# Approach to asset health: Jacobs report

## Chapter 4: 3rd Party Report

## Document Reference: T9035

This report is the output of an assessment by Jacobs of how our approach to asset health compares to best practice. The report considers where UU could take additional action to further improve the robustness of its approach, the outcomes of the project are also intended to support UU's business plan for the 2019 price review.

**United Utilities Water Limited**

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# Review of United Utilities' Approach to Asset Health

## Summary Report

470185.AH.18.01 | 1.4

19 June 2018

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| Project No: | 470185 |
| Document Title: | Summary Report |
| Document No.: | 470185.AH.18.01 |
| Revision: | 1.4 |
| Date: | 19 June 2018 |
| Client Name: | United Utilities |
| Project Manager: | Glen Hawken |
| Author: | Alex Lane, Paul Conroy |
| File Name: | 470185_UU-AH_SummaryReport_v1.4.docx |

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## Document history and status

| Revision | Date | Description | By | Review | Approved |
|---|---|---|---|---|---|
| 0.3 | 23 March 2018 | Draft for client comment | Alex Lane | Paul Conroy | Paul Conroy |
| 1.4 | 19 June 2018 | Final | Alex Lane | Paul Conroy | Paul Conroy |
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## Contents

# Executive Summary

This review of asset health project has used face-to-face interviews and desk-based review of documentation to evaluate and benchmark how United Utilities Water Limited (UU) measures and manages the health of its assets.

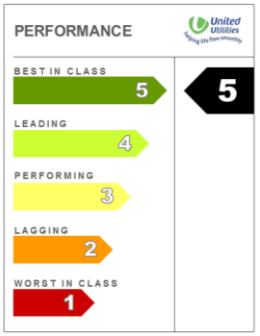
As well as identifying where UU could take additional action to further improve the robustness of its approach, the outcomes of the project are also intended to support UU's business plan for the 2019 price review.

We interviewed more than 20 UU staff from a variety of departments and asked them questions covering five topic areas. Our observations on current practice, alongside our view of UU's relative performance among water companies in England and Wales, are presented in the subsequent tables:

## Understanding of asset health

- All interviewed staff were aware of the concept of 'asset health' and several have or are proactively developing bespoke asset health metrics to inform decision making.
- UU's base asset health indicator (BAH) is considered industry-leading. It acknowledges the importance of asset health and it supports the use of asset health in decision making.
- Care needs to be taken to control how the 'asset health' term is defined and how asset health metrics are used within the organisation.

*Note: we are not able to comment on how complete asset records are and how accurate asset health information is compared to other water companies.*




## Measurement of asset health (physical)

- Many of the pieces of data UU collects relate to asset health. A clear link between this data and BAH, and to the resilience scorecard, should be embedded in practice.
- UU's enthusiasm to learn from approaches to asset health and asset management from other industries has been influential in implementing new ways of working.
- We were told that UU has been relatively quick to adopt new condition monitoring technologies but less effective at embedding the necessary supporting process or developing the required staff skills.
- UU has and continues to trial a variety of asset health monitoring technologies. Measures are required to ensure that the cost of trialling new technologies does not hinder advances in monitoring and performance.


## The link between asset health, performance, service and outcomes

- The linking and visualisation of UU's BAH, and its roll out to operational teams will help to establish links to performance, service and criticality, and in turn to reinforce the awareness of these measures within the organisation.
- The development of a validated database (EXAsol) has the potential to significantly improve data governance, and confidence in decision making.
- UU's aspiration to move to a more structured and consistent approach to contingency planning should be prioritised.

## Influence of asset health on investment planning and decision making

- The application of BAH to support decision making (with appropriate controls) should be encouraged and championed by senior leadership.
- The use of BAH in the assessment of competing projects in OPTIMUS is an important advancement, as is the parallel development of a tool which enables the user to vary the extent to which certain service outcomes are pursued in planning.
- It is important that projects which maintain base asset health compete effectively for investment with projects that address acute issues.
- The transfer of information, and methods of communication between planning and operations is recognised as an area of required improvement by UU and several initiatives are underway to address this.


## Communication and the views of the customer

- UU recognises the importance of asset health to service delivery and is committed to engaging customers directly on this topic to understand their views on asset health.
- UU is actively working to develop ways to discuss asset health (a challenging concept) directly with its customers. To support this process, it needs to be clear about what it means by asset health and how this concept is measured and used in planning for service delivery.
- Conducting an internal asset health survey would provide valuable insight into the relative understanding of the concept and help target future awareness raising.


## Asset health assurance

- The ability to identify operational performance issues is constrained by limited human resources. Data analytics and machine learning therefore have significant potential.
- Assurance of data quality typically occurs once draft conclusions or business cases have been prepared. The EXAsol platform presents an opportunity to address this inefficiency, thanks to its application of quality checks each time data is uploaded.
- Concise and visually powerful reporting of asset health information to Board should continue, using the dashboards being developed by the Asset Management directorate for example.
- State of the Assets reports or scorecards provide a valuable means of aligning reporting across asset types and geographies, and can help track performance, spot system trends and inform long-term planning.


## Innovation and collaboration

- Innovation is a core component of UU corporate culture, as instilled by its leadership. A variety of platforms for innovation exist, however they could benefit from an overarching framework.
- UU's Innovation Lab provides a valuable platform for suppliers to innovate in partnership with UU. By evolving the programme into a continually available platform, potential suppliers would have a constant avenue through which to engage UU.
- We understand that UU is undertaking planning to determine the skills it will require to deliver its future services. A roadmap for capacity building will be important.

## Recommendations

***Understanding and measuring asset health:***

- Awareness of BAH within UU teams is now widespread and its application to support decision making is beginning to occur. This process should be encouraged, and championed by senior leadership
- UU should develop a corporate glossary to ensure that asset health terms are used in the appropriate context
- UU should seek to partner with other water companies to reduce the cost of developing new technologies
- UU should build on its existing process to more formally recognise the importance of less tangible assets, particularly data and natural capital

***Establishing the link between asset health, performance, service and outcomes:***

- The development of a validated database (EXAsol) has the potential to significantly improve data governance, and confidence in decision making. The rollout of the EXAsol platform should be prioritised
- UU's aspiration to move to a more structured and consistent approach to contingency planning should be prioritised. The recent Haweswater Aqueduct contingency planning project could be used as a catalyst
- A formal means for UU staff to raise concerns or requests for technology development and trialling to the Innovation Team should be established. This would help to prioritise where investment should occur

***Influence of asset health on expenditure planning and decision making:***

- It is recommended that a governance structure is established to control the application of asset health measures in decision making
- Current BAH values could be used alongside future forecasts to set targets and track progress. Combining UU's BAH with a time-base element could aide decision making and help justify investment
- Multi-scenario planning and visioning exercises and reverse stress testing can improve understanding of the possible chains of events within a system associated with high impact, low probability events

***Communication and the views of the customer:***

- In its direct customer engagement on asset health, UU should be clear about what it means by this concept
- The proposed customer questionnaire on asset health could also be circulated internally. This process may provide insight into the relative understanding of different departments

***Asset health assurance:***

- The rollout of UU's EXAsol platform presents an opportunity to move quality assurance earlier in the decision-making process
- Concise and visually powerful reporting of asset health information to Board should continue. The dashboards being developed by the Asset Management directorate and Range Managers are a suitable approach
- Development of 'State of the Assets' reports could provide a valuable means of aligning reporting across asset types, help to track performance, spot system trends, inform long-term planning and justify investment

***Innovation:***

- By evolving the Innovation Lab programme into a continually available platform, potential suppliers would have a clear and accessible avenue through which to engage UU
- Additional internal innovation platforms, or an overarching framework, could help ensure a collective focus on innovation from all staff (i.e. those not involved in the CEO Challenge or Innovation Lab)

# 1. Introduction

## 1.1 Purpose and objectives of the project

This report summarises the findings of a review to investigate how United Utilities Water Limited (UU) measures and manages the health of its assets.

Asset health is a core component of operational resilience, itself one of Ofwat's key themes for the 2019 price review (PR19). In September 2017, CH2M (now Jacobs) completed the *Targeted Review of Asset Health and Resilience in the Water Industry* on behalf of Ofwat. The findings of this report were published by Ofwat alongside its *Resilience in the Round* report.

The *Targeted Review of Asset Health* aimed to better understand how the water companies in England and Wales were approaching the measurement and management of asset health. It involved interviews with a small number of key individuals at each water company, including UU. The study concluded that companies need to continue to focus on a number of issues, including:

- Engaging effectively with customers
- Driving greater innovation
- Ensuring a long-term mindset
- Developing a stronger understanding of how asset health affects service, especially for high-consequence, low-probability events

UU now requires a more detailed and wide-ranging investigation of how its approach to asset health compares to best practice (as outlined in the *Targeted Review of Asset Health*), and to highlight where it could take additional action to further improve the robustness of its approach. The study has also considered how effectively key corporate systems support and can apply outcomes from the asset health processes and where UU could focus further effort to allow development of industry-leading asset health management practices.

The outcomes of this project are also intended to support UU's business plan for PR19, helping it to demonstrate how the company has addressed, and is addressing, asset health in its broader commitments to delivering resilience in the round. We highlight that ***Ofwat expects companies to have identified and, if necessary, addressed any existing issues related to asset health in the current price control period***. Business plans for PR19 should not seek funding from customers to address any shortcomings of the past.

It should be noted that we have sought to draw together insights based on learnings about other water companies taken from the *Targeted Review of Asset Health* and have not benefited from a deeper investigation of the other water companies. The accuracy of some of the comparisons may therefore be open to challenge.

## 1.2 Defining asset health

Asset health is a term open to interpretation. The *Targeted Review of Asset Health* identified that although no consistent definition was used by all companies, most associated good asset health with achieving good levels of service and performance. The general view was that good, stable, measured performance was a strong indicator of good asset health and conversely, that inadequate or declining performance might indicate poor asset health. There was widespread use of the original Ofwat serviceability indicators (and variants of these) as a surrogate or proxy indicator of asset health, although some companies had refined these measures.

Several company responses also indicated a need for greater clarity in understanding exactly how asset health influences asset resilience and systems resilience. Many companies were looking at how the 'four R's' of resilience (Reliability, Resistance, Redundancy and Response & Recovery) proposed by The Cabinet Office in 2011, apply to different asset groups. An interpretation of Ofwat's view of resilience is presented in **Figure 1-1**.

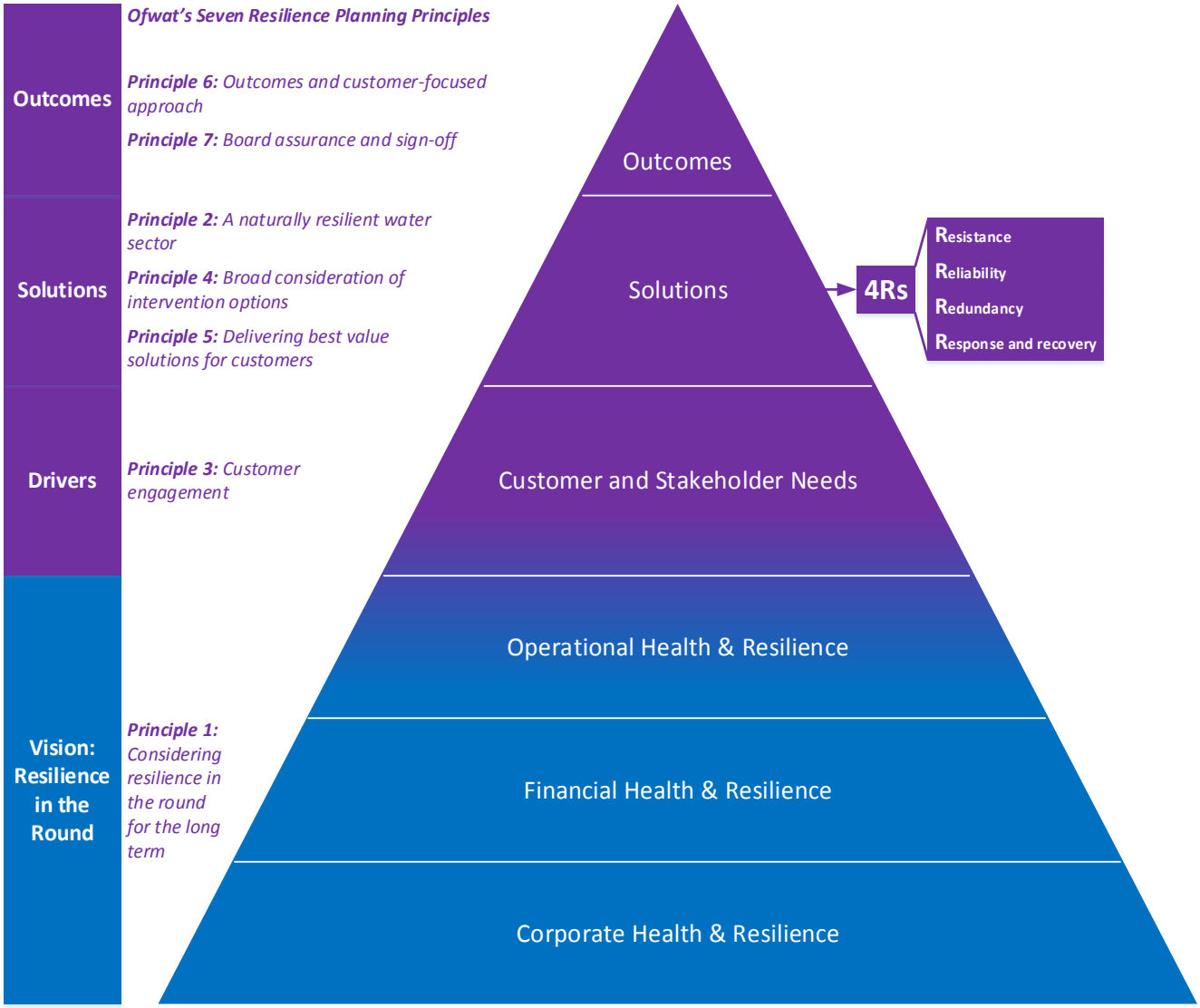



**Figure 1-1: Interpretation of Ofwat's View of Resilience**

## 1.3 Methodology

This project for UU has comprised desk-based analysis and review of existing reports, data and information, supported by face-to-face interviews with 20+ UU staff from a variety of departments, including both planning and operational roles.

Interview questions were prepared to cover the same broad topic areas as the *Targeted Review of Asset Health*, building on this foundation to explore particular issues in greater detail. Questions were also asked to a much broader range of staff (both roles and responsibilities). The questions asked covered the following topic areas:

- Understanding of asset health and risk to service
- Establishing the link between asset health, performance, service and outcomes
- The influence of asset health on investment planning and decision making
- Communication and the views of the customer
- Asset health assurance
- Innovation and collaboration

**Appendix A** lists the interview questions posed to each interviewee.

Using the responses to interview questions, and a review of associated supporting data and documentation, this Summary Report records our observations and recommendations. A summary slide deck of findings is included as **Appendix B**.

# 2. United Utilities' approach to asset health

The following section of the report summarises the outcomes of interviews held with UU staff. Where appropriate, recommended improvements have been outlined. Relative scoring against industry best practice is presented in **Section 4**. Recommendations are re-stated and expanded upon in the context of industry and cross-sector best practice in **Section 6**.

## 2.1 Defining asset health

All staff we spoke to were asked what they understood by the term 'asset health' and to explain how they used the concept to support/inform their day-to-day activities, if at all.

**Headline observations:**

- *All interviewed staff were aware of the concept of 'asset health' and several have or are proactively developing bespoke asset health metrics to inform decision making.*
- *Care needs to be taken to control how the 'asset health' term is defined and how asset health metrics are used within the organisation to inform decision making.*
- *The importance of data to asset health is implicitly recognised in a large number of UU initiatives. The influence of healthy data on healthy assets should be formally acknowledged in asset health governance.*

**Recommendations:**

- *Develop a corporate glossary to ensure asset health and associated terminology is used appropriately.*
- *This should include recognition of intangible or less tangible assets, particularly data and natural capital.*

All the interviewed staff were aware of the term 'asset health' and all knew that the Asset Management directorate has developed an asset health metric, termed base asset health (BAH).

No single definition of asset health was used by all interviewed staff. Many interviewees defined asset health in terms of serviceability, relating it to the ability of a physical asset to deliver its intended service. Some staff expanded this definition to include an ability of an asset to continue to deliver its intended service in the face of a shock or unexpected event.

Several staff used an analogy to explain their understanding of asset health, often using human language such as 'fitness' and 'tired', or expanded to include an ability to react effectively or 'sprint' in response to a shock. Most interviewed staff considered asset health to be affected by age and condition.

Although all staff were aware of the concept of asset health, it is apparent that several related but distinct terms are sometimes being conflated, particularly health, service risk and criticality. The distinction between these terms is important and it is recommended that UU develops a corporate glossary to ensure these terms are used in the appropriate context, for example:

> ***Asset Health: the ability of the asset to deliver service now and in the future*** *- though care should be taken to ensure understanding of failure probability for high impact, low probability of failure assets*
>
> ***Risk: an assessment including both the likelihood and credible impact of a failure or fault*** *(Source: UU Maintenance Policy)*
>
> ***Criticality: the significance of an asset or system in preventing a customer, environmental, compliance, safety or high cost incident*** *(Source: UU Maintenance Policy)*

We believe that the range of asset health definitions described by different UU staff reflects the gradual evolution of the asset health concept over time, influenced by a variety of concepts. These include, for example, Ofwat's

Licence Condition L regarding the maintenance of assets, Ofwat's original serviceability indicators, the UKWIR Common Framework, UU's asset health related performance commitments during AMP6, Ofwat's Resilience in the Round publication and the approaches to asset management described in ISO 55001 and by the Institute for Asset Management.

Where an interviewee used the concept of asset health to support the delivery of their responsibilities, it was typically used as one of a basket of indicators to inform decision making. Examples included using an asset health score as one of the input parameters to the OPTIMUS decision support tool, and using asset health in combination with criticality to inform operational decision making (both of these examples are expanded in subsequent sections of the report).

It was apparent that asset health is increasingly being used by staff as a decision-making aide, and that these applications are developing organically, in response to specific needs or the initiative of certain individuals. It is recommended that a governance structure is established to control and manage the use of the asset health concept, and the application of asset health measures in decision making.

Several interviewees highlighted the importance of quality data and robust data management to the health of assets. It is important that data is recognised as an asset in its own right. A large proportion of UU's existing and planned asset management initiatives relate to data capture, management and transformation and it is important that the link between healthy data and healthy assets is formalised.

Natural capital is another important asset for UU, and is one of the key themes in Defra's 25 Year Environment Plan (2018). UU leadership has acknowledged the reliance of its performance and delivery of good service to customers on natural assets and the OPTIMUS system includes biodiversity, sequestered carbon, and recreation as valued benefits. We understand that UU is currently formalising these benefits under a natural capital framework. UU also acknowledges the importance of working with stakeholders in understanding and managing natural capital, and it has previously taken part in Corporate Natural Capital Accounting projects for the Natural Capital Committee.

