MANAGING FUTURE UNCERTAINTIES USING IWM AND THE ADAPTIVE PLANNING APPROACH

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ABSTRACT (500 WORDS MAXIMUM)

Future uncertainties in climate change impacts, disruptive technology, legislation, cultural and community expectations and population demographics will impact today's decision-making on investments in 3-water networks. This paper promotes adoption of Integrated Water Management (IWM) that embraces future uncertainties by exploring the impact of multiple plausible futures and potential shocks and uses an Adaptive Pathways Planning (APP) approach with built-in triggers for decision-making on investments.

Best practice in IWM from Melbourne, Sydney and the USA was applied to a GHD Callaghan Innovation funded project to assess the effectiveness of rainwater storage solutions for water supply resilience in Auckland considering future uncertainties.

GHD's IWM toolkit, a software package for the assessment of integrated water balances was used for the analysis and modelling of a hypothetical scenario to assess effects of rainwater re-use on Auckland's total dam water storage volume. The Toolkit uses an intuitive graphical interface (MS Visio) to construct alternative water servicing strategies and perform time-series water balance calculations for multiple combinations of options. The scenario was that in January 2019, 10% (and 20%) of residential households in Auckland had access to roof rainwater tanks (plumbed to toilet flushing, washing and shower). Using actual rainfall series data, the toolkit was used to assess the impact of the scenario on the total dam storage volume in December 2020 and then in December 2022 if the Auckland drought continued for another 2 years.

Options for 1,000, 2,000 and 5,000 litre tanks were assessed, and it was found that by December 2020, for the 20% residential uptake, an additional buffer of about 14 million cubic metres would have been added to the total dam storage volume (Auckland's average water use is about 450 million litres per day). It was evident that rainwater tank use during the rainy season builds the total storage volumes in the dams and provides security of supply in the dry season. Considering an IWM approach and potential future changes, additional benefits (e.g. flood reduction, alternative to detention tanks, sustainable practice promoter) and potential solutions to obstacles (e.g. first flush diverters, UV filters, smart tanks, slimline tanks, incentives) of city-wide rainwater tank use were explored.

The conclusion was that rainwater tanks and other water source alternatives (e.g. grey water re-use, stormwater harvesting) could be triggered by future changes in criteria (economics, resilience-readiness, technological breakthroughs). Therefore, all potential options can be kept "alive" and an (APP) approach can be used to optimise investment decision-making as future uncertainties become more certain. Importantly, feasibility of the options, the triggers and the timelines for planning, design, consenting, and construction need to be assessed to understand implementation requirements of the options in time to meet the required level of service.

As the Water Reform takes shape in NZ, we will need detailed analysis, modelling and feasibility assessments of multiple integrated 3-water strategies and options, that consider the impact of potential future changes to put us in a better position with respect to long-term resilience planning and optimising investments in 3-water networks.

KEYWORDS

Integrated Water Management (IWM), Adaptive Pathways Planning (APP), water reform, Auckland drought, water supply resilience, rainwater tanks, optimising infrastructure investments

PRESENTER PROFILE

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1 INTRODUCTION

The purpose of the Water Reform in NZ is to play catch up on the renewal of ageing water assets. Reports released as part of the Department of Internal Affairs (DIA) June 2021 update identified that investment of between $120 billion and $185 billion is needed over the next 30 years to ensure the 3-waters infrastructure meets acceptable public health and environmental standards. The primary focus of the reports (and reform) is on reducing the number of entities that manage the 3 waters infrastructure from 67 to around 4 to 6 and hence improving the affordability equation from average forecasted household bills in 2051 of between $1900 to $13,900 (without reform) to $800 to $1800 (with reform and with 5 entities).

It appears we were unprepared in managing future uncertainties in population growth and demographics, climate change impacts, legislation changes, cultural and community expectations, and the increasing cost of infrastructure renewals.

As the water reform takes shape, transparency around decision-making on the management of 3-water networks is increasingly becoming more important. As water practitioners tasked with NZ's future 3-waters security, we need to have the facts and figures to answer the many questions that are being raised.

The 2019/2020 drought in Auckland has also highlighted just how unprepared we are in our understanding and management of the potential impacts of future uncertainties on our water infrastructure assets. Many questions from the community and key stakeholders remain unanswered and some of these have been well debated in mainstream media:

Why are we in this situation? What is our strategy to manage severe droughts? Do we need more dams? Would rainwater tanks be a viable solution? What is international best practice? Where is the transparency?

Based on the current situation that the water industry in NZ finds itself in, it appears that there is much more room for improvement. Specifically, in how we develop infrastructure strategies, assess options, and plan and prioritise investments that consider the impact of future uncertainties. We know that this will only become more complex as we are faced with an increasing number of future uncertainties and a fast-changing external environment.

