MAKING NEW ZEALAND GREEN AGAIN – A ‘LIVING’ ROOF STORY

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ABSTRACT

Auckland Council has installed a living roof (green or vegetated roof) on the Auckland Central City Library in response to delivering climate change targets and raising awareness of the environmental, economic, social, and cultural benefits living infrastructure can provide.

Living roofs are becoming increasingly common in cities worldwide for their ability to improve climate change adaptation, energy conservation, food production, and the potential to develop more sustainable and environmentally friendly living environments. Rapid population growth, advanced stages of urbanisation and the alteration of the natural environment defined by increments of hard impervious surfaces, pollution and a lack of contact with nature underline the importance and relevance of green infrastructure solutions, such as living roofs. Despite this, in New Zealand, living roofs are rarely included in developments, and if they are, most are being designed in isolation.

This paper outlines the multiple stormwater management benefits of living roofs, including reducing runoff and improving runoff quality, ultimately reducing some of the pressures placed on the public stormwater network and the receiving environment. Additional recognised benefits that are important for climate change adaptation and sustainability within our cities will also be described, including enhanced biodiversity, energy savings, urban heat island mitigation, air quality improvement, noise reduction, biophilic amenity and resulting human productivity improvements, and increased real estate values.

Some of the actual benefits will be measured and quantified using the Auckland Central City Library Living Roof as a local test case. A comparison study is proposed utilising a replica of the installed living roof, the pre-living roof as control, alongside several other options. This paper will describe the monitoring methodology and programme that will take place over the next five years to help Tāmaki Makaurau understand the benefits from both a building owner and the broader environmental perspective.

The paper also describes how the living roof installation responds to Auckland Council’s desire to lead by example in meeting environmental objectives related to our changing climate. The paper will outline the current legislation and some of the overseas possibilities through policies or incentives that have been found to support better outcomes. The overall monitoring project aims to discuss the legislative differences that encourage the uptake of living roofs in cities and to educate and raise awareness of the benefits of living infrastructure.

KEYWORDS

Living roof, nature-based solutions, green infrastructure, climate resilience, stormwater management, sustainability, urban heat island effect, biodiversity

PRESENTER PROFILE

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Zoë is an urbanist, passionate about urban design, landscape architecture, planning, and the environment. She is the Associate Director of Design (Urban Planning), School of Architecture and Planning at the University of Auckland and Director at The Urbanist. For more than twenty years, Zoë has focused on sustainability in policy and development, including incorporating nature-based solutions into our urban environments.

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Hillary is an Environmental Specialist at Tektus Consultants. Hillary holds specialist knowledge of resource consent and compliance requirements in the disciplines of stormwater, wastewater, and industrial trade, built through experience in local government and consulting across a broad range of projects. Her expertise includes the development of stormwater management and monitoring plans.

1.0 INTRODUCTION

1.1 LIVING ROOFS

Living roofs are intentionally vegetated roofs and include ornamental roof gardens, naturally vegetated roofs, and biodiversity roofs (Grant, 2006). Living roofs range from the commonly seen extensively vegetated to intensively vegetated roofs. They are classified into different categories according to three main aspects: the intended use, physical properties (depth of substrate), and maintenance requirements (European Federation of Green Roof Associations., 2018).

Figure 1: **Living Roof, London, UK**

Source: **Zoë Avery, The Urbanist**

Living roofs are a form of green infrastructure, a nature-based solution that intersects between landscape, urban built form, nature, people, and place. These systems have significant relevance to addressing pressing global issues related to climate change, rapid population growth, urbanisation and alteration of natural environments defined by increments of hard surfaces, pollution, and people's increasing lack of contact with nature (Milliken, 2018).

Living roofs can blend beauty and function. The multifaceted benefits can help address both environmental factors (IPCC AR6 WGIII, 2022) caused by urbanisation, assist non-human life within the city, and engage with beneficial human processes. When living roofs are utilised in cities and are designed well, a more climate resilient city that provides amenities for city residents, both human and non-human in a changing world can be realised (Milliken, 2018).

