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CMA Water Redeterminations

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Dear Panel Members,

Further to my independent submission to this panel earlier this year, Anglian Water has now commissioned me to more fully explore and explain the impacts of soil-related and weather-related environmental hazards on their pipe network.

In the CMA's provisional findings, paragraph 8.34 suggested that regional differences may have helped Anglian Water achieve its high levels of performance on leakage. So, to explore this suggestion, in this report we consider how both soil and weather hazards impact on pipe networks, and how the environment in the Anglian Water region compares with that of the rest of England and Wales.

We conclude that the disproportionately aggressive soils, extreme weather patterns and vulnerable pipes in this operating area make the east of England one of the most challenging regions in which to achieve good leakage performance.

As ever, if you have any questions, please do let me know.

Wishing you all the very best,

[redacted]

Dr. Timothy S. Farewell

MapleSky Ltd

The impact of environmental factors on leakage in the Anglian Water region

Dr Timothy S. Farewell PhD, MSc, BSc, M.I.SoilSci, SFHEA

MapleSky Ltd

October 2020

Executive Summary

In this report, we seek to determine if Anglian Water's good leakage performance has been helped or hindered by environmental conditions in its operating region relative to those found across the rest of the England and Wales.

To do so, we explore the impact that the soil and weather conditions have on failure rates in water distribution pipes. We find increased rates of pipe failure when temperatures are extremely cold or extremely hot, and when the soils are particularly chemically or physically aggressive to pipe materials. We also explore how the environmental conditions in the Anglian Water region compare with average conditions across England and Wales.

We find that, far from being benign, the Anglian Water region contains some of the most aggressive ground conditions for water networks in the UK. The ground hazards present in this region arise from extreme soil types including highly shrinkable clay soils, as well as compressible, unstable, corrosive and peatland soils (which all increase the rate of pipe failure). Freely draining, very sandy soils are also present, which make the initial observation of leaks more difficult. We observe that the three soils with the highest failure rates for water pipes in the Anglian Water region are each approximately 1.3, 3, and 4 times as common in this area as the rest of the England and Wales.

We observe that in the summer months, East Anglia is quantifiably hotter and drier than most of the rest of England and Wales, and that these extreme conditions measurably increase the risk of failure to buried pipes. Furthermore, it is observed that the disproportionately long lengths of aging asbestos cement (AC) pipes in much of the Anglian Water region are very susceptible to the particular ground hazards which are so prevalent in this part of the country.

Like many water companies, Anglian Water's aging network is also particularly susceptible to high rates of failure in cold winter temperatures. We find that winter temperatures in the Anglian Water region are broadly similar to average winter temperatures in England and Wales.

Finally, it would be remiss not to highlight that the climate in this region is already changing and will continue to do so. Climate models indicate that the summers in this region are predicted to continue to become even hotter and drier. Our models indicate that these even more extreme, environmental conditions will have a significant impact upon seasonal leakage rates from these aging pipe assets.

We conclude that the combination of 1) aggressive soils, 2) extreme weather conditions and 3) vulnerable and aging pipes makes the attainment of high performance levels on leakage, and more severe bursts, very challenging in the Anglian Water region.

Introduction:

A comment in paragraph 8.45 of the CMA's provisional findings suggested that some people have concerns that the reasons for good leakage performance in the Anglian Water region are *"likely to de due to a combination of regional differences, historical levels of investment and past efficiencies in achieving targets."*

While I am not very well placed to comment on Anglian Water's past investments or past efficiencies, I have spent much of the last two decades researching the impacts of the environment on infrastructure failures. My specific expertise lies in modelling the interactions between soil hazards, weather patterns and linear infrastructure failures in the UK, so this will be the main focus of this report.

To investigate the possible regional differences mentioned in the CMA comment, first of all, we quantify the impact that the environment has on the water distribution network. Secondly, we determine if the level and extent of environmental hazards faced by Anglian Water's pipe network are consistent with the rest of England and Wales.

As a way of introduction, I am an academic environmental data scientist who has spent many years developing infrastructure-focused environmental hazard models for the whole of the UK, some of which contributed to the award of the Queen's Anniversary Prize in 2017. Over my career in the university environment, and now as an independent academic and a director of two geohazard companies, I have helped most major UK water companies, as well as other infrastructure companies, local highways agencies, insurance companies and mortgage lenders to understand the impact of the environment on their assets, properties and investments.

Throughout these UK-wide projects carried out across different business sectors, I have found many consistent environmental-impact patterns, which at the simplest level can be reduced to: "infrastructure fails more under extreme soil and weather conditions". Despite the many national-scale ground hazard models I have built, much of the more in-depth research that I have undertaken, along with my research colleagues and my students, has been focussed on the eastern side of the UK. This focus has been guided by the unique and fascinating combination of environmental hazards present in this area.

Over the last ten years, Anglian Water has provided both me and my postgraduate students with access to many of their datasets so that we can study and model the impacts of the soil and weather on buried water pipes. In this report we refer to some of this existing research, and draw upon the techniques used in our Ofwat-approved WISPA models to explore more fully some of the quantifiable impacts of the environment on Anglian Water's pipe network. We also consider how representative the environmental conditions of East Anglia are of the rest of England and Wales. To test what difference average English and Welsh weather patterns would have on failure rates in the region, we modify the weather inputs to our models to roughly simulate those of average conditions and predict the resulting change in pipe failures.

As well as considering Anglian Water's own infrastructure data, we draw on supporting evidence about the environment from a range of third-party organisations. These include the Met Office and Hadley Centre, the National Soil Resources Institute (NSRI) at Cranfield University, the British Geological Survey (BGS) and the Environment Agency (EA).

Leakage and burst mains

In this analysis, available data and published research is used to quantify the relationship between environmental hazards and the number of pipe failures and associated leakage in the Anglian Water region.

Compared to minor leaks, burst mains are typically large, and rapidly noticeable failure events on the network, which allow us to observe more accurately where, and when, they occur. This is important, as it allows us to measure and model the impact of changing environmental conditions on the network.

Burst mains accounted for an average of 25% (IQR:22-27%) of all annual leakage related repairs on the Anglian Water network between 2006 and 2019 (Figure 1). As such, burst mains provide a useful surrogate to quantify the impact of environmental hazards on leakage across the Anglian Water (AW) region.

So, in this report, bursts are used an expedient proxy for the number of leakage related impacts (both minor and major) on the Anglian Water network as influenced by the environmental hazards present in this region. A rule of thumb has been that for every large burst, there are another 3 smaller leaks which require attention, although in recent years the proportion of smaller leakage jobs has been increasing and currently stands around 3.7 leakage jobs per burst (Figure 1) in this region. From the data, it appears that small failures on the network, associated with leakage, are being more commonly detected and repaired than in past years.

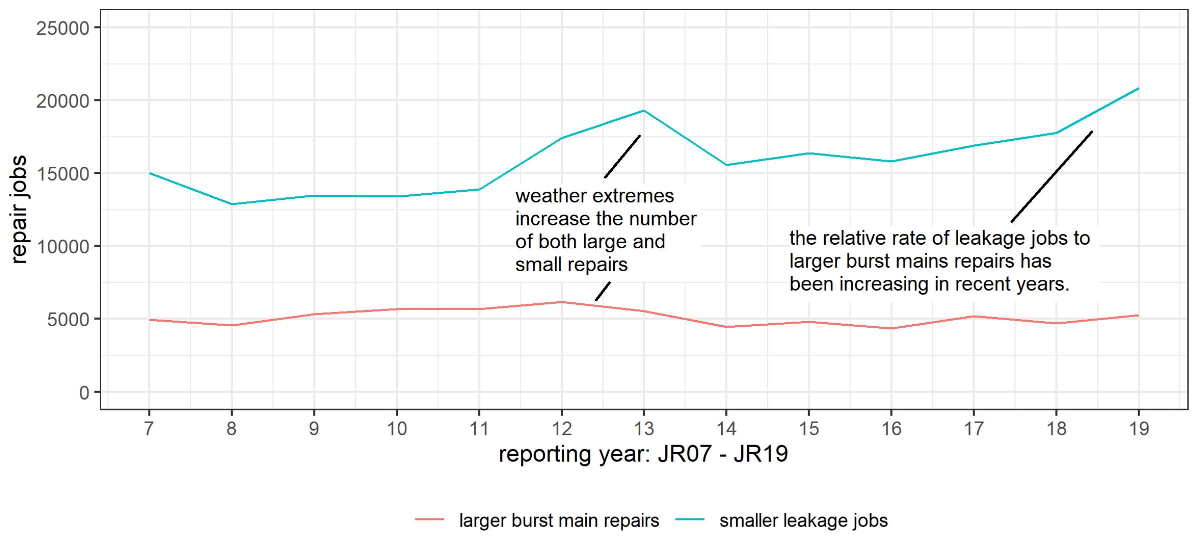

Figure 1- leakage jobs and burst mains repairs in the Anglian Region by reporting year.

Pipes fail more in unstable, changing, and extreme environments

Pipes are particularly susceptible to both extremes and rapid changes in their physical and operating environments. Where vulnerable pipes lie in aggressive soils, and are acted upon by extreme and changing weather patterns, more leakage and bursts can be expected (Figure 2). Higher leakage and burst rates are associated with hot and cold temperature extremes, large fluctuations in soil moisture content, highly shrinkable or corrosive soils and rapid changes in water temperature or pressure (Barton et al, 2019 & 2020). East Anglia is prone to all these conditions.

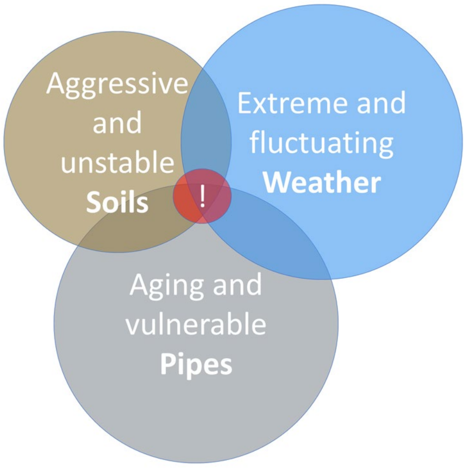

Figure 2 - leakage and bursts are more likely to occur where aging and vulnerable pipes are buried in hazardous soil and acted on by extreme and changing weather patterns

Environmental geohazards and leakage in East Anglia

There are three components, which when combined, make large parts of Anglian Water's network particularly susceptible to leakage issues, compared to the national average conditions.

1. **Infrastructure vulnerability:** The pipe materials used are particularly susceptible to ground hazards in the Anglian Water region.

2. **Soils:** The soils are particularly aggressive to pipes in the Anglian Water region. At the same time, due to the nature of the network and some of the soils, leaks can take longer to find.

3. **Climate:** Extreme temperatures and droughts are common in the Anglian Water region which impact on rates of pipe failure.

While all these components interact with each other, we will look at each of these in turn. We will then briefly discuss the expected impacts from our changing climate on the pipe network.

Figure 3 demonstrates how fluctuations in moisture content in clay-rich soils can lead to increased leakage and bursts, especially from asbestos cement (AC), iron and PVC pipes, which are prevalent in the Anglian Water region.

For an in-depth review of the many interrelated factors which lead to pipe failures, you may wish to read our 2019 paper: *Improving pipe failure predictions: Factors affecting pipe failure in drinking water networks* (Barton et al, 2019).

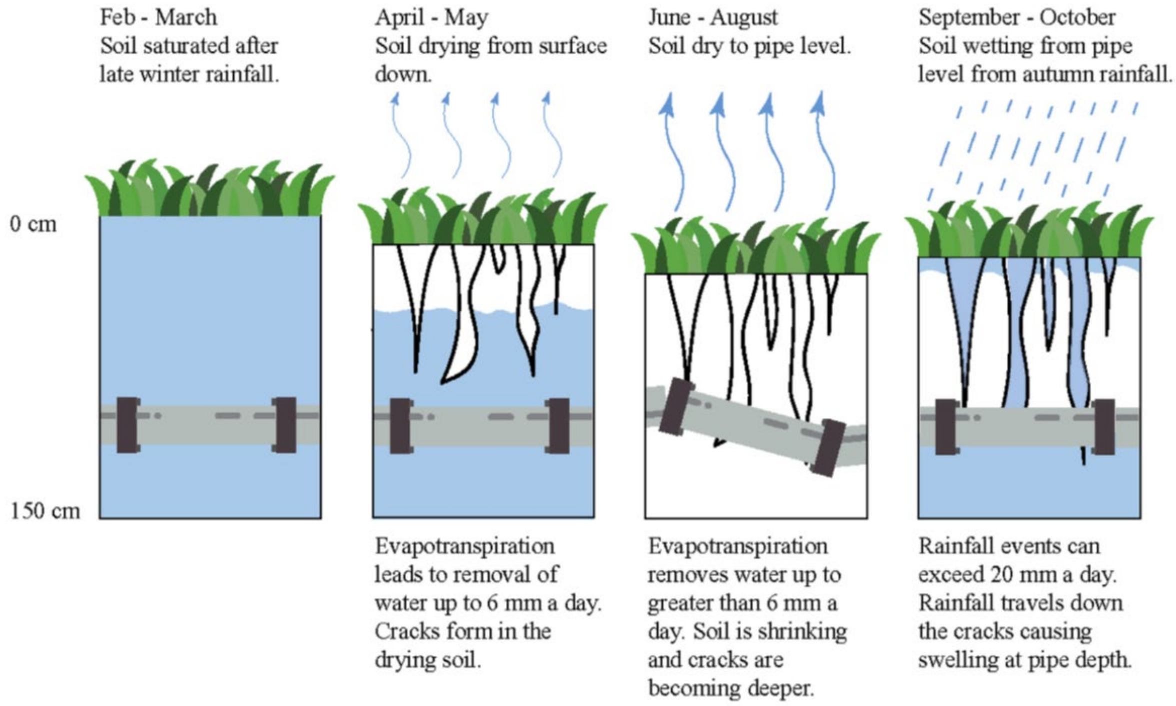

Figure 3 The impact on pipes of seasonal shrink-swell clay rich soils (adapted from Barton et al, 2019 & Farewell et. al, 2012;)

1. Vulnerable and aging pipe materials

- The Anglian Water region comprises abnormally large amounts of Asbestos Cement pipes compared to other English Regions
- Asbestos Cement pipes are particularly vulnerable to the ground hazards prevalent in East Anglia

The material of the pipe is important to consider when assessing the impact of the environmental conditions on the network. Anglian Water's network has an unusually large proportion of pipes made from Asbestos Cement (AC) due to an early, pre-privatisation pipe replacement scheme in the 1960s and 1970s (Figure 4).

