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Measuring resilience in the water industry

June 2017

Introduction

Measuring resilience is one of the key challenges facing the water industry in its preparation for PR19. Being able to consistently measure resilience across companies would be useful in helping customers understand their relative risk exposure, regulators and stakeholders in understanding and challenging company performance and to the companies themselves in learning from best practice and driving up standards.

Given the breadth in activity that the term resilience covers, it is unlikely that it can be reflected in a single metric and we have seen some prospective metrics come to the fore through the work of the Water and Wastewater Resilience Action Group and the working groups that have been setup to tackle this issue.

This report recommends that resilience is measured through a basket of measures and we have developed a potential metric to contribute to the current debate.

It fits into the basket of metrics as a measure of asset system vulnerability and has been developed initially to consider the resilience of water supply from water treatment works. It could, however, equally be adapted to cover other single points of failure such as aqueducts, trunk mains, service reservoirs and pumping stations. A wastewater equivalent is also achievable but would be adjusted to different consequences such as sewer flooding and pollution.

Through publishing this report, we are keen to see how the industry perceives such a metric and whether there is support to take this concept forward.

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Executive summary

Addressing the resilience gap

Resilience is one of the key issues facing the UK water industry. As recent service interruptions have shown, better resilience planning in future will be crucial, particularly given the context of the long term sustainability, operating and financial challenges facing the industry.

As an industry we need to measure resilience in a consistent way to identify areas of weakness and targets for improvement. A balanced approach, covering a range of resilience risks, would complement the current metrics in use, such as drought and asset health indices. This would encourage proactive interventions across the 4Rs of resilience:

- Resistance
- Reliability
- Redundancy
- Response & Recovery

The challenge is to develop a practical metric that assesses current resilience levels in a consistent manner and drives improvement across all aspects of the service, without being overly complicated and inefficient to implement.

A common resilience metric for the industry

We are proposing that companies adopt a measure to indicate the population served by satisfactorily resilient services, by employing a risk based resilience assessment. It focuses on common critical hazards and drives improvement over time across the 4Rs. The methodology is based upon existing international best practices and has been adapted to be suitable for use by the UK water industry.

Companies will need a comprehensive resilience framework to assess and understand the opportunities for improvement that will to enable them to efficiently maintain services to customers. However, as companies prepare their business plans to 2025 and beyond, an urgent priority is to ensure that there are resilient high quality water supplies for customers. It is with this in mind that we propose this evolving framework (see Figure A opposite).

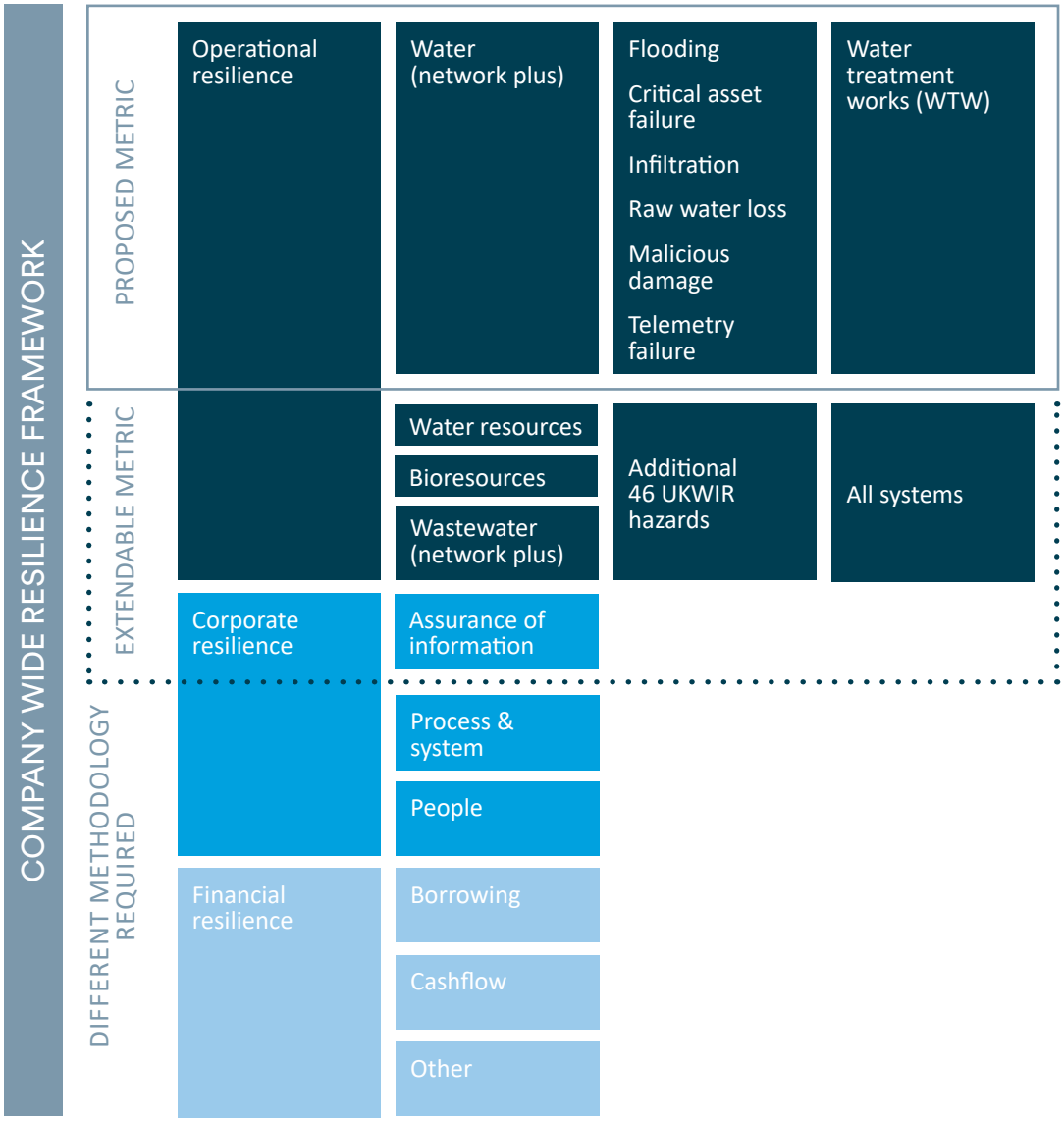


Figure A: Scope of the metric

Key assumptions

- A focus on operational resilience as this is the aspect that impacts customers the most
- A focus on certain critical systems and hazards within water to test a practical approach, but easily extendable to cover all aspects of operational resilience
- Simple questions and clear guidelines to drive consistency
- A different methodology is required to measure corporate and financial resilience, but could all fit under a company wide framework
- Drought is not included, as drought is not an instantaneous event – a different metric would be required

Key benefits of the resilience metric

IMPROVEMENT OF KNOWLEDGE REQUIRED FOR UNDERSTANDING RESILIENCE

A minimum level of data must be collected to complete the assessment.

- Where data is not available it increases overall risk score, encouraging companies to collect the required data
- Distinguishes between lack of resilience knowledge and poor resilience, enabling businesses to focus attention appropriately
- Sets standards for the minimum level of data that all companies should collect

ABILITY TO BENCHMARK AND IMPROVE RESILIENCE ACROSS THE INDUSTRY

The metric produces a normalised company resilience score and a resilience score by system and hazard.

This enables companies to:

- Benchmark their level of resilience against other companies, driving more proactive improvements
- Understand which hazards present the greatest challenges in their specific circumstances, collaboratively driving innovations
- See their resilience score change over time, demonstrating improvements

IDENTIFICATION OF THE AREAS WHERE CUSTOMERS ARE MOST EXPOSED TO HAZARDS

By assessing resilience at a system level, the metric can be used to:

- Identify systems exposing customers to service interruption risks
- Understand the interventions required to improve the resilience scores
- Prioritise investments

ABILITY FOR CUSTOMERS TO ACCESS TRANSPARENT INFORMATION ACROSS THE COUNTRY

Resilience is assessed by system and demand management zone, allowing customers to:

- Understand which hazards present the greatest challenges in the area they live
- See how they rank compared to other areas and what organisations are doing to improve their rankings

Methodology

We are proposing a methodology that is tailored to the UK water industry to address the resilience gaps whilst meeting key objectives of the sector. We consider the methodology best in class as it:

- Ensures all organisations take a bottom up risk approach to resilience
- Measures multiple hazards in one metric, providing a more holistic assessment of resilience
- Encourages efficient solutions across the 4Rs, rather than purely focusing on capex

The level of resilience is determined based on the following equations:

Risk =
C (consequence) x
V (vulnerability) x
T (threat likelihood)

Resilience =
R (risk) x 4Rs
(control factor)

Our methodology assesses the risk the hazard presents to the system. This gross risk score is then adjusted to take account of the controls and mitigation in place to combat such risks. This assessment is based on the government's guidance around the 4Rs of resilience, ensuring that the full range of responses to resilience risk are taken into account in reducing the risk score.

Classify what to measure	Assess risk score	Assess control factor	Calculate resilience score
Hazard characterisation A hazard is something that is potentially dangerous or harmful, often the root cause of an undesirable outcome, for example flooding, malicious damage, or an untriggered asset failure	Scale of impact	Redundancy	Resilience score: 1 Normalised company resilience score 2 A customer focused score by zone
System characterisation Systems, or system elements, are critical components of collecting, treating and conveying water to and from customers, for example water treatment works, pumping stations or trunk mains.	Duration of impact	Response & Recovery	
	Likelihood	Resistance	
	Vulnerability	Reliability	

Figure B: High level methodology for assessing resilience

A practical, user friendly resilience metric

The metric guides the user through three simple steps that aim to collect a basic level of data and gain an understanding of the system's vulnerability to specific hazards.

1. Asset list

Understanding the systems for assessment

- Lists systems and collects basic connectivity data
- Checks whether the system is resilient on the basis of full redundancy
- Selects only systems that are relevant and where data is available to be assessed

2. Hazard assessments

Simple, practical, data driven questions to assess relevant systems against key hazards

- Assessments by hazard for relevant systems
- Standardised, multiple choice questions against each of the risk and control factors (see opposite)

3. Resilience score

An easily comparable, customer focused scoring system

- Resilience scores by system and hazard – comparable across the industry and showing improvement over time
- Highlights confidence levels (e.g. where data is not robust)
- Scores mapped by Demand Monitoring Zone (DMZ)

Case study

Testing on water treatment works

The metric has been tested on water treatment works to confirm the methodology and ensure accurate scores are generated.

