The impacts of the drought in 2022 were most acute in the Worth Valley system and in addition to company-wide measures including a temporary use ban (26 August 2022 to 6 December 2022) and communications campaign, we implemented a number of temporary engineering and operational solutions to reduce the risk of interruption to customers supplies in the Worth Valley. This included emergency treated water transfers.

Following the outcome of the AMP7 WSSS reviews and the lessons learned from the 2022 drought (Appendix F Lessons from 2022 Drought in the WRMP24 Technical Document), the need to improve resilience in the Worth Valley is clear. We believe there is a need for a permanent treated water transfer allowing us to support local reservoir resources and thus provide resilience and flexibility to climate change and power supply resilience.

Key investments:

Power Supply Resilience

Power outages

For the purposes of this submission, a power outage constitutes either short and/or long-duration disruption or outage, including a significant voltage dip on 1 or more phases to the normal sinusoidal current and voltage waveforms (see Introduction to power quality conditioning, Patricio Revuelta and Jaime Thomas, 2016) provided to the incoming power supply of a treatment or pumping asset.

UK power, in an article published on their web page in August 2023(Link here), suggests UK households can experience 21 power outage per year and that the consequences of these are extremely disruptive with wide ranging impacts including creating safety risk and causing environmental harm. Yorkshire Water's treatment and pumping assets are connected to the same power supplies as UK households, and we experience power outages at the same frequency. Evidence of this is provided later.

Climate change driven power outages

Climate change driven power outages are increasing the resilience risk to treatment and pumping across Yorkshire Water for 2 reasons: (1) extreme weather conditions and (2) the fossil fuels power sources conversion to renewables, as generally explained below:

a. The growth in electricity demand attributed to extreme weather conditions combined with the pursuit of low CO_2 emitting technologies such as EVs, heat pumps and resistive heating is forecast to out-strip the growth in electricity generation capacity which will lead to power outages increases (see UK Government Science and Technology Committee – First Report). The UK's planned response to this is to increase renewable generation capacity from 42.5GW to 282GW by 2050. (see: Renewable energy journal Vol 212. August 2023). However, renewable electricity sources are not only less reliable than fossil fuels, they create complex and difficult to model / manage challenges to the generation and distribution of power around the UK.

b. UK electricity consumption has already increased and will continue to increase meaning "the grid" cables and switchgear already at or approaching their rated capacity will inevitably increase asset failures. (see UK Government Science and Technology Committee – First Report). This will lead to short term power outages when the network re-configures to compensate. Improvements undertaken by electricity suppliers on "the grid" to reduce long-term power outages have led to more frequent, automated switching events in "the grid". Short duration power outages are causing operational assets to fail or enter an automated shut-down/start-up process which in turn disrupts our treatment and pumping processes and disrupts customer service and environmental protection.

c. Power generated by large fossil fuels power stations are far more stable than power that is generated by numerous solar, wind micro-generation units. The migration of power generation from large fossil fuels power stations to numerous solar, wind micro-generation units is creating more frequent switching of electrical supply equipment in “the grid” as weather conditions vary. The Institute of Engineering and Technology has identified a number of risk factors for the stability of supplies in the 2030 UK electricity network (see Future GB Power System Stability Challenges and Modelling), concluding that, “the dynamic characteristics and hence the stability of the GB power system is changing as new forms of generation displace conventional steam units”. Our experience is that migration away from fossil fuels is already increasing the frequency of short duration power outages. In turn this is impacting the stability of water production/distribution as well as waste treatment and disposal.

d. Extreme weather incidence is increasing the risk of damage to power supply cables that feed our assets where they are located in, or passes through, rural exposed moorlands and are more prone to water, wind and moorland fire damage.

e. Extreme weather has the net effect of increasing power consumption in the UK which erodes the grid’s spare capacity which has fallen to c.1.2% (see Moylan 2015). This also increases the risk of power outage/disturbance as generation sources and electricity networks are re-configured or when load shedding is initiated.

All of the above factors aggregate to undermine the resilience of the electrical supplies to our assets, which translates directly into water production, distribution and wastewater treatment resilience risks that we need to reduce.

Impact of power outage

The impact of a power outage affects customers, the environment, colleagues and business sustainability with consequences that could involve:

- Loss of customer water supplies and poor customer service.
- Water quality events such as discoloration.
- Release of sewage or treated/untreated water int a water course.
- Asset damage.
- Extra workload for colleagues including out of normal working hours.
- Financial loss & reputational harm.
- Loss of critically important process safety protection systems.

Unless targeted enhancement investment is made to reduce the consequences of climate change driven power outages, then the risk of climate change outages will increase proportionally with the number of events. The activity proposed in this enhancement case will be targeted to reduce both the consequences of a power outage and improve our asset’s ability to withstand a power outage which in turn will improve customer service, protect water quality and protect the environment.

We proposed to implement targeted asset improvements that will establish new and more robust layers of protection against power outages as outlined below:

Clean water production power resilience
In 2021, Graincliffe WTW suffered a prolonged outage resulting in loss of supply to customers that was triggered by a power outage.