Changes are happening fast, faster than we are prepared to manage them. Right now, we are still planning and making long-term investment decisions on infrastructure using methods we have always relied on, deciding one option over multiple options. To manage this better, a much more integrated approach is required.

This paper promotes adoption of Integrated Water Management (IWM) and an Adaptive Pathways Planning (APP) approach. This approach embraces future uncertainties by exploring the impact of multiple plausible futures and potential shocks and using built-in triggers for decision-making on investments.

To demonstrate the value of IWM and the APP approach, best practice from Australia and the USA was applied as part of a GHD Callahan Innovation funded project. In this project, a hypothetical scenario was used to test the effectiveness of rainwater tanks for water supply resilience in Auckland.

2 INTEGRATED WATER MANAGEMENT AND THE ADAPTIVE PATHWAYS PLANNING APPROACH

IWM involves the consideration of impacts and opportunities across a wider set of social, environmental, economic, and political factors. It is much more complex and requires collaboration, planning and analysis to understand the impacts and opportunities of multiple plausible futures. The outcome, however, is the development of multiple potential solutions or combination of solutions that have intertwined pathways over a long-term period. The APP approach (Fig 1) keeps the multiple solutions and pathways ‘alive’ and provides the flexibility to change via built-in Triggers in response to:

- New technology
- Climate change
- Community expectations
- Government policies
- Cost fluctuation

The approach leads to strategies that are 'robust' because option pathways are tested against multiple plausible futures and 'flexible' because a diverse range of option pathways are considered to avoid 'lock-in' and maladaptation if the future unfolds differently than expected.

The approach is valuable because it helps develop short and medium-term actions in the context of a long-term strategic vision.

