WHERE ARE WE AS A WATER SENSITIVE CITY? A CASE STUDY ON A SUSTAINABLE URBAN DEVELOPMENT

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ABSTRACT (300 WORDS MAXIMUM)

Development in Auckland is becoming more intensive to meet the city's growth needs and the lifestyle desires of its residents. Intensive residential development is encouraged in the Auckland Unitary Plan, but comes with environmental and infrastructure challenges such as the provision of three-water services.

A three level residential development, 'Element', is proposed at 20 Pukerangi Crescent, Ellerslie, Auckland, on land that is currently occupied by a single house. Element seeks to incorporate a high level of sustainable, environmentally friendly features and, as part of this, proposes to adopt on-site water management solutions and reduced potable water demand from Auckland's water supplier, Watercare Services Ltd. The philosophy for the water management is to manage stormwater runoff on-site and reuse it as a resource.

For the water management design, a continuous simulation water balance model was used, based on 60 years of historical rainfall record. The model simulated the performance of the water reuse tanks taking into account the runoff, on-site potable and irrigation reuse, and the available infiltration. The design includes for water supplementation from the town water supply. The Building Management System (BMS), which includes the management of the pumping and treatment plant of the potable reuse supply, will play an important role in maintaining non-stagnant conditions and ensuring that the dual supply system is maintained correctly.

Water Sensitive Design promotes viewing stormwater as a resource. To become a Water Sensitive City is seen by some as the ultimate goal in Management. The recently adopted Auckland Unitary Plan embraces some of the principles of Water Sensitive Design, helping Auckland to progress beyond being a Water Supply, Sewered and Drained city to being a Waterways City. This case study is an example of a development which embraces numerous principles of Water Sensitive Design, progressing beyond the policy requirements for stormwater management in Auckland.

KEYWORDS

Urban development, Growth, Sustainable development, Water management, Low impact design, Water re-use, Water sensitive urban design

PRESENTER PROFILE

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1 INTRODUCTION

Development in Auckland is becoming more intensive to meet the city's growth needs and the lifestyle desires of its residents. Intensive residential development is encouraged in the Auckland Unitary Plan, but comes with environmental and infrastructure challenges such as the provision of three-water services. Globally, emphasis is being placed on the importance of environmental sustainability and resilience, as cities endeavour to reduce their impact on the environment and to manage infrastructure costs.

Auckland Council was particularly keen for the residential development, 'Element', at 20 Pukerangi Crescent to be an exemplar of sustainable, on-site stormwater practice. The Developer, beyond his personal sustainability values, also recognized the increasing interest in the market for sustainable, environmentally friendly development. These aspirations have resulted in an integrated water management.

The urban residential development of 35 apartments is on 1860m^2 land currently occupied by a single house. Element inherently contributes positively towards Auckland's planning objectives by providing increased residential density in a part of Auckland that is within easy access to public transport options and local town centre amenities. Element incorporates a high level of sustainable, environmentally friendly features and, as part of this, it includes the on-site management of stormwater as a potable resource.

The site is located in a part of Auckland that generally relies on groundwater soakage as the primary means of stormwater disposal. The site has historically been serviced by a soakage pit although soil testing as part of the site investigations revealed low infiltration rate at the site.

As a prelude, this paper reviews the status of stormwater management in Auckland within the context of water sensitive urban design (WSUD). The philosophy and design approach adopted for the Element case study is then presented. The paper also describes the technical aspects of the design of the water management system adopted for the development.

2 AUCKLAND'S STORMWATER MANAGEMENT VISION

Population projections for Auckland predict the region's population will grow by 833,000 people to over 2.3 million by 2043 (2013 predictions, Stats NZ). The Auckland Unitary

Plan (AUP) came into effect in September 2017. This plan is intended to enable Auckland to accommodate the necessary growth and development while providing regulatory framework to help make Auckland a quality place to live (AUP, 2016). The plan shares a vision to become the world's most liveable city, with protection of the environment a cornerstone of that.