Asbestos Cement is unfortunately a material which is very vulnerable to the impacts of ground movement. As it has aged, it has become more susceptible to failure and is now one of the most at-risk pipe materials in the network. This is particularly true in the hot and dry summer months (Figure 5 & Figure 6) which are becoming increasingly common in the Anglian Water region.

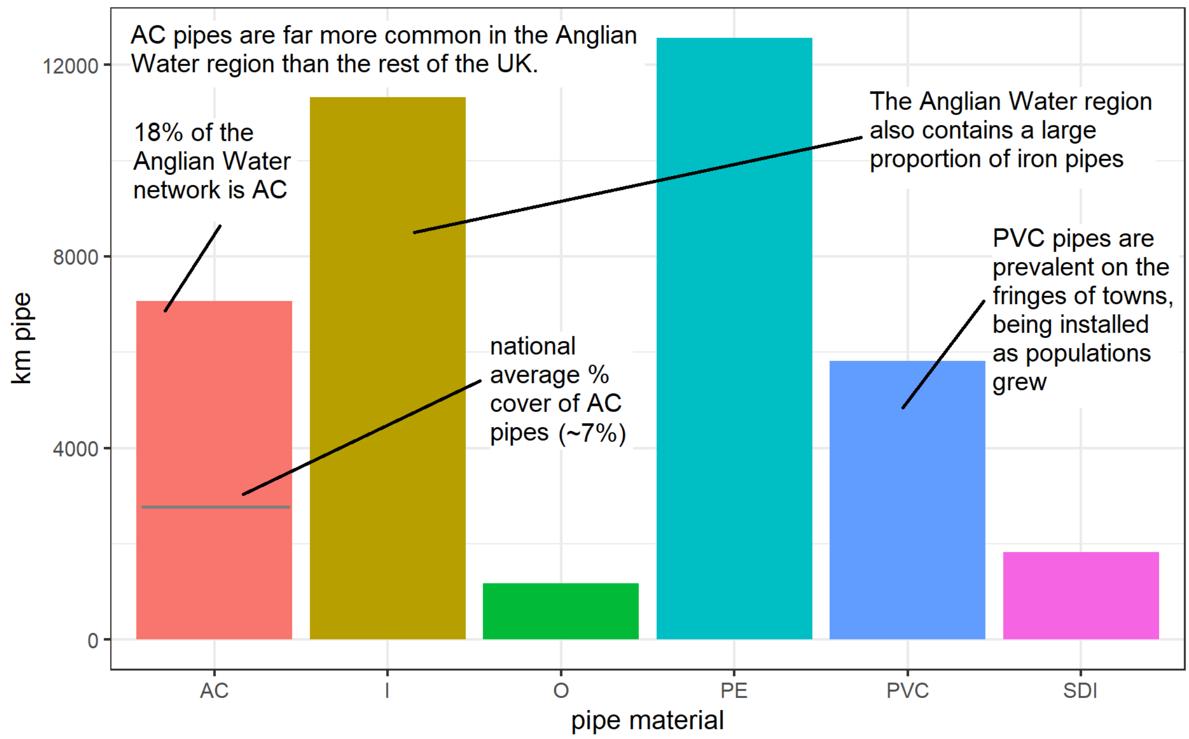

Figure 4 - lengths of pipe materials in the Anglian Water Network. AC: asbestos cement; I: Iron; O: other / unknown; PE: polyethylene; PVC: polyvinylchloride; SDI: steel and ductile iron

Approximately 18% of Anglian Water's network is made of AC pipes – about 2.5 times as much as the national average (7%). Other highly vulnerable pipe materials in the network include cast iron (I) pipes and PVC pipes. Many of the iron pipes date back to the early 1900s and are particularly susceptible to the twin hazards of corrosive and moveable soils. PVC pipes appear to have often been installed as the towns in the region expanded in around 1980s but have unfortunately since been shown to not be very resilient. Thankfully, modern pipe replacement schemes typically employ polyethylene (PE) pipes, which have a very low rate of pipe failure, even in the most aggressive soils. Nevertheless, a significant proportion of the network is liable to the increasingly volatile ground and weather hazards we are witnessing.

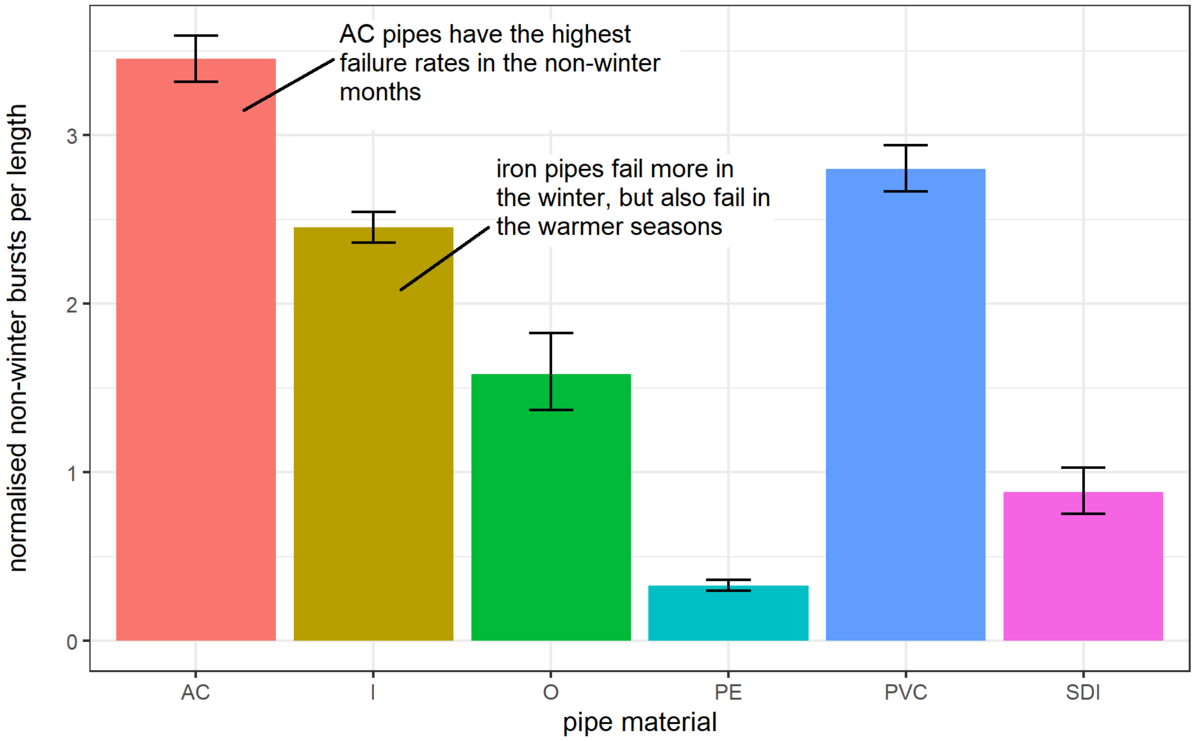

Figure 5- normalised rate of non-winter failures per 10 km pipe for recent years (May-October, 2017-2019) AC: asbestos cement; I: Iron; O: other / unknown; PE: polyethylene; PVC: polyvinylchloride; SDI: steel and ductile iron

Figure 6 shows the average weekly failure rates, by material, between 2009 and 2019. There are two main seasonal peaks – one in the winter (affecting iron pipes very badly) and one in the summer and autumn as the soils shrink and swell with changing moisture conditions. This movement impacts the failure rate of iron and asbestos cement in particular (and PVC pipes to some extent). This particular movement and failure mechanism is illustrated in Figure 3.

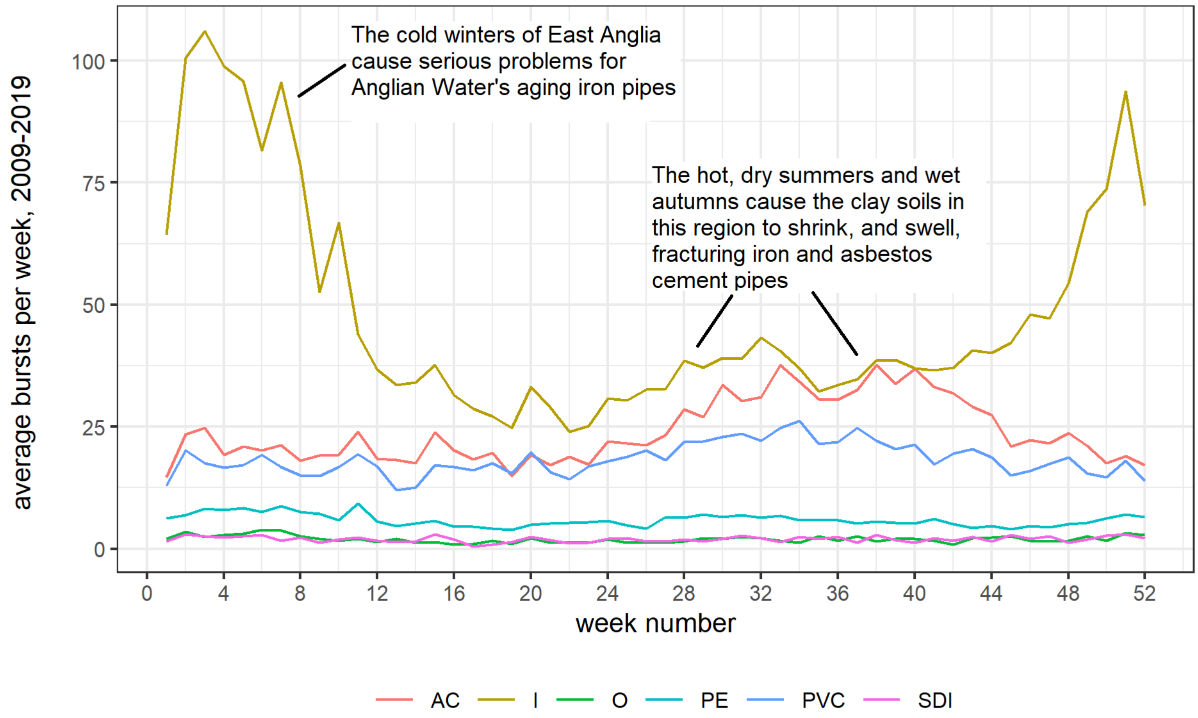

Figure 6 - average bursts per week (2009 - 2019) in the Anglian Water region, by material

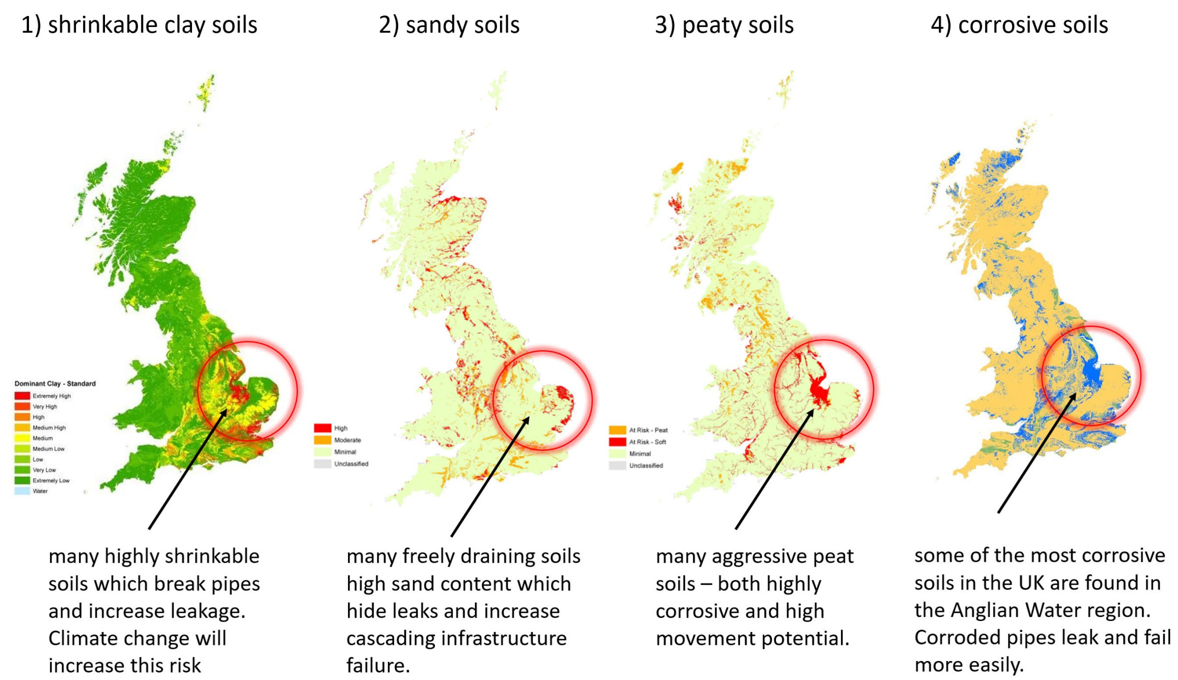

Figure 7 - The prevalence of soil related geohazards in the Anglian Water region. Adapted from NPD User Guide (Cranfield University, 2019) and BGS Civils Data (2020)

2. Aggressive and challenging soil conditions

- The Anglian Water region has a greater proportion of high-risk soils (corrosive, compressible, shrinkable) than is typical in other regions in England and Wales

- Preventing and detecting leaks in many soils in the Anglian region is a real challenge.

The ground in the Anglian Water region is fascinating from both a geographical and historical perspective. Soil is made up of a mixture of sand, silt and clay particles, as well as organic matter. The varying combinations of these particles describe the soil texture. Due to its unique geography, many of the soils of East Anglia are at the extremes of soil textures. When the soil is comprised of roughly equal amounts of these components, we would classify this as a loamy soil. Loamy soils are not typically very damaging to pipes. However, when a soil is predominantly comprised of either clay, sand or peat, the dominance of the homogeneous components can lead to soil properties which increase risk of pipe damage, or make leak detection more problematic.

The Anglian Water region contains a diverse range of soils, with a disproportionate coverage of the region with soils which have quite extreme properties. Some of the most aggressive soil types in the region are found almost nowhere else in the UK (Figure 11). In this discussion we make reference to data on the geology and soils from the British Geological Survey (BGS) and the National Soils Resources Institute (NSRI) at Cranfield University.