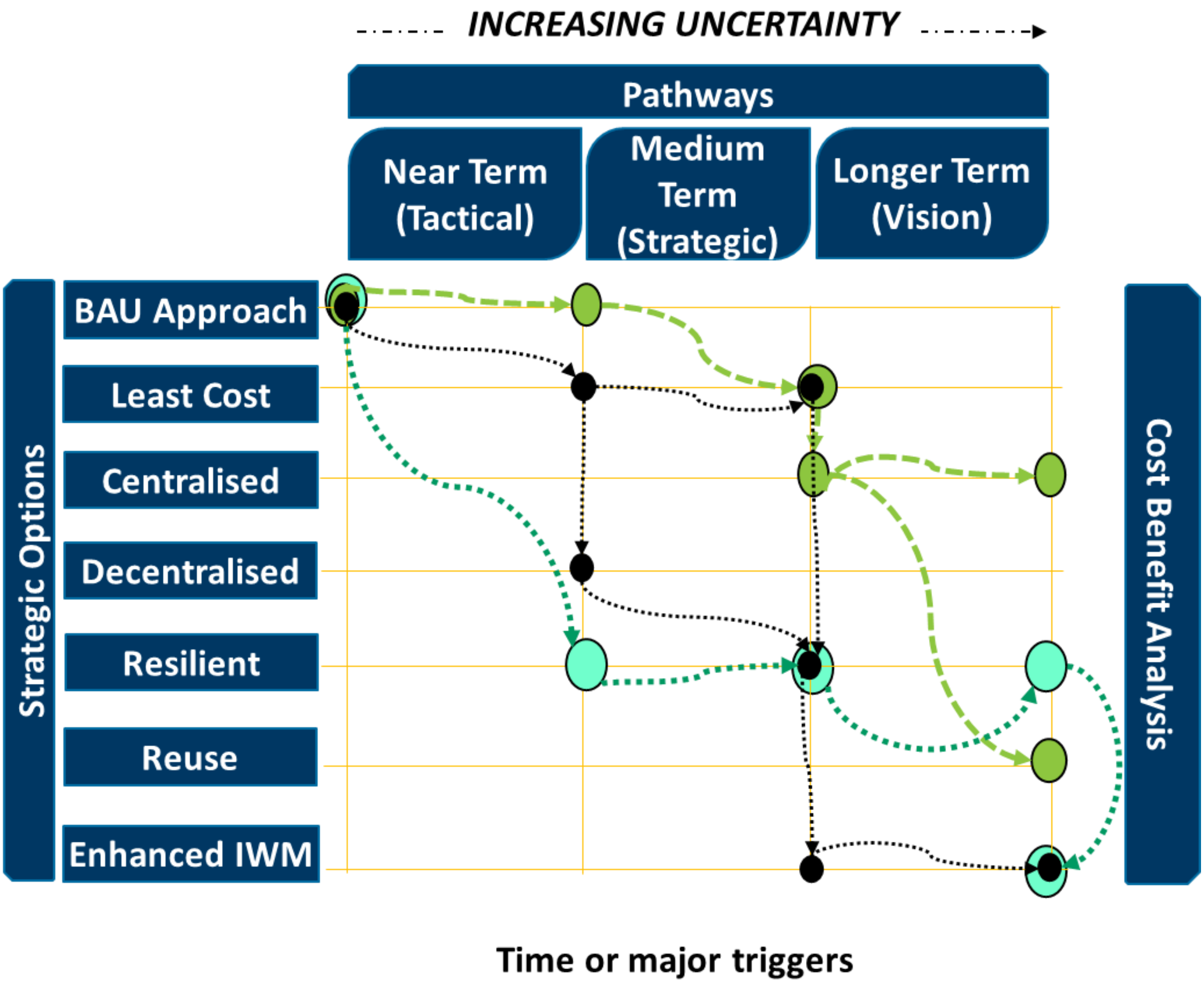

Figure 1: Adaptive pathways planning framework for water infrastructure

This approach is being used internationally in the USA and in Australia as cities are finding it difficult to plan for future uncertainties in not only climate change but also population growth, technology, socio-economic conditions, and community preferences.

As an example, GHD have been working with the City of Austin in Texas, USA, to provide inputs to its 100 year ['Water Forward' Integrated Water Resources Plan (IWRP) Plan]() to evaluate the city's water needs, and examine and make recommendations regarding future water planning.

This includes consideration and detailed analysis of multiple solutions including the use of recycled wastewater, greywater, stormwater, and rainwater implemented at both the building and community scale. An adaptive management planning and implementation approach has been adopted where the IWRP will be updated on a five-year cycle, using new data about changing conditions to inform potential adjustments to the planned implementation strategy to ensure that the City of Austin is on a path to meet its goals.

In Australia, Water Services Association of Australia has recently published a report '[All options on the table – Lessons from the journeys of others']() which promotes having all options on the table for consideration to manage future uncertainties, including purified recycled water alongside desalination, water efficiency, dams and recycling for non-drinking purposes.

3 RAINWATER STORAGE SOLUTION FOR WATER SUPPLY RESILIENCE IN AUCKLAND

3.1 Auckland drought

The dams in Auckland's Hunua and Waitakere ranges solely rely on rainfall to replenish. The Auckland region has been experiencing a drought, which has resulted in lower-than-normal dam storage levels going into the summer of 20/21. The total water storage dropped to a concerning mid-40 per cent mark at one point (Watercare, 2020). Despite water-saving initiatives by Auckland residents and periodic rainfall, the total storage was only slightly over 60% of total storage volume in Jan-2021, which is well below the 90% of total storage volume expected at that time of the year (Watercare, 2021).

3.2 Outcomes of previous studies on the effectiveness of rainwater tanks

Rainwater storage solution as an option for water supply resilience in Auckland has largely being discarded for several reasons up to now. Previous studies have investigated the viability of rainwater re-use in Auckland. However, none have supported this option as significant in augmenting Auckland's water supply. Most research concludes that rainwater tanks themselves cannot meet complete demand.

An investigation by Watercare modelled various scenarios where "Outputs demonstrated that the most favourable scenario would result in tanks supplying up to 16% of the forecast demand at the drought level of service and 35% at the peak level of service" (Klein et al. 2016). Furthermore, Klein mentioned that "the capital cost of implementation of (rainwater tanks) would be of four times that of a river source able to supply 100% of the forecast demand at both levels of service" (2016).

However, in an earlier study, Tauranga City Council in partnership with GHD carried out an investigation using the IWM Toolkit. Their results indicated that "significant reductions (14 %– 41%) can be made to domestic drinking water demand through the implementation of water-saving devices (WSD), rainwater tanks (RWST) and greywater re-use" (Bowles & Moodie, 2009).

3.3 Hypothetical scenario in Auckland

To assess the effectiveness of rainwater storage solutions for water supply resilience in Auckland in more detail than previous studies and research, we applied best practice in IWM and APP from Australia and the USA as part of a GHD Callahan Innovation funded project using a hypothetical scenario.

Hypothetical Scenario – in January 2019, (10% and 20%) of residential properties in Auckland on town water supply were also using rainwater tanks for toilet flushing, washing, shower and irrigation. The benefit of working back in time from January 2019 was to enable the use of actual rainfall data and actual total dam water volumes in the analysis during the Auckland drought period.

3.4 Modelling and analysis using GHD's IWM toolkit

GHD's IWM toolkit, a software package for the assessment of integrated water balances was used for the analysis and modelling of a hypothetical scenario to assess the effects of rainwater re-use on Auckland's total dam water storage volume. The Toolkit uses an intuitive graphical interface (MS Visio) to construct alternative water servicing strategies and perform time-series water balance calculations for multiple combinations of options.