## 2.2 Understanding of asset health and risk to service

This first group of interview questions focused on measures of asset health, how these relate to broader definitions of resilience, the extent to which the link between asset health and service impact has been defined, and how critical assets are identified and managed.

**Questions asked:**

- *Elaborate and explain the logic for your definition and calculation of your asset health measure.*
- *Are consistent definitions of asset health (and associated supporting metrics) applied consistently across asset groups?*
- *Is asset data quality and type sufficient for effective quantification of asset health? If not, what steps have been taken to address this?*
- *How is asset health integrated into broader definitions of resilience?*
- *Are critical assets identified? Are all critical assets identified and ranked, considering failure likelihood and impact on services?*
- *Do you have an integrated asset management / resilience plan for your critical assets? Has this plan been stress tested?*

**Headline observations:**

- *The application of BAH to support planning and decision making is beginning to occur.*
- *UU's eagerness to learn about asset health approaches and asset management in other industries was highlighted by several interviewees and this has resulted in the adoption of several new practices.*
- *UU's incident response and contingency planning has utilised best practice government insight and planning principles however the quality of contingency plans varies between assets. UU acknowledges the need to address this.*

**Recommendations:**

- *As application of BAH grows, governance controls should be used to ensure consistency of approach and to prevent dilution of understanding.*
- *A clear line of sight from individual asset health measures to BAH and up to the Resilience Scorecard should be embedded in understanding and practice.*
- *UU's aspiration to move to a more structured and consistent approach to contingency planning should be prioritised. The recent Haweswater Aqueduct contingency planning could be used as a catalyst.*

### 2.2.1 Base Asset Health

Approximately 18 months ago, UU's Asset Management directorate developed the base asset health indicator (BAH). This was informed by a review of approaches to asset health adopted in other industries which found that several defined asset health on the basis of asset life expended. UU's eagerness to learn from approaches to asset health and other elements of asset management from other industries was highlighted by several interviewees and should be continued.

UU's BAH is calculated as the percentage of the economic life of an asset that has elapsed (with the option of applying a Bayesian adjustment), weighted by the gross modern equivalent value (GMEAV) of the asset. This weighting permits the comparison of asset health across all asset types and as such, BAH is considered a powerful metric which has the potential to support transparent prioritisation of investment decisions.

The accuracy of BAH, and therefore the benefit that can be derived from its use, depends on the accuracy of the likelihood and consequence models in PIONEER (Proactive Identification and OptimisatioN of Expenditure and Evaluation of Risk) which are used to determine when the cost of repairing an asset (and its impact on service) exceeds the cost of replacing the asset. BAH is available for most asset types though it is not universally applied.

The Asset Management directorate is currently developing dashboards in Tableau to present non-infrastructure BAH and GIS visualisations for infrastructure BAH. These dashboards are currently hosted on a SharePoint site; however, it is understood that future hosting on the DataHub is planned. Consideration should be given to ensuring the finalised dashboards source data from a validated, and ideally single source of truth. UU's development of a EXAsol database which can deliver this functionality is described in **Section 2.3.1**.

Reporting standards for BAH have yet to be defined, but should consider:

- Who BAH is reported to - Board reporting of asset health is discussed in **Section 2.6.3** and dashboards could be a powerful means of quickly communicating key information and trends at this level
- How frequently BAH reporting occurs
- At what scale BAH is aggregated for reporting purposes – this decision should be made considering the intended audience, and the decisions BAH will be used to inform. Care should be taken to avoid the potential of overlooking an important asset with a poor BAH by adopting too coarse an aggregation
- What procedures are required to ensure consistency in the application of Bayesian adjustments. It is understood that the following data for Bayesian adjustments is currently used:

- For civil assets, asset condition (though this is not regularly collected)
- For above ground and moving assets, reactive work order information
- For below ground assets, burst rates and blockage rates

- The medium for BAH reporting (such as a hosted dashboard or a standalone report)

Awareness of BAH within UU teams is now widespread and its application to support decision making is beginning to occur. This process should be encouraged, and championed by senior leadership; however, as awareness grows, governance controls will be necessary to ensure consistency of approach and to prevent dilution of understanding.

One example of the adoption and adaptation of BAH was provided by the Operational Engineering team. This group is combining BAH with asset criticality on a pilot site, Fleetwood Wastewater Treatment Works (WWTW), to assess the benefit of this bespoke measure in optimising operational decision making. Another example of the use of BAH is as one of the data entries that supports ranking of risk interventions. Clear procedures need to be developed to explain how BAH should be used and for which purposes.

In response to Ofwat guidance at PR14, UU adopted several performance commitments (PCs) for the AMP6 period which included measures of asset health. In particular, the wastewater network performance index includes the three asset performance indicators from the AMP5 sewerage infrastructure serviceability assessment (collapses, blockages and equipment failures), as well as rising main failures, which is the most heavily weighted of the four sub-measures. The wastewater network performance index is incentivised as penalty only. UU outperformed against this PC in years 1 and 2 with an index score of 90.95 and 89.47 against a target of 106.2 and 103.2 respectively. A breakdown of performance against each of the four sub-measures is reported and this helps to ensure particular asset health concerns are not hidden behind the overall PC score.

At the time of the interviews, a decision on the inclusion of company-specific asset health PCs at PR19 had yet to be made. Advantages and disadvantages of the adoption of BAH as a PC are presented in **Table 2-1**.

**Table 2-1: Advantages and Disadvantages of adopting BAH as a Company-Specific PC at PR19**

| Advantages | Disadvantages |
|---|---|
| • Provides a means of justifying expenditure in activities that maintain or improve asset health.<br>• Continues to build awareness and appreciation of importance of asset health to service delivery within UU.<br>• Helps to raise customer awareness, making ongoing engagement and discussions around future investment more straightforward. | • BAH is a component of asset health but does not give a complete understanding of the health of an asset. Its adoption as a PC could therefore risk other important components of asset health, such as condition or ability to respond to shock, being overlooked.<br>• Challenge of identifying appropriate targets.<br>• Potential cost to compile. |

### 2.2.2 Other asset health metrics and the link to service

UU collects a variety of data, on a wide range of assets that could be considered to reflect measures of asset health. Currently, this basket of measures is not organised under a corporate definition of asset health. By clearly defining which pieces of data support UU's understanding of asset health and by defining how each is used to inform decision making, collective understanding of the importance of asset health to decision making will be elevated. ***This will help to establish a line of sight to outcomes and demonstrate the linkages between asset health, service and customer impact.***

The basket of measures that collectively describe the health of UU's assets also aide the understanding of operational resilience, defined by Ofwat (2017) as "*the ability of an organisation's infrastructure, and the skills to*

*run that infrastructure, to avoid, cope with and recover from, disruption in its performance*". UU maintains resilience scorecards for water and wastewater and BAH is one of the measures reported. A clear line of sight from individual asset health measures to BAH and up to the Resilience Scorecard (see conceptual example in **Figure 2-1**) should be embedded in understanding and practice via a clear procedure or guidance document.

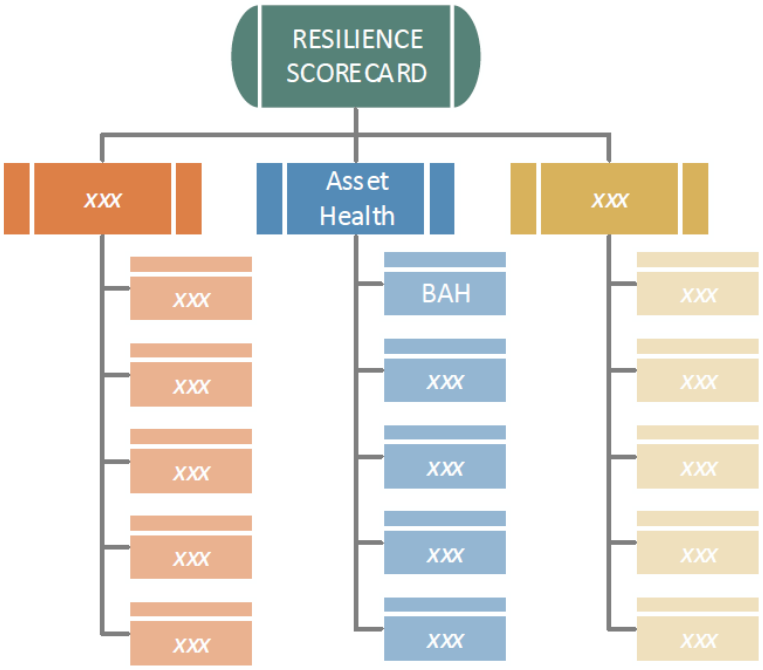



**Figure 2-1: Example Line of Sight from Asset Health Measures to Resilience Scorecard**

### 2.2.3 Criticality

The concept of criticality was widely understood by interviewees as relating to the consequence of asset failure and the significance of an asset in delivering customer service, environmental compliance and / or safety. It is therefore distinct to asset health and should not be confused or conflated. UU's maintenance policy defines criticality as "*the significance of an asset or system in preventing a customer, environmental, compliance, safety or high cost incident*".

As a component of its wider maintenance strategy, UU's Operational Engineering department is undertaking a regional exercise to assign a criticality ranking to all above-ground, non-infrastructure assets. Criticality scores (on a scale from A to E) are typically assigned by subject-matter experts (SMEs), considering outputs from consequence models in PIONEER. These models consider asset configuration and redundancy and some, for example for below ground assets, have been calibrated against real data. This process needs to be completed for above ground assets. Proximity to key receptors is accounted for on a site-by-site basis. A concern about visibility of consequence information in PIONEER was raised.

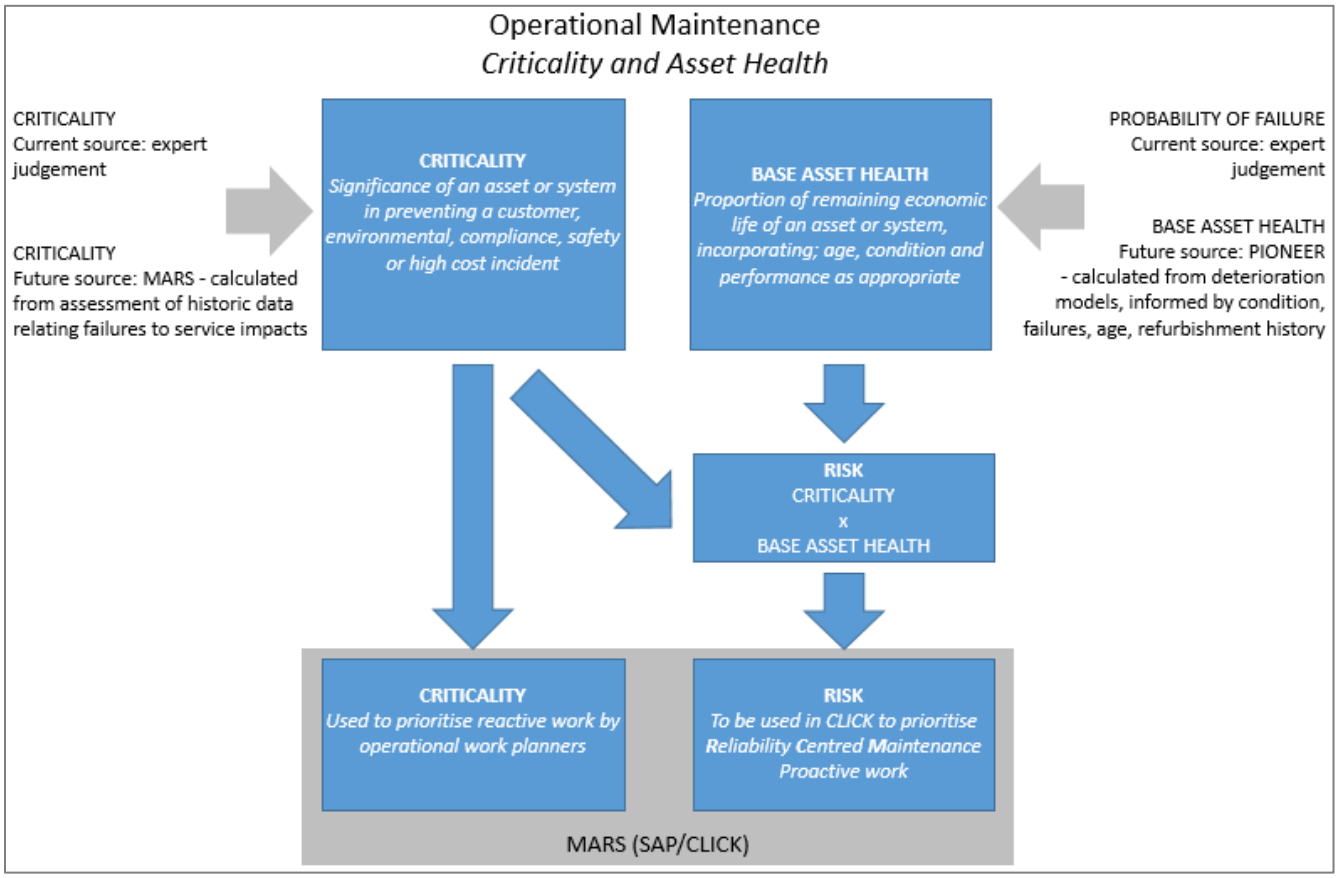
In general, the Operational Engineering department is attempting to increase the extent to which data is assessed during the assignment of criticality scores, by working more closely with Range Managers (refer **Section 2.4.3**) and the Asset Management directorate. For example, under the wastewater resilience strategy, criticality was assessed in two stages: at a site level by SMEs, and at an asset level by using data to consider what assets were likely to have the biggest impact to the site. We support this approach to ensuring criticality is assigned based on a broad appreciation of data and operational expertise.

The combined consideration of criticality, asset health and risk information to inform decision making is recognised as a powerful decision-making aide and it was explained how this approach is planned to be progressively

implemented (see **Figure 2-2**). Figure 2-2 is interesting because it starts to show how asset health is influenced by asset failure probability and by deterioration. This also highlights that there is a need for further granularity and understanding of these influencing variables. ***UU should ensure that the surrogates and parameters that are being used to estimate these factors are the most reliable, accurate and cost effective for each asset type. This understanding will be influenced by the scale of the risk that failure of such assets will present.***

Expanding the guidance presented in **Figure 2-2** to indicate how the output data should be used in decision making would be a useful enhancement for staff. The importance of maintaining distinct definitions of asset health and criticality, and explaining where and why these metrics should be brought together to inform decision making was emphasised by several interviewees.

Another approach to combining asset health and criticality information, though without the risk information presented in **Figure 2-2**, is being explored in the Fleetwood WWTW pilot referred to in **Section 2.2.1**. In this example, plots of asset value against BAH are prepared for each of UU's five criticality bands. This information is then used to inform the operational team's maintenance plans and is receiving good feedback from the site team, particularly because it provides a means of distinguishing between assets within a given criticality band.




Note: MARS (Maintenance and Asset Resource Scheduling) is a comprehensive work and inventory management system for above ground assets, built on SAP and CLICK software. PIONEER (Proactive Identification and OptimisatioN of Expenditure and Evaluation of Risk) is a corporate forecasting and optimising system for long term risk and expenditure planning. CLICK is scheduling software closely coupled to the SAP asset management software system as part of MARS

**Figure 2-2: Application of Base Asset Health and Criticality to Operational Maintenance**

### 2.2.4 Contingency planning

UU's event response planning is divided into business continuity planning (related to the recovery of office-based activities), and contingency planning (related to asset recovery). Our review focussed on contingency planning only.

We understand that existing contingency planning varies between assets, largely dependent on the experience or role of the person/s originally tasked with developing them. Although some contingency plans are detailed, asset-specific and customer-based (utilising defined customer segments and knowledge of sensitivity to different events), others are very simple, presenting standardised information and response measures only. Ownership of contingency plans is also split between central operations and asset owners.

We were told that UU has been quick to engage with Government under the *Civil Contingencies Act 2004*, especially in relation to planning for reservoir embankment failure and loss of service. UU has also adopted the Joint Emergency Services Interoperability Principles (JESIP).

To keep abreast of contemporary emergency planning, UU's approach to horizon scanning utilises Government resources and local resilience forums. The Cabinet Office Emergency Planning College is used for training and knowledge sharing and UU participates in a water industry network on emergency planning.

It was explained by interviewees that contingency plans to address relatively common events tend to be more refined, whereas those for infrequent scenarios are often less robust. This is likely to be a common situation among water companies and it is noted that UU performed comparatively well during the March 2018 freeze/thaw event. UU's response to this event indicates that it has effective contingency planning measures in place for high impact, low probability (HILP) events however these could be further strengthened by applying a consistent, risk-based approach to the development of contingency plans. We were told about the structure of incident management teams and in particular, the role of one team member to focus on identifying and planning for the worst-case scenario. We recognise this to be a valuable role, helping to ensure a wide range of potential events and their effects are considered and planned for.

It was explained that a contingency planning project for the Haweswater Aqueduct is underway and we were told that it is hoped this project can act as a catalyst to develop a more structured and consistent approach to contingency planning across the asset base.

## 2.3 Establishing the link between asset health, performance, service and outcomes

This group of interview questions focused on investigating the link between asset health and outcomes, considering the suitability of existing asset data and the line of sight from asset health to service and outcomes.

**Questions asked:**

- *Are assets and associated health data identified and described in robust data storage systems?*
- *Is asset health understood in terms of impact on asset performance, service and outcomes?*
- *What tools do you use to help model and predict asset health (now and in the future)? How do you link this to service impacts e.g. FMECA, deterioration analysis?*

**Headline observations:**

- *UU's asset data is currently housed on a number of systems which are, in some cases, isolated from one another. The MARS rollout is expected to help address this issue.*
- *We were told that UU has been relatively quick to adopt new condition monitoring technologies but less effective at embedding the necessary supporting process or developing the required staff skills.*

- *The development of a validated database (EXAsol) has the potential to significantly improve data governance, and confidence in decision making.*
- *UU has and continues to trial a variety of asset health monitoring technologies. Measures are required to ensure that the cost of trialling new technologies does not hinder advances in monitoring and performance.*

**Recommendations:**

- *The rollout of the EXAsol platform should be prioritised.*
- *To reduce the costs of developing and trialling new technologies, UU should seek to partner with other water companies.*
- *A formal means for UU staff to raise concerns or requests for technology development and trialling to the Innovation Team should be established. This would help to prioritise where investment should occur and would help to reduce the likelihood of particular aspects of asset health being overlooked.*

### 2.3.1 Collection and management of asset health data

It was clear from interviewee responses that UU already collects a large amount of asset data. Generally, interviewees characterised data challenges as relating to transforming existing data into useful and actionable information and improving consistency in data quality standards. Interviewees did explain that improvements to the existing asset registry had been made and that the digitising of old data is progressing. With this improved dataset, analyses such as T-RAM (Throughput, Reliability, Availability and. Maintainability) can be better supported.