Before the 1600s, the landscape of East Anglia was quite different. What is now the highly productive agricultural land of the Fens was predominantly coastal marshes. This part of the region was drained by human intervention, starting in the 1600s, through the means of dykes, ditches and pumps. As a result of this draining, the land surface has subsided over the past few centuries, and, as this drainage is still ongoing, the land continues to subside. Indeed, parts of East Anglia are now below sea-level; only protected by the network of dykes and ditches. Some parts of the region have sunk by over 3 meters in the last 100 years.

Clay soils are prevalent in the Anglian Water region. Many clay soils can shrink when they dry, leading to subsidence of the ground. This is particularly problematic for pipes when the soil along the pipe shrinks by varying amounts. This is called differential movement, and can cause stress to build up in the pipe structure, leading to joint dislocation or more serious pipe failures (Figure 3).

It is not just water pipes that are affected by such movements. Other research we have carried out in this region has involved the impact of such soils on minor roads. In Lincolnshire, in the more northern section of the Anglian Water region, we worked with the local highways team to help them understand why certain of their roads were requiring disproportionate amounts of resurfacing and other maintenance. When we overlaid the roads that they had identified as being more "at risk" on the soil shrinkability map, we found near perfect alignment (Figure 8, Pritchard et al, 2015).

The ideal soils for pipes are those which have a spatially constant loamy texture, neutral pH and consistent moisture level. Such chemically, structurally and hydraulically stable soils are rare in East Anglia. Instead, there are a wide range of fascinating soils, often varying over short distances. As part of this review I was investigating one district metered area (DMA) with particularly high leakage levels, and with the leaks very difficult to detect. In this one DMA there were corrosive and compressible peat soils, highly moveable clays, and freely draining sands (where a leak can remain hidden for a long time).

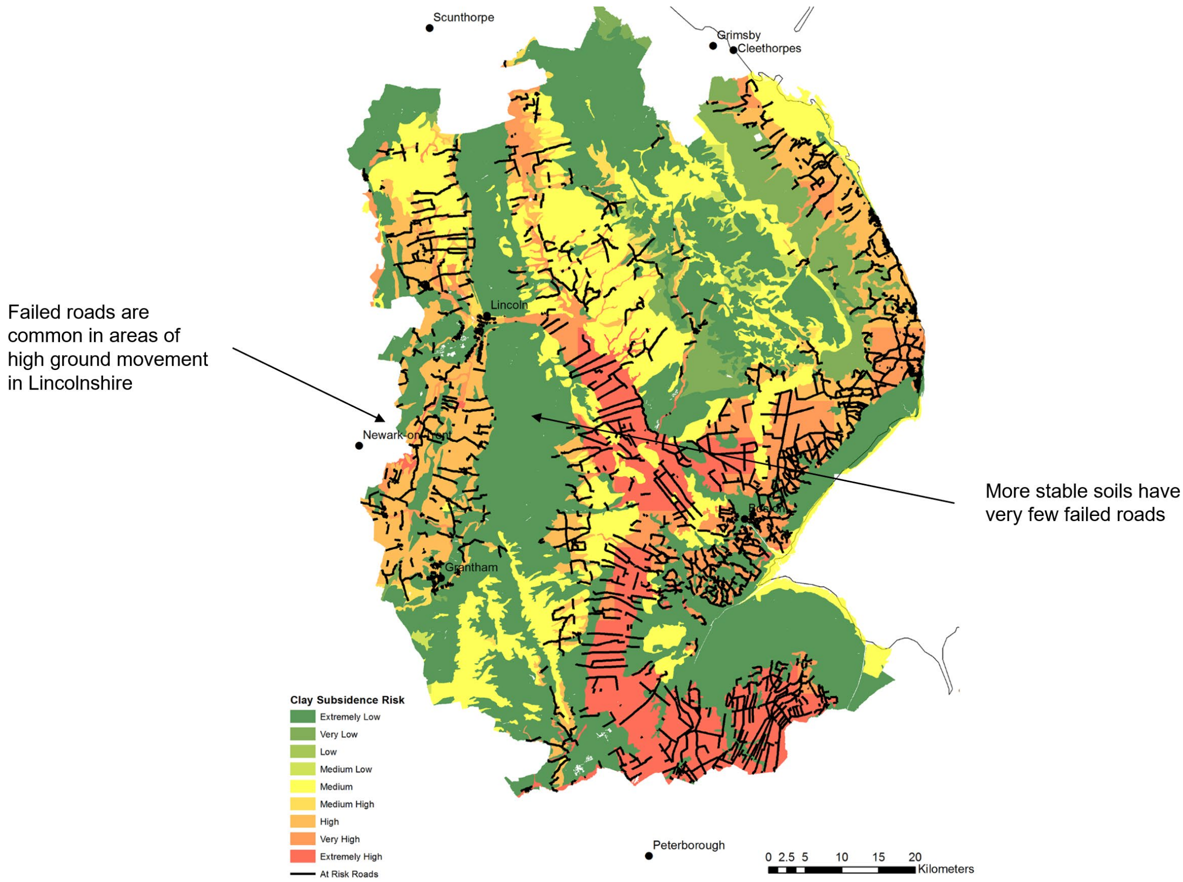

Figure 8 - the near perfect overlap minor roads identified by local highways officers as being "at risk", and soils with high ground movement potential (Source: Pritchard et al, 2015, contains data from Lincolnshire County Council and the Natural Perils Directory from Cranfield University)

In this section we will discuss just a few particularly hazardous soil types and their interaction with the Anglian Water pipe network.

Shrinkable clay soils

When soils shrink and swell, they increase the chance of pipe failure and leakage, especially in older pipes such as iron and asbestos cement (Figure 6 & Figure 3). Soils which are prone to shrinking and swelling are more common in the Anglian Water region than in the rest of England. If we consider the Natural Perils Directory's clay-related shrink-swell class (0-9), 46% of Anglian Water's region is covered by soils in the highest 3 classes (7-9). The average rate for water companies in England and Wales is 32%. While some soils in the region shrink more than others and cause more damage to pipes, the fact that East Anglia is the driest part of the country means that most of the soils dry out to very deep levels. This means that the impact of ground movement on the failure rates in the pipe network can be observed not only on highly shrinkable soils, but also in only moderately shrinkable soils (Figure 10).

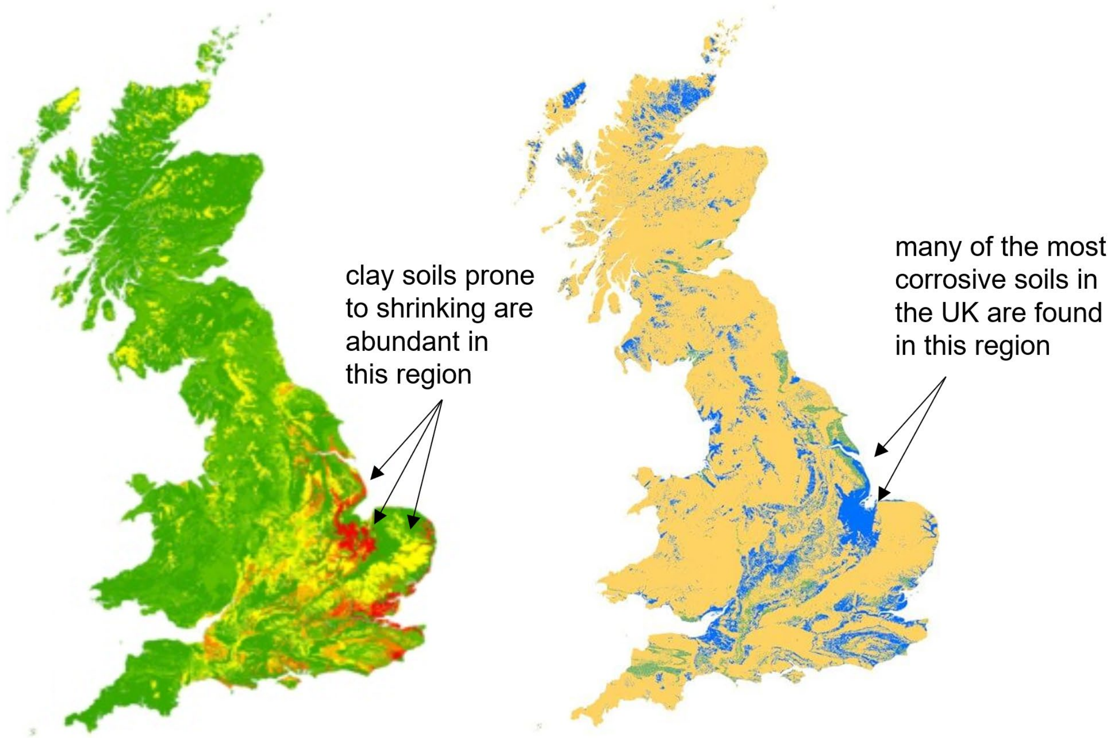

Figure 9 – (left) clay-related ground movement potential from the Naturals Perils Directory (adapted from Pritchard, 2014) and (right) from BGS civils: corrosivity map (Source: BGS, 2020)

Lowland peats, other naturally wet soils and compressible soils

Lowland peats and other naturally wet soils are associated with the highest pipe failure rates in the Anglian Water region (Figure 11). These soils, while not the most extensive, are far more common in the Anglian Water region than the rest of the country (Defra, 2020). For example, Fen peat soils (Soilscape unit 27) are almost three times as common in East Anglia compared to the rest of England, while soils with a peaty surface (Soilscape unit 23) are more than four times as common in this region.

An interactive viewer for these Soilscapes units, their properties and percentage cover of the country can be found at: http://www.landis.org.uk/soilscapes/, and also on Defra's Magic Map viewer https://magic.defra.gov.uk/ (Defra, 2020).

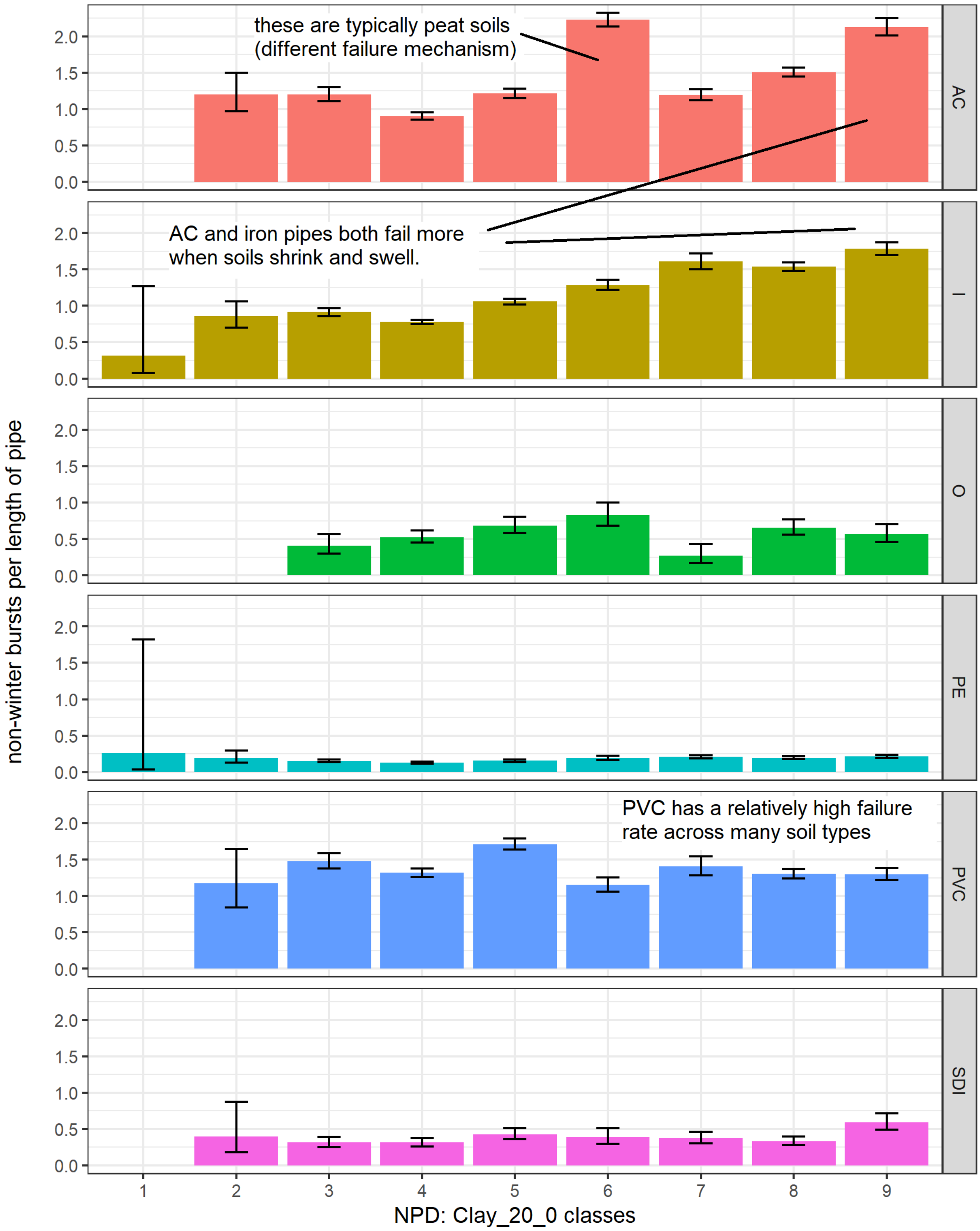

Figure 10 - failure rates by pipe material and the Natural Perils Directory (NPD) shrinkability class under typical climates (Clay_20_0). AC: asbestos cement; I: Iron; O: other / unknown; PE: polyethylene; PVC: polyvinylchloride; SDI: steel and ductile iron