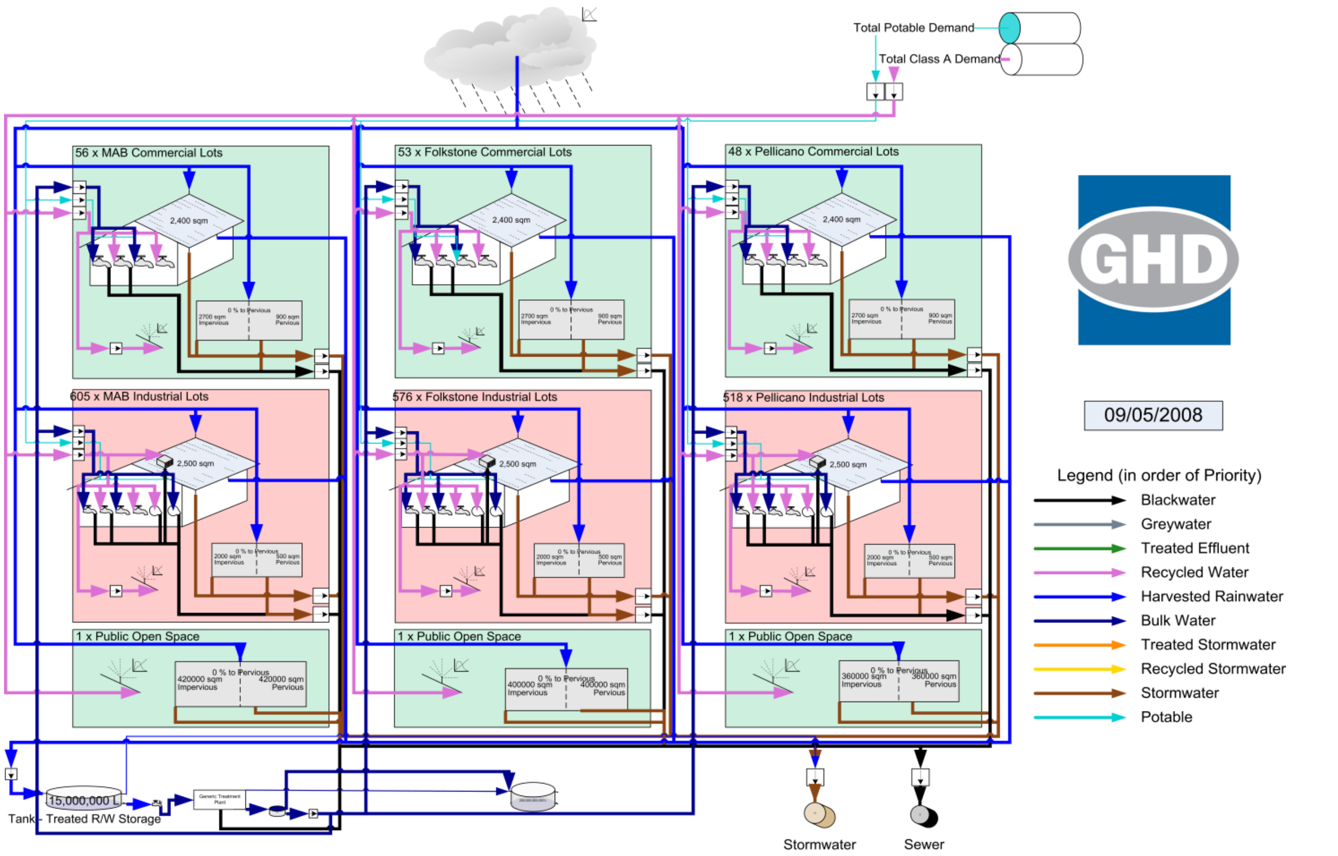

Figure 2: GHD integrated water management toolkit

The IWM toolkit:

A water balance software that allows for large scale and long-term analysis of water systems.

- Allows for a holistic approach that is effective for water design strategy.
- Allocates any source water to any end-use and any surplus waters to various treatment or receiving waters at any spatial scale - from the property scale up to a catchment/watershed scale.
- Has the ability to integrate the output from other external software tools such as hydrologic and hydraulic models.

