WATER FUTURES IN THE SOUTH EAST TOWARDS 2050

Renewal, regeneration and innovation: re-engineering for the long-term

Stantec

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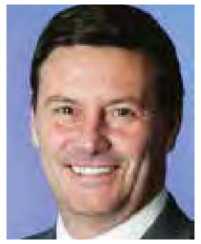
FOREWORD



Water plays a unique and vital role in all our daily lives. Without exception it is critical to our communities, homes, schools, businesses and environment.

We commissioned this report to provide an independent view on the future of water in the South East, to support and inform our long term planning as we navigate our way through a time of great change both within the water sector and across wider society.

We need to make sure the water and wastewater services of tomorrow are resilient and can adapt to the needs of our customers and our region by facilitating growth and enhancing the environment.

The future holds many challenges and opportunities and I believe, by understanding these more fully, we can manage water wisely to add value to our region, both for the people living and working within it and the precious environment which makes the South East unique.

I hope you enjoy the information presented in 'Water Futures' and that it helps you think about, and perhaps contribute to, the creation of a valuable and sustainable future for us and the generation who follow us.

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Chief Executive Officer Southern Water

Southern Water

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The Stantec community unites approximately 22,000 employees working in over 400 locations across six continents. We collaborate across disciplines and industries to bring water and infrastructure projects to life.

INTRODUCTION

The South East & Southern Water Towards 2050

Southern Water forms a vital part of the core infrastructure of the South East, one of the fastest growing, culturally rich and environmentally sensitive regions in the UK. It is also one of the most varied, ranging from major cities such as Brighton, to areas of outstanding natural beauty, exceptional farming land, rivers and beaches.

This strategic, long-term review explores the critical driving forces and 'high impact' uncertain variables within which Southern Water operates, from global to community levels. Interpreting how these may interact and play out over time creates the initial framework within which present-day decisions can begin to be made. Some macro-level variables, such as demographics, are relatively predictable. Others are highly uncertain. The changing relationships between them will have far-reaching and unpredictable consequences. The overarching challenge and opportunity is to create flexible strategies that will work in any future scenario, no matter how extreme.

The variables range from global climate and environment at one extreme, to possible new forms of regional governance, 'ecosystem thinking', new technologies such as nano-scale filtration sensors and artificial intelligence and beyond, to radical innovation and the changing cultural values of the public, customers and the broader range of stakeholders. We operate within a global 'systems of systems' world, characterised by increasing overlaps and interconnections that increase complexity, uncertainty and the likelihood of non-linear disruption. Water and waste water services do not operate in isolation, but are deeply interconnected with energy and agriculture, as well as communications, transport, urban development and wider economic, health care, social systems and public services.

Our approach in this review is not just to explore these variables, but point to how the relationships between them may change. How, for example, might a growing population, combined with public attitudes that amount to zero tolerance of pollution, or flash flooding, shape public responses to extreme weather events? What are the emerging cultural narratives that will change how we see the environment?

The global water industry is at a turning point and is facing unprecedented change, driven not simply by potentially volatile climate, but by increased demands for cost effective basic services, particularly to meet the needs of vulnerable customers, growing, diverse and yet ageing populations, changing social attitudes and priorities, technological disruption and more challenging requirements for environmental security and long-term sustainability.

Conventional approaches can no longer guarantee resilience. We explore signs of potentially disruptive change, from individual breakthrough inventions to systemic innovation – where multiple inventions are combined and integrated – to the re-invention of innovation itself.

The critical driving forces and high impact variables covered in this 'Water Futures' review, and each the subject of separate yet related essays, are:

#1 Changing Climate
#2 Ecosystem Thinking
#3 Collaboration Redefined
#4 Digital Transformational Change
#5 Nanotechnology Advances
#6 Cultural and Social Change

Essentially, the first question is to ask 'what might happen?' and explore the early signs of structural change.

The answers to this question form the framework for options-based strategies designed to deliver resilience and the flexibility to make course corrections, adapting as the dynamics of the world around the South East and the water industry changes. These dynamics in a South East and Southern Water context are explored in the final chapter of this review.

The ultimate test is to deliver hedging strategies to respond to emerging risk, but also to accelerate innovation.

THE SOUTH EAST & SOUTHERN WATER TOWARDS 2050:

CRITICAL DRIVING FORCES & 'HIGH IMPACT' VARIABLES

#1 CHANGING CLIMATE

Changing climate and the potential for, at one extreme, rapid, non-linear and dangerous change, with extended droughts and prolonged periods of hot weather and frequent, intense rainfall and flooding events and at the other, more benign, gradual change. **The South East is the first region in the UK expected to face the full challenge of planning for and adapting to the consequences of a changing climate**

#2 ECOSYSTEM THINKING

The increasing importance of **ecosystem thinking**, particularly in relation to catchment areas and natural capital assets, ranging from water abstraction and security of water supplies, to land and water use by farmers, communities, leisure industries and beyond, to how inventive approaches may drive changes in agricultural practice, energy production, water management and reduced pollution. **The South East and Southern Water faces particular challenges, such as the possibility that river flows may fall by as much as 35% as the combination of population increases and climate change bite**

#3 COLLABORATION REDEFINED

'Collaboration redefined' with the emergence of new, collaborative regional governance models between multiple infrastructure providers, regions, cities, local communities and policy-makers around a shared sense of vision and purpose aimed at delivering resilience, new efficiencies, lower costs and higher environmental standards. **The South East is, from a policy and governance perspective, fragmented, which puts a premium on collaboration**

#4 DIGITAL TRANSFORMATIONAL CHANGE

Digital transformational change and the potential impact of novel design, artificial intelligence and predictive technology approaches to roll-out of localised bio-sensor and security networks, accelerating the practical integration of water, energy and agriculture, together with distributed network management, and wider 'mass-automation'. **The opportunity for Southern Water, in common with other infrastructure companies throughout the UK, is to identify and evaluate how to integrate systems across regional and institutional boundaries**

#5 NANOTECHNOLOGY ADVANCES

Nanotechnology advances and the evolution of nano-filtration, graphene and 'clean' technologies that will make desalination increasingly economic and bring energy reduction, water purification, waste filtration, recycling and disposal benefits at all scales, from major installations, to domestic levels. Economically viable desalination is a potential game-changer. **Opportunity lies in understanding the technology landscape and developing options that may be piloted or implemented at the right time in the context of conventional asset renewal and maintenance programmes**

#6 CULTURAL & SOCIAL CHANGE

The changing dynamics of **cultural and social change** towards environmental standards, particularly at community and city level, but also in small rural communities and areas of natural special interest, will play an increasingly important role. Imagined futures are cultural realities and will shape public attitudes to the environment and basic infrastructures. **Younger people and the next generation of customers future needs will be radically different from today, as values, attitudes, the public mood, and the tools communities and society use to interact, change rapidly and reframe dialogues**

#1 CHANGING CLIMATE

The South East in a global context: over the next three decades we may see the emergence of a volatile, unstable natural environment.

We are entering an era in which abrupt and unpredictable biosphere and climate changes may create large-scale disruption, as linked and increasingly complex human and natural systems come under increasing stress and expose underlying fragility of socio-political and economic systems.

The Great Acceleration

This is not new. Evidence of the 'Great Acceleration', characterised by both rapid increases in damage to the biosphere and unsustainable, social, technical and industrial consumption patterns has long been clear. The rate of change seen from the 1950s has stepped up since the turn of the century. The graphs of everything from population, to fertiliser consumption, to water use and tourism have a similar shape: near exponential rates of change, with few signs slowing.

This helps to explain why policy and public attitudes are aligning around action on the so-called 'planetary boundaries'. These are usually seen as the fundamental 'safe' limits of the global biosphere, beyond which civilisation may be vulnerable to irreversible and non-linear change. These create the context for policy-makers, regulators, business leaders, investors and the broader financial markets and one of the frameworks within which to stress test long-term security.

Conventional thinking is focused around nine variables that interact dynamically and shape the global system: climate change, ocean acidification, chemical pollution, nitrogen and phosphorous loading, freshwater withdrawals, land conversion, bio-diversity loss, air pollution and ozone depletion. Other than the ozone layer, all these measures point in the wrong direction. Even so, many of these vital changes are invisible in people's daily lives. Air pollution is the exception, concentrating political action in major cities as far apart as London and Beijing. As real-time water and pollution monitoring increase transparency, this will change.

Whilst these variables are global in scope, they all influence the South East's environment. Cultural attitudes are crystallising around a set of shared sustainability-with-progress narratives and will permeate the region. In other words, they set the context in which the South East, as a region and Southern Water more specifically may develop long-term strategies.

From an ecological perspective, policy will be shaped both by a deeper understanding of how interlinked global systems threaten regional security and act as the trigger for innovative intervention in managing and controlling the natural environment.

Water, energy and agriculture

Against this background, we cannot view the South East, or the water, wastewater and core infrastructures in isolation. They must be seen as part of a 'systems of systems' environment in which everything, at some level, is connected.

Energy services are major consumers of water and vice versa. Agriculture, the major driver of water demand from a global perspective, is also a source of 'ecosystem services'. Estimates vary, but food production accounts for more than 70% of global water consumption. Electricity generation comes second, at about 16%, with domestic and industrial water consumption totally about 6%. Water supplies, in particular, are

The Great Acceleration

The term 'aims to capture the holistic, comprehensive and interlinked nature of the post-1950 changes simultaneously sweeping across the socio-economic and biophysical spheres of the Earth System, encompassing far more than climate change.'