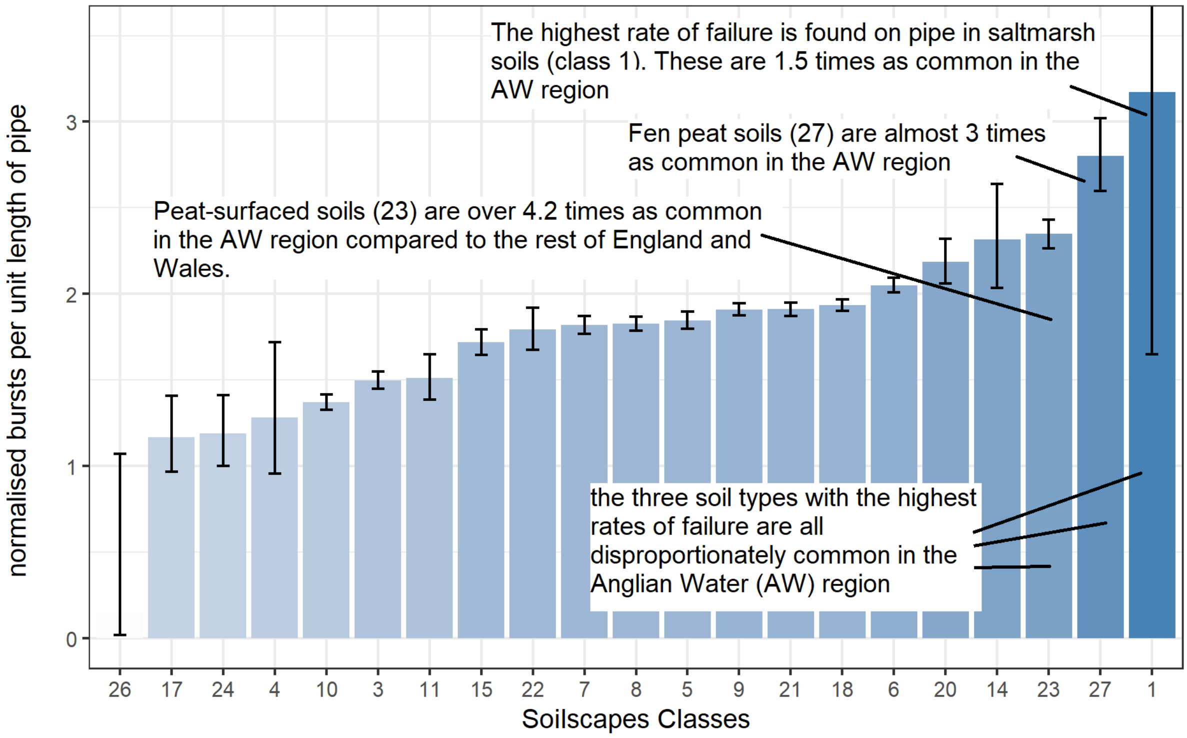

Figure 11- normalised rate of pipe failure by NSRI's Soilscapes Classes

The British Geological Survey (BGS) have also produced maps of ground compressibility (BGS, 2017) and found that the Anglian Water region contains a disproportionate amount of compressible ground, compared to the rest of the country (Figure 12). We intersected the BGS GeoSure compressibility 5 km hexgrid with the water company boundaries and found that 22% of the Anglian Water area has been flagged as "Significant" for compressibility, compared to the national average of 8% coverage (BGS, 2020b).

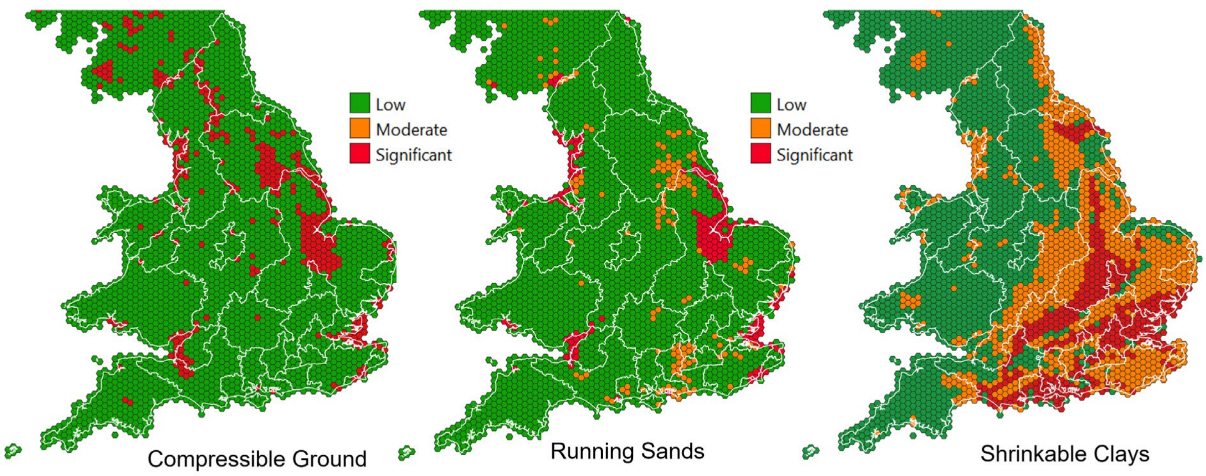

Figure 12- Water company areas of England and Wales and indication of areas with aggressive ground conditions (BGS Geosure) Note that for shrink-swell, it is the combination of both shrinkable soils and hot and dry climates that leads to ground movement. This map only shows BGS's indication of the shrinkability of the ground.

Highly corrosive soils and sandy soils

10.5 % of the Anglian Water region is covered in soils which are highly corrosive (NSRI corrosion class 5*). This is approximately three times the average coverage for all other water companies in England and Wales for these soils. Even if we consider moderately corrosive soils (NSRI classes: 4, 4*, 4, 5*), the Anglian Water region is still disproportionately affected; about 30% more than average (see Pritchard, 2014).

The British Geological Survey shares this view (Figure 7 & BGS, 2020b), showing corrosive soils to be much more common in the Anglian Water region than in much of the rest of the country. Corrosive soils have a particular impact on metallic (e.g. iron) and cement based (e.g. AC) pipes, as the corrosion can weaken the structure of the pipes, making them more susceptible to moderate ground movements.

In addition, corrosion can lead to pin-hole leak formation particularly in iron pipes, which can be particularly difficult to detect and resolve. What is more, often the most acidic soils are highly sandy, which can result in the leaked water draining away, with no surface expression. Thus, such soils provide a double impact on leakage – both increasing the chances of a leak developing, and making such leaks hard to detect through traditional means.

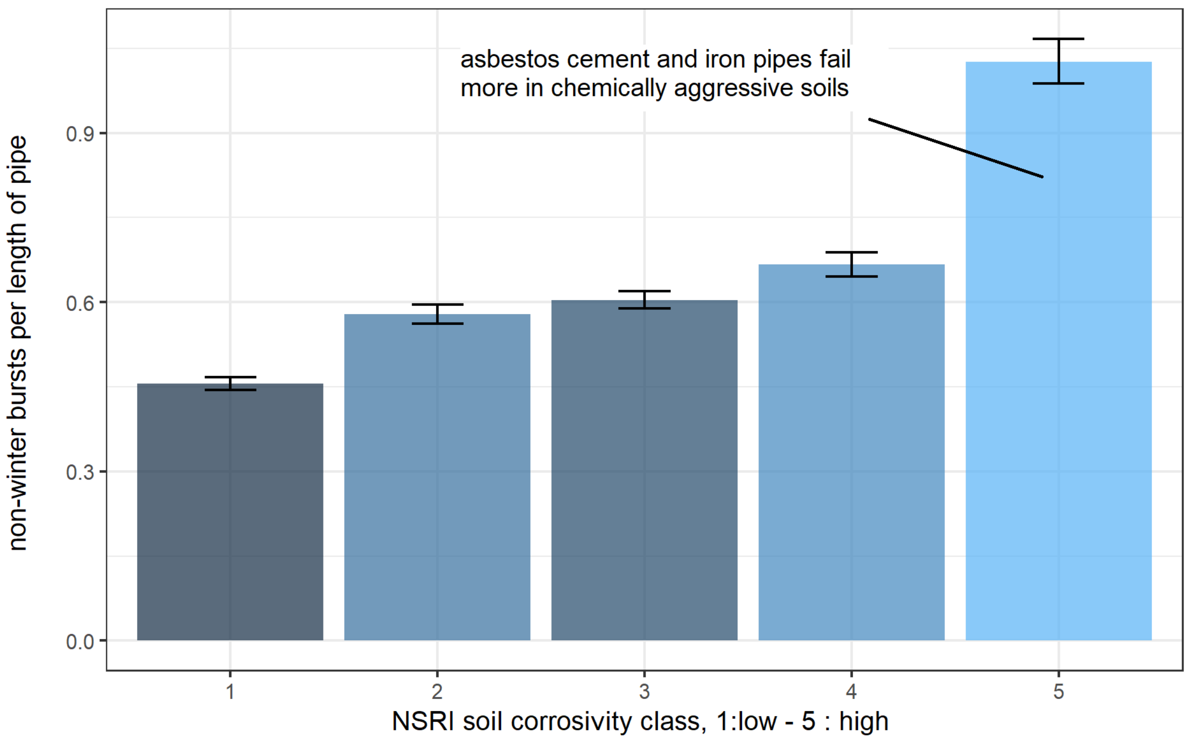

Figure 13 – normalised failure rate for AC and iron pipes by NSRI's simplified soil corrosivity class (March-October, 2004-2019)

3. Extreme and volatile weather patterns

- For the three key weather metrics which I have found to most influence the number of burst mains and pipe leakage repairs, the Anglian Water region is either more extreme than, or at least comparable with other regions in England and Wales.
- The Anglian Water region has **higher** than average summer temperatures (associated with bursts) compared with the rest of England and Wales
- The Anglian Water region has **higher** soil moisture deficits than the rest of England
- The Anglian Water region has **average** winter temperatures for England and Wales
- Soil moisture deficit and summer temperatures are **rising at a faster rate** in the Anglian Water region than the national-average rate.

The patterns of temperature and precipitation across the UK do vary, with influences from prevailing winds, topography and even warm ocean currents. As a result, some areas of the UK are warmer or cooler, wetter or drier in at different times of the year than the national average. A series of maps (Figure 18, Figure 19 and Figure 22) have been compiled to illustrate the variation of these measurements across the UK, and to demonstrate that the East of England is certainly not meteorologically benign in terms of the weather patterns that impact on water pipes.

I have been researching the impact of weather on buried pipeline failure for many years. My research has covered both the water and gas industries, and in both the north and south of the country. Three meteorological patterns have consistent and particularly strong influences on the rate of pipe failures and leakage repairs. These are:

1) Extremely cold winter in temperatures (East Anglia is comparable with English average)

2) Extremely hot temperatures in summer (East Anglia is more extreme than the English average)

3) High soil moisture deficits in summer and autumn (East Anglia is the most extreme in England)

We shall first of all consider the impact of extreme temperatures in both winter and summer, and then look at the impact of high soil moisture deficits (dry soils) in this region, as it contains many shrinkable soils.

The impact of extreme temperatures on Anglian Water's pipes

Cold winter temperatures

In the Anglian region, winter temperatures and the number of days of air frost are approximately average for the UK (2000 – 2020 averages: East Anglia: 4.87 ºC vs English and Welsh average 4.68 ºC, Figure 15). As it is less influenced by ocean currents warmed in the Gulf of Mexico, the Anglian Water region is cooler in winter than more southern and western parts of the UK, but slightly warmer than some of the northernmost regions with higher latitudes and altitudes.

Thus, like much of central and northern England, the pipes in the Anglian Water network are badly affected by periods of intense cold in the winter time (Figure 14). The influence of cold weather is particularly pronounced on Anglian Water's extensive lengths of cast iron pipes, which are the second most common material in the network (Figure 4).

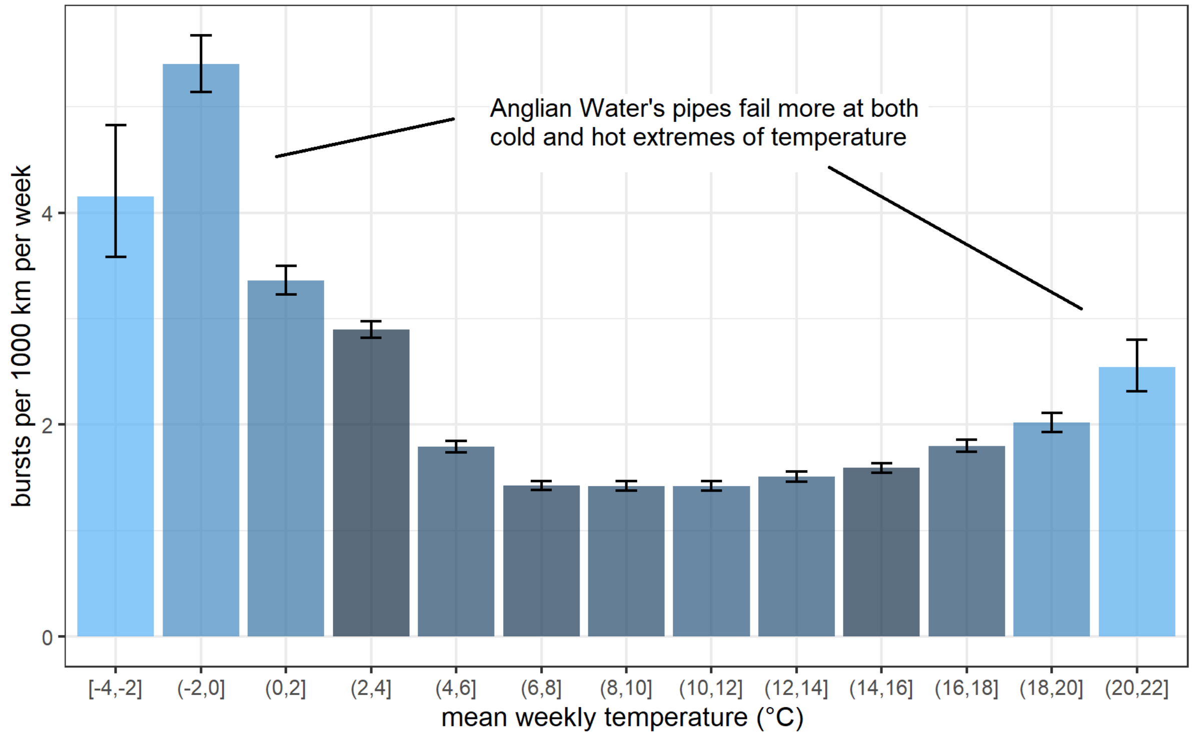

Figure 14 - failure rate (bursts per 1000 km per week) by temperature band, for all materials together, 2009-2019

Extremely hot summers

While cold winters can cause high numbers of leakage-related repairs in the Anglian Water region, it is in the summer that the weather in East Anglia is quantifiably more extreme than the rest of England (Figure 24). In terms of soil moisture deficit (SMD) and summer temperatures, the Anglian Water region is demonstrably hotter and drier than the national average (Figure 23).