Following a detailed investigation, the DWI served an enforcement notice on YW to improve the resilience of its WTW ICA infrastructure on 14 sites and also undertake a series of detailed, intrusive investigations across all remaining Water Production and Distribution assets to determine necessary future investments that would de-risk customer supplies and water quality. The fulfilment of the Legal Instrument is approaching conclusion and the resulting investigation findings have been analysed. This analysis has identified several electrical resilience risks within our assets. These are:

- Individual motor starters are unable to detect and respond to short duration power outages; when these occur, the motor can become inhibited from auto re-start.
- Electrical supplies to several assets are particularly exposed to the environment and are suffering frequent, short- and long-term power disturbances.
- Standby generation systems take time to accelerate and become able to support treatment and pumping processes. During this acceleration time many instruments are reporting inaccurate data which is prolonging the restart period.
- Existing water quality shutdown control systems are reliant upon the functionality of basic process control systems, instrumentation and data networks that do not respond to power failure in a consistent manner.

Impacts of outages on the clean water business

We are already experiencing a significant number of site shutdowns resulting from power outages with a typical range of 120 to 230 power outages per year across all the clean water assets, with an underlying increasing trend (Figure 1).

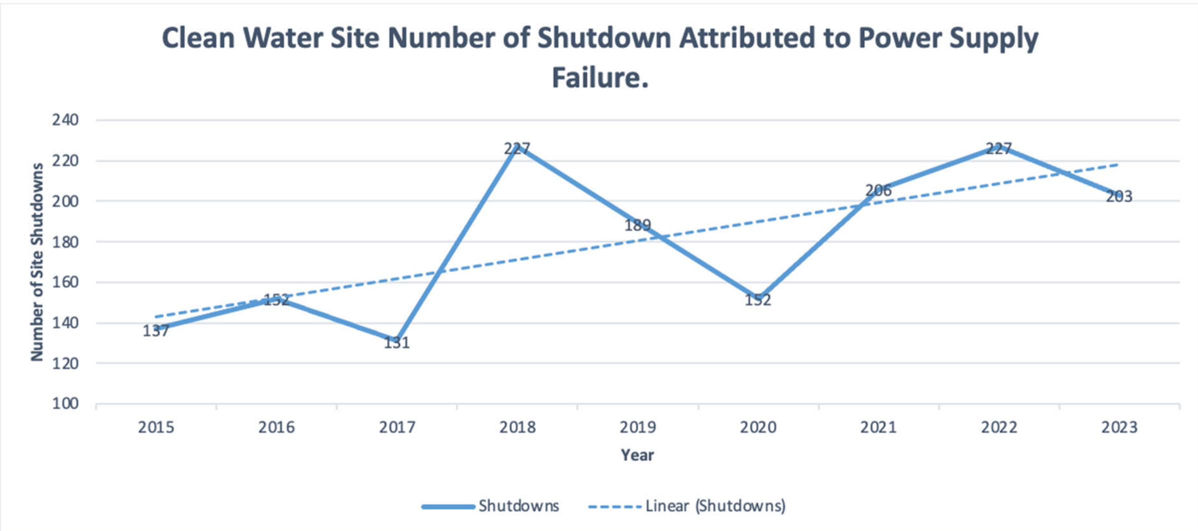

Figure 1 - No. of shutdowns on clean water assets

In discussions with our Distribution Network Operator, Northern Power Grid (NPG), we understand future NPG investment will be targeted at power network automation. This is expected to lead to a greater number of short duration power outages that will bring the majority of the outages below the threshold where they are required to be reported to Ofgem to count against their "Customer interruptions and minutes lost: Electrical distribution (R110-ED1)" KPI (ref).

All indications suggest that the underlying trend of increasing site shutdowns due to power issues will, if appropriate mitigation is not put in place soon, continue to increase. Combined with climate change impacts, a greater rate of increase over the forthcoming years is more likely to occur.

Best value for customers, in our view, would not be created by only upgrading or installing standby-power generation assets. A more integrated approach is needed. The effectiveness of such an approach would be modest at best because standby power generation takes time to start, accelerate and stabilise before it can be used; this would not protect customers from the impact of short duration disturbances/outages. Instead, we propose to enhance power supply resilience by addressing the anticipated increased frequency of short duration power outage/disturbances whilst retaining existing resilience against extended periods of power loss which means we will:

- Ensure that any asset which cannot be tolerated as “out of service” for a long period of time has suitable mitigation in place through the provision of:
    - An alternative power supply (known as a secondary power supply).
    - A long-term method of being supplied with power (e.g. a fixed or mobile generator).
    - Appropriate power storage.

  The added benefit of this part of our solution would be to partially insulate these key assets from an eventuality whereby the capacity of the grid overall is exceeded by the consumption demand and the resulting load-shedding events that are predicted.

- Ensure that upon restoration of power, the equipment automatically reverted to a “ready to operate state” and where possible/safe, automatically restarts.

- Improve assets to (a) ensure short term power outages/disturbances do not “lock up” our control systems and cause a site shut down and (b) short-term power disturbances (e.g. <1 second) do not trigger inappropriate plant shutdowns.

