RESPONDING TO CLIMATE CHANGE CHALLENGES FACING THE WATER AND WASTEWATER INDUSTRY

O Philpott, R Klein, M Bishop and A Boyle-Gotla (Watercare Services Limited)

ABSTRACT

Changing climate patterns have the potential to significantly impact the way in which Watercare Services Limited (Watercare), delivers reliable, safe, and efficient water and wastewater services. To address this, Watercare (an Auckland Council CCO) is developing a climate change mitigation and adaptation strategy. This will centre on its existing operations and future capital investments related to the delivery of water and wastewater services. A goal of Watercare's strategy is to integrate climate change considerations into Watercare's 'Business as Usual' decision making process, as has already been the case with the design of some assets to date.

The most significant changes in climate for the Auckland region over the next 100 years have been identified by the National Institute of Water and Atmospheric Research (NIWA) in their *Auckland Region climate change projections and impacts* report. Based on these projections, Watercare have identified a series of vulnerabilities regarding its existing infrastructure and operations.

This paper discusses how Watercare is developing a process to incorporate NIWA's climate change projections for the Auckland region into a climate change mitigation and adaptation strategy that will guide its strategic planning and operations. Many of these challenges will be applicable to other service providers throughout New Zealand. The water and wastewater industry is in a position to adopt timely and coordinated climate change mitigation and adaptation actions to future-proof their assets and services.

Keywords: climate change, mitigation, adaptation, resilience, natural hazards

1 Introduction

"Climate change is one of the most complex issues facing society today" (NASA, 2018) and it undisputedly poses challenges to the water and wastewater industry. Planning for unknown conditions caused by climate change is a challenge, given the deeply uncertain nature of climate change. Overestimating the impacts could lead to oversized infrastructure and financial waste. Underestimating the effects could lead to failure of our services and stranded assets. We need to prioritise now for consequences expected in the distant future. However, through advanced computer modelling which includes observed changes to date, we can predict with some certainty an increasing number of extreme climate related impacts and for us, the case is that "Imperfect action is better than perfect inaction" - Harry Truman.

Watercare has a commitment to our customers as a lifeline utility provider and a responsibility to secure supply of water and wastewater services in perpetuity. The sustainability of these services is threatened by our actions and inactions right now.

In response to these uncertainties, Watercare is developing a climate change mitigation and adaptation strategy. This will guide our actions towards the goal of becoming climate resilient. This paper details the process of developing this strategy in the hope that it may help and inspire other water and wastewater service providers to work towards greater overall climate resilience. While there are many transitional risks associated with climate change (including financial, technological, policy, legal, and reputational) Watercare's strategy focuses on where our physical assets and environment are vulnerable if we fail to adapt and mitigate.

Watercare will continue to balance the challenges of adapting to the projected impacts of climate change, while at the same time servicing Auckland's rapid population growth. From June 2016 to June 2017, Auckland saw a 2.6% increase in population, or over 100,000 new customers (Stats NZ, 2017). This growth with its associated land use change increases the amount of impervious surfaces that drain to both the stormwater and wastewater systems. This population growth will intensify the impact of climate change on our infrastructure, and dealing with this is a long-term complex challenge.

2 Climate change context

2.1 Global context

There is general agreement that climate change action is needed. Over 97% of actively publishing climate scientists agreeing that our climate is changing and that the main driver for the change is greenhouse gas emissions from human activity (Cook *et al*, 2016).

The United Nations Framework Convention on Climate Change (UNFCCC) states in Article 2:

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties (COP) may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The 21st Conference of the Parties of the UNFCCC (COP 21) took place in Paris in December 2015 and led to the 'Paris Climate Agreement', ratified by 170 countries including New Zealand. The Paris Agreement's central aim is to address the threat of climate change by keeping global temperature rise this century to well below 2° Celsius (as compared to pre-industrial levels), and to pursue efforts to limit temperature increase to 1.5° Celsius. This threshold of 2° Celsius has been established by the UNFCCC as 'the limit to prevent dangerous anthropogenic interference with the climate system', which is commonly seen as the limit before catastrophic impacts occur. We are currently in a +1° world and impacts from climate change such as sea level rise through thermal expansion, are already occurring. As a local example of this, the Port of Auckland tidal gauge has measured a total sea level rise of almost 19 centimetres since 1899 (Ministry for the Environment, 2017).