Across the summer, the temperatures in East Anglia are on average 1.4 ºC warmer than the rest of England and Wales (Figure 16). In the winter, this region is very close to average winter temperatures for the UK (Figure 15).

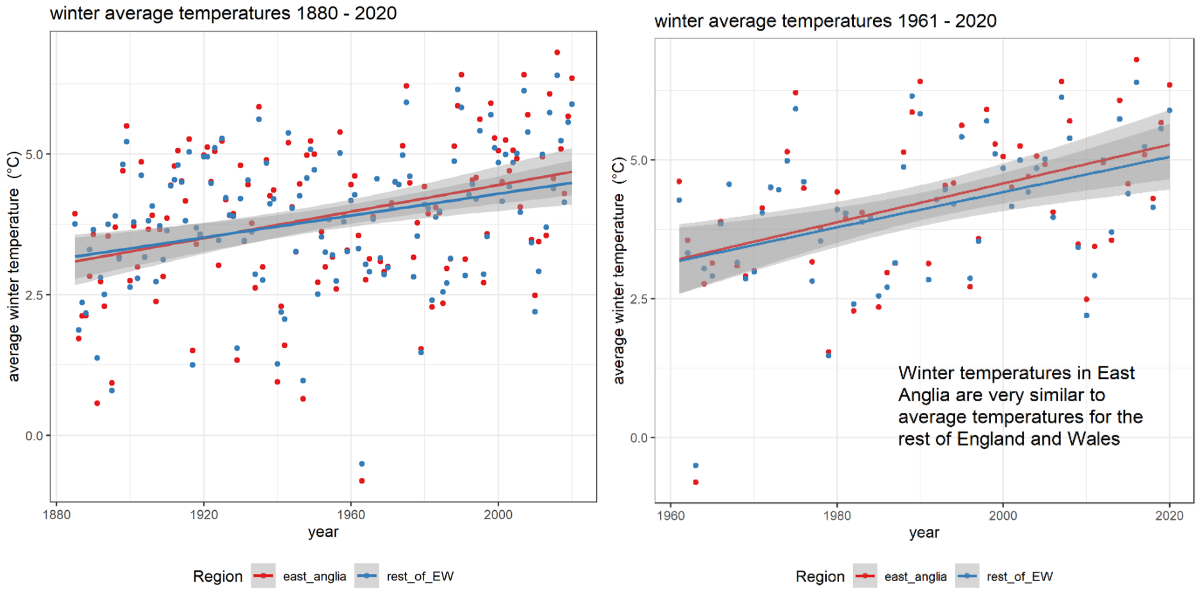

Figure 15- Average winter temperatures in East Anglia vs the rest of England and Wales over the longer term (1880-2020), and shorter term (1961-2020); data source: Met Office (2020b)

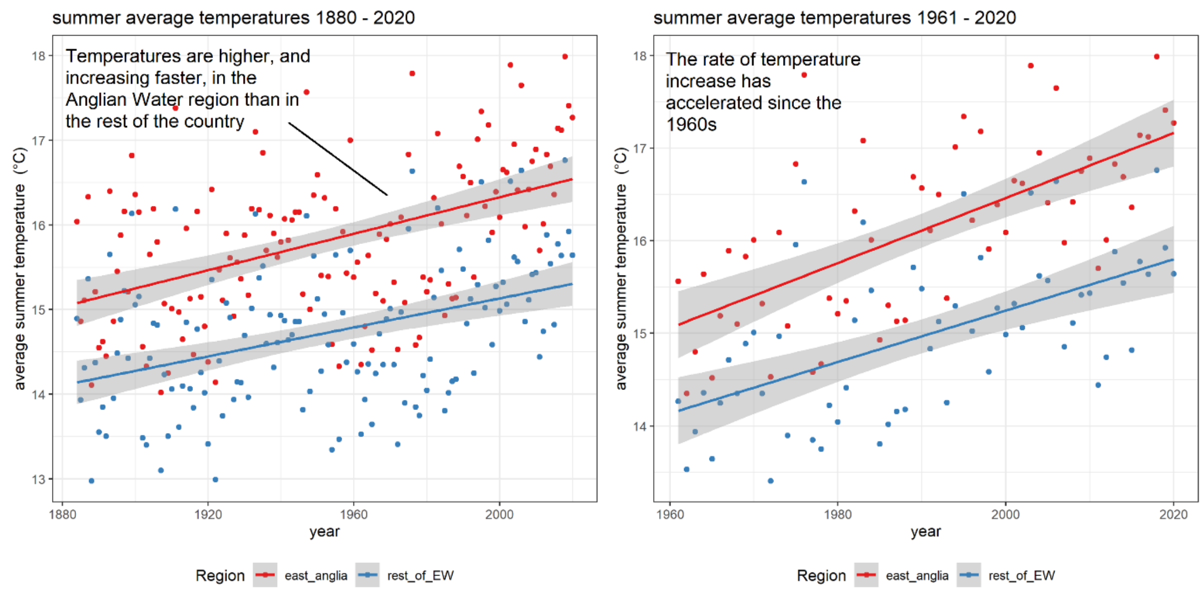

Figure 16- Increase in summer temperatures in East Anglia vs the rest of England and Wales over the longer term (1880-2020), and shorter term (1961-2020); data source: Met Office (2020b)

Temperature and rate of failure by material

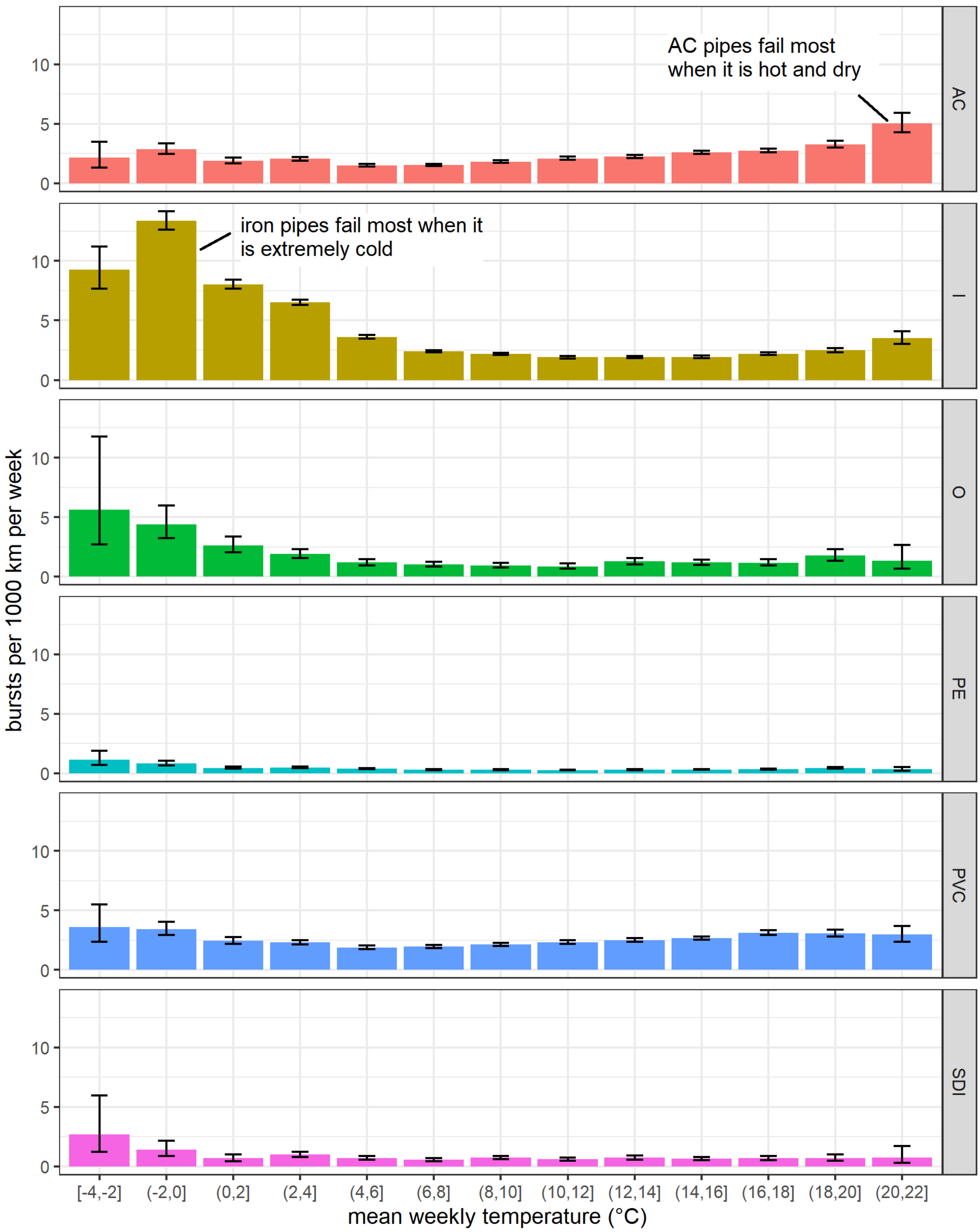

Figure 17 - the rate of failure per 1000 km pipe, per week, by mean weekly temperature. AC: asbestos cement; I: Iron; O: other / unknown; PE: polyethylene; PVC: polyvinylchloride; SDI: steel and ductile iron

Mean Minimum Winter Temperature

- Cold weather is associated with more pipe failures (Figure 14)
- The Anglian Water region has average winter temperatures for the UK.

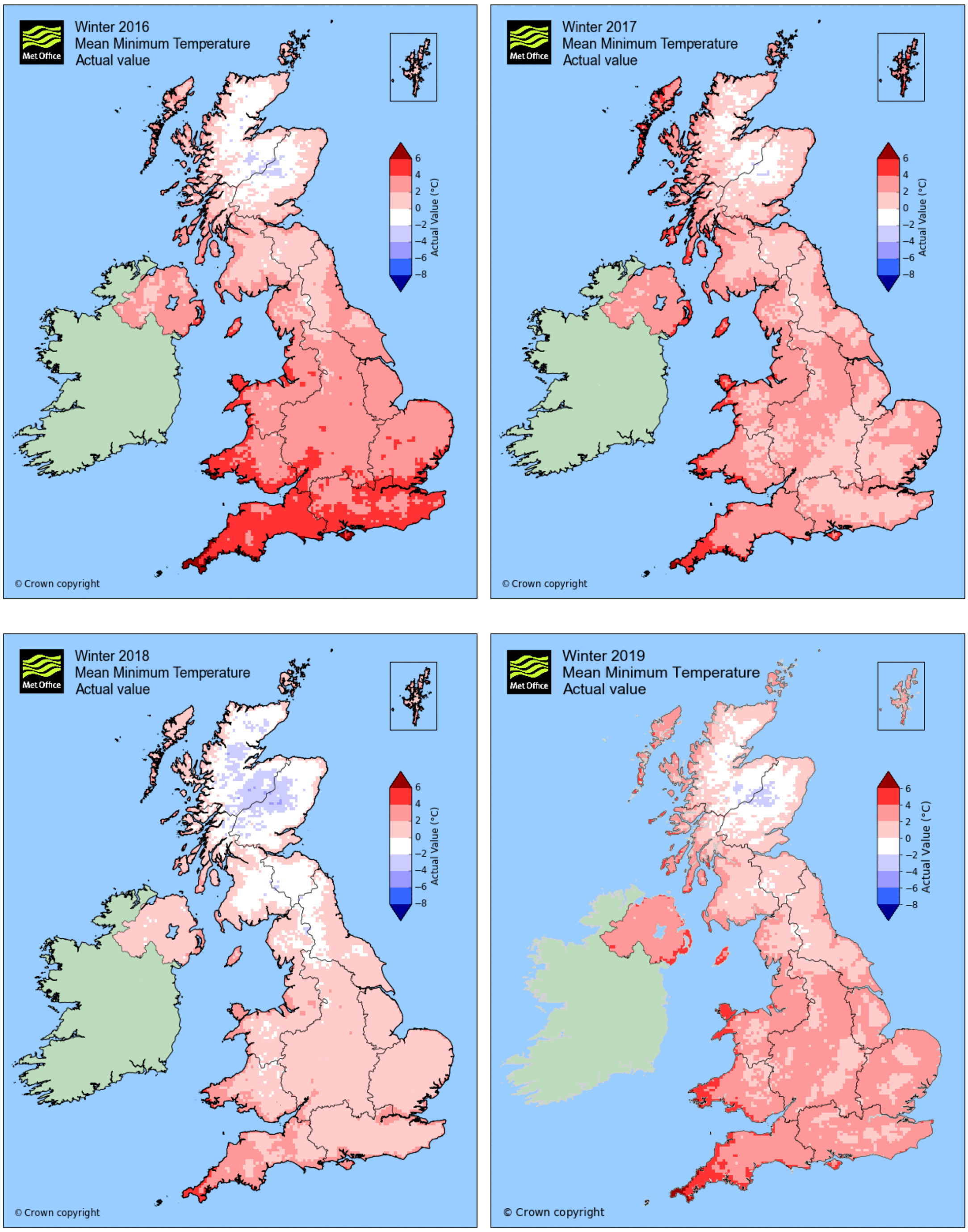

Figure 18 - mean minimum winter temperature for the UK. Source: The Met Office (2020)

Mean Maximum Summer Temperatures

- Hotter temperatures are associated with more pipe failures (Figure 14).
- The Anglian Water region has hotter than average temperatures for the UK.