Stormwater Management aspirations for Auckland are encompassed in the Guideline document 'Water Sensitive Design for Stormwater' released March 2015, known as GD04. The water sensitive design aspirations in the document aim to minimize negative effects of development on the environment, while taking into account urban design objectives, landscape amenity and community issues. It also seeks to protect and enhance natural freshwater systems, sustainably manage water resources and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities. It also acknowledges that it is also important to achieve low risk and improved return on investment for development.

2.1 WHERE DOES AUCKLAND SIT?

Auckland Council commissioned a benchmarking study of Auckland's Stormwater management practices in 2014. The qualitative assessment was undertaken drawing on the perspectives of stakeholders within and outside Auckland Council, as well as key policy and organizational materials (TR2014007).

Figure 1 shows where this study evaluated Auckland's stormwater management practices to be. The study found that the city aspired to be a 'Waterways City', which valued its harbours and beaches, and whose Māori have a strong cultural value in maintaining healthy waterways. It observed that there has been an increasing adoption of water sensitive language, with increasing individual stakeholders desiring to have a water sensitive city.

The city's policy was between a 'Drained' and 'Waterways City'. It found that positive environmental outcomes are pursued when the opportunity arises on specific projects, rather that requiring it as standard practice. Stormwater management action was classified as a 'Drained City', where drainage and flood mitigation are the major drivers for stormwater initiatives.

The study recommended that Auckland develop a strategic pathway to become a Water Sensitive City, which is considered the ultimate goal in urban water management. As described by Brown et al, (2008) a Water Sensitive City is one which considers all available water resources (including rainwater and stormwater) as valuable, water infrastructure is designed both functionally and aesthetically, and communities engage in water sensitive behaviours. To achieve this requires "adaptive, multifunctional infrastructure and urban design, reinforcing water sensitive values and behaviours".

GD04 was issued subsequent to this study to improve the knowledge base and to expand the number of professionals and stakeholders creating and operating in the area of water sensitive urban design. The Auckland Unitary Plan (AUP) included additional measures to minimise and mitigate hydrological effects. Therefore, we consider that GD04 and AUP extends the position of Auckland's policy beyond the 'Waterways City' classification and towards the "Water Cycle City".

Element demonstrates water management and is an exemplar of actions consistent with a "Water Cycle City" and aspects of a "Water Sensitive City". It treats water as a resource, which is something that Auckland's policy does not yet require developers to do. The conventional approach to wastewater generated by the development prevents it from moving further into the Water Sensitive City space.

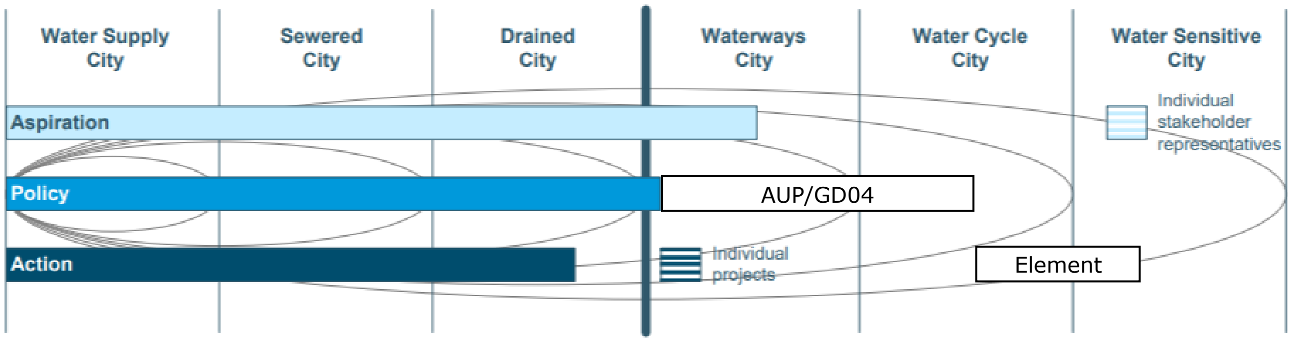

Figure 1: Assessment of Auckland's aspiration, policy and action for stormwater management practice in 2014, (TR2014007), updated to reflect GD04 and the Element

3 WATER SENSITIVE DESIGN APPLIED TO ELEMENT

Element incorporates water sensitive urban design principles and harmonises with Auckland's stormwater management aspirations. It utilises stormwater on-site as a resource for both non-potable and potable reuse and, as such, elevates stormwater management practice to water management practice.