2.2 National context

Greenhouse gas emissions in New Zealand are increasing. In an effort to counter this and to improve approaches to climate change adaptation, a number of research and policy/statutory initiatives have been established. The 'Deep South Challenge' is one of the National Science Challenges initiated by the government to focus on developing a model to improve future projections of climate change on New Zealand. In relation to statutory change, the government has begun development on a Zero Carbon Bill for New Zealand. The drafting of the Bill will be influenced by the UK Carbon Change Act 2008, as well as reports such as *Adapting to Climate Change in New Zealand* produced by the Climate Change Adaptation Technical Working Group (CCATWG), and the NZ Productivity Commission's *Low emissions economy: Draft report*.

2.3 Auckland context

Auckland's long term spatial plan (Auckland Plan 2050) acknowledges that climate change is a key challenge facing Auckland. This is also mentioned in Auckland Council's Long-Term Plan 2018-2028. Further guidance is given via a number of provisions in the Unitary Plan that specifically acknowledge a 1-metre sea level rise with 1 in 100-year coastal inundation. This level has been shown on the Auckland Unitary Plan maps.

Auckland Council's Chief Sustainability Office is developing the Auckland Climate Action Plan (ACAP). Watercare is working collaboratively with Auckland Council on the creation of ACAP and it is expected to be completed by March 2019.

2.4 Watercare context

Watercare is committed to the United Nations Sustainable Development Goals (UN SDGs), as part of the organisation's 'Fully Sustainable' strategic priority. Key to delivering on this vision is our climate change work which is twofold. While climate change adaptation aims at preparing our infrastructure and operations for a changing climate, climate change mitigation addresses the root cause by doing all that we can to limit the magnitude of change. Watercare is doing this by reducing our greenhouse gas emissions to the atmosphere (e.g. energy efficiency/low carbon projects) and increasing their removal and storage (e.g. planting trees). We have reported our greenhouse gas emissions publicly in our annual report for more than 10 years. In 2016, Watercare started an ambitious energy efficiency programme aiming at achieving energy neutrality at the Mangere and Rosedale wastewater treatment plants by 2025, which is in the order of a 37GWh reduction in energy use from the network, and efficiency gains of 8GWh company-wide by the end of 2018. Energy neutrality at a plant the size of Mangere would be a world first.

From 2016 onwards we included the objective of Net Zero Carbon by 2050 in Watercare's Energy Policy. In the past we had approached climate change adaptation on a case by case basis, however, in 2017 we put a concerted effort into establishing a company-wide approach to adaptation with the goal of becoming a climate resilient organisation. A series of high intensity storm events in March 2017 acted as a driver for this change because it highlighted Watercare's vulnerability to these types of events, which are expected to increase in frequency and intensity due to climate change. Following an extended dry period over summer, Auckland experienced the equivalent of two months of average rainfall within a 24-hour period (241mm). Over 350 slips occurred in the water catchments of the Hunua ranges, which challenged our water treatment processes at the Ardmore Water Treatment Plant as turbidity in the dams increased from 2-3 nephelometric turbidity units (ntu) to over 1500 ntu. This event became known as the Tasman Tempest and demonstrated that our infrastructure may be exposed to extreme storm events that had not previously been encountered.

3 Considering Impacts on Watercare

In mid-2017, Auckland Council, various Council Controlled Organisations and the Auckland based District Health Boards commissioned the National Institute of Water and Atmospheric Research (NIWA) to model projected climate changes for the Auckland Region and to assess the potential impacts of climate change on Auckland's environment and various sectors (Pearce *et al*, 2018). In essence, NIWA took the climate projections for New Zealand and downscaled them for the Auckland region. This was a major step in allowing us to plan our activities for a different and ever-changing environment. Their report provided data that gives a more specific understanding of the direction of climate change between now and 2120 and has allowed for more detailed analysis of the expected impacts to our infrastructure.