The IWM Toolkit can represent a unique range of water cycle elements to quantify on a daily time step:

- Traditional and alternative water sources
- Rainfall and stormwater runoff
- Wastewater discharge
- Irrigation watering requirements
- Sewerage system inflow and infiltration

Using actual historical rainfall series data, the toolkit was used to assess the impact of the hypothetical scenario on the total dam storage volume in December 2020 and then in December 2022 if the Auckland drought continued for another 2 years. The total dam water storage information was obtained via the Watercare website (2019). Forecasted values until December 2022 was assumed using a worst-case scenario where rainfall continues to reduce by the same amount it reduced from 2019 to 2020.

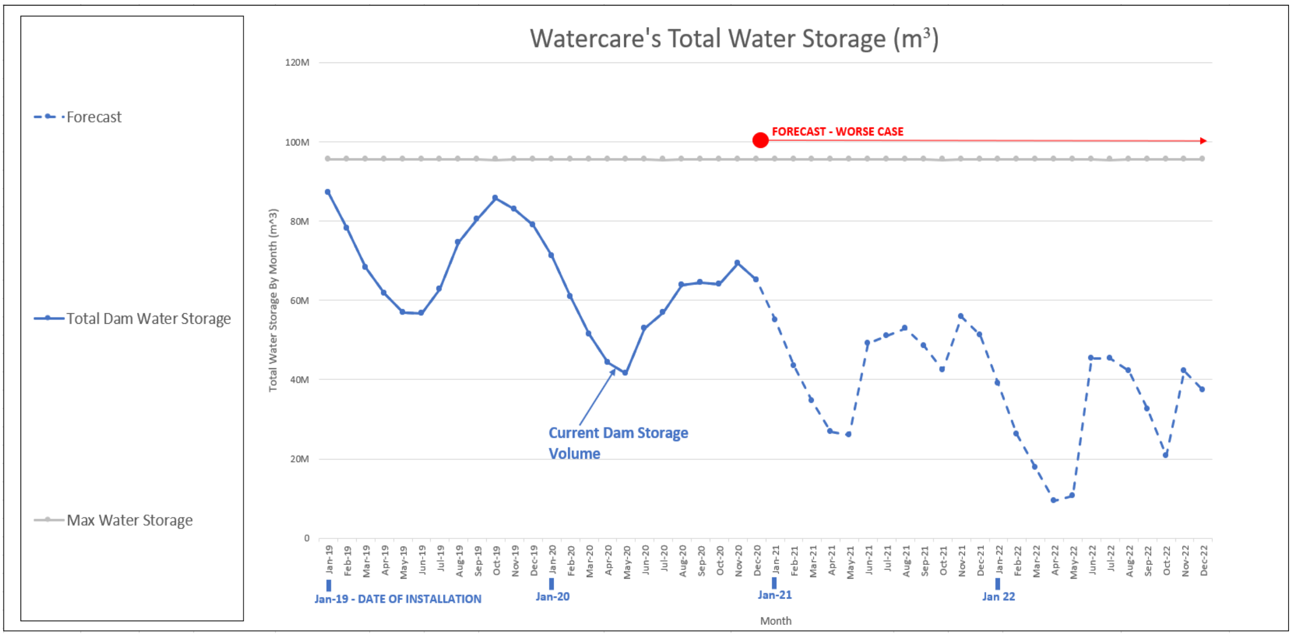

Figure 3: Total dam storage volume Jan-20 to Jan-21 (source – Watercare website) & forecasted volume to Dec-22

Fig 3 shows the total dam storage volume from Jan-19 to Dec-20 and a forecasted storage volume from Dec-20 to Dec-22 which was used as the baseline for the analysis. A representative residential unit, including a rainwater tank, was first created in the model. The representative unit consisted of typical household appliances and components: kitchen, dishwasher, washing machine, hand basin, toilet, and dishwasher. The rainwater tank was attached to washing machine, toilet, shower, and irrigation demand components (i.e., non-potable uses). If the rainwater tank was empty, then potable water would be substituted from the reticulated supply. Potable water from the reticulated supply remained connected to the dishwasher, hand basin, and kitchen.

Briefly, some of the inputs and assumptions of the analysis are listed below:

- Average usage values were found for each household component to input into the toolkit. The Australian water rating system (WELS) was used to obtain these average usage values. It was assumed that these Australian guidelines would provide reasonable estimates for the strategy level design in New Zealand. (see table below).

Household Appliance	Usage (L/Person/Day)	Connection to RWT (yes/no)
Shower	83.3	Yes
Washing Machine	43	Yes
Hand Basin	10.8	No
Toilet	23.4	Yes
Dishwasher	8.5	No
Kitchen	54	No
Irrigation Demand	Based on area	Yes

Table 1: Household appliance usage rate

- First flush of 0.5 mm, wetting loss of 1 mm, and 1 mm percolation were fixed values based on previous projects completed in Australia.
- The rainfall data from 2016 to 2020 was obtained from Alexandra Park, Greenlane (Auckland) rainfall gauge. Evaporation data was also obtained from this location.
- Since this analysis primarily focuses on residential uptake of rainwater tanks, an approximate number of residential properties was determined using GIS. The number of residential properties in Auckland was approximated to be: 476,536 households.
- The irrigation demand area was determined by assuming that 10% of the total household's property area was considered a 'green area'.
- It was assumed all households were inefficient and had high water usage values.
- 1,000, 2,000 and 5000 L rainwater tanks were chosen for the analysis.
- An average household was composed of three people.