UU's condition monitoring team has a regular inspection regime for non-infrastructure assets using vibration monitors and thermography. We were told that UU has been relatively quick to adopt new condition monitoring technologies but less effective to date at embedding the necessary supporting process or developing the required staff skills.

Procuring and installing the equipment required to collect UU's existing asset data and the associated data management provisions, are typically implemented through individual projects and hence UU's asset data is currently housed on a number of systems which are in some cases isolated from one another. UU is also in the process of digitising existing hard-copy asset data and is prioritising this process based on criticality.

A challenge for UU is that the staff who undertake repairs are not generally asset condition experts (repairs are contracted out). It is therefore hard to obtain good data on failure modes and as a result, standard values are often used (often the only piece of reliable information is the repair completed data).

UU's existing DataHub brings together some of its existing datasets to support decision making (OPTIMUS for example) however it does not incorporate any form of data quality assurance or validation. Any quality assurance checks must be initiated on a case-by-case basis and performed manually, typically towards the end of decision making process (see further discussion in **Section 2.6**). It should be noted that where followed, existing quality assurance measures were described as robust, and diligently applied by interviewees.

UU's Information Quality Management department is currently delivering a project with Talend to transfer data from UU's geospatial information system (GIS) and MAMS (inventory master for below ground assets) into a validated database (EXAsol). This data transfer occurs daily along with data quality checks (standard automated checks and bespoke SQL rules covering validity, consistency and accuracy). Any exceptions are recorded and presented to asset owners (generally at process level) for action.

Through these data checks, UU is moving the process of data quality assurance earlier in the assurance chain, thereby improving the health of its asset data, and the associated decision making it is used to inform. By ensuring that future decision making is based on data from EXAsol, governance will be strengthened and confidence in decision making increased. The EXAsol project has currently been rolled out for market reform datasets only

however the process acts as a blueprint for business-wide implementation. MARS data has recently (in the last six months) been added to EXAsol.

As a further step to improve data quality, during AMP7, the Information Quality Management department is planning to implement a master data management project, ensuring that new data is only ever entered into a UU data system once and then automatically linked to other associated data sets.

### 2.3.2 Tools and technologies to help model and predict asset health

The interviewees we spoke to provided details of a number of technologies and tools related to the measuring and modelling of asset health. These included:

- Sahara – acoustic logging and CCTV – used extensively on large diameter trunk mains to identify leaks
- SmartBall – UU is planning to deploy this technology to track the route of a main which provides entire potable supply to the Wirral
- Vyrnwy Aqueduct Project – UU worked with MWH and Exova to develop assess lining techniques. This led to academic paper and concluded that the pipe could utilise a semi-structural liner
- Australian consortium – consortium is assessing when a leak becomes a burst and is testing strain from passing vehicles using gauges. The work also included an assessment of available non-destructive testing (NDT) techniques and found limitations with all of these
- Microwave sensor research (expected project) – UU plans to test this technology, an alternative to acoustic sensing which can construct profile of internal and external pipe condition
- Pipediver – with WRc. An internal full-length pipe inspection tool – acoustics, ultrasonic and sensors
- Pipeguard Robotics – essentially a free-flowing version of Sahara. UU exploring whether this technology can be trialled
- Metering of all trunk mains – to enable water balance calculations – helps to pinpoint detection work
- Satellite detection – of leaks, informed by tile balance, then use Snipe the dog to pinpoint leaks
- UU looking at Syrinix for trunk mains (TrunkMinder) and transient monitoring – UU plans to trial this
- Smart pipe with strain sensors, either built in or retrofitting. UU currently has an above ground pilot. Concern over the smart element potentially becoming a constraint or limiting factor on maintenance
- Sewers – testing the use of fibre optic cables in sewers that can give depth, velocity and acoustics readings (as well as providing a telecommunications service). In this instance, the challenge of knowing how to use the data that could be provided was highlighted

UU's primary means of horizon scanning on asset inspection technologies is through the Technology Approval Group (TAG) run by Isle and launched in 2005. This group maintains a database of technologies, including technology readiness levels. The Innovation Team maintains this relationship and also acts as the entry point for suppliers. The Innovation Team is responsible for meeting UU's strategic aim in this respect.

UU staff can inform the Innovation Team of gaps in knowledge or concerns to explore. The Innovation Team can then explore these issues with contacts or at conferences for example. UU's other avenues for engaging with the industry are as follows:

- Through its relationship with UKWIR, UU can help to guide to guide the organisation's research. UU also has an interest in a major piece of work between UKWIR and an Australian consortium on NDT technologies
- WaterUK water distribution infrastructure network (run by industry) meet once a quarter and this often leads to follow on research/projects

- UU supports STREAM to encourage academic involvement in the industry. The STREAM programme is delivered by a consortium of five collaborating universities and brings together diverse areas of expertise to train engineers and scientists with the skills, knowledge and confidence to tackle the challenges faced by the water sector

## 2.4 The influence of asset health on investment planning and decision making

This group of interview questions focused on assessing how, and to what extent, asset health influences investment planning and operational decision making.

**Questions asked:**

- *How are asset health metrics used to inform decisions made on (timely and cost effective) interventions to maintain appropriate levels of asset heath and service?*
- *How will the underlying pressures affecting decision making for PR19 impact asset health and constrain asset health initiatives? How are these factors being addressed and considered when prioritising investments?*

**Headline observations:**

- *The mandated use of BAH in the assessment of competing projects in OPTIMUS is an important advancement, as is the parallel development of a tool which enables the user to vary the extent to which certain service outcomes are pursued.*
- *It is important that projects which maintain a base level of asset health compete effectively for investment with projects that address acute issues.*
- *The transfer of information, and methods of communication between planning and operations is recognised as an area of required improvement by UU and several initiatives are underway to address this. The Range Manager role appears to be a powerful means of re-establishing the connection between engineering and operations and for improving the flow of information from planning to operations and, importantly, vice versa.*

**Recommendations:**

- *A leadership focus on systems thinking and the importance of integrated decision making across planning and operations would help to emphasise the role of asset health to the overall performance of the system.*
- *The importance of BAH as a decision making and long-term planning metric should be promoted (regular Board reporting would support this aim). Clearly linking BAH and asset health to performance commitments would be beneficial (the leakage target for example).*
- *The number of Range Managers should be regularly reviewed to ensure all disciplines and asset types are appropriately represented.*

### 2.4.1 Asset health in investment planning

We were told that OPTIMUS is the tool used to inform the selection of risk mitigation options, on the basis of benefit and value for money. OPTIMUS utilises a set of monetised investment drivers (grouped into outcome delivery incentives (ODIs), statutory requirements, and spend to save drivers) which have been mapped to performance commitments (PCs) and the asset base. A user who wishes to score a project selects the investment drivers to which it relates. Each investment driver has a series of predefined questions which then prompt the user to consider the risks and risk benefits associated with their proposed project, as well as the level of confidence they have in their answers. Some questions are automatically answered by drawing on stored data whilst others require user entry.

Once the above process has been used to derive an aggregated risk score, this score is then automatically monetised (we were told that this process utilises willingness-to-pay information) resulting in a risk benefit value assuming the project is implemented. The Investment Planning department can then use this score (and its relative

ranking against other potential projects) as a factor to inform the development of an investment portfolio. The process of prioritising investments is therefore manual, and to an extent, subjective.

OPTIMUS has been used by UU for approximately eight years and has recently been updated to automatically include BAH in its calculations. BAH was previously an optional data entry, but typically unused.

The updated version of OPTIMUS has been used in AMP7 planning, with GMEAV-weighted BAH values extracted from PIONEER and then analysed to determine an average (mean) BAH for each component (civil, mechanical, etc) for each site. This procedure gives the user a value for a metric termed the Asset Health Risk Factor (AHRF), though it should be noted that the value can be overwritten by the user if required.

In the version of OPTIMUS used for AMP6 planning, projects were ranked by monetising the risk benefit assuming the risk mitigation measure / project had been implemented. In the newer version (used for AMP7 planning), monetised risk positions are estimated before and after the implementation of the potential project.

It is unclear what impact the changes to OPTIMUS for AMP7 planning will have on prioritisation and UU could consider exploring this impact in more detail. Questions to consider include:

- Whether mandating the inclusion of BAH alters the risk scores generated. Do certain types of project or projects on certain types of asset now achieve higher risk benefit scores?
- Does the pre-intervention assessment of risk influence option selection?

Because OPTIMUS combines automated and user-controlled data entry, the accuracy of the final risk benefit score could vary significantly. Whilst it is noted that users are required to assign a level of confidence to their data entries, a means of standardising this assessment may help to overcome opinions of confidence and help to enhance the comparability of risk benefit scores. The potential development of a data quality indicator in EXAsol, described in **Section 2.6.1**, has potential benefit in this respect. A mechanism to allow users to annotate their scores to justify data entries would also help.

A new tool to support option prioritisation is also being developed by UU which tags potential projects to particular service outcomes and then allows the user to vary the extent to which certain service outcomes are pursued. This allows a user to consider which portfolio of potential projects might best achieve a certain outcome, and appears to provide a powerful and flexible decision-support tool to complement the monetised benefit scoring in OPTIMUS.

One query that was raised with interviewees was the approach for comparing HILP and low impact, high probability risk mitigations with the same monetised risk benefit. ***It was stated that there was no formal policy to address such a scenario, but that attention would typically be addressed towards high probability risks first***. The presence of any 'materials of concern' (e.g. asbestos) is also used as a differentiating factor.

***Case Study: February and March 2018 Freeze/Thaw Event***

One example of the potential impacts of deteriorating asset health are the freeze/thaw events that effected several water companies over February and March 2018. UU's review of this event found that:

- Proactive measures implemented in advance of the thaw were effective in ensuring customer awareness and operational readiness which in turn provided an effective foundation for the response phase.
    - This included a detailed customer communications plan, including the development of specific video content to help customers manage frozen pipes within their homes. UU's ability to reach a large portion of its customer base with this content appears to be aided by its broader winter readiness digital campaign on Facebook, Twitter and YouTube which achieved 3.78 million views of its winter advice.

- Other preparatory actions included suspending planed asset improvement works, increasing out of hours resource levels and boosting the availability of contingency options such as alternative supply vehicles and bottled water.

- During the thaw response phase, UU deployed a 24/7 team to proactively manage operations, including managing supplies within the network and between storage facilities, as well as to coordinate proactive and reactive customer communication.
- Over the period of the freeze/thaw event, no service reservoir ran empty and water treatment works production was maintained throughout. Customer impact was considered to be managed effectively with low customer contact rates given the scale of the weather impact (total 356 customer contacts). There were more than 96,000 proactive communications to customers, over 50,000 views of UU's incident web page, over 18,000 views of its information on dealing with frozen pipes and over 15,000 views of its video on defrosting frozen pipework.

Ofwat's (2018) report into the event states that UU "performed well and largely met its customers' expectations". In particular, it commented that:

- UU's preparations and the nature of the company's response meant that it was able to maintain relatively normal levels of service to customers
- UU's incident management appears to have worked well with clear timelines on the implementation of the company's response plan and clear structures, responsibilities demonstrated and evidence that staff were aware of, and had been given adequate training, in relation to that plan.
- UU's ability to monitor the network and its access to real time information on network performance, enabled it to identify the sources of leaks and respond and complete repairs quickly.
- UU was proactive in communications with customers and used a range of different channels to raise awareness, provide advice on preparing for the cold weather and to update customers during the incident.
- Early and ongoing engagement and collaboration with Local Resilience Forums, local councils, NHS Cumbria etc, formed an essential part of UU's planning for, and response to, the incident.

***Ofwat commented that it would like UU to help share best practice across the sector.***

Another query raised during the interviews was the difficulty of making an investment case for the base level of expenditure necessary to maintain asset health. It is challenging to link this type of investment to an immediate benefit, unlike for acute problems. As such, there is a risk that asset health may gradually deteriorate, potentially crossing some currently unforeseen threshold that in turn requires significant corrective investment. To address this concern, the Investment Planning department and Asset Management directorate are working together to try and identify ways to ensure base levels of maintenance compete effectively for investment with other potential projects. These could include:

- Utilising data to better understand asset health in a systems context (to an extent, this has been done on the Manchester Resilience Project)
- Better utilising and transforming existing data to enable asset and incident management to become less reactive (the forecasts in PIONEER do support this aim to an extent)
- To further elevate the awareness of asset health and BAH, for example via regular internal reporting
- Adopting BAH as a company-specific PC or KPI during AMP7 to provide a clear justification for investment to understand and maintain asset health
- In wastewater networks, using the requirement on UU to demonstrate resilience to justify developer charges

### 2.4.2 Decision making for PR19

It was highlighted by a number of interviewees that investment during AMP7 is likely to be targeted towards smaller, more tactical projects which focus on making existing assets work more effectively. There is a risk therefore that whilst operational innovations and response measures (such as advanced vehicle fleet and pressure management) may improve the overall levels of service that UU delivers to its customers, asset health may deteriorate over the investment cycle. One asset type where this scenario was highlighted as of particular relevance was water networks (it was highlighted that UU's rate of mains replacement has fallen during AMP6).

If the health of a particular asset does gradually deteriorate, it may make the future crossing of a particular asset health linked performance threshold more likely. It may also make the asset in question less capable of effectively responding to or accommodating a shock to the system, such as the March 2018 freeze/thaw event. To address the potential for a decline in underlying asset health, UU could:

- Promote the importance of BAH as a decision making and long-term planning metric. Regular Board reporting would support this aim, as would adopting BAH as a PC or KPI for AMP7
- If BAH is not adopted as a PC, clearly linking BAH and asset health to PCs would be beneficial (the leakage target for example). It will be important to understand and acknowledge the relationships between trends in different performance commitments e.g. a focus on leakage reduction will drive up the number of proactive repairs hence the proxy for asset health (repairs) will rise even if burst rates fall
- Focus on systems thinking and the importance of integrated decision making across planning and operations. This would emphasise the role of asset health to the overall performance of the system and would help to optimise activities such as inspection regimes
- Seek ways to demonstrate the importance of expenditure in data management systems which can help to support an improved understanding of asset health (some of the resilience initiatives e.g. telemetry and monitoring, will help to generate valuable data in this regard). Particular assets which interviewees highlighted as requiring improved data on asset health were brick sewers and some trunk mains

### 2.4.3 Asset health in operational decision making

Whereas the cost-benefit analysis presented in OPTIMUS is the method primarily used to inform investment planning, operational decision making within UU has typically prioritised action towards assets which exhibit the greatest perceived risk. Situations can therefore arise in which operations staff are presented with investment decisions made on the basis of cost-benefit analysis which may not align with their own perception of where investment should be targeted.

The transfer of information and methods of communication between planning and operations is recognised as an area of required improvement by UU and several initiatives are underway to address this. The Operational Engineering department was established in 2016 to move engineering expertise closer to the field (an ethos of 'pervasive engineering' was conveyed by interviewees). This has enabled operational problems and challenges to be reconsidered from an engineering mindset and, alongside a reinforced focus on root cause analysis and T-RAM (adopted from the nuclear industry), this has helped Operations better target its interventions. For example:

- By revisiting data analysis procedures at WWTWs, and by sourcing new data on inlet screen performance from generators, a new inspection regime was developed. UU is now using a pilot site to demonstrate new ways of working and to record benefits to justify roll out of approach
- UU has deployed pressure monitoring and modulating valves to a portion of its network and is using learning algorithms to optimise operation. Proliferation of this technology will depend to a considerable extent on battery technologies
- The network modelling team uses Optimatics software to test multiple options and assess multi-criteria performance in order to prioritise projects using Infoworks modelling data

In recognition of the specific engineering expertise necessary to obtain maximum value from different asset types, UU has established the roles of Range Managers and Field Engineers. The pool of Field Engineers (currently numbering around 40) have the responsibility of ensuring that as projects are constructed, asset supportability is also developed. Range Managers are experts in a particular price control (e.g. water resources, network plus, bioresources) and use data from Field Engineers to make better decisions about issues such as maintenance regimes and to develop improved guidance, including dashboards focused on reliability and maintainability, for operators of particular asset types. Range Managers are currently working to i) obtain accurate asset inventories ii) ensure all assets are coded iii) ensure appropriate maintenance planning and deployment (proactive, inspections, reactive) in accordance with an 11-stage process (see **Figure 2-3**).

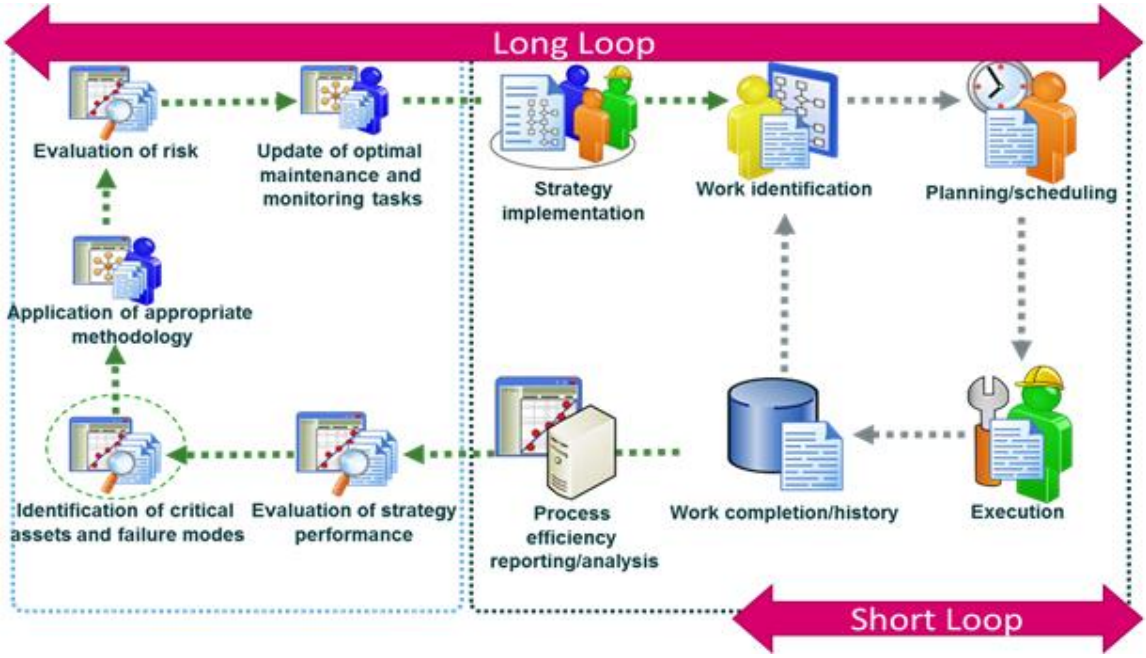



**Figure 2-3: Wholesale Maintenance Planning and Deployment 11 Box Model**

There are currently nine Range Managers and an intention to increase this number. The Range Manager role appears to be a powerful means of re-establishing the connection between engineering and operations and for improving the flow of information from planning to operations and, importantly, vice versa. We were shown updates to Board reporting templates which present charts, traffic-light scores and registers in PowerPoint. These templates provide a visually stimulating and effective means of identifying and conveying important information.