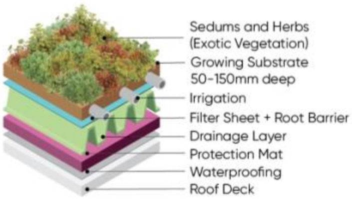

Figure 2: Extensive Living Roof Typology

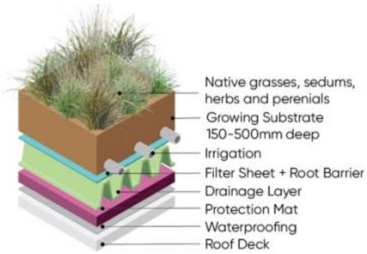

Figure 3: Semi-Intensive Living Roof Typology

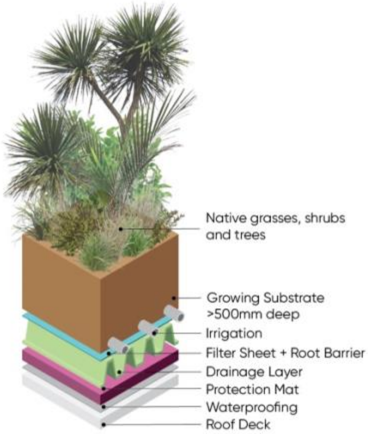

Figure 4: Intensive Living Roof Typology

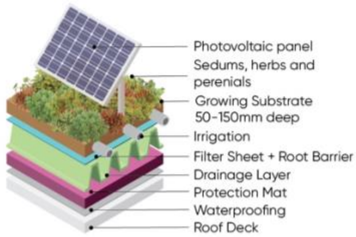

Figure 5: Bio-solar Living Roof Typology

Figure 6: Biodiverse Living Roof Typology

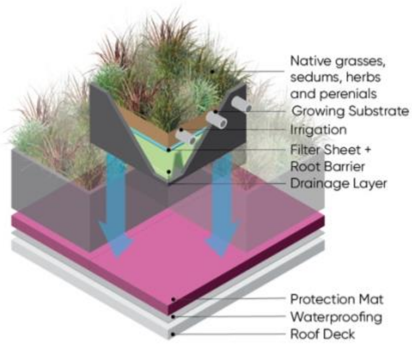

Figure 7: Modular Living Roof Typology

Source: Pukapuka tātaki ki te mataora tuanui, Whangārei Living Roof Guide

1.2 THE PROBLEM

Despite the myriad of benefits achieved in cities internationally, there is a lack of living roofs incorporated into New Zealand's urban developments. In the isolated cases they are utilised, most are being designed with limited function, resulting in living roofs that realise a limited number of potential benefits. For example, they can be disconnected and inaccessible from the building or street, lack biodiversity, or are designed for one benefit alone (e.g. aesthetics), or are inappropriate for their location. This means that many of the benefits living roofs can provide are overlooked and not realised. It is possible that the lack of living roof uptake in New Zealand does not relate solely to increased cost or perceived additional risk but to a lack of knowledge about the benefits they can provide and of how the design of living roofs translates into the realised benefits (Curry & Larsson, 2017).

Figure 8: **Sedum Living Roof**

Humankind is riding the largest wave of urban growth in history, with more than half of the world's population now living in towns and cities. This number is expected to swell to five billion, or 60%, by 2030. With more people living in cities globally, the state of the urban environment will directly influence the quality of life. While cities occupy only five percent of the world's land surface, they consume 75% of its natural resources and account for 80% of global greenhouse gas emissions (United Nations, 2016).

Figure 9: **Impacts of urban built form with and without living roofs**
Source: **The Urbanist**

Cities have more hard surfaces, less green space, and less permeable areas reinforcing human disconnect from nature while also contributing to the impacts of surface runoff and flash flooding, along with interrupted or damaged ecological systems and processes. Although cities can be places that are arguably unfit for human physical and psychological needs, cities are not inherently bad as increased density has many benefits and efficiencies. However, sustainability, climate change resilience and wellbeing challenges must be resolved within cities – at the source of the problem. This is important to mitigate climate change risks, such as flooding and urban heat island effects because productivity is directly linked to well-being. With 85% of global domestic product generated in cities, small increments of productivity gain can have a significant impact (United Nations, 2016).

Cities are urban systems that can create a range of adverse outcomes for people and the environment if not designed with holistic human and environmental considerations in mind. They usually have large areas of impervious surface that contribute to flood risk and generate pollution and heat from commerce, industry, and transportation (Milliken, 2018). These impacts occur alongside the buildings and hard surfaces retention of solar energy leading to a warmer city environment (Dover, 2018).

There is a growing interest around the world in nature-based solutions as a toolkit for integrating nature with the built form to mitigate problems associated with urbanisation. Where the standard approach has been utilising parks and open spaces or street trees, more recently, rain gardens, living roofs and facades have added to the palette of opportunities. These systems help restore natural processes utilising the built environment (Dover, 2018).

Worldwide, living roofs are being prioritised and promoted by local, regional and national governments via a mix of guidelines, policies and incentives (Malina, 2011). Where these interventions have been utilised, thriving living roof industries have developed along with significant urban roof space being converted or built with living roofs (Dong, et al., 2020). Notably, policies focused on encouraging living roofs within New Zealand are lacking.

2.0 BENEFITS

Living roofs are a form of sustainable urban drainage, replicating natural drainage patterns, reducing stormwater runoff, and reducing the impacts of flash flooding. Through stormwater attenuation, living roofs absorb rainwater through their soil and vegetation, then gradually release it back into the atmosphere through evapotranspiration. Excess rainfall is diverted to the onsite drainage system. In many cases living roofs can absorb up to 70% of stormwater, depending on the substrate depth and environmental factors (Voyde, et al., 2008).

It is widely acknowledged through international research and case studies that living roofs offer significant benefits, both environmentally, socially, and economically. *"Few, if any, public policies can accomplish so much with so little, as green roof requirements. They leverage private investment for multiple public benefits, generate private benefits, do so on otherwise squandered space, and are relatively easy and low cost to administer"* (Stern, et al., 2019).

They protect the roof membrane from UV and weather damage and can extend the roof life by as much as two or three times (ARUP, 2011). They can add to property values by providing additional and more marketable living space, increasing rents by up to 16% (Ichihara & Cohen, 2011), and can save a significant amount of energy by reducing heating and cooling bills through the insulation of the building, which reduces energy expenditure and carbon emissions (Berardi, 2016).

With global temperatures increasing along with the associated health problems and increased heat-related morbidity, living roofs are a low-cost way of reducing the urban heat island effect (Horwitz-Bennett, 2013). They can reduce noise levels entering and leaving the building by up to 18 decibels (dB) and reflective noise by 3 dB or more (Van Renterghem, 2017).

Living roofs can provide a valuable public amenity for residents and workers and improve views from surrounding buildings (Ichihara & Cohen, 2011). They can raise a company's green credentials and are an effective way to demonstrate corporate social responsibility. The potential benefits are far-reaching, as shown in the diagram below.