3.1 BACKGROUND

The design solution was shaped not only by Council's desire for an exemplar project but by the local constraints: poor on-site soakage capacity and inadequate stormwater infrastructure drainage capacity nearby. Soakage is used by many of the neighbouring properties for stormwater disposal but site testing revealed the presence of low infiltration soils. The site geology is residual (East Coast Bays Formation) soils, consisting of clayey silts with very low permeability with poor soakage potential.

Some of the neighbouring properties discharge their stormwater to the kerbside, but this option is not generally promoted by Council for new developments. Connection to the public stormwater network would have involved an extension of the public network to the site by 300 m. Council preferred that an on-site stormwater management solution be adopted by the developers which embraced the city's aspirations on WSUD.

Council's expectations were therefore very challenging: despite low on-site soakage capacity, the developers had to provide an on-site stormwater management solution for rainfall events up to a 1 in 10 year average recurrence interval (ARI) event such that little or no stormwater leaves the boundary of the property. Council did however agree to occasional low flow discharges to kerb.

Early planning of the WSUD goals of the project were instrumental in shaping the direction of the project. Meetings with Council in the early stages of the project helped guide the direction of the design and affirming Council's support of the project philosophy as it developed. As a result of the early stage discussions, both Council and the development team were motivated to create an exemplar project showcasing WSUD.

The on-site management of the stormwater which includes potable reuse has also been favourably supported by Auckland's water supplier, Watercare Services Ltd (referred to here on as Watercare). It recognizes that such projects can reduce water demand from the town supply and could help to defer the implementation of capacity upgrades.

3.2 ON-SITE STORMWATER MANAGEMENT PHILOSOPHY

The essence of the adopted stormwater management solution is to minimise the generation of on-site stormwater runoff and to reuse the runoff generated.

Initially, reuse for non-potable purposes was considered, namely, for toilet flushing, for washing machine use and for site irrigation. Limitations with this reuse scenario are the need for a dual pipe system within the apartments and the fact that the non-potable reuse precludes the use of the water for other relatively high volume activities such as bath, shower and kitchen use. This made the balance between runoff generation and reuse more challenging and required a very large balancing storage volume. This prompted the developers to consider full potable reuse of the stormwater runoff.

Treatment of roof runoff for potable reuse is relatively straightforward, typically involving particle removal using different levels of filtration and disinfection. The treatment of paved runoff for potable reuse is more challenging because of the wide range of potential contaminants that may be present, particularly hydrocarbons and heavy metals from vehicle use of the driveway and parking area. Reuse of paved runoff for potable reuse was not cost effective and instead will be reused for irrigation of the raingardens and the other landscaped areas within Element.

The on-site stormwater management system selected for Element is shown diagrammatically in Figure 2 and comprises the following:

- Runoff minimisation by limiting the building footprint and using permeable paving,
- Runoff detention and retention within bioretention devices and landscaped areas,
- Runoff reuse for potable supply,
- Runoff reuse for irrigation supply.