A number of different stakeholders ran the assessments, drawing upon available industry data and company records. In order to conduct a 'blind' testing, those who were not involved in creating the metric were asked to complete the assessments without prior guidance.

To test the functionality of the metric, the results were verified against current investment priorities. For example, we found that where treatment works had been identified for additional investment, the resilience metric was indeed signalling a higher risk score based on current arrangements.

During the testing process, we learnt, and built in to the metric, the following:

- The assessor required clear guidelines and an understanding of data required to complete the metric accurately and efficiently
- Questions need to be as simple as possible to ensure a universal understanding
- Scoring needs to use a combination of different techniques to realistically reflect the impact on customers

System	Flood	Critical asset failure	Infiltration	Raw water loss	Malicious damage	Telemetry failure	TOTAL	Confidence
WTW 1	●	●	●	●	●	N/A	●	92%
WTW 2	●	●	N/A	N/A	●	●	●	73%

Figure C: Testing of United Utilities Water Treatment Works (this data is available in more detail on page 18)

Recommendation to the industry

This report proposes a metric that, if implemented, would improve resilience understanding and planning in an efficient manner. We believe this approach is capable of wide adoption across the industry.

Further development of this metric for use at PR19 could include:

- Further testing by other water companies to ensure the metric works on their systems and aligns with their processes
- Once proven in water, the metric could be extended to wastewater to present a holistic view of operational resilience

We believe a metric focusing on treatment works across water is ready be included in PR19. However, with support from the industry, there is an opportunity for a more complete metric to be included in PR19. This would cover additional systems and hazards across both water and wastewater.

Context

Building resilience and protecting customers in vulnerable circumstances are the UK government's top two priorities for the water industry. This is driven from five key challenges facing the sector.

To be able to tackle these issues companies must develop ways to better understand their existing levels of resilience. It is through developing this understanding that they are then able to target interventions, in a cost effective manner, providing customers with the continuity of service they expect and rely on.

POPULATION GROWTH

AGEING INFRASTRUCTURE

ENVIRONMENTAL DEGRADATION

CLIMATE CHANGE[1]

AFFORDABILITY

Defining resilience

Resilience is not new within the water industry. There has been much debate around an industry wide definition of resilience, as well as potential measures. For the purpose of this report we are adopting Ofwat's definition as set out in its 2015 paper *Towards Resilience*, reconfirmed by the task and finish group.

"Resilience will be a key theme of our next price review and its importance will be reflected in our methodology"

Ofwat, 10 May 2017

Ofwat has been working towards[2]:

- Creating a framework that enables, incentivises and encourages the sector to deliver the resilience its customers want and need – in innovative, efficient and sustainable ways
- Making sure that this framework creates the right regulatory climate for service providers to plan and invest for resilient services now and in the future
- Ensuring that companies are putting in place the necessary protections and safety net for the customers they serve

"Resilience is the ability to cope with, and recover from, disruption, and anticipate trends and variability in order to maintain services for people and protect the natural environment, now and in the future."

Ofwat Definition,
Towards Resilience, December 2015

A resilience metric for the water industry

In 2015 Ofwat established a task and finish group on resilience. It concluded that the industry should work together to develop a method of comparing resilience, reflecting customer views, local context, the environment and company ownership of plans.

Such metrics need to:

- Be at a level of detail appropriate to the scale of the risk (i.e. measurement of resilience to material risks)
- Be practical to measure
- Measure impacts on customers and the environment
- Establish the minimum levels of resilience expected

Companies should report against a set of resilience criteria. This should be qualitative but will ensure all company boards have properly assessed resilience in a way that goes beyond their risk register.[3]

The challenge

The challenge is to find a metric that is simple enough to define and ensure some consistency yet sophisticated enough to be of value in providing a comparison of relative resilience.

This metric also needs to ensure the water sector continues to drive efficiencies whilst also considering long term resilience planning and incentivising customer focused outcomes.

Companies can be more transparent and help customers understand their relative service resilience. To achieve this a common assessment is proposed.

Improving resilience: a risk based measure

Much has been discussed around defining and measuring resilience in the water industry, and there is comprehensive guidance published covering resilience planning for critical infrastructure or specific aspects such as drought planning metrics.

However, most measures tend to be focused around one specific hazard or one particular means of mitigation when what is needed is a holistic approach to measuring current resilience that encompasses the key concerns of industry, government, customers and other stakeholders. At present we observe a clear gap when it comes to applying a bottom up approach to measuring resilience that demonstrates current risk exposure and what is being done to reduce it.

A tried and tested approach to measuring resilience

Taking a risk based approach is established in the global water industry. For example, the J100 standard for measuring resilience in the US embodies several key requirements:

- Resilience is always defined with respect to a disruption or hazard
- Resilience is always defined with respect to a specific asset or system
- Resilience metrics are defined to focus on the consequences of the system failing, likelihood of the hazards occurring, vulnerability of system to that threat, and resilience controls that can reduce any of the above[4]

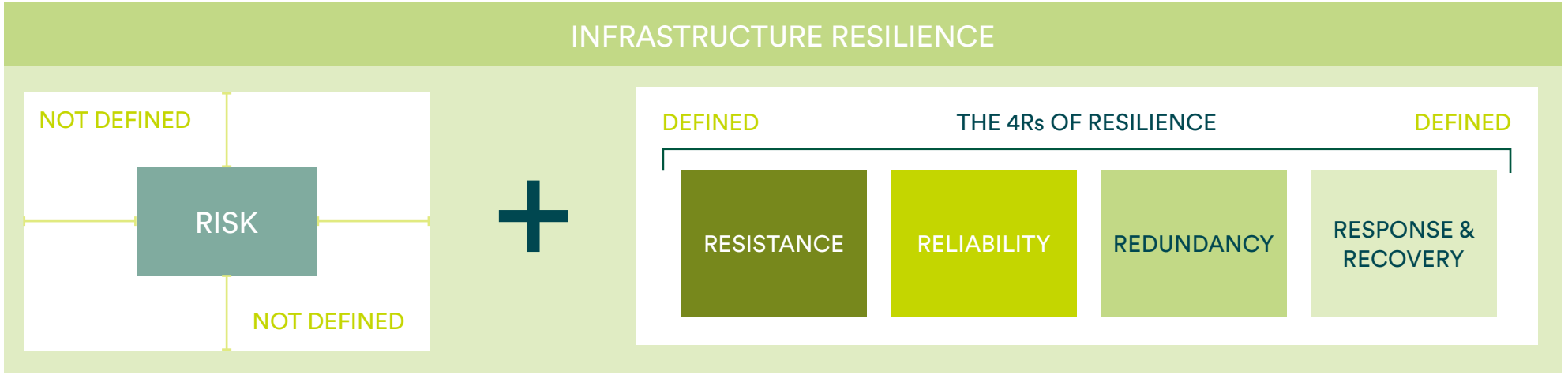
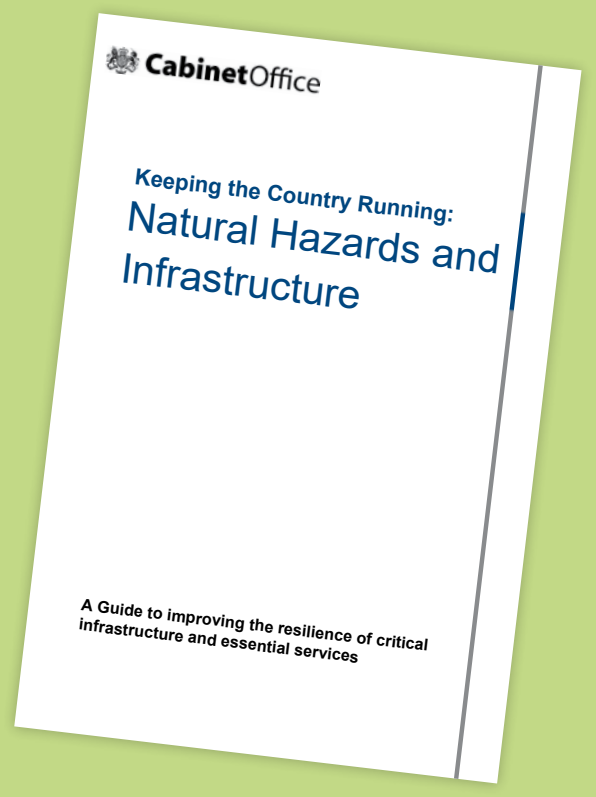


Figure D: The 4Rs of Resilience

Keeping the Country Running: Natural Hazards and Infrastructure

The 2011 publication by the Cabinet Office "Keeping the Country Running", is the current UK government guidance on resilience for critical infrastructure. It sets out the four principal strategic components of resilience. Given the range of risks, organisations should select combinations of responses from all four of these components to develop a strategy that will deliver the most cost effective and proportionate risk management response to the hazards and threats.[5]



A focused risk based approach to measuring resilience is what the industry needs

Given the challenges presented, only a risk based approach can achieve all the objectives. We have looked into a range of options, and set out the pros and cons of each in more detail within this report. However at a high level, a standardised risk assessment is beneficial as:

- It drives the right behaviours in the customers' interest (such as focusing on potential service failures)
- Standardised risk assessment can be consistently applied across organisations using two approaches: common data where it exists, and simple question sets
- It enables prioritisation in the long term and helps to focus on the critical systems in the short term
- The risk assessment considers all aspects of resilience, all 4 of the Rs, encouraging more than one sort of intervention

Methodology

The metric provides a risk based approach to measuring resilience by focusing on several key systems and assessing these against several key hazards.
A resilience score is determined based on the following fundamental equations:

Risk = C (consequence) x V (vulnerability) x T (threat likelihood)

Resilience = R (risk) x 4Rs (control factor)