Source: The trajectory of the Anthropocene: The Great Acceleration, Steffen et al 2015

under growing stress and projected to worsen in even the most favourable climate scenarios.

The International Energy Agency's (IEA) projections suggest an 85% rise in energy-related water use to 2032. The uncertainties surrounding these projections revolve around the fundamental drivers: patterns of population growth and extending energy availability – 1.4 billion people around the world have no access to electricity. They also depend on the rate of adoption of electric vehicles, which may increase both energy and water demand.

In practice, life-cycle costs of water consumption of primary energy sources vary from wind power at one end of the scale, to concentrated solar and oil and at the other, hydropower. Some primary sources are particularly vulnerable to a changing climate. To illustrate, droughts in the US since 2015 are well-known to have had adverse impact on power production. The power capacity of the Hoover Dam has dropped almost 25% since 2000. New turbine designs may alleviate the problem, but the inter-relationships are clear.

The deeper long-term uncertainties revolve around not only how individual inventions, such as perovskite solar cells, transform the picture in their own right, but the rate at which new inventions are integrated in water, energy and food production systems. This in turn depends on the strategic vision of city leaders and policy decisions both at national and international level.

Since the relationships between water, energy and agriculture are tri-directional, the policy implication is simple: long-term decisions must take account of all three. The most resource efficient design, taking into account conflicting needs may not, for example, be the cheapest source of 'clean' energy, but the most water efficient.

The risks of water shortages to the energy sector range from reduced capacity to investment uncertainty about utilities' license to operate. In Brazil, drought has led to power rationing. Some natural gas and oil fracking operators have faced increases in water costs, or have been refused access.

Not only are water, energy and agriculture deeply interconnected, but they are dependent on communications infrastructures and linked to transport networks and urban environments. They are also part of the pervasive but not always recognised cultural fabric of local communities, as well as the political and economic systems. Above all, the global climate is increasingly volatile. 2017 is forecast to be amongst the hottest on record. In 2016, CO_2 concentrations breached the scientifically and symbolically important 400 parts per million level, widely regarded as a potential trigger point.

These and many other factors drive daily headlines. Growing risks include methane emissions from both melting tundra and expanding global dairy farming. The melting Arctic sea ice is both a symbol and a predictive measure of future temperature variation, shaping how we think, but also directly influencing the global climate. The list goes on. Heatwaves. Drought. Flood. Failing Greenland ice-shelves. Rising sea levels. Intense rainfall. Storm surges. Collapse in bio-diversity. Declining fisheries. Crop failures.

At a regional level, recent UK Met Office simulations found that there is a 7% chance of a monthly rainfall record being set in the South East in any one year – worse than earlier estimates. This reflects a worsening outlook, but also that knowledge of global systems is improving through better climate models and more rigorous evidence. This is particularly important, because South East infrastructures may be particularly vulnerable to extreme winter rainfall.

The critical climate variables

Against this background, the first critical variable that will shape the next thirty years and beyond is the climate itself, which may enter a so-called 'runaway' phase, or at the other extreme, evolve slowly, as the earth's natural systems create more benign feedback loops.

The second is whether global leaders build and maintain a publicly supported and substantive vision for a sustainable, resilient, adaptive and secure world, setting the context for large-scale investment in radical innovation. One uncertainty will remain. Even 'maximal' global and ground roots level innovation may not succeed in maintaining global temperatures below the two-degree post-industrial levels.

Similarly, staying within the two-degree limit may not be enough to stabilise the climate. It is possible that rapid, chaotic, dangerous impacts will emerge regardless of progress on carbon emissions, with the potential to disrupt water supplies and undermine resilience of waste water networks.

Adapting to change

Yet there are positives from a regional perspective. The consequences of rising temperatures, storm surges and extreme rainfall may be disruptive, but there will be major benefits from the waves of invention and systemic innovation sweeping in from all corners of the world. More imaginative and purposeful narratives are emerging, in which control of the environment is in human hands and that ecosystem thinking and technology, combined with fundamental structural changes in societal and cultural attitudes, offers answers.

Faced with increasing complexity and with that uncertainty, the challenge is to not only develop a deeper understanding of the world, but re-invent how to think about the future, particularly in relation to the future of core infrastructures.

There are positive signs that reflect rapid progress in identifying the root causes of pollution, impurities and more broadly ecosystem environmental stress and fragility. The bio-chemistry of the natural world is under deepening scrutiny and the knowledge emerging from science is changing behaviours and governance structures, driving the 'grand challenges' of technological innovation.

From another perspective, financial regulators are urging corporate leaders to take a long view and provide investors with greater protection by outlining how they will respond to the most extreme climate-induced disruption.

UK government policy may be to raise environmental standards and performance requirements across the board and take a leadership role in everything from air pollution and water quality to incentives to farmers to act as guardians of the natural environment.

There are signs of a growing consensus across industry, the investment community and particularly amongst the leading regions and cities, who are taking the lead in translating changing public attitudes into action. The grand challenge for investors, regional, city and corporate leaders alike is to develop innovative strategic options that work in any future scenario and in effect, to invent hedging strategies.

This is important, because changing market dynamics and emerging narratives on climate change will shape not just the prospects for investment in major oil, gas and energy and water companies, but investment in innovation.

This applies particularly to water, energy and agriculture and the links between them. Innovation, both in working with nature at local levels in low-tech, low-cost ways (such as re-thinking water meadow systems) and in adopting radical technology is no longer an option, but an imperative.

These broad scenarios raise questions about the future of the natural environment, natural assets and both land and water resources, to which we now turn.

#2 ECOSYSTEM THINKING

The ecosystem worldview will, over time, create fundamental changes in the structure of the water, energy and agricultural sectors, as well as open up new opportunities for radical, systemic innovation.

Natural and human-made ecosystems are interconnected and interdependent both explicitly and implicitly, and in simple and complex ways.

Cities and communities are inseparable from their geographical context, natural assets and resources – the rivers, watercourses, landscapes and seascapes that underpin basic services and the character of the region.

Looking back, these natural assets have often come under pressure through decades of intensive but often ill-considered development, including, for example, building on flood plains, or basing planning decisions on outdated geographic, environmental or climate models.

Ecosystem design & services

Humans have always shaped the natural world. Looking forward, we will have the knowledge, tools and ever-deepening understanding of natural and human systems to shape the environment and create a sustainable balance.

In the short term, 'ecosystem design' will focus on low-tech environmental management, drawing on naturalistic principles and in many cases on well established, proven methodologies. It is not technology free, since modelling techniques have an important role in understanding the behaviour of say floodwaters in urban environments or, from another viewpoint, the diffusion of pollution through farming land, rivers and water-courses.

Water catchment strategies, land use and environmental management are already being transformed around the world. Agriculture and food production are well-known to be inseparable from the need to deliver 'ecosystem services', reduce flooding and pollution risks and conserve the environment. This means that farmers and land owners are already seen as guardians of natural assets, with responsibility for developing 'catchment sensitive' farming.

The critical uncertainty facing the UK and the South East is how agriculture and food production can be secured and ecosystem services reconciled in an era of volatile climate.

The interlinked challenge is to meet the demands of a combination of a growing population (estimated to rise by 25% by 2050); increasing pressures on unique river catchments driven by global warming (that may reduce water flows by 35%); and rising demand from industry.

From 'zero harm' to regeneration

Ecosystem thinking is already encouraging more ambitious policy-making and inventive local solutions.

The well-established idea of 'zero harm', essentially of conservation and sustainability, is being superseded by a new narrative, which envisions a radical endgame: the regeneration of the natural environment.

This is radical in several senses, not least in terms of potential costs and how it might be financed. In other terms, the narrative is not about 'waste', but about 'resources'. This begins to frame natural assets in a new way, by describing the long-term vision within which policy decisions are made.

In this changing context, the challenges faced by all water companies will range from zero uncontrolled discharges from sewers; to zero leakage; to carbon neutrality and ultimately negative emission energy consumption.

To illustrate, the government plans to ban microbeads might be seen as one of many indicators of the direction of travel and as one step towards more comprehensive measures to cut the volume of what might be called 'deep pollution'. These forms of pollution are typically hidden and not measured, but enter and can pervade natural systems and water networks. There is little transparency, but there are indications that pharmaceuticals, endocrine disruptors, nitrates and pesticides will come under increasing scrutiny both by the public and regulators. New rules for farmers may focus on diffuse pollution risks associated with phosphorous, fertilisers and manures.

From another perspective regulators are placing more emphasis on conservation. To take one example, the rules on water abstraction from the environment may change radically,[1] as groundwater and streams are seen to be more vulnerable to global warming and biosphere risks. The key is that policy-makers and regulators may act long before the events themselves emerge, placing fresh demands on infrastructure companies to anticipate long-term developments and act on them in the here and now.

In extreme scenarios, this may put primary water sources at risk and may mean accelerating investment in efficiency, re-use and desalination strategies, even in regions with relatively secure fresh water supplies.

From theory to practice: keep it simple

This creates the context for both short-term practical action and strategic pilot schemes designed to explore novel new methodologies.

To illustrate, in rural upper catchment areas, peatland, woodlands, wetlands and downstream water meadows are well-known to absorb and hold back water from running off to rivers during extreme rain events. These traditional methods, illustrated locally by the restoration of the Winnall Moors nature reserve, have reduced flooding in Winchester. Schemes such as this demonstrate that the community as a whole can benefit from resilience and security against flooding, as well as lower insurance risks.