The projections are divided into three time periods which cover the current century and the early 22nd century:

Year 2040 (The period between years 2031 – 2050)

Year 2090 (The period between years 2081 – 2100)

Year 2110 (The period between years 2101 – 2120)

These periods can be described as the medium term, long term, and very-long term respectively. Of specific interest to Watercare's planning are the projections out to 2110 because planned 'long lived' infrastructure has a life in excess of 100 years.

There is uncertainty around future variation of climate change projections as a result of anthropogenic activity as they rely on estimates for future greenhouse gas (GHG) concentrations. These concentrations can be influenced by global economic activity, population changes, technology advances and various countries' policy settings. This uncertainty has been addressed through the consideration of a range of global greenhouse gas 'emissions scenarios'. The NIWA report (and Watercare's strategy) uses two emission scenarios (formally known as Representative Concentration Pathways (RCPs)):

- RCP4.5 – This emulates the global greenhouse gas emissions scenario known as 'stabilisation'. This means that emissions world-wide would be fully stabilised by the year 2100 and would never increase beyond this level. This emissions scenario closely mimics the

outcomes of the 'Paris Agreement 2015' whose objective is to achieve net-carbon neutrality by around the year 2050. This would result in a +2.5°C world.

- RCP8.5 – This emission scenario emulates 'business as usual' meaning global GHG emissions continue to climb, unabated, at their current projected rate. This would lead to high global greenhouse gas concentration levels resulting in a +4°C world.

As an overview, the seasonal and spatial distribution of rainfall is projected to change markedly in Auckland. The projected changes are not uniform across the region. It is likely that spring rainfall will decline and autumn rainfall will increase, but total annual rainfall may not change significantly. Extreme rainfall events are likely to increase in frequency and severity in Auckland due to a warmer atmosphere being able to hold more moisture. Watercare's southern dams are likely to see much more intense rainfall events than those in the north-west. March 2017's Tasman Tempest was an example of the kind of intense rainfall event (following an extended dry period) that is characteristic of expected climate change scenarios.

Auckland is projected to warm considerably. A mean annual temperature increase of 1.6 °C or 3.4 °C is projected for RCP 4.5 and RCP 8.5 respectively by the year 2110. Currently Auckland experiences 20 hot days (defined as days hotter than 25°C) but is projected to experience over 40-50 additional hot days per year under RCP4.5 and 70+ under RCP8.5. The number of cold nights (negative temperatures) declines across Auckland.

The projected changes in rainfall patterns and increased temperatures will result in an increased frequency and intensity of droughts. There are currently 237 dry days (defined as days with less than 1 mm of rainfall) at the Auckland Airport. By the year 2110, this is projected to increase by six to nine more dry days per year under RCP4.5 or 12 to 21 more per year, under RCP8.5. Closely linked to this is days of soil moisture deficit (SMD) of which we currently experience over 70 days on average per year. This increases by 20 days over the majority of the region under RCP4.5 by 2110 and by over 32 days under RCP8.5 in the same time frame.

The combined effects of increasing temperatures, lower rainfall, and more droughts will lead to an increased fire risk. A 10-30% increase in Seasonal Severity Rating is projected for Auckland in the mid and late 21st century, compared to the historical period. It is projected that by the end of the 21st century there will be an increase in the number of very high and extreme forest fire danger days, with a 50-100% increase north of the Auckland Isthmus and a 40-50% increase south of the isthmus.

The Ministry for the Environments publication *Coastal Hazards and Climate Change: Guidance for Local Government* (2017) notes that the east coast of Auckland is more sensitive to sea level rise related erosion and storm surge inundation than the west coast due to different exposure, geology, landforms, tidal range, and variation in wave height (Ministry for the Environment, 2017). Sea level rise is of significant concern to Auckland and New Zealand because many of our communities and associated infrastructure are near the coast. This is reflected in the Unitary Planning maps which display 1m of sea level rise + 1% annual exceedance probability storm event inundation. Sea level rise is of particular concern to wastewater infrastructure as it is often constructed in low-lying locations in order to utilise gravity flows and for convenient discharge to a receiving marine environment. By 2100 global sea level rise will likely be in the range of 0.28-0.98 m. This may be compounded by the collapse of Antarctic Ice sheets (IPCC, 2013). A RCP8.5 scenario is for a 1.9 m rise by year 2150.