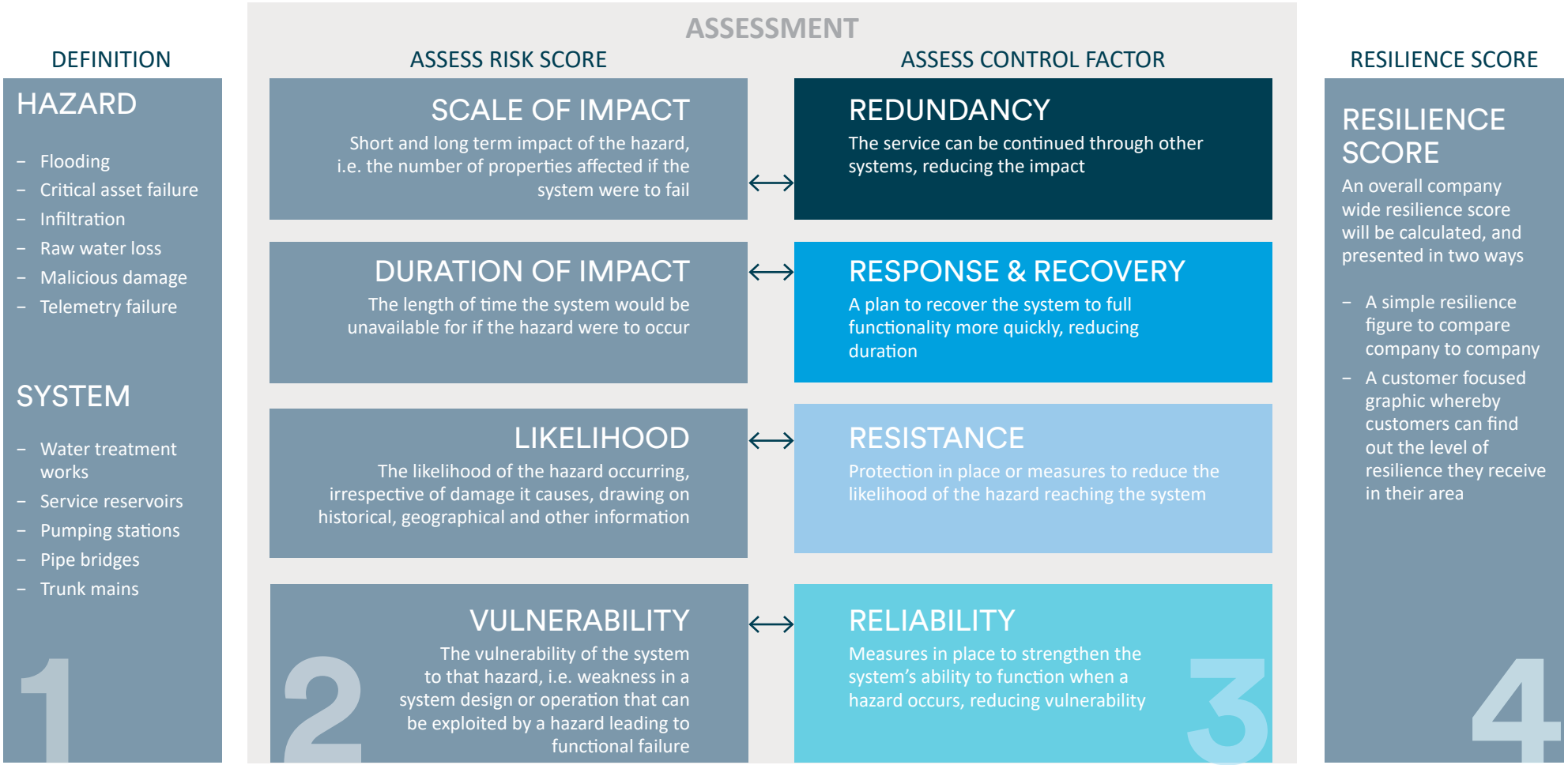


Figure E: Methodology

Consequence

SCALE OF IMPACT

The measure for the scale of impact is determined by the number of properties impacted if the system were to fail.

This includes:

- The number of properties linked to the system in total
- The number of major institutions – such as hospitals, prisons or schools – that would be affected

DURATION

Including duration of impact within the metric is particularly important. Whether a system is out of service for several hours, several days or several weeks is likely to have a major bearing on the scale of the impact on services to customers.

Therefore, with reference to a range of industry standards, we have defined boundaries and corresponding risk scores, based on the time it would take to get the system back to full functionality. These contribute to the overall risk score.

Likelihood and vulnerability

When considering the "probability" of the system failing due to the effects of a hazard, the assessment must be split into:

- The likelihood of the hazard actually occurring, for example whether it is more or less likely to flood in a particular area. This is determined by using historical data of previous occurrences, geographical locations and other forward looking questions

- The vulnerability of the system to the hazard, for example if all the critical assets can continue functioning even when the system has been flooded, the system is not vulnerable to the hazard. This is judged by specific questions focused around the existence of single points of failure and the ability of these to survive during the hazard

Common question sets have been drawn up for each hazard and system. Answering these requires only industry standard data or simple datasets that organisations should already hold.

Control factor

In order to provide a true indication of resilience, it is also necessary to understand the controls. These are resilience activities that have been applied beyond the inherent design and standard operation of the asset, to reduce the consequence, likelihood or vulnerability of hazards.

This is achieved by defining common questions in line with the 4Rs of resilience. This method[5] applies a number of qualitative questions against each hazard to assess:

REDUNDANCY

THE ADAPTABILITY OF A SYSTEM OR NETWORK, E.G. THE INSTALLATION OF BACK–UP DATA CENTRES

RESPONSE AND RECOVERY

AN ORGANISATION'S ABILITY TO RESPOND TO AND RECOVER FROM DISRUPTION.

RESISTANCE

CONCERNS DIRECT PHYSICAL PROTECTION, E.G. THE ERECTION OF FLOOD DEFENCES

RELIABILITY

THE CAPABILITY OF INFRASTRUCTURE TO MAINTAIN OPERATIONS UNDER A RANGE OF CONDITIONS, E.G. ELECTRICAL CABLING IS ABLE TO OPERATE IN EXTREMES OF HEAT AND COLD

Calculating resilience scores

Parameters for scoring

Each question results in a score between 0 and 1, depending upon the multiple choice option selected. In some cases the potential impact to customers vary more significantly between the options than in others. For example, the difference between a system flooding once versus never flooding is substantial, whereas the difference between a system flooding four times or five times is less significant as the difference in resilience is relatively minor.

This means that, depending upon the question, the scoring approach can be either linear, logarithmic or exponential in order to provide an appropriate weighting for each response. Examples of these are set out opposite.

Therefore, each question requires one of the following scoring methodologies. A real example from the metric is included.

Linear scoring – equally proportioned

IS THERE A FLOOD BARRIER IN PLACE AND WHAT FLOOD LEVEL IS THIS DESIGNED TO?

Barrier design to a 1 in 1000 / > 0.1%	Barrier designed to a 1 in 100 / > 1%	Temporary barrier	No barrier	Don't know
0.25	0.50	0.75	1.00	1.00

Logarithmic scoring – decreasing difference between the scores

HOW MANY SECURITY INCIDENTS OR MALICIOUS ATTACKS HAVE THERE BEEN IN THE LAST 5 YEARS?

None	Once	Twice	Three/Four times over 5 years	At least once every year	Don't know
0.00	0.42	0.71	0.88	1.00	1.00

Exponential scoring – increasing difference between the scores

IN THE EVENT OF A CRITICAL ASSET FAILURE, WHAT IS THE EXPECTED DURATION THE SYSTEM WOULD BE OUT OF SERVICE FOR?

Up to 12 hours	Up to 24 hours	Up to 72 hours	Up to 7 days	More than 7 days	Don't know
0.00	0.05	0.14	0.37	1.00	1.00

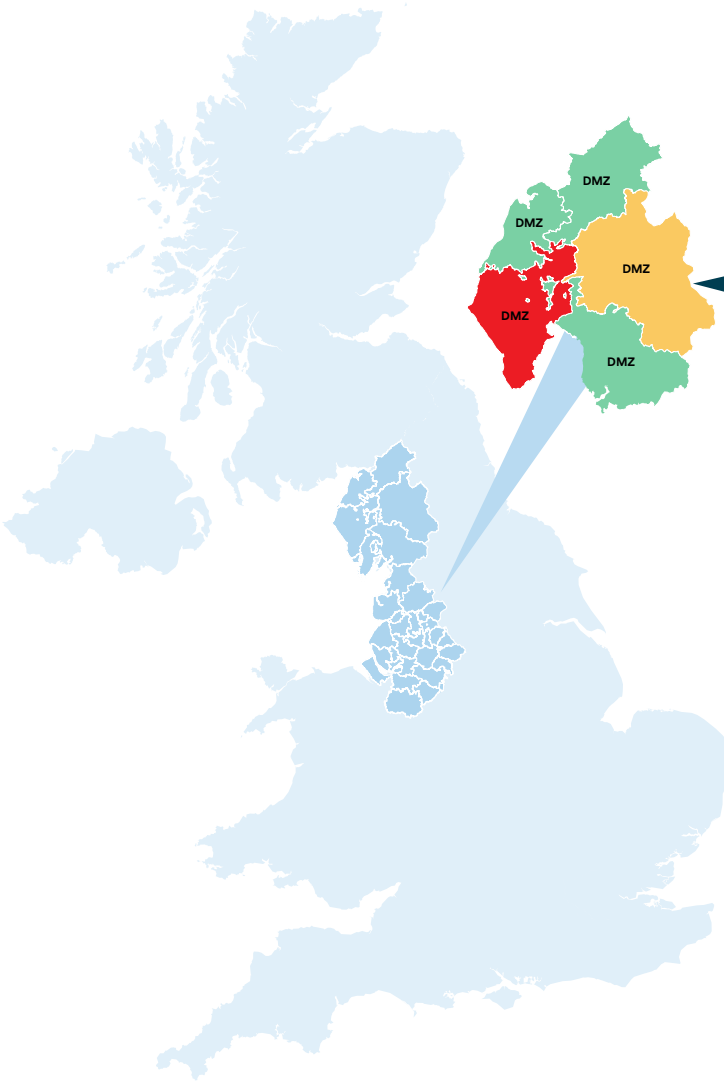
Figure F: Scoring methodologies

Presentation of overall scores

The final resilience scores are presented in two ways:

1. As an overall figure. This figure represents the level of resilience existing today, and can be compared across the industry. Investment prioritisation can then be done in relation to the reduction in score achieved by the planned intervention
2. As a customer focused level of resilience by Demand Monitoring Zone (DMZ). With each system linked to a DMZ, customers will be able to see the level of resilience they receive against these six hazards, compared to other parts of the country. An interactive map could be made available for customers to click on their DMZ.