In urban areas, complex structural vulnerabilities in the built environment, communications networks and transport infrastructure amplify the risks from more frequent, heavy rain and extreme flooding, so are primary targets for new designs. This means that the interdependencies between water, waste water systems and the wider environment and between local communities and infrastructure providers are critical. In practice, it means re-thinking urban environments, introducing everything from rain gardens to water capture and storage and fast-draining, permeable surfaces.

The lesson is that not all solutions to increasing climate volatility depend on new technology or investment in modern building methods, but on new designs. Ecosystem thinking and integration is the primary defence against complexity and the risks of systemic failure. With relatively little investment in either capital or ongoing maintenance, there are many 'natural capital' options available to improve resilience and to regenerate rivers, beaches and landscapes.

Ecosystem futures

To recap, the future of natural assets depends above all on the rate at which 'ecosystem thinking' is translated into practice.

Complexity, ecosystem thinking and integration are inseparable concepts and both part of problem and part of the portfolio of solutions. In this sense, distributed systems are the emerging new paradigm, but depend on governance, new ways of thinking and predictive modelling.

Technology has a part to play, but the first step is to think about the future in new ways. In other words, how we think about the future is just as important as how we imagine radical new technologies, such as digital systems and nano-filtration might emerge.

This leads to the implications for regional governance, policy and leadership, to which we now turn.

[1]Current estimates are in a wide range, from 5% to 50% by 2025

#3 COLLABORATION REDEFINED

Collaborative governance and co-creation at local level and across industry boundaries has the potential to deliver resilience and accelerate innovation. Ecosystem thinking, at regional governance, cities, and local community level will be the new paradigm.

Complexity and the rise of integration

One of the fundamental challenges to leadership teams around the world is how to map and navigate complexity and growing uncertainty.

Complex systems become fragile when they are fragmented and difficult – or even impossible – to understand. Complexity is one of the root causes of uncertainty. Systems become stressed when there are increasing numbers of interconnections that change quickly, or when the network becomes 'tightly coupled' and measures of uncertainty reach what is usually called 'the edge of chaos', beyond which linked, synchronous change can emerge with little warning.

In other terms, policy makers, investors, business leaders and the public lose confidence when there are too many moving parts with ill-defined boundaries and they lack the knowledge, understanding or inventive capacity to see the big picture clearly.

Integration redefined

The antidote, in practice, is to re-design the ecosystem at regional, city and community levels. This explains why 'ecosystem thinking' is emerging as a guiding worldview and driver of policy innovation. The aim is to reduce interdependency, complexity and uncertainty in the system. Typically, this means creating order by design, through service integration, business engagement and clear agreements, ultimately in the interests of customers and the public.

'Integration' is overused to the point it has lost much of its meaning, but in practice, it is about designing the ecosystem from basic principles, rather than allowing it to continue to grow organically. At best, it is about innovation in working practices, primarily by focusing on inclusive co-creation amongst groups of stakeholders who share a common vision, identity and sense of purpose.[1]

The benefits of integration and collaboration in broad terms are:

- Improved control and resilience, by designing the system around benefits for the whole, in the common interest;
- Greater security, particularly in the context of climate change, terrorist risk and cyberwar;
- Improved service levels; and
- Transparency and accountability.

Above all, integration is about cost savings. This is because seen holistically, ecosystems that evolve over time typically waste resources. In a stressed economic and potentially fragile financial environment, cost-reduction is a primary driver. By and large, future customers will expect reduced expenses and better performance, so integration offers some of the answers.

[1]Integration is not entirely new. In the South East, for example, the 'Water Resources' initiative, in place for 20 years, has developed strategies to meet the need for bulk transfers and new resources between water companies.

Cities as ecosystems

The link between ecosystem thinking and integration is an emerging narrative, but so too are 'distributed networks' that use new technologies to design more flexible and resilient systems based on both centralised, large-scale plants and localised services.

There are indications that miniaturised water and waste water treatment will emerge within the next decade, opening up new design options for systems integrators at all levels and accelerating the transition. This approach is already being adopted by major cities, in response to the threats and opportunities presented by climate change.

As the promotional material for Sydney's Green Infrastructure Plan to 2030 put it:

> "Similar to centralized energy, centralized water solutions are inefficient, unsustainable and highly vulnerable to climate change. Similarly, the amount of pollutants entering our waterways is not acceptable. We cannot allow such outdated solutions to compromise the social, economic and environmental well-being of the city."

As a recent Organisation for Economic Cooperation and Development (OECD) report put it cities in particular are well placed to deliver 'systemic change that raises only slightly, or even lowers, overall investment costs'. With estimates of the total investment required to overhaul the world's infrastructures ranging up to US $ 90 trillion over the next 20 years, this is vital both from financial and social perspectives. To put this in context, cities have long recognised that one of their primary purposes is to deliver attractive places to live. Many have adopted the holistic 'creative cities' ethos, focusing on the relationships between economic success and the arts, culture, education, well-being and the built environment. In this sense, the collaborative '100RC' or 'Resilient Cities' movement is the latest example of the most forward-looking cities and local communities thinking as systems integrators.

This is important, because in an uncertain political, economic and regulatory environment, funding decisions will depend on options that will work irrespective of the long-term outcomes, in even the most extreme scenarios. From an investment perspective, the arguments in favour of systems perspectives and integration are well established, since one of the central concerns for investors is that the infrastructure 'industry' is fragmented and lacks cohesive, integrated visions.

The EU expert group report on financial stability sets out two objectives and underlines the point:

> "The first is to strengthen financial stability and asset pricing, by improving the assessment and management of long-term material risks and intangible factors of value creation, including those related to environmental, social and governance (ESG) issues. The second is to improve the contribution of the financial sector to sustainable and inclusive growth, notably by financing long-term needs such as innovation and infrastructure, and accelerating the shift to a low carbon and resource-efficient economy."

This is consistent with the direction of global regulations and guidance from Ofwat.

It both highlights the inter-relations between 'environmental, social and governance' issues and positions 'innovation' and broader 'infrastructure' as primary concerns. In other words, the 'long-term' perspective is emerging as a critical factor in both financial and policy terms, which forms the context in which water companies will operate. This represents a sea-change. There is an argument that infrastructure services, seen together, are amongst the few remaining sectors that have not been subject to disruptive innovation. Yet growing pressures on the water, energy and agricultural sectors are now driving large-scale investment in innovation, which means that from a regional perspective, cross-border and cross-asset trade and licensing in ideas and expertise will become a vital contributor to local resilience.

Catchments and communities as ecosystems

Cities may be the prime movers, but the 'ecosystem' model works at local levels. There are several cities and communities in the South East that might pilot fresh thinking, given their governance structures and all-important sense of shared identity and purpose, from Brighton to the Isle of Wight. Catchment areas are also the natural focus for new governance models. Think of water catchments as ecosystems. The same principles can be extended to villages, individual businesses and small communities.

> **The South East is already well-known as a region facing water stress and given the possible impact of further global warming, the first region in the UK to face the full challenge of developing innovative, active plans to deal with long-term water shortages and rising environmental standards.**

The success of these initiatives will depend on the effectiveness of multi-stakeholder collaboration across institutional and regulatory boundaries. Catchments, for example, do not map to governance boundaries.

In broad terms, amidst the many uncertainties, there are two possible scenario outcomes, over time.

The Long-Term View

At one extreme, visionary leadership teams will transform regions, cities and local communities by taking the long view and delivering efficiency, minimal pollution, lower costs, higher environment standards and security to water, energy and agricultural ecosystems. At the other, fragmented policy-making, regulation and siloed core infrastructure networks become increasingly fragile, operationally expensive, slow to adapt to climate change and unable to invest in innovation.

Against this backdrop, we now turn to how such radical digital technologies may play a role in ecosystem design, mass-automation and innovation.

#4 DIGITAL TRANSFORMATIONAL CHANGE

Pervasive bio-sensors, imaging systems and predictive analysis will emerge to enable systematic integration of water, energy and agriculture systems and mass automation.

Whilst 'natural' ecosystem thinking will offer opportunities to address many of the emerging challenges facing the South East and provide a foundation in the short-term, we can expect waves of radical, digital innovation to both accelerate the rate of change and create broader, deeper opportunities to improve resilience and performance.

Digital technologies, in the form of sensors, big data, artificial intelligence and predictive analytics have the potential to accelerate the integration of water, energy and agriculture, as well as bring benefits to interdependent core infrastructures, such as communications, transport and the wider urban environment.

Whereas many natural solutions are highly location-specific and relatively low-tech, high-tech invention will emerge from around the world. Many regions and countries are leading the way in specific areas that address clear and present dangers. The US, for example, is pioneering 'connected farms' and fully automated irrigation systems. Israel leads the way in desalination and irrigation systems.

On the horizon, we can see mass-automation, from autonomous electric vehicles and the merger of public and private transport 'on demand', to real-time monitoring and control of water, energy and service infrastructures. Machine-controlled, semi-autonomous cities and rural environments will redefine social and economic life.

To illustrate, cheap, cloud-connected 'lab on chip' sensors will pick up changes in chemical composition, specific pollutants, water quality, temperature and other vital indicators, for monitoring, real-time analysis, maintenance and emergency alerts. Some estimates suggest that US $ 250 billion a year will be invested in 'Internet of Things' (IoT), half of which will be in manufacturing, transport and utilities.

