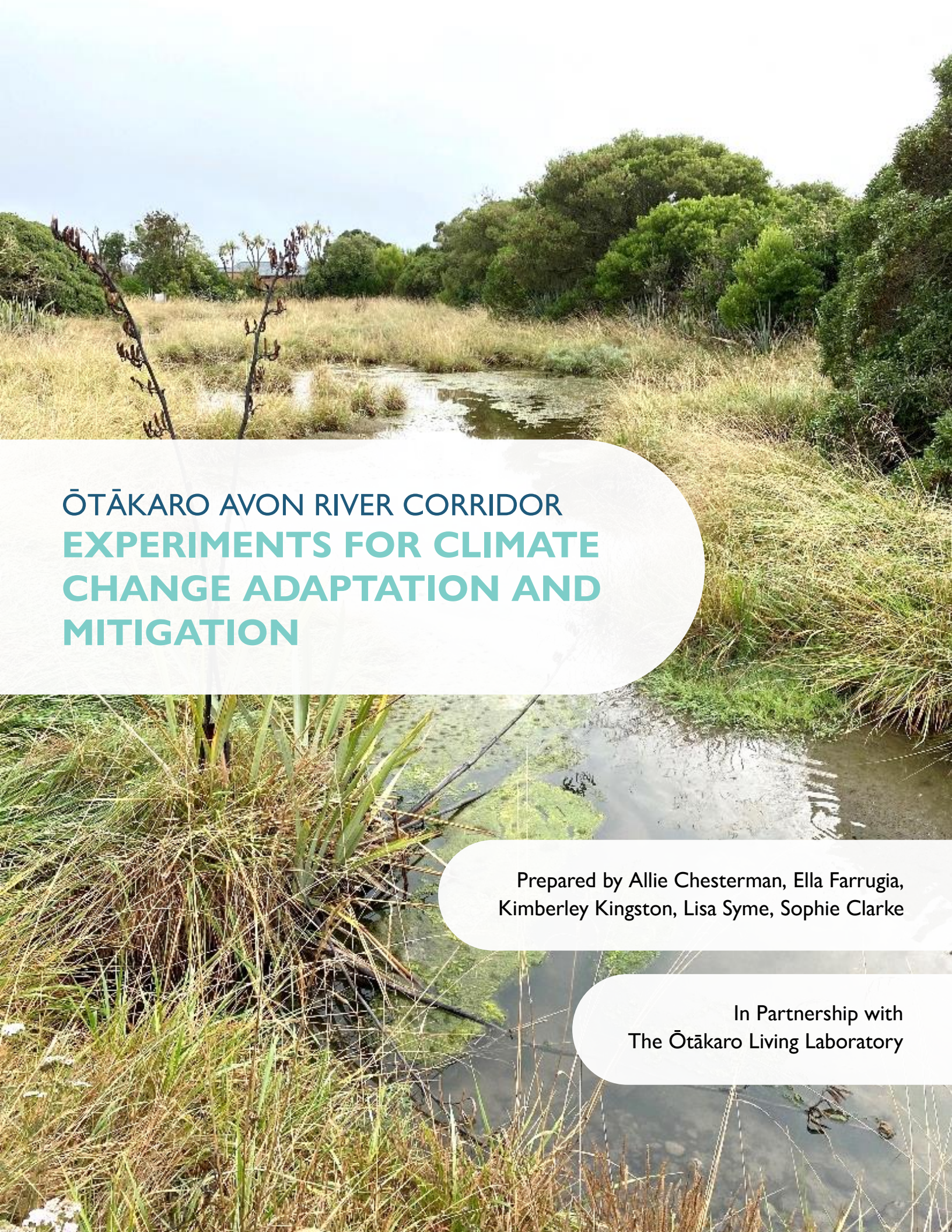


ŌTĀKARO AVON RIVER CORRIDOR
EXPERIMENTS FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

Prepared by Allie Chesterman, Ella Farrugia, Kimberley Kingston, Lisa Syme, Sophie Clarke

In Partnership with
The Ōtākaro Living Laboratory

Table of Contents

Executive Summary 2

Introduction 3

Literature Review 3

Methods 5

Results And Discussion 8

Recommendations 15

Conclusions 17

Acknowledgements 17

References 19

Appendix A - Current Public And Private Programmes And Initiatives 24

Appendix B - Available Grants And Funding 25

Appendix C – Definitions 30

Appendix D – Framework Table 32

Appendix E – Case Studies 34

Appendix F - Interview Questions 47

EXECUTIVE SUMMARY

- Climate change adaptation and mitigation is the largest challenge people will face in the coming decades.
- Climate change impacts include sea level rise, increased global temperatures, increased extreme weather event frequency, and ecosystem degradation.
- This research investigates what trials and experiments could be pursued in the Ōtākaro Avon River Corridor to contribute to climate change mitigation and adaptation, and how these can be enabled.
- Literature focuses on nature-based solutions, with fewer technological solutions.
- Frameworks are useful to ensure equitable funding allocation. They need to be robust for the coming decades and provide holistic outcomes.
- Effective engagement with stakeholders involves consulting diverse groups, conducting semi-structured interviews, and communicating knowledge with frameworks.
- We used stakeholder interviews to understand community groups and specialist's views. Semi-structured interviews enabled open conversations to gain insights.
- We use literature to perform secondary data analysis on experiment ideas. This allowed us to understand what had already been done and what gaps exist.
- We developed a framework from literature that discussed the structure and overarching outcomes. We then refined the framework based on stakeholder opinions and experiences.
- In the stakeholder interviews, riparian planting and wetlands received the most support, and sustainable housing had controversial opinions. New experiment ideas and barriers were discussed.
- We developed five case studies based on secondary data analysis and stakeholder opinions. The case studies were analysed using the framework.
- We recommend wetlands incorporating pā harakeke, and both sustainable and community housing. These case studies are recommended due to multiple areas having strong expected outcomes.
- We do not recommend diversifying lawns due to poor expected outcomes in multiple areas.
- The framework's limitations were layout, its technicality, and the required knowledge for the inputs section.
- We suggest the Ōtākaro Living Laboratory continues to connect with stakeholders, creates a technical group for input assessment, and expands infrastructure and governance knowledge.
- We recommend further research into relevant stakeholders, formalising the process of developing and implementing experiments and understanding the future co-governance arrangement.

INTRODUCTION

Climate change is a global issue that requires new thinking for mitigation and adaptation. Mitigation is defined by the IPCC as "A human intervention to reduce the sources or enhance greenhouse gass (GHGs) sinks". Adaptation is defined by the IPCC as "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects". The Ōtākaro Avon River Corridor (the Corridor) has the potential to contribute to this. After the 2011 Christchurch earthquakes, areas in the Corridor sunk by up to 1.5 metres (Ōtākaro Living Laboratory, 2022). In the coming decades, urban areas worldwide are predicted to experience similar conditions due to sea level rise (Hopkins et al., 2015). This research, therefore, investigates what trials and experiments can be pursued in the Corridor to contribute to climate change mitigation and adaptation, and how these can be enabled. It aims to develop a decision-making framework for climate mitigative and adaptative projects; provide experiment ideas that could be implemented in the Corridor; produce a map visualising suitable experiment locations; and identify barriers to participation and suggest how the Ōtākaro Living Laboratory (the Living Laboratory) can provide solutions. This sets the foundation for experiments to be planned and conducted, contributing to local, national, and global climate change responses. Definitions for terms used in the report are in Appendix C.

LITERATURE REVIEW

To understand the previous work on the topic, five sub-themes were researched.

Climate Change Vulnerability

We researched climate change impacts, the area's vulnerabilities, and the area's most concerning climate change impacts. Identifying the effects which threaten the area most enables adaptation and mitigation strategy prioritisation. One climate change impact that poses risk for the Corridor is sea level rise (SLR). There is no definitive figure for predicted SLR around New Zealand, but by comparing figures from different studies, we concluded that SLR could be anywhere between 0.5m and 2.2m by 2100 (Rive, 2011). Additionally, a 1–2-degree increase will be produced by fewer extremely cold days and an increase in days of hotter maximum temperatures (O'Donnell, 2007). This creates the foundation for an increase in extreme weather events which lead to increased extreme event frequency such as flooding, longer drought periods, tropical storms, and coastal inundation (Hopkins et al., 2015). Rising temperatures are expected to increase flood risk by up to 4 times by 2100, due to climate change. A warmer atmosphere holds more moisture, therefore, an increase in temperature is likely to increase rainfall intensity (O'Donnell 2007).

Climate change increases ecosystem vulnerability and causes decreasing water quality. Research has found that the projected rates of climate change and its associated effects are very likely to exceed evolutionary adaptation rates in many New Zealand species (Fitzharris, 2007). Climate change impacts on ecosystems are likely to include habitat fragmentation and loss (Rive, 2011), and this is likely to limit species migration in response to shifting climatic zones, which will ultimately lead to declining number terrestrial and aquatic species numbers (Fitzharris, 2007). A reverberation of increased precipitation is that it will have adverse effects on surface water quality due to the potential to increase sedimentation, river erosion and turbidity and nutrient runoff (O'Donnell, 2007).

Existing Living Laboratories and Experimentation

This literature review researched past studies done on living laboratories and the innovation within these for climate change mitigation and adaptation. Multiple studies discussed urban green space's cooling ability to mitigate rising temperature and flooding effects ((Kim, 2021; Giannakis et al., 2016). Additionally, complexifying urban lawns improve heat mitigation (Francoeur et al., 2021). Currently, the Corridor is maintained and mowed regularly, however, the research findings highlight that increasing plant structural complexity and/or diversity increased heat mitigation, increased biodiversity, and decreased mowing emissions (Francoeur et al., 2021). Increased biodiversity and ecosystem services increase urban dwellers' well-being and climate change resilience (Pedersen Zari et al., 2022). In Pedersen Zari et al., 2022 article, climate adaptation and mitigation solutions incorporate parks, urban wetlands, and green roofs. Additional innovative solutions discussed were rainwater harvesting systems, solar panels, riparian planting, green corridors, green roofs, bio-retention systems (such as rain gardens), trees, and swales, detention basins, retention ponds and wetlands (slow water, store and treat runoff while draining it through the site and encouraging biodiversity) (Kabisch et al., 2017). This highlights past studies' focus on nature-based solutions within a river corridor environment. It would be beneficial for this study to investigate more diverse solutions.

Area Relationships

We researched how relationships within the Corridor have changed over time. Māori used the Ōtākaro as a source of mahinga kai, being rich with wildlife. It was visited seasonally to gather and preserve food (Regenerate Christchurch, 2019). The area's mana whenua is hapu Ngāi Tūāhuriri and the iwi Te rūnanga o Ngāi Tahu. Ngāi Tahu aims to maintain the area through indigenous riparian corridors, restore mahinga kai to recognise cultural and heritage values, restore ecosystems, and enhance biodiversity (Jenkins, 2017).