The impacts outlined above which were detailed in the NIWA report (Pearce *et al*, 2018) have provided Watercare with a large amount of complex information to incorporate into its planning for

future service provision as well as a clearer understanding of what the consequences of inaction would be.

4 Strategy Development

4.1 Setting the Framework

The need for a climate change strategy was identified and a project team was established with strong buy in from the Executive Leadership Team. The 'climate change project team' was assembled from different areas of the business. The strategy objectives were presented to the Board in February 2018. This included the development of Watercare's climate change mitigation and adaptation strategy, supporting Auckland Council in their ACAP work and contributing to innovation in climate change action in New Zealand. It was recognised that some actions would require more monitoring data and new models to be established. These actions would need lead in times to inform further decisions. The strategy calls for two 'whole of business' outcomes to be achieved:

1. Climate change adaptation: To adapt our organisation to be fit for purpose in a changing climate
2. Climate change mitigation: To operate a low-carbon organisation, aiming for Net Zero Carbon 2050

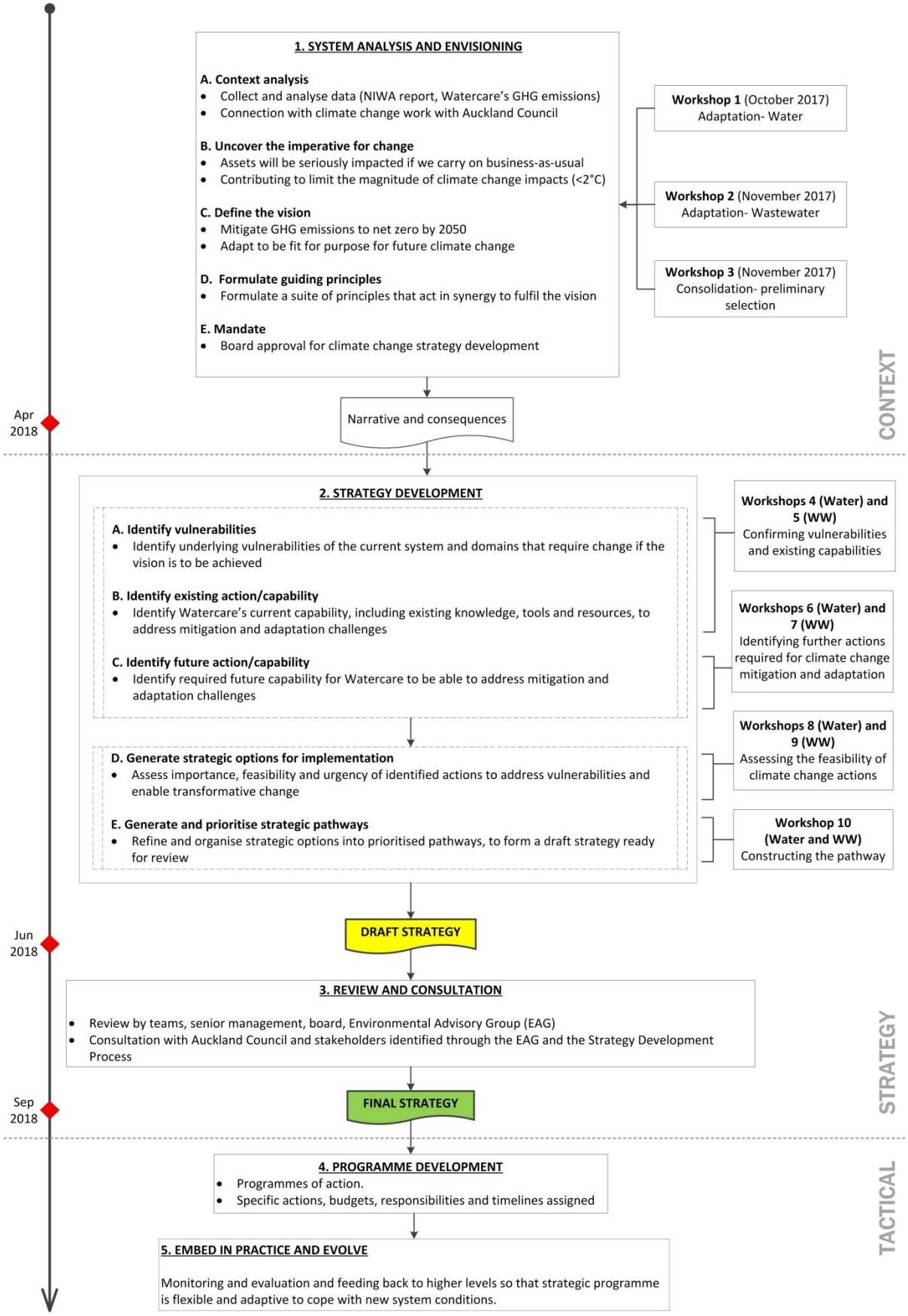
The principles guiding the development of the strategy and its implementation are:

- **Factor climate change into decision making and operationalize it** - Make business as usual the consideration of medium and long-term climate changes in relevant investment and planning decisions.
- **Avoid carbon lock-in solutions –** Consider climate change mitigation as we develop adaptation solutions, to reduce our greenhouse gas emissions on an on-going basis.
- **Enact a 'no regrets' approach –** Take action now on measures that can begin to be enacted without being certain about all dimensions of future climate change.
- **Implement adaptive planning pathways -** An adaptive plan specifies actions to be taken immediately to be prepared for the near future and actions to keep options open to adapt if needed in the future. Tipping points and triggers are determined.
- **Identify areas of control and acknowledge dependencies with external factors,** e.g. with third party providers, and find mechanisms of addressing these dependencies.

The development of this strategy represents a new style of work for Watercare. The team used Agile work philosophies to create manageable tasks, facilitate the work and make it as easy and efficient as possible for the wider organisation to give input.

A methodology for developing the strategy was created and is shown in Figure 1 below. The flowchart was shared early on to lay out the next six months work and show how the wider team's input would be contributing to the objectives for the year. This greatly helped to get people engaged in the process

Figure 1: Workshop Process and Stages Flowchart



Regarding our climate change mitigation strategy, there were a few work streams that had already been initiated: energy neutrality, thermal hydrolysis (a process of applying heat and pressure to sludge to increase its ability to be biodegradable), and the Hunua ranges re-vegetation project. As part of the strategy, these will be the first steps toward Net Zero Carbon 2050. Throughout the process it was decided that mitigation would be addressed in a separate workshop to adaptation because both topics are too large to tackle at a merged workshop. However, mitigation considerations are included in many of the adaptation actions (e.g. adaptation actions should not generate more carbon than the current practices).

Once the strategy has been reviewed, finalised and approved in September 2018, the tactical phase of the process will address the implementation of how it is rolled out into individual team responsibilities.

4.2 Consultation and Innovation

To help gather information, generate innovation and consult on the development of the strategy, a series of workshops were tailored to deliver progress and drive outcomes.

Workshops 1-3

Three workshops were held involving selected Watercare staff as well as members from Watercare's Environmental Advisory Group (EAG). The EAG is a stakeholder panel brought together by Watercare to advise, support, and challenge its approach to sustainability generally and environmental matters in particular. The group helped to widen the scope of the discussion to include our vulnerabilities regarding the natural capital, social impacts, and public perception, rather than being focused specifically on infrastructure.

Describing the climate change projections in a clear and accessible form to all workshop participants was the vital first step in the sequence of workshops because this knowledge is driving our actions.

These initial workshops were the first time we had company-wide engagement which allowed us to understand the scale and complexity of potential climate change effects on our organisation and present that to the Board. At the first workshop, we split the water supply system into four categories; supply, treatment, conveyance and demand. For each category, the workshop participants were asked to think of ways in which our system and processes were vulnerable to the impacts of climate change. It was noted that there is often the temptation for participants to jump to actions and solutions. It was important to slow the pace down in order to facilitate thorough discussions around understanding the vulnerabilities. This approach was duplicated at the second workshop which focussed on the wastewater system. The categories were wastewater treatment, natural receiving environments, conveyance, and human behaviour. A third workshop was run to draft actions that could address these vulnerabilities for both water and wastewater. These three initial workshops created engagement and gave us a high level overview of the situation. The Watercare Executives and the Board supported the continuation of this work following the success of these workshops and agreed with the objective of needing a strategy.