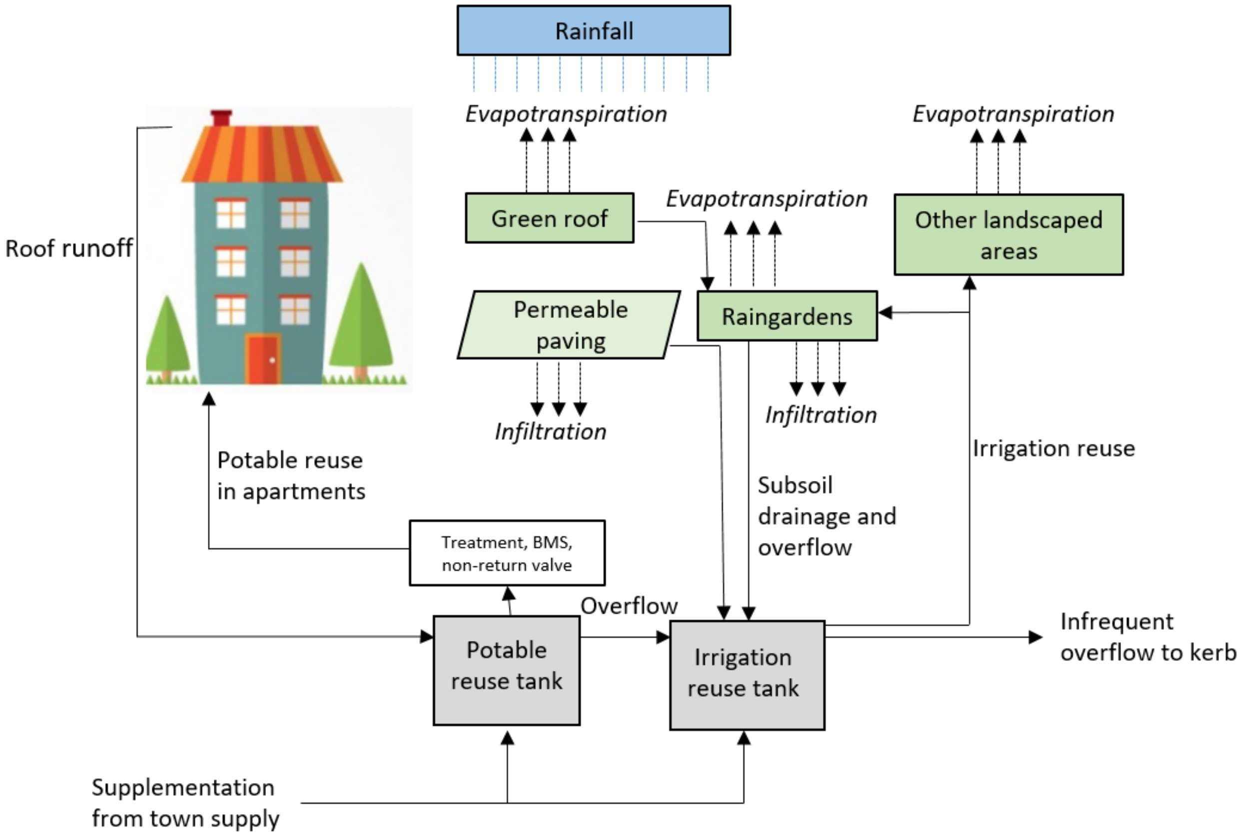

Figure 2: On-site stormwater management system

3.3 ON-SITE STORMWATER MANAGEMENT ELEMENTS

The on-site solution selected for the management of Element's stormwater incorporates the following elements:

- Minimisation of the building footprint by using medium-rise apartments and maximising of landscaping and planting areas and pervious surfaces,
- Minimisation of external car parking areas,
- Use of permeable paving for the driveway and open car parking area ,
- Provision of a green roof over the lobby area for bioretention and detention,
- Use of raingardens as bioretention and detention devices,
- Reuse of runoff from the majority of the roof area as a potable supply for the development,
- Reuse of paved runoff as an irrigation supply to the raingardens and other landscaped areas,

- Provision of 200 m^3 of on-site storage to balance the runoff generation and the reuse profile,

- Provision of a pipe for infrequent discharges to kerb at a flow not exceeding 2 L/s.

A layout plan of the on-site stormwater management provisions is shown in Figure 3.

3.3.1 ROOF RUNOFF

Runoff from the majority of Element's roof will initially be piped to a central proprietary device for the capture of any sediment and coarse pollutants. This will avoid the use of local first-flush devices on downpipes and maximize the volume of roof runoff captured.

The runoff will then enter an underground reinforced concrete storage tank of 100 m^3 capacity and dimensions 10 m long x 5 wide x 2 m deep. The water will enter the tank at one end via a spreader pipe. A submersible triplex pump arrangement at the other end will pump the water through treatment plant beside the tank and onward to the apartments for potable reuse.

Runoff from the lobby green roof will be discharged into the raingarden system.

A supply connection from the town water supply will be provided at the tank to replenish the tank when the runoff supply is insufficient to meet potable reuse demand and the tank is depleted.