In 1851, Europeans settled along the Corridor, developing land into housing (Regenerate Christchurch, 2019). The 2011-2012 earthquakes caused large-scale liquefaction and land subsidence; in some areas up

to 1.5 metres (Hughes et al., 2015). This led to 602 hectares being red-zoned, causing thousands to leave their homes. When implementing innovative ideas, these experiences should be considered.

Stakeholder Engagement

We reviewed methods for engaging stakeholders effectively. Key findings included the need to understand existing area plans (Regenerate Christchurch, 2019). The literature emphasises including diverse stakeholder groups in consultation, such as residents, Mana Whenua, infrastructure providers, technical specialists, the private sector, and NGOs. Those marginalized should be actively included in consultation and planning, to reduce community resistance (Simon et al., 2019). Outlining climate change effects early on in reports engages readers (Khan et al., 2012); When gathering stakeholder perceptions, semi-structured interviews (Simon et al., 2019) and focus groups (Apelu-Uili et al., 2013) are suitable since they support structured responses and discussion of other ideas; Applying case studies to explore issues raised by stakeholders is beneficial. Finally, literature suggested using frameworks to communicate with non-specialist audiences (Khan et al., 2012). Such methods will be considered to improve stakeholder engagement.

Current Frameworks

This literature review investigated current frameworks for assessing climate adaptation and mitigation. There is a consensus that equitable and effective frameworks are needed for funding and resource allocation (Coleman & Bragg, 2021; Ministry for the Environment, 2022). However, there are differences in what areas the frameworks are designed to address and whether the focus is human or ecological (Coleman & Bragg, 2021). Most literature preferred adaptation frameworks over mitigation. The difference between mitigation and adaption in the literature is due to the complexity and considerations involved in adaptation projects compared to mitigation projects. The literature identified key outcome areas: social, cultural, environmental, economic, and equitable (Brechin & Espinoza, 2017; Ministry for the Environment, 2022; IPCC, 2022; Schlosberg, 2012). Incorporating Tangata Whenua, mātauranga Māori, and Te Tiriti o Waitangi principles is essential for a robust framework (Ministry for the Environment, 2022). There must be a focus on providing equitable outcomes and the framework's ability to change over time (Schlosberg, 2012).

METHODS

Semi-structured interviews

The semi-structured interview method was chosen to understand what community groups, council workers, engineers and scientists thought were the most viable and suitable experiments to be carried out in the Corridor. An important component of this research method is participant selection (Cameron, 2005). We

selected individuals to interview based on their experience in the field and their knowledge and involvement in projects already taking place in the Corridor. Such purposive sampling allowed us to interview a wide range of people from different groups and with different expertise to give us a wide data range, whilst sticking to our short time frame (Clifford et al., 2016).

We used this method because our aim was not to be representative, as would be the case for random sampling (Clifford et al., 2016), but to gain as much insight as possible into people's ideas surrounding the most effective solutions. Another benefit is that it allows an open conversation to happen, rather than just simple 'yes' or 'no' answers (Dunn, 2005). This gave us the chance to consider ideas and perspectives we had not yet come across. The interview questions, shown in Appendix F, were formulated to address many research aspects. This was done by breaking down the research question and identifying what information is required to answer the question.

Case Studies

To build on interview data, potential experiment case studies were created through secondary data analysis. Secondary data is an essential information source for projects like this due to resource limitations including time and having an extensive area to research (Clifford et al., 2016). Experiments were selected based on those our stakeholders suggested would be most suitable. We researched the experiments, reviewing and comparing secondary data sources for a more informed view of the processes and resources required for the proposed experiments.

The Framework

Developing the framework, we drew from a variety of literature including IPCC reports, the New Zealand Adaption plan, the Ōtākaro Avon River Corridor Regeneration Plan (the Regeneration Plan) and the Ngai Tahu vision 2025. The literature informed us on what is included in frameworks and how they are useful. We selected the overarching categories for both outcomes and inputs as seen in Figure 1 we brainstormed potential outcomes to provide an example for users as seen in Appendix D. These outcomes are based mostly on information from the Adaptation Plan and Regeneration Plan. When consulting with stakeholders we asked for feedback on our framework. Stakeholders added to our example outcomes any overarching areas. They commented on the framework being visually complex which led to us creating a simpler framework as seen in Figure 1.

To analyse case studies with the framework, we created a table. The table outlines strengths in each category, then improvements or further considerations in each category. Based on this, a number between one

and five was generated to show the alignment with each category and visualised in radar charts. These were useful tools to further our qualitative analysis as they provided a quick strengths overview and a comparison between projects on overall strength. However, this analysis is subjective and numerical alignment to outcomes can change. We recommend that the outcomes are addressed before moving on to the inputs section. If the outcomes are not strong enough, a decision should be made to improve the outcomes, or the experiment is dropped. The inputs section was filled out using knowledge from literature and stakeholder interviews. We recommend the Living Laboratory supports community groups through the input process with a technical group or targeted consultation.

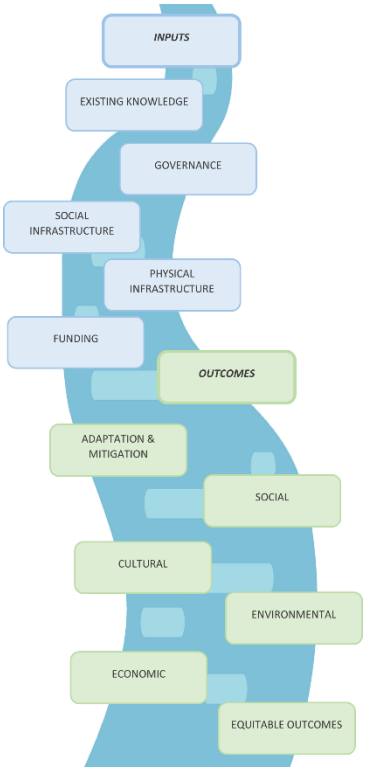


Figure 1: Simplified version of the decision-making framework

Area Mapping

Understanding experiment feasibility includes identifying suitable areas to conduct them. This is included in the framework through the inputs section: physical infrastructure. In the suggested decision-making process, the technical group will have this responsibility, as they will have resources and knowledge of the area's physical characteristics. For this research, we took a simplified approach. We visited the Corridor to identify existing land uses and available spaces and compared this to the Regeneration Plan.

RESULTS AND DISCUSSION

From the interviews and secondary data analysis, we found several potential experiments and significant evidence to support them. We found a cross-section of stakeholder opinions which informed our analysis.

Stakeholder interviews Summary

Eight experiment ideas from existing knowledge and literature were presented in the stakeholder interviews to gather feedback from people involved in the Corridor. Riparian planting and wetlands received the most support, however, there was reservation from a surface water engineer around riparian planting decreasing floodplain effectiveness. This was the same for pā harakeke with additional concerns around the product's commercial feasibility. However, in general, pā harakeke was supported. There were comments on ensuring these nature-based solutions respond to tidal inundation and a saline environment.

Complexifying lawns was deemed a less effective strategy as other options were thought to use space and resources better and unmaintained lawns could be a fire hazard. Solar panel use was supported when combining it with housing or green roofs, however, comments were made about the missed ecological and tourism benefits of using space in the Corridor. Finally, flood-resilient and energy-efficient housing was a highly controversial experiment. Some stakeholders mentioned the reluctance for housing to be back in the red-zone, especially regarding this experiment's sensitivity to previous red-zone homeowners. However, there was more acceptance when incorporating it with educational opportunities.

New experiment ideas from stakeholders were discussed including active transport, bees, aquaculture nurseries, food forests, seaweed nutrient reduction, and food production. Barriers preventing involvement in projects were identified as governance, lease acquisition, bureaucracy, funding, and time. To encourage people to get involved, stakeholders suggested having a funding Appendix, developing a followable framework, developing synergies between the projects, and having global consent for the Corridor.

From the interview results interviews and secondary literature analysis we investigated five different innovative ideas' feasibility using case studies and framework analysis. These include Wetlands, Diversifying lawns, Pā harakeke, Sustainable housing, and Community Housing.

Case Studies for Experiment Outcomes

Wetlands and Riparian Planting

One experiment that was further investigated is restoring wetlands and riparian areas. Wetlands' framework analysis yielded the results shown in Figure 3. This illustrates that wetlands and riparian planting strongly

address adaptation and mitigation, and environmental outcomes, however, lack of economic outcomes, so further considerations would be needed in this area.

This experiment has mitigative and adaptative potential and scored highly in this category. Wetland restoration and enhancement are beneficial for mitigative carbon sequestration (Adhikar et al., 2009). Wetlands are very effective for this due to their high biodiversity and having the highest soil carbon density of all land-based ecosystems (Were et al., 2019). Wetland adaptation properties include providing resilience to hazards such as flooding, storm surge and coastal inundation (Kabisch & Haase, 2017). Restoring these biodiverse areas is an ideal nature-based mitigative due to their pollutant fixation and flood water retention properties, which is particularly useful along the Corridor (Burley et al., 2012). Restored and maintained riparian zones increase bank stability and reduce erosion and soil runoff which is important during climate change induced extreme events that put the Corridor at risk (Soeter, 2020). Riparian planting mitigates flooding and storm risks by enhancing riparian zone resilience and, therefore, protects the river and freshwater ecosystem health. As seen in Figure 3 this experiment scored moderately high in the social, cultural, and equitable outcomes categories, but low in economic outcomes. The reasons as to why these scores were given are explained in Table 1 in Appendix E.

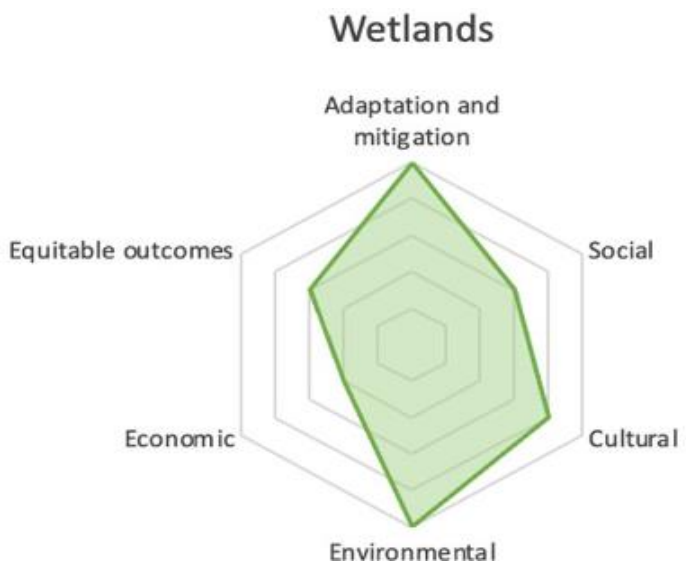


Figure 2: Radar chart illustrating alignment of the wetlands and riparian planting experiment to the outcomes of the framework

Diversifying Lawns

Diversifying lawns is another experiment we investigated. This is essentially letting nature take its path rather than maintaining the lawns. Research shows that maintaining lawns leads to an increase in harmful environmental impacts, including increased carbon emissions, suppressing plant growth, increased soil temperatures and harmful effects on soil microbes and biodiversity (Shaiyen, 2016). Therefore, diverse lawns in the Corridor would help mitigate climate change by reducing GHGs, improving plant quality and growth an creates habitat for native wildlife and exotic and native plant species. Appendix E, Table 4, discusses how this case study aligns with the framework. When assessing diverse lawns against the framework, it strongly aligns with environmental outcomes. However weakly aligns with all other outcomes, such as social, economic, and equitable, as seen in Figure 3.