Workshops 4 and 5

We took the vulnerabilities identified from workshops one and two and turned them into a narrative which became the basis for the next steps of the work. The narrative is an 18 page document that summarises the projected climate changes and subsequent impacts on our future ability to deliver

water and wastewater. Workshops four and five challenged and confirmed those vulnerabilities. It was important to record and interpret these accurately into the narrative without precluding opportunity for further ideas to be included. We also asked the workshop participants to identify processes within our current activities or specific projects that address some of these vulnerabilities. For example, the Central Interceptor project will reduce many of the overflows across the region which would otherwise increase due to the expected increase in frequency of higher magnitude rainfall events.

Workshops 6 and 7

The focus of workshops six and seven was to identify all relevant actions that would minimise, mitigate, or avoid vulnerabilities to become fully resilient. These actions were captured in a format that divided the asset life cycle into strategy, planning, design, construction, and operations. While we had previously drafted potential actions at workshop three, these more detailed workshops were the most important step toward building climate resilience. It encompassed modifications and optimisation of supply, treatment and conveyance as well as interactions with the natural environment. In addition to this we identified dependencies on policy and regulatory frameworks. In addition to this, policy, regulatory framework, and environmental adaptation were brought out. It was important to reiterate to the participants that this was not the time to think about whether it was feasible to carry out these actions with our current capabilities, but rather to focus on what action was needed to tackle the vulnerabilities they had identified. This stage provided the content of the strategy which would be turned into programmes of works.

Workshops 8 and 9

In workshops eight and nine, the focus shifted to assessing each of the actions feasibility and contribution toward climate resilience. The feasibility included cost, timeframes, our current capability (people and technology). The outcomes of asking how much each action would contribute towards the overall goal of becoming climate resilient could be put into three categories: information gathering, somewhat addressing the vulnerabilities, and significantly addressing the vulnerabilities. Through this process we were able to arrange the actions into portfolios which would be put into planning pathways.

4.3 Outcomes

Climate change action is a change management process. Assessing where change is needed can be difficult to do when the processes that are currently in place are working well under present climate conditions. Asking how these might be challenged under projected changes to the climate was new for us.

Some of the key findings from the workshops were:

- The importance to firstly establish a clear understanding with all workshop participants what the specific and relevant climate change projections are for the region. Only once a consistent understanding has been established, can the identification of the vulnerabilities can be investigated.
- We require more data on how the current state of the climate is affecting and influencing our processes. There were many actions for increased monitoring and modelling because this data will inform decision making and help measure progress.
- Watercare’s mitigation actions are more advanced compared to our adaptation actions.

- Even though the number of workshops seemed large, we found that moving through the workshop process together helped to build trust and improve communication across the many diverse work groups. This will enable easier implementation of the work programme.
- Watercare depends on a series of external service providers including road infrastructure, telecommunications, power and our chemical and material supply chains. We needed to further consider our dependencies as we cannot control how other businesses will build their climate resiliency.

The process utilised a wide breadth of technical knowledge encompassing many teams of the Operations, Strategy & Planning, Infrastructure, Procurement, and Risk business units. Each workshop involved between 10 and 20 people. The level of trust between colleagues and the structure of the workshops enabled many in-depth discussions to happen and excellent information to be collected. A benefit of the workshop approach was to get people engaged early so they could be part of the strategy development as opposed to having it happen to them. This allowed people to see the opportunities in the strategy making process and will encourage everyone to adopt it into their business as usual processes.

4.4 Adaptive Planning

In order to turn the results of the workshops into a tangible strategy, we used adaptive planning pathways. This enabled the strategy to have a clear direction with time frames while considering lead-in times and inter-dependencies of actions.