Sensors will be embedded in the natural environment, in rivers, water treatment plants, buildings and objects of all kinds. They will form part of networks of airborne 'swarms' of autonomous drones, equipped with high-resolution cameras and linked to real-time imaging analysis systems. Sensors herald the emergence of a pervasive layer of digital intelligence over the physical world, delivering highly granular, live intelligence pictures of places, objects and people. Everything and everyone will be encoded, connected and transparent, driving the development of novel environmental risk monitoring systems.

It is easy to focus on the devices and gadgets, but these technologies will produce pervasive change. There is, however, a counter-narrative. Concerns about machine intelligence and surveillance are well-founded, since core infrastructures are well-known cyberwar targets.

Whilst governments around the world are investing heavily in protecting core energy, water, air traffic control, transport and communications networks, the long-term outlook is uncertain.[1] Recent reports of alleged nation-state attacks on the UK energy grid follow a series of similar high-profile incidents around the world.

Whilst the long-anticipated IoT has the potential to transform the landscape, botnets represent a growing threat, taking over inherently weak webcams, video systems and consumer devices. Even so, ultimately these systems will increase resilience, providing early warnings of everything from floods to farming pollution and beyond, to monitoring of plastic and waste in disposal and recycling processes.

Leaving aside technology security, the question of physical network structures is also key. In simple terms, there is a case for creating diversity as a means of delivering security by design, by implementing decentralised and distributed networks to reducing reliance on large-scale plants that present high profile targets.

There are several interconnected threads in the emerging story, from the practical applications of 'big data', to the digital revolution in precision agriculture.

Simulation and prediction

The less obvious benefit of pervasive sensors is that predictive models and analysis will enable better understanding and acute sensitivity to water quality and pollution, from upper catchment areas right down to individual homes.

Within a decade, everyone will be in the 'big data' business. It already pervades all industries and new, more sophisticated applications emerge by the day. More than 17,000 patents in 9,500 patent families have been granted, with the total doubling since 2005.

The revolution in predictive analytics has only just begun. We can expect to see waves of innovation, particularly at the intersection of water, energy and agriculture.

Ecosystem design, engineering and transparency

The overarching benefit will, however, be in ecosystem design and modelling. Armed with deep intelligence about the natural and human-made environment, design will transform infrastructure engineering. It will enable not simply greater security, efficiency and lower costs, but open up opportunities for water and energy 'on demand', as trading networks connect infrastructure providers and domestic users alike.

The less obvious emerging benefit is transparency. Water quality and environmental measures will be made visible and widely available for public scrutiny. This means they will make infrastructure providers more accountable.

At the same time, knowledge about the long-term impacts of impurities will expand exponentially. Sensitivity to health will become vitally important as an indirect driver of environmental standards. Contrast this with present-day. Over time, transparency of basic quality criteria, from reliability to water quality standards and environmental pollution will revolutionise the industry.

Energy

Digital networks will also play a vital role in the integration of water and energy. The clearest benefits will emerge through the introduction of solar, wind and new battery storage technologies that will solve the 'intermittency' problem in small scale, local installations. Solar technologies are already at 'grid parity' in many parts of the world and the relationship between price and performance will continue to improve.

The patent landscapes of five or six years ago sent a clear signal to investors and utility operators: batteries, novel forms of storage and renewables will transform primary power. From a water perspective, local integration of water and energy with digital network management, will drive distributed network design.

The key point is that these technologies are not heavy users of water. A win-win of sustainable energy and improved water efficiency is on the horizon.

Wind turbines have improved rapidly and the performance of photovoltaic systems break new records each year, converting more power from sunlight. Solar thermal systems and molten salt energy storage are beginning to realise their potential. Technologies that do not necessarily involve large-scale re-investment in grid infrastructure will play a critical role. To illustrate, perovskite solar cells, have three apparent advantages over silicon cells – they can be used everywhere; are simpler to manufacture; and are more efficient over the longer term.

Ultimately, the links between energy and water are crucial for the simple reason that water availability will directly determine the sustainability, and so viability, of energy sources and vice versa.

Precision agriculture

Digital networks will also have major impacts on farming, food production and environmental protection. Typically, the general expression 'precision agriculture' is applied to large-scale 'agri-business', but there is growing evidence that digital technologies will also create important benefits to small farms.

Crop and livestock-monitoring drones, agricultural robots, autonomous vehicles, real-time local weather forecasts, bio-sensors and above all 'smart', machine-controlled irrigation and water management will all have a role, as will networks designed for pest control, monitoring of soil conditions, crop analysis and optimised fertilisation.

'Field level' imaging, sensor and data management software is already finding a way into 'connected farming' systems aimed at improving soil quality, water efficiency, animal welfare and yields. There are indications that robotics, biometrics, image sensors and image analysis will become 'hotspots' of product and service models and that they will be applied across the boundaries between agriculture, water and pollution sensing. In other words, the future of farming will be shaped by both 'ecosystem' thinking and digital networks.

From another perspective, agriculture and food production itself will be transformed as water scarcity emerges as a dominant international security issue and force innovation. To put this in context, only 3% of the world's water can be used for farming and drinking and much of it is held in the polar regions. Just half of one per cent of the world's water is accessible and about 70% of this is used in agriculture.

With a rapidly growing population, the pressure to produce more food with less water will become critical to avoid what is usually referred to as 'water wars'. The reality is that 'water conflict' is not new. Most recently, the 2010 drought in Russia triggered the collapse in wheat production and exports to the Middle East and North Africa were cut back, contributing to the Arab Spring.

What is new is that knowledge of biological systems is expanding fast, drawing on large-scale data collection and increasingly powerful modelling. There are some early suggestions that one of the main beneficiaries of emerging quantum computing power may be molecular biochemistry.

From a more local perspective, in extreme climate scenarios, food shortages across Europe and the Middle East may have an impact on domestic food markets, which are heavily dependent on imports. Coupled with political and regulatory changes, food security may become one of the UK's most pressing security challenges.

Technology-driven, intensive agriculture that uses minimal water and maximises natural processes to avoid pollution will become less an option, more an imperative. State of the art 'drip irrigation' systems, such as Netafim, illustrate what might be achieved. Netafim claims crop yields can be improved by up to 100% against conventional and still dominant flooding methods. ~To put this in context, the South East ranks third amongst the English regions in the value of crop output, according to DEFRA estimates from 2015. The region has extensive cereal and horticulture production. The efficiency of irrigation systems will become a critical issue in the more extreme climate scenarios.

The built environment and transport

Long-term urban resilience depends on both re-thinking river catchments and designing 'permeable' infrastructures to route storm water away from homes, critical buildings and industrial plants. Once again, ecosystem thinking and network modelling has a vital role to play in minimising flood risks to buildings, drainage systems and sewerage networks.

From a transport perspective, cars have long-dominated modern culture and structured the urban landscape, but the endgame is in sight. The convergence of cheap, easily maintained, long-lasting, clean autonomous electric vehicles and digital networked management services herald the convergence and integration of public and private transport.

There is growing uncertainty about how cities, long structured around the private car, will be transformed. From a macro perspective, consumers will free up spending, capital and above all time for more

[1] https://www.ft.com/content/ca2d7684-ed15-11e5-bb79-2303682345c8

productive activities, or more leisure and so see improvements in quality of life. Ultimately traffic density will be reduced. Cities will benefit from reduced air pollution, overcrowding and lower management costs. **One of the many possible consequences of autonomous vehicles is that there may be an exodus from cities to suburban and areas to the country.**

Taken together, bio-sensor networks, artificial intelligence and predictive technologies are best seen as the means by which efficiencies and lower costs can be delivered; resilience and security improved; and how integrated systems can be better designed. The challenge in the South East and for Southern Water in particular is to optimise these new systems across regional, industry and institutional boundaries.

Where next?

Against this background, there are two broad scenarios.

In the first, design and infrastructure will remain siloed and fragmented, leaving little scope for cost reduction, improved security or environmental regeneration. The risks of synchronised systemic failures will grow. The IoT will fail to gain traction, both because of the lack of standards and through weak security. This is a world of centralised water and waste water networks that rely on the renewal of existing infrastructures and investment in new facilities.

In the second, water, energy and agriculture, together with new technologies and holistic ecosystem design and engineering philosophy will create resource efficiencies and security in urban centres, farming and leisure areas alike.

Secure, sensor-driven monitoring, Internet of Things (IoT) devices and design-centric simulations and predictive analytics will reduce costs and improve performance. Remote monitoring of water quality; network capacity and failures; security against terror events will become standard practice.

Lab on chips technologies, chemical analysis devices, airborne sensors and live weather forecasts will form part of pervasive networks in homes and near to potential sources of industrial waste risks.

In this scenario, distributed, decentralised and flexible networks will encourage architects, builders and planners in both urban settings and environmentally sensitive areas to adopt new technologies. The economics of localised services will be transformed, yet deliver ever-higher environmental and quality standards.

With pervasive digital technology driving fundamental change, Nanotechnology advances, to which we now turn, similarly provides game-changing opportunities.

#5 NANOTECHNOLOGY ADVANCES

A wide variety of applications of nano-scale filtration methods, materials, and sensors promise to transform the water, energy and agriculture industries, at all scales, over the next decade.

The patent landscapes tell the story: in 2000, there were almost 140 - in total - nanotechnology applications related to water treatment. The first signs of the potential novel techniques such as nano-tubes, nano-bubbles, aquaporins and graphene emerged. By 2010 the total had risen to almost 400 a year.

