AUCKLAND UNITARY PLAN SMAF RULES: A STORMWATER ENGINEER'S EXPERIENCE

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ABSTRACT

Traditionally stormwater management of urban developments within Auckland comprised of water quantity and quality management. Although Low Impact Design (LID) was promoted by Auckland Council for many years, the most common approach was to provide hydrological mitigation using end of pipe stormwater solutions, such as wetlands.

Since the implementation of the Auckland Unitary Plan Operative in Part (AUP OP), the focus of stormwater management in Auckland has shifted to Water Sensitive Design. The stormwater management philosophy promoted by the AUP OP is to mimic the pre-development natural water cycle, in particular by provision of at-source volume management (i.e. by groundwater recharge or reuse). The balance of runoff is then released slowly (detention) to the receiving environment. Stormwater Management Areas - Flow (SMAF) have been created to define where the new approach is to be applied. The focus is on protecting sensitive stream catchments throughout the Auckland region. SMAF has essentially turned the tide on traditional stormwater management.

At the same time, there are increasing pressures to produce residential developments with higher yields and more affordable housing due to the rapid population growth in Auckland. With more compact housing, there are significant challenges in the selection and integration of at source stormwater management devices within residential lots.

This paper will discuss the challenges of implementing at source SMAF devices within high density residential developments. The authors will share their experiences of the constraints encountered and the lessons learned for implementing successful on lot SMAF devices.

KEYWORDS

Auckland Unitary Plan, Water Sensitive Design, SMAF rules, at source stormwater management

PRESENTER PROFILES

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1 INTRODUCTION

1.1 CURRENT LAND DEVELOPMENT PRACTICES

With an additional one million residents anticipated to settle in Auckland in the 30 years following publication of The Auckland Plan in 2012, the Auckland region will account for more than half of New Zealand's population growth by 2043. With increasing pressures on housing availability and affordability in Auckland, The Auckland Plan has identified a need for an improved supply of affordable housing.

Incentivised by the housing shortage and elevated property values in Auckland, land development practices have shifted to focus on higher density residential subdivisions. These developments generally consist of small residential lots, with a large proportion of terraced and duplex housing typologies. Retaining structures and decentralised, at source (i.e. on-lot) stormwater management devices are now typically seen throughout developments in order to maximise yield. Widespread use of compacted, imported fill material reduces the infiltration potential of the pervious coverage tends towards Maximum Probable Density limits, maximising runoff volumes and peak flow rates.

Site compaction, disruptions to natural flow paths, earthworking, and construction of impervious hardstand areas are examples of hydrologically disruptive land development practices typically found in Auckland developments. These practices reduce the infiltration capacity of pervious areas, thereby disrupting the natural hydrology of the receiving environment. Mass alteration of natural site features by land development processes does not align with WSD principles, and may also contradict the requirements set out in the Auckland Code of Practice for Land Development and Subdivision: Chapter 4 - Stormwater.

1.2 AUCKLAND'S BLEND OF WATER SENSITIVE DESIGN

Stormwater management considerations introduced under the Proposed Auckland Unitary Plan (PAUP) and later under the Auckland Unitary Plan Operative in Part (AUP OP) require consideration of cultural values, social needs and natural features as part of the functional design of the stormwater network. Successful application of Water Sensitive Design (WSD) principles, which promote land use planning practices that balance land development with the ecosystem services necessary to support it, is essential to supporting the vision of The Auckland Plan to create the world's most livable city.

WSD principles applicable to stormwater management listed in Auckland Council's Guideline Document 2015/004 (GD 04) are shown below.

- Promoting inter-disciplinary planning and design
- Protecting and enhancing the values and functions of natural ecosystems
- Addressing stormwater effects as close to the source as possible
- Mimicking natural systems and processes for stormwater management

Water Sensitive Design requirements are applied through provision of SMAF retention (through infiltration or non-potable reuse) and detention on most development sites throughout the region. Developers may also be required to provide treatment of runoff or attenuation of peak runoff rates in extreme rainfall events depending on the receiving environment, network capacity, and the type of activity proposed.

These requirements are listed below.

- Provide retention (volume reduction) of a 5 mm, 24 hour rainfall event for the impervious area for which hydrology mitigation is required.

- Provide detention (temporary storage) with a volume equal to the runoff volume from the $95^{th}/90^{th}$ percentile, 24 hour rainfall event for the impervious area for which hydrology mitigation is required.

2 THE STORMWATER ENGINEER'S TOOLBOX

In the case of Auckland's large-scale residential developments, it common for developers to construct a subdivision consisting of vacant lots. The vacant lots are sold and ultimately designed and constructed by another developer. As a result, the final layout of each lot is unknown throughout the entire subdivision design process.