3.3.2 PAVED RUNOFF

The main paved area in Element is the driveway and external car park with 10 parking lots. The area will have permeable paving to reduce the runoff generated. The runoff will be captured in a catchpit equipped with a filter bag device to capture coarse sediment and debris before the runoff enters a separate underground storage tank of 100 m^3 capacity and of similar depth to the potable reuse tank.

A submersible pump with a floating intake will pump the water for reuse as irrigation of the raingardens and other landscaped areas of Element.

The tank will receive overflow from the potable reuse tank via a connecting pipe equipped with a non-return valve which will prevent reverse flow into the potable reuse tank. The tank will also receive any flow from the basement subsoil pipe system of the main building.

A supply connection from the town water supply will be provided at the tank to replenish the tank if the runoff supply is insufficient to meet irrigation reuse demand and the tank is depleted.

3.3.3 RAINGARDENS

Raingardens totalling 165 m^2 will be provided on site to act as bioretention facilities as part of the on-site stormwater management system. Plant species will be used in the raingardens with good evapotranspiration properties to maximise their water disposal (retention) capacity. The raingardens will also have open bases to allow infiltration into the ground.

The raingardens will provide water detention properties via their deep growth layer of sand/topsoil as well as their surface mulch and contouring to encourage temporary ponding on their surface. The raingardens will be equipped with a subsoil pipe system to convey excess water away to discharge into the irrigation reuse tank. Each raingarden will have a catchpit type sump to trap silt from the subsoil pipe system and to capture high surface runoff through the grate of the sump.

Only limited runoff from paved areas will enter the raingardens. Their irrigation will mainly be from the irrigation reuse tank via a pump system. The frequency of irrigation will be tuned to allow for seasonal weather patterns.

3.3.4 OVERLAND FLOW

There is no overland flow from upstream areas through Element. The overland flow within the site for rainfall events greater than a 1 in 10 year ARI will run towards the north-east corner of the site where a grassed swale will convey the flow to the property boundary and into Pukerangi Crescent.

Figure 3: Element site plan

4 WATER TREATMENT & QUALITY FOR POTABLE USE

The Health (Drinking Water) Amendment Act 2007 is a risk management based legislative framework that introduces statutory requirements for water supplies serving a population of a certain size. The document that outlines the standards, and compliance methods to achieve these requirements is the Drinking-water Standards for New Zealand (DWSNZ). Under the Act, Element is considered to be a Neighborhood drinking-water supply.

Water treatment and monitoring can be achieved a number of ways and DWSNZ uses a log credit system based on the water source and filtration method. As an example water sourced from a roof catchment has a lower log credit than say that of an unprotected catchment area such as livestock near a body of water. In the unlikely event the irrigation tank overflow becomes blocked, a non-return valve has been provided on the overflow outlet of the potable reuse tank to prevent backflow into the potable reuse tank.

For this project the chosen method to treat and monitor the water is by appropriately sized filter banks, turbidity meter and UV lamps (40 mJ/cm^2). The filter banks and UV lamps are a run/standby arrangement with the pressure drop of each filter bank being constantly monitored. When the pressure drop reaches a predetermined level, the Building Management System (BMS) changes over to the filter bank in standby by means of an actuated three way diverting valve, as shown schematically in Figure 4.

The turbidity of the water downstream of the filter banks is also constantly monitored to ensure that efficacy of the UV lamps is achieved. If the turbidity falls outside the acceptable limits or the UV lamp faults, the BMS can notify offsite personnel by SMS messaging or similar.

Along with the treatment system the BMS also monitors others systems and plant in the building such as pump faults and hot water production.

This monitoring can be used to confirm that the treatment system is working within the flow rate and quality for which it was validated, for at least 95 percent of the time which is a requirement of DWSNZ.

The aesthetic determined guideline values in DWSNZ were considered. The potential taste differential between the potable reuse water and the town supplementary supply was considered and ruled out because supplementation is expected to be required most of the time i.e. it will be a blended supply.

Furthermore, water freshness within the reuse tanks and the avoidance of stagnant water within the town supply supplementation pipework will be achieved by regular flushing of the town supplementation pipework via the BMS.