Not all patents lead to commercial applications. Nor are patent numbers a reliable guide, since they do not account for quality.

Yet the evidence pointed to a growing likelihood of breakthroughs and structural changes in filtration and materials for a wide variety of applications and as expected, some of these patents are now emerging in the real world.

There are clear indications that the technologies are maturing, with applications ranging from simple water filtration, purification and re-use, to mineral and metals extraction, fuel production, recycling and, above all, desalination. The patent landscapes for desalination showed the number of cumulative patent families rising from 2,000 in 1996 to 4,500 in 2011.

Nano-filtration: variety and rapid growth

Nano-scale filtration is a hot spot for scientists, academic researchers and commercial companies for the simple reason that it operates at molecular level – the same scale at which the water industry aims to separate pollutants and micro-organisms from water.

Several technologies are in advanced trials and moving into production, primarily in large-scale plants. To illustrate, aquaporins, described as "the plumbing system for cells"[1] by Peter Agre, who was jointly awarded the 2003 Nobel Prize in Chemistry for their discovery, are particularly important. They are made up of minute protein channels that control water flux across biological membranes.

The Danish company Aquaporin has been granted more than 50 patents and is piloting or researching systems as diverse as the removal of micro plastics, to treatment of waste water from the semi-conductor industry. Their forward osmosis technology was tested by astronauts in the International Space Station, with the aim of demonstrating that water can be extracted from body fluids. There are applications focused on water re-use and on meeting growing consumer interest in naturally pure products in the food and beverage industry.

Another illustration is NanoH_2O, which was acquired by LG Chem in 2014, scaled up production and have been commissioned to integrate their technology in major desalination plants in Oman and Egypt. NanoH_2O say the membranes can allow up to a 20 percent reduction in energy consumption and up to a 70 percent increase in water production over similar sized state-of-the-art reverse osmosis membranes.

Similar technology is deployed in electronics manufacturing applications, where 'ultrapure' water is a basic requirement.

At the other end of the scale, Liquidity, a California based start-up has launched 'Naked Filter', a small water bottle that uses a nanofiber membrane to remove 99.9999% of disease causing bacteria. This may hint at the idea that Nanotechnology

[1] A Conversation With Peter Agre: Using a Leadership Role to Put a Human Face on Science, By Claudia Dreifus, New York Times, January 26, 2009

filtration may mature to the point where it can be installed 'at tap' and more broadly in domestic waste water applications. Other examples include modern versions of solar stills to purify water, using 'carbon paper', which is cheaper than nanomaterials. More promising is a novel method shown to enable the 'harvesting' of water from desert air, using 'metal organic frameworks' integrated in a device that uses sunlight and solar power to absorb water vapour.[2]

Graphene: 'wonder material'?

Yet it is graphene, hailed as a 'wonder material' that is attracting most interest. Graphene is a general purpose, fundamental invention, with high electrical and thermal conductivity; strength; impermeability; and elasticity. It has countless applications across all industries.

These include new membranes for water treatment, to new low-friction pipe materials, to composite materials used in 3D printing, to a new generation of batteries, fuel and solar cells, to a wide range of bio-chemical, pressure and acidity sensors. There are multiple lab on chip and bio-medical applications, as well as more obvious electronic variations. A new generation of imaging systems will emerge with new, high-performance photodetectors and high capacity optical communications.

Yet water, waste water and energy are widely regarded as the first and most promising targets for the first ground-breaking, real-world applications.

The progress of graphene will be driven over the next ten years by specific applications and by new, large-scale production methods.

This 'sweet spot' between commercial application and science explains the interest in desalination and filtration applications developed at the University of Manchester, most recently through the announcement of the 'ultrafast molecular sieve'. As they put it:

> **"Graphene-based materials can have well-defined nanometre pores and can exhibit low frictional water flow inside them, making their properties of interest for filtration and separation. We can investigate permeation through micrometre-thick laminates prepared by means of vacuum filtration of graphene oxide suspensions."**

This illustrates the ambition in both policy terms and in science. In the US, research is focused on breakthroughs to reduce the price, energy cost and emissions and to achieve 'pipe parity' between conventional water delivery and desalination by 2025.

There are also indications that graphene coating may be used in anti-fouling applications in water and waste water treatment, protecting against the growth of micro-organisms and biological material. 'Laser Induced Graphene' (LIG), invented at Rice University, has been shown to resist biofilm formation, which makes it well suited to water treatment plants and underwater pipes that are sensitive to fouling.

There are further waste water applications in development, including graphene-based sludge treatment systems for energy production and low energy, low cost digestion systems designed to remove nutrients for fertiliser production. Mineral and metal extraction may fundamentally change the assumptions about the economics of desalination. 'Mining the brine' techniques are attracting widespread interest, since they will generate income and contribute to solving brine disposal problems.

Taken together, there are indications of the convergence of novel filtration methods and small-scale filtration membranes and devices, bringing so far unimagined purity to water in domestic and industrial applications.

Nano-filtration may create a revolution in water-reuse and waste recycling. Economically viable desalination is a potential game-changer. The challenge is to understand the technology landscape and develop options that may be piloted or implemented at the right time in the context of conventional asset renewal and maintenance programmes.

In other words, the water industry faces a common problem: how to assess intelligence about the likelihood of radical innovations and technologies that might allow 'wait and see' or 'no regrets' decisions on asset renewal, design and development, without risking the resilience and adaptive capacity of existing networks.
Some nano-filtration, 'pipe parity' desalination solutions and breakthrough solar and battery storage may emerge within a decade.

These may have the potential to lower capital and operating costs; improve system resilience through diversity of water sources; and achieve higher environmental performance. Understanding the dynamics and time to market of these inventions is a critical issue, with particularly important implications for the South East.

[2] http://www.sciencemag.org/news/2017/04/new-solar-powered-device-can-pull-water-straight-desert-air

#6 CULTURAL AND SOCIAL CHANGE

Imagined futures shape present public attitudes to the environment and basic infrastructures. They may change rapidly and reframe the dialogue about long-term trade-offs between environmental standards and value for money.

One of the critical uncertainties facing policy-makers, water companies and utilities around the world is how cultural values and attitudes to climate change, environmental standards and pollution may evolve over the long-term. The challenge is to anticipate customers unarticulated future needs in scenarios radically different from today.

At various levels, this becomes a question of future attitudes to innovation, investment and possible future price rises. Yet this is too simplistic, since the trade-offs are more complex than generally assumed.

The questions are particularly difficult when the critical questions are about projected and highly uncertain future worlds, one, two or three decades ahead. They are even more difficult in relation to water, which is seen as a public good that should be as cheap as possible and universally available to all. **Natural assets are similarly part of a shared commons.** Waste water treatment is seen as a basic service, closely linked to attitudes to public health and safety. Flood prevention and management is a question of basic security.

Imagined futures

To put this in context, many of the most important drivers of the future landscape are shaped not by policy-making, technologies, or by their commercial potential, but by competing narratives – by imagined future worlds projected by inventors, political leaders, policy makers and corporations.

Contrary to conventional thinking, these imagined worlds are real: they influence present day decision-making, judgment about investment priorities and shape behaviour in the here and now. They determine values, attitudes and the public mood. To illustrate, if the future is characterised in the public imagination by dramatic shifts in basic relationships, say the endgame for the fossil fuel industry, then the cultural upheavals will emerge long before the events themselves.
In the same way, the world's financial institutions are beginning to recognise that investors are positioning themselves in the short-term against long-term climate change scenarios. In the short-term, asset revaluations may emerge as shockwaves to the financial system. Cultural attitudes will change in the short-term in anticipation of long-term structural disruption that may only crystallise over decades.

To be more specific, investor activists are increasing pressure on the oil industry as alternative, imagined futures of electric vehicles, cheap renewables, falling demand and environmental pressure take shape in people's minds, shaping their investment decisions. The same principles apply to the water and waste water industry.

This means that from a cultural perspective, hedging strategies against climate change are not abstract or theoretical challenges that can be put off. They are about strategy development and near-term decisions.

This reflects one of the most important shifts in understanding how the world works and has begun to influence policy-making, particularly in the financial and infrastructure sectors, where the long-term risks of stranded or uneconomic assets are critical challenges.

It raises important questions about what we can expect of today's younger people as we look to 2050. Will the boundaries between consumer and citizen become even more blurred than today? What sorts of communities will people identify with - will they be virtual or physical and will they be local/regional or national/global? How will people expect to protect and provide for those who are in more difficult circumstances? What kinds of relationship will they expect to have with the natural environment? What leisure activities will they be pursuing?

Four emerging grand theories

With this in mind, whilst cultural values, attitudes and lifestyles will remain uncertain, emerging and competing narratives are part of the evidence base and a good place to start.

Slow cultural change does not make headlines, but culture is more fundamental than politics and has a predictive quality. The problem is that 'culture' is an exceptionally complex word. In practice, culture is defined by imagined futures and the 'values, customs, beliefs and symbolic practices' by which people live their lives – distinct from artistic expression.

There are four cultural theories that have varying degrees of influence. Whilst the outcomes they describe will remain deeply uncertain they nonetheless guide short-term policy and public attitudes.

The first is that nature can be controlled and that focused human action, in the form of new ways of thinking, policy changes, heavy investment in infrastructure and technology, will slow global warming and reverse the growing biosphere crisis. This is at the centre of 'ecosystem' and 'circular economy' thinking.

The second is that runaway, non-linear climate change and environmental failure will be prevented by maintaining overall temperature increases within the two-degrees centigrade above pre-industrial level.