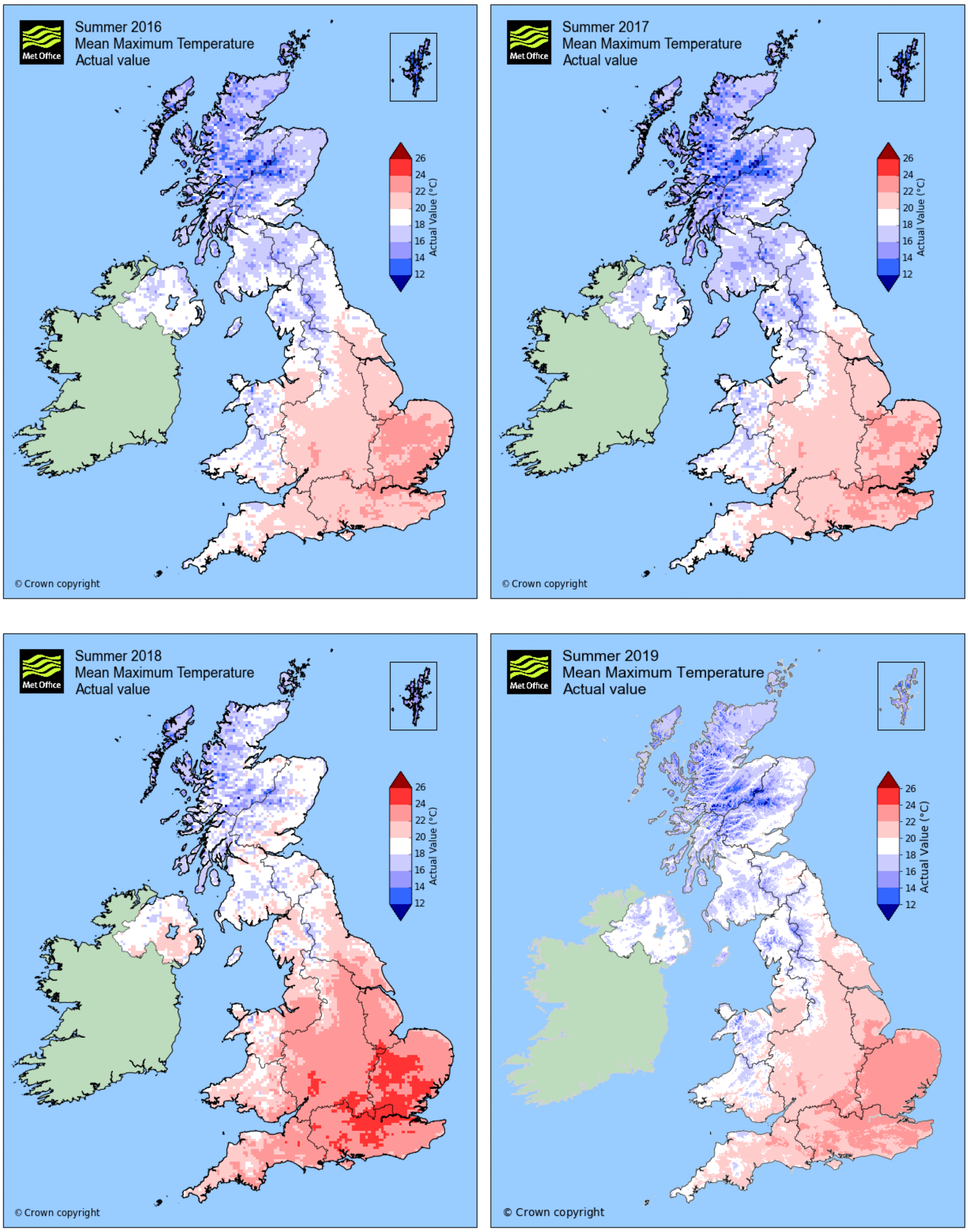

Figure 19 – Summer temperatures in the Anglian Water region for 2016-2019. Note that these temperatures are consistently some of the highest in the UK. Source: The Met Office, 2020

The impact of extremely dry soils on Anglian Water's pipes

Soil moisture deficits (SMD) are higher in the Eastern region than all other regions (Figure 23) and approximately 30% higher than the national average in summer time. Furthermore, they appear to be increasing (Figure 26). More asbestos cement and iron pipes fail when the soil dries out to deeper levels, and then re-wets (Figure 20).

The Anglian Water region has the highest regional soil moisture deficits in the UK (Figure 23).

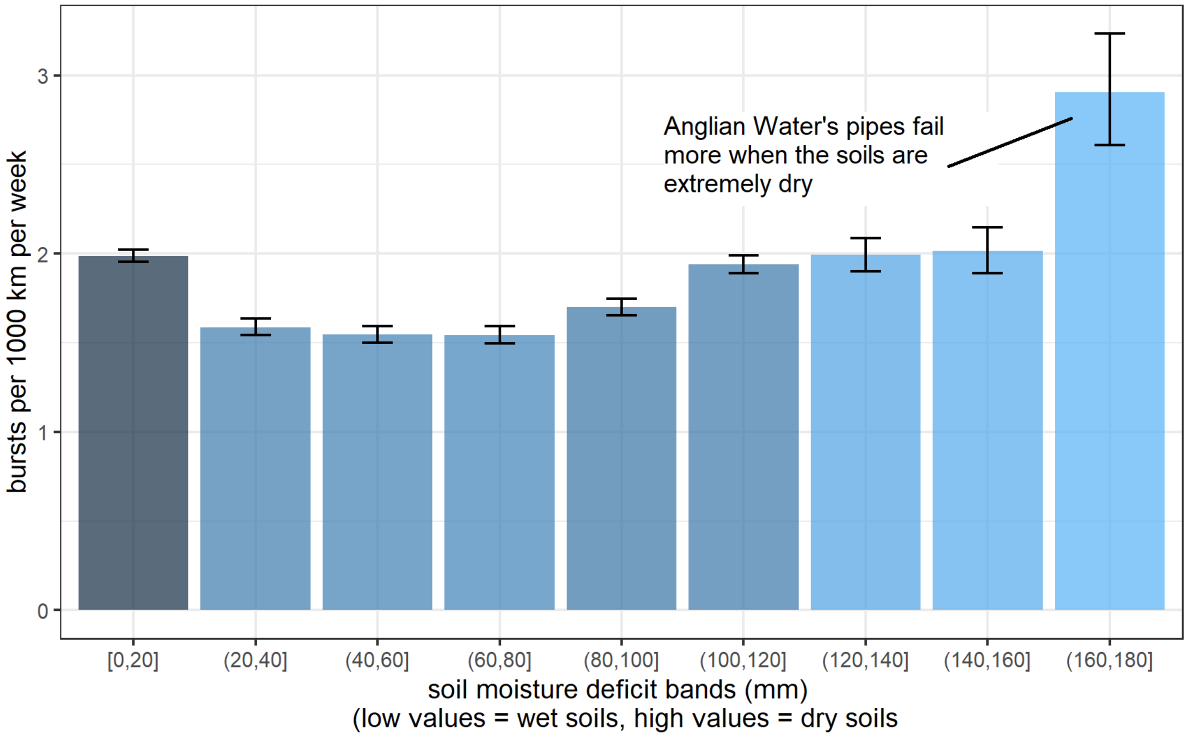

Figure 20 - rate of failure (bursts per 1000 km pipe per week) by soil moisture deficit band, for all materials, 2009-2019

Low annual and summer rainfall

While this analysis is primarily focussed on the environmental impacts of weather and soil on increasing leakage in the Anglian Water region, it would be remiss not to highlight that the very low levels of rainfall seen in the Anglian Water region makes this one of the driest regions in the country (Figure 22).

Faced with low rainfall, and the increasing environmental risks to pipes, both from hotter and drier summers, and also increasing pipe age, I believe there is a real need to continue to minimise leakage in this region, to ensure cost effective long term water security.

Soil moisture deficit (SMD) and rate of failure by material

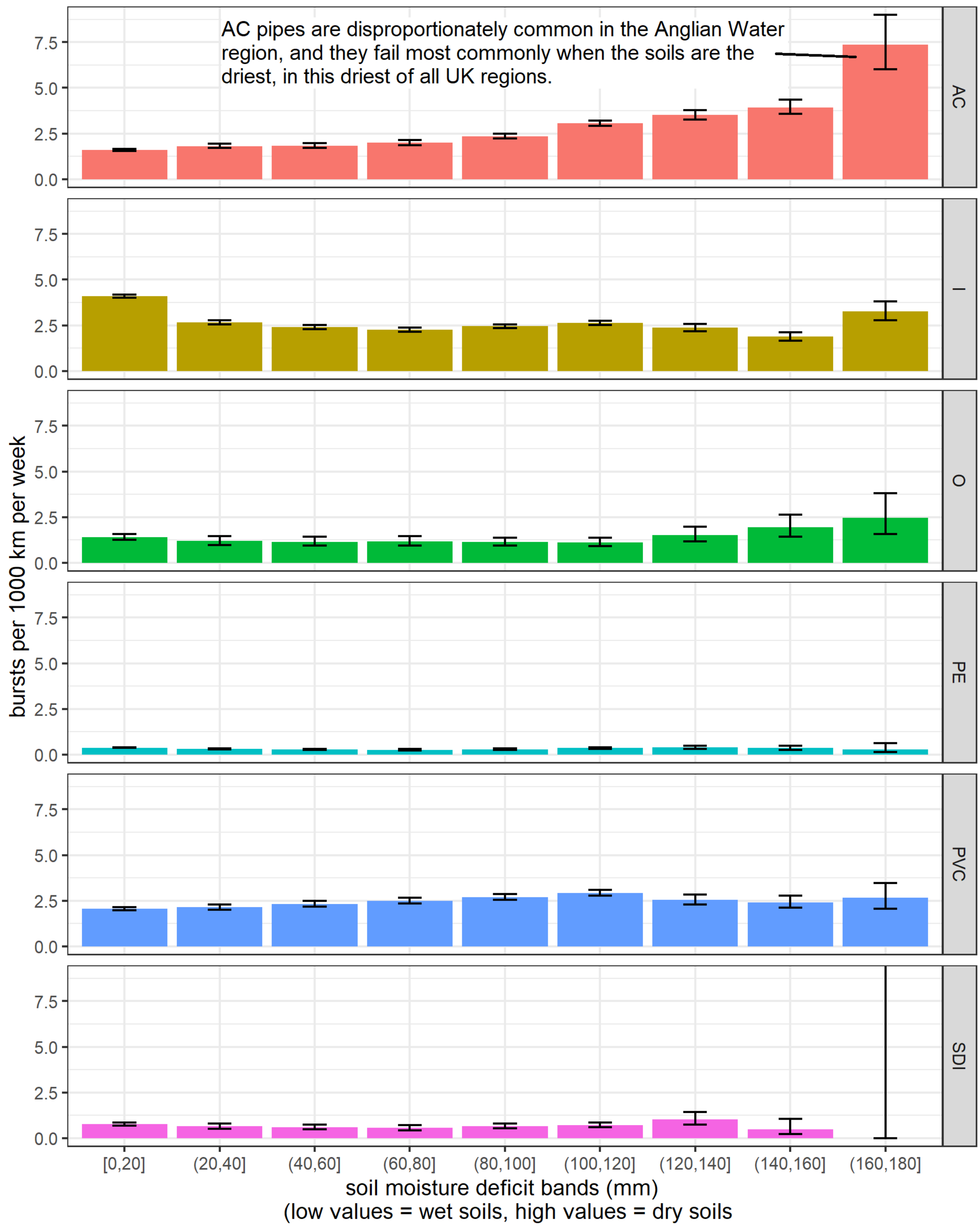

Figure 21 - the rate of failure per 1000 km pipe, per week, by soil moisture deficit bands. AC: asbestos cement; I: Iron; O: other / unknown; PE: polyethylene; PVC: polyvinylchloride; SDI: steel and ductile iron

Accumulated Annual Rainfall

- Water scarcity is more of an issue in areas with low rainfall.
- The Anglian Water region has some of the lowest rainfall levels in the UK. The low levels of rain also give rise to the highest soil moisture deficits (SMD) in the country.

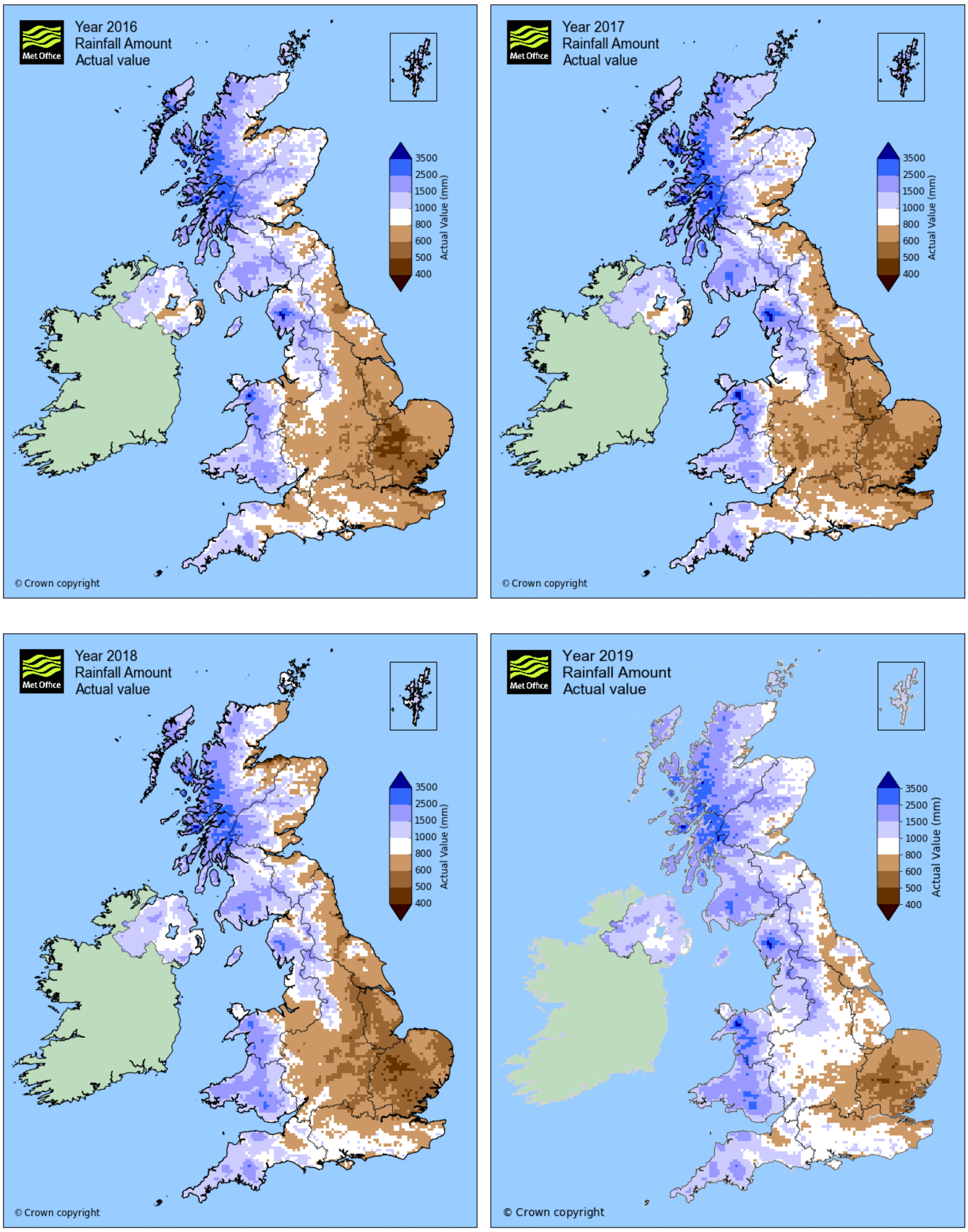

Figure 22- Annual Rainfall levels for 2016-2019), showing that the Anglian Water region is consistently one of the driest parts of the UK. Source: The Met Office, 2020.