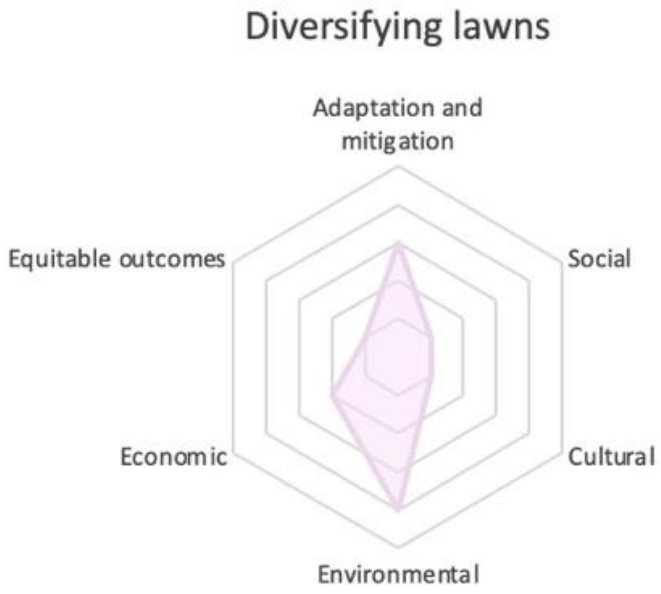


Figure 3: Radar chart illustrating alignment of diversifying lawns experiment to the outcomes of the framework

Pā Harakeke

A Pā Harakeke is a harakeke (common flax) plantation (Department of Conservation, n.d.). A Wellington-based group is currently working to form the Te Papa Pā harakeke and building one into the Corridor is an option with the potential to improve cultural, environmental, social, and economic outcomes. It was traditionally used for qualities such as strength, softness, durability, ease of extraction and muka (fibre) quantity

(Scheele, 2005). It was used for clothing, baskets, wound dressing, and internal medication. Landcare Research holds national collections of unique cultivars and distributes plants to weaving groups and marae throughout the country (Department of Conservation, n.d.).

Conducting framework analysis, pā harakeke strongly aligns with cultural outcomes and economic outcomes. It moderately aligns with social outcomes, environmental outcomes, and equitable outcomes. These results are visualized in Figure 4. The reasoning behind these alignments is in Appendix E, Table 2.

The experiment weakly aligns with adaptative and mitigative outcomes (scoring 2.5). Harakeke can be beneficial for adapting to climate change, as it is resilient to a large amount of silt deposition during storm events (Gisborne District Council, 2022). Ben Scales, CEO of KiwiFibre, states that harakeke use as an alternative to carbon fibre involves 85% less carbon emission (Standing Room Only, 2022). While harakeke is commonly used for river restoration and biodiversity, little research is found on harakeke's direct carbon sequestration abilities. However, growth could take place in wetland areas, providing biodiverse areas with great carbon sequestration effects. The major adaptation drawback, suggested by David Little (Christchurch City Council (CCC)), is the tendency for stems to block flood plain water flow. This interrupts other adaptative initiatives.

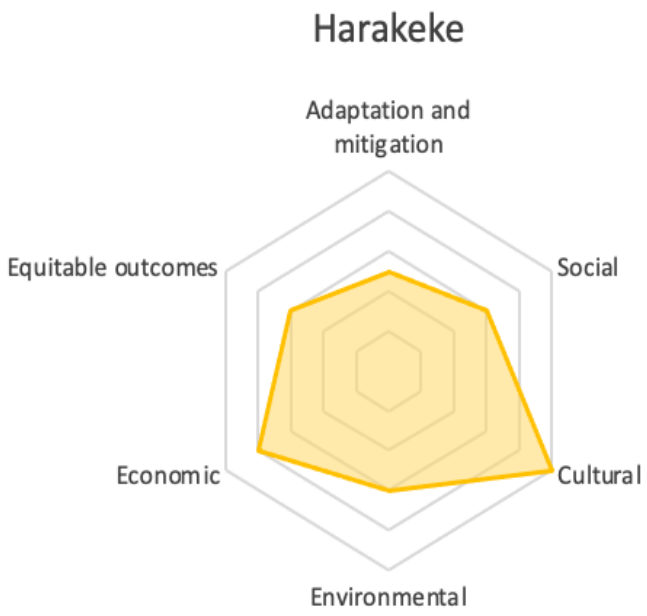


Figure 4: Radar chart illustrating alignment of the Harakeke experiment to the outcomes of the framework

Sustainable Housing

Housing has numerous environmental challenges including excessive energy consumption, resource depletion, and environmental pollution (Roufechaei, et al., 2014). Housing design and construction, therefore, play a major role in mitigating climate change. In addition to this, the building planning must account for projected climate change effects like sea level, storm frequencies, and temperature and rainfall extremes to support climate change adaptation.

Firstly, passive housing is a technique to improve a house's energy efficiency and decrease rising temperature effects. A passive construction has a highly insulated, airtight building envelope, which uses an air-to-air heat exchanger for space heating and ventilation (Walliser et al., 2012). Cool paints, and solar thermal panels (photovoltaics) situated on the roof also increase energy efficiency. The building therefore relies on electricity (as opposed to gas or oil) from the renewable electricity generated from the solar panels (Kinnane et al., 2016).

Green roofs are commonly discussed in literature, whereby a roof is laid with soil and planted to help insulate the house, decrease cooling demands, reduce pollution and runoff. Use of photovoltaic-green roofs (using the two systems together on the roof) increases each other's functions (solar panels and green roofs) with cooling and shading effects (Catalbas et al., 2021). Flood-resistant buildings were investigated with solutions such as having a multi-story house with the lower story being able to take on water by being built with flood-resistant materials such as hempcrete or recycled plastics (Saqib, et al., 2014).

Appendix E, Table 3, discusses how sustainable housing aligns with each framework category. The experiment's ability to address climate change adaptation and mitigation scored a 4 as seen in Figure 5, due to the multiple areas innovative housing addresses including energy consumption, flood resilience, sea level rise, and energy efficiency (temperature). Environment and equitable outcomes scored highly. Social outcomes scored in the mid-ranges with a 3 and cultural and equitable outcomes scored lower.

Figure 5: Radar chart illustrating alignment of the sustainable housing experiment to the outcomes of the framework

Community Housing

With the potential for housing redevelopment in the Corridor, there are social innovations that are considered beneficial to community well-being and resilience and provide climate adaptation benefits. These innovations include co-operative housing, hazard fund development, active transport options, and microgrids. These ideas are experimental because they have not been explored in a New Zealand context or the global north. During stakeholder interviews, there has been a divide between community groups and professionals on housing. However, when we clarified that the housing would be experimental and not just subdivisions community members were more onboard with the proposal.

Framework analysis was applied to this experiment, shown in full in Table 5, in Appendix E. All these ideas provide climate adaptation as they increase community and infrastructure resilience. This allows them to adapt to risks such as increased extreme weather event frequency and temperature changes (Lamb et al., 2022; Anderson, 2022). Hazard funds, active transport and microgrids provide mitigation by reducing emissions in the transport and energy sectors. (Koetse & Rietveld, 2012; Papageorgiou et al., 2020). Therefore, mitigation and adaptation are ranked four. As seen in Figure 6 adaptation and mitigation, social, and economic areas scored the highest as there are more positive outcomes expected in these categories. Environmental and equitable outcomes scored moderately as positive outcomes are expected in these categories but there is also potential for some negative impacts. Cultural scored the lowest as some ideas are not as relevant culturally so there are fewer expected outcomes. Figure 6 shows that holistically, community housing is a good option for the Living Laboratory.

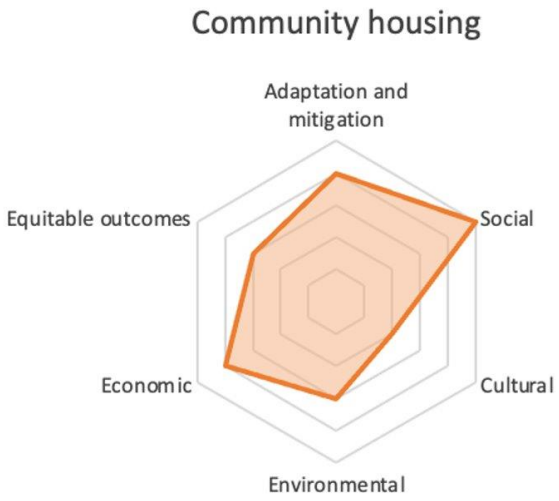


Figure 6: Radar chart illustrating alignment of the community housing experiment to the outcomes of the framework

Experiment Inputs

The inputs section requires knowledge of existing experiments and knowledge, social infrastructure, physical infrastructure, governance, and funding. See Appendix D for example considerations within each category. Most experiments considered require similar inputs. We discuss known existing inputs, which should be expanded on by those with more technical knowledge.

Existing knowledge is what we have gained from our case studies and literature review and exists throughout the community, particularly mātauranga Māori.

There is a lot of existing physical infrastructure from before the earthquakes. This includes underground services such as sewage, stormwater, drinking water pipes, power cables, and fibre cables. The underground infrastructure is still in use today. Overground infrastructure includes the road network and powerlines and other electricity infrastructure. Some roads are still in use such as state highway 74, while others are only open to foot and cycle traffic. All the electricity gird components are still live and used.

As a result of the research and the interviews that were conducted, a list of organisations who in the past or are presently carrying out projects and initiatives in the area was complied. This is listed in Appendix A these groups can be used as inspiration, contacts, advice sources, and partnerships for those wishing to carry out future experiments. This Appendix was created based on information shared in the semi-structured interviews as well as from additional research. Other social infrastructure includes technical specialists and professionals who can provide advice.

The red-zoned Corridor is currently being transferred to CCC ownership from Land and Information New Zealand. The governance structure currently requires several forms to be filled out to lease the land. There is a developing co-governance arrangement that will be put into place soon. Some experiments may require consent from CCC and Environment Canterbury.