An example of the customer facing information is shown in Figure G opposite.



FICTIONAL EXAMPLE FOR PRESENTATION OF DATA

DMZ

No. of properties in Zone

100,000

Total Zone resilience score

20,000

Rank

50/100

Telemetry **LOW**	**HIGH** Flood	Raw Water Loss **LOW**
Malicious Damage **MODERATE**	Critical Asset Failure **LOW**	**HIGH** Infiltration

20% of customers are at HIGH RISK OF SERVICE INTERRUPTION

Figure G: Example resilience data available to customers in their area

Example question set – Flood

QUESTION DEVELOPMENT FRAMEWORK FOR THE RESILIENCE METRIC

TAB	Flood

Resilience Metric	RISK									
Assessments	Consequence			Likelihood				Vulnerability		
Categories of Risk Factors	Impact	Duration		Historical / Forward Looking Factors				Design / Operational / Conditional Factors		
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?	In the event of a probable maximum extent flood, what is the expected duration the system would be out of service for?		How many times has the system flooded in the last 5 years?		Referring to the EA coastal / fluvial flood maps, in what zone is the system?		Within the system, are the critical aspects located within the flood zone (i.e. that would potentially impact the ability to function - e.g power, filters etc.)		
Parameter for scoring	Number of properties	Up to 12 hours	0.00	None	0.00	Zone 1 / Less than 1 in 1000 / < 0.1%	0.14	No critical aspects impacted	0.25	
		Up to 24 hours	0.05	Once	0.42	Zone 2 / More than 1 in 1000 / > 0.1%	0.37	Up to 25% of water production impacted	0.50	
		Up to 72 hours	0.14	Twice	0.71	Zone 3a or 3b / More than 1 in 100 / >1%	1.00	Up to 50% of water production impacted	0.75	
		Up to 7 days	0.37	Three or four times over 5 years	0.88	Don't know	1.00	Over 50% of water production impacted	1.00	
		More than 7 days	1.00	At least once every year	1.00		1.00	Don't know	1.00	
		Don't know	1.00	Don't know	1		1.00		1.00	
WTW 1	29000	More than 7 days	1	None	0	Zone 2 / More than 1 in 1000 / > 0.1%	0.37	Up to 50% of water production impacted	0.75	
WTW 2	63170	Up to 72 hours	0.14	Twice	0.71	Zone 3a or 3b / More than 1 in 100 / >1%	1	Over 50% of water production impacted	1	
WTW 3	93600	Up to 72 hours	0.14	None	0	Zone 1 / Less than 1 in 1000 / < 0.1%	0.14	No critical aspects impacted	0.25	
WTW 4	173070	Up to 72 hours	0.14	Twice	0.71	Zone 3a or 3b / More than 1 in 100 / >1%	1	Over 50% of water production impacted	1	
WTW 5	181765	Up to 12 hours	0	None	0	Zone 1 / Less than 1 in 1000 / < 0.1%	0.14	No critical aspects impacted	0.25	
WTW 6	5300	Up to 12 hours	0	None	0	Zone 1 / Less than 1 in 1000 / < 0.1%	0.14	No critical aspects impacted	0.25	
WTW 7	23281	Up to 7 days	0.37	Three or four times over 5 years	0.88	Zone 3a or 3b / More than 1 in 100 / >1%	1	Over 50% of water production impacted	1	
WTW 8	17000	Up to 7 days	0.37	Once	0.42	Zone 2 / More than 1 in 1000 / > 0.1%	0.37	Up to 50% of water production impacted	0.75	

Resilience Metric	CONTROLS							
Assessments	Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors								
Questions / Industry standard measures	Is there a flood barrier in place and what flood level is this designed to?		Has the system either been designed, or upgraged, to be able to continue functioning in the event of a flood (relevant to its EA flood zone)		Is there an on-site and regularly reviewed recovery plan for flooding and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	Barrier design to - at least 1 in 1000 / > 0.1%	0.25	Yes	0.00	ERP in place for this hazard and embedded	0.50	0	0
	Barrier design to - at least 1 in 100 / >1%	0.50	No	1.00	ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	Temporary barrier in place	0.75	Don't know	1.00	Generic ERP developed	0.80	Up to 25%	0.5
	No Barrier	1.00		1.00	No ERP	1.00	Up to 50%	0.75
	Don't know	1.00		1.00	Don't know	1.00	50% plus	1
		1.00		1.00		1.00	Don't know	1
WTW 1	No Barrier	1	Don't know	1	Generic ERP developed	0.8	Up to 50%	0.75
WTW 2	No Barrier	1	No	1	Generic ERP developed	0.8	50% plus	1
WTW 3	No Barrier	1	Don't know	1	ERP developed for this hazard to best practice	0.65	50% plus	1
WTW 4	No Barrier	1	No	1	ERP developed for this hazard to best practice	0.65	50% plus	1
WTW 5	No Barrier	1	Don't know	1	ERP developed for this hazard to best practice	0.65	Up to 25%	0.5
WTW 6	Barrier design to - at least 1 in 1000 / > 0.1%	0.25	No	1	Generic ERP developed	0.8	50% plus	1
WTW 7	No Barrier	1	No	1	Generic ERP developed	0.8	50% plus	1
WTW 8	Barrier design to - at least 1 in 100 / >1%	0.5	No	1	ERP developed for this hazard to best practice	0.65	50% plus	1

Figure H: Example question sets

Example question set – Critical Asset Failure

TAB	Critical Asset Failure

Resilience Metric	RISK											
Assessments	Consequence			Likelihood								
Categories of Risk Factors	Impact	Duration		Historical / Forward Looking Factors								
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?	In the event of a critical asset failure, what is the expected duration the system would be out of service for?		How many times has the system failed in the last 5 years due to a critical asset failure?		Based upon the Ofwat condition grade system, what is the worst asset condition grade for the critical assets within the system?		Is the system operated at 100% capacity for the majority of time?				
Parameter for scoring	Number of properties	Up to 12 hours	0.00	None	0.00	1	0.00	50% or below	0.00			
		Up to 24 hours	0.05	Once	0.42	2	0.05	70% or below	0.05			
		Up to 72 hours	0.14	Twice	0.71	3	0.14	80% or below	0.14			
		Up to 7 days	0.37	Three or four times over 5 years	0.88	4	0.37	90% or below	0.37			
		More than 7 days	1.00	At least once every year	1.00	5	1.00	Above 90%	1.00			
		Don't know	1.00	Don't know	1.00	Don't know	1.00	Don't know	1.00			
WTW 1	29000	More than 7 days	1.00	At least once every year	1	5	1	70% or below	0.0498			
WTW 2	63170	Up to 7 days	0.37	Once	0.42	2	0.05	70% or below	0.0498			
WTW 3	93600	Up to 7 days	0.37	None	0	2	0.05	70% or below	0.0498			
WTW 4	173070	Up to 72 hours	0.14	Once	0.42	2	0.05	Don't know	1			
WTW 5	181765	More than 7 days	1.00	At least once every year	1	5	1	Above 90%	1			
WTW 7	23281	More than 7 days	1.00	At least once every year	1	5	1	Don't know	1			
WTW 8	17000	More than 7 days	1.00	Three or four times over 5 years	0.88	5	1	Don't know	1			

Resilience Metric		CONTROLS							
Assessments	Vulnerability	Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors	Design / Operational / Conditional Factors								
Questions / Industry standard measures	How many critical assets are there within the system? These are single assets that, if they fail, would cause the whole system to fail - i.e. single failure modes	Is there a proactive maintenance and monitoring approach for the critical assets within the system?		*No Reliability Control Question*		Is there an on-site and regularly reviewed recovery plan for critical asset failure and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	0	0.00	Yes, proactive maintenance and monitoring	0.50	1		ERP in place for this hazard and embedded	0.50	0	0.00
	1	0.70	Proactive maintenance but not monitored	0.65	1		ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	2	0.80	Inconsistently applied	0.80	1		Generic ERP developed	0.80	Up to 25%	0.50
	3	0.90	No	1.00	1		No ERP	1.00	Up to 50%	0.75
	4+	1.00	Don't know	1.00	1		Don't know	1.00	50% plus	1.00
	Don't know	1.00		1.00	1			1.00	Don't know	1.00
WTW 1	2	0.8	Yes, proactive maintenance and monitoring	0.5	1		Generic ERP developed	0.8	50% plus	1
WTW 2	3	0.9	Yes, proactive maintenance and monitoring	0.5	1		Generic ERP developed	0.8	50% plus	1
WTW 3	1	0.7	Proactive maintenance but not monitored	0.65	1		ERP in place for this hazard and embedded	0.5	50% plus	1
WTW 4	2	0.8	Proactive maintenance but not monitored	0.65	1		Generic ERP developed	0.8	Up to 25%	0.5
WTW 5	1	0.7	Inconsistently applied	0.8	1		Generic ERP developed	0.8	50% plus	1
WTW 7	4+	1	Proactive maintenance but not monitored	0.65	1		Generic ERP developed	0.8	50% plus	1
WTW 8	4+	1	Proactive maintenance but not monitored	0.65	1		Generic ERP developed	0.8	Up to 50%	0.75