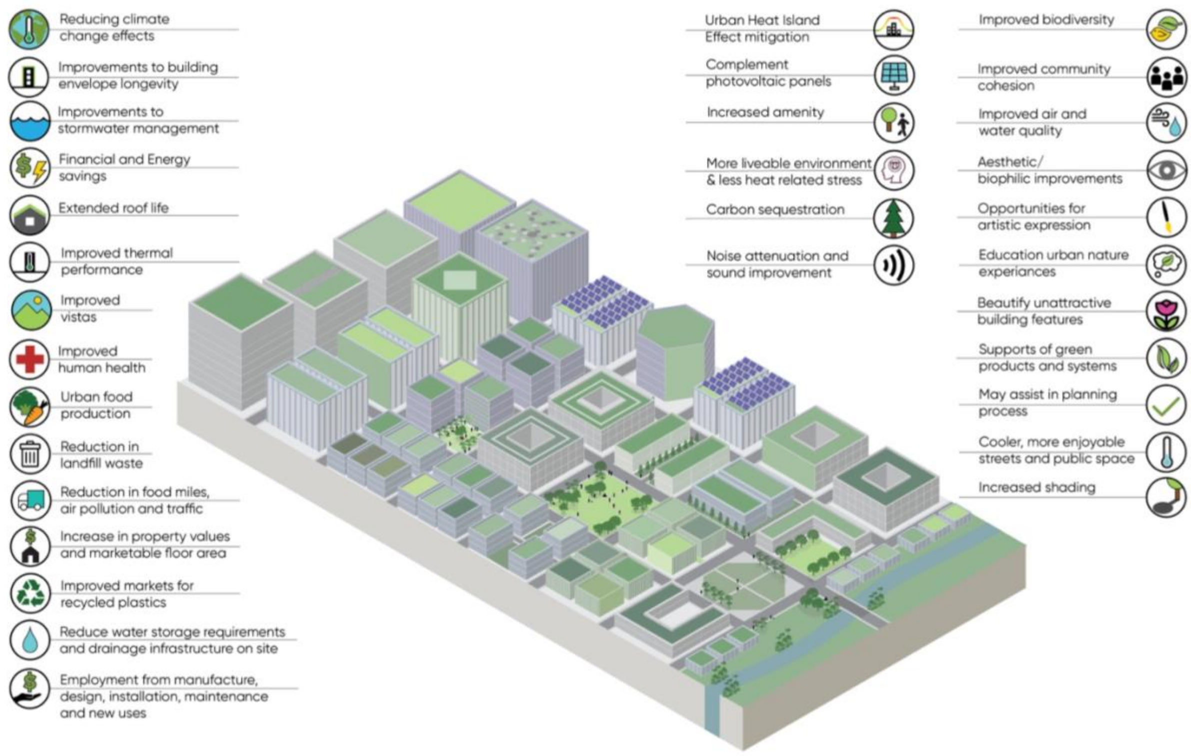

Figure 10: **Benefits of nature-based solutions**
Source: **Whangārei Living Roof Guide (adapted by The Urbanist)**

Tāmaki Makaurau has few living roofs, and uptake is slow compared to other international cities.

2.1 STORMWATER MANAGEMENT

Living roofs are systems commonly used for water-sensitive urban design (Razzaghmanesh, et al., 2014). Stormwater management is a common topic we address in our cities and requires significant infrastructure and associated management costs.

Most of our existing urban drainage systems are at capacity (Quinn & Neale, 2018). Many have been designed so long ago as a system of combined surface water and wastewater (Sharman, et al., 2012). Moreover, we have a local problem of storm events causing stormwater systems to be overwhelmed and mix with sewerage, causing contamination of outflows to our oceans and tributaries (Voyde, et al., 2010).

The nature of climate change at a regional level will vary in New Zealand. Projections of future climate change indicate that there will be more frequent, short-duration, high-intensity rain (Ministry for the Environment, 2018). Extreme rainfall is likely to increase in most areas, with the most significant increases seen in regions where mean rainfall is also increasing, such as the West Coast. Living roofs can support stormwater management due to their attenuation capabilities, reducing what would otherwise be placed on the stormwater network (ARUP, 2011).

2.2 BIODIVERSITY & HABITAT CREATION

Living Roofs can provide significant biodiversity benefits enhancing sustainability. Many countries see the merits in installing living roofs to provide habitats and 'green links' (connecting points) for birds, insects and other species that contribute to broader ecosystem health. Switzerland has moved towards introducing living roof systems that mimic natural habitats found locally (Kazmierczak & Carter, 2010).

Living Roofs can improve biodiversity by providing much-needed green spaces, especially in industrial or commercial areas. They create new green links/ corridors for species to network and move along. They may also provide a mosaic of habitats for endangered plants, invertebrates, and birds (Mayrand & Clergeau, 2018). Living roofs can provide connections across cities that short-range species would not be able to cross otherwise. This is important in ensuring populations do not become isolated.

It has been demonstrated that to create an invertebrate-rich living roof, you need to consider varying substrates, varying depths, different local plants and the incorporation of dry wood or rocks for habitat (Brenneisen, 2006).

Figure 112: **Biodiverse living roof, Whangārei, Northland, Aotearoa**
Source: **Zoë Avery, The Urbanist**

2.3 INCREASE IN PROPERTY VALUES

The provision of a living roof can result in increased property values because of:

- Enhanced aesthetic appeal;
- Increased marketable floor space, in the case of accessible living roofs; and
- Lower building operating costs.

Living roofs benefit workplace productivity, recruitment and staff retention (Loder, 2014). The more attractive and environmentally friendly a building is, the more sought-after it will be; therefore, higher leases and property values can be demanded (Ichihara & Cohen, 2011).

Canadian research estimates that buildings with a recreational living roof can achieve an 11% increase in property value, and buildings with views onto living roofs may have a 4.5% increase in property value (Tomalty & Komorowski, 2010).

On a broader scale, overseas studies show that aesthetics and biodiversity in an urban context appeal to city dwellers (Qiu, et al., 2013) and that green infrastructure will be essential to the long-term sustainability of city environments (Pinho, et al., 2016).

2.4 IMPROVED BUILDING PERFORMANCE

Living roofs can benefit the 'whole life' cost of the building. Whole life costing is an investment appraisal and management tool that assesses an asset's total cost over its life (The Chartered Institute of Public Finance & Accountancy, 2011). Research in London has shown a benefit to the whole life cost of a building with the incorporation of a living roof (Feng & Hewage, 2018).

New Zealand has an independent green building rating system called 'Green Star NZ and Homestar NZ' that promotes better buildings because better buildings mean healthier, happier people (The New Zealand Green Building Council, 2018). Living roofs can provide more benefits than living walls, and the benefits could be extended, providing more points from energy and ecology to emissions. For example, under 'Homestar V5', living roofs and walls can receive a higher score in native ecology (if they are planted with native species) and on-site food production (vegetable gardens and fruit producing plants) credits. Living roofs are also recognised for their stormwater management benefits by Homestar, with an additional 0.5 to 1.5 points to be gained depending on the criteria met. Living roofs can also receive an innovation score depending on the type proposed. As such, they can increase the score achieved in the tool.