The third, more ambitious, is that the biosphere can be brought under control over the next two or three decades, overcoming the fundamental problem that warming is already 'stored' in the atmosphere, by reversing human impact and if necessary by introducing radical geo-engineering and more extreme measures to cool the planet through 'negative emissions'.

The fourth is explicitly cultural, operating at largely subliminal level: that in the face of mounting pressures, political, economic and social security can be maintained to guide the transition to an orderly, sustainable world.

Developing local context

The cultural changes already underway take more specific forms, which are critical to the South East. The weight and levels of commitment behind these more local narratives are vital, since customer and public values and attitudes to environmental standards, innovation, pricing and land use, particularly in areas of special interest, will shape outcomes.

For example, in the past, Southern Water customers have expressed preferences for improving aquifer storage and recovery; water re-use; leakage reduction; and desalination above water efficiency, storage reservoirs and variations in seasonal tariffs. They have said they are willing to invest in reliable water.

These preferences may change. Interpreting and predicting changes in cultural values and customer attitudes is particularly challenging in times of turbulent change and uncertainty.

Emerging narratives are particularly important in relation to long-term, possible futures. They are early indicators of cultural change and the best have a predictive quality. They typically crystallise and transition to become dominant as evidence builds up (say science on particular forms of pollution, or carbon emissions) and large-scale public support develops.

Sustainable, strong or 'dominant' narratives work at multiple levels, from headlines at the top of the pyramid structure, to the deeper assumptions at the base. The now dominant narrative on human influence on climate change has followed this pattern.

The emerging, next level narratives include:

- Ecosystem system thinking, that is taking multiple forms, such as the 'circular economy' gaining ground as the science of complexity develops and shows more explanatory power;
- The related idea of 'local' solutions, supported in earlier customer surveys, which imply growing support for localised regional, city, catchment and community level strategies. Local values, from a sense of identity and place, to locally produced food and community-centric well-being, are clear indications of changing cultural norms.
- The shift in thinking from 'zero harm' to regeneration of the natural environment – beyond protection or preservation. This may become the endpoint of the journey, as technology advances may make these ideals economically feasible. This may in turn mean greater transparency, monitoring and accountability. We can expect growing support for deepening knowledge of the relationships between pollution, environmental conditions (say heatwaves and water quality), particularly in relation to well-being and health to support this narrative.

With these narratives in mind, the idea of 'meta-utilities', that may, for example, integrate all waste services within a unitary structure, is also on the horizon may gain ground at community level. We may see 'shared service' models emerge, such that pollution and waste of all kinds and from both industrial and domestic sources is treated, materials recycled, and converted into energy using common facilities.

Catchments are one of the most important factors in developing local solutions. Ecosystem thinking can be applied within communities that share a single cultural context and sense of identity, sensitive to natural asset thinking, flood management and the relationships between both urban areas and farmers interests and rewards.

Creating a vision of the future

Decoding emerging narratives paints part of the picture but does not necessarily involve engaging customers and stakeholders to judge their future value and attitudes. This explains why it has become widely accepted that customer surveys have limitations. The water industry is not alone, typically testing public attitudes through focus groups, asking questions framed by the challenges in the here and now and what customers are willing to pay for.

This has some value, but alternative approaches are moving into the mainstream, particularly those focused on 'design thinking' and 'world building', which can involve video production and simulation. Both these methods paint pictures of imagined future worlds, immersing customers in the kind of environments that may emerge over the long-term and sometimes over decades.

In practical terms, these might include, for example, sophisticated simulations of climate extremes, radical technologies and new lifestyles, creating the sense of 'being there', so that customers are in a better position to judge how they might feel about policies, services and their relationship to infrastructure in a variety of futures. This translates what is inherently abstract into something tangible and frees customers to think more openly about what will be important to them tomorrow, not what is perceived to be important today.

RE-INVENTING INNOVATION

From the widespread adoption of ecosystem thinking, to machines as inventors, the future of innovation foreshadows volatility and radical change. Water, energy and agriculture will emerge as hotspots of systemic invention and benefit from global marketplaces of ideas.

Globalised innovation

Over the next decade, systemic, accelerating and radical innovation will herald the emergence of an age of mass-automation, cross-border electronic trading in ideas and remote manufacturing.

Entirely novel forms of socially inclusive innovation may emerge to create a new economy, focused on sustainability, well-being, quality of life and regeneration of the biosphere.

The water industry, above all, stands to benefit from waves of innovation from around the world. Whilst intellectual property is politicised and the source of national competitive edge, water is a special case, since inventions are more likely to be shared openly. This means they are likely to scale more rapidly than in any other industrial sector.

Invention at the intersection of water, energy and agriculture is emerging as a hotspot and attracting growing investment. There is increasing demand for radical innovation, driven by widespread fears about the impacts of global warming on water supplies and food production.

Re-inventing innovation

Yet whilst novel governance models, ecosystem thinking, nano-filtration, sensors and artificial intelligence will transform the landscape, it is innovation itself that is being re-invented and may have the most impact.

In practice, new innovation models will have as much impact as individual inventions themselves, if not more, since they will deepen the creative engagement of people around the world and accelerate the development of new solutions to what may appear intractable problems.

There are many competing and conflicting innovation philosophies already at work. To put this in context, there is tension between the extremes of 'open innovation' and both national and commercial competition.

Even so, this is not straightforward. The future innovation landscape will most likely be diverse, heterogeneous and itself the result of Schumpeter-style 'creative destruction',[1] the signs of which are already clear. Conventional research and development is in retreat, even amongst the leading innovators and is already complemented by crowd-sourced creativity, 'open innovation', patent cross-licensing and localised, mass-scale 'maker culture'. 'Computational creativity' and machine intelligence are on the horizon.

Secret worlds

One of the challenges to policy-makers and business strategists alike is that ideas belong to a secret world.

[1] According to Joseph Schumpeter, the "gale of creative destruction" describes the "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one."

WATER FUTURES IN THE SOUTH EAST TOWARDS 2050

Secrecy is nothing new. Many ideas are not yet articulated, or even imagined. Inventors in small firms and corporates alike protect big ideas.

From another perspective, at a macro level, systemic innovation is non-linear. Open, highly networked innovation has emergent properties and so is inherently unpredictable, making it difficult to estimate outcomes, even when patterns become clear.

So whilst combinatorial patents are ballooning, as often disparate inventions are brought together, the linkages are not obvious. The future will be about not just connecting individual inventions, but entire ecosystems.

The reality is that beneath the radar, systemic innovation is already creating compound growth. This kind of innovation is often underestimated. Yet the rapid rise in the number of 'combinatorial patents' is clear. Ideas are distributed and integrated at an accelerating rate around the world. Recent meta-analysis of US patents concluded that:

> **"The generation of novel technological combinations engenders a practically infinite space of technological configurations."** [2]

It is possible that deeper ecosystem linkages, such as the relationships between the water cycle, the nitrogen cycle (which releases nitric oxides from fertilizers to rivers and estuaries) and the phosphorous cycle (which is linked to the extinction of aquatic life), can be addressed by combining and integrating multiple emerging technologies. This form of integration will become one of the dominant models, which means that utilities will focus on systems design in order to accelerate progress.

Finally, one of the fundamental challenges is that many inventions cannot be more secret: they may not have been made yet, but they are there, latent in the 'white space' of new markets and technologies targeted by the most sophisticated corporations and by leading fund managers.

Open innovation

Open innovation is becoming pervasive, driven by the idea that inventions belong to society as a whole. Many national governments are making public sector information available as part of the 'open data' initiative to encourage public interest innovation, in everything from food standards and pollution monitoring, to security and crisis management.

This is particularly important in the water industry, where water is seen as a public good. Perry Alagappan's 'at tap' water purifier, mentioned earlier, is symbolic – an invention that might have been patented, but has been gifted to the world.[3]

In parallel, there is a drive towards 'mass innovation', illustrated by 'maker culture', which brings 3D manufacturing designs to distributed networks via the web for local production, assembly and distribution. This is taking hold not only in the West, but in China and is one of many examples of decentralised, grass roots 'mass flourishing'.[4] Maker culture, within which open innovation is central, will move from the margins to the mainstream.

The convergence of 3D printers, artificial intelligence and remotely operated robotics will become highly localised, using remote 3D techniques for everything from household goods to food production, purification systems and in turn cutting demand for transport. Why ship around the world if low cost production is just across town?

The best inventions will transcend national boundaries, licenced and downloaded from new forms of App stores. Ideas and digital 'Apps' are already copied instantly and distributed around the world. Replication is a core element of innovation culture and is now the norm.

Patents and commercialisation

Open sharing has surged, but the instinct to hoard, protect and commercialise via patents is following a similar pattern. This is partly reflected in the rapid increase in new patent filings around the world, which reached 2.9 million in 2015, driven above all by an explosion in applications in China.

China is set to become the world's largest investor in R&D and in patent protection by 2020. China's patent office received over 1.1 million new applications in 2015. About 1.24 million patents were granted around the world in 2015, with China accounting for almost 360,000 against the US total of 298,000, making it the largest patent office. There are similar patterns in trademark applications.

[2] 'Invention as a combinatorial process' http://rsif.royalsocietypublishing.org/
[3] http://www.theguardian.com/sustainable-business/2015/aug/27/texas-teenager-water-purifier-toxic-e-waste-pollution?CMP=Share_iOSApp_Other
[4] Edmund Phelps: Mass Flourishing: How Grassroots Innovation Created Jobs, Challenge and Change.