The stormwater provisions and management approach for the development should be determined at the project outset in order to reduce the impacts of increased runoff from the development on the receiving environment. However as lot layouts, roof areas, and impervious site coverage are so often unknown variables at the subdivision stage the water sensitive designer is unable to ensure there is sufficient space within each lot for the devices, the minimum size of which can only be estimated using Maximum Probable Density limits.

It is common practice to instead produce a range or 'toolbox' of on–lot stormwater management options, which can be used to meet the required stormwater provisions. Keeping the toolbox open (proposing a wide range of options for stormwater management) gives the lot developer the freedom to select a preferred option based on cost, practicality, amenity value, and natural site features. However due to uncertainties surrounding device sizing and lot layout it is often impossible to assess the feasibility of each option in the toolbox during the resource consenting process. It is not uncommon for stormwater management requirements to be glazed over at this stage. Once the civil aspect of the development is constructed there is often only one or two stormwater management devices remaining in the toolbox.

The Auckland Council Guideline Document 2017/001 (GD 01) recommends a number of stormwater management devices options to provide retention and detention. These devices are summarised below in Table 1.

Table 1: Typical On Lot SMAF Device Options

Stormwater Management Device	Retention	Detention
Bioretention	✓	✓
Infiltration Devices	✓	✓ (if detention volume is infiltrated into the underlying soil)
Pervious Paving	✓	✓
Living Roofs	✓	
Rainwater Tanks	✓	✓
Wetlands (collecting runoff from the development stormwater network)		✓
Ponds (collecting runoff from the development stormwater network)		✓

3 LIMITATIONS TO LOCATING ON-LOT SMAF DEVICES

When each residential lot is developed, the on lot SMAF device will be selected based on the individual site and device limitations, construction and maintenance cost, device design life and the resource consent conditions of the development. General limitations which affect the on-lot device selection are summarised in Table 2.

Table 2: General Limitations to On-Lot SMAF Device Options

General Limitations	Description
Client/Developer Priorities	Device selection can be limited by the priorities of the client or developer's priorities such as cost, building guarantees and green star building ratings.
Safety Risks	Safe design should begin early in the design process to eliminate or minimise the risks of death, injury or illness to those who will construct, operate, maintain, inspect, decommission and demolish any asset.
Operation and Maintenance	The Auckland Council Stormwater Bylaw 2015 requires that the owner and manager of any private stormwater systems must ensure that they are maintained in good operating condition. The devices must be frequently inspected and maintained to ensure that they do not become blocked. As a result, device selection can be limited due to maintenance access, cost, ease and frequency.
Construction Cost	Construction costs of stormwater devices can also be a significant limitation on device selection.
Client Stormwater Management Education	Previously, extended detention was normally provided to mitigate runoff generated from new impervious development areas which discharge into watercourses. Since the introduction of retention requirements in the Auckland Unitary Plan, there is often resistance from experienced clients or developers to provide on-lot retention via infiltration.

Failure to consider WSD from the offset and throughout the subdivision design	Lot layouts are often unknown during the subdivision design process. The location of on-lot stormwater devices is therefore not considered when determining the subdivision contours, retaining wall locations, public infrastructure and lot connection locations. To meet the setback requirements from these structures and services in accordance with GD 01 and the Auckland Council Code of Practice for Land Development and Subdivision (Chapter 4- Stormwater), the flexibility of on lot stormwater device locations and number of viable stormwater device options from the toolbox has reduced due to the predetermined site layout.

To ensure that the AUP OP stormwater provisions are met for each lot, SMAF devices must be designed in accordance with GD 01. There are therefore design limitations which affect the SMAF device size, selection and location. The advantages and disadvantages for each on-lot SMAF toolbox option are discussed below.

As wetland and ponds are not on-lot SMAF devices, their associated limitations will not be discussed in this paper. It should be noted that the use of ponds and wetlands are no longer considered to provide retention for impervious areas located within lots, therefore on-lot mitigation for the retention volume is still required within the lots.

3.1 BIORETENTION

Bioretention devices are generally well supported by current policies and guidelines. They are widely used throughout development within road corridors. However, there are limitations to their application in the context of residential lots within medium to high density developments.

Bioretention devices include bioretention swales, raingardens, planter boxes and tree pits. Due to design requirements and cost implications, tree pits and swales are not considered to be feasible options for on-lot SMAF mitigation. Therefore, they have not been discussed in this paper.

Table 3: Advantages and Disadvantages of On-Lot SMAF Bioretention Devices

Advantages	Disadvantages
General Bioretention Devices	
Groundwater recharge and restoration of stream baseflow can be provided through infiltration of the retention volume.	Landscape architects will be required to specify suitable plants for the bioretention device.
Provide functionality as well as increased amenity value.	Plant growth and die-off management is needed during establishment phase.