There are many funding avenues available depending on the intention for projects and any outcomes they may produce. There is a funds list in Appendix B.

RECOMMENDATIONS

By comparing each experiment's success against the framework and viewing the resulting radar charts we can make recommendations to the Living Laboratory on potential experiments. As seen in Figure 7, wetlands, sustainable housing, and community housing have the strongest holistic alignment to the outcomes. Based on this we recommend pursuing wetlands, sustainable housing, and community housing. Pā harakeke however had moderate alignment with outcomes and diversifying lawns has poor alignment with outcomes. Therefore, we do not recommend diversifying lawns due to their poor expected outcomes, however pā harakeke could be incorporated into wetland areas to promote and enhance mahinga kai.

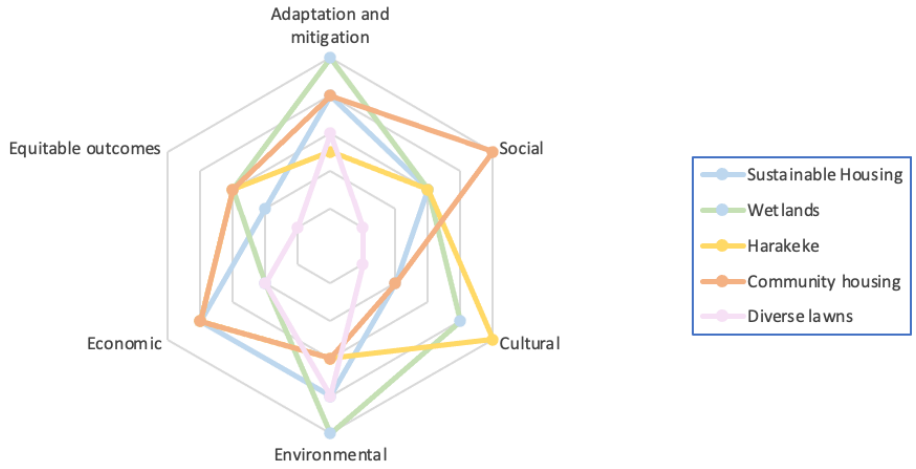


Figure 7: Radar chart illustrating comparisons of experiments against each other in terms of alignment to outcomes

Limitations in our framework were identified from carrying out the case studies and stakeholder interviews. Stakeholders were confused about what the inputs section was trying to achieve, and we found difficulty in filling this section out when completing the case study analysis. Additionally, stakeholders were unsure of what to consider for each category. This led us to making a resource of examples for users seen in Appendix D. For the inputs we are making some recommendations to the Living Laboratory about this section. Limited access to spatial land-use and flooding data reduced our ability to conduct spatial analysis. Furthermore, the word count was a major limiting factor, as we had to add case study reasoning to Appendix E which affects the report's flow.

Experiment Locations

There are many suitable areas for these experiments which align with current area plans. Flood-resilient housing should be in flood-prone areas. Bexley is one such area, with regular surface water flooding. Further research and surface water mapping would identify other such areas. Community housing experiments could be closer to the city. The Regeneration plan has several trial housing areas in these two experiments can be incorporated into. Wetlands are suitable in flood-prone areas too, Bexley, the eastern reaches, and Horseshoe Reach are all suitable and align with the Regeneration Plan. Pā harakeke does not thrive in consistently wet areas but can be integrated into proposed mahinga kai exemplars in the eastern reaches, and around wetlands in horseshoe reach. It would need to be accessible to those wanting to use it, with other surrounding amenities such as gathering areas, public restrooms, and security measures. See Figure 8 (map) for potential locations.

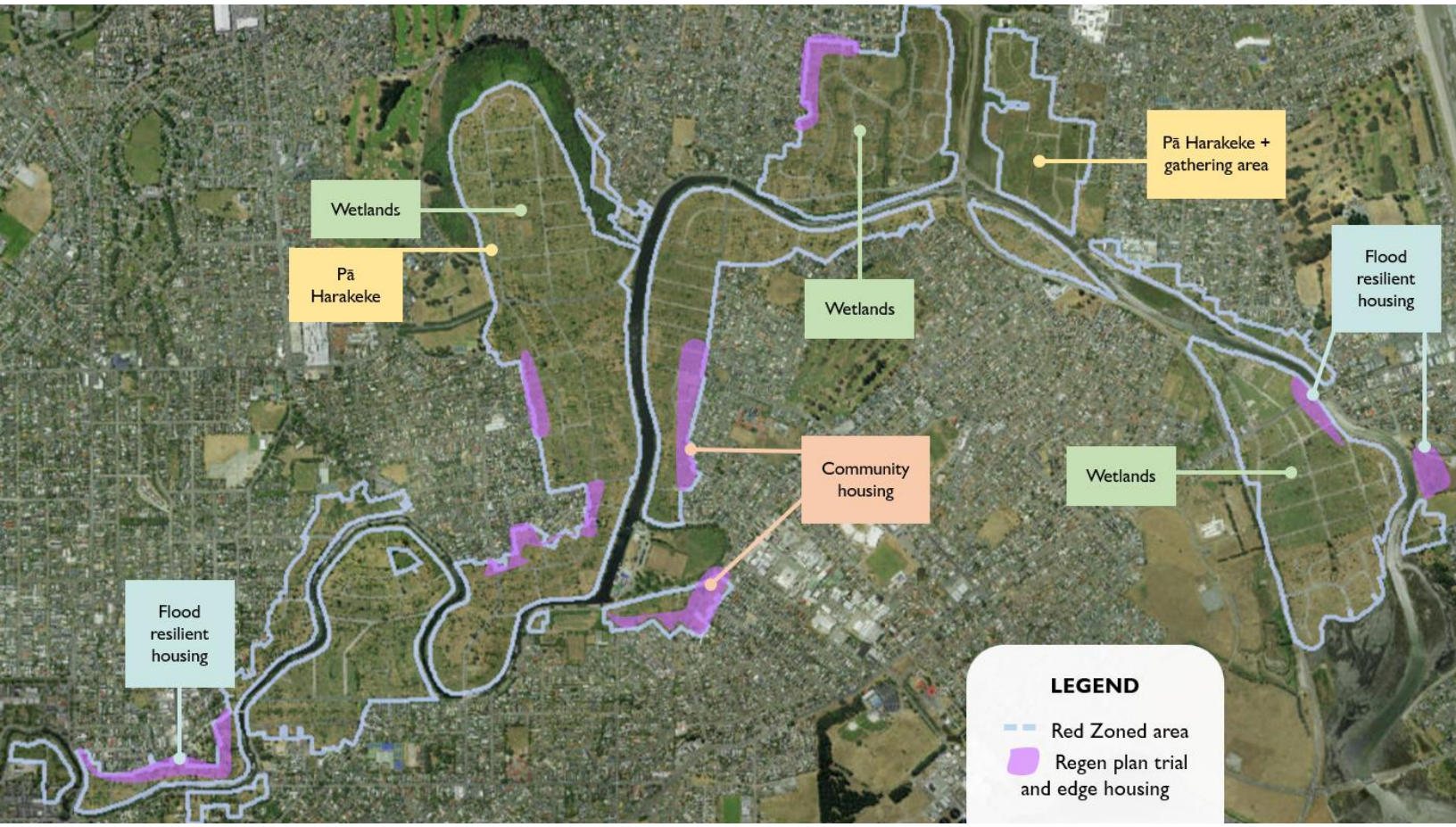


Figure 8: Map of proposed locations of experiments along the river corridor

Living Laboratory Recommendations

The Living Laboratory can support further idea exploration and implementation. Firstly, we suggest identifying relevant stakeholders and engaging further with them. The lab could act as a go-between for stakeholders, experts, and government associations. This would benefit experiment outcomes as it improves relationships which could increase experiment implementation. Secondly, gather a technical group of specialists and professionals in various fields to further the study's feasibility. This would give the lab informed advice on how to move forward and implement experiments. Finally, expand on the input processes that exist and identify what inputs need to be developed. Many barriers were suggested by stakeholders related to this. We suggest providing access to grant resources to support funding, resources for filling out land-use applications to reduce time spent on paperwork, and governance structure advice.

Further Research

Further research can support experiment implementation. Firstly, we suggest identifying all stakeholders who may have an interest in the experiments. Formalise the process of developing experiment ideas, how the analysis using the framework will proceed in a professional setting, and how the experiments can be implemented. Create land use, flooding, and underground infrastructure maps to communicate suitable areas effectively to stakeholders. Understand the developing co-governance in the area and how this could impact our results. Finally, investigate the feasibility of stakeholder ideas using the formalised process.

CONCLUSIONS

From our research and analysis, we recommend pursuing wetlands with pā harakeke incorporated, and both sustainable and community housing in the locations outlined on the map in Figure 8. These experiments require further development before implementation. Our recommendations are based on data from stakeholder interviews, secondary data analysis, and our values. However, these are still reliable, based on the wide research scope and stakeholder and literature diversity.

ACKNOWLEDGEMENTS

Throughout our project, we had a considerable amount of support. We thank our community partner, Rob Kerr from the Ōtākaro Living Laboratory, for his direction. We thank our supervisor Sally Gaw from the

University of Canterbury for advising us. We acknowledge the community members who provided information in stakeholder interviews. This includes Bebe Frayle from the Dallington Residents Association, David Little from CCC, an ENGEO representative, Surface water engineer Tom Parsons, Roz Rolls from Edible Canterbury, John Reid, Ecologist Shelley McMurtrie, Tony Moore from CCC, and Vicki Buck from the Climate Action Campus. We thank them and all others for their work in the Corridor.

REFERENCES

Adhikari, S., Bajracharaya, R.M., Sitaula, B.K. (2009) A review of carbon dynamics and sequestration in wetlands. J Wetl Ecol 2:42–46. https://doi.org/10.3126/jowe.v2i1.1855

Altus, D. E., & Mathews, R. M. (2002). Comparing the satisfaction of rural seniors with housing co-ops and congregate apartments: Is home ownership important? *Journal of Housing for the Elderly*, *16*(1-2), 39-50.

Anderson, K., Farthing, A., Elgqvist, E., & Warren, A. (2022). Looking beyond bill savings to equity in renewable energy microgrid deployment. *Renewable Energy Focus*, *41*, 15-32.

Apelu-Uili, T., Martin, A., & Risi, D. (2013). A Future for the Avon River Improving water quality and management. University of Canterbury, GEOG402 School of Earth and Environment. Retrieved from https://www.canterbury.ac.nz/media/documents/oexp-science/geography/community-engagement/geog402/2013/A-Future-for-the-Avon-River.pdf

Berghan, J. (2021). Kaupapakāinga: The potential for Māori cohousing. Report for Building Better Homes, Towns and Cities: Affordable Housing for Generations, September 2021, Wellington: BBHTC

Brechin, S. R., & Espinoza, M. I. (2017). A case for further refinement of the Green Climate Fund's 50: 50 ratio climate change mitigation and adaptation allocation framework: toward a more targeted approach. *Climatic Change*, *142*(3), 311-320.