- Ensure that assets incapable of being restarted automatically are protected from as many power disturbances as possible.

To address the worsening impacts of climate change on power resilience, enhancement investment is required to:

Ensure appropriate mitigation against a power supply blackout is provided

Typical storage or secondary power supplies (e.g. generators and standby supplies) are fitted widely across the business to manage power blackouts. It is acknowledged that changes in criticality (resulting from changes in legislation and expectations from the public) have caused the criticality of impacted assets to increase. For these assets a secondary power supply risk assessment (and where necessary mitigation) is required to ensure appropriate and proportionate mitigation from power failure is provided to meet customers’ expectations.

Ensure uninterruptable power supplies are available, working and maintainable

Uninterruptable power supply (UPS) systems provide uninterrupted power to critical process control equipment. The risk of losing power to such systems during power interruption events is that the system does not recover when power returns and a whole site / process areas will be lost for a prolonged period. Funding is required to addresses inadequacies in the current UPS installed or due to an absence of the UPS.

For UPS systems to retain their integrity they must be maintained. While all UPSs have been constructed to be maintainable, only basic maintenance can be completed without impacting on the load. More thorough intrusive maintenance which can predict the failure of the UPS cannot currently take place without the UPS’s load being isolated for a short period of time, resulting in additional plant shutdowns. To enable the more thorough intrusive maintenance to take place on all UPSs while retaining process operations a specialised enhanced maintenance by-pass switch must be fitted to all UPS systems. A move to the more thorough intrusive maintenance will enable YW to predict many of the failures of UPS systems before they occur making sites more resilient to power disturbances and meeting customer expectations.

Improve ICA system resilience

Resilient and effective control systems are vital for the running of our sites and processes. Control systems are increasingly having to deal with more and different types of short-term power disturbances. Control systems, upon reinstatement of power, may lock up and prevent restart of the site. It is proposed to re-assess the resilience of control systems and carry out targeted enhancement work to ensure control systems achieve the level of resilience proportionate to the criticality of site and appropriately manage the increased number of and differing type of power disturbances resulting from the direct effects and indirect effects of climate change. As part of the same initiative, we will improve the integrity of water quality protection shutdown systems by insulating them from the effects of power disturbances.

Install enhanced brown out protection and recovery circuits

To ensure that short-term power disturbance (lasting factions of a second) do not lock up our electrical systems and lead to an inappropriate site shut down we will undertake targeted improvement to electrical assets, so they detect power disturbances and respond to ensure that when power stabilises the asset continues automatic operation.

The strain placed upon our electrical infrastructure resulting from the need to decarbonise to prevent climate global warming has resulted in the nature and type of power disturbances changing. This has resulted in a number of disturbances locking out different control systems on various sites across YW. To prevent this from happening, brown out timers capable of identifying all types of power disturbances and UPSs need to be fitted to sensitive equipment. Note: the proposed brown out timers are significantly more sensitive and are relatively new to the marketplace.

Minimise the number of power disturbances impacting on unavoidably delicate sites

Power dip resilience is best dealt with by ensuring sites, when subjected to a power disturbance, will self-reset themselves and then automatically restart. Tightening (particularly water quality) standards has resulted in YW having to install ever more complex shut down systems. These sensitive shut down system are incapable of managing the consequence of power disturbances on site and when a power disturbance impacts on asset availability, the shutdown system automatically shut the works down. In these circumstances, the only way to prevent a shut down on site is to install a Dynamic Voltage Regulator which will remove any short period dips or sags coming from NPGs electrical network from impacting the site. The suitability of a site to fit a Dynamic Voltage Regulator is based not only on the number of voltage disturbances impacting the site but also the characteristic of the disturbances (which requires the site power to be monitored for a period of time). Graincliffe WTW is proposed to be the first site to be fitted with a Dynamic Voltage Regulator followed by Eccup WTW 1 & 2, Thornton Steward WTW and Holmebridge WTW. The remaining 3 sites will be selected using a risk-based approach to ensure maximum benefit is derived from the investment.

Figure 2 - Unplanned shutdowns by site

Worth Valley climate change and supply resilience

Keighley WSS supplies 32493 properties from Sladen Valley and Oldfield WTWs. The significant imports into Keighley WSS are directed into Blackhill CRE. From here, most of Bracken Bank CRE's demand can be rezoned onto the Blackhill CRE system. This leaves everything upstream of Blackhill and Bracken Bank CREs vulnerable to supply/demand issues. Worth Valley is part of the Lane End CRE system, which is fed mainly by Sladen Valley WTW, and Oldfield WTW.

Due to being located at the head of the WSS and valley, it is not currently possible to reverse flows through the network from Blackhill CRE to Lane End CRE. In the event of having insufficient raw water stocks to meet the Lane End CRE system demand, this system would experience a significant interruption to supply/low pressure/discolouration event. Worst case scenario, this would impact up to 11,952 properties. Once the only available rezone is in place, the event would impact up to 10,890 properties. The maximum average demand to be met on the Lane End CRE system is 6.5 MLD. Currently there is no way to provide this.