The important point is that China's focus is on the entire range of sustainable development applications, particularly water, waste water, pollution and air quality.

Whilst the volume of patent applications is only one way of looking at growth, performance and future value, in 2015, WIPO showed China's share of global filings at 13.7%, after the US, at 26.3% and Japan at 20.3%.[5]

This reflects the fact that patents remain a primary means by which to protect commercial returns. Research in the US found that the 'patent premium' averages 50% over the 'no patenting', ranging from 60% in health-related industries to 40% in electronics'.[6] Meantime, global small business venture funding, corporate open innovation and off-balance sheet R&D has continued to rise.

In parallel, hybrid approaches, such as, 'patent pooling' and collaborative cross-licensing will grow rapidly, which is particularly important in sustainable development, where there is a strong public good argument and social benefits may be more important than profit.

There is growing evidence that philanthropists are focusing on long-term grand challenges and seeding global innovation by gifting inventions to the public. We can expect social entrepreneurs to take a similar route: invent, file patent and distribute free to the world to prevent commercial interests developing so-called derivative works and capturing consumer relationships and markets.

Hotspots, white space and unknown unknowns.

Against this background, the fundamental challenge is to navigate the emerging secret worlds of invention, developing intelligence about early stage ideas.

Given the lag between invention and commercialisation, intellectual property (IP) landscapes – networks of ideas maps – will become essential, since patterns of ideas give vital early clues of the shape and structure of industrial, product and economic shifts well before commercial products and services emerge. They will form the evidence base and intelligence that drives predictive models and strategic development.

> **These IP landscapes also highlight network linkages that point to emerging systemic innovation – 'hot spots' where there is intense activity. Hot spots not only create context and predict the shape of the future industrial landscape, they are also where to look for early stage inventions that might be integrated and which are vital and as important as origination.**

From the perspective of the UK water industry, regional and community innovation is vitally important, but so too is the idea that inventions and best practice may be 'imported' from around the world as a means by which to accelerate development.

They also highlight opportunities to focus inventive talent and capacity and to invent into 'white space'. To put this in perspective, white space is usually defined as an area at the intersection of technologies and markets where the products or patent coverage is weak or non-existent, but valuable. From a commercial perspective, inventing in white space is about creating new opportunities and by definition market leadership; higher margins and returns; and sustainable differentiation.

Creativity re-invented: the rise of the machines?

Yet this is not simply a question of specialist intelligence and integration: it is, above all, about creative imagination.

The missing ingredient in all these narratives is the nature of creativity and invention itself. This, like everything else, is changing at an ever-increasing rate. What is known as 'computational creativity' may soon emerge to stretch adaptive capacity more than ever.
IBM's 'Discovery Advisor',[7] released as a commercial product from the Watson project, already provides machine advice on where researchers should look for new ideas.

This will change quickly, moving from research to origination, as 'general purpose learning machines', hinted at by Deep Mind's 'Alpha Go' evolve from problem solving systems to delivering novelty. Alpha Go surprised experts not because it produced results a decade ahead of forecasts, but because there were hints at 'intuition', one of the defining characteristics of human creativity.

[5] http://www.wipo.int/export/sites/www/ipstats/en/docs/infographics_systems_2015.pdf
[6] Source: Carnegie Mellon University, Georgia Institute of Technology, and Duke University entitled "R&D and the Patent Premium"

It may be that machines are about to change the formula. Power may indeed shift from humans to machines and from labour to capital. This may be decisive and shift competitive advantage to large-scale AI-centric firms, or follow the route put forward by Elon Musk in support of the argument for OpenAI:

> **"I think the best defense against the misuse of AI is to empower as many people as possible to have AI. If everyone has AI powers, then there's not any one person or a small set of individuals who can have AI superpower."** [8]

In an era of increasing complexity and deepening, fundamental uncertainty, both understanding and creativity will likely emerge as the driving force behind ground up, systemic innovation.

Big data, open information and more recently open innovation has, for some time, driven the knowledge economy.

Computational methods may hold the key to a new creative age. We may see innovation and globalisation transformed: an open, networked marketplace of ideas, with everything from food production to advanced manufacturing part of vast new App store from which everything from algorithms to 3D designs can be licenced and downloaded. If such a marketplace, vital to water, energy and agriculture emerges, then we can expect novel structures to emerge at an accelerating rate.

[7] http://www.ibm.com/watson/discovery-advisor.html
[8] Levy, 2015, quoted by Bostrom.

FROM HERE TO THERE...

Opportunities and challenges for the South East and Southern Water.

Of course, Southern Water is already a core part of the South East region, interacting on a daily basis with over 3.5 million people and the environment, and is already targeting transformation projects that embrace aspects of the major variables described in this 'Water Futures' review.

This Southern Water (SWS) 'ecosystem', inclusive of current future plans and forward-thinking transformation projects, is shown in the following Ecosystem map.

The South East: Natural Capital and Ecosystems Thinking

Amongst the possible integrated 'ecosystem' projects in the South East, there are several opportunities to translate the theory into practice.

Southern Water has identified a number of transformational projects, these include:

- An integrated catchment area approach to the River Test to improve environmental resilience and natural capital benefits, both upstream and downstream and engaging communities in water efficiency programmes
- Adapting Peacehaven, a modern water plant, to create a community resource, generate energy from sludge, recover heat for local distribution, extract metals and minerals, creating rain gardens upstream and sustainable urban drainage systems
- In Brighton, enhanced demand management through smart metering, combined water and energy and improved resilience through surface water strategies and flood management
- The opportunity to develop integrated water, energy, transport and leisure facilities within the Ebbsfleet Garden City new town development, including a Theme Park powered by food waste; green energy production; grey water and water re-use

Integrated Water Cycle Management

Pilot schemes for integrated water cycle management for particular catchment systems, drawing on system mapping, modelling, data management principles and stakeholder engagement include the River Arun, the Medway and the Western Rother.

Each of these schemes address a variety of local challenges, from dealing with phosphorous pressures, to sediment, nutrient, water supply quality, pesticide risks and protection of natural habitats.

SOUTHERN WATER ECOSYSTEM:
PLANNING A RESILIENT WATER FUTURE FOR COMMUNITIES IN THE SOUTH EAST

Pressures & Performance

- Population is expected to increase by 25% by 2050
- River flows could fall 35% as population & climate change pressures bite
- Extreme droughts could be over 50% worse than current systems may be resilient to
- Increase in Bio-fuel needed to meet demands of energy use by 2050

Environment Quality & Protection

- 231 surface waters need to achieve good ecological status by 2027
- A need to improve performance in meeting energy, emissions, sewer flooding and pollution compliance targets

Impact on water quality by sector

Agriculture	30%
Water	29%
Other Uses	41%

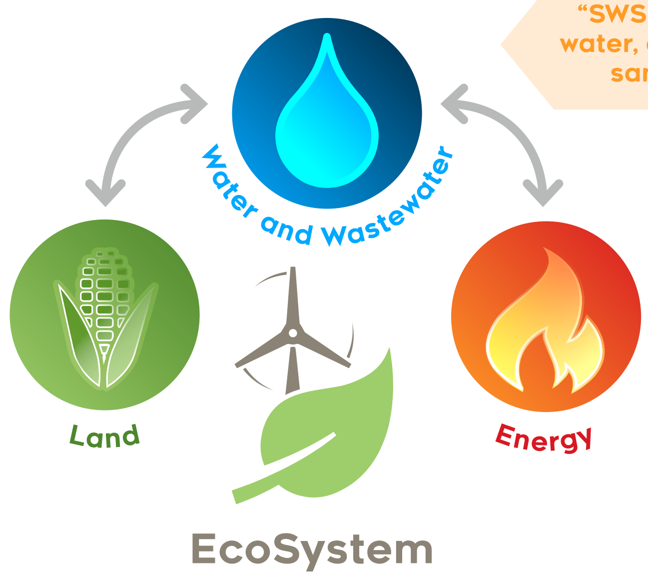
Multi-sector impacts on water quality means a need to work in partnership across the region