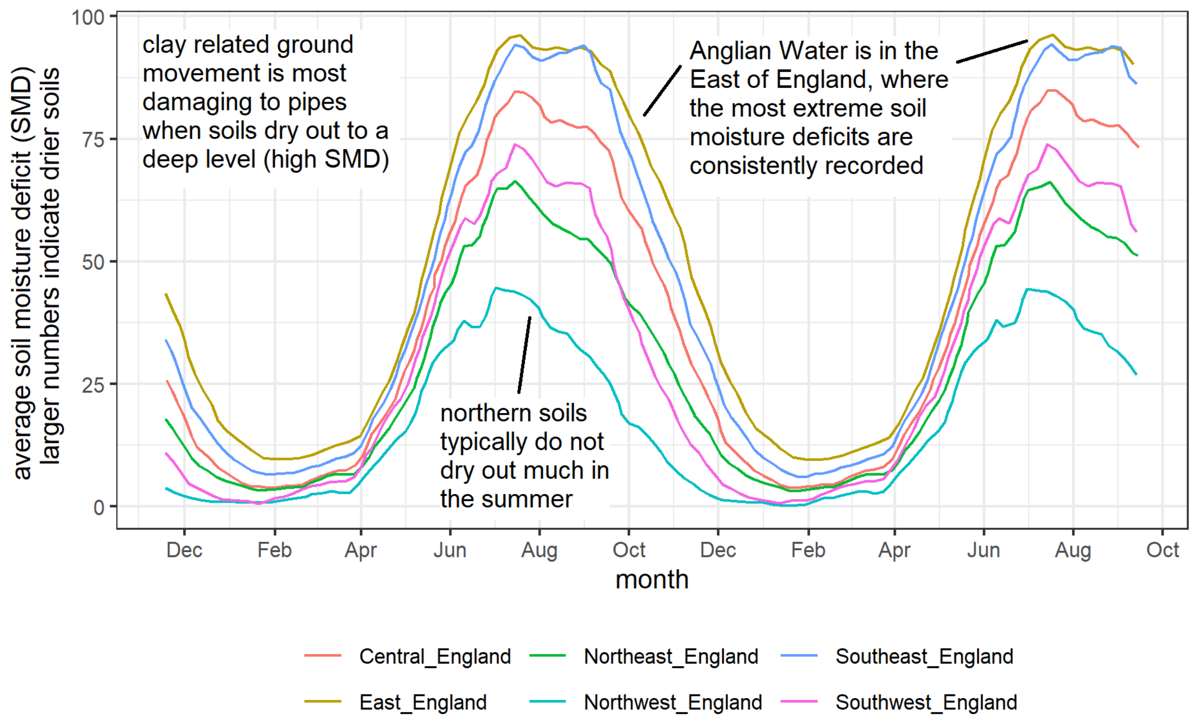

Figure 23 - a comparison of average soil moisture deficits (SMD) by English Region based on the long term average (LTA: 1961-1990) Source: Adapted from Environment Agency (2019)

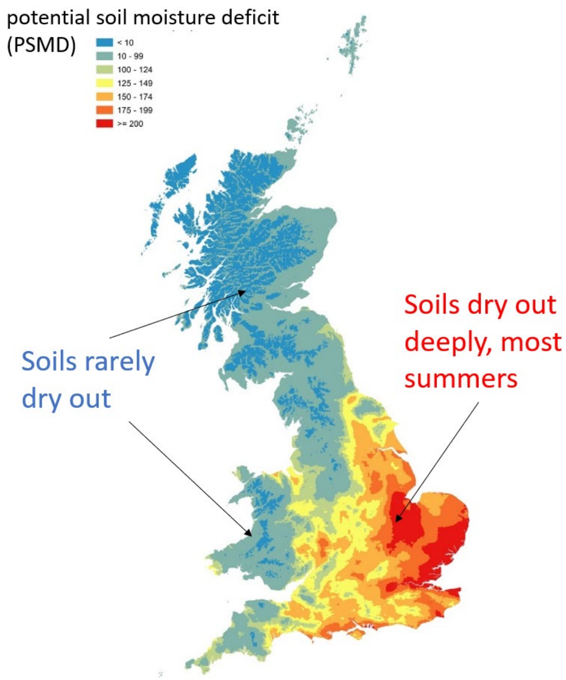

Figure 24 - average potential soil moisture deficit (PSMD) across the UK. (From Farewell; 2019, and an input to the Natural Perils Directory, Cranfield University (2019).

Quantifying the impact of extreme environmental conditions on pipe failures and leakage

As we have seen, the Anglian Water region suffers from more extreme soil and climatic conditions than the national averages. Furthermore, it is clear that the pipe materials used in the Anglian Water network make it particularly susceptible to ground hazards. Notably, these are of the type which are becoming more common in hot and dry summers.

Leakage jobs are being reported at an increasing rate across the Anglian Water region, and this trend seems set to continue.

The impact of weather on pipe failures has been estimated with a modified WISPA model, similar to that used for regulatory purposes in the last AMP period for Anglian Water. The weather parameters have been adjusted to lower summer SMD by up to 30%, and decrease summer temperatures by 1.4 °C for the mean weather conditions across the Anglian Water region.

When running the model for the "mean Anglian Water year" and the same year with "nationally-adjusted weather conditions", all other variables (including pipe and soil parameters) we kept constant. Only the weather data was adjusted.

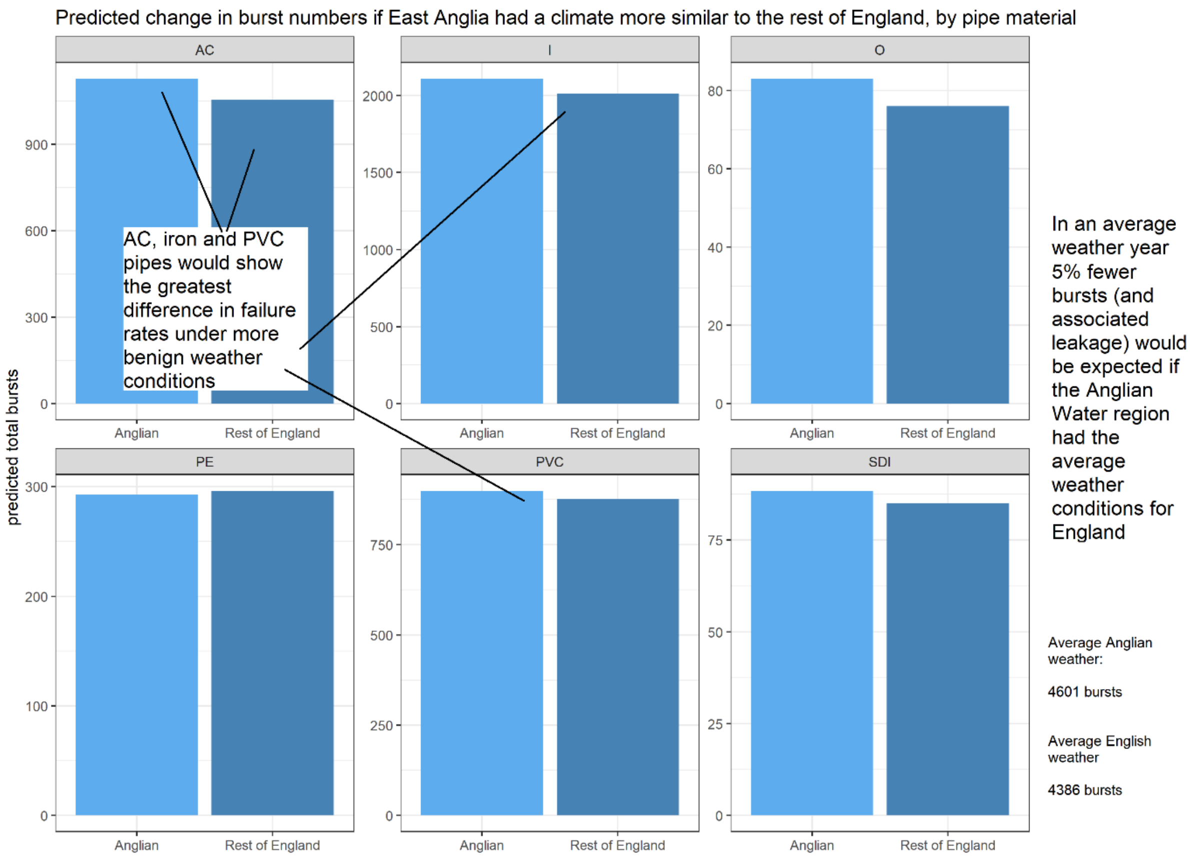

Figure 25 - predicted number of burst mains under average Anglian Water conditions (50%ile) and the same conditions adjusted to more closely match English averages (SMD reduced by up to 30%, summer temperature reduced by 1.4 C) Note: AC: Asbestos Cement, I: Iron; O: Other or unclassified materials; PE: Polyethylene; PVC: Polyvinylchloride; SDI: Steel and Ductile Iron

We found that large mains repairs reduced by 5% (4601 to 4386) under the more benign weather conditions more representative of national averages. The biggest impact of modifying the Anglian climate to more closely match that of average English and Welsh conditions was seen in asbestos cement (AC), iron (I) and PVC pipes.

It is clear that it is the combination of 1) aggressive soils and 2) extreme weather acting on 3) vulnerable pipes which lead to the highest levels of pipe failure. Furthermore, we have demonstrated that all 3 elements are disproportionately strong in the Anglian Water region. So, if we made similar adjustments in our models to match the soil distribution and network materials to the more benign national averages, I would estimate the reduction in the predicted number of bursts and associated leakage would be significantly more than the 5% achieved through just adjusting the climate.

Climate change

The climate is already changing

There is currently, and rightly, much discussion about future climate change. However, climate change is not something that will only happen in the coming years. The UK climate is already changing, but not at the same rate across the country. Some areas of the country have temperatures increasing at a faster rate than others.

Based on the period of 1961-2020, the summer temperatures in East Anglia have risen approximately 1.6 times as fast as the rest of England and Wales (Figure 16 & Figure 27). These extreme temperatures look set to continue to cause disproportionate problems for the pipe networks in this part of the country, as they respond to the increasingly hazardous environmental conditions.

The increase in temperature is also leading to higher levels of soil moisture deficit being recorded. When we compare the average soil moisture deficits over the last decade in the Anglian Water region with those from the long term average (LTA: 1961-1990) we see that already we are witnessing a shift towards drier soils, and these lasting later into the autumn (Figure 26). It is also worth point out that as the winters get wetter, more of the soils are likely to fully reach field capacity (fully saturated with water) in the winter time, thus creating a larger SMD differential throughout the year.

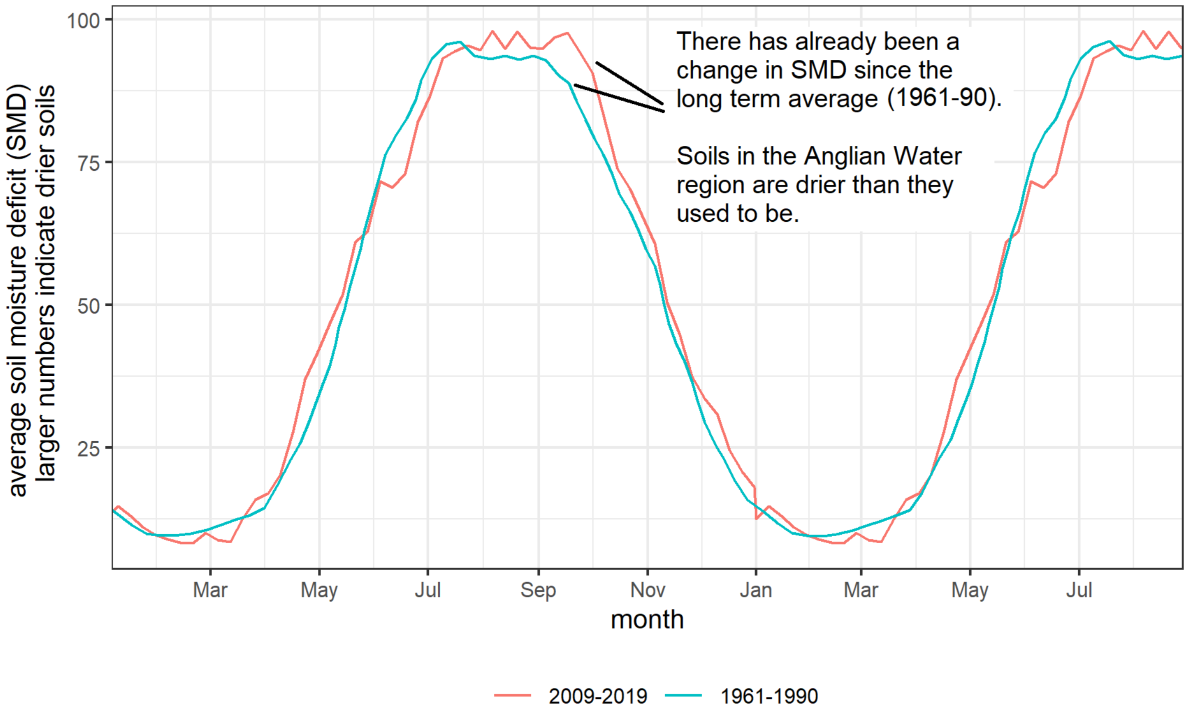

Figure 26 - Change in SMD in the East of England: 1961-1990 vs 2009-2019. Increasing soil moisture deficits between long term average (LTA: 1961-1990) and recent decade (2009-2019)

Change in mean maximum summer temperatures since 1961-1990 baseline

- Hotter temperatures are associated with more pipe failures (Figure 14).
- The summer temperature in the Anglian Water region is increasing at one of the fastest rates in the UK.