The drought experienced in 2022 meant the company Bronze escalation process was initiated for this specific risk, feeding into an ongoing Bronze, Silver and Gold for overall drought management. By August 2022, reservoir levels were tracking below the regional average at 27.5% versus a regional average of 41.2%. This is shown in Figure 4. The risk of reservoir levels falling below 20% meant uncertainty of being able to treat this water. Network reconfigurations, maximised leakage detection and drought permits were all enacted. In order to reduce the risk of supplies being interrupted, 2.1km of overland temporary pipework with associated pumping, was installed from a separate reservoir group into the Worth Valley reservoirs. This emergency scheme was installed in September 2022 via a number of measures including lifting pipework via helicopter over the moorland to ensure the scheme could be completed prior to the Worth Valley Reservoirs going below 20%. This scheme provided a temporary solution, with the need for a more permanent solution being required. Images of the emergency measures are shown in Figure 5.

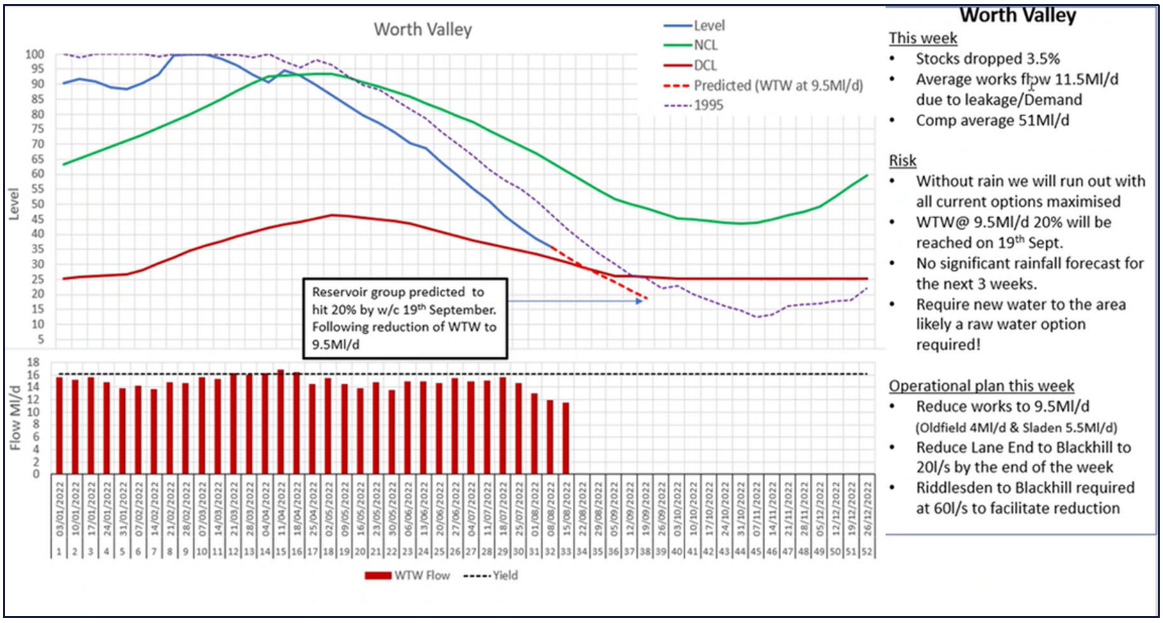

Figure 4 - Worth Valley Reservoir Stocks in August 2022

Figure 5 - Images of the emergency scheme to transfer raw water into the Worth Valley

1.4.2 The scale and timing of the investment

The scale and timing of the investment is fully justified. This is due to two reasons:

1. **Scale:** Our proposed investments align with the enhancement uplift (based on 0.7% of base allowances) allowed by Ofwat in the draft determination for companies to prioritise their biggest climate related risks.
2. **Timing of investment:** Our proposals are timely due to the changes in climate that are projected to occur during the 21st century, and because proactive investment in climate adaptation is proven to be cost-effective. The Global Commission on Adaptation estimates every £1 spent on adaptation action now leads to avoided costs of £2 - £10 in the future (GCA.org).

1.4.3 Interactions with base or previous funding

To achieve power supply resilience some base maintenance work will also need to take place. This base maintenance work falls outside of the work listed in this Appendix and relates to

Generator and UPS systems repairs, remediation/asset replacement of the Electrical Distribution Systems and remediation/asset replacement of ICA equipment.

For the Thornton Moore SRE to Haworth scheme we do not believe this scheme overlaps with base maintenance funding. This is a new main that connects two WSSs with the risk specifically to Keighley WSS as a result of drought issues that are likely to be more common in the future owing to changes in the climate. There is no base funding that overlaps with the scheme being proposed.

1.4.4 Long-term delivery strategy alignment

Clean water resilience costs are included in our core pathway within our Long-term delivery strategy (table LS4) in recognition of the long-term risks that we face as a business due to climate change and other exogenous factors.