Cameron, J. (2005) 'Focusing on the focus group', in I. Hay (ed.) Qualitative Research Methods in Human Geography (2nd edn). Melbourne: Oxford University Press, pp. 116–132.

Chapple, G. (n.d.). *The greening of the red zone*. Retrieved from New Zealand Geographic. https://www.nzgeo.com/stories/the-greening-of-the-red-zone/

Christchurch city council. (n.d.). *Inner-city and coastal heritage trails.* Retrieved from Christchurch before 1850: https://www.ccc.govt.nz/assets/Documents/Culture-Community/Heritage/christchurch-before1850-re-printed-june-2009-publications.pdf

Clifford, N., French, S., & Valentine, G. (2016). Key Methods in Geography, 3 rd edn. Sage, London.

Coleman, M. A., & Bragg, J. G. (2021). A decision framework for evidence-based climate adaptation interventions. *Global change biology*, *27*(3), 472-474.

Curtin, D. J., & Zovod, S. J. (2003). Geologic Hazard Abatement Districts: California's Experience with Hazard Mitigation through Special Purpose Districts. *Land Use Law & Zoning Digest*, *55*(6), 3-7.

Department of Conservation. (n.d.). Harakeke/flax. https://www.doc.govt.nz/nature/native-plants/harakeke-flax

Dunn, K. (2005) 'Interviewing', in I. Hay (ed.) Qualitative Research Methods in Human Geography (2nd edn). Melbourne: Oxford University Press, pp. 79–105

Ellerman, D. P. (1983). A model structure for cooperatives: worker co-ops and housing co-ops. *Review of Social Economy*, *41*(1), 52-67.

Faherty, T., & Morrissey, J. (2014). Challenges to active transport in a car-dependent urban environment: A case study of Auckland, New Zealand. *International Journal of Environmental Science and Technology*, *11*(8), 2369-2386.

Fitzharris, B. (2007). How vulnerable is New Zealand to the impacts of climate change? New Zealand Geographer. 63. 160 - 168. 10.1111/j.1745-7939.2007.00119.x.

Francoeur, X. W., Dagenais, D., Paquette, A., Dupras, J., & Messier, C. (2021). Complexifying the urban lawn improves heat mitigation and arthropod biodiversity. Urban forestry & urban greening, 60, 127007. https://www.sciencedirect.com/science/article/pii/S1618866721000327

Giannakis, E., Bruggeman, A., Poulou, D., Zoumides, C., & Eliades, M. (2016). Linear parks along urban rivers: Perceptions of thermal comfort and climate change adaptation in Cyprus. Sustainability, 8(10), 1023. https://www.mdpi.com/2071-1050/8/10/1023

Gisborne District Council. (2022). Harakeke used for river restoration. https://www.gdc.govt.nz/environment/reports-and-publications/panui-taiao/june-2022/harakeke-used-for-river-restoration

Hopkins, D., Campbell-Hunt, C., Carter, L., Higham, J.E.S. and Rosin, C. (2015), Climate change and Aotearoa New Zealand. WIREs Climate Change, 6: 559-583. https://doi.org/10.1002/wcc.355

Hughes, M. W., Quigley, M. C., Van Ballegooy, S., Deam, B. L., Bradley, B. A., Hart, D. E., & Measures, R. (2015). The sinking city: Earthquakes increase flood hazard in Christchurch, New Zealand. *GSA Today*, *25*(3), 4-10.

IPCC. (2014) Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate, IPCC, Geneva, Switzerland, pp. 117-130.

Jenkins, B. (2017). Avon—Ōtākaro Network Vision for Regeneration of the Avon—Ōtākaro Corridor Red Zone. *Landscape Review*, *17*(2).

Kabisch, N., Haase, D. (2017.), Nature-based Solutions to Climate Change Adaptation in Urban Areas, Theory and Practice of Urban Sustainability Transitions, DOI 10.1007/978-3-319-56091-5_7

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (2017). Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy, and practice. Springer Nature. https://library.oapen.org/bitstream/handle/20.500.12657/27761/1002244.pdf?sequence=1

Kane, F., Kilford, A., Ruka, T., Le Guen, M. J., & Brorrens, P. (2019). Exploring a Place-Based Approach to Materials Design: Harakeke Nonwovens in Aotearoa New Zealand. Loughborough University. Conference contribution. https://doi.org/10.17028/rd.lboro.9724661.v1

Khan, A. S., Ramachandran, A., Usha, N., Aram, I. A., & Selvam, V. (2012). Rising sea and threatened mangroves: a case study on stakeholders, engagement in climate change communication and non-formal education. International Journal of Sustainable Development & World Ecology, 19(4), 330-338. https://doi.org/10.1080/13504509.2011.650230

Kim, H. Y. (2021). Analyzing green space as flooding mitigation–storm Chaba case in South Korea. Geomatics, Natural Hazards, and Risk, 12(1), 1181-1194. https://www.tandfonline.com/doi/full/10.1080/19475705.2021.1920478

King, D. E., & Morgan, M. G. (2007). Customer-focused assessment of electric power microgrids. *Journal of Energy Engineering*, *133*(3), 150-164.

Koetse, M. J., & Rietveld, P. (2012). Adaptation to climate change in the transport sector. *Transport Reviews*, *32*(3), 267-286.

Lamb, Z., Shi, L., Silva, S., & Spicer, J. (2022). Resident-Owned Resilience: Can Cooperative Land Ownership Enable Transformative Climate Adaptation for Manufactured Housing Communities? *Housing Policy Debate*, 1-23.

Law, T. (2021). Building 101km of cycleways across Christchurch to cost $301m. *The Press*. https://www.stuff.co.nz/the-press/news/124611551/building-101km-of-cycleways-across-christchurch-to-cost-301m

Pathak, M., Slade, R., Shukla, P. R., Skea, J., Pichs-Madruga, R., Ürge-Vorsatz, D. (2022). Technical Summary. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working

Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.002

Manning, M., Lawrence, J., & King, D.N. (2015) Dealing with changing risks: a New Zealand perspective on climate change adaptation. Reg Environ Change 15, 581–594. https://doi.org/10.1007/s10113-014-0673-1

Ministry for the Environment. (2022). *Aotearoa New Zealand's first national adaptation plan.* Wellington: Ministry for the Environment

O'Donnell, L. (2007). Climate Change, An analysis of the policy considerations for climate change for the review of the Canterbury Regional Policy Statement.

Olin, C. V., Berghan, J., Thompson-Fawcett, M., Ivory, V., Witten, K., Howden-Chapman, P., Duncan, S., Ka'ai, T., Yates, A., & O'Sullivan, K. C. (2022). Inclusive and collective urban home spaces: The future of housing in Aotearoa New Zealand. *Wellbeing, Space and Society*, *3*, 100080.

Olshansky, R. B. (1996). Financing landslide hazard mitigation in the United States. *Journal of Environmental Planning and Management*, *39*(3), 371-386.

Orchard, S. (2017). *Floodplain restoration principles for the Avon Ōtākaro Red Zone.* Christchurch: Avon Ōtākaro Network. Retrieved from Avon Ōtākaro Network.

Ōtākaro Living Laboratory. (2022). Ōtākaro Living Laboratory. https://www.otakarolivinglab.org.nz/

Papageorgiou, A., Ashok, A., Farzad, T. H., & Sundberg, C. (2020). Climate change impact of integrating a solar microgrid system into the Swedish electricity grid. *Applied energy*, *268*, 114981.

Pedersen Zari, M., MacKinnon, M., Varshney, K., & Bakshi, N. (2022). Regenerative living cities and the urban climate–biodiversity–wellbeing nexus. Nature Climate Change, 12(7), 601-604. https://www.nature.com/articles/s41558-022-01390-w

Regenerate Christchurch. (2019). Ōtākaro Avon River Corridor Regeneration Plan. https://dpmc.govt.nz/sites/default/files/2019/08/Otakaro%20Avon%20River%20Corridor%20Regeneration%20PlanReducedSize.pdf

Regenerate Christchurch. (2019). *Ōtākaro Avon River Corridor Regeneration Plan.* Christchurch: Department of the Prime Minister and Cabinet.

Rive, V. (2011). Adaptation to Climate Change in New Zealand. Climate Change Law and Policy in New Zealand. Editors: Cameron A. 346-372, Lexis Nexis, Wellington, July 2011, Available at SSRN: https://ssrn.com/abstract=2328637

Scheele, S. (2005). Harakeke: The Rene Orchiston collection. Manaaki Whenua Press. https://www.landcareresearch.co.nz/uploads/public/Tools-And-Resources/collections/Harakeke-collection/Harakeke_3rdEd.pdf

Schlosberg, D. (2012). Climate Justice and Capabilities: A Framework for Adaptation Policy. *Ethics & International Affairs* (26(4)), 445-461. https://doi.org/10.1017/S0892679412000615

Simon, K., Diprose, G., & Thomas, A. C. (2019). Community-led initiatives for climate adaptation and mitigation. Kōtuitui: New Zealand Journal of Social Sciences Online, 15(1), 93-105. https://doi.org/10.1080/1177083X.2019.1652659

Standing Room Only. (2022). Harvesting the international potential of harakeke. Radio New Zealand. https://www.rnz.co.nz/national/programmes/standing-room-only/audio/2018860204/harvesting-the-international-potential-of-harakeke

Te Herenga Waka. (2022). Te Papa Pā Harakeke. https://www.myview.co.nz/te-papa-pa-harakeke/

Tuominen, A., Sundqvist-Andberg, H., Aittasalo, M., Silonsaari, J., Kiviluoto, K., & Tapio, P. (2022). Building transformative capacity towards active sustainable transport in urban areas–Experiences from local actions in Finland. *Case Studies on Transport Policy*.