Adaptive planning pathways are a method of optioneering that sets up a framework of short, medium and long term actions. Popularised by Haasnoot et al (2012) as 'Dynamic adaptive policy pathways', it is particularly useful when decision makers are facing problems containing deep uncertainty such as climate change. This method results in plans that are appropriate under a wide variety of futures and can be adapted periodically as conditions change. Actions identified during workshops were discussed with the teams regarding key assessment criteria which included their impact on climate change adaptation, costs, and sell-by dates. The actions were put into portfolios, each providing a complete solution to a climate change consequence given our current knowledge. The portfolios were then arranged in sequence to provide a solution for the duration of the plan. Each of these sequences forms a pathway option. The collection of pathways will form the skeleton of our strategy with immediate portfolios of actions prioritised in the short term. Signposts and triggers from climate change models were placed on the plan to inform initial timing of actions. Implementation of short-term portfolios of actions will further clarify signposts and their trigger values. Workshop ten will discuss the pathways to agree on what to present to the Board for review.

The climate will not stop changing after the dates the report has considered 'very long term'. When considering long-term change, it has been indicated that the full climatic effect from GHG emissions may not be felt for decades or even centuries. Therefore we need to plan beyond the end date of 2110 (Zickfield & Herrington, 2015).

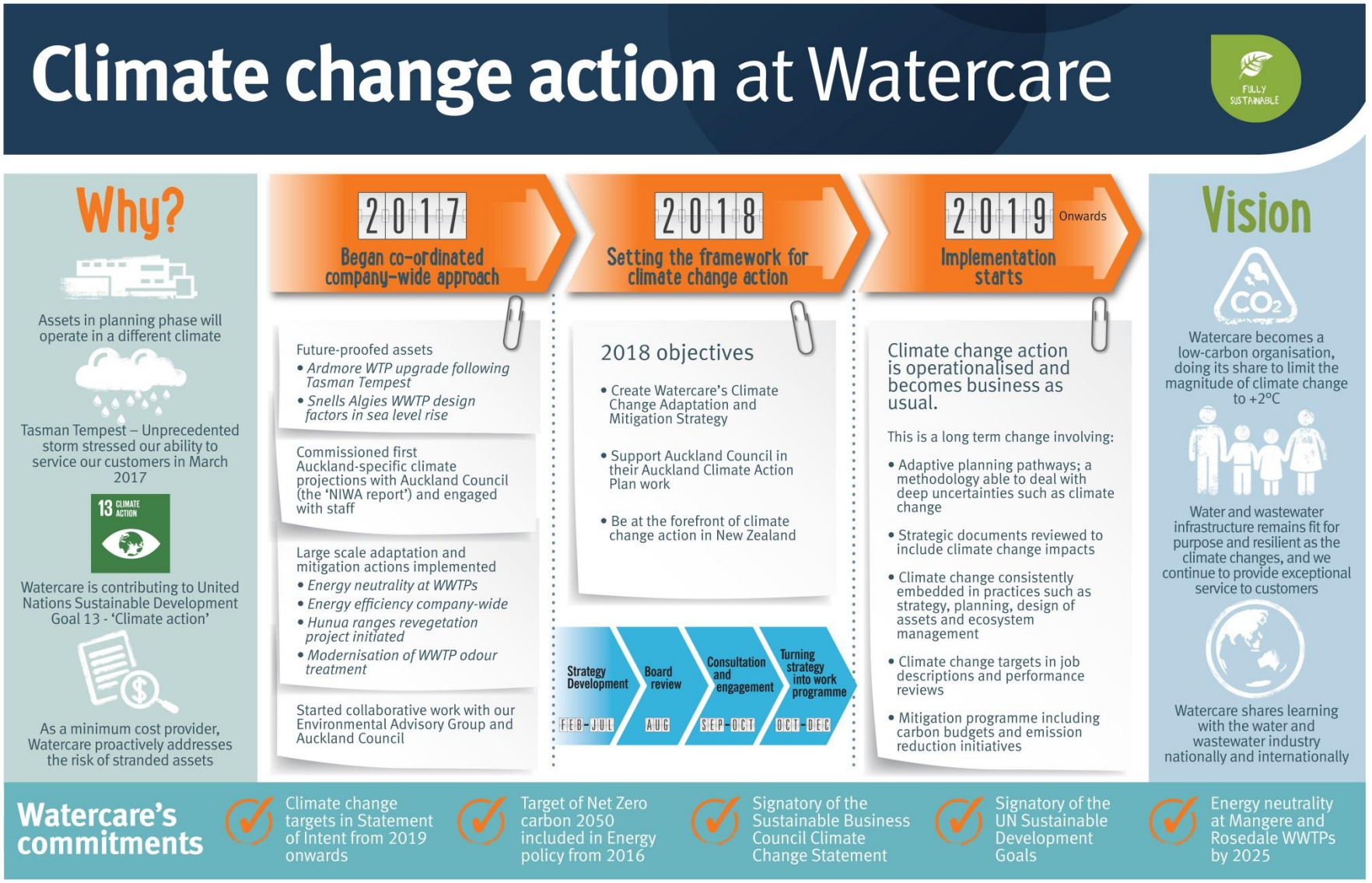
4.5 Next steps for the strategy development