Figure H: Example question sets

Completing the metric

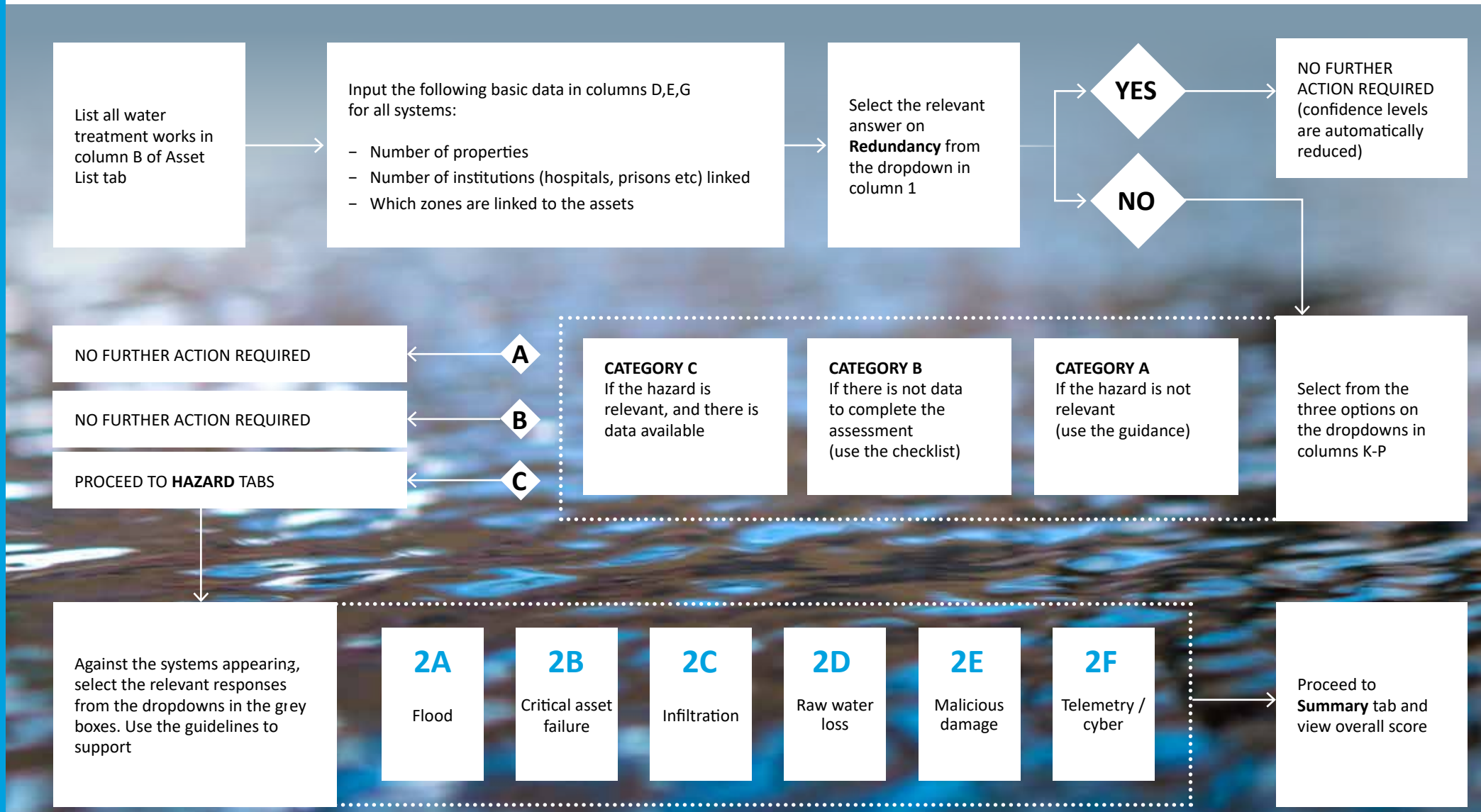


Figure I: Metric flowchart

Overview of the steps to complete the metric

The metric is comprised of three key sections: The Asset List, the Hazard Assessments, and the Scores. The flow chart shows how to successfully complete the metric and view the resilience scores. The descriptions opposite give more detail around these steps.

There is currently generic guidance to help navigate the assessor through the metric, step by step. However, company specific guidance will also be required, and a guide to collecting data sources. This will need to be developed as the metric is integrated into company processes.

Asset list

The assessor lists all relevant assets owned by the company and inserts data for

- Which zones are linked to the assets
- Number of properties linked to the asset
- Number of institutions (hospitals, prisons, schools etc.) linked to the asset
- Full redundancy
- Select dropdown option around hazard relevance and data availability

At the end of this tab, assets are filtered by:

- Redundancy
- Relevance of the hazard for assessment
- Data available to conduct assessment

TAB 1

Assessment by hazard

For the relevant systems and hazards (coming through the filter), complete the matrix of questions. There are standardised, multiple choice questions for each of the following:

- Consequence (Scale x Duration)
- Likelihood
- Vulnerability
- Control (4Rs of Resilience)

TAB 2

View summary and overall score

The results are presented as:

- Individual resilience score by system and hazard, along with a company total score, which is comparable across the industry, and able to see improvement over time
- A highlighted list of key systems where risks are high and/or where confidence is low due to non-availability of data
- A customer focused graphic, showing key scores in each DMZ

TAB 3

Case study: Testing on United Utilities WTW

Case Study

Systems tested

The methodology was tested on water treatment works. We selected a range of systems varying in size, area served, and those which we knew already to be high risk or low risk in order to check the metric was scoring realistically.

Testing method

We used a number of different stakeholders to run the assessments, ensuring that those who were not involved in any way in creating the metric could conduct a blind testing, without prior guidance.

Assessors were instructed to use the range of data available, either through industry wide published sources or UU internal records, to complete the assessment.

Results

Results are presented in the table below. By comparing these with UU internal assessments, and aligning with existing knowledge, we were able to verify the scores to ensure appropriate functionality of the metric.

What we learnt

- Clear guidelines were required to support the assessor complete the metric accurately
- Questions needed to be as simple as possible in order to ensure a good level of common understanding
- Scoring needed to be carefully apportioned, using a mixture of logarithmic, exponential and linear systems depending on the question

Next steps

- The metric would now benefit from being tested by other water companies to ensure it can be assessed and appropriately scores systems
- The approach could also be enhanced through the automation of data collection, alignment to company systems and use in developing resilience plans for the period to 2025 and beyond

Risk Boundaries per Hazard	Risk Boundaries per System	Assumptions
High: 50,000	High: 300,000	Data not available = max score
Mid: 10,000	Mid: 50,000	Hazard not relevant = 0
Low: 0	Low: 0	

Total Company Score	No. of Properties	Normalised Score
416,100	**1,000,000**	**0.416**

System Name	Flood	Critical Asset Failure	Infiltration	Raw Water Loss	Malicious Damage	Telemetry Failure	Total System	Risk Category	Confidence
WTW 1	2,400	6,341	7,540	3,759	1,133	Hazard not relevant	21,173	Low	91%
WTW 2	5,846	1,446	Data not available	3,943	1,481	2,151	78,036	Moderate	71%
WTW 3	139	260	Data not available	Hazard not relevant	0	3,187	97,186	Moderate	73%
WTW 4	13,013	2,385	5,145	14,307	7,894	0	42,744	Low	87%
WTW 5	0	81,431	18,179	Hazard not relevant	0	0	99,610	Moderate	90%
WTW 6	0	Hazard not relevant	1,893	2,112	0	180	4,185	Low	90%
WTW 7	6,439	12,106	7,377	Data not available	0	Hazard not relevant	49,203	Low	82%
WTW 8	600	6,364	Data not available	Hazard not relevant	0	Hazard not relevant	23,963	Low	82%

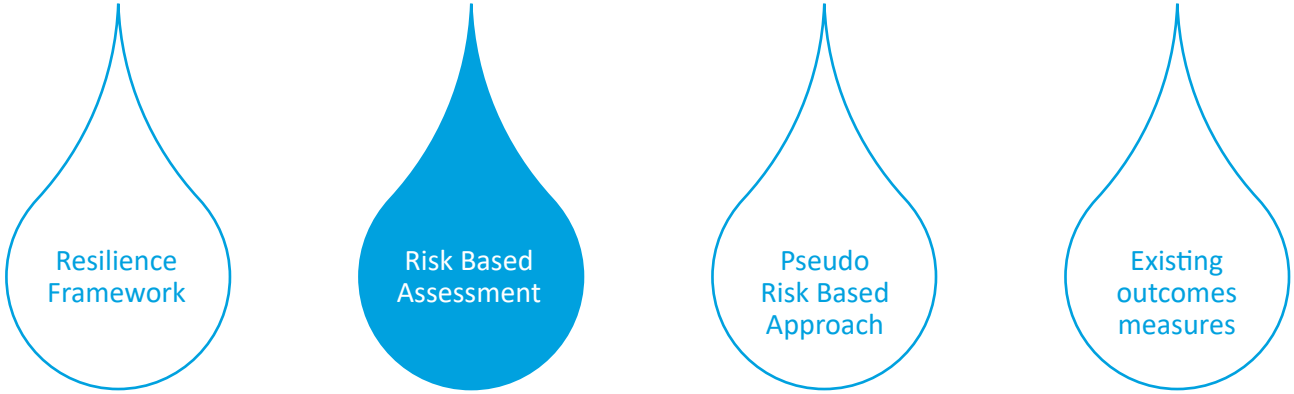
Figure J: Results of selected UU WTW

The approach to developing the metric

Within the water industry, there has been a wide debate about potential resilience metrics. They tend to fall to two extremes; a complex risk framework that is all encompassing but would be challenging to setup and rank consistently; or simplistic lagging measures of performance that would be quick and easy to implement but of very limited value in understanding the true resilience of companies. The challenge is to find a metric that sits at a point between these two extremes. The table below presents four categories of measures we have considered.

Metric type	Examples	Advantages	Disadvantages
Resilience framework Set a framework over a range of resilience issues such as leadership, strategy, environment, people and assets and compare companies to a scale of best practice	– Such as USAID: Community Resilience Framework[7]	– Broad assessment of resilience to hazards and trends – Not limited to an asset focus but demonstrates an awareness of wider stresses and trends such as skills shortages & finance – Is not a 'capex justifying' measure as it drives policy and procedure change	– Would always be somewhat subjective to score and would require auditing to give confidence – Does not include quantitative risk assessment – Arguably distracts from the highest priority which is risk of service failure
Risk based assessment Set a methodology for assessing service risk on an asset by asset basis	– An assessment based on site by site analysis of consequence of failure and vulnerability to hazards	– Consistent with the common framework approach adopted for asset management planning – Allows comparison at a site by site and company by company level – Can be used for investment prioritisation by allowing cost-benefit assessment – Can demonstrate risk reduction over time	– Complex to setup in a way that would allow comparisons between companies – Would require clear rules and consistent application, possibly requiring a horizontal audit exercise – Would require additional work to translate asset-centric analysis into meaningful results about customer-centric services
Pseudo risk based measures Limited assessment of service risk to customers focusing on one area of resilience	– Percentage of water treatment / wastewater treatment works at risk from flooding that have protection in place – Percentage of customers with more than one source of supply	– Simpler to assess than a full risk based assessment – Would allow companies to track change over time, so could be used to set aspirational long term resilience targets	– Measures miss aspects of a true risk assessment, as they do not consider the full picture – Could drive the wrong behaviours as only certain intervention types would appear effective – Measures usually depend on local conditions, can't be used to compare
Existing outcome measures Using a selection of existing outcome type measures would give an indication of relative resilience performance	– Security of supply index – Customer minutes lost	– Most already being calculated so straightforward to develop once agreed which measures are in	– Most are lagging measures so variation of hazards will be significant score impact, does not necessarily act as a strong indicator of resilience – Many are dependent on local conditions, and cannot be used to compare

Figure K: Options for resilience metrics



Our recommendation: A risk based approach

We are recommending that a standardised risk assessment offers the most appropriate balance between simplicity and the usefulness of the data provided in delivering a form of comparison of relative resilience between companies. However, this does not preclude the use of more detailed company specific approaches by individual companies and at least offers a means of tracking change at a company level over time, enabling the cost-benefit of interventions to be assessed and improvement to be seen over time.