Some key limitations of the analysis are listed below:

- The IWM toolkit allows for approximate analysis and assumptions had to be made where information was not certain. For example, New Zealand does not have a comprehensive water rating system like Australia's WELS data which meant that WELS data was the best option in determining the water usage breakdown. However, it is relatively easy to make changes and re-run the model.
- The scope for the IWM toolkit modelling was limited to proving the effectiveness of rainwater tank use in offsetting water usage from the total dam storage volumes.

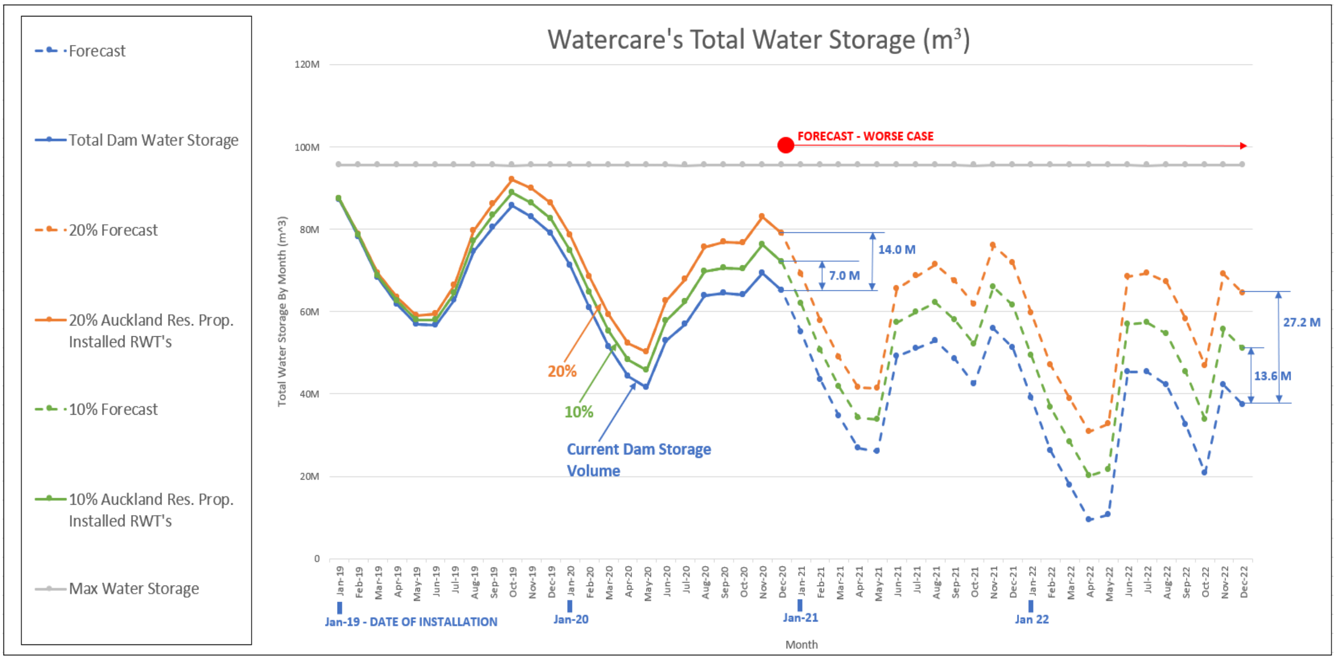

Figure 4: Modelled results for 10% and 20% of Total Residential Property Uptake of 2,000 L rainwater tanks in drought period Jan-2019 to Dec-2022

	1,000 L Rainwater tank		**2,000 L Rainwater tank**		**5,000 L Rainwater tank**	
Dates	Buffer for 10% res prop (M m³)	Buffer for 20% res prop (M m³)	Buffer for 10% res prop (M m³)	Buffer for 20% res prop (M m³)	Buffer for 10% res prop (M m³)	Buffer for 20% res prop (M m³)
Jan-2019	0	0	0	0	0	0
Dec-2020	5.7	11.4	7.0	14.0	9.0	18.0
Dec-2022	11.2	22.4	13.6	27.2	17.2	34.4