NIWA's climate change projections have enabled Watercare to understand our specific vulnerabilities. As we see the effects of climate change we will be able to review the effectiveness of our actions and optimise the timing of their implementation. The adaptive planning methodology allows us to adjust our pathways based on what, and when, various climate change impacts unfold.

We are currently in the process of turning the developed pathways into a strategy document that will explain how we will address the challenges. The process for developing the strategy has been turned into a poster for communication with the staff and external stakeholders (Figure 2).

The strategy will lead to a programme of work that will include actions, responsibilities and budgets. The strategy will be implemented by each business team taking responsibility for the actions in their remit. The aim is to have climate change considerations become integrated in the 'business as usual' processes throughout all areas of the organisation. This will include staff having climate change as part of their Key Performance Indicators (KPIs), in their job descriptions and in their performance reviews. A process will be established for reporting back on actions and updating trigger points and dependencies identified in the strategy. It will be important to periodically review the programme of work as new information emerges and our understanding grows.

Figure 2: Climate Change Action at Watercare poster



5 Conclusions

Watercare is developing an approach to climate change mitigation and adaptation that will guide the organisation on a path toward climate resilience. We have recognised the value of considering specific climate change projections for the Auckland region, of fully understanding the science before identifying vulnerabilities and actions, and of collaborative problem solving. The process that we followed to develop our strategy could be of use to other utility service providers. We hope it is an opportunity for us to connect with other water and wastewater utilities across New Zealand on this topic and build on our collective climate resilience.

Acknowledgements

The authors are grateful for the support of Watercare staff and the Environmental Advisory Group for their continued engagement in contributing toward the strategy. This process would not have been possible without the report from NIWA and the funding contributions from the Auckland Council family and district health boards.

References

Cook, J., Oreskes, N., Doran, P. T., Anderegg, W. R. L., Verheggen, B., Maibach, E. W., … Rice, K. (2016). Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. *Environmental Research Letters*, *11*(4), 048002. http://doi.org/10.1088/1748-9326/11/4/048002

Coastal hazards and climate change: Guidance for local government, Coastal hazards and climate change: Guidance for local government (2017). Retrieved from http://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-local-government

Global climate change adaptation and mitigation. (2018, February 8). Retrieved July 11, 2018, from https://climate.nasa.gov/solutions/adaptation-mitigation/

IPCC, 2013: Climate Change 2013: The Physical Science Basis, Chapter 13 – Sea Level Change. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Pearce, P., Bell, R., Bostock, H., Carey-Smith, T., Collins, D. Fedaeff, N., Kachhara, A., Macara, G., Mullan, B., Paulik, R., Somervell, E., Sood, A., Tait, A., Wadhwa, S., Woolley, J.-M. (2018). Auckland Region climate change projections and impacts. Revised January 2018. Prepared by the National Institute of Water and Atmospheric Research, NIWA, for Auckland Council. Auckland Council Technical Report TR2017/030-2

Population growth fastest in Northland, Auckland, and Waikato | Stats NZ. (2017, October 24). Retrieved June 29, 2018, from https://www.stats.govt.nz/news/population-growth-fastest-in-northland-auckland-and-waikato

Zickfeld, K., & Herrington, T. (2015). The time lag between a carbon dioxide emission and maximum warming increases with the size of the emission. *Environmental Research Letters*, *10*(3), 031001. http://doi.org/10.1088/1748-9326/10/3/031001