1.4.5 Customer support

Numerous customer research studies we have conducted have shown that avoiding interruptions and ensuring a continuous and resilient supply is one of the customers biggest priorities. They are therefore supportive of investments made to strengthen supply security.

In our Valuing Water study (where we spoke to 391 customers on our Your Water community), 83% of customers selected it as being their most important priority above all other service areas and in Ofwat's preferences study, it was ranked second overall when compared to all service aspects. In a separate Valuing Water study where we spoke to 1,500 households and non-households, both these customer cohorts again rated 'Providing a continuous supply of water' as their top priority (75% of households and 68% of non-households).

Following Ofwat's guidance, qualitative research was undertaken during our Affordability and Acceptability Testing. This demonstrated that 92% of future bill payers were supportive of us investing in enhancing our water supply resilience (we spoke to 13 future customers). Furthermore, when non-household customers were asked which service aspect is the most important, 52% rated water supply resilience as the most important, substantially higher than any other service aspect (we spoke to 31 businesses).

1.4.6 Factors outside management control

The primary source of power to our sites will always be via the local Distribution Network Operating company, which is mainly Norther Power Grid. While this is a regulated industry largely offering high levels of resilience, it is not and can never be 100% resilient. Factors out of both our control include:

Excessive weather impacts - As power distribution assets are exposed to the elements, excessive weather condition driven by climate change can directly impact on many electrical assets. Excessive Wind, Heavy Snow and Excessive High Temperatures can all impact on power supply resilience and result in power disturbances to our assets.

Impacts of systems reaching capacity – As systems and distribution networks approach full capacity to facilitate renewable energy and low carbon technology, the likelihood of faults (many of a complex form) on the electrical system increases.

Historically these events would become apparent to us as power blackouts for which they had been addressed via system storage or a secondary power supplies. However, automation on the

Distribution Network Operating company's assets to reduce the blackouts has significantly reduced the length of power outages largely to less than 3 min (the period at which the outage starts to count as a KPI). These shorter outages can and often are significantly harder to manage than long duration outages and currently still lead to site shut down. This investment is to deal with the increasing number of short-term outages in order to improve the asset resilience to power disturbances.

1.5 Best option for customers

We developed a long list of potential options to be considered for resilience funding across our water asset base. A cross-business, multi-disciplinary team appraised these options based upon a series of critical success factors.

1.6 Prioritised resilience schemes to be delivered

1.6.1 Power supply resilience

The proposed solution looks to take a 4-stage approach to addressing the increasingly challenging environment of power supply resilience as a result of climate change.

Stage 1 – Provision of adequate long term backup power is provided.

Stage 2 – Ensure equipment resets itself (and if possible restarts automatically) after a power disturbance.

Stage 3 – Ensure equipment does not get lockup/tripped out upon a short term power disturbance.

Stage 4 – Where equipment cannot be restarted automatically following a power disturbance, minimise the number of power disturbances that equipment sees.

While this approach does not seek to remove or eradicate the effects of power disturbances impacting on the asset, it looks to identify the presence of a power disturbance and ensure the asset reacts in an appropriate way to have no noticeable impact on the customer. As such this 4 stage approach takes a targeted approach to modify specific elements of the control systems, hence it offers a least capex, least opex solution to resolving power supply resilience while improving the reliability of the water supply to the customer in order to meet the customer's aspirations of a resilient and reliable water supply.

Based upon the 4-stage process, Figure 3 shows £42.7m of investment to address resilience associated with power outage. As a result of the approach used by Ofwat to determine the amount of available investment (0.7% of base allowance), two scenarios have been developed. The first scenario includes the Thornton Moor SRE to Haworth climate change resilience scheme, costed at £3.8m, with the remaining £8.9m of the most beneficial power related schemes, taken from Figure 3.

The second scenario shows the most beneficial £12.7m of power related climate change resilience solutions only. In order to become ever more resilient in the long term, future AMP9 and AMP10 investment would continue based upon the solutions presented in Figure 3, with regular reviews taking place based upon emerging risks and new technologies.

Scenario 1

Scheme		Total (£m)
Thornton Moor SRE to Haworth	CAPEX	3.6

Dynamic Voltage Regulator – Graincliffe WTW	CAPEX	1
Secondary Power Supply Assessments	CAPEX	0.21
Roll-out of Enhanced UPS Bypass Systems	CAPEX	0.44
ICA Resilience - Instruments	CAPEX	3.02
ICA Resilience – Reg 26	CAPEX	1.86
ICA Resilience – Control Systems	CAPEX	2.32
Roll-out of Enhanced recovery systems (SCADA Sites only)	CAPEX	0.26
Total		**12.7**

Figure 1 – Climate change resilience including Thornton Moor to Haworth SRE

Scenario 2

Scheme		**Total (£m)**
Dynamic Voltage Regulator – Graincliffe WTWCAPEX1Dynamic Voltage Regulator – Huby WTWCAPEX1Secondary Power Supply AssessmentsCAPEX0.28Roll-out of Enhanced UPS Bypass SystemsCAPEX0.58ICA Resilience - Instruments	CAPEX	3.99
ICA Resilience – Reg 26	CAPEX	2.45
ICA Resilience – Control Systems	CAPEX	3.07
Roll-out of Enhanced recovery systems (SCADA Sites only)	CAPEX	0.34
Total		**12.7**