Not all interviewees were aware of the Range Manager role, and/or how Range Managers and their responsibilities would influence their work. Whilst this may, to a large extent, reflect the limited time this role has existed, it is recommended that company-wide communications are undertaken to explain the role of Range Managers and how this role can benefit their performance. In turn, this should improve the extent to which operational guidance is followed, a concern that was highlighted by several interviewees. The improved accessibility of data that is expected to accompany MARS should also help to address this concern.

Area asset management meetings were identified as useful forums through which operational teams can raise concerns with the persons and teams with authority to respond. They were praised by several interviewees as being helpful in quickly agreeing operational responses. Concerns over the transfer of information between planning and operations remained however and were flagged by many interviewees. This suggests that the area meetings should be made more regular, or formalised as a more important avenue for decision making.

## 2.5 Communication and the views of the customer

This group of interview questions focused on evaluating the extent to which UU has engaged its customers on its approach to asset health.

**Questions asked:**

- *Have you developed an effective 'language' for conveying asset health concepts to customers?*
- *Have you had a dialogue with your customers regarding asset health?*
- *Do asset health metrics and associated data support this dialogue?*
- *What value do your customers place on asset health and how is this evidenced?*

**Headline observations:**

- *UU recognises the importance of asset health to service delivery and is therefore committed to engaging customers to understand their views of asset health.*
- *UU is actively developing ways to discuss asset health (a challenging concept) directly with its customers.*

**Recommendations:**

- *To support its customer engagement, UU should be clear about what it means by asset health and how this concept is measured and used in the business.*
- *Conducting an asset health questionnaire internally would provide valuable insight to the relative understanding of the concept and would help to target future awareness raising.*

Asset health is a challenging concept to convey to the public and as such, it is our understanding that the majority of water companies have not had direct discussions about asset health with their customers. Whilst this is also true of UU, we were told that it has inferred its customers' views on asset health from discussions regarding service. It has also held asset resilience discussions with customers in relation to the Manchester Resilience Project.

We were told that inferred links between customers' views of service and asset health were based on a recent study and were shown a report which linked service valuation rates (for example for flooding instances or improving rivers to good status) to asset health measures (such as collapses or non-compliant WWTWs).

We were told that UU is planning to engage its customers directly on the subject of asset health during 2018. It is understood that this engagement will be through its WaterTalk group of approximately 7,000 customer volunteers and will also include its customer challenge group (CCG). A draft of the proposed questions was shared with us. In general, we commend UU's commitment to discussing asset health directly with its customers and we believe that UU is leading the UK water industry in this respect. The proposed engagement could be enhanced by:

- Being clearer about what UU means by asset health. This comment reflects a broader observation that UU should develop a clear lexicon for its assets, covering topics that include health, resilience, risk and criticality
- Being clearer about how UU measures asset health and how this links to the services customers receive

We support the idea of holding asset health discussions with customers in two forms: a pop-up community of talks over three to four days, and a more focused engagement process using specific questions.

To support the common understanding of asset health language, and to continue to raise the profile of asset health with UU staff, the proposed customer questionnaire on asset health could also be circulated internally. This process may provide valuable insight into the relative understanding of different departments.

## 2.6 Asset health assurance

This group of interview questions focused on understanding how UU assesses and responds to its asset health performance and to what extent asset health performance is reported at Board level.

**Questions asked:**

- *How successful have you been in delivering your asset health commitments and why?*
- *What assurance processes do you have in place to ensure that your asset heath related obligations (the general duty to maintain your system) are being met?*
- *What assurance and testing is done on new assets to help ensure that they will achieve their intended design life?*
- *Do asset health metrics and associated data support dialogue with the Board and reporting to Ofwat?*

**Headline observations:**

- *UU use a triple line approach to business planning assurance involving internal departments and business processes, third-party assurance and Board sign off of the plan. This is industry-leading practice.*
- *UU's Maintenance Optimisation team conducts investigations to identify operational performance issues however their ability to do this is constrained by limited human resource.*
- *UU's assurance of data quality typically occurs after data processing and once draft conclusions or business cases has been prepared. The rollout of UU's EXAsol platform presents an opportunity to address this inefficiency, thanks to its application of quality checks each time data is drawn from a source system.*

**Recommendations:**

- *Given the human resource constraints on identifying operational performance issues, data analytics and machine learning have significant potential and should be prioritised for investigation.*
- *Concise and visually powerful reporting of asset health information to Board should continue. The dashboards being developed by the Asset Management directorate appear to be a suitable approach.*

### 2.6.1 Assurance of operational data

UU responds to asset health performance in two ways. For asset health metrics that have associated targets or commitments, and in instances when performance is off-track, UU mobilises an audit team to investigate the issue, identify a cause or causes, and initiate processes to rectify the problem.

In addition, UU's Maintenance Optimisation team analyses operational data and alarms from the integrated control centre (ICC), a hub for control of operations, to identify potential issues for root cause analysis and action. This team currently comprises three persons and therefore its ability to evaluate data is significantly constrained. As such, there is significant potential for the application of data analytics and machine learning to convert data on asset health performance into actionable insights (this is discussed further in **Section 4.7**).

UU's assurance of data quality typically occurs after data processing and once draft conclusions or business cases have been prepared. This introduces potential inefficiencies if data errors are observed and analysis has to be repeated. The rollout of UU's EXAsol platform (referred to in **Section 2.3.1**) presents an opportunity to address this issue, thanks to its application of quality checks each time data is drawn from a source system. The dashboards the validated database can then be designed to include an indication of data quality and suitability for use. ***This initiative is an excellent example of a lifecycle approach to data quality assurance and would support more efficient and reliable decision making***.

### 2.6.2 Assurance of project delivery

UU's approaches to project risk appraisal and project delivery assurance were discussed with interviewees. We were told that project risk appraisal occurs throughout project optioneering and that risk appraisal at outline design drives the identification of which components of the project require assurance, and at what level (either UU assurance activities, contractor assurance activities, or a recording and tracking of risks). We were told that UU and contractor assurance activities run in parallel and that UU's approach to project assurance has four components:

1. Technical governance (will the contractor meet the solution requirements)
2. Commercial assurance
3. Programme and project management
4. Safety, Health, Environment and Quality (SHEQ): with safety, health and environment focused on construction, and quality focussed on the final asset, including construction supervision and commissioning to ensure UU operators can confidently operate the equipment safely and effectively. Product guarantees also provide a level of assurance over quality

We were told that UU is working to develop more targeted assurance practices (a concept of predictive assurance) focussed towards the highest risk components. Accurate and reliable data is crucial to this process and the need for better data on contractor systems was highlighted, by harnessing the benefit from recent technology advances in time lapse or feature recognition for example.

These observations point to the need for continued advancements in the implementation of Building Information Modelling (BIM). UU's BIM excellence programme has already delivered a number of significant advances, including:

- Information requirements (e.g. common data environment and BIM) are mandated through Section 13 requirements (developed by the BIM/Digital Steering Group). This has been a challenge for smaller suppliers and the extended supply chain (for example, associated with licence requirements, though this particular issue has been addressed in some cases by migrating to a cloud-based platform).
- UU has worked with its supply chain to optimise elements of its data and information system (C2V+[1] and ProjectWise[2] for example).
- UU requires suppliers to price for a legacy Digital Asset Information Model separately. On large projects, some supplies have opted to incorporate this as a core component of their offer.
- Suppliers are increasingly seeking to deliver added value through technology, for example, using drones, developing intelligent piping and instrumentation diagrams, virtual reality and augmented reality (such as by overlaying condition).

Tackling legacy data issues and embedding BIM as an integral component of project delivery were flagged by interviewees as ongoing tasks. We were shown slides describing the BIM self-assessment and consider this to be a useful tool for understanding the relative progress of BIM implementation in different parts of the business.

One interviewee understood that it would be a requirement of future projects and programmes of work to report on their impacts on asset health. It is not clear if this is a formal strategy and it is understood that the specifics of the process are still being developed.

[1] C2V+ is a joint venture between Jacobs-CH2M and VolkerStevin delivering end-to-end infrastructure solutions. It currently operates on UU's AMP6 construction delivery partners framework.
[2] ProjectWise is a platform for collaborative work sharing.

### 2.6.3 Asset health reporting to Board

Currently, UU's regular reporting to Board is largely based on the company's PCs and ODIs. If BAH were to be adopted as company-specific PC, the Board's awareness of asset health, and appreciation for its importance in the delivery of service to customers, would continue to grow. Current periodic Board reporting also includes the tracking of significant risks and their mitigation, or which asset health is an important factor. Ofwat also expects board-level assurance around resilience, of which asset health is one component.

Whilst interviewees acknowledged the importance of Board awareness of asset health, concerns were raised that regular reporting on asset health might overwhelm the Board members with information. This concern reflects a need to effectively structure reporting, rather than reflecting a justification for not reporting at all. Concise dashboards (as currently being developed by the Asset Management directorate) might be an effective communication method, allowing Board members to drill down through asset health information as desired. These dashboards could then be supported by an annual State of the Assets report.

## 2.7 Innovation and collaboration

This group of interview questions focused on evaluating how UU is encouraging innovation in initiatives and technologies that support improvements in asset health.

**Questions asked:**

- *How is UU's asset health strategy and project history shared to promote future innovation and collaboration? How are continuous improvement and lessons learnt captured and implemented?*
- *How does UU obtain information on best practice approaches to asset health?*
- *Does UU engage peers, other organisations and its supply chain in this process?*
- *Are there barriers to innovative approaches to asset health management and how can these be overcome?*

**Headline observations:**

- *UU's Innovation Lab is a valuable platform for suppliers to innovate in partnership with UU experts.*
- *It is clear that innovation is a core component of UU corporate culture, as instilled by its leadership. A variety of platforms for innovation exist, however they could benefit from an overarching framework.*
- *We understand that UU is determining the skills it will require to deliver its future services.*

**Recommendations:**

- *The Innovation Lab should be evolved into a continually available platform, providing potential suppliers with a clear and continually-available avenue through which to engage UU.*
- *Additional internal innovation platforms, or an overarching framework, could help ensure a collective focus on innovation from all staff.*
- *A tool which automatically interrogates a lessons learnt / innovation database and pushes examples to project developers and decision makers at appropriate points in the project lifecycle would be beneficial.*
- *We recommend that UU develops a clear roadmap for the progressive development of staff skills to meet future requirements.*

### 2.7.1 Internal information sharing

It is clear that innovation is a core component of UU corporate culture and that this message is regularly promoted by its leadership. We understand that staff surveys indicate that a large majority of staff (84%) feel able to develop new ideas.

UU's internal sharing of new innovations, best practice and lessons learnt occurs through several means:

- An Innovation Hub, where Range Managers, the GIS team and UU technology experts co-locate, allowing ideas and information to be quickly shared and refined
- A lesson learnt / innovation database where staff can record and access examples of best practice. It is not clear whether this includes observations from maintenance optimisation audits, and the associated actions, responses and benefits
- Sharing of best practice on Yammer (a corporate information sharing platform), such as the example of combining BAH with criticality by the Operational Engineering department
- A series of dashboards, being developed by a variety of teams (Asset Management directorate and Range Managers for example)

We were also told about UU's CEO Challenge for new graduates, a structured platform for teams to test and trial new technologies. As well as leading to new innovations for the business, it was highlighted that the programme gives new starters the opportunity to quickly build an internal network of contacts, and knowledge of internal project development processes, which they can they harness throughout their careers. Notwithstanding this benefit, a formal platform for innovation for non-graduate staff may help to reinforce some of the learning from the CEO Challenge, and help to explain UU's approach to innovation to those that join the organisation later in their careers.

It is understood that UU's existing lessons learnt / innovation database is currently being refined. Several interviewees highlighted that the existing structure, and requirement for users to manually search through case studies is clumsy and time consuming. We agree that a tool which automatically interrogates the database and pushes relevant examples to project developers and decision makers at appropriate points in the project lifecycle would be beneficial. Clear guidance on the recording of lessons learnt and innovations will also ensure that the database remains up to date and as comprehensive a resource as possible.

Using dashboards to convey important information can be highly effective and we endorse their use within the organisation. Care should be taken to ensure that the dashboards developed by different teams communicate a compatible message and that they use common data, ideally sourced from the validated EXAsol database.

We asked interviewees about current barriers to the collaborative development of new solutions and were told that these typically stem from issues concerning data, for example, consistency of data structures and understanding of the reliability and accuracy of particular pieces of data. Several interviewees were also concerned that the data components of projects can sometimes be descoped from business cases. This observation highlights the need to communicate the importance of healthy data to healthy assets and healthy projects. The BIM Excellence Program is an important component in this respect.

We understand from the supporting information we were provided that UU does not currently have a dedicated internal platform to facilitate and refine ideas and potential innovations (we note the externally-facing Innovation Lab described in **Section 2.7.2**, and the CEO Challenge for new graduates). It was explained that the Range Manager role, and the business focus on pervasive engineering should help to empower engineers to investigate operational issues and devise solutions by working with operations colleagues. Depending on how well the Range Manager role is able to deliver these outcomes, it may be beneficial for UU to develop a dedicated innovation platform accessible to all its staff.

We spoke to the Wholesale Technology Manager and were told that UU is currently developing a vision and technology roadmap to integrate strategies related to physical assets, operational data and information and digital technology, informed by an assessment of approaches adopted in the energy industry. This process highlights the importance of ensuring that decisions made in one domain of UU's business consider the knock-on impacts in others, and that initiatives deliver outcomes that benefit all areas, thereby optimising UU's delivery of services to its customers.

UU is also mapping capability requirements on to the technology roadmap, improving visibility of the skills that UU will require to operate its business in future. We understand that this activity is part of broader planning to determine the skills UU will require to deliver its future services. This is a prudent step and we recommend that UU develops a clear roadmap for the progressive development of skills in all services.

### 2.7.2 Industry and supply chain engagement

Our discussions with interviewees suggest that UU currently promotes innovation in its supply chain by three principle means: via its Innovation Lab, via twice yearly innovation days, and by engaging the supply chain and academia in response to specific problems or needs.

UU's Innovation Lab is a programme consisting of a call for applications for innovations that could benefit UU's business, a short-listing and selection process, and a 10-week programme for seven successful applicants that includes:

- Colocation and mentoring by UU business leaders
- Access to test, improve and demonstrate their product/service in live customer environments to UU experts and decision makers
- Access to potential investment opportunities

We agree that the structure of UU's Innovation Lab programme provides a valuable platform for suppliers to innovate in partnership with UU experts and we consider that UU's platform compares well to those of other UK water companies. We believe that:

- The use of an independent innovation specialist (in the current programme this is L Marks[3]) to facilitate the programme will help to ensure that the challenges commonly faced by small companies developing and commercialising new products can be addressed
- As the current programme matures, developing an ongoing and continually available avenue for innovators to present their ideas will maximise the benefits that UU can derive from its supply chain (the current programme occurs over a fixed period of time). We understand that plans to repeat the Innovation Lab programme are being developed
- Keeping the supply chain up to date on UU's priorities, emerging concerns and acute issues will give potential suppliers the opportunity to align their research and development programmes to UU's needs

We were also told that in instances when suppliers approach UU directly with a new idea or product outside the Innovation Lab programme, the Innovation department reviews the product/idea and, if of potential value, provides opportunities to develop the product/idea with UU staff. By evolving the Innovation Lab programme into a continually available platform, potential suppliers would have a clear and continually-available avenue through which to engage UU.

The interviewees we spoke to provided several examples of how UU has innovated in response to particular problems or issues, often engaging academia and experts outside the industry. For example:

- UU experienced a 'near miss' emergency event at one of its dams in 2002. In response, UU worked with the Health and Safety Executive (HSE) and subsequently engaged the University of Utah to develop a methodology to calculate the likelihood and impact of dam failure. This process provided a means of calculating the probability and consequence of failure for every dam in the fleet. With this information, UU's long term objective is to manage the risk of dam failure so that there are no dams remaining in the red or

[3] https://lmarks.com/

yellow categories of HSE-defined ‘intolerable risk’. UU has also committed to repeating the portfolio risk assessment every AMP cycle, to ensure that its decisions are based on the best available evidence

- UU engages in Water Industry Maintenance Workshops which include participants from all water companies, and Heathrow Airport. This platform was praised by interviewees for promoting information and best practice sharing and has included a workshop on asset health
- UU also continues to engage the industry via peer bodies and professional networks (e.g. Panel Engineers)

# 3. Analysis of United Utilities' approach to asset health against Ofwat expectations

Ofwat considers assets health to be an indicator of a company's ability to continue to perform its functions for the benefit of customers and the environment, now and in the future. It contributes particularly to the reliability and response / recovery elements of infrastructure resilience. Poor asset health is when assets deteriorate to a point where the risk of failures (which will impact on customers and the environment) becomes unacceptably high (note: this is a conflated view of asset health). The health of a companies' assets is therefore a crucial element of achieving resilience.

At PR14, Ofwat encouraged companies to develop bespoke approaches to asset health. It believes that whilst this approach did lead to some innovation (particularly through the use of different indicators and different methods of assessing performance), it is also their opinion that it resulted in inconsistency in approaches across companies, thereby reducing comparability and transparency. In addition, many companies combined asset health measures into aggregated performance commitments.

The *Water Act 2014* gave Ofwat an additional primary duty to further the long-term resilience of water and wastewater services, and the UK Government has also made it clear that the resilience of the UK's water resources infrastructure is a key priority in its approach to water sector policy.

At PR19, Ofwat would like companies to:

- Have four common performance commitments on asset health: mains bursts, unplanned outages, sewer collapses and treatment works compliance (though Ofwat notes that metrics of asset health are imperfect and that it is therefore appropriate that asset health outcomes are only part of Ofwat's, and other stakeholders', approaches to ensure companies maintain asset health)
- Select metrics for bespoke performance commitments from a long list of asset health metrics with standard definitions
- Choose, where appropriate, their own asset health performance commitments outside of the common performance commitments and the long list, to enable companies to innovate in their approach to asset health and reflect any asset health issues specific to the company. Companies should engage with their customers and local stakeholders on their bespoke performance commitments
- Use individual performance commitments for asset health, and not aggregate them when reporting, to promote transparency
- Clearly present the approach to asset health outcomes in business plans
- Engage with customers on how their asset health performance commitments protect current customers, future customers and the environment
- Ensure that asset health performance commitments are easy to understand

Ofwat expects companies to have identified and, if necessary, addressed any existing issues (such as those identified through the *Targeted Review of Asset Health*) in the current price control period.