A standardised risk assessment:

- Drives the right behaviours in the customer's interest (such as focusing on potential service failures)
- Can be consistently applied across organisations using two approaches: common data where it exists, and standardised question sets
- Enables prioritisation in the long term and helps to focus on the critical systems in the short term
- Considers all aspects of resilience, all 4 of the Rs, encouraging more than one sort of intervention

A pathway to resilience

With all the debate around resilience in the water industry, there is no shortage of suggested methodologies. There is an opportunity to collaborate across industry and develop a methodology that works for all.

Currently, individual organisations or sub-groups collaborate to develop resilience measures that focus on pressing needs within local areas or regions. Some lessons can be learnt from these existing practices to drive collaborative development of a balanced industry wide metric.

With this in mind, we have taken a range of industry perspectives when determining the scope of the metric. Our thought process for this scope is set out over the next few slides, and this remains open for challenge by industry stakeholders.

However, it is important to note that what we are proposing is not the end game, rather a foundation for guiding the industry on a 'pathway to resilience'. The high level steps to creating a comprehensive resilience framework are laid out below.

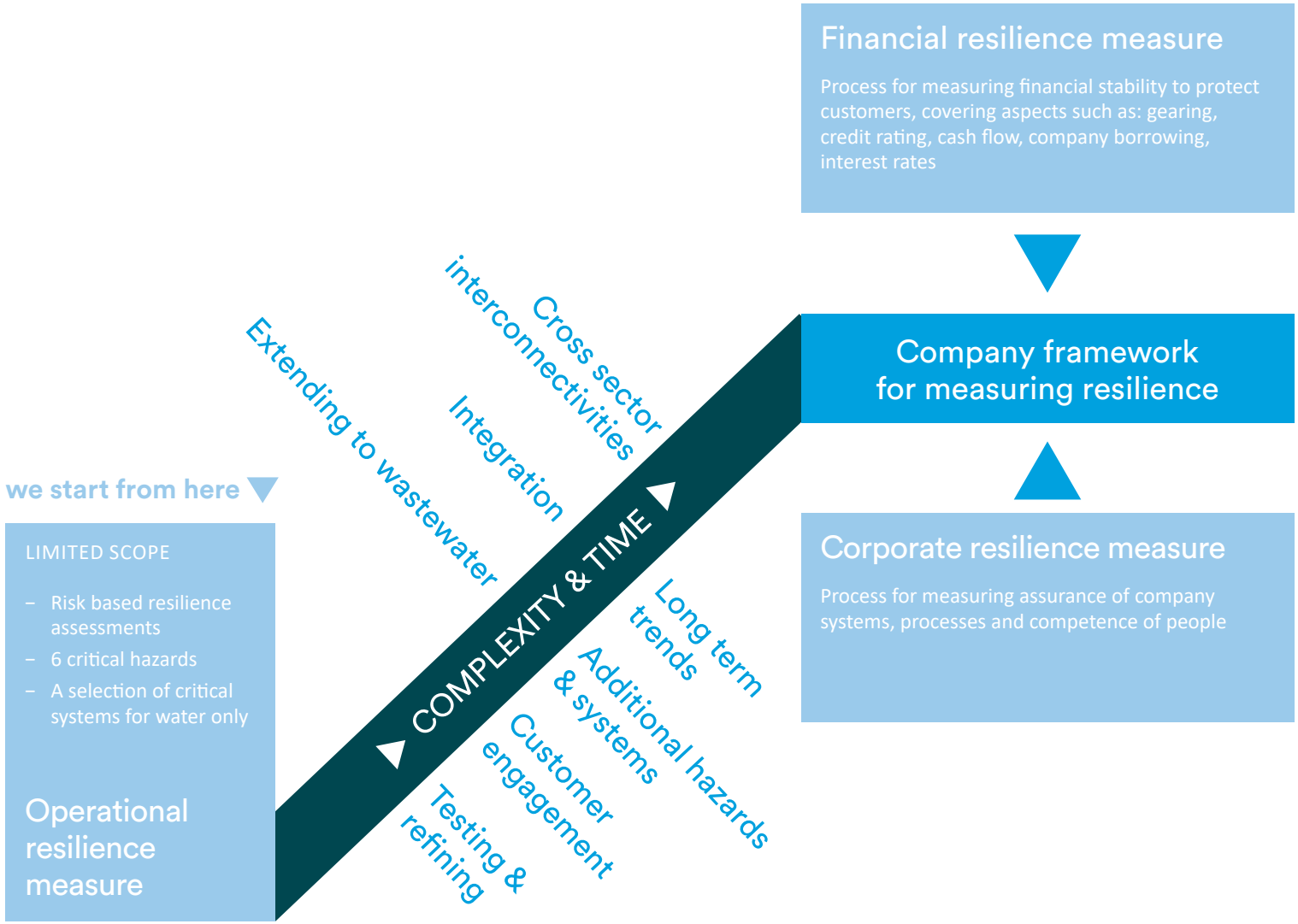


Figure L: Pathway to resilience

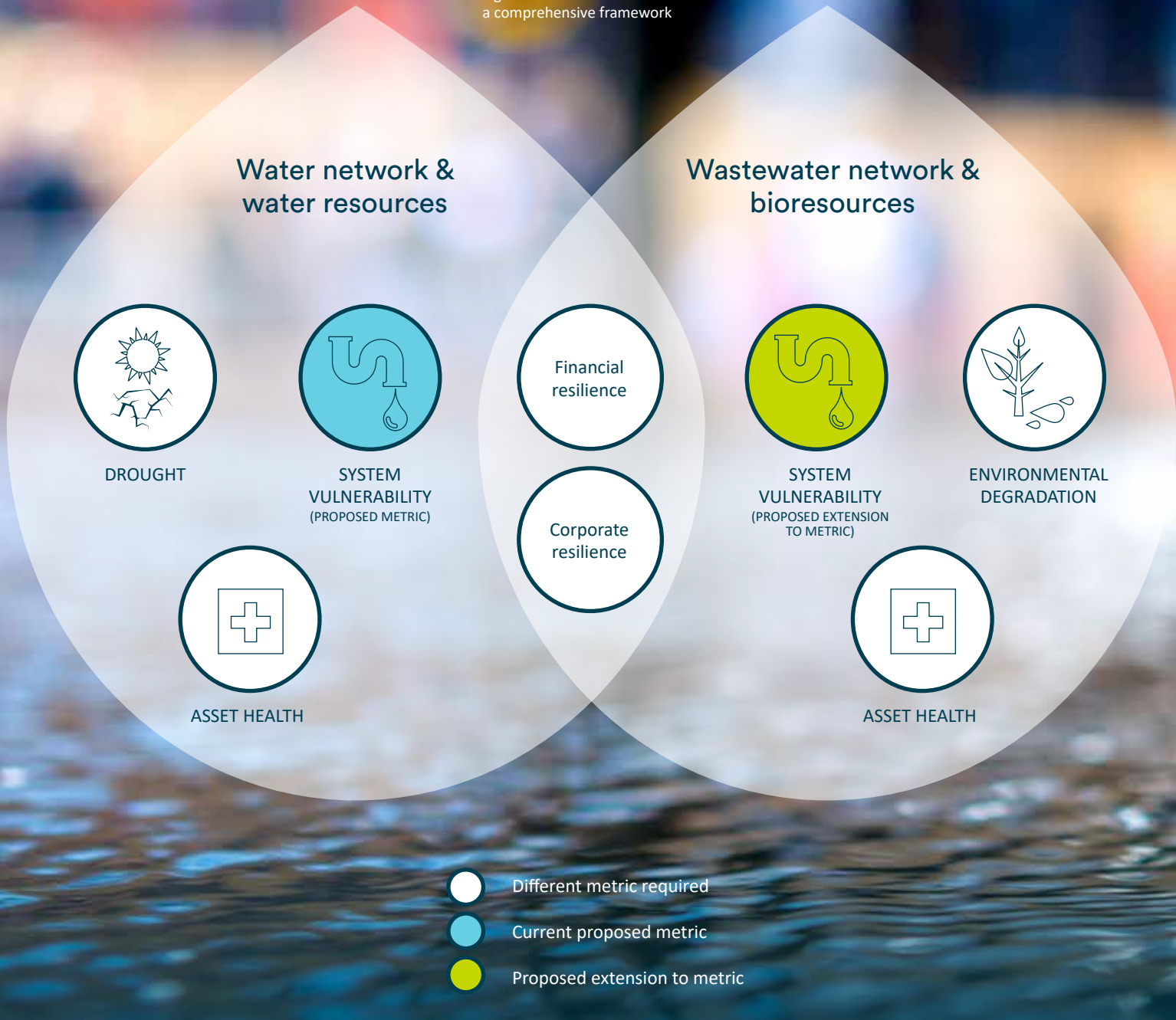
End goal: a comprehensive framework

Whilst the current metric focuses predominantly on operational resilience, companies will eventually require a comprehensive company-wide framework covering all aspects of resilience: operational, corporate and financial.

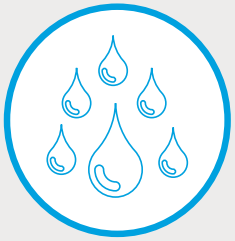
There is no current metric that could cover all these aspects under one methodology. Therefore, as reasoned in this report, the proposed metric focuses on operational resilience only. However, this could be integrated under a wider 'basket of measures' approach, whereby different aspects of resilience are defined and measured using separate methodologies.
See Figure M opposite.