Studies show that the membrane temperature beneath a living roof can be significantly lower than where the membrane is exposed. In one study, temperature fluctuations during spring and summer on a conventional roof were 45°C, whereas, under a living roof, the fluctuations were 6°C (Liu, 2013). The reduction in membrane temperature fluctuations, in conjunction with protection from sunlight, frost and other weather damage, means that a living roof can extend the life of the membrane by two to three times, thus providing further cost savings over the life of the building.

2.5 URBAN HEAT ISLAND

Our urban areas have a higher average temperature than our rural areas (Zhao, et al., 2014). The urban heat island effect is the term used to describe the difference in these temperatures. With climate change increasing, the number of hot days we experience in our cities and our reliance on air conditioning will increase. Living roofs are a proven technique to help mitigate the urban heat island effect (Susca, et al., 2011).

The two most recognised methods for reducing the urban heat island effect are to:

- Introduce more vegetation into the urban environment, providing shading and cooling through evapotranspiration.
- Increase the albedo or reflectiveness of roofs to reflect a higher amount of solar radiation into the atmosphere and capture less heat.

Living roofs are now commonly being used overseas to mitigate the effects of the urban heat island effect.

2.6 ENERGY

Living roofs can reduce insulation requirements, energy demands and associated costs. Research undertaken in Toronto estimated that there could be a $21 million energy saving from implementing a citywide living roofing scheme, based on annual energy savings of 4.15 kWh/m (Banting, et al., 2005). Studies in Germany and the United States also suggest that cities can have significant energy savings from the introduction of living roofs (Castleton, et al., 2010).

Environment Canada has undertaken research showing that the upper floor of a building with a living roof will likely save 20% of its energy demand by reducing cooling needs. A five-storey or higher building in summer could save in the region of 6%, and a two-storey building in summer would be between 10-12% (Environment Canada, 2008: Dr Brad Bass, personal communication, March 2016).

2.7 URBAN AGRICULTURE

Living roofs are being considered more for food production, with the increasing cost of food transportation and reducing "food miles" (Walters & Midden, 2018). Inner city market gardens are being installed in Europe, the US and China and more often and more widespread are living roofs used for hydroponic or container food production. On occasion, this approach has been expanded to include living walls and facades, with fruiting climbing plants as a means for food production.

Living roofs are particularly important for densely populated cities where space is at a premium. Singapore, China and the United States have many thriving food-producing living roofs (Ehrenberg, 2008). Incorporating beehives on rooftops is becoming more common worldwide to support and enhance the urban bee population (Hofmann & Renner, 2018).

2.8 ACOUSTICS

Living roofs can act as a significant barrier to sound. The components of a living roof system, from the soil, vegetation and drainage layers, all act to absorb, reflect or deflect sound waves. Studies suggest that a living roof can reduce sound compared to a standard roof (Galbrun & Scerri, 2017). Urban areas that suffer from high levels of noise pollution, such as buildings within flight paths, could benefit from the installation of living roofs.

2.9 AIR AND WATER QUALITY

Vegetation and soil have been proven to help filter pollutants and dust from the air and water (Wang, et al., 2017). Wetlands are being trialled on living roofs in the United Kingdom, which can provide sustainability by helping filter and treat water (Thurling, 2007).

2.10 BIOPHILIC AMENITY AND WELLBEING

We are riding the largest wave of urban growth in history, with more than half of our world's population now living in towns and cities. This number is expected to grow, adding 2.5 billion to the world's urban population by 2050 (United Nations, 2018). Yet urban environments have inadvertently disconnected us from nature, an important psychological need (Kellert, et al., 2008).

Biophilia is proposed as an innate and genetically determined affinity that humans have with the natural world, with evidence that contact with greenery or vegetation benefits humans (Heerwagen & Hase, 2001). Reduced stress levels and cleaner water and air have been attributed to the provision of green space (Richardson, et al., 2013).

Not only does our connection with nature improve our mental well-being, research shows we are also more productive (Kellert, et al., 2008). Economically, these benefits promote reduced mental health and wellbeing costs, improved workplace productivity, and increased happiness and fulfilment. Although we are beginning to understand this impact, we are still creating 'hard' spaces with limited opportunities for nature (Dover, 2018). Research shows that people benefit from contact with other living things, where we engage all five senses - touch, taste, sight, smell, and sound (Franco, et al., 2017).

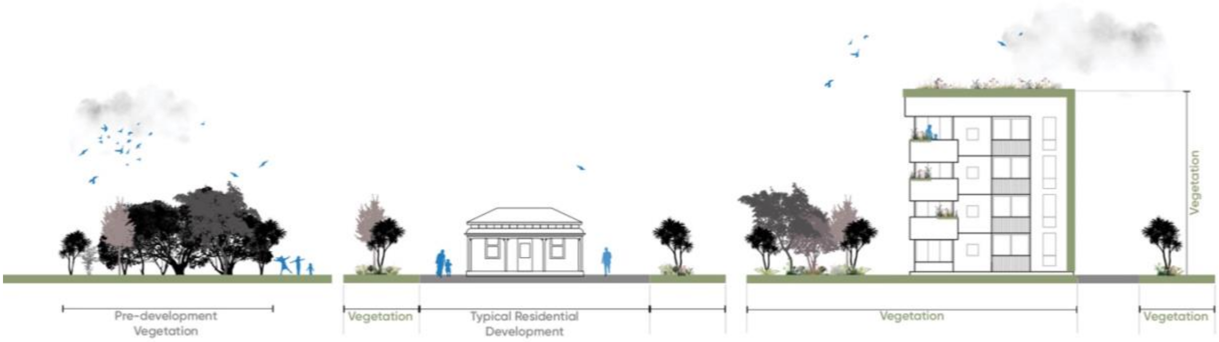

Figure 12: **Living Roofs, walls and facades protecting biomass**
Source: **Whangārei Living Roof Guide (adapted by The Urbanist)**

As the Austrian artist and architect Friedensreich Hundertwasser (1928-2000) noted, *"When one creates green roofs, one doesn't need to fear the so-called paving of the landscape: the houses themselves become part of the landscape. People must use the roofs to return to nature what we unlawfully took from her by constructing our homes and buildings – the layer of earth for grasses and trees."*

As described by Dusty Gedge, director of LivingRoofs.org and president of the European Green Roof Association a *"roof on the Kanton Hospital in Basel was redesigned 20 years ago by vegetating it, as it was felt that patients in intensive care would benefit from looking out onto this rather than the existing grey space. A few community hospitals in the United Kingdom (UK) are now being designed with greater consideration of green space provision"* (Gedge, 2018).