The concept of asset health feeds into the broader concept of resilience and Ofwat's PR19 methodology includes resilience tests for the assessment of business plans. Its concept of Resilience in the Round is core to how companies should approach this issue. It includes:

- Corporate resilience: the ability of an organisations governance, accountability and assurance processes to help avoid, cope with and recover from, disruption of all types; and to anticipate trends and variability in its business operations

- Financial resilience: an organisation's ability to avoid, cope with and recover from, disruption to its finances
- Operational resilience: the ability of an organisations infrastructure, and the skills to run that infrastructure, to avoid, cope with and recover from, disruption in its performance

**Table 3-1** presents Ofwat's asset health outcome expectations for PR19, reproduced from Appendix 2 of the 2019 price review methodology. Our initial assessments of UU's compliance or likely compliance with each expectation is also outlined.

**Table 3-1: Ofwat's Asset Health Outcome Expectations for PR19**

| Expectation | UU Approach |
|---|---|
| Companies should clearly present in their business plans, their approach to asset health and which of their performance commitments and ODIs relate to it. | *NA – no draft business plans have been reviewed as part of this project* |
| Companies should engage with their customers and CCGs on how their asset health metrics protect current and future customers and the environment. | UU is planning to engage its WaterTalk group and CCG on asset health and we have reviewed draft questions and proposed enhancements to the approach. |
| Companies should ensure their asset health performance commitments are easy to understand. | Meeting this expectation will be aided by implementing the recommendation to prepare a glossary of key terms (including health, risk, criticality and resilience) so that UU staff prepare business cases utilising consistent language. This glossary will also help support effective customer engagement and enable customer views to be clearly linked to AMP7 proposals |
| Companies should ensure their asset health performance commitment levels are stretching. | Demonstrating conformance to this expectation will be supported if UU develops a framework that links its various asset health metrics, and that links these to the broader Resilience Scorecard. In so doing, it should be able to clearly demonstrate where a particular activity influences an asset health measure, and in turn how this improvement propagates to a customer service benefit. |
| Companies should explain to their customers, CCGs and us, the size of their asset health underperformance penalties (and any outperformance payments) | *NA – no draft business plans have been reviewed as part of this project* |
| Companies should submit their asset health performance commitment definitions to us ahead of business plans. | *NA – no draft business plans have been reviewed as part of this project* |
| Companies must include our four common asset health performance commitments as part of their asset health commitments. | *NA – no draft business plans have been reviewed as part of this project* |

# 4. Asset health approaches across the UK water sector

In this part of the report we compare our refreshed appreciation of UU's approach to asset health to that described by other water companies in the *Targeted Review of Asset Health*. We also consider the relationship between asset health and resilience.

Whilst noting that the water companies in England and Wales may have started to respond to the review's observations, and that therefore, the basis for comparison may have changed, we consider that this benchmarking continues to provide an effective means of identifying perceived gaps and opportunities.

## 4.1 Defining asset health

Asset health remains a term that is open to interpretation and several variations on the theme were put forward by different companies, mirroring the views aired by different UU staff. As is the case with UU, it is common across the industry to draw an analogy between asset health and human health which includes consideration of age, remaining life expectation and fitness.

Across the sector, asset performance indicators and historical serviceability indicators have been used extensively as a basis for monitoring asset health. Many of the water companies we spoke during the targeted review described asset health as:

***"the ability of the asset to deliver service now and in the future"***

This definition is nuanced and service can be influenced by asset reliability and the 'fitness for purpose' of the asset, as well as by operational and system response; asset health is therefore widely acknowledged as having several component parts.

The *Targeted Review of Asset Health* also established that ***asset health is one component of resilience***, specifically the components relating to asset ***resistance*** (ability to resist stresses and loads) and ***reliability*** (breakdown rates). We also found that risk to service (the probability and consequence of service losses) is also impacted by ***redundancy*** (spare capacity in the system) and operational ***response/recovery***. The *Targeted Review of Asset Health* established that most of the asset health indicators used by the water companies are lag indicators and there is a need to develop lead indicators (such as condition and forecast remaining life).

Each of the component parts of asset health (and resilience) can impact on risk to service and hence, during the *Targeted Review of Asset Health,* we had concerns that conflated measures of asset health could mask the root cause of current and future risks. For example, headline burst and leakage rates might be stable, propagating a belief that asset health is acceptable, but this would not highlight the potential vulnerabilities of individual critical trunk mains, or the risks associated with widespread failures of aging distribution infrastructure in the event of an extreme low temperature event.

Considering this potential scenario, we were concerned that companies were potentially not fully aware of how the state of the assets could impact service risk, and we were therefore looking to see evidence that companies were aware of all components of asset health (for example remaining life and failure probability), as well as the wider aspects of resilience, when making their investment decisions. We wanted to make sure that there was not a backlog of poor condition assets or a future 'bow wave' developing (associated with deterioration) that could result in an unexpected and unmanageable increase in future risk to service.

In summary, our *Targeted Review of Asset Health* concluded that companies were focussed on service measures and that good service was used as an indication that asset health was also acceptable. Most companies did however recognise that more needed to be done to develop lead indicators and that asset heath merited further investigation.

In contrast to many of the water companies in England and Wales, UU has developed a clear measure of asset health, BAH, which is focussed on percentage remaining life. UU produces a grading for each asset (healthy/minor issue/poor health) based on percentage remaining economic life and is developing dashboards using visualisation tools to help users understand where poor remaining life assets could be influencing service risk.

***We believe that UU's focus on asset health, provided it is sustained, and the insights expressed by a number of members of staff, will help to raise awareness of the relationship between asset health and service risk and enable better targeting of future investment to help avoid concerns around critical assets, aging populations of assets and systemic failure.***

UU recognise that the term 'asset health' includes consideration of both asset reliability and ability to deliver service and to fully understand the role of asset health, there needs to be visibility of measures of asset life and failure probability. Having this visibility will help to understand how best to balance operational measures and capital investment to maintain service now and in the future and to be resilient against unexpected events. ***UU requires a glossary and clear line of sight to indicate how asset health measures support BAH and in turn, the broader measurement of resilience.***

### 4.1.1 Opportunities for peer learning

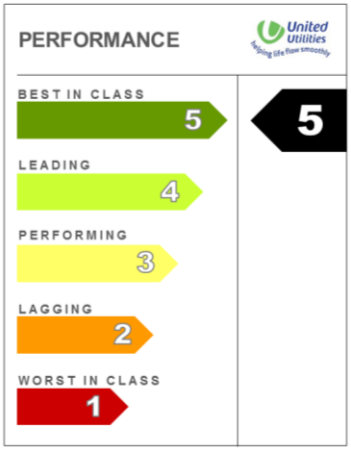
There are some areas where other companies are starting to propose improvements to the historical approach (i.e. a serviceability indicator type approach) that UU should consider and ideally participate in knowledge sharing:

- All companies recognise that existing serviceability based asset health measures are lag indicators and there will be benefits in developing lead indicators
- Welsh Water was considering a new set of asset health indicators, based on understanding asset condition and failure probability - deterioration model outputs were being explored as part of this development
- Northumbrian Water talked about using asset health phraseology within the workforce to develop and embed the concept and encourage innovative thinking
- Thames Water has a specific asset health measure for each sub-service area. This is based on a basket of indicators. The water infrastructure measure includes planned asset replacement as one of the indicators. We think an indicator that infers assumed asset life is useful and merits consideration

### 4.1.2 UU's understanding of asset health compared to other water companies in England and Wales

Our view is that UU is currently demonstrating **Best in Class** performance compared to the Ofwat regulated water company peer group in terms of understanding and defining asset health. This conclusion is based on observations that:

- UU recognises that asset health as a general definition conflates condition, failure probability, age, life, performance and service. As such, there will be efforts made to develop a better understanding of the effects of each of these elements and to measure them. ***A clear lexicon of asset health language is required***
- UU's BAH is consistent and forward looking, and it is unique to UU. It provides visibility specific to asset health, focussed on the state of the asset in terms of its remaining life relative to the expected economic life.
- BAH is being rolled out to operational teams helping to provide a 'line of sight' through the organisation, though further efforts are required to control this process and avoid definitions of asset health and the use of BAH becoming confused.



Should UU follow through with efforts to standardise asset health language, to develop and highlight additional health measures, and to implement governance around the use of asset health measures, it should be able to remain Best in Class.

UU should also formally recognise the importance of data and natural capital as vital assets for service delivery.

## 4.2 Understanding of asset health and risk to service: measurement of asset health

In our targeted review of the regulated water companies in England and Wales, we took stock of the technologies that have been trialled and that are being used to capture and help forecast asset health information. Ofwat was particularly keen to understand how technology was being used to help ensure that companies were aware of service risks associated with pipeline assets.

We established that water companies have trialled and are testing a wide range of technologies that are aimed at gathering asset information and that this has the potential to support routine operation of the assets and longer-term planning. 'Technology' could be seen to fall into a number of general categories, for example:

- Data analysis and forecasting
- Sensors and telemetry that enable continuous monitoring
- Inspection devices that are aimed at capturing discrete information (typically condition data)

For trunk mains, the issue of inconsistencies and gaps in data, and of difficulties in understanding condition is an industry-wide issue. In a review of Thames Water trunk main incidents, Cuthill (2017) identified that:

- Currently there is no tool/system that can be procured 'off-the-shelf' to gain an understanding of the internal and external condition of trunk mains
- Efforts are needed to further develop predictive analytics and data infill capability, as well as to ensure effective data capture occurs pre-event (i.e. burst), during an event and post event. Thames Water's monitoring is mainly conducted using Hydroguard and Syrinix units, as well as Sahara leakage detection tools. Cuthill (2017) considers the Syrinix solution to arguably represent the forefront of currently available monitoring tools for this type of asset. Hydroguard can be considered reactive and Syrinix has the potential to be proactive if correctly used as well as reactive
- Generally, across the water industry, customers and other stakeholders are often relied upon to provide notification or confirmation of a burst, rather than this being achieved by the water companies' own monitoring equipment
- Thames Water has engaged the University of Surrey to improve its understanding of trunk main condition and is planning to trial an acoustic response tool patented by Breivoll Inspection Technologies. Thames Water is also currently looking into developing a testing area where it can carry out testing on different monitoring solutions without having to access the live trunk main network

We were told that UU has been relatively quick to adopt new condition monitoring technologies (and we were provided with several examples) but that it has been less effective at embedding the necessary supporting process or developing the required staff skills. UU appears to have an opportunity to strengthen processes and skills which support asset inspection and monitoring technologies.

We were told about the implementation of new processes e.g. RCM, T-RAM, which have the potential to enable improved asset availability (a good measure of asset health) and innovative use of data analytics and visualisation to support forecasting and decision making. We also heard about the technology road-mapping exercise (see **Section 2.7.1**). These initiatives are to be encouraged and represent good practice for the sector.

### 4.2.1 Opportunities for peer learning

There are some technology trials and implementations related to asset health data capture being carried out by peers that would merit review. It should be noted that we are not endorsing the effectiveness of these technologies but recommend that UU explores the options and makes appropriate decisions based on their potential benefits versus costs:

- For water mains, several companies are exploring pressure transient monitoring for detecting and avoiding leaks and bursts in water mains. Thames Water appear quite advanced with this technology. It is understood that UU has tested pressure monitoring and modulating valves in a portion of its network but that, at the time, battery technologies were perceived to be a significant constraint on widespread uptake
- Use of critical mains discrete pipe analysis to determine condition, which is currently done by only a minority of companies as routine procedure
- There are numerous examples of advanced condition monitoring on Mechanical, Electrical, Instrumentation, Control and Automation (MEICA) assets e.g. thermal imaging, vibration, oils analysis. It seems that these have started to be more commonly used, but routine and extensive use is not yet established
- Localised NDT on critical trunk mains seems to have fallen from favour among the water companies, with one or two exceptions. In some cases, local physical inspection of critical assets could be a valuable means of supplementing deterioration data which is increasingly sourced from models
- In the case of sewers, Wessex Water and Thames Water reported trials using Electro Scan (defects/infiltration) and SewerBatt (defects, blockages). There were mixed reports of effectiveness, so it is important to understand the circumstances and identify where the technology could be successful by careful review of the experiences of others, undertaking controlled trials and continuing to 'horizon scan' for opportunities
- In the case of water networks, pressure and flow monitoring is being used increasingly and has the potential to support the implementation of 'Smart Networks'. This is still a work in progress, though sensor technology is progressing quickly, as is data processing and machine learning, so this is an area for current and increasing future focus

### 4.2.2 UU's approach to measuring asset health compared to other water companies in England and Wales


At the present time, it is clear that UU is proactive in horizon scanning for new technologies, and trialling these when it can. We consider its current performance as **Level 3 - Performing**. It is clear that UU is relatively nimble in moving quickly to adopt new condition monitoring technologies. Historically, it is potentially less effective at embedding the necessary supporting process or developing the required staff skills. UU's focus on **pervasive engineering**, and the role of Range Managers should help to address this.

UU could seek to establish a formal means for UU staff to raise concerns or requests for technology development and trialling to the Innovation Team. This would help to prioritise where investment should occur and would help to reduce the likelihood of particular aspects of asset health being overlooked. UU could also seek to develop technology trials in collaboration with other utilities, helping to reduce costs.

Should these initiatives be delivered and sustained, UU will improve its level of performance in this area. Recommendations made in relation to innovation (see **Section 4.7**) are also relevant.

## 4.3 Establishing the link between asset health, performance, service and outcomes

During the *Targeted Review of Asset Health*, we heard that techniques such as root cause analysis, event tree/fault tree and failure modes and effects analysis (FMEA) were used by water companies to link asset failure to service impact. As we noted in our review:

> *'All companies appreciate the linkages between asset health, service and expenditure and recognise that in certain cases they can be difficult to quantify due to the effect of factors such as the environment and non-asset health related resilience.*
>
> *Companies develop a framework of indicators and measures that enables forecasting of outcomes and estimation of the costs and benefits of expenditure. These frameworks typically include a set of service measures that can be monetised (typically based on customer research) and hence used to appraise the costs and benefits of expenditure. The estimation of probability and consequence of failure is used to determine risk to service'.*

UU was no exception to this sector-wide observation. Most, if not all companies model the effects of asset failure on service using deterioration models and are using scorecards and dashboards to monitor asset data and to visualise cause and effect relationships. We note that UU is deploying tools such as MISER (an optimising mass balance network model) which are being used to assess the consequences of water pipe failure at a systems level. Developing this type of system awareness is good practice. We also note that rainfall impact on sewer networks is being appraised by UU using hydraulic models and that this includes climate change considerations and extreme storm event analysis.

The previously identified industry-wide challenge of understanding network condition propagates to uncertainty in decision making for investment. As this situation improves (see **Section 4.1.2** for potential opportunities), investment planning would benefit from an ability to consider dynamic risks which can be updated based on the latest asset data.

### 4.3.1 Opportunities for peer learning

Learning opportunities are considered to be more limited for this topic area (as compared to asset health data capture) however there is some scope for further improvement and peer learning:

- Consequence mapping techniques are used within some of the expenditure planning tools of peer companies to help link asset failure to service impact. This provides a simple means of ensuring consistent linkages and relationships. Service measures are mapped to PCs to enable predictions and forecasts
- Assumed links and relationships should be validated by comparing observed and expected data
- Dynamic simulation is being used by Thames Water to look at system risk and resilience, however the MISER analysis used by UU may provide similar benefits
- Yorkshire Water has produced a clear visual (**Figure 4-1**, below) that illustrates the linkages between key performance indicators (KPIs) and service (although it does not explain how this is configured and validated in their expenditure planning tool). There is merit in producing an equivalent overview and providing a narrative that explains the methodology for quantifying links between asset health and service.

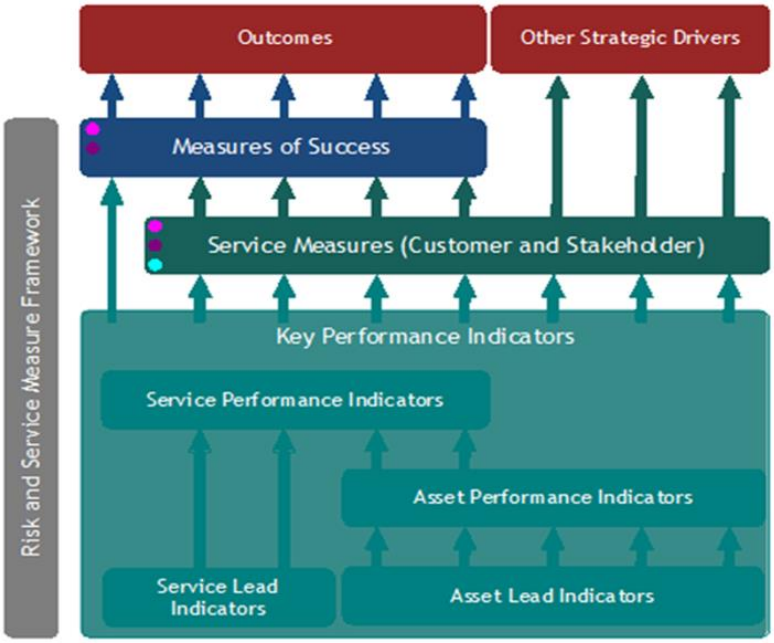



**Figure 4-1: Yorkshire Water Links between KPIs and Service Measures**

### 4.3.2 UU's approach to linking asset health to service compared to other water companies in England and Wales


We believe that UU's approach to linking asset health to service can be defined as **Performing**, for the following reasons:

- System modelling is a powerful basis for informing risk and the resilience of the network. It helps to determine the critical assets in the system
- The linking and visualisation of UU's unique asset health measure and the roll out of BAH to operational teams will help to establish links to performance, service and criticality/consequence

Notwithstanding these observations, we note that ***the clarity of the hierarchy of measures and the links between asset health, service and outcomes are not as clear as for some other companies***

## 4.4 The influence of asset health on expenditure planning and decision making

The questions of whether and how an understanding of asset health is used to inform water company expenditure planning and decision making depend on the definition of asset health. For example, whilst asset condition is not typically directly used to inform investment, asset failure probability, mean time to failure (MTTF) and remaining life are used. Measures of **probability of asset failure** are used to determine risk, based on the general equation:

**(Probability of asset failure) X (likelihood that asset failure causes a service impact X consequence [service measure impact factored by scale/extent/duration]) = Risk to service**

All companies use this general approach for estimating risk and calculating costs and benefits of intervention options. However, managing service risk can be achieved through different means, as summarised in **Figure 4-2** below, which shows the '4Rs' concept for providing resilient services and onto which we have mapped the elements that we consider to best define asset health.