Figure 2 – Climate change resilience excluding Thornton Moor to Haworth SRE

All power resilience options

Scheme Name		**Total (£m)**
Secondary Power Supply Assessments	CAPEX	0.9
Roll-out of Enhanced UPS Bypass Systems	CAPEX	1.9
ICA Resilience - Instruments	CAPEX	13
ICA Resilience – Reg 26	CAPEX	8
ICA Resilience – Control Systems	CAPEX	10
Roll-out of Enhanced recovery systems (SCADA Sites only)	CAPEX	1.1
Dynamic Voltage Regulator – Graincliffe WTW	CAPEX	1.0
Dynamic Voltage Regulator - (7 other sites)	CAPEX	6.8
TOTAL	**CAPEX**	**42.7**

Figure 3 - Cost breakdown for power supply resilience work (full funding)

Figure **Error! Reference source not found.**3 shows a cost breakdown of all power related resilience investment. This investment will be prioritised based upon highest risk site with the funding that is available.

1.6.2 Keighley WSS Resilience Scheme

The proposed permanent solution is to lay approximately 6.8km of treated water main from Thornton Moor SRE into a 15-inch main in Haworth. This will then connect the Bradford system to the Keighley system and provide additional resilience via a treated water supply. In the event of future droughts, this solution will allow flexibility to provide water from an alternative WSS without the need to lay overland pipework between impounding reservoirs to allow enough raw water to feed the local WTWs.

Benefits of Thornton Moor SRE to DMA K704 Haworth resilience main:

- The calculated benefit of this resilience main on stocks if it had been available in spring 2022 is that YW have lost the opportunity to save 280-290ML of Worth Valley raw water over 13-14 weeks (from crossing NCL in April to early September). This import main would have enabled us to operate at WTW minimum flows of 6-7MLD sooner. Operating at minimum flows would have saved a further approximately 40ML from Worth Valley raw water stocks.

- Combined, this is a missed benefit of approximately 310-330ML in stocks in the Worth Valley. The 310-330ML equates to 10% of stocks and **Error! Reference source not found.** illustrates the benefit of this treated water connection. Had this solution been in place in 2022 YW would not have been in the scenario of considering a long duration supply interruption event to 10,890 properties.

- This scheme would provide resilience to the upstream end of Keighley WSS. There are no alternative ways to supply these areas in the event of a significant failure at Sladen Valley WTW or Oldfield WTW and the import link also removes demand from Lane End CRE. With Sladen Valley WTW having the 12th most frequent shutdowns out of all the water treatment facilities, with many of these being power related, being able to supply a significant proportion of these properties from an alternative source adds further resilience to this part of the region.