Figure 13: **Hundertwasser Art Gallery**
Source: **Zoë Avery, The Urbanist**

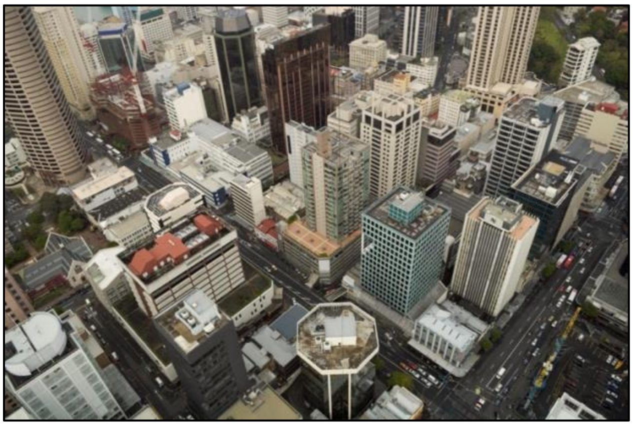

Figure 14: **Auckland, Central Business District**
Source: **Stock photo ID:116142300**

Our appreciation of an area can be significantly increased by installing living roofs (Veisten, et al., 2012). This is apparent when looking over the roofscape of Tāmaki Makaurau – i.e. there is a lot of potential for greening roof environments. It is important to provide aesthetic green space for people living, working or visiting Tāmaki Makaurau. Living roofs can provide visually appealing green space, visually soften the built environment, and help people's mental and physical health. They have an important ecological role, supporting biodiversity, and providing a sense of place.

Tāmaki Makaurau's rooftops can be seen as an under-utilised asset. Within urban centres, there is a need for increased residential densities as cities continue to grow in population and expand in area. As residential infill occurs, aesthetic green space and amenities are lost. Tāmaki Makaurau's rooftops can be seen as an under-utilised asset, and living roofs are a solution to help mitigate these adverse effects.

3.0 AUCKLAND CENTRAL LIBRARY LIVING ROOF

3.1 OBJECTIVES

In 2020 Auckland Council commissioned the Central Library Roof Remediation Project. Extensive roof remedial works were undertaken as the roof envelop claddings had reached or exceeded the end of their serviceable life. Low-cost design decisions were favoured due to managing uncertainties associated with the covid-19 pandemic. However, in early 2021 the possibility of installing a living roof on the library was revisited with strong support to pursue this pathway. As the Library Remediation Project was already underway, commitments to a stone ballast top layer on the roof, the project team looked into options for installing a living roof that would:

- reduce the risk of timeline elongation;
- ensure that any building consent amendments were minimal (reduced impact on cost and time);
- maximise on efficiencies (teams already engaged, familiar and providers that could provide a suite of services); and
- reduce general potential project risks (due to lack of unfamiliarity with the site profile, personnel and systems involved.)

This coordinated effort allowed the originally proposed stone ballast finish to be substituted for a vegetated roof at pace with minimal disruption. No change to the specified and consented waterproofing membrane was required to install the living roof system, with only slight modification to the protection elements above the membrane required to support the plant medium. The installation of the living roof was completed in mid-March 2022.

Figure 15: **Auckland Central Library Living Roof**
Source: **Zoë Avery, The Urbanist**

The living roof installation responds to Auckland Council's desire to lead by example in meeting environmental objectives related to our changing climate and sustainable outcomes responsibilities. Auckland Council plans to showcase the Central City Library Living Roof to inspire future implementation within the city and throughout the Region and to educate and raise awareness of living roofs' benefits. The project aims to contribute to Auckland Council by providing an active leadership role in implementing green infrastructure and nature-based solutions.

3.2 CONTEXT

The Auckland Central City Library is located at 44 – 48 Lorne Street in the heart of Tāmaki Makaurau's CBD (Figure6).

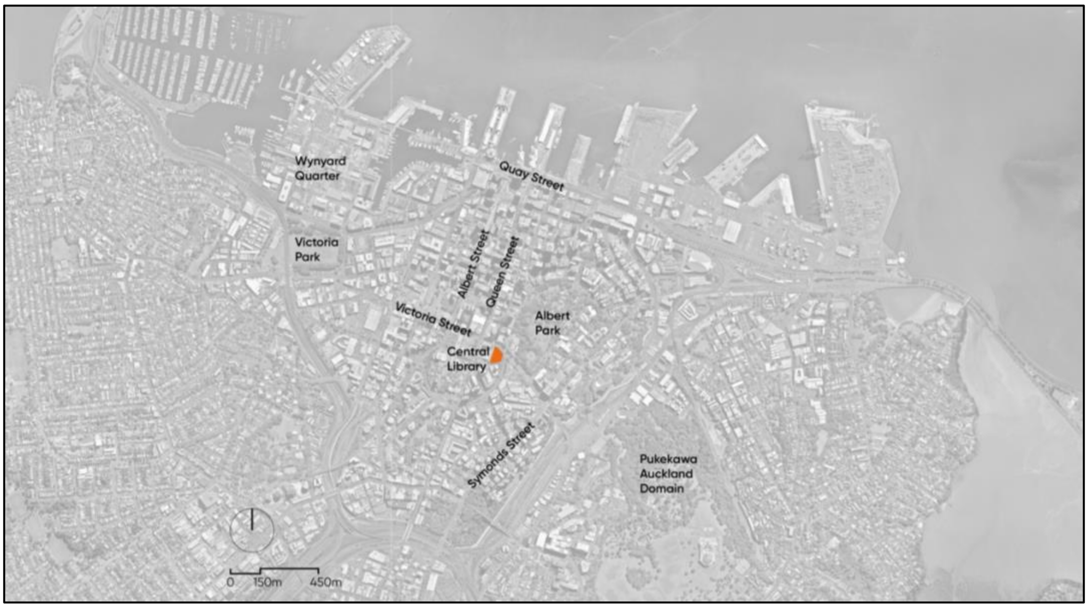

Figure 16: **Auckland Central Library Living Roof**
Source: **The Urbanist**

3.3 DESIGN

The living roof utilises Natural Habitats' proprietary living roof system – the 'Eco-Pillow'. Approximately 560 Eco-Pillows have been installed across the library roof area. Due to budget constraints, the Eco-Pillow installation has achieved ~50% coverage of the roof area. Plant growth is anticipated to infill within the spaces between the Eco-Pillows over time.