A company-wide framework would bring operational, corporate and financial resilience together under one process, standardising as much as possible, but also allowing for each area to be measured with the most appropriate metric.

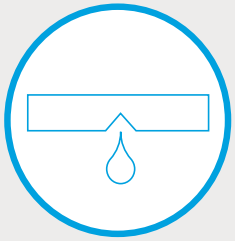
Figure M: Basket of measures for a comprehensive framework



Our approach to hazards



FLOODING



CRITICAL ASSET FAILURE

INFILTRATION

RAW WATER LOSS

MALICIOUS DAMAGE

TELEMETRY FAILURE

This metric is an opportunity to collaborate across the industry and develop a methodology that works for all. Therefore balancing stakeholder priorities from across the industry was key. Current measures of resilience mostly focus on singular issues, such as drought, flooding, or water treatment works 'too big to fail'. This metric can cover all these aspects in one.

We took a broad view of industry concerns and priorities when determining which hazards to measure. We list some of these, which have either been directly taken into account, or will be extended to cover in the future.

Many of the long term trends are not individually measurable. A future metric could include these trends more specifically, but would require a slightly adjusted approach to account for the more gradual and longer term impact. A metric similar to the current drought planning tool could be built upon and aligned.

The six hazards identified align with the 46 UKWIR defined hazards[8]. Going forward these hazards could be reviewed and incorporated into a fully detailed risk based resilience metric.

THE INDUSTRY KEY PRIORITIES

- Environmental degradation
- Climate change
- Population growth
- Ageing infrastructure
- Drought
- Flooding
- Storms
- Leakages
- Critical assets failing
- Water quality
- Water availability
- Contamination
- Security
- Cyber attacks
- Affordability
- Customer focus

Our point of view on systems

We are proposing a focus on providing clean water to customers. In order to build a more useful and effective measure of resilience, we are proposing a bottom up approach focusing on certain systems, and the individual assets that make up those systems. This supports the industry challenge as:

- It ensures water companies focus their efforts initially on the critical aspects of delivering the service, and the biggest potential impact to customers. Too broad a focus will distract from these key issues
- The industry requires an indication of resilience, but one that is practical to complete and easy to implement. Starting with a water only approach will support this

More specifically, there will be an initial focus on certain systems that are deemed critical to end to end service provision. This will further encourage a focus in the right areas, and a more practical approach than measuring every single asset. These systems are:

- **Water treatment works (initial focus)**
- Service reservoirs
- Pumping stations
- Pipe bridges
- Trunk mains

Once the metric has been implemented, trialled and tested, it is possible to then expand the scope to cover additional systems. It can also be expanded to define the level of data that companies should collect regarding resilience. A separate measure must be defined for corporate and financial resilience although they could be joined together to form a single framework.

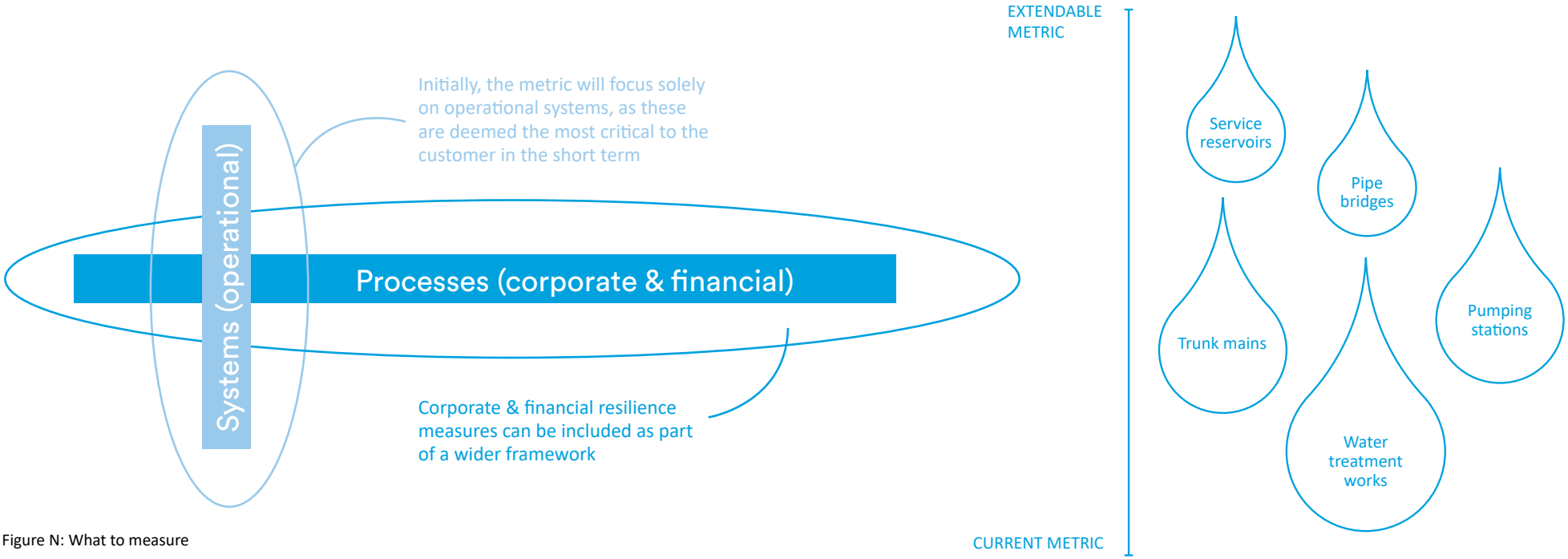


Figure N: What to measure

Recommendations

Recommendation to the industry

This report proposes a metric that, if implemented, would improve resilience understanding and planning in an efficient manner. We believe this approach is capable of wide adoption across the industry.

Further development of this metric for use at PR19 could include:

- Further testing by other water companies to ensure the metric works on their systems and aligns with their processes
- Once proven in water, the metric could be extended to Wastewater to present a holistic view of operational resilience

We believe a metric focusing on treatment works across water is ready be included in PR19. However, with support from the industry, there is an opportunity for a more complete metric could be included in PR19. This would cover additional systems and hazards across both water and wastewater.

TESTING

Further testing by other water companies to ensure the metric works on their systems and aligns with their processes

EXTENDING

Once proven in water, the metric could be extended to:

- **Wastewater**
- **Additional systems, such as service reservoirs or pumping stations**
- **Additional hazards, such as power failure or human error**

IMPLEMENTING

Including the metric within the PR19 methodology, alongside other resilience measures proposed

Appendix– Question Sets

Flood

Resilience Metric	RISK									
Assessments	Consequence				Likelihood				Vulnerability	
Categories of Risk Factors	Impact		Duration		Historical / Forward Looking Factors				Design / Operational / Conditional Factors	
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?		In the event of a probable maximum extent flood, what is the expected duration the system would be out of service for?		How many times has the system flooded in the last 5 years?		Referring to the EA coastal / fluvial flood maps, in what zone is the system?		Within the system, are the critical aspects located within the flood zone (i.e. that would potentially impact the ability to function - e.g power, filters etc.)	
Parameter for scoring	Number of properties		Up to 12 hours	0.00	None	0.00	Zone 1 / Less than 1 in 1000 / < 0.1%	0.14	No critical aspects impacted	0.25
			Up to 24 hours	0.05	Once	0.42	Zone 2 / More than 1 in 1000 / > 0.1%	0.37	Up to 25% of water production impacted	0.50
			Up to 72 hours	0.14	Twice	0.71	Zone 3a or 3b / More than 1 in 100 / >1%	1.00	Up to 50% of water production impacted	0.75
			Up to 7 days	0.37	Three or four times over 5 years	0.88	Don't know	1.00	Over 50% of water production impacted	1.00
			More than 7 days	1.00	At least once every year	1.00		1.00	Don't know	1.00
			Don't know	1.00	Don't know	1		1.00		1.00

Resilience Metric	CONTROLS							
Assessments	Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors								
Questions / Industry standard measures	Is there a flood barrier in place and what flood level is this designed to?		Has the system either been designed, or upgraged, to be able to continue functioning in the event of a flood (relevant to its EA flood zone)		Is there an on-site and regularly reviewed recovery plan for flooding and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	Barrier design to - at least 1 in 1000 / > 0.1%	0.25	Yes	0.00	ERP in place for this hazard and embedded	0.50	0	0
	Barrier design to - at least 1 in 100 / >1%	0.50	No	1.00	ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	Temporary barrier in place	0.75	Don't know	1.00	Generic ERP developed	0.80	Up to 25%	0.5
	No Barrier	1.00		1.00	No ERP	1.00	Up to 50%	0.75
	Don't know	1.00		1.00	Don't know	1.00	50% plus	1
		1.00		1.00		1.00	Don't know	1

Critical asset failure

Resilience Metric	RISK									
Assessments	Consequence				Likelihood					
Categories of Risk Factors	Impact		Duration		Historical / Forward Looking Factors					
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?		In the event of a critical asset failure, what is the expected duration the system would be out of service for?		How many times has the system failed in the last 5 years due to a critical asset failure?		Based upon the Ofwat condition grade system, what is the worst asset condition grade for the critical assets within the system?		Is the system operated at 100% capacity for the majority of time?	
Parameter for scoring	Number of properties		Up to 12 hours	0.00	None	0.00	1	0.00	50% or below	0.00
			Up to 24 hours	0.05	Once	0.42	2	0.05	70% or below	0.05
			Up to 72 hours	0.14	Twice	0.71	3	0.14	80% or below	0.14
			Up to 7 days	0.37	Three or four times over 5 years	0.88	4	0.37	90% or below	0.37
			More than 7 days	1.00	At least once every year	1.00	5	1.00	Above 90%	1.00
			Don't know	1.00	Don't know	1.00	Don't know	1.00	Don't know	1.00