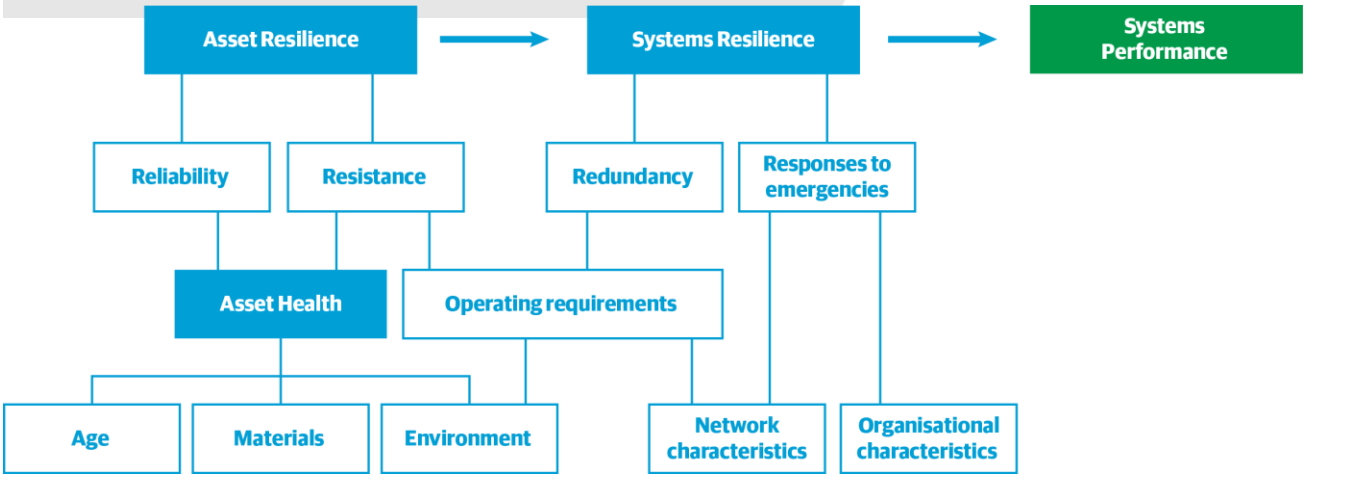



**Figure 4-2: Conceptual Relationship between Asset Health and the 'four R's' of Resilience**

Risks associated with asset reliability and resistance can be mitigated operationally. During the *Targeted Review of Asset Health*, we had concerns that some companies may not be sufficiently aware of the extent to which the state of the asset, poor condition and low remaining life could be storing up a problem for the future.

UU's BAH provides a consistent basis for targeting investment to address risks associated with asset deterioration and/or failure probability. It also enables prediction of the change in asset health (residual life) associated with the expenditure plan and hence potential future risks.

UU uses OPTIMUS to inform the selection of competing risk mitigation options, based on benefit and value for money. It has recently been updated to automatically include BAH in its calculations. It is also understood that a new tool to support option prioritisation is also being developed by UU which tags potential projects to service outcomes and then allows the user to vary the extent to which certain service outcomes are pursued.

One challenge that is common to the sector is that of selecting between high impact, low probability (HILP) and low impact, high probability risk mitigations with the same monetised risk benefit. We were told that for UU, attention would typically be addressed towards high probability risks first. Whilst all the companies have deterioration models that help to understand how asset failure will affect service, it is not so clear that the issue of the state of the asset is being considered in terms of the special risks that a population of aging assets could present. Two risks that we felt are typically not managed well across the industry are:

i) **Critical, long life assets** – the so called HILP assets such as large diameter water mains, which may fail unexpectedly, affecting large populations, and which are difficult to repair. UU's Manchester Resilience project illustrates a multi-AMP strategy to address this problem and should be commended. Investments to support resilience should be supported by effective contingency plans and UU has acknowledged the importance of further improving the consistency of its approach across different assets in this respect.

ii) **Large populations of low consequence, poor condition** assets (such as corroded water distribution mains) that are vulnerable to failure in extreme weather and which are individually low impact, but collectively can cause severe disruption if widespread failure occurs and the operational response is over-whelmed. UU's comparatively good performance during the March 2018 freeze/thaw event shows that it does have effective contingency measures in place to address HILP events such as this. It should continue to improve its approach by focussing on developing consistent contingency plans across its assets.

UU is aware of the need to increase the influence of asset health in investment decision making and its Investment Planning department and Asset Management directorate are working together to try and identify ways to ensure base levels of maintenance compete effectively for investment with other potential projects. At an operational

level, UU's establishment of an Operational Engineering department is gradually moving engineering expertise closer to the field. For example, one site has been trialling combining BAH and criticality information to inform operational decision making.

To support operational decision making with engineering expertise and improved data, UU has established the role of Range Managers as a source of expertise and guidance for assets related to a price control. This action addresses observations made in relation to other companies that knowledge, ownership and investment decision responsibilities for key assets (e.g. trunk mains) may be spread across multiple departments (for example, Cuthill 2017). It is also beneficial that the role of Range Managers includes preparation of clear guidance material for operators. This helps to avoid another concern of the industry, the holding of information by a limited number of asset experts, and the associated concerns over succession planning and loss of critical expertise.

### 4.4.1 Opportunities for peer learning

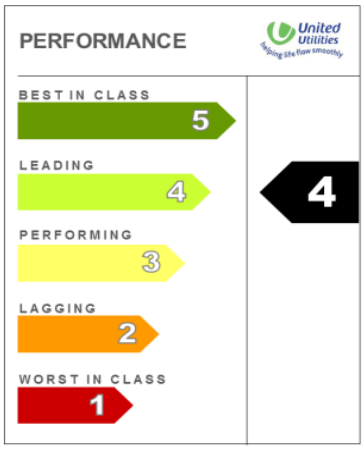
In this case of linking asset health to expenditure planning, we think that peer learning opportunities are relatively limited. Exceptions to this statement that may merit consideration include:

- Considering and exploring ways to ensure that projects which help to maintain a base level of asset health compete effectively for investment with projects that address acute issues and that directly benefit ODIs
- Sharing experiences of developing expertise and programmes of study related to particular asset types, such as trunk mains
- Failure forecasting models which include weather parameters and can be used to inform operational response and capital maintenance needs

### 4.4.2 UU's approach to using asset health in expenditure planning and decision making compared to other water companies in England and Wales

UU's approach to using asset health in expenditure planning is considered to be reflective of **Leading** performance on the basis that:

- UU's BAH is being used to highlight the use of asset health in decision making (through OPTIMUS for example) and is becoming a common measure used across the business. Further efforts are needed to ensure its consistent application, and its support via a basket of wider asset health measures
- The MISER consequence modelling, combined with asset health information, provides a valuable basis for making effective decisions
- UU is committed to increasing the extent to which operational decision making utilises engineering expertise and asset health data, and has formalised a number of roles and responsibilities (Range Managers and Field Engineers for example) to achieve this.




## 4.5 Communication and the views of the customer

Asset health is a challenging concept to convey to customers and as such, at the time of the *Targeted Review of Asset Health*, it was our understanding that only a minority of water company peers had held direct conversations on asset health with customer groups. Companies told us customers do not generally understand what is meant by asset health and that they are more interested in asset service and performance, which are concepts they can relate to. Most companies felt that other questions/queries with customers could be considered as appropriate proxies for asset health or, rather, the service delivered by assets that are healthy. UU has also taken this indirect approach and we were shown evidence inferring asset health customer opinions and values from service outcomes. Similar work has also been done by Anglian Water, Severn Trent Water and Thames Water.

Like UU, most companies have discussed the wider topic of resilience with their customers, of which asset health is a component part, and all companies have had discussions about specific service parameters such as supply interruptions which have a causal linkage with asset health. Ofwat's *Resilience in the Round* document gives the example of Anglian Water's 'Keep it Clear' campaign as an example of effective customer engagement around an issue related to asset health.

South Staffordshire Water and Southern Water stated they had discussed asset health directly with customers at the time of the *Targeted Review of Asset Health*. Southern Water appeared to have gone the furthest, stating it had conducted direct customer surveys to understand whether customers value affordable, stable asset health and service resilience including for future generations. This aligns with Ofwat's expectations for PR19, namely to engage with customers on how their asset health performance commitments protect current customers, future customers and the environment.

To address Ofwat's PR19 expectation, UU has designed a package of direct customer engagement on asset health, utilising its WaterTalk group of around 7,000 customers, as well as its CCG. This group is regularly engaged by UU and is therefore more likely to be in a position to understand how asset health relates to service. Based on the findings of this engagement, UU should be able to modify its approach such that it is suitable for broader engagement with a wider range of customers.

During the *Targeted Review of Asset Health*, planned initiatives by other companies included:

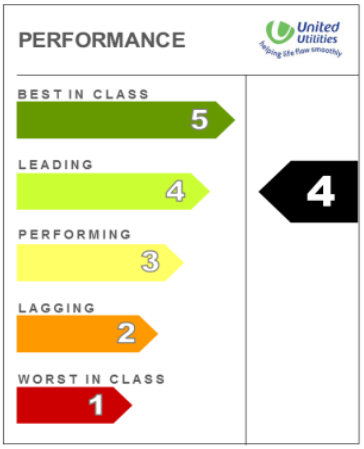
- Severn Trent Water, Thames Water and Anglian Water each plan to implement research (qualitative and quantitative, including willingness to pay) with people previously impacted by service failures due to asset health or related to resilience
- Severn Trent Water, Thames Water, Anglian Water and Northumbrian Water are all planning to use gamification or simulation to develop an immersive approach to explore how to better help customers understand and appreciate the potential impact of a service failure on their daily lives. This work may have some significance with respect to asset health

### 4.5.1 Opportunities for peer learning

Customer engagement on asset health is a challenge common to all water companies, and all companies are at a similar level of progress. It is therefore the component of this study that is perhaps best suited to company-wide sharing of initiatives and ideas.

During the *Targeted Review of Asset Health*, we were impressed by some of the tailored media and consideration of demography used by Yorkshire Water. Anglian Water's approach to characterising its customer base was also considered powerful and it may be beneficial to engage these companies, and others, to understand what components of asset health communication have worked well, and which have not. UU's customer engagement related to its Manchester Resilience Project, and its intended approach to direct communication on asset health with the WaterTalk group would benefit the broader industry.

### 4.5.2 UU's approach to communication of asset health compared to other water companies in England and Wales




UU's approach to engaging its customers on the topic of asset health is comparable to that of the other water companies; all companies have had indirect discussions on asset health but few have been able to devise effective means of discussing this issue directly.

UU does however appear to be focussed on progressively refining its asset health engagement, and we have seen its draft proposal for direct engagement. We consider that current performance is therefore **Leading**, but that UU would benefit from sharing its customer engagement experiences and learning from other companies. Considering Ofwat's PR19 expectations, this collaboration would be in the interest of all companies.

## 4.6 Asset health assurance

UU use a triple line approach to business planning assurance involving internal departments and business processes, third-party assurance and Board sign off. This is industry-leading practice.

During the *Targeted Review of Asset Health*, specific examples of independent assurance were provided by all companies over a range of subject areas. In the majority of cases there was reference to the assurance of infrastructure and non-infrastructure deterioration and service impact models. As responses generally referred to specific examples, it was not evident that assurance was targeted at those assets considered to have the most risk attached to them and that might be difficult to assure.

For the assurance of new assets, a concern of several companies during the *Targeted Review of Asset Health* was the reliance on contractors and the supply chain to carry out some of the quality control and assurance, particularly on infrastructure assets. In this regard a number of companies presented early steps on their delivery partner selection and procurement processes to ensure quality management processes were aligned, and that client expectations of acceptable quality standards were understood from the outset.

We were told that UU is working to develop more targeted assurance practices (predictive assurance) focussed towards the highest risk components of this process. Accurate and reliable data is crucial to this aim and the need for better data on contractor systems was highlighted, harnessing the benefit from recent technology advance in time lapse or feature recognition for example.

In line with the majority of other water companies, UU's assurance of data quality has typically occurred after data processing and once draft conclusions or business cases has been prepared. This introduces potential inefficiencies if data errors are observed and analysis has to be repeated. The rollout of UU's EXAsol platform (referred to in **Section 2.3.1**) presents an opportunity to address this issue, thanks to its application of quality checks each time data is drawn from a source system. The dashboards the validated database will be used to create can then be designed to include an indication of data quality and suitability for use. This measure is an excellent example of a lifecycle approach to data quality assurance and would support more efficient and reliable decision making.

### 4.6.1 Opportunities for peer learning

We consider there to be the following opportunities for peer learning in relation to asset health assurance:

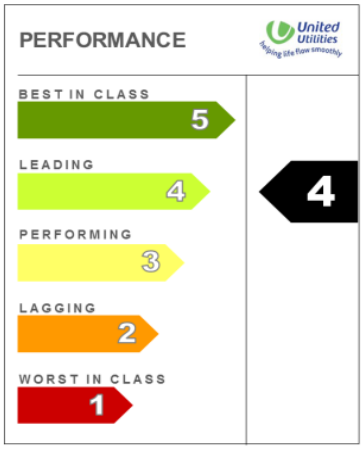
- ISO 55000 is considered to provide an effective structure for asset management good practice; developing a clear line of sight and continuous improvement; it does provide an additional level of assurance, and is being adopted increasingly by UK water companies (e.g. Anglian Water, Yorkshire Water, Wessex Water, Northumbrian Water) The feedback of lessons learned, post incident reviews and the like, are a key element

to asset management and the improvement of long term asset performance (it is formal requirement for ISO 55000 certification)

- Best practice examples from BIM implementation and supply chain collaboration
- Cyber security and data integrity - South West Water highlighted their monitoring and reporting of IT hacking attempts to Board in relation to assurance of IT security

### 4.6.2 UU's approach to asset health assurance compared to other water companies in England and Wales

By adopting a triple line approach to assurance and by promoting means to move towards predictive assurance, we believe UU's current performance in asset health assurance can be considered **Leading** amongst its peer group of Ofwat-regulated water companies.




The continuing rollout of EXAsol and its capability to incorporate data quality checks each time data is imported from source systems has significant potential to improve the efficiency of assurance processes, moving this important check much earlier in the decision making process.

## 4.7 Innovation and collaboration

Innovation and collaboration are key themes for Ofwat and it has high expectations of the water companies in these areas for PR19. Ofwat believes that innovation is critical if the water sector is to address the challenges of long-term resilience, affordability and customer service. During February 2018, Ofwat ran an innovation programme called Spark to encourage discussion throughout the sector about the benefits that innovation can bring for customers, the environment and wider society. A variety of innovative approaches and collaborative initiatives were shared by water companies through the Ofwat website and Twitter including experiences from organisations outside the water sector.

Anglian Water has previously been highlighted as an example of industry best practice in innovation via its 'Shop Window', which provides a physical location, where new technologies are tested with its supply chain. It is claimed that 150 companies are partnering with Anglian Water and trailing 30+ technologies. UU is currently delivering its Innovation Lab programme, which is analogous to the Shop Window. The Innovation Lab programme is a structured platform through which potential suppliers can pitch ideas to UU and, if successful, develop their plans in a co-located environment utilising UU expertise and local knowledge. UU has also repeatedly taken steps to learn from approaches taken in other sectors and has implemented initiatives as a result (the adoption of BAH is one example).

To promote innovation among its staff and suppliers, UU initiatives include:

- The Innovation Lab, which is intended to be repeated on a regular cycle
- The Innovation Hub, co-locating operational engineering and technology teams to facilitate idea and project development
- Holding innovation days at its Warrington head office twice a year, focussing on different disciplines. Suppliers attending these days are typically identified and confirmed through existing staff contacts
- Engaging suppliers and academia on specific problems or concerns (such as reservoir risk assessment)

At this stage, it does not appear that UU has a clear mechanism, or series of connected mechanisms, to promote internal collaboration and innovation. We were told about some existing mechanisms (the CEO Challenge and the

innovation days at Warrington head office for example) and promising early-stage initiatives (such as the focus on pervasive engineering and the role of Range Managers, as well as planned improvements to the lessons learnt database). However, further efforts are required to ensure these ideas are integrated and embedded into everyday practice. The need to improve and act upon event learning processes is not unique to UU and has been raised by Cuthill (2017) in relation to Thames Water trunk main burst events.

### 4.7.1 Opportunities for peer learning

Areas related to innovation where UU could share and learn from best practice include:

- Establishment and operation of innovation platforms (such as the Innovation Lab), particularly identifying ways to support and empower small companies to engage in the process (smoothing procurement issues, addressing data licenses etc). UU has taken several important steps in this respect, including securing independent support to facilitate the Innovation Lab
- Fostering internal innovation, particularly related to the application of data analytics and machine learning to convert data on asset health performance into actionable insights. For example, Thames Water plans to establish an innovation testing area where trunk main innovations can be tested away from the live network (Cuthill 2017)
- Continuing to learn from other sectors - UU can be considered to be leading the industry in this respect but should seek to continue to explore these avenues of best practice. One opportunity would be through benchmarking studies and initiatives

### 4.7.2 UU's approach to innovation compared to other water companies in England and Wales


Innovation is a key focus for Ofwat at PR19 and it expects all companies to have innovation at their core. Ofwat also considers that to date, the scale, depth and pace of innovation in the water sector has been modest (and typically incremental), as compared to the transformational change that has occurred in other sectors.

At present, we consider that UU's performance across the various components of innovation is, at least, on par with the other water companies. Several aspects of UU's approach, such as the Innovation Lab, can be considered leading, however we also believe that this and other components could be further enhanced, for example by establishing a continually available innovation platform for suppliers.

We also note that UU's approach to promoting innovation amongst its own staff is being aided by the CEO Challenge, as well as the initiatives of the Operational Engineering department and Range Managers. These initiatives could however be developed into a broader platform of supporting tools and guidance.

Overall, we consider UU to be **Performing** on innovation, but with good potential to become a leading company as current processes and initiatives flourish and become embedded as business as usual.

# 5. Asset health approach in other geographies and sectors

## 5.1 Lessons from international practice in the water sector

Approaches to asset health adopted by water utilities outside England and Wales were reviewed and reported in the *Targeted Review of Asset Health*. These observations are briefly revisited below, with additional information added where new information is known.

**Insights for United Utilities**

- *One approach to reporting and performance tracking of asset health which may have benefit to UU are the State of the Asset reports produced by some of the water companies in Australia.*
- *It is evident that many geographies are increasingly utilising innovation platforms and data sharing forums to identify and refine new solutions and to share best practice.*

### 5.1.1 Understanding of asset health and its relationship with service

There is no evidence that water and sewerage companies in other countries are significantly different to the UK in how they understand and use asset health as a factor in investment planning. Other water utility communities do not appear to be using the phrase 'asset health' explicitly as a driver of investment.

In the US, for pipelines, a concept used is level of failure (LOF) and this metric is informed by inspection data (condition), hydraulic modelling (performance), inspection data and work order history analysis (maintenance status), and desktop analysis (resiliency). The LOF metric is used as part of a risk assessment and is similar to approaches followed by water companies in England and Wales.

In the US, for vertical assets (non-infrastructure), condition is considered a key asset health parameter. Condition (based on a set of criteria) is used to estimate remaining useful life (RUL). For example, 'Condition 1' (the best condition) might equate to 95% of the original useful life remaining (or 95% RUL). Condition 2 might equate to about 80% of original useful life remaining and so on. Asset health is then considered as a mix of performance and RUL.