Appendix A - Current Public and Private Programmes and Initiatives

Name	Mahi	Location
Radio controlled trucks	A group has built a temporary track for their radio-controlled trucks and diggers.	Bordered by Anzac Drive, New Brighton Road and Brooker Ave
East x East	This 9ha area in Burwood features a range of public activities including a Learn to Ride track (pictured), sports fields, pump track, and a nine-hole fris-bee golf course.	Bordered by Anzac Drive, New Brighton Road and Brooker Ave
Beehives	Beekeepers are using the red-zone with its abundance of fruit trees to strengthen the local bee population.	Dallington, Riverlution
Richmond community Gar-dens	Garden of Curiosities, Matariki in the Zone, Riverlution Community Hub	Avebury House, 9 Evelyn Couzins Drive
Life in Vacant Spaces	Memorial Garden, East x East Games	Projects over multiple locations
Avon Ōtākaro Forest Park Inc	a community-led vision to transform the city to sea corridor into a vibrant native forest park along the Avon-Ōtākaro River. Work is currently underway to turn Brooker Reserve into a forest and wetland park. Schools and communities take part in working bees to plant and maintain native vegetation.	49A Surrey Street, Linwood
Greening the Rubble Trust	Three Tree Platforms	Projects over multiple locations
Avebury House Community Trust	Heritage and Arts Trail	Avebury House, 9 Evelyn Couzins Drive
Riverlution Tiny House Vil-lage	Tiny House Initiatives, the Funghi Farm, offers bookable spaces for organisations	46a Vogel Street

	and includes an outdoor space, computer room, kitchen and multiple meeting rooms.	
The Barkery Christchurch Limited	New Zealand's first adoptable dog cafe	395 New Brighton road, Christchurch
Ao Tawhiti Unlimited Discovery Board of Trustees	Climate action campus	44 Cowlishaw Street, Avonside, Christchurch
Canine Neuro Park Trust	Canine Neuro Park	Bexley
Dallington Residents Association	Glenarm Gardens	Dallington
Eco-Action Nursery Trust	Tree plantings, school programs, Eco-Action Nursery and Revegetation Project	Normans Road, Strowan, Christchurch

Appendix B - Available Grants and Funding

Name	Who	Eligibility	Purpose of the fund
Christchurch Biodiversity fund https://ccc.govt.nz/culture-and-community/community-funding/christchurch-biodiversity-fund/	Christchurch City Council	An applicant must be a legal entity with the capacity to contract to the Council: - Individual - Rūnanga - Businesses - Trusts - Societies - Universities - Schools - Landcare groups	- To protect areas of significant ecological value on private land within the boundaries of Christchurch City Council; - To support and encourage initiatives that protect and enhance indigenous biodiversity on private land.
Sustainability fund	Christchurch City Council	- Community organisations, schools, social	- To encourage community, school, social enterprise or

https://ccc.govt.nz/culture-and-community/community-funding/sustainability-fund/		enterprises and businesses can apply to this fund. - Applicants must be a legal entity registered in New Zealand, such as an incorporated society, charitable trust or limited liability company.	business projects that help meet our climate change objectives and targets.
Red Zones Transitional Use Fund https://ccc.govt.nz/culture-and-community/community-funding/red-zones-transitional-use-fund/	Christchurch City Council	- This fund is open to individuals, community organisations and social enterprise.	- To provide support to projects and events which help create activity and vibrancy in the red-zone areas, ahead of longer-term regeneration. This includes the Corridor - Te Tira Kāhikuhiku has been established to provide advice and recommendations to us and the Council on applications for temporary land-use initiatives.
Strengthening Communities Fund https://ccc.govt.nz/culture-and-community/community-funding/scfund/	Christchurch City Council	- You must be able to demonstrate that you are a sustainable, strategic, community-focused group with a significant presence within the community.	- This fund supports community-focused organisations whose projects contribute to the strengthening of community wellbeing in the Christchurch city area.
Rātā Foundation Funds • Learn	Rātā Foundation	- Funding is available for non-profit organisations including incorporated society,	- This fund supports projects, programmes or services involving people in actions benefiting our natural environment

• Participate • Support • Connect • Sustain https://ratafoundation.org.nz/en/funding		associations or organisations, charities and not-for-profit educational institution.	- Projects that aim to develop knowledge and skills through Environment Education or sustainability programmes to bring about positive environmental change
Community Organisation Grants Scheme (COGS) https://www.communitymatters.govt.nz/community-organisations-grants-scheme/	Community matters	Organisations requesting COGS grants need to show how their community-based services or projects will contribute to: - encouraging participation in communities - promoting community leadership - developing community capability - promoting social, economic and cultural equity, or - reducing the downstream social and economic costs to communities and government.	COGS provides grants to non-profit community groups and organisations delivering community-based social services, projects and events. Grants are one-off contributions for: - the running or operational costs of organisations that provide community-based social services - community development costs, such as hui, training, planning, evaluation and facilitator fees - community projects or event costs that: - encourage participation in communities - promote community leadership - promote social, economic and cultural equity.
Community and Volunteering Capability Fund	Community matters	Requests must align with 1 of the following 4 priorities to be considered for funding: - sector leadership	- The fund provides grants to not-for-profit organisations for services and projects that improve leadership and

https://www.communitymatters.govt.nz/community-and-volunteering-capability-fund/		- volunteering - organisational capability (through internships) - youth worker training.	strengthen the capability and capacity of New Zealand's diverse community and voluntary sector.
Community Environment Fund https://environment.govt.nz/what-you-can-do/funding/community-environment-fund/	Ministry for the Environment	Currently not accepting applications but may re-open in the future	- The Community Environment Fund empowers New Zealanders to make a positive difference to the environment. It supports projects that strengthen environmental partnerships, raise environmental awareness and encourage participation in environmental initiatives in the community.
Lottery Environment and Heritage Committee Grants https://www.communitymatters.govt.nz/lottery-environment-and-heritage/	Lottery NZ	The project must be aimed at achieving at least one of the following: - protect and restore habitats and ecosystems for native plants or animals - protect and conserve native plants or animals that are rare, in danger or at risk in their habitats - improve public access and information about native plants and animals.	- This fund provides grants for plans, reports and one-off projects that will protect, conserve and promote New Zealand's natural, cultural and physical heritage.

		- improve public access and information, particularly for young people to learn about and experience our cultural heritage	
Department of Conservation	Links to national organisations who provide funding and grants for community conservation groups: https://www.doc.govt.nz/get-involved/funding/other-funding-organisations/		

Appendix C – Definitions

Adaptation is defined by the IPCC as "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects".

Mitigation is defined by the IPCC as "A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). This report assesses human interventions to reduce the sources of other substances which may contribute directly or indirectly to limiting climate change, including, for example, the reduction of particulate matter emissions that can directly alter the radiation balance (e.g., black carbon) or measures that control emissions of carbon monoxide, nitrogen oxides, Volatile Organic Compounds and other pollutants that can alter the concentration of tropospheric ozone which has an indirect effect on the climate".

Co-operative housing is a form of home ownership. Residents own a share in a company which owns the building or land title.

Active transport are modes of transport where some or all the journey requires physical exertion.

Hazard funds are independent organisations. They oversee the funding of hazard mitigation, adaptation, and clean-up. They are organised by areas that are deemed to have high hazard risks. Residents in these areas pay into the fund monthly.

Mahinga Kai is about the value of natural resources that sustain life, including the life of people.

Microgrids are defined as "A microgrid is a self-sufficient energy system that serves a discrete geographic footprint, such as a college campus, hospital complex, business center or neighborhood. Within microgrids are one or more kinds of distributed energy (solar panels, wind turbines, combined heat and power, generators) that produce its power. In addition, many newer microgrids contain energy storage, typically from batteries. Some also now have electric vehicle charging stations."

Gentrification is defined by Miriam-Webster as "a process in which a poor area (as of a city) experiences an influx of middle-class or wealthy people who renovate and rebuild homes and businesses and which often results in an increase in property values and the displacement of earlier, usually poorer residents".

Ecological is defined by Merriam-Webster as "of or relating to the environments of living things or to the relationships between living things and their environments".

Carbon sequestration is defined by the IPCC as “The uptake (i.e., the addition of a substance of concern to a reservoir) of carbon containing substances, in particular carbon dioxide (CO2), in terrestrial or marine reservoirs. Biological sequestration includes direct removal of CO2 from the atmosphere through land-use change (LUC), afforestation, reforestation, revegetation, carbon storage in landfills and practices that enhance soil carbon in agriculture (cropland management, grazing land management).”.

Resilience is defined by Merriam-Webster as “an ability to recover from or adjust easily to misfortune or change”.

Ecological niche is defined in the Encyclopaedia of Ecology second edition as “Ecological niche is a term for the position of a species within an ecosystem, describing both the range of conditions necessary for persistence of the species, and its ecological role in the ecosystem.”

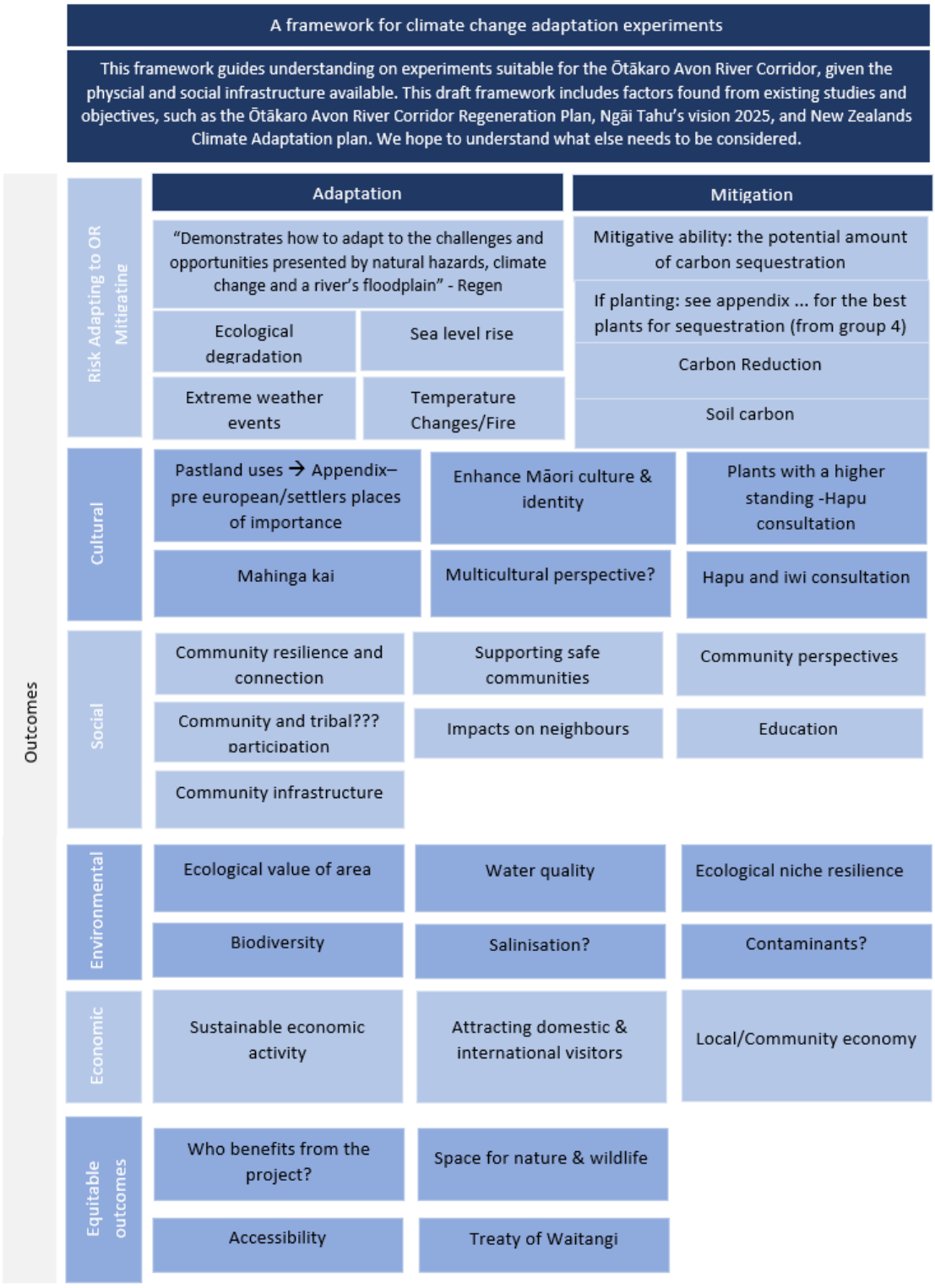
Accessibility is how easily is the site reached and how usable is it by people from different backgrounds or with different needs and mobility. It can also include nature's ability to access and use the sites.