Resilience Metric			CONTROLS							
Assessments	Vulnerability		Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors	Design / Operational / Conditional Factors									
Questions / Industry standard measures	How many critical assets are there within the system? These are single assets that, if they fail, would cause the whole system to fail - i.e. single failure modes		Is there a proactive maintenance and monitoring approach for the critical assets within the system?		*No Reliability Control Question*		Is there an on-site and regularly reviewed recovery plan for critical asset failure and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	0	0.00	Yes, proactive maintenance and monitoring	0.50		1	ERP in place for this hazard and embedded	0.50	0	0.00
	1	0.70	Proactive maintenance but not monitored	0.65		1	ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	2	0.80	Inconsistently applied	0.80		1	Generic ERP developed	0.80	Up to 25%	0.50
	3	0.90	No	1.00		1	No ERP	1.00	Up to 50%	0.75
	4+	1.00	Don't know	1.00		1	Don't know	1.00	50% plus	1.00
	Don't know	1.00		1.00		1		1.00	Don't know	1.00

Infiltration

Resilience Metric	RISK											
Assessments	Consequence			Likelihood								
Categories of Risk Factors	Impact	Duration		Historical / Forward Looking Factors								
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?	In the event of severe contamination through infiltration, what is the expected duration the system would be out of service for?		How many times have you had contamination issues downstream of the water treatment works in the last 5 years that has caused a loss of service?		Based upon the Ofwat condition grade system, what is the worst asset condition grade for the assets within the system?		Is the system within close proximity to contaminated land or a source of industrial pollution?		Are the assets accessible by wildlife or livestock?	
Parameter for scoring	Number of properties	Up to 12 hours	0.00	None	0.00	1	0.00	No	0.50	No	0.50
		Up to 24 hours	0.05	Once	0.42	2	0.05	Yes	1.00	Yes	1.00
		Up to 72 hours	0.14	Twice	0.71	3	0.14	Don't know	1.00	Don't know	1.00
		Up to 7 days	0.37	Three or four times over 5 years	0.88	4	0.37		1.00		1.00
		More than 7 days	1.00	At least once every year	1.00	5	1.00		1.00		1.00
		Don't know	1.00	Don't know	1	Don't know	1.00		1.00		1.00

Resilience Metric		CONTROLS							
Assessments	Vulnerability	Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors	Design / Operational / Conditional Factors								
Questions / Industry standard measures	Does the system operate at atmospheric pressure, or is it pumped / otherwise pressurised?	Is there a proactive maintenance and monitoring approach for the system?		Has the system been constructed / maintained in a way that it can withstand water intrusion?		Is there an on-site and regularly reviewed recovery plan for Infiltration and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	Pressurised	0.48	Yes, proactive maintenance and monitoring	0.50	Yes	0.25	ERP in place for this hazard and embedded	0.50	0	0.00
	Occasional operation at atmospheric pressure	0.81	Proactive maintenance but not monitored	0.65	No	1.00	ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	Never pressurised	1.00	Inconsistently applied	0.80	Don't know	1.00	Generic ERP developed	0.80	Up to 25%	0.50
	Don't know	1.00	No	1.00		1.00	No ERP	1.00	Up to 50%	0.75
		1.00	Don't know	1.00		1.00	Don't know	1.00	50% plus	1.00
		1.00		1.00		1.00		1.00	Don't know	1.00

Raw water loss

Resilience Metric	RISK									
Assessments	Consequence			Likelihood				Vulnerability	
Categories of Risk Factors	Impact	Duration		Historical / Forward Looking Factors				Design / Operational / Conditional Factors	
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?	In the event of deterioration of raw water beyond treatment capability, what is the expected duration the system would be out of service for?		How many times in the last 5 years has the source water become contaminated or there been a raw water main failure?		What is the predominant source of the water serving the treatment works?		Does the system draw its raw water from a single source, or are there mulitple sources available?	
Parameter for scoring	Number of properties	Up to 12 hours	0.00	None	0.00	Ground Water	###	Multiple Sources	0.25
		Up to 24 hours	0.05	Once	0.42	Open reservoir	###	Single Source	1.00
		Up to 72 hours	0.14	Twice	0.71	River	###	Don't know	1.00
		Up to 7 days	0.37	Three or four times over 5 years	0.88	Don't know	###		1
		More than 7 days	1.00	At least once every year	1.00		###		1
		Don't know	1.00	Don't know	1.00		###		1

Resilience Metric	CONTROLS							
Assessments	Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors								
Questions / Industry standard measures	Do you (as an organisation) control/manage the catchment land?		Are there any raw water controls in place that minimize the service risk supplying clean water? For example: reservoir mixers, mobile PAC plants etc.		Is there an on-site and regularly reviewed recovery plan for Raw Water Loss and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	100% of land owned	0.50	Yes, significantly reducing contamination	0.50	ERP in place for this hazard and embedded	0.50	0	0.00
	100% of land owned or controlled	0.60	Yes, but with mixed results	0.75	ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	Over 75% on land owned or controlled	0.75	Nothing in place	1.00	Generic ERP developed	0.80	Up to 25%	0.50
	Over 50% of land owned or controlled	0.90	Don't know	1.00	No ERP	1.00	Up to 50%	0.75
	Under 50% of land owned of controlled	1.00		1.00	Don't know	1.00	50% plus	1.00
	Don't know	1.00		1.00		1.00	Don't know	1.00

Malicious damage

Resilience Metric	RISK									
Assessments	Consequence			Likelihood			Vulnerability			
Categories of Risk Factors	Impact	Duration		Historical / Forward Looking Factors			Design / Operational / Conditional Factors			
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?	In the event of severe malicious damage, what is the expected duration the system would be out of service for?		How many security incidents or malicious attacks have there been in the last 5 years?		In which morphological class (according to the RUC2011 units) is the majority of the system located?		Are there critical assets (single points of failure) that could be impacted through malicious damage ?	
Parameter for scoring	Number of properties	Up to 12 hours	0.00	None	0.00	Rural: Village / Dispersed	0.25	No	0.25	No critical assets onsite	0.50
		Up to 24 hours	0.05	Once	0.42	Rural: Town / Fringe	0.50	Yes	1.00	Critical Assets onsite	1.00
		Up to 72 hours	0.14	Twice	0.71	Urban: City / Town	0.75	Don't know	1.00	Don't know	1.00
		Up to 7 days	0.37	Three or four times over 5 years	0.88	Urban: Major / Lesser conurbation	1.00		1.00		1.00
		More than 7 days	1.00	At least once every year	1.00	Don't know	1.00		1.00		1.00
		Don't know	1.00	Don't know	1.00		1.00		1.00		1.00

Resilience Metric	CONTROLS							
Assessments	Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors								
Questions / Industry standard measures	Is the system located with a perimeter that is innaccessable to the public?		What security systems are in place to ensure the critical assets are protected from physical attacks?		Is there an on-site and regularly reviewed recovery plan for Malicious Damage and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	Electric fence / barbed wire around entire perimeter	0.25	Site staffed 24/7	0.25	ERP in place for this hazard and embedded	0.50	0%	0.00
	High fence around entire perimeter	0.50	CCTV systems installed and monitored	0.50	ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	Fencing or barrier in place but with vulnerabilities	0.75	Security Staff on site	0.75	Generic ERP developed	0.80	Up to 25%	0.50
	No fencing or barrier around the perimeter	1.00	Intruder detection systems (PIDS) installed	0.90	No ERP	1.00	Up to 50%	0.75
	Don't know	1.00	Nothing in place	1.00	Don't know	1.00	50% plus	1.00
		1.00	Don't know	1.00		1.00	Don't know	1.00

Telemetry failure

Resilience Metric	RISK									
Assessments	Consequence			Likelihood			Vulnerability			
Categories of Risk Factors	Impact	Duration		Historical / Forward Looking Factors			Design / Operational / Conditional Factors			
Questions / Industry standard measures	In normal circumstances, how many properties are served by the system?	In the event of a severe telemetry / SCADA / DCS failure or cyber security attack, what is the expected duration the system would be out of service for?		How many times in the last 5 years has there been a telemetry / SCADA / DCS failure, or cyber security incident that has affected the system?		How old is the telemetry / SCADA / DCS system (the oldest part, either outstation or central server)?		What is the complexity of the telemetry / SCADA / DCS system?		Is any of the system subject to remote control?	
Parameter for scoring	Number of properties	Up to 12 hours	0.00	None	0.00	Less than 2 years old	0.25	No telemetry / SCADA / DCS	0.00	No	0.00
		Up to 24 hours	0.05	Once	0.42	Less than 5 years old	0.50	Basic telemetry / SCADA / DCS	0.50	Yes	0.50
		Up to 72 hours	0.14	Twice	0.71	Less than 10 years ol	0.75	Complex telemetry / SCADA / DCS	1.00	Don't know	1.00
		Up to 7 days	0.37	Three or four times over 5 years	0.88	Over 10 years old	1.00	Don't know	1.00		1.00
		More than 7 days	1.00	At least once every year	1.00	Don't know	1.00		1.00		1.00
		Don't know	1.00	Don't know	1.00		1.00		1.00		1.00

Resilience Metric	CONTROLS							
Assessments	Resistance		Reliability		Response and Recovery		Redundancy	
Categories of Risk Factors								
Questions / Industry standard measures	Is there a plan in place to proactively test the telemetry system, identify the latest cyber security risks and update the system to prevent failure?		Is there an alternative/manual arrangement in place to ensure control in the event of a telemetry failure?		Is there an on-site and regularly reviewed recovery plan for Telemetry and has this been embedded?		Assuming your answer provided to [Duration], during this period what is the maximum percentage of properties that would be off supply, taking into account contingency measures?	
Parameter for scoring	Yes - comprehensive plan (covering all aspects)	0.25	Yes - no impact to service	0.25	ERP in place for this hazard and embedded	0.50	0%	0.00
	Partial Plan in place	0.50	Yes - but with reduced functionality for a period	0.50	ERP developed for this hazard to best practice	0.65	Up to 10%	0.25
	No plan in place	1.00	No	1.00	Generic ERP developed	0.80	Up to 25%	0.50
	Don't know	1.00	Don't know	1.00	No ERP	1.00	Up to 50%	0.75
		1.00		1.00	Don't know	1.00	50% plus	1.00
		1.00		1.00		1.00	Don't know	1.00

List of references:

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5 Keeping the Country Running, Natural Hazards and Infrastructure, October 2011 (Page 8)
6 Cabinet Office, Summary of the 2016 Sector Security and Resilience Plans, November 2016 (Page 10)
7 USAID: Community Resilience: Conceptual Framework and Measurement Feed the Future Learning Agenda, 2013 (Page 19)
8 UKWIR Resilience Planning: Good Practice Guide, October 2013 (Page 23)

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