### 5.1.2 Asset health reporting

One approach to reporting and performance tracking of asset health which may have benefit to UU are the State of the Asset reports produced by some of the water companies in Australia. State of the Asset reports are also prepared in other sectors, see **Section 5.2.2**.

Under the regulation of the Independent Pricing and Regulatory Tribunal New South Wales (IPART), Sydney Water and other utilities in NSW must prepare a report on the state of each group of assets for certain financial years. Sydney Water's report must include:

- A description of each group of assets managed
- Sydney Water's assessment of the expected capability of the assets to deliver the services and to meet the existing obligations consistent with the licence, the customer contract, and all applicable laws with which Sydney Water must comply
- Sydney Water's assessment of the major issues or constraints on current and future performance of the assets
- The strategies and expected costs of future investment in assets
- Such other matters reasonably required by IPART

In NSW, public water utilities are also required by their licence to have an asset management system in place, consistent with ISO55001. The water utilities must ensure that the management system is fully implemented and that all relevant activities are carried out in accordance with the management system.

Across Australian water companies, the State of the Asset reports come in various forms, but tend to provide a high-level overview, and an indication of change over time, of key asset metrics such as:

- Average remaining life (percentage of design life)
- Average condition rating by asset type
- Renewal funding versus demand
- Proportion of preventative maintenance to corrective maintenance
- Other metrics such as actual vs published mean time between failure and operational hours vs duty hours

### 5.1.3 Inspection and monitoring technologies

Across the countries reviewed during the *Targeted Review of Asset Health*, there were a number of examples of innovative emerging technology being piloted by water companies to good effect. However, as in the UK, progress is typically restricted by an individual utilities' budgets, and consideration of the practical limitations of the technology. Summary observations are as follows:

- There do not appear to be major differences in terms of the inspection technologies commonly in use for either infrastructure or non-infrastructure assets
- The most commonly used monitoring tool is CCTV, which could reflect its relatively low unit cost as much as the quality or value of the data it provides
- US Environmental Protection Agency report EPA/600/R-10/101 discusses technologies that can be used to gather more comprehensive data (than CCTV) on below ground infrastructure. The report notes that the use of laser, sonar, and electrical scanning to evaluate such features is established in the US, and that emerging technologies such as impact echo, spectral wave analysis, and ultrasonic testing are also being explored for application to sewer condition assessment
- In Australia and New Zealand, drones are increasingly being used for asset inspection and review purposes. For example, Melbourne Water has trialled the use of drones for inspecting large assets such as reservoirs and treatment plants. Drones are increasingly being used by UK water companies for inspection purposes
- In the US, the number of non-destructive condition assessment technologies that use electromagnetic or acoustic fields to measure the level of asset deterioration grows each year. Much of this technology comes from the oil and gas market and is slowly infiltrating in to the water sector. Some UK water companies have already made use of this type of technology
- In Canada and the US, one of the emerging technologies is Pure Technologies' SmartBall for leakage detection, which has been used by utilities including the City of Ottawa. SmartBall is a free-swimming, in-line, leak detection technology designed to operate in live large diameter water mains. We note that this technology has been trialled by UU for rising mains inspection

### 5.1.4 Deterioration and failure forecasting

During the *Targeted Review of Asset Health*, we found little in the way of advanced techniques for deterioration and failure forecasting that are not already used or known to UK water companies. The most typical approach found was to base forecasting on historical failure data, much as the UK companies have historically done.

It is likely that, at least in the water industry, the UK is one of the leading geographies for innovations in deterioration and failure forecasting.

### 5.1.5 Innovation and data sharing platforms

It is evident that many geographies are increasingly using innovation platforms and data sharing forums to identify and refine new solutions and to share best practice. The water sector is no exception to this observation and we identified several such forums in operation:

- SmartWater4Europe, which contributes to the European Innovation Partnership on water by speeding up innovations in priority areas of work
- Technology Approval Group (TAG), a global innovation forum of the world's leading water utilities. The TAG model was first launched in the UK in 2005, and TAG groups now exist in Europe, Australia, the US, Singapore and Brazil. UU is a member of TAG Europe
- American Water Works Association benchmarking programme

In the UK, partnerships such as the Linking Innovation to Societal Needs (LITSoN) database, as well as the work of cross-sector bodies such as the National Infrastructure Commission (NIC) provide significant opportunities for the sharing of ideas and the efficient development of solutions. In April 2018, the NIC set out its advice on how to address England's water supply challenges and to deliver an appropriate level of resilience for the long term.

## 5.2 Lessons from other sectors

**Insights for United Utilities**

- *An asset health index should be representative of the overall asset health, rather than sub-components. This requires careful assessment of appropriate indicators for each asset class.*
- *Widespread adoption and understanding of an asset health index and its benefit to the organisation requires a committed leadership.*
- *Collaboration with the regulator during development and refinement of an asset health index can be beneficial.*
- *Current asset health index values can be used alongside forecast of how this will change in future to set targets and track progress.*
- *State of the Assets reports or scorecards provide a valuable means of aligning reporting across asset types and can help to track performance, spot system trends, inform long-term planning and justify investment.*
- *Multi-scenario planning and visioning exercises and reverse stress testing can facilitate better understanding of the possible chains of events within a system associated with HILP events. Collaborative platforms and benchmarking initiatives are also valuable and other sectors may already be planning effectively for certain scenarios.*

### 5.2.1 Asset health indices in the electricity and gas sector

Asset health indices are a relatively common metric in the gas and electricity industries, developed in response to an ageing asset base, pressure to keep customer bills low, and regulatory requirements for information about asset health and condition. In some countries, such as in the UK through the Office of Gas and Electricity Markets (Ofgem), company forecasts of asset health have been used to set performance requirements. In such instances, asset health indices become an effective means of tracking progress.

In conjunction with the Canadian Electricity Association, Deloitte (2014) prepared a report analysing the use of asset health indices by 15 Canadian utilities. Around half were already using some form of asset health indexing whilst the others were planning for it, or evaluating it. The asset health indices used by the Canadian utilities were developed using varying amounts of specific data parameters for an asset type, summarised into a single number. To identify which parameters should be included in the index, data analytics packages were used to look for trends in data to determine why assets were failing and the causative indicators of failure. This information varies by asset type, and in some cases by region or usage. Because of this variability, it is important that multiple

stakeholders from across an organisation are involved in the development of an asset health index. This ensures that the approach adopted for each asset class is appropriate and consistent.

In a separate example presented by EPCOR in 2018 (an electricity, water and wastewater utility operating in Canada and the USA), it was explained how an asset health index helps the company to inform the likelihood component of a risk-based approach to the management of power generation and distribution assets. It was explained how failure data was analysed to identify degradation factors for a given asset type. These were then weighted and combined to derive an asset health index (an approach analogous to that adopted above). EPCOR also utilised a confidence factor and data age index to refine their asset health information.

In its study, Deloitte (2014) concluded that an effective asset health index:

- Should provide a clear indication of the suitability of the asset for ongoing usage
- Should be representative of the overall asset health, rather than sub-components
- Should ideally contain objective and measurable characteristics of asset condition where possible (indirect measures, such as age, location, etc., can be used in the absence of direct measurable data)
- Should be easy to understand and readily accepted within the organisation

Deloitte identified five success factors which would support these outcomes:

- **Dedicated asset management staff** - reflecting the high level of complexity and requirement for significant engagement with various internal stakeholders
- **Understanding of maintenance and reliability impacts** - realisation that performing predictive and/or proactive maintenance on assets is beneficial
- **Committed leadership** - to foster the integration of processes across many different service areas which historically may not have interacted regularly
- **Clear communication** - of purpose and process, to gain support, and to increase the quality of data
- **Collaboration with the regulator** - some of the Canadian utilities specifically mentioned strong regulator communication as being key to the success of their asset health indices

In the UK, in order to allow Ofgem to monitor the asset health performance of distribution network operators on a consistent basis and in turn, to ensure long-term delivery and value for money, the operators have worked together to develop the Common Network Asset Indices Methodology (DNO Working Group 2017).

***Ofgem considers asset health to be a measure of the condition of an asset and the proximity to the end of its useful life***. The common methodology includes current asset health (informed by observed and measured condition factors - this is analogous to the asset health indices described by Deloitte and EPCOR) and future asset health (using assumptions regarding likely future deterioration). The current asset health score for an individual asset is derived from:

- The age of the asset
- The Normal Expected Life for an asset of its type
- Factors relating to aspects of the environment in which the asset is installed that may impact on its Expected Life (Location Factors)
- Factors relating to the usage of the asset at its specific location that may impact on its Expected Life (Duty Factors)
- Factors relating to the observed condition of the asset (Observed Condition Inputs)

- Factors relating to the condition/health of the asset determined by measurements, tests or functional checks (Measured Condition Inputs)
- A factor relating to generic reliability issues associated with the individual make and type of an asset (Reliability Modifier)

The calculation of current health score is performed in two main steps:

- Calculation of an initial age-based health score (the Initial Health Score) using an age-based degradation model
- Modification of the Initial Health Score using known condition information for the asset and a reliability modifier, if appropriate

This approach is analogous to UU's BAH, and its application of Bayesian tuning to modify the initial asset health value based on asset-specific factors. Ofgem's approach then relates asset health to the associated probability of condition-based failure (PoF). For each asset type, the methodology specifies the relationship between the health score and the PoF.

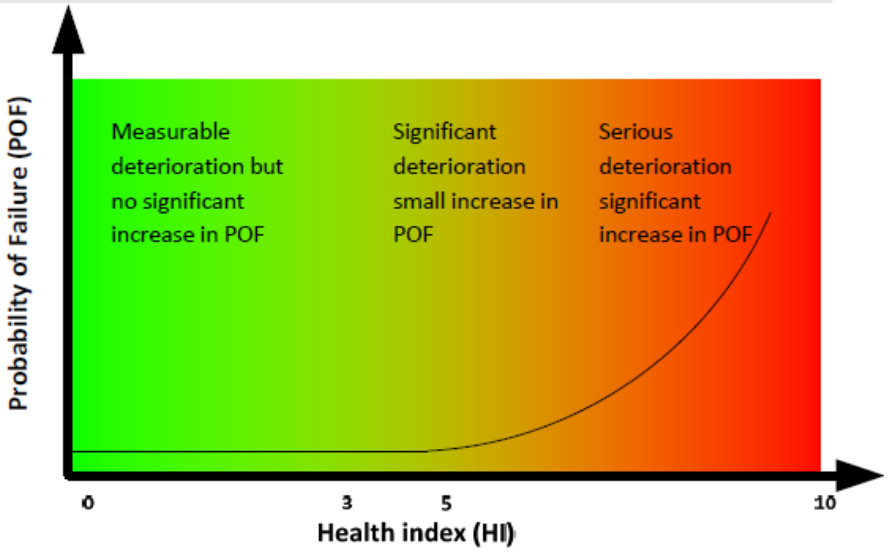
As part of the current price control for the 14 electricity distribution network operators, each provided Ofgem with a forecast of its asset health and criticality positions 'with intervention' and 'without intervention'. Ofgem then used these forecasts to set out an improvement in asset health and criticality required of each operator's asset base during the price control. ***Combining UU's BAH with a time-base element of planning, e.g. forecast deterioration, could aide decision making and help to justify asset health investment.***

In its regulatory business plan for 2013-2021, Wales and West Utilities (2011) explain how it has used a health index as a single indicator of the overall condition of an asset - a representation of where an asset is along its useful life from commissioning through to the end of its life (where its likely performance would not meet stakeholder expectations). Whilst the health index is a proxy for the life of an asset, the factors are significantly more complex than age. To estimate the health index value, Wales and West Utilities considered multiple factors such as:

- The visual condition
- The environment in which the asset operates
- The duty that the asset is exposed to
- The expected asset life, drawn from the company's experience
- The fault history
- 'Maintainability' issues, such as obsolescence

This approach allowed Wales and West Utilities to score the asset with a health index between 0 and 10. The models are calibrated such that a health index of 7 indicates an asset is rapidly approaching the end of its serviceable life and therefore an intervention is required. A health index above 7 is unacceptable because it is beyond this point that serious deterioration and a significant increase in the probability of failure occurs.

Knowing the health index of assets, whilst useful in being able to describe risk qualitatively, does not help the utility determine risk without a quantifiable relationship with PoF. That association has been determined by Wales and West Utilities using research into actual failures on similar assets. The asset can then be mapped on to the below chart (**Figure 5-1**) to inform decision making.




*Source: Wales and West Utilities 2011*

**Figure 5-1: Wales and West Utilities Health Index against Probability of Failure**

In New Zealand, Transpower, the owner and operator of the national grid, is required to provide the Commerce Commission with information about asset health, based on average remaining life for three asset classes: tower coating of transmission towers; outdoor circuit breakers; and power transformers (Transpower 2017).

Transpower first developed asset health models for its 2011 to 2015 regulatory control period, and used these to help develop its refurbishment and replacement plans for the 2015 to 2020 period. Transpower's asset health indicator represents an asset's proximity to the end of its useful life (when the asset will need replacement or major refurbishment to extend its life). When combined with other information and decision frameworks, the index can inform the optimal time for various asset interventions, when combined with engineering judgement. Transpower regularly updates its asset health indicator with the latest asset condition data.

To provide forecast asset health targets, Transpower takes the current asset health and applies:

- The estimated deterioration rate for the assets
- The forecast investment plan (replacement and refurbishment)

The asset health targets are based on an estimated rate of deterioration, a forecast replacement and refurbishment plan and the current asset health scores for selected assets. The targets will therefore indicate the desired outcome or profile for assets in terms of asset health that Transpower intends to have for its assets once deterioration and investment have been accounted for.

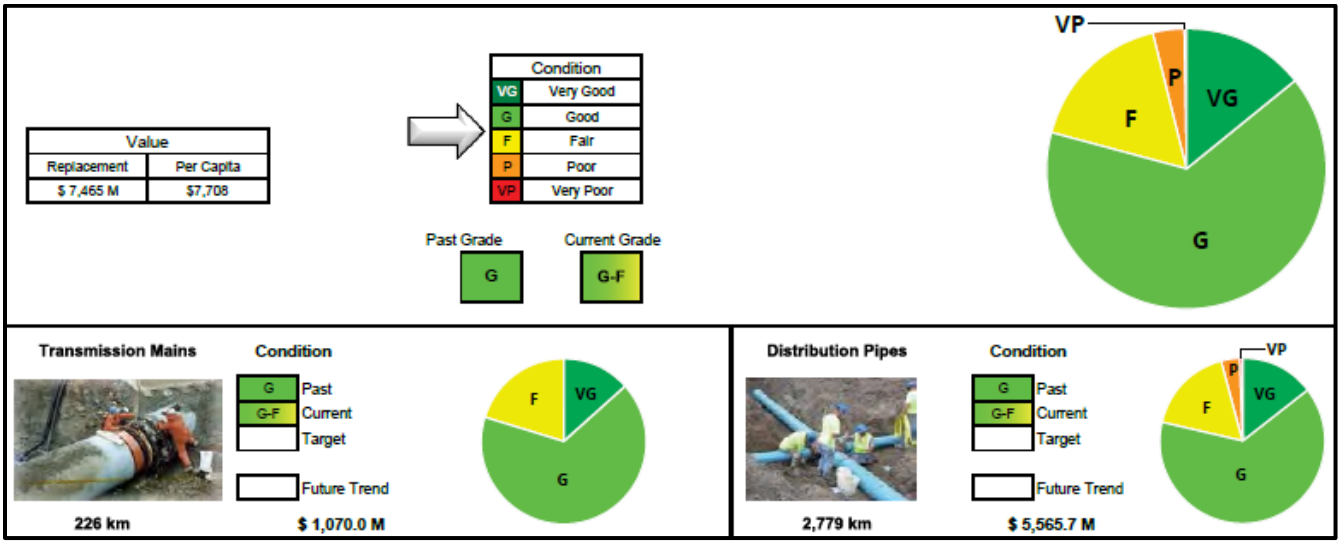
### 5.2.2 Government State of the Asset reporting

State of the Assets reports referred to in **Section 5.1.3** are also prepared by local governments in Australia and Canada, and then rolled up to a national level. Reporting typically covers the full range of asset types and associated services provided by local governments, including stormwater and where applicable, water and wastewater. The Australian Local Government Association (2015) defines the benefits of aligned and national reporting as being to provide:

- A sound rationale and model for appropriate and targeted decision making, which can also be considered by other spheres of government
- A performance assessment of the current stock of community infrastructure in terms of condition, function and capacity, with associated confidence levels

- An assessment of the current position of councils in relation to implementation of asset management and long term financial plans
- Additional data perspectives, such as rural and urban classifications across each State and Territory

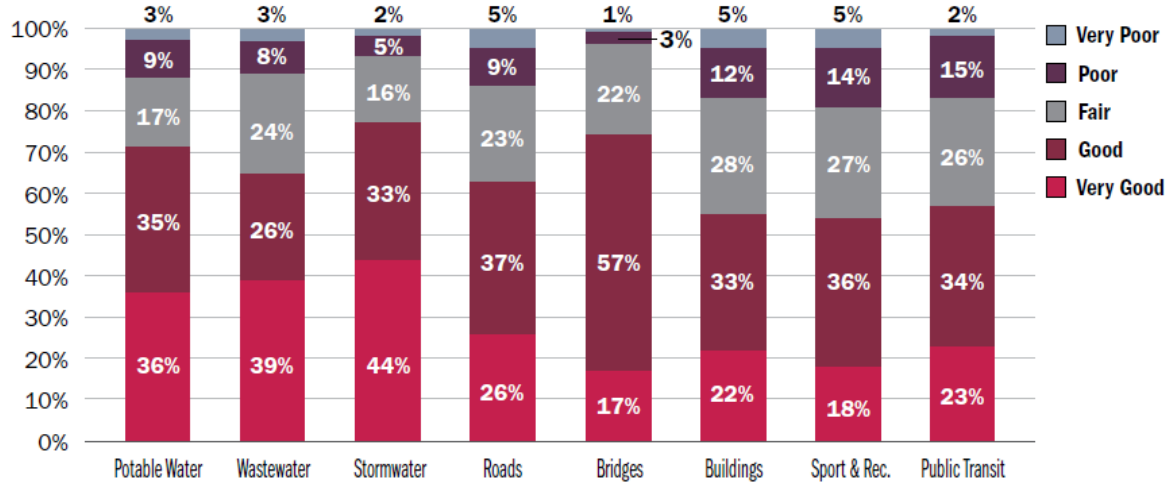
In Canada, local government asset health information is also reported for a variety of asset types. An example for water assets for the City of Ottawa is presented in **Figure 5-2**.