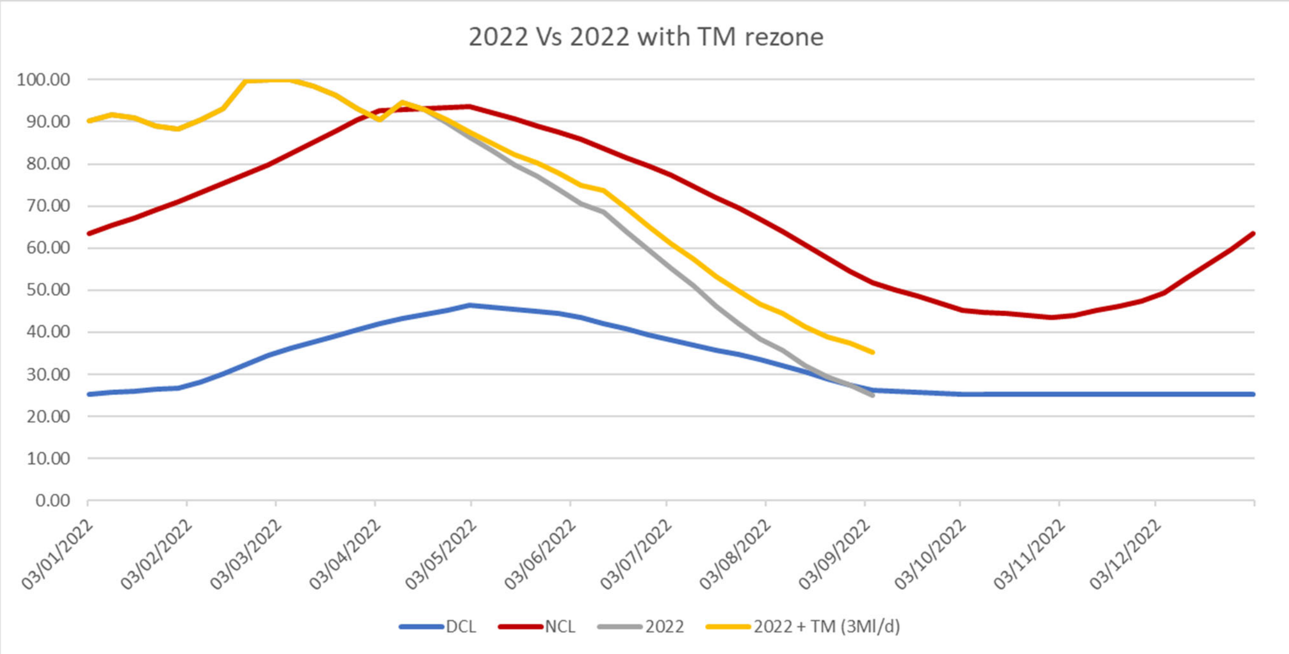

Figure 6 - Worth Valley raw water stocks and control lines in 2022, compared with calculated raw water stock saving if this resilience main from Thornton Moor SRE had been available

1.7 Summary of investment costs

	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	**Total**
Opex (£m)	0.2	0.2	0.5	0.5	0.5	1.9
Capex (£m)	0.5	0.5	7.8	1	1	10.8
Total (£m)	0.7	0.7	8.3	1.5	1.5	12.7

1.7.1 Options considered for power resilience funding

A number of technologies have been selected to collectively provide protection against the increasingly challenging environment of power supply resilience. These technologies are namely standby feeds (with automatic changeover systems), generators (with automatic changeover systems), enhanced UPS systems, battery systems, brown out relays and dynamic voltage regulators. A number of technologies and solutions have been discounted. These include, but are not limited to:

Option	Reason for discounting
Power Resilience	
1. **Site-wide UPS Systems** – Battery based large scale	Based on knowledge of YW's currently, owned, operated and maintained fleet of UPSs, discounted

UPS systems to support the entire site from a power outage.	due to the low asset life of batteries (5-10years), the high value of the UPSs (and batteries) and regularly maintenance required to keep the asset running (6 monthly). Site-wide battery-based UPS systems are seen to require an extremely large whole life cost (totex) to maintain normal operation and hence offering poor value to our customers.
2. **Site-wide Rotary UPS Systems** – Mechanical fly-wheel/generator based UPS system providing power to the whole of the site.	Based on knowledge of YW's currently owned, operated and maintained fleet of Generators and Fly-wheel systems, discounted due to an expensive complex electro-mechanical system with an intense high level of maintenance (6 monthly) to keep the asset going. Site-wide Rotary UPS systems are seen to require an extremely large whole life cost (totex) to maintain normal operation and hence offering poor value to our customers.
3. **Widescale rewiring of panel/rewriting of software** - The widescale rewiring of panels/rewriting of software to achieve sites and process that are inherently resilient to power disturbances.	While such a solution would significantly reduce opex it would be at an unaffordable level of CAPEX (based on the assumption that a large part of the control and automation system on site would have to be rewired leading to a requirement for £100s millions of capex to achieve the same outcome as is laid out in this proposal) and would offer poor value to our customers.

1.7.2 Options considered for the Keighley WSS Resilience Scheme

Option	Reason for discounting
Keighley WSS Resilience Scheme	
1. **Lay a treated water main from Thornton Moor SRE to Sladen Valley WTW SRE common outlet.**	This option was considered and ruled out due to: • Sladen Valley WTW SRE common outlet requiring additional fittings and layers of protection to ensure that imported Chellow WSS water would not backfeed into Sladen Valley WTW and SRE, therefore compromising water quality risk. • The installation of a NRV (non-return valve) would have required a shut off of at Sladen Valley WTW outflow on order to install, risking supply interruption as well as an increase in cost. • The solution would require an additional 700m of mainlaying, adding unnecessary cost to the scheme. • The proposed route into Haworth directly serves the population without any means of alternative supply in the event of WTW shutdowns at Sladen Valley and Oldfield, providing immediate supply restoration by directly connecting the DMAs. The route to Sladen Valley would have taken longer to reach those same customers, due to having to be pumped from Sladen Valley WPS up to Lane End CRE, before then gravitating through the trunk main systems to the DMAs.

2. The permanent installation of the raw water emergency scheme from August 2002	Ruled out due to the requirement of a raw water pumping station being needed, and the substantial installation and maintenance costs for an asset that would only be required in an emergency situation.
3. Other treated water solutions	All other treated water solutions were ruled out in the early optioneering phase due to the requirement of a water pumping station rather than the supply being gravity fed, resulting in increased opex costs.

1.7.3 Cost-benefit appraisal

Six Capitals and cost-benefit analysis

Our service measure and valuation framework aids us in identifying the reasons we need to invest and the value of doing so. It enables us to link expenditure to service and understand the benefits of our programme at a much more detailed level. We have mapped each service measure against the 'Six Capitals' framework - natural, social, human, financial, intellectual and manufactured. These benefits are measured and valued according to the different service impacts.

Once we have understood our risks to service, identified our potential interventions and estimated efficient costs, we assess whether the solutions are viable using cost benefit analysis.

This assessment of potential investment options considers the overall value added rather than simply selecting the lowest absolute cost.