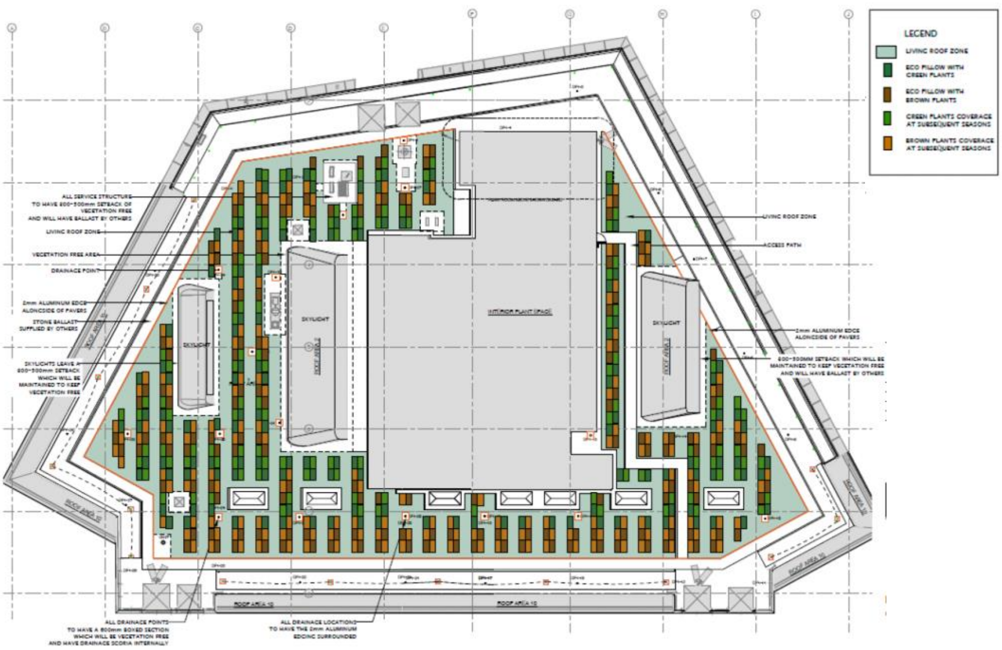

Figure 17: **Auckland Central Library eco-pillow layout**
Source: **Natural Habitats Ltd**

The Natural Habitats Eco-Pillow is a lightweight rectangular block of living roof media encased within layers of geotextile fabric. The engineered growing media within the 'Eco-Pillow' has been developed by Natural Habitats and includes specified aggregate size and components, pH value, nutrients, degree of porosity, and permeability. The objective Eco-Pillow media is to be ultra-low weight and long-lasting. A main component of the engineered lightweight media (polystyrene) is recycled from waste streams.

Figure 183: **Photograph of eco-pillow**
Source: **Natural Habitats Ltd**

Local iwi Ngāti Whātua Ōrākei developed the roof design inspired by whāriki (woven mat), a plaiting style of weaving representing the laying of foundations for all that it bears. The stepped pattern, known as "poutama", is achieved with green and brown alternating planting typologies, representing education, progress, and ascension. The Ngāti Whātua Ōrākei Design Statement for the Project also describes that the design pays homage to the library as a place where people seek greater knowledge and understanding.

Ngāti Whātua Ōrākei additionally supplied plants for the Project, undertaking a large portion of the vegetation pre-establishment within their Pourewa Nursery. Ngāti Whātua Ōrākei added native plant species to the planting palate, which would have been on the original shoreline of the Waihorotiu Stream – a waterbody that historically ran down the Queen Street gully to the Waitematā Harbour.

The modular proprietary system approach was considered the most feasible option to implement within the constraints of the existing remedial project underway and the associated short timeframes. The installation of the proprietary system provides an opportunity to understand the function of the Eco-Pillow compared to natural systems previously researched and to gain a greater knowledge of the suite of systems available and their relative benefits.

3.4 MONITORING METHODOLOGIES

3.4.1 OVERVIEW

A comparison study is planned to enable greater data collection than possible at the existing Library roof configuration. Testbeds replicating the configuration of the Eco-Pillows installed on the Library roof will be monitored and analysed at the University of Auckland. The objective is to simulate runoff from the Library Living Roof Eco-Pillows. Due to the proximity of the Library to the University (approximately 400m), it is assumed that the replica test beds will be exposed to similar environmental conditions as the Library Living Roof.

Figure 19: **Relative proximity – Library Roof to University of Auckland test site**
Source: **The Urbanist**

Alongside the replica Eco-Pillow test beds, it is also proposed to monitor alternate configurations. The alternate configurations will include varied substrate depths and media compositions. Monitoring alternate configurations will provide comparative data that can be assessed with the intent of establishing recommended or optimal conditions.

Monitoring will be undertaken in partnership with students and researchers from the University of Auckland, Maanaki Whenua (Landcare Research) and Ngāti Whātua Ōrākei (NWŌ). The University's School of Engineering Building (B405) includes a purpose-built rooftop monitoring area proposed to be used over the monitoring period.

Figure 20: **School of Engineering, University of Auckland rooftop test site**
Source: **The Urbanist**

The monitoring will expand on previous living roof research by the University of Auckland and Maanaki Whenua (Landcare Research), which is foundational to existing technical publications released by Auckland Council (Auckland Council, 2013). It is envisaged that further research and information obtained throughout the monitoring period will inform further technical publication(s) on living roofs in a Tāmaki Makaurau environment for release by Auckland Council.