It is expected that maintenance of the treatment plant will be similar to that of central domestic hot water plant to an apartment. At practical completion, an energy monitoring company takes over ownership, metering and maintenance of the plant and charge each apartment for the hot and cold water used.

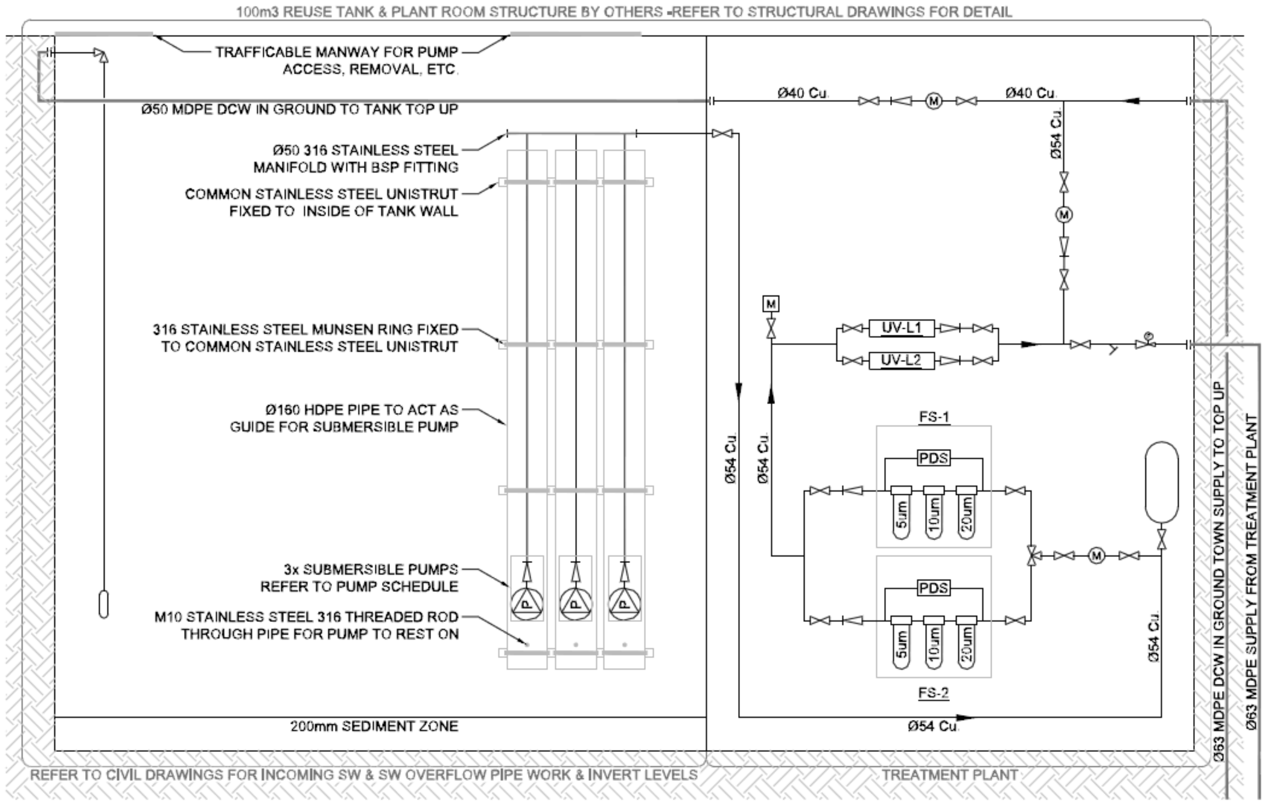

Figure 4: BMS schematic of water treatment and monitoring

5 REUSE TANK AND WATER BALANCE

The total reuse volume storage volume of 200 m^3 provided for Element comprises the runoff volume for a 24 hour duration, 1 in 10 year ARI rainfall event. It was Council's expectation that this volume be provided as part of the on-site stormwater management for Element.