Table 2: Results - additional buffer (million m³) created in Dam Storage Volume for range of scenarios during drought period Jan-2019 to Dec-2022

Rainwater tank Size (L)	**Number of Days Over 2019 -2020 (731 days) RWT is Empty**	**Comments**
1,000	527	Savings are on tank costs but unreliable
2,000	467	An ideal size for reliability
5,000	440	Higher tank cost/slightly increased reliability/good for high water usage requirements

Table 3 Optimising rainwater tank size for reliability/costs

3.5 Results and discussions

The outcome of the modelling using the GHD IWM toolkit is provided above in Fig 4 and Tables 2 and 3. Fig 4 shows the increase in total storage volume overtime for a 2,000 L rainwater tank with an uptake of 10% and 20% of total residential properties (7 and 14 million m^3 in Dec-2020 and 13.6 and 27.2 million m^3 in Dec-2022). In comparison, Auckland's daily usage ranges from an average of approximately 400 million litres per day to a peak of 568 million litres a day (summer 2020). A buffer of approximately 28 days of water supply has been made available by the hypothetical scenario in Dec-2020 with the 20% uptake. And the buffer only grows over the following 2 years if the drought was to continue providing a good level of confidence in the security of supply. Table 2 provides the results for the three rainwater tank sizes modelled and Table 3 provides a reliability/cost check for the most cost-effective rainwater tank size.

It is evident from the results that rainwater tank use by only 20% of Auckland residential properties during the wet season builds a significant safety buffer to the total storage volume in the dams and provides security of supply in the dry season of a drought period. Increasing the percentage of properties from 20% and including other options such as greywater harvesting, and stormwater harvesting will only strengthen the case for the rainwater tank option and negate any questionable modelling inputs in this study.

The most concerning future uncertainty is whether droughts will become a regular occurrence in a fast-growing thirsty Auckland. We can either lock ourselves into costly infrastructure solutions that may not be required in the short to medium-term or long-term future or take multiple pathways as the future plays out and delay major investments as long as we can. Rainwater tanks can be implemented in stages providing an opportunity for an APP approach where we manage future uncertainties as they materialise.

3.6 Applying integrated water management and adaptive pathways planning

We have demonstrated that rainwater tank use in Auckland can provide a significant buffer to the total dam volume over time but how can we apply an integrated approach to realise the cost-effectiveness and other benefits of this option and what are the other triggers apart from regular droughts to inform pathways in future? Considering IWM and the APP approach, additional benefits, and potential solutions to obstacles of city-wide rainwater tank use were explored with potential future changes and triggers. Tables 4 and 5 below provide the outcomes of this assessment.

Additional Benefits of Rainwater tank Solution	Current Practice	Future Changes - Triggers for Pathway Options
Detention tanks are required as part of many new developments in Auckland to control flooding, stream erosion and combined sewer overflows for specific catchments. Costs of rainwater tanks can be offset if they can be used as an alternative to detention tanks.	Detention tanks and rainwater tanks are separate assets. Cost of rainwater tank cannot be offset currently.	• Development of smart digitally controlled retention tanks that serve as both rainwater tanks and detention tanks. • Council acceptance of retention tanks.
Rainwater tanks installed as part of existing households can reduce flooding in flood-prone areas, minimise stream erosion and combined sewer overflows for specific catchments.	Retrofitting detention tanks by council for existing households is not a current preferred option to control flooding, minimize stream erosion and combined sewer overflows.	• Availability of detailed IWM analysis to inform decisions. • Council-led programmes to facilitate installation of rainwater or retention tanks. • Council incentives to property owners where rainwater tanks provide multiple benefits.
Rainwater tanks promote sustainable practices including vegetable growing and composting which in turn provide financial returns, reduction in waste volumes and positively impacts wellness.	A small number of property owners are installing rainwater tanks for this purpose.	• Community education and promotion of sustainable practices. • Availability of online guideline and information on best practice vegetable gardening using rainwater tanks and composting.
Rainwater tanks can reduce household water bills if they are also plumbed to household appliances.	High costs to plumb rainwater tanks to existing households.	• Council incentives for rainwater tank installation to provide increased return on investment.
Rainwater tanks allow flexibility of use during water restrictions.	Flexibility of use during water restrictions.	• Council policies to promote rainwater tank installation.
During non-drought years, Rainwater tanks can reduce dam water supply operational costs.	High operational costs of pumping and water treatment.	• Rainwater tanks considered as an opportunity to reduce operations costs.
Rainwater tanks can be a resilience option for seismic events that pose a risk to Auckland's dams and water pipelines.	Currently the Auckland region is considered to be at low risk for seismic events.	• A study just released (2020) found that reservoir dams in the Hunua Ranges could be more at risk from earthquakes than originally thought. Risk mitigation measures may be required in future.