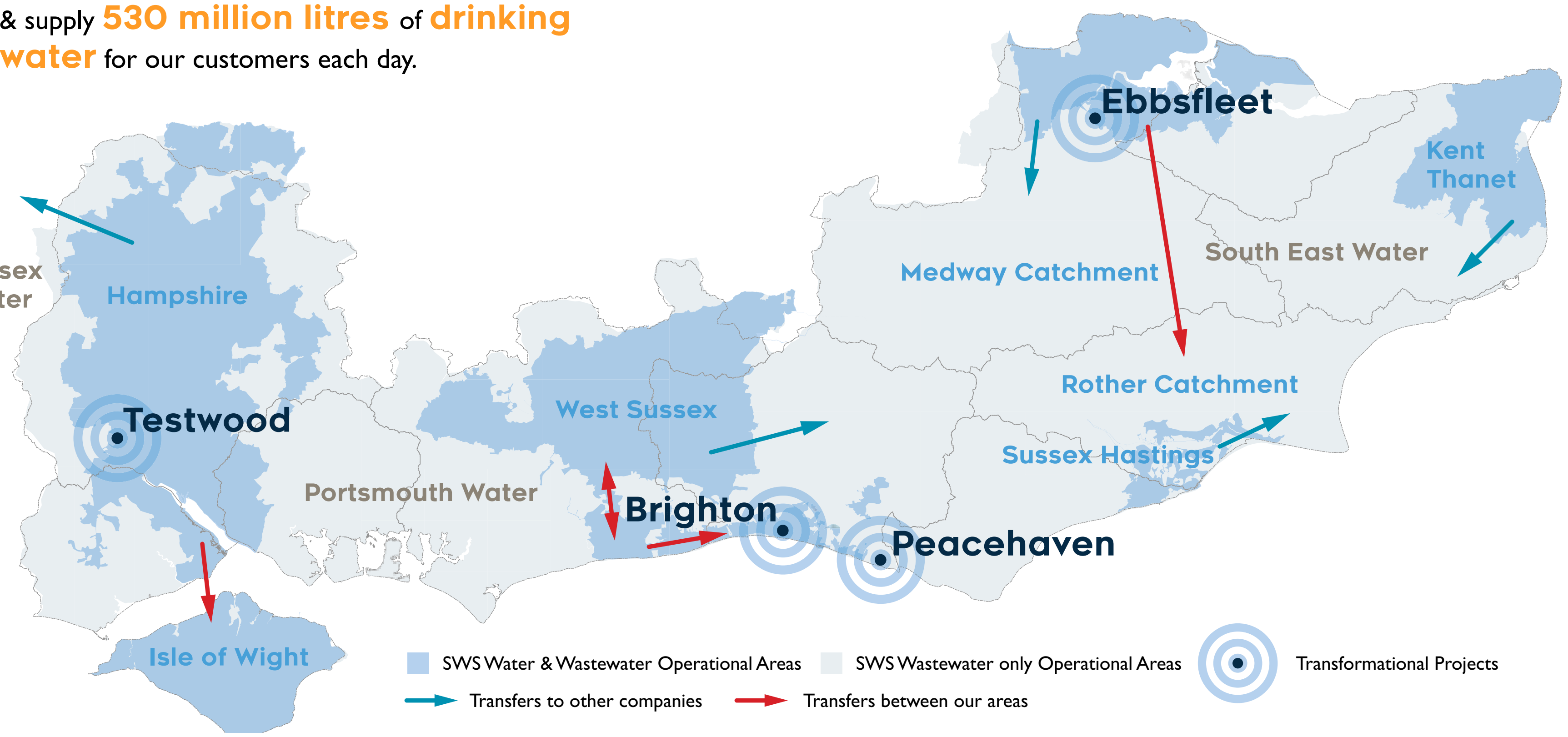
SWS operations cover:

3.5million people in the south east
315 ground & surface water bodies
9 management catchments
10 Water Resource Zones (WRZ's)
98% of the regions wastewater service
A region known for **"severe water stress"**

SWS treat **730 million litres** of **wastewater** & supply **530 million litres** of **drinking water** for our customers each day.

"SWS services depend on an ecosystem comprising water, energy and agriculture sectors that rely on the same natural capital and community to operate".





SWS Water & Wastewater Operational Areas · SWS Wastewater only Operational Areas · Transformational Projects
Transfers to other companies · Transfers between our areas

Areas Most Reliant on Transfers (Ml/d)

	Current	2050	Change
Isle of Wight	8.3	32.5	+24.2
Kent Thanet	2.7	17.6	+14.9
Sussex H	10.2	23.5	+13.3

Pioneering Solutions

Water Resource Management Plan

SWS will meet long-term water security needs by harnessing a range of innovative solutions for:

- Rain & storm-water re-use
- Water storage
- Effluent re-use
- Ground water re-charge
- Desalination
- Leakage reduction
- Demand management
- Bulk water transfers

Integrated Water Cycle Management (IWCM)

Approaches being trialled across two catchments will pioneer community, environment & system wide improvement options over AMP7.

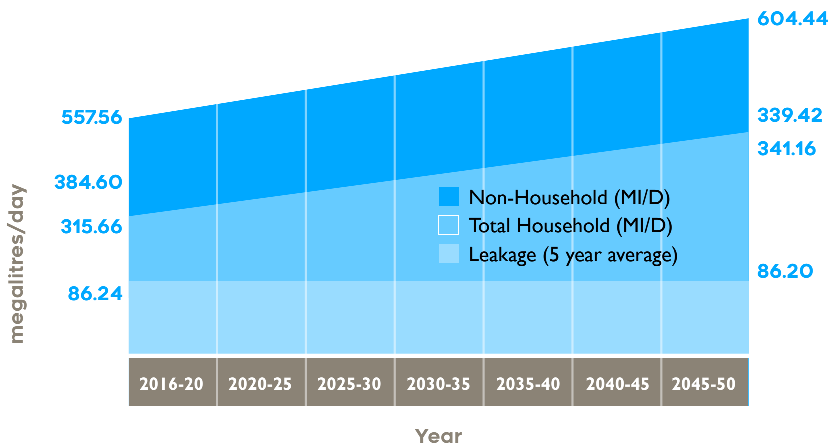
By 2040, SWS are committed to operating a fully integrated water environment, working seamlessly with a range of stakeholders.

Long-term Bio-resources strategy

SWS' strategy explains how it intends to make greater use of markets, including how it will maximise renewable energy generation.

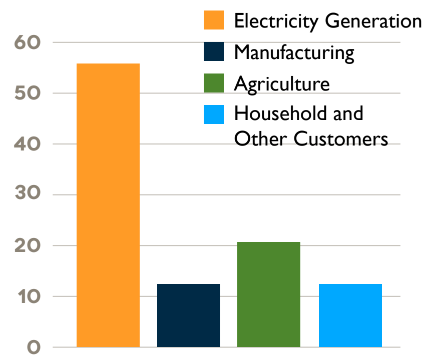
Water Demand & Leakage

- In addition to population growth driving household demand, economic growth is expected to increase commercial water use
- SWS have a commitment to reduce water use per person to below 130 litres/person/day and achieve an overall leakage target of 75 mega-litres/day by 2040, as part of their Target 100 initiative



source: Southern Water, WRMP forecast, July 2019.

Water consumption by sector (%)



Four Transformational Projects

Testwood
- environmental resilience & natural capital benefits

Peacehaven
- community water-reuse & energy enhancement

Brighton
- collaborating to build a sustainable, resilient city for the 21st century

Ebbsfleet Garden City
- an integrated multi-benefit water system for the future

For consideration

We are in a time of great change and the situation is extremely dynamic. The high impact, high uncertainty major variables described in Water Futures will have an increased and fundamental impact on the South East region. These major variables will in combination create an unprecedented, unpredictable environment that is fast-moving and complex with both opportunity and threat.

It is within this context that Southern Water must plan ahead in order to provide the best customer service, optimal investment, and with the agility and flexibility needed to take advantage of the enormous opportunities that will emerge over time to do business differently; collaborating across the region, with cities, and with local communities and customers.

The Water Futures' major variables need to be considered by Southern Water as it develops its long-term and short-term plans. Raised by Water Futures, some preliminary questions for Southern Water include:

Q1 **Water and wastewater services do not operate in isolation. They form a vital, interconnected part of the core infrastructure in the South East. How should Southern Water be working with others to support integration, 'ecosystem design and engineering' and systems-thinking across regional, community and institutional boundaries? What are the options?**

Q2 **The next thirty years will show whether global warming can be slowed, but climate outcomes remain an uncertain and major variable. This raises several questions, including:**

- What options might be developed that will deliver infrastructure resilience, raise environmental standards and value for money, however extreme the impacts of global warming may be on the UK and South East? Will a 'real-options' strategy be feasible, allowing Southern Water to hedge against both an uncertain climate and technology landscape, essentially keeping options open until the range of uncertainty narrows?
- Should Southern Water be doing more to support and drive an agenda of renewable, localised energy generation, energy security and carbon emissions reduction in the South East region, particularly at the intersection of water, energy and agriculture?

Q3 **How can Southern Water do more to engage and influence values on environmental standards, water efficiency and ecosystem planning with customers, stakeholders and policy-makers in the region? Should Southern Water explore developing a leadership role? Again, what are the options?**

Q4 **Given that the South East faces water resource challenges, coupled with an uncertain climate and high projected population growth, should Southern Water invest in developing intelligence about the invention landscape with the aim of piloting potential game changing innovation in water re-use and desalination options, as a more sustainable and cost-effective approach to meeting future water demands in the region?**

Q5 **Building on initiatives such as Integrated Water Cycle Management (IWCM), how can Southern Water ensure effective, multi-stakeholder collaboration to support catchment management and eco-systems management beyond 'zero-harm' and towards more ambitious 'regeneration of the natural environment'? What are the alternative approaches?**

Q6 **Technology-driven, intensive agriculture that uses minimal water and maximizes natural processes to avoid pollution will become less of an option and more of an imperative. How can Southern Water work better with farmers and landowners in the region to pilot and introduce more sustainable, 'precision-based' agricultural approaches?**

Q7 **With the opportunities that innovative, yet disruptive technologies may present, how can Southern Water ensure it takes advantage of these to deliver game-changing efficiencies for customers and wider benefits in the region? Timing is critical - what investments should be delayed to take advantage of new future innovative solutions and what investments should proceed, and in what form?**

Q8 **Should Southern Water be investing more in pervasive sensor networks, 'big data' and predictive analytics to accelerate the adoption of digital intelligence and create broader and deeper opportunities to improve resilience and transparency of performance in the South East region?**

To answer these and other questions, development of in-depth scenarios and further investigation into potential technological, societal and environmental innovations is required. In simple terms, the ultimate challenge is to develop a portfolio of options that will work in any future scenario.

Stantec