Source: City of Ottawa 2017

**Figure 5-2: City of Ottawa 2017 – State of the Assets Summary for Water**

In Canada, local government reporting rolls up to the Canadian Infrastructure Report Card (CIRC), which provides an assessment of the health of municipal infrastructure as reported by cities and communities across Canada (see example outputs in **Figure 5-3** and **Figure 5-4**). By reporting every four years, improvements in both data quality and asset health are incentivised. In an analogous fashion, UU could develop a report card across the business as a whole, with the functionality to drill down by geography, price control, asset type etc. By regularly reporting on this data, valuable trend analysis can then be performed and used to justify investment.




Source: Canadian Infrastructure Report Card 2016

**Figure 5-3: CIRC 2016 – Summary of Average Physical Condition Rating**

| Infrastructure | Extrapolated Replacement Value of All Assets | Assets in Very Poor and Poor Condition | Assets in Fair Physical Condition | Anticipated Condition Based on Reported Reinvestment Levels (Improving, Stable, Declining) |
|---|---|---|---|---|
| | | Replacement Value | Replacement Value | |
| Potable Water | $207 billion | $25 billion (12%) | $35 billion (17%) | Declining |
| Wastewater | $234 billion | $26 billion (11%) | $56 billion (24%) | Declining |
| Stormwater | $134 billion | $10 billion (7%) | $21 billion (16%) | Declining |
| Roads | $330 billion | $48 billion (15%) | $75 billion (23%) | Declining |
| Bridges | $50 billion | $2 billion (4%) | $11 billion (22%) | Declining |
| Buildings | $70 billion | $12 billion (17%) | $20 billion (28%) | Declining |
| Sport and Recreation Facilities | $51 billion | $9 billion (18%) | $14 billion (27%) | Declining |
| Transit | $57 billion | $9 billion (16%) | $15 billion (27%) | Unavailable |
| **Total** | **$1.1 trillion** | **$141 billion (12%)** | **$247 billion (22%)** | |
| **Replacement Value per Household** | **$80,000** | **$10,000** | **$18,000** | |

Source: Canadian Infrastructure Report Card 2016

**Figure 5-4: CIRC 2016 – Summary of Physical Condition of Infrastructure by Replacement Value, Extrapolated to Entire Country**

### 5.2.3 High impact, low probability events

High-impact, low-probability (HILP) events can manifest themselves not only as ‘black swans’, which by their nature are impossible to predict, but also as known hazards such as floods, storms and extreme cold which, owing to the low likelihood of occurrence or the high cost of mitigating action, remain un- or under-prepared for. Measures highlighted in the literature as having potential benefit in improving preparedness for HILP events include:

- Maximising the value obtained from existing data by using algorithms and machine learning to search for trends that might forewarn of a HILP event in sufficient time to allow mitigating actions to occur
- Focusing on potential impact at Board level, not on probability weighted impact
- Scenario identification of combinations of possible events - multi-scenario planning and visioning exercises can facilitate better understanding of the possible chains of events within this system, and could help mitigate costs associated with response-oriented approaches
- Horizon scanning - ‘black swans’ in the water industry may not be ‘black swans’ in other industries. Collaborative platforms and benchmarking initiatives therefore have significant potential benefit
- Reverse stress testing – focusing on managing knock-on effects or consequences, rather than the events themselves. This can help to protect against unknown risks

The electricity distribution sector has undertaken research into approaches to managing HILP events and would be an appropriate sector from which to gain knowledge of good practice. Transpower, the owner and operator of the national grid in New Zealand, develops business case portfolios of investment aimed at reducing the extent of HILP events. An example is available at https://www.transpower.co.nz/sites/default/files/uncontrolled_docs/PD40%20-%20POD%20-%20High%20Impact%20Low%20Probability%20Event%20Mitigation.pdf

### 5.2.4 Extreme event planning in the aviation sector

Following the severe weather at Heathrow in December 2010, BAA, which then owned the airport, commissioned the Heathrow Winter Resilience Enquiry. The review made a number of important recommendations advising how BAA could learn lessons to improve Heathrow's resilience to disruption. In its 2011 programme update, Heathrow explained its interim responses, including a number related to incident response:

- It has adopted the three-level command structure used by government and emergency services in responding to a crisis. This clearly defines different roles and responsibilities and helps ensure that the most appropriate people are making decisions and that Heathrow can respond to major incidents in a more co-ordinated and controlled way
- It has improved protocols for communication across the Gold/Silver/Bronze response levels and with stakeholders at each level, including pre-agreed early warning indicators for escalation
- It conducts annual resilience exercises and drill programmes as part of normal operating procedures

# 6. Summary and recommendations

## 6.1 Summary of performance

Based on the interviews conducted and documentation reviewed in support of this project, we consider that UU's approach to asset health is robust and compares well to its peers in England and Wales (see **Figure 6-1**). Furthermore, it is clear that organisational structures have been established that should continue to advance the awareness, appreciation and application of asset health to support the performance of the company. This report has identified several opportunities to ensure that this trend is continued and accelerated, drawing on experiences from other sectors where appropriate.

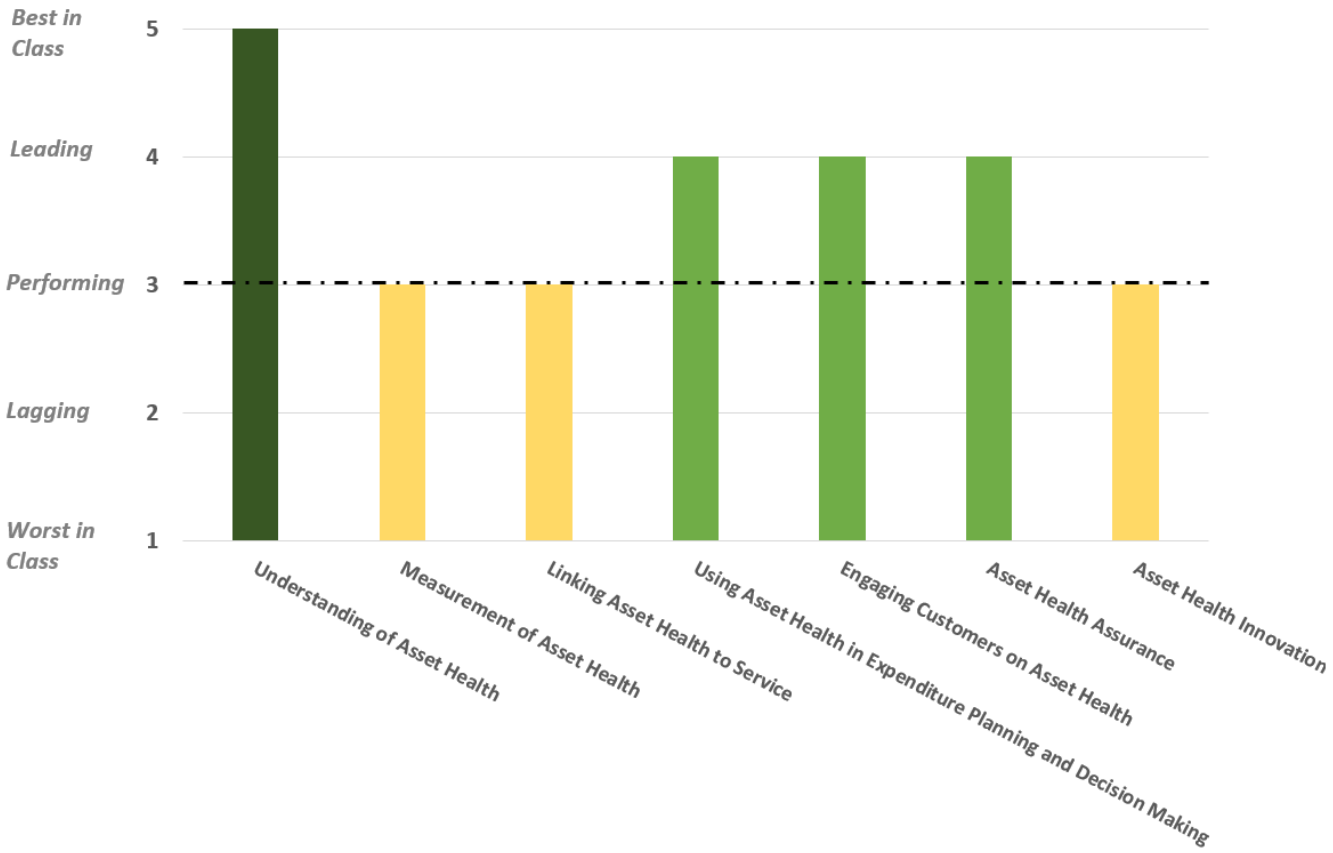



**Figure 6-1: Summary of the Asset Health Performance of United Utilities**

## 6.2 Recommendations

**Understanding of asset health:**

- Awareness of BAH within UU teams is now widespread and its application to support decision making is beginning to occur. This process should be encouraged, and championed by senior leadership
- It is recommended that UU develops a corporate glossary to ensure that key terms, particularly health, service risk and criticality, are used in the appropriate context
- UU should continue to strengthen recognition of the importance of intangible or less tangible assets, particularly data and natural capital
- UU's aspiration to move to a more structured and consistent approach to contingency planning should be prioritised. The recent Haweswater Aqueduct contingency planning could be used as a catalyst

**Establishing the link between asset health, performance, service and outcomes:**

- The development of a validated database (EXAsol) has the potential to significantly improve data governance, and confidence in decision making. The rollout of the EXAsol platform should be prioritised
- UU should seek to partner with other water companies to reduce the costs of trialling new technologies
- A formal means for UU staff to raise concerns or requests for technology development and trialling to the Innovation Team should be established. This would help to prioritise where investment should occur and would help to reduce the likelihood of particular aspects of asset health being overlooked

**Influence of asset health on expenditure planning and decision making:**

- It is recommended that a governance structure is established to control the application of asset health measures in decision making. This will help to establish a line of sight to outcomes and demonstrate the linkages between asset health, service and customer impact. A leadership focus on systems thinking and the importance of integrated decision making across planning and operations would help to emphasise the role of asset health to the overall performance of the system
- UU's eagerness to learn from approaches to asset health and other elements of asset management from other industries should be continued. For example, current BAH values could be used alongside forecasts of how this will change in future to set targets and track progress
- Multi-scenario planning and visioning exercises and reverse stress testing can improve understanding of the possible chains of events within a system associated with HILP events

**Communication and the views of the customer:**

- In its direct customer engagement on asset health, UU should be clear about what it means by this concept
- The proposed customer questionnaire on asset health could also be circulated internally, providing insight into the relative understanding of different departments

**Asset health assurance:**

- The ability of UU's Maintenance Optimisation team to identify operational performance issues is constrained by limited human resource. Data analytics and machine learning therefore have significant potential
- UU's assurance of data quality typically occurs after data processing and once draft conclusions or business cases has been prepared. The rollout of UU's EXAsol platform presents an opportunity to address this inefficiency, thanks to its application of quality checks each time data is drawn from a source system
- Concise and visually powerful reporting of asset health information to Board should continue. The dashboards being developed by the Asset Management directorate and Range Managers are a suitable approach
- State of the Assets reports or scorecards provide a valuable means of aligning reporting across asset types and can help to track performance, spot system trends, inform long-term planning and justify investment

**Innovation:**

- UU's Innovation Lab programme provides a valuable platform for suppliers to innovate in partnership with UU experts. By evolving the Innovation Lab programme into a continually available platform, potential suppliers would have a clear and continually-available avenue through which to engage UU
- A tool which automatically interrogates a lessons learnt database and pushes relevant examples to project developers and decision makers at appropriate points in the project lifecycle would be beneficial
- Additional internal innovation platforms, or an overarching framework, could help ensure a collective focus on innovation from all staff (i.e. those not involved in the CEO Challenge or Innovation Lab)
- We recommend that UU develops a clear roadmap for the progressive development of staff skills

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# Appendix A. Interviewees and Interview Questions

| No. | Person | Position | Meeting Date | Meeting Time |
|---|---|---|---|---|
| 1 | Keith Gregory | Statistical Information Manager | 13 Feb 2018 | 1000hrs |
| 2 | Caroline Howarth | Maintenance Decision Support Manager | | 1100hrs |
| 3 | Dave Lamb | Totex Decision Support Manager (OPTIMUS lead) | | 1300hrs |
| 4 | Simon Boyland | Head of Asset Systems and Planning | | 1400hrs |
| 5 | Gary Nodwell | Building Information Modelling Manager | | 1500hrs |
| 6 | James Fox | Asset Performance and Reporting Manager | 14 Feb 2018 | 0900hrs |
| 7 | Ed Dalton | Resilience Strategy Manager | | 1100hrs |
| 8 | Nick Folkes | Reservoir Safety Strategy Manager | | 1400hrs |
| 9 | Will Eyre | Programme Delivery Manager | | 1500hrs |
| 10 | Adam Lechmere | Network Strategy Development Manager | 22 Feb 2018 | 0900hrs |
| 11 | Ged Hyland | Maintenance Manager | | 1000hrs |
| 12 | John Chappell | Head of Operational Engineering | | 1230hrs |
| 13 | Jon Cockram | Network Performance Manager | | 1400hrs |
| 14 | Alison Summersfield | Lead Range Manager | 23 Feb 2018 | 0900hrs |
| 15 | Glyn Roberts | Wholesale Data Governance Manager | | 1000hrs |
| 16 | Richard Curwen | Investment Planning Manager | | 1100hrs |
| 17 | Steve Kenney | Chief Engineer for Network Modelling (W and Ww) | | 1300hrs |
| 18 | Ken Dillon, Tom Morris | Customer Research Manager, Asset Management Directorate Business Analyst | | 1400hrs |
| 19 | Dave Ogden | Wholesale Technology Manager | | 1500hrs |
| 20 | Adam Lechmere | Network Strategy Development Manager | 11 Apr 2018 | 1330hrs |
| 21 | Christopher Bates | Maintenance Strategy | | 1430hrs |
| 22 | Niall Clarke | Business Continuity Manager | | 1530hrs |

| No. | Question | Interviewees |
|---|---|---|
| ***Intro*** | | |
| | What asset health means to you | All |
| ***Understanding of asset health and risk to service*** | | |
| 1 | Elaborate and explain the logic for your definition and calculation of your asset health measure | Keith Gregory<br>Caroline Howarth<br>Dave Ogden |
| 2 | Are consistent definitions of asset health (and associated supporting metrics) applied consistently across asset groups? | James Fox<br>Adam Lechmere<br>Ged Hyland<br>Jon Cockram |
| 3 | How is asset health integrated into broader definitions of resilience? | Simon Boyland<br>Ed Dalton |
| 4 | Is there a clear line of sight from asset health to customer impact? | Simon Boyland<br>Ed Dalton |
| 5 | Are critical assets identified? Do you have an integrated asset management / resilience plan for your critical assets? | James Fox<br>Niall Clarke |
| 6 | Has this plan been stress tested? | Niall Clarke |
| ***Establishing the link between asset health, performance, service and outcomes*** | | |
| 7 | What asset level and performance indicators do you currently use and plan to use to measure asset health? Do they vary between asset groups? | Caroline Howarth |
| 8 | Is asset data quality and type sufficient for effective quantification of asset health? If not, what steps have been taken to address this? | Keith Gregory<br>Caroline Howarth<br>Gary Nodwell<br>Adam Lechmere<br>Glyn Roberts<br>Richard Curwen<br>Steve Kenney |
| 9 | Are assets and associated health data identified and described in robust data storage systems? | Glyn Roberts |
| 10 | How are critical assets defined? Are all critical assets identified and ranked, considering failure likelihood and impact on services? | Ged Hyland |
| 11 | Is asset health understood in terms of impact on asset performance, service and outcomes? Line of Sight. | *Is sufficiently addressed in and can be inferred from responses to other questions.* |
| 12 | What tools do you use to help model and predict asset health (now and in the future). How do you link this to service impacts e.g. FMECA, deterioration analysis? | Caroline Howarth<br>Jon Cockram<br>Steve Kenney<br>Adam Lechmere<br>Christopher Bates |
| 13 | In cases where failures cannot be prevented, or are unexpected, what are your rapid response emergency measures and longer term care plans and how do these mitigate the impacts of failure? | Niall Clarke |

| No. | Question | Interviewees |
|---|---|---|
| ***The influence of asset health on investment planning and decision making*** | | |
| 14 | How are asset health metrics used to inform decisions made on (timely and cost effective) interventions to maintain appropriate levels of asset heath and service? | Caroline Howarth<br>Dave Lamb<br>Adam Lechmere<br>Jon Cockram<br>Alison Summersfield<br>Glyn Roberts<br>Richard Curwen<br>Steve Kenney<br>Dave Ogden |
| 15 | How is the 'value' of asset health captured in decision making? | *Is sufficiently addressed in and can be inferred from responses to other questions.* |
| 16 | How will the underlying pressures affecting decision making for PR19 impact asset health and constrain asset health initiatives? | Simon Boyland<br>James Fox<br>Ed Dalton<br>Adam Lechmere |
| 17 | How are the above factors being addressed and considered when prioritising investments? Are risk trade-off studies undertaken? | Ed Dalton |
| 18 | Are asset health strategies/projects developed and delivered in collaboration with the supply chain? | Gary Nodwell |
| ***Communication and the views of the customer*** | | |
| 19 | Have you developed an effective ‘language’ for conveying asset health concepts to customers? | Simon Boyland<br>Ed Dalton<br>Ken Dillon / Tom Morris |
| 20 | Have you had a dialogue with your customers regarding asset health? | Ken Dillon / Tom Morris |
| 21 | Do asset health metrics and associated data support this dialogue? | Ken Dillon / Tom Morris |
| 22 | What value do your customers place on asset health and how is this evidenced? | Ken Dillon / Tom Morris |
| ***Asset health assurance*** | | |
| 23 | How successful have you been in delivering your asset health commitments? Why? | Simon Boyland |
| 24 | What assurance processes do you have in place to ensure that your asset heath related obligations (the general duty to maintain your system) are being met? | Ged Hyland<br>Glyn Roberts |
| 25 | What assurance and testing is done on new assets to help ensure that they will achieve their intended design life? | Nick Folkes<br>Will Eyre |
| 26 | Do asset health metrics and associated data support dialogue with the Board and reporting to Ofwat? | Keith Gregory<br>Simon Boyland<br>Ed Dalton |
| ***Innovation and collaboration*** | | |

| No. | Question | Interviewees |
|---|---|---|
| 27 | How is UU's asset health strategy and project history shared to promote future innovation and collaboration? | Ged Hyland |
| 28 | How does UU obtain information on best practice approaches to asset health? | Gary Nodwell<br>Nick Folkes<br>Ged Hyland<br>Alison Summersfield<br>Adam Lechmere |
| 29 | Does UU engage peers, other organisations and its supply chain in this process? | Ged Hyland<br>Alison Summersfield<br>Dave Ogden |
| 30 | Are there barriers to innovative approaches to asset health management and what needs to be done to overcome them? | Keith Gregory<br>Dave Ogden<br>Adam Lechmere |
| 31 | How are continuous improvement and lessons learnt captured and implemented? | Gary Nodwell<br>Dave Ogden |

# Appendix B. Summary Slide Deck