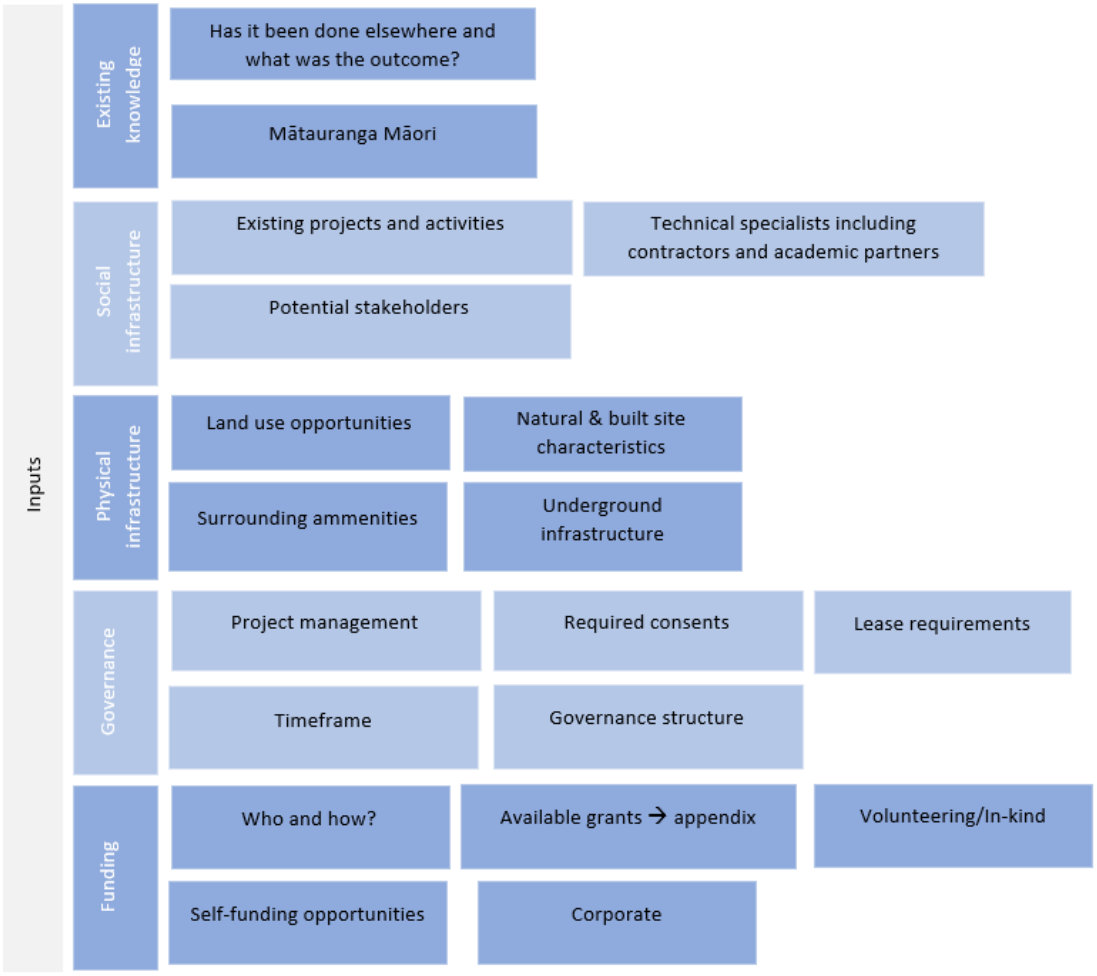
Stakeholders are people who are either affected by a project or interested in a project or involved in a project.

Natural and built site characteristics identifies what already exists at the site.

Underground infrastructure includes three waters pipes, electricity cables, and broadband cables.

Appendix D – framework table




Inputs
Existing knowledge
Has it been done elsewhere and what was the outcome?
Mātauranga Māori
Social infrastructure
Existing projects and activities
Technical specialists including contractors and academic partners
Potential stakeholders
Physical infrastructure
Land use opportunities
Natural & built site characteristics
Surrounding ammenities
Underground infrastructure
Governance
Project management
Required consents
Lease requirements
Timeframe
Governance structure
Funding
Who and how?
Available grants → appendix
Volunteering/In-kind
Self-funding opportunities
Corporate

Appendix E – Case Studies

Table 1 – Wetland and Riparian planting experiment tested against the framework

OUTCOMES			
	How the experiment address this area	**Improvements and further considerations required**	**Alignment with framework**
Adaptation and Mitigation	This experiment has the potential for both mitigation and adaptation to climate change. To mitigate the effects of climate change, wetland restoration and enhancement can be used as a form of carbon sequestration. Wetlands are so effective for sequestering carbon due to their high biodiversity and having the highest soil carbon density of all land-based ecosystems. Wetland adaptation properties include providing resilience to hazards such as flooding, storm surge and coastal inundation. Restoring these biodiverse areas is an ideal nature-based solution to mitigate the effects of climate change due to their pollutant fixation and flood water retention properties. Restored and maintained riparian zones increase bank stability and reduce erosion and runoff of soil which is particularly important when it comes to the risk of climate change induced extreme events that put the river corridor at risk. Riparian planting can mitigate the risk of flooding and storms through enhancing the resilience of the riparian zone of the river and, therefore, protecting the health of the river and its freshwater ecosystems.	Research in to the most suitable plants for wetlands and riparian planting would need to occur. Root depth and structure and depth would need to be considered to allow for good soil drainage and allowing the flood plain to flood when needed.	5
Social	Restoration and creation of riparian and wetland areas can provide social amenities and create areas in which people can gather and enjoy nature. This would also contribute to	There is potential for community involvement and participation to be enhanced by this experiment but it would need to be carried out in a way	3

	community resilience and creating safer communities by increasing resilience to flooding events and bringing more people in to the area and therefore making the river corridor a safer area for recreation.	where community involvement is accessible.	
Cultural	Restoration of wetlands aligns with pre-settler past land uses and restoring these areas would bring back significant Mahinga Kai sites.	Consultation with Iwi would need to occur to make sure that the right plants are planted for the land and for Mahinga Kai purposes. Plant standings would also need to be considered.	4
Environmental	This experiment would meet the environmental expectations of the framework by enhancing the ecological value of the area, increasing ecological niche resilience, increasing biodiversity and enhancing water quality.	Planting and restoration activities would need to be carried out in a way that does not disturb existing ecosystems and only enhances them, and not taking away from existing ecological areas.	5
Economic	This project is low cost and effective compared to other adaptation and mitigation measures. It has the potential to enhance local economies by bringing more people in to the area through increase amenity value. Eco system services flooding prevention cost reductions	The experiment should be carried out in a way that ensures sustainable economic activity where maintenance of the riparian and wetland areas is considered in the budget.	2
Equitable outcomes	Space for nature and wildlife is enhanced by this experiment. The benefits of this experiment will be widespread as the area will be able to be enjoyed by a range of communities.	The Treaty of Waitangi and Mātauranga Māori principles should be taken in to consideration in this experiment to ensure equitable outcomes.	3
INPUTS			
Existing Knowledge	Mātauranga Māori can provide a wealth of knowledge in this area that can be applied to this experiment. Wetland restoration and riparian planting has been successfully carried out all over New Zealand.	Which plants more suitable	
Social Infrastructure	Aspects of this experiment are already being carried out or there are plans in place in the area and this experiment could	Consideration should be taken to not overlap or disregard existing plans	

	increase the extent and effectiveness of this. Existing plans and contacts can be used for this.		
Physical infrastructure	The area already has a large number of remnant wetlands that are suitable for this experiment.	Potential underground infrastructure should be taken in to consideration as it may interfere with planting activities.	
Funding	This experiment/ project is eligible for a number of community grants.		
Governance		Consideration should be taken in to what consents are required and what kind of specialists need to be involved in this.	

Table 2 – Pa Harakeke experiment tested against the framework

	How the experiment addresses this area	**Considerations/improvements required**	**Alignment**
OUTCOMES			
Adaptation and Mitigation	Low carbon alternative material Contributes to wetland sequestration	Research into harakeke sequestration potential River blockages, reduces flood plain effectiveness	**2.5**
Social	They provide space for raranga rōpū (weaving groups), gathering, community participation, and the education of school groups (Te Herenga Waka, 2022). There is the risk only a select group may interact with them, so considerations need to be made to optimise engagement	Only people willing/able to be involved	**3**
Cultural	Harakeke is a taonga species for iwi, hapū, and whanau. The mātauranga (knowledge) around harakeke cultivation, and harvesting is also considered taonga (Kane et al., 2019). The contribution towards		**5**

	mahinga kai also builds cultural knowledge and participation.		
Environmental	Roz Rolls mentioned the biodiversity benefits, with their attraction as a habitat for native birds. Incorporating it into riparian planting and wetlands contributes to ecological restoration, including countering pollutant runoff (Te Herenga Waka, 2022)		**3**
Economic	In the early 20th century, Harakeke muka was New Zealand's biggest export. Production declined due to competition from other fibres (increasing synthetics) and yellow-leaf disease (Scheele, 2005). Today, as mentioned by a number of stakeholders, garments, soaps, oils, and other cosmetics are made with harakeke (Department of Conservation, n.d.). Natural composites are also making a resurgence. KiwiFibre CEO also sees potential for use in fibreglass replacements, decking, jib board, and the geospatial engineering industry (Standing Room Only, 2022).	From a business perspective, gaining patents on Harakeke uses can be difficult (RNZ). Many techniques can't be patented because the knowledge is not new, but is mātauranga māori, so has been passed on for generations. in future early stages processing in NZ but later processing overseas	**4**
Equitable outcomes	Allows people to gather their own resources. It also engages people with matauranga māori, furthering understanding and inclusion.	Some groups may be excluded from product consumption, as they are likely to be expensive (Department of Conservation, n.d.).	**3**
INPUTS			
Existing Knowledge	**Not much**		
Social Infrastructure	Ngāi Tahu weavers including Ranui Ngarimu, Reihana Parata (Aunty Doe), Morehu Flutey-Henare and others are recognised as		

	some of the best weavers in Aotearoa (Ngai tahu) Manaaki Whenua continues to research harakeke taxonomy and properties, and to add other cultivars to the National Collection (landcare research)		
Physical infrastructure	According to Landcare research, the best quality plants grow on fertile, well-drained soil. They do not thrive in stagnant water, but do not mind occasional flooding, and are suitable for river edges and non-shaded, sunny areas. Mature plants can withstand drought and non-prolonged frosts. Young plants are more susceptible to these so would need to be attended to. This experiment could come in different forms and sizes. If it were to involve large Harakeke plantations to be harvested for commercial material production, large areas of such land would be required. If a more community-based experiment was conducted, the area would not need to be as large, but it would need to be accessible to those wanting to use it, with other surrounding amenities such as gathering areas, public restrooms, and security measures. Old processing flax mills		
Funding	Industry revenue into it Partnership In-kind		
Governance			