Table 4 Additional benefits of rainwater tanks and future changes – triggers for pathways

Obstacles for Rainwater tank Solution	Current Management/Consideration of Obstacles	Future Changes - Triggers for Pathway Options
Costs of rainwater tanks are considered to be approximately 4 times higher than other options	• Cost of rainwater tanks are compared to water from existing town water supply and not for new dams and pipelines. • Water rates are increasing by 7.5% for the next 2 years and then 9.5% for each of the following 7 years, therefore rainwater tanks will become more cost-effective. • Rainwater tanks are funded by individual property owners and costs do not come out of council funds/budgets; therefore, it is not appropriate to compare costs with other options. • Other benefits based on Integrated Water Management are not considered in cost comparisons.	• Price of town water keeps increasing to a point that rainwater tanks are more cost effective. • Consent approvals to take more water from Waikato River are restricted.
Public stigma on water quality from roofs (acid rain, chemical seepage, birds, and possums)	• Advanced filtration devices are available in NZ from approx. $700. • First flush divertors are available for as little as $80.	• More advanced Filtration devices. • Appropriate roofing material. • Bird and animal control methods.
Space restrictions on residential properties	• Manufacturers are providing a wider range of rainwater tank configurations to fit into smaller and tighter spaces. • Underground rainwater tanks are available to fit under driveways of multi-unit dwellings.	• Innovation by manufacturers for fitting rainwater tanks in small tight spaces.
Rainwater tank maintenance difficulties	• Maintenance practices are undertaken on an adhoc basis. • Specialists are engaged for regular maintenance.	• Low maintenance or self-cleaning innovative rainwater tanks.
Implementation costs are much higher for retrofitting into existing properties	• Relaxation of consent requirements but for irrigation only. • Uptake of rainwater tanks is only for irrigation purposes and for larger gardens for higher return on investment. • Uptake of rainwater tanks is only based on environmental stewardship.	• Council fast track consent process, incentives, and implementation programmes.
Rainwater tanks considered to have higher carbon emissions than town water supply	• Solar power generation for pumps and filtration devices to offset carbon emissions. • Research on carbon emissions of different rainwater tank material. • New dams, pipelines and pumps may have higher carbon emissions.	• Advanced solar power generation and innovative low-carbon rainwater tanks.

Table 5: Obstacles for rainwater tank solution and future changes – triggers for pathways

Tables 4 and 5 show that when IWM is considered together with future uncertainties and changes, potentially there are many additional benefits of rainwater tanks. The tables also show that many obstacles that are currently perceived with rainwater tanks can be managed or will become irrelevant in future.

The project outcomes show that rainwater tanks and other water source alternatives (e.g. grey water re-use, stormwater harvesting) could be triggered by future changes in criteria (economics, resilience-readiness, technological breakthroughs). Therefore, all potential options can be kept "alive" and an (APP) approach can be used to optimise investment decision-making as future uncertainties become more certain. Importantly, feasibility of the options, the triggers and the timelines for planning, design, consenting, and construction need to be assessed to understand implementation requirements of the options in time to meet the required level of service.

4 CONCLUSIONS

The Callaghan Innovation project has used a water industry case study to demonstrate the benefits of Integrated Water Management using an Adaptive Pathways Planning approach.

It has also demonstrated the importance of analysis, modelling and detailed feasibility assessments of multiple integrated 3-water strategies and options, that consider the impact of potential future changes.

As the Water Reform takes shape, we will need transparent evidence-based outcomes to provide confidence to the community that we are making optimal decisions on investments, decisions that have considered the impact of future uncertainties. In the past, we have planned and built infrastructure for a 50-to-100-year life and this has served us well, but it would be wise to now consider the impact of future uncertainties on locked-in infrastructure options.

The key questions we should be asking which are also aligned to the proposed Te Waihanga Infrastructure vision 2050 Strategy investment decision- making principles:

- **Future- focussed** - will we need this infrastructure in this form for the next 30, 50, 100 years? what future uncertainties could make this infrastructure redundant in the medium to long term future?
- **Focussed on options** – Have we considered all potential options?
- **Integrated** – Have we considered an integrated approach across asset networks, stakeholders, and communities?
- **Evidence-based** - have we undertaken detailed analysis and feasibility assessments using appropriate tools of all relevant options. Are we confident we have considered all risks, impacts and opportunities?
- **Adaptive pathway planning** - are there other less costly options we should choose now and then change tact when there is more certainty? Are there options that may become more attractive with future changes? Do we have a road map over the next 100 years?
- **Transparent** - can we support and provide full transparency of our analysis and decision-making process?

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