3.4.2 CONSTRAINTS

Establishing a Baseline

When the installation of a living on the Library roof had been confirmed, preparation for works to replace the existing waterproofing membrane had already begun – the roof had already been encased by shrink wrapping and as such establishing baseline conditions was not possible.

Identifying a paired Council-owned building to provide a baseline reference has proven challenging. This project's preferred approach is to rely on published literature, with a preference for Tāmaki Makaurau-based research, which describes the environment, including stormwater runoff characteristics from traditional ballast roof surfaces.

Existing Utilities

Given the age and design of the existing building, defining the outlets for runoff from the Library roof area has proven challenging. Stormwater runoff from the Library roof is collected by multiple drainage inlets connected to internal guttering within the building. Onsite drainage was investigated during the preparation of the Building Consent Application; however, connectivity of many downpipes could not be confirmed due to the inability of cameras to navigate pipe bends in the existing network.

As the building includes internal roof drainage, interception of runoff from the roof area is challenging and likely could not be safely implemented. An additional concern is that interception of runoff from the internal roof drainage network could increase blockage risk. Given the Library houses priceless records, the minimisation of interaction with the internal drainage network of the building has been prioritised.

Access to the library roof

Due to health and safety concerns, frequent access to the Library Living Roof is limited. Initial indications from Auckland Council's Property Management Team suggest that the Library roof can be visited once every quarter for monitoring purposes with a supervisory warden present. Therefore, frequent inspection of the roof and collection of data such as runoff from the Library roof stormwater outlets is impossible. Remotely managed technology such as smart metering systems will be implemented where possible.

Living Roof Coverage

Most living roofs previously studied in Tāmaki Makaurau and many other international studies are full coverage, meaning that the planting and media cover the entire roof surface. The design and placement of the Eco-Pillows on the Library roof are not full coverage, although it is anticipated that plant growth over time will reduce the spacing between the pillows.

3.4.3 PARAMETERS

Hydrology

Roof areas, particularly within urban centres, contribute to a large portion of the overall impervious area. The implementation of living roofs has the potential to mitigate the effects of runoff from impervious roof areas significantly.

Living roofs are commonly recognised for the stormwater management benefits that they provide. The retention function of living roofs is achieved primarily through evapotranspiration, which can contribute to reducing peak flow rates and runoff volumes. After rain falls onto a living roof surface, a large portion is absorbed by plants via the associated growing media before being evaporated back into the atmosphere (evapotranspiration). The growing media holds on to a portion of the rainfall that plants eventually take up. Rain will not drain through the living roof's drainage layer until the planting media's field capacity is reached.

Auckland Council's Technical Report 2010/018: 'Extensive Green (Living) Roofs for Stormwater Mitigation Part 2: Performance Monitoring' (TR2010-018) summarises the findings of a study of four living roofs within Tāmaki Makaurau (with varying substrate depths) over monitoring periods of 8 to 28 months (Auckland Council, 2013). Most individual storm events within Tāmaki Makaurau are small storms with low rainfall depths – 90% of events produce an average rainfall depth of less than approximately 31mm 0 (Shamseldin, 2010). Throughout the monitoring period of the living roofs studied as part of the development of TR2010-018, during individual rainfall events up to 25mm, there was no meaningful runoff from any of the living roofs. Cumulative runoff from the living roofs studied was between 39% and 57% less than conventional roofs at the same sites. Across all events studied during the monitoring period of each of the roofs, the median retention was between 56% and 76%.

A combination of i) when the living roof scope was approved within the existing work programme (the building was already under plastic wrap); ii) the expedited construction timeframe (in order not to compromise the original work programme); iii) Covid-19 restrictions; and iv) the drainage design of the existing building prevented the direct measurement of runoff from the original Library roof surface. Volume and peak flow comparisons against a conventional roof surface will be enabled by using rainfall data and monitoring of replica test beds established to emulate a pre-living roof condition.

The objective of simulation monitoring of the replica test beds in the context of hydrology is to quantify the retention capability of the Eco-Pillow for comparison against other living roofs previously studied in Tāmaki Makaurau. Total volume and peak flow data will be compared to other data obtained from living roofs within Tāmaki Makaurau, such as those discussed within Auckland Council's TR2010-018 (Auckland Council, 2013).

Monitoring rainfall depths and runoff volumes of the Eco-Pillows within the replica test beds will help further determine the influence of the configuration and vegetation establishment of the Eco-Pillows on runoff volumes. Monitoring of the Eco-Pillows will evaluate the effectiveness of the proprietary system as a hydrology mitigation device.

It is proposed to continuously monitor the replica test beds' rainfall depth and runoff volumes throughout the monitoring period. The partial coverage of the Library Living Roof compared to existing full coverage living roofs will need to be considered for cross-analysis of any results.

Water quality

Living roofs are not typically used as water quality improvement devices within Tāmaki Makaurau. However, the vegetation and media provide a breadth of water quality benefits beyond the biological filtration of contaminants, such as the capture and treatment of settled atmospheric contaminants and cooling of stormwater runoff from roof surfaces.

Due to the inaccessibility of the Library roof stormwater outlets, water quality monitoring of runoff from the Library roof is impossible. Therefore, monitoring the replica Eco-Pillow test beds will allow the inference of the water quality performance and output of the Eco-Pillows installed on the Library roof.

Contaminants of concern within runoff from a living roof are likely to be constrained to atmospheric deposits and the components of the living roof itself, such as metals, fertilisers, and herbicides (Auckland Council, 2017). Identified parameters that will be monitored have been based on concern of impact in receiving waters in Tāmaki Makaurau (TSS and heavy metals) or because of prevailing evidence in the literature regarding leaching potential (nutrients, Nitrogen and Phosphorus).

It is important to determine if runoff quality is influenced by the components of the proprietary living roof system. Monitoring of emerging contaminants such as microplastics is proposed. Including emerging contaminant monitoring will enable a better understanding of any potential leaching of contaminants from the Eco-Pillow and the identification of contaminant contribution from the Eco-Pillow over time.