Table 3 – Sustainable Housing experiment tested against the framework

	How the experiments addresses this area	Considerations/improvements required	Alignment with Framework
OUTCOMES			
Adaptation and Mitigation	-Energy consumption (manufacturing and use) -Flood resilience -Sea level rise -Energy efficiency (temperature)	-Use of resources (reusing)	4
Social	-Community resilience (place to go) -Community infrastructure -Community participation (get local builders and consultants to educate them on innovative building methods), this also incorporates community perspectives -If new development; building designs could be released for others to use etc. -More housing increases the safety of space	-Community participation (get kids involved from climate action campus to design) -Impacts on neighbours; noise (go to area door knocking, talk to people in area, explain purpose of development for their understanding and acceptance)	3
Cultural	-If communal, incorporate cultural designs etc. -Looking after resources, reusing etc. -Looking after land; kaitiakitanga	-Past land uses; consider where it is culturally inappropriate to develop housing -Discuss with Ngāi Tūāhuriri	2
Environmental	-Shedding of contaminants (runoff etc.); reduced with green roof -Refer to list of recommended plants -Biodiversity; green roof	-Reusing greywater -Housing takes up space that could be used for restoration etc. -Increase people/pets could affect surrounding area wildlife -Consideration of ecological area prior -Consideration of where materials have come from	4
Economic	-Jobs with building		4

	-Reduces sprawl of city onto productive land -Less power/energy (sustainable economic activity) -Exhibition building could entice people -People back in area could increase people in area to start business's etc. increasing local economy		
Equitable outcomes	-Making sure homes are accessible to users -Gardens, green roofs, greenspaces for wildlife -Native planting for native wildlife	-Gentrified (increase price with attraction of area, decreasing accessibility)	2
INPUTS			
Existing Knowledge	-Has not been done so much in New Zealand, but has been done internationally -Housing has been in this area in past -TC3 land requirements	-Further research required to see how this type of housing works in a New Zealand setting	n/a
Physical infrastructure	-Present underground infrastructure not being used -Existing roads, transport links, river access		n/a
Social Infrastructure	-Lots of different people/experts to help	-Activities are already happening in the planned area	n/a
Governance		-Who is developing it -Long-term timeframe	n/a
Funding		-Private sale of house -Investments -Rates (council)	n/a

Table 4 - Diverse lawns experiment tested against the framework

OUTCOMES	

	How the experiment addresses this section of the framework	Improvements and further considerations required	Alignment with Framework (0-5)
Adaptation and Mitigation	- Diverse lawns have the chance to significantly reduce greenhouse gas emissions due to no heavy machinery or lawn mowers. - Increase plant growth by improving soil quality and soil moisture - Allows for a sustainable environment letting nature grow its own path. - With more plants, more carbon dioxide absorbed through photosynthesis as exchange for oxygen	-	3
Social	- Diverse lawns in the Avon river corridor could have the potential to change people's attitudes		1

	towards maintained lawns and could apply to their own gardens.		
Cultural	- Source of mahinga kai by Waitaha, Ngāti Māmoe and Ngāi Tahu.	- planting more native species including harakeke.	1
Environmental	- Allows habitat for wildlife - Improves soil quality with soil moisture - Pollination -	- Minimal leaching issue with nutrients in the soil	4
Economic	- It would save the council mowing/maintaining the land		2
Equitable outcomes	- Provides space from nature for bees and attracts birds to the area		1
INPUTS			
Existing Knowledge	- Diverse lawns haven't been done a lot in New Zealand this is because		

	people are unaware of the benefits and people are in habits of identifying maintained lawns as 'tidy' and in the U.S		
Social Infrastructure	N/A		
Physical infrastructure	N/A		
Funding	- Little to no cost involved	N/A	

Table 5 – Community Housing experiment tested against the framework

OUTCOMES			
Adaptation and Mitigation	**How the experiment addresses this section of the framework**	**Improvements and further considerations required**	**Alignment**
Which climate challenge will the experiment help adapt to and how?	Hazard funds, microgrids, co-operative housing and active transport all provide adaptative benefits as they increase community and infrastructure resilience and can increase adaptation to risks like increased extreme weather events (Lamb et al., 2022; Papageorgiou et al., 2020). Microgrids, hazard funds and active transport can also be mitigative as they can reduce emissions from transport and infrastructure	Further site-specific assessment for the most prominent risks that require adaptation would be needed.	4

	(Curtin Jr & Zovod, 2003; Koetse & Rietveld, 2012; Papageorgiou et al., 2020).		
Social	All these experiments support improved social outcomes, particularly community resilience, participation, understanding perspectives, community infrastructure and safer communities (Altus & Mathews, 2002; Faherty & Morrissey, 2014).		5
Cultural	Some of these experiments could provide cultural benefits. There in potential in the co-operative housing and hazard fund for a co-governance arrangement. Co-operative housing could also become more like traditional Māori housing. Microgrids and active transport are more infrastructure based so do not directly impact cultural outcomes (Berghan, 2021; Olin et al., 2022).	An investigation into how co-governance could be incorporated into co-operative housing and hazard funds would be needed.	2
Environmental	All these experiments can have some environmental benefits. Hazard funds can protect nature, people and infrastructure as well as preferring nature-based solutions and reducing the impacts of any hazard mitigation they undertake (Curtin Jr & Zovod, 2003; Olshansky, 1996). Co-operative housing tends to… Active transport uses less land area than private vehicles, reduces and reduces emissions (Koetse & Rietveld, 2012; Tuominen et al., 2022). The microgrid allows for less land to be used to generate electricity for	There are a few considerations in the environmental area. Active transport routes will need to be planned to reduce untreated surface runoff. Hazard fund actions cannot degrade the environment further.	3

	the national grid (Papageorgiou et al., 2020). It may reduce the need for new hydro schemes.		
Economic	All the experiments have economic benefits. Co-operative housing allows for more people to own housing for less (Olin et al., 2022). The hazard fund benefits as it reduces the amount spent by councils or government on hazard mitigation and clean up (Olshansky, 1996). Active transport provides economic benefits as land along transit corridors tend to increase in value, there is potential to set up a value recapture scheme which could pay for part of the installation of the transport (Tuominen et al., 2022). Microgrids provide economic benefits as they allow for cheaper energy and energy that customers have control over (King & Morgan, 2007).	There are considerations with how the hazard fund will be set up and how much it will cost the residents. Other considerations are the cost of developing active transport. Currently in Christchurch a cycleway costs $3 million per kilometre (Law, 2021).	4
Equitable outcomes	All these experiments have the potential for equitable outcomes. Co-operative housing allows all residents a say in the organization and running of the area (Ellerman**, 1983). The hazard fund can be spent to protect more at-risk people and infrastructure (Curtin Jr & Zovod, 2003). Active transport is equitable if it is equally accessible (Faherty & Morrissey, 2014). Microgrids are equitable as the increase community power and reduce the power of corporations to take advantage of them (Anderson et al., 2022).	The biggest equitability issue with developing the river corridor is the potential of gentrification. This would reduce access to the space and have negative equitable outcomes.	3
INPUTS			

Existing Knowledge	Co-operative housing is common overseas, however there are only three in New Zealand. Hazard funds are used overseas such as in California (GHAD). Active transport is being developed in Christchurch already. Microgrids are becoming more common overseas particularly in the global south.	How would a hazard fund work in New Zealand within the law.	
Social Infra-structure	There are many people who are interested in the river corridor, some of these people have technical knowledge, others are community members. The co-operative creates its own social infrastructure and microgrids could be installed by existing solar installers.		
Physical infra-structure	There is both underground and overground infrastructure already in place in the river corridor. Much of it is still in use. The roading network is not maintained but is currently adequate for non-car usage.		
Funding	The hazard fund would be self-funding with the ability to take out loans against it as capital and a steady source of income. Active transport would require funding from Christchurch City Council or Waka Kotahi. The microgrid has the potential to gain back all initial capital invested. The co-operative housing would require investment from members.	How is the hazard fund is structured.	

Appendix F - Interview Questions

1. How have you been involved in working in the Ōtākaro Avon river corridor?
2. What climate change vulnerabilities are you aware of in urban areas such as this, now and in the future?
3. The living lab is aiming to support experimentation in the river corridor for climate mitigation and adaptation. We have compiled a few ideas for experiments from other stakeholders. Out of these ideas, what are the top three ideas you would see working the best in the river corridor? And why?
    - Riparian Planting
    - Harakeke Industry
    - Wetlands
    - Wildflower/regenerative/diverse lawns (complexifying lawns):
    - Solar panels
    - Cooling park
    - Energy efficient housing (green roofs, insulation, building materials etc)
    - Flood and earthquake resistant housing (stilts, water resistant material etc.)
4. What other ideas do you have for experimentation in the Ōtākaro Avon river corridor for climate mitigation and adaptation? Are you aware of any sections of the river corridor that would be suitable for these?
5. What are barriers preventing involvement in projects in the Ōtākaro Avon river corridor and do you have any suggestions to mitigate these?
6. What current funding avenues do you have for this kind of work?
7. One outcome of our research is a creating a framework that guides stakeholders to understand what experiments would be suitable for the area, given the physical and social infrastructure available. There are a number of factors that need to be included in this. We have drafted a framework that includes factors we've found from existing studies and objectives, such as the Ōtākaro Avon River Corridor Regeneration Plan, Ngāi Tahu's vision 2025, and New Zealands Climate Adaptation plan. Do you have any suggestions for our framework? Such as other things that need to be considered.
8. Are you interested in working on innovative experiments in the river corridor in the future?
9. Do you have any ideas for what would encourage you and other groups to be involved in experiments in the river corridor? For example, decision making tools, frameworks.