A water balance model was developed to confirm the adequacy of 200 m^3 of storage for the potable and irrigation reuse and for ensuring that only infrequent discharges to the kerbside occur for rainfall events up to 1 in 10 years ARI. The performance of the tanks in response to rainfall, losses, infiltration and water reuse was assessed using a daily continuous simulation water balance model.

5.1 HYDROLOGY

The use of a historical rainfall record was adopted as the method for evaluating the adequacy of the reuse storage. The effect of climate change was accounted for by multiplying the rainfall record by the ratios required by Council.

A composite rainfall record was used to provide 60 years of historical rainfall record from 1949 to the present. Two rain gauges were used to create this record (Owairaka (1949 – 2008) and Mangere EWS (2008 – present) gauges). The rainfall data from both gauges was adjusted by a factor of 0.93 (based on design rainfall maps) to account for the spatial variability of rainfall between the gauge locations and the Ellerslie site.

5.2 REUSE DEMAND

Water demand for Element was based on the following provisions:

- A potable reuse rate of 150 L/day/person based on a rainwater tank based water supply. For a town based supply, per capita water demand is typically 200-250 L/day. Using this demand range in the analysis would result in more favourable, less conservative results.

- Full apartment occupancy and 75% apartment occupancy.

- An average irrigation reuse rate of 2.5 mm/m^2/day over a total area of 450 m^2 of bioretention and landscape areas. The irrigation use amounts to 2.3 m^3/day.

- An area of 210 m^2 available for infiltration. At the measured infiltration rate of 8.6 mm/day, the site infiltration volume that can be disposed of is 1.3 m^3/day, allowing for derating factor for infiltration.

- Infrequent discharge to kerb at a rate of not more than 2 L/s.

5.3 WATER REUSE STORAGE PERFORMANCE

The water reuse storage has dual objectives: to minimise stormwater discharges from site via detention and to provide a potable and irrigation reuse supplies. These two purposes can have competing requirements from the storage tank, where to perform optimally stormwater detention requires the storage tank to be empty, whereas reuse requires that the tank storage to be as full as possible.

The water balance analysis showed that, with full occupancy, the volume of the potable reuse tank is sufficient for only a few days' supply. For this reason, the tank will require supplementation from the Watercare supply most of the time. This is to be expected given that the 35 apartments share a common, limited roof area.

The irrigation reuse tank volume is sufficient for over 40 days' supply with no rainfall replenishment. The tank will also have a pipe connection from Watercare supply to supplement the supply when the tank storage is depleted. This could occur during the drier months.

The expected frequency and duration of discharge to the kerb from each the two reuse tanks are shown in Table 1. Figure 4 shows an example of the storage of the potable reuse tank in response to an unusually large rainfall event, which results in the tank overflowing and spilling to kerb.

Table 1: Water reuse storage performance

Tank size & use (m^3)	Potable reuse (L/d/p)	Average number of discharges to kerb per year	Average duration of discharges to kerb (days)	Percent of days or partial days tank is empty/ requires top up	% reuse of potable or non-potable water runoff from site
Potable, 100 m^3	150	0.03	1.0	92%	99.8%
Irrigation, 100 m^3	-	0.2	1.1	77%	99.4%