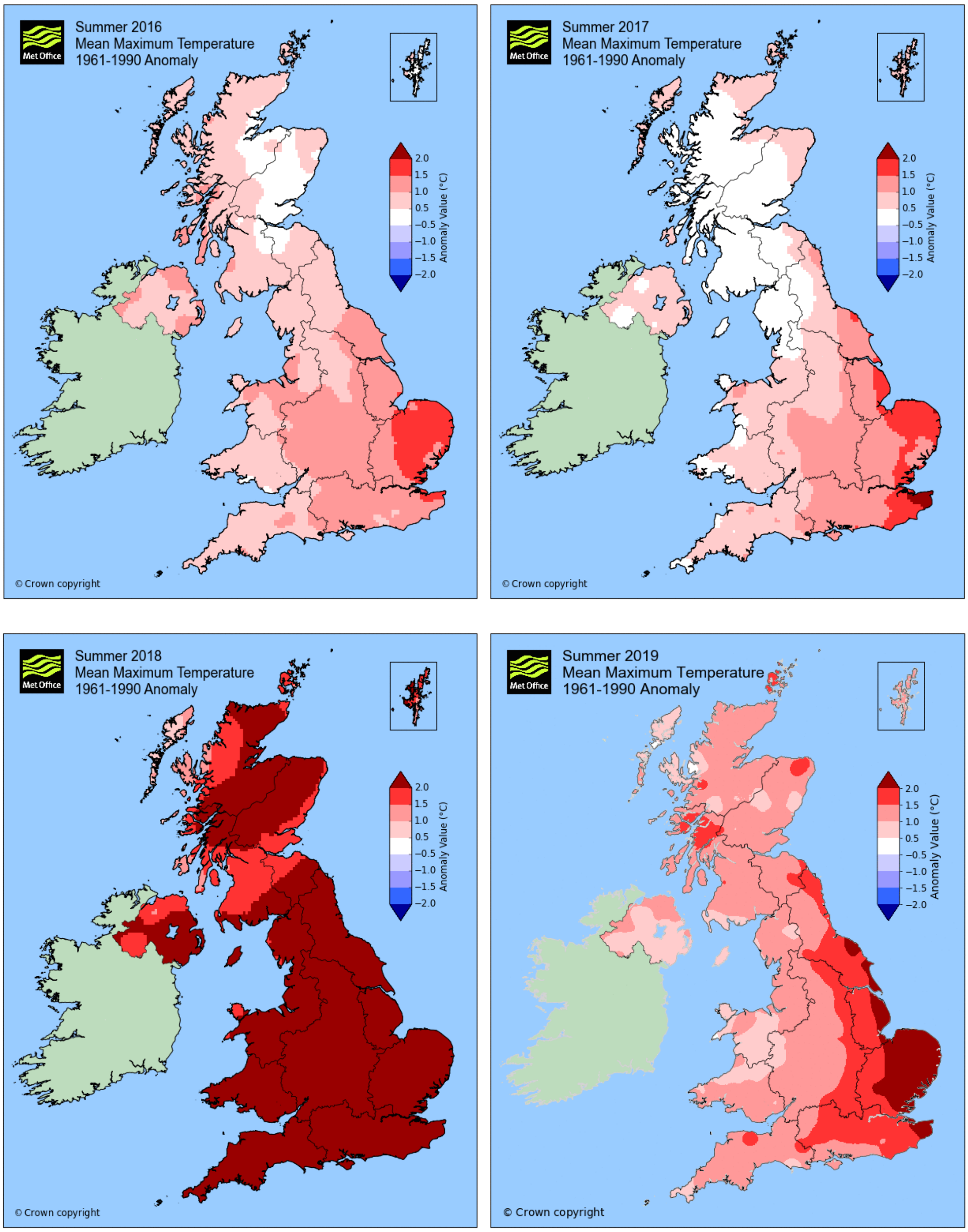

Figure 27- Summer temperature anomaly data for 2016-2019 (LTA: 1961-1990), showing that the temperatures in the Anglian Water region, while already hot, are increasing at a faster rate than much of the rest of the UK. Source: The Met Office, 2020.

The climate will continue to change

As discussed above, the impact of extreme weather events on the network can be profound. A few years back we modelled the changing patterns of soil moisture deficit across the UK, and the impact that this would have on ground movement potentials (Figure 29 and Pritchard et al, 2015).

It is apparent that the summers are set to become hotter, and drier. Not only will changing spatio-temporal rainfall patterns make water scarcity more common in some regions in the summer months, but also the impact of this weather on even moderately shrinkable soils will increase the number of bursts and the overall level of leakage.

Some initial research I have undertaken has indicated that in the Anglian Region, which is already very dry, we can expect a large increase (20-30%) in the number of summer + autumn bursts from AC, iron and PVC pipes (Figure 28) as these soils dry out even more deeply.

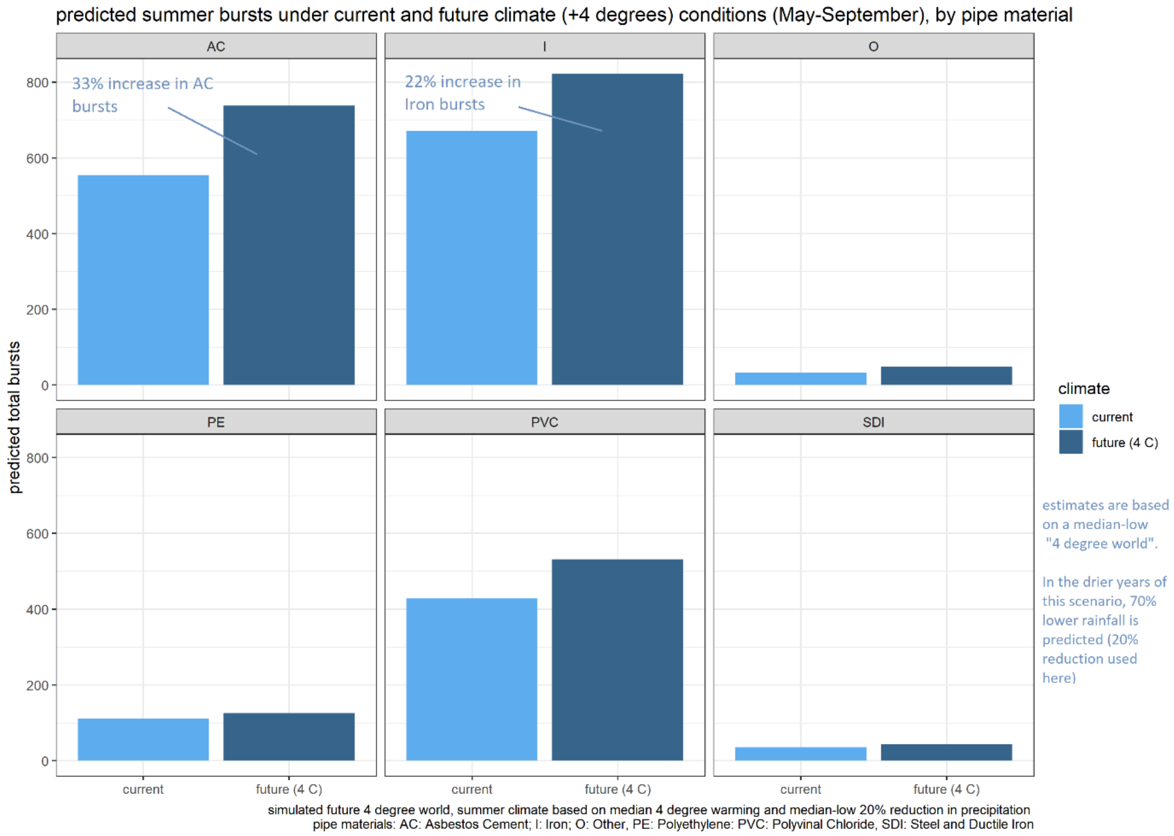

Figure 28 - the expected increase in burst mains under future climates in summer months . AC: asbestos cement; I: Iron; O: other / unknown; PE: polyethylene; PVC: polyvinylchloride; SDI: steel and ductile iron

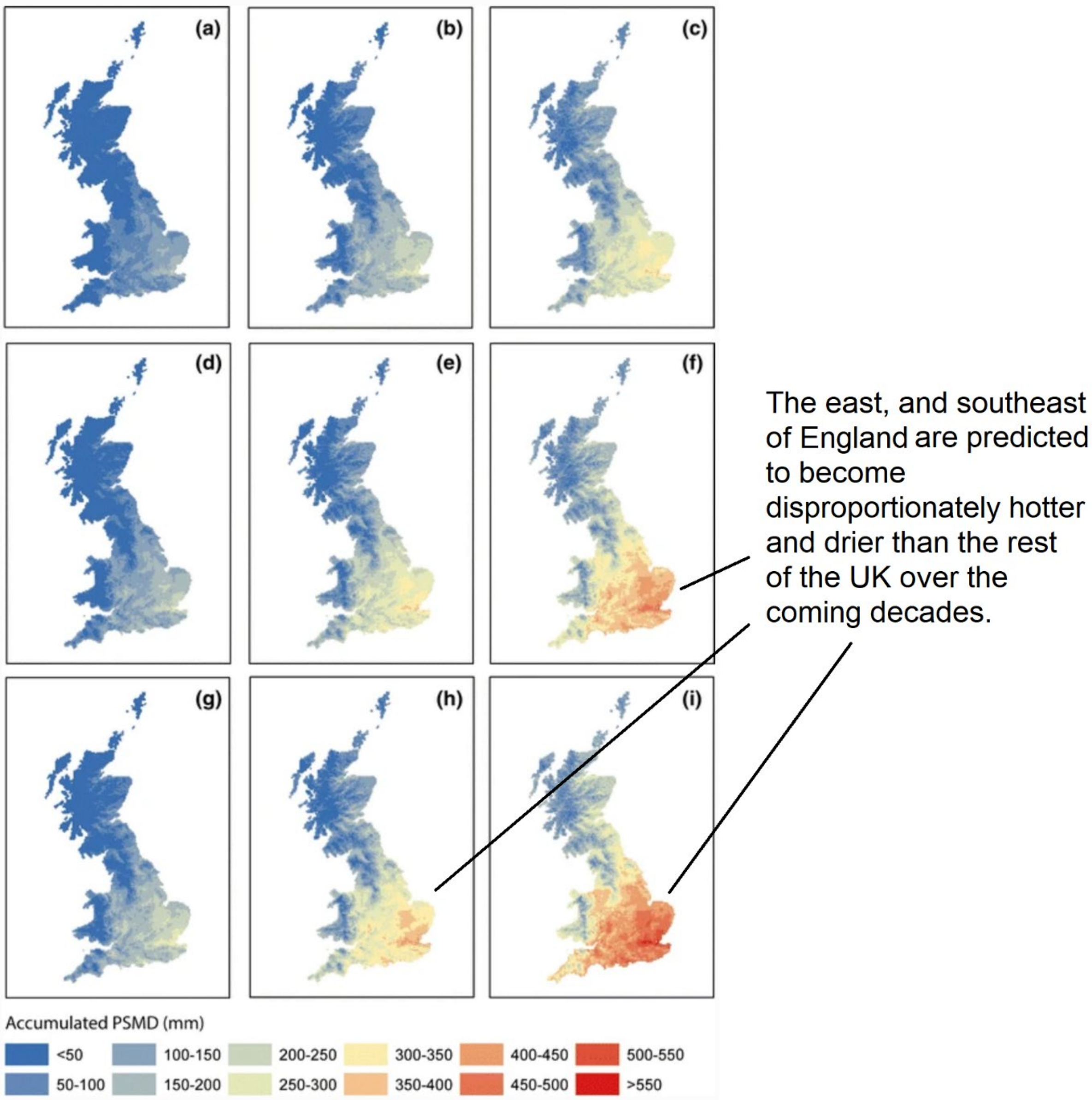

Figure 29- Increasingly hot and dry summers are expected moving from the baseline (1961-1990s a:10%, b: 50%, c: 90%) to our emerging climate (2020-2049 d:10%, e: 50%, f:90%) and then to the future (2040-2069 g: 10%, h: 50%, i: 90%) PSMD: Potential Soil Moisture Deficit. (From Pritchard et al, 2015).

Concluding remarks

We set out to determine if regional differences played a part in Anglian Water's good leakage performance. We found that there are, indeed, environmental differences between the Anglian Water region and the rest of the UK.

However, far from being an environmentally benign part of the country, we found that the Anglian Water region has disproportionately aggressive soil conditions and extreme and variable weather patterns. Our analysis, and published research demonstrate that both aggressive soils and extreme weather are associated with higher rates of pipe failure. Furthermore, Anglian Water's aging distribution network contains long lengths of pipes of particularly vulnerable materials, such as asbestos cement. These three independent factors of (1) aggressive soils, (2) extreme weather and (3) vulnerable pipes, and their interrelationships, arguably make the east of England one of the most challenging regions in the UK to achieve good leakage performance.

We have seen that the water pipes in the Anglian Water region are already experiencing the impacts of global climate change. Pipes fail more when soils are dry and temperatures are extreme. Soil moisture deficit in the region is the highest in the UK, and already increasing compared to the 1961-1990 long term average. Also, compared to this baseline, average summer temperatures in the last decade (2010-2019) have also already increased in the Anglian Water region by 1.6 ºC, compared to 1.2 ºC for the other regions.

These hotter summer temperatures are predicted to continue to increase in this region, and to continue to increase at a faster rate than the rest of the UK. The rising hazard levels from such environmental factors will likely make leakage reductions in the Anglian Water region even harder in the 2020s than it has been in the 2010s, especially in periods of lower rainfall and drought, when water resources will be even more scarce.

We have more evidence now than ever before to demonstrate the very real impacts of aggressive soil environments and extreme weather on the performance of aging and degrading water networks. It is my view that more needs to be done now to prepare the Anglian Water network (especially its AC pipes) for the environmental risks it is facing now, and will increasing continue to face, to ensure that it is resilient to serve the communities in this region for the coming decade.

Reducing leakage is vital to long term water security. This is especially important for Anglian Water given the increasingly challenging environmental hazards that are present in this region.

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