Bioretention devices sized to meet SMAF 1 or SMAF 2 stormwater management provisions also provide water quality treatment of runoff.	If retention is provided, GD 01 requires that the bioretention device footprint must be sized to infiltrate the retention volume into the underlying soil over 72 hours (based on a minimum soil infiltration rate of 2mm/hour). If an infiltration rate of 2mm/hour is assumed, a minimum bioretention device footprint size of 3.5% of the impervious catchment area is required. As a result, the space requirements for this device can become a significant limitation.
	Specific operation and maintenance is required for bioretention devices.
	The asset owner must understand how to operate and maintain the device. There is risk that the asset owner does not understand that the raingarden is a stormwater management device, and therefore does not maintain it appropriately.
	Specific design is required for raingardens. An "off the shelf" product cannot solely be used.
	There must be sufficient setback from structures (including buildings and retaining walls), slopes, roads, public and private services located within the lot and lot boundaries (in accordance with GD 01 and the Auckland Council Code of Practice for Land Development and Subdivisions (Chapter 4- Stormwater). Therefore devices can be difficult to locate within lots.
	There must be sufficient clearance from seasonal high groundwater level (in accordance with GD 01).
Raingardens	
Can be used to provide retention and detention for runoff generated from roof and impervious surface areas.	Can be costly to construct if concrete units are used.
	An external bypass for high flows is required for the raingarden unit. This often consists of a catchpit or scruffy dome connected to the stormwater network. This therefore increases the construction costs when compared to a planter box.
	Natural slope raingardens often need a larger footprint area to achieve the required retention and detention volumes than concrete unit raingardens.
	It can be difficult to drain all lot impervious surface areas to the raingarden via surface flow.
Planter Boxes	
Can be placed against the external wall of a building.	Concrete units are preferred for planted boxes due to their design life. This can increase construction costs of the planter box.
Can be used to provide retention and detention for runoff generated from roof areas.	It is not practical to discharge runoff from lot impervious surface areas to the device. Therefore planter boxes can only provide retention and detention for runoff generated form roof areas.
	There is added complexity in the design due to waterproofing of the building has to be factored in.
	Design could be difficult to construct due to close proximity to building.

3.2 INFILTRATION DEVICES

Infiltration devices can be designed to collect and infiltrate the SMAF retention volumes from roof and impervious surface areas. The devices can also be used to provide detention through infiltration into the underlying soils.

Typical infiltration devices used within residential lots are aggregate infiltration trenches and underground infiltration chambers, such as crates, arches, and sealed pipes.

Table 4: Advantages and Disadvantages of On-Lot SMAF Infiltration Devices

Advantages	Disadvantages
General Infiltration Devices	
Groundwater recharge and restoration of stream baseflow can be provided through infiltration of the retention volume.	There must be sufficient setback from structures (including buildings and retaining walls), slopes, roads, public and private services located within the lot and lot boundaries (in accordance with GD 01 and the Auckland Council Code of Practice for Land Development and Subdivisions (Chapter 4- Stormwater). Therefore devices can be difficult to locate within lots.
Less hard-engineered approach to provide retention.	Minimum underlying soil infiltration rate of 10mm/hour is required for infiltration devices. This restricts their use to a few small areas of the Auckland Region, some of which use soakpits to discharge stormwater runoff. They majority of subdivisions use imported fill during the earthworks process, which are normally clay soils. As a result of the imported fill and compaction during the earth working process, the infiltration rates of the development soils increase, reducing the likelihood of achieving a minimum infiltration rate of 10mm/hour.
Minimal impact on landscape design compared to other toolbox options.	Geotechnical evaluation of site subsoils is required needed prior to selecting infiltration devices.
	Infiltration must not be used where soils are susceptible to instability (including expansive soils).
	GD 01 requires that the infiltration device footprint must be sized to infiltrate the retention and/or detention volume into the underlying soil over 72 hours (based on a minimum soil infiltration rate of 10mm/hour). If detention volume to be provided, the minimum footprint area of the device significantly increases when compared to the device size for retention only, making it an infeasible option on small lots.
	Infiltration devices are prone to clogging. The asset owner must understand how to operate and maintain the device to prevent clogging. They are often difficult to maintain and may require replacing if blocked.
	Maintenance access if difficult on small lots.
	There must be sufficient clearance from seasonal high groundwater level (in accordance with GD 01).
	Infiltration devices should not be constructed on steep or unstable slopes.
Infiltration Trenches	
	Drainage aggregates with a sufficient void space ratio (for example scoria) can be costly and difficult to source.
	When infiltrations are constructed at ground level, it can be detrimental to the lot aesthetic if not properly integrated into the landscape architecture.

Infiltration Chambers	
Smaller device footprint area compared to infiltration trenches due to the high void space ratio of device.	Purchase of modular tanks can be costly.
	Depth of excavation required can be costly and can be a risk to safety during construction.