We use best-practice industry standard for the economic value assessment:

- Financial, Social and Environmental Impacts (via 'Six Capitals').
- Net Present Value (NPV).
- Value of costs and benefits over several years.
- Capex is annuitized to reflect smoothed repayment profile rather than lumpy spend profile.
- All costs and benefits are discounted to reflect a present value.

By understanding the costs and monetised benefits, we can calculate the net-benefit of a given scheme.

1.8 Customer protection

We do not propose any customer protections for this base adjustment, over and above the existing sharing mechanisms.

1.9 External assurance

Independent external assurance was undertaken over the resilience uplift expenditure. The assurance concluded that we have established the credibility of the case, options and customer protection by showing the data gathered and processes followed. It found that cost efficiency was based on the best available data to the team in the limited time available.

Power Resilience

All costs submitted are based on quotes from approved partners.

Thornton Moor SRE to Haworth resilience scheme

As part of the early investigation into this scheme, we instructed one of our capital partners, MWS, to undertake a desktop and initial site walkover to identify the best option. This not only involved identifying the best route, but also enabled the scheme to be costed. Details of the costing exercise are shown in Annex 2. These costs are then assured by the YW commercial team to ensure they represent the best value.

2. Annex 1: Details of proposed early start works

Please note, is deemed to be enhancement work.

Asset Area	Scope	Site Name		
		Graincliffe WTW	Sladen Valley WTW, Longwood WTW, Blackmoorfoot WTW, Langsett WTW, Ewden WTW, Fixby WTW Carlton Mill Lane WTW, Irton WTW, Haisthorpe WTW, Kirkhamgate WTW, Cayton Car Lane WTW, Holmebridge WTW, Austerfield, Cowick WTW, Aindenby WTW, Aysgarth WTW, Hutton Cranswick, Eccup 2 WTW, Harlow Hill WTW, Chelkar RPS, Elland Lodge RPS, Brayton WPS, Aughton WPS, Horton WPS, Market Weighton WPS, Oldfield WTW	Kelgate WTW and associated remote borehole sites.
Power	Install a Dynamic Voltage Regulator	Yes	No	No
UPS / Power	UPS Review for Shortfalls, add new UPS where required & Add Alarms for condition monitoring SCADA & Telemetry Status.	No	Yes	No
UPS / Power	Review of Westermo Power supply resilence. Not all units are power backed.	No	Yes	Yes
PLC Network	Replace lynx Plus and L300 Units with new current Version. Connect alarms where missing Giving Improved Diagnostics and capacity.	No	Yes	No

PLC Network	Review of Network Fiber Infrastructure redundancy.	No	Yes	Yes
SCADA	Create new Topology & ICA system page	No	Yes	No
PLC Network	Replace obsolete E1043 data Exchange Units, with Higher integrity solution.	No	Yes	No
PLC Network	Migrate to DP2 Files to latest Version for enhanced diagnostics and reporting.	No	Yes	No
Instrume ntation	ABB Magmasters on profibus to replace with ABB Water Masters.	No	Yes	Yes
PLC Network	Biejer E Terminal obsolescence, - Migrate to GOT to improve user interface and functionality	No	Yes	Yes
PLC Network	QxxHCPU I obsolescence, - Migrate to QDV ? & GXW2 For Improved support on future operating systems Eg Win 11.	No	Yes	No

3. Annex 2: Costing of Thornton Moor SRE to Haworth resilience scheme

MWS cost estimate of the Thornton Moor SRE to Haworth scheme. These costs exclude YW on-costs

Project Number:	**YW**
Project Title:	Thornton Moor to Haworth
Date:	
Revision:	**0**

	Location	Depth	Size	Length / No.	Forecast Price
DIRECTS COSTS					
STANDARD ITEMS					
PE 100 315mm SDR11 FIELD					573,769.28
PE 100 315mm SDR11 Type 2 Carriageway					236,828.27
PE 100 315mm SDR 9 Type 3/4 Carriageway					99,040.24
PE 100 180mm SDR9 Type 3/4 Carriageway					103,982.85
PE 100 315mm SDR11 Type 3/4 carriageway					464,784.08
Crossings					20,333.02
Access into working area (Fields)					24,944.40
					£ -
					£ -
					£ -

NON-STANDARD ITEMS					
INDIRECT COSTS					
PRELIMINARIES					£ 378,695.88
LAND LEASE					£ 7,000.00
TRAFFIC MANAGEMENT					£ 64,000.00
DESIGN COSTS					
GEOTECHNICAL INVESTIGATIONS					£ 10,000.00
ALL OTHER INVESTIGATIONS / SURVEYS	Topo Survey	Eco Survey	Pre-condition		£ 27,500.00
OUTINE DESIGN	11.45%				£ 153,497.02
DETAILED DESIGN					£ 76,748.51
3RD PARTY COSTS					£ -

FEES AND OVERHEADS			
SITE MANAGEMENT	12.40%	£	249,348.87
RISK	10.00%	£	249,047.24
CONTRACTOR FEES	15.01%	£	411,201.90
TOTAL OF THE PRICES		**£**	**3,150,721.57**