Biodiversity

The establishment of vegetation on living roofs is essential to realising benefits relating to stormwater management, habitat, temperature, and aesthetics. The success of several benefits provided by living roofs, including habitat facilitation and processes such as evapotranspiration, is linked to vegetation establishment. Due to the harsh environmental conditions of the Library Living Roof, including extreme temperatures, high winds, shallow substrate depth, and variable water availability, only a select range of species will achieve successful establishment. Plant selection for the Central Library Living Roof has considered these environmental factors.

Living roofs within urban centres may be the only 'green space' available, providing ecological links or steppingstones to other adjacent habitats. They can provide habitats for tolerant invertebrates (spiders, beetles, bees) and bird species.

It is proposed to monitor plant establishment and biodiversity at the Library Living Roof and the replica test beds. Monitoring the replica test beds and the Library Living Roof will allow correlation of vegetation establishment with other observations, such as hydrology or water quality data. Any correlated data from the replica test beds can be further scaled to represent the Library Living Roof context.

Monitoring quadrats will be utilised on the Library Living Roof. Vegetation establishment monitoring will include quarterly identification of species absence or presence and percentage plant cover. Species establishment (represented by percentage) and size (plant diameter and height) will be assessed as part of quarterly quadrat monitoring. Information collected from the monitoring quadrats will be supplemented with general observations, including signs of stress, flowering or seeding, and footage from the Auckland Council time-lapse cameras installed on adjacent buildings before the completion of the living roof.

Biodiversity monitoring will include abundance and diversity assessments and will be undertaken simultaneously as the vegetation quadrat monitoring. A combination of wooden refugia, emergence trapping, and pitfall traps are proposed to be utilised, comparable with monitoring methods implemented at the Waitakere Civic Centre Roof as described by (Davies, 2010).

Economics

Internationally economic modelling of living roofs has varying results. This is mainly due to many of the benefits being difficult to quantify or qualify (Dong, et al., 2020). Significant variation can be derived from living roof design, environmental differences, and the area's legislative, political, and social framework (Liberalesso, et al., 2020).

The proposed research will identify the range of benefits that living roofs can bring to Tāmaki Makaurau in the local context and provide quantifiable data. It will compare different substrate types and depths to understand the effect substrate changes have on costs vs benefits. The study will be conducted across a five-year timeframe. Results will then be used to inform a cost-benefit analysis. They will consider the costs and benefits different stakeholders realise based on current policy and propose changes to the existing policies that could better support the uptake of living roofs.

A comparison against international exemplar cases will also be conducted. We expect significant variation in benefits depending on the legislative framework in the international comparisons, as most cities with a high uptake of living roofs either mandate or incentivise their use.

In the United States, for example, a significant benefit to the building owner is a reduction in stormwater fees and/or additional incentives. Quantifying this, the USA average benefit from a 2011 study, converted to 2022 NZD, gives a stormwater-related NPV of NZ$306.61/$m^2$ (ARUP, 2011). Moreover, the NPV of living roof installation to the building owner is neutral (our conversion gives a $1.35NZD/$m^2$ benefit across 50 years). And an accumulated NPV incorporating building owners, owner occupiers, tenants and community of NZ$930.21/$m^2$ (ARUP, 2011).

Legislation

The legislative framework in Tāmaki Makaurau gives little support to the uptake of living roofs. Many benefits are realised at a city scale, while most of the cost falls with the building owner or developer. This is a fundamental deterrent to the uptake of living roofs in Tāmaki Makaurau and New Zealand.

The utilisation of living roofs in Tāmaki Makaurau is affected by market dynamics, including regulatory, legislative, market competition, social perception, and industry knowledge levels. Understanding the local market allows us to critically assess what we could change or improve to assist in the uptake of living roofs.

It is proposed to review international living roof policies to develop a framework for applying appropriate guidance, policies and incentives in Tāmaki Makaurau. There are no policies requiring or incentives enabling the uptake of living roofs in Aotearoa. Developers or building owners pay for the installation and maintenance, while most benefits are recognised in the wider environment. In Europe, it has been noted that without policy interventions living roofs are unlikely to move from the ecological niche to the routine design tool (Brudermann & Sangkakool, 2017).

There is an opportunity to focus policies or incentives to help address issues such as lack of stormwater capacity, flood risk, low vegetation or canopy cover, lack of biodiversity connections, and areas with high heat vulnerability index to maximise the overall return on investment (ROI). It is hoped that the library living roof monitoring data can be used to help inform future policy or incentive opportunities.

3.4.4 OUTPUTS

Key objectives of the Project include raising public awareness of the benefits of living infrastructure to encourage further uptake and upskilling of our community in the living infrastructure space. The monitoring undertaken will provide both academic outputs and resource for community education.

Auckland Council currently hosts a website page[1] promoting and providing the community with information on the Library Living Roof, including a time-lapse video. It is anticipated that this webpage could be progressively updated with monitoring

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[1] https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-projects/projects-central-auckland/projects-auckland-city-centre/Pages/central-city-library-living-roof.aspx

information collected, summarised, and distilled for accessibility. Informative resources are envisaged to be available at the Library for the public. A public access viewing platform has also been considered, facilitating field trips from local schools and community groups.

It is envisaged that data and information collected will be summarised within milestone reporting at the end of each monitoring year. Information obtained throughout the monitoring period is intended to inform a further technical publication on living roofs in a Tāmaki Makaurau environment for release by Auckland Council.

4.0 CONCLUSIONS

Living roofs are increasingly being used in cities for climate change adaptation, stormwater management, energy conservation, food production, and the potential to develop localised amenity, community and biodiversity. The Auckland Central Library living roof project is a pilot project specifically aimed to grow public awareness of living infrastructure and its benefits.

Comparing the Auckland Central Library and the test site at University of Auckland it is anticipated that data on stormwater management (attenuation and water quality), biodiversity, economics and current legislative environment will provide valuable data for living infrastructure in the Auckland context.

The intention of this monitoring study is to inform and encourage nature based solutions within our cities based on technical research to increase the uptake of living roof systems in Aotearoa. The findings will help develop strategic plans for future living roof development, promote the installation of nature based solutions and improve biodiversity throughout our urban fabric.

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