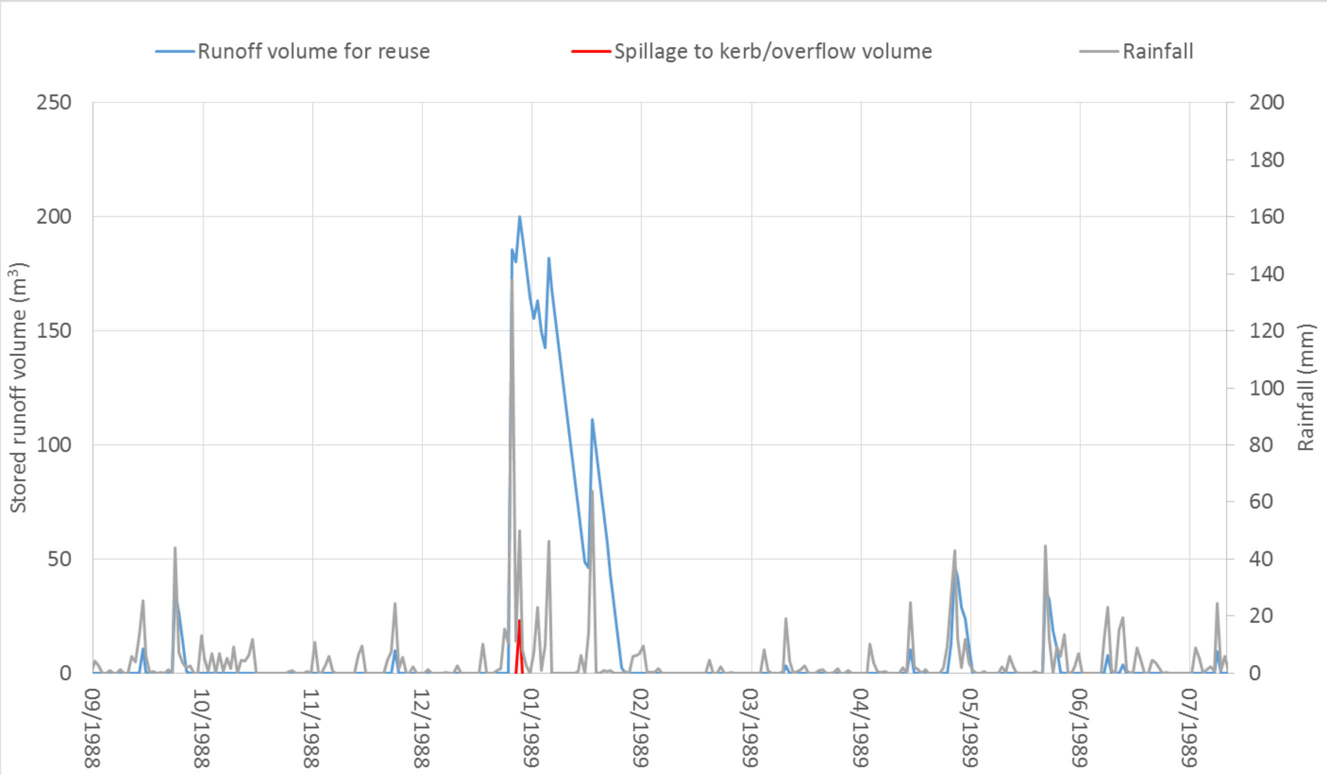

Figure 4: Hydrograph showing potable reuse storage tank response to a rain event

6 SUMMARY AND CONCLUSIONS

Auckland City is working towards becoming a Water Sensitive City. On its path towards this aspiration, the consensus is that the city has progressed beyond being merely a Water Supply, Sewered and Drained city to being a Waterways City. Beyond this and along the continuum, the city is aspiring to reach the ultimate goal of being a Water Sensitive City. This is typified by a city which considers all available water resources as valuable, water infrastructure is designed both functionally and aesthetically, and in which communities engage in water sensitive behaviours.

The city's aspiration, together with the challenge of limited stormwater disposal options for the Element development, has resulted in the adoption of an on-site stormwater management solution which reflects the practice of a Water Sensitive City and which constitutes water sensitive urban design.

The stormwater management solution incorporates the minimisation of building footprint and impervious area, the provision of bioretention in the form of raingardens for detention and retention, and the reuse, after treatment, of most of the site runoff as a potable supply to the apartments and for irrigation of the bioretention facilities. The potable reuse supply has the benefit of obviating the need for a dual pipe system within the apartments.

The provision of 200 m^3 of storage volume on site is adequate to result in only infrequent stormwater discharges from the site for rainfall events up to a 1 in 10 year average recurrence interval. The volume is also adequate to meet irrigation reuse requirements for long periods. For potable reuse, the runoff volume is adequate for a few days at full occupancy and demand, and supplementation from Watercare will make up the shortfall. The stormwater reuse proposals take into account the need for maintaining freshness of supply and for maintaining a wholesome quality of supply.

The Element apartment development is an apt example of sustainable development and reflects a positive step towards Auckland City's aspirations. The project is considered to be an exemplar project which has been achieved by a collaborative approach with Council. The project is expected to foster water conscious citizens, as well as provide a sense of place.

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