3.3 PERVIOUS PAVING

Pervious paving is commonly used in Auckland, particularly on private or jointly owned access lots. GD 01 considers that there 2 two different types of pervious paving systems; active and passive. Active systems collect runoff generated from the receiving impervious catchment area, and is sized to meet SMAF stormwater provisions. Passive systems collect runoff generated from the surface of the pervious paving, and are therefore considered in the Auckland Unitary Plan pervious surfaces. As a result, passive systems do not trigger the provision stormwater mitigation requirements in the AUP OP.

Table 5: Advantages and Disadvantages of On-Lot SMAF Pervious Paving

Advantages	Disadvantages
Groundwater recharge and restoration of stream baseflow can be provided through infiltration of the retention volume.	Pervious paving cannot be used to provide stormwater mitigation for runoff generated from roof areas.
Can used as an amenity feature and can be incorporated into the landscape/architectural design of the lot.	For active systems, it can be difficult to drain all lot impervious surface areas to the pervious paving.
Pervious paving reduces the impervious cover of the lot.	Can be costly to construct due to material and labour costs.
For active systems, pervious paving can be used to provide retention and detention for impervious surface areas.	The asset owner must understand how to operate and maintain the device. Poorly maintained devices can become a risk to safety, for example loose paving blocks are tripping hazards.
Passive pervious paving systems do not trigger stormwater management requirements in the AUP OP.	Pervious paving can easily become clogged. To prevent clogging, regular maintenance is required by a professional, which increases the cost of maintenance.
For passive systems, specific sizing is not required as it is assumed that the detention and retention volumes will not produce runoff from the surface.	Maximum slope for active and passive pervious paving designs are 5% and 7% respectively. Driveways often exceed these grades, therefore pervious paving cannot be used, and additional stormwater management devices will be required to mitigate runoff generated from the driveway.
	For active systems, specific design is required for raingardens. An “off the shelf” product cannot solely be used.
	There must be sufficient clearance from seasonal high groundwater level (in accordance with GD 01).
	There must be sufficient setback from steep slopes (in accordance with GD 01).
	Pervious paving must not be used where soils are susceptible to instability.

3.4 LIVING ROOFS

Similar to pervious paving, if living roofs are used as a passive device, they are considered to be a pervious surface area under the AUP OP, and are therefore excluded from any impervious area calculations. Therefore if a living roof is used, the stormwater management provisions in the AUP OP are not triggered for the roof area.

Living roofs are very rarely seen in residential developments in Auckland, presumably due to the structural and consenting costs associated with their design and construction. We expect they will be increasingly adopted to mitigate roof runoff from industrial and commercial sites in the coming years as a means of reducing reliance on communal devices or large rainwater tanks.

Table 6: Advantages and Disadvantages of On-Lot SMAF Living Roofs

Advantages	Disadvantages
Ecological – can act as an "urban sanctuary" for wildlife, and provide a more diverse urban ecology.	Living roofs can add significant dead loading to the structure. Therefore an assessment must be carried out by a structural engineer to ensure that the roof is capable of supporting the living roof.
Passive living roof systems do not trigger stormwater management requirements for the roof area in the AUP OP. Therefore mitigation of the roof are does not need to rely on underground infrastructure or devices at the ground level.	Intensive monitoring of plant health is required in addition to standard operation and maintenance requirements. It may also be necessary to provide additional watering for the plants during the summer months, or during extended periods of dry weather. This may prove to be overwhelming for asset owner.
Increased green spaces within a development	The minimum and maximum roof slopes required for a living roof are 3.5% and 26.8% respectively. Roof slopes between 17.6% and 26.8% require additional structures (such as anti-slip protection). If roof slopes less than 3.5% are unavoidable, a drainage layer must be installed. Limitations on roof slopes can cause difficulties when integrating the stormwater management design with the architectural design. This reduces the feasibility of a living roof when selecting a stormwater management device from the toolbox.
Contributes to reducing urban temperatures, and can provide insulation for a residence	A building consent is required for the installation of a living roof, which can slow down the lot development process.
	Building heating, ventilation and air conditioning (HVAC) can compromise the waterproofing membrane of the living roof system. As leaky homes are significant concerns in the New Zealand housing market, it may cause discourage potential buyers of the property.
	Careful consideration of safety needs to be given for the inspection and maintenance of the living roof.
	Construction and maintenance of living roofs can be costly, and therefore may not be a feasible option for small residential buildings.

3.5 RAINWATER TANKS

Rainwater tanks can be used to provide detention by collecting runoff generated from the impervious catchment area, and slowly discharging it through an orifice, into the stormwater network over 24 hours. The SMAF retention mitigation volume can also be provided using rainwater tanks through non-potable reuse, which must be used within 72 hours. Water from the dual purpose rainwater tank can only be used for household use (laundry or toilet water supply) or outside (garden watering).

Above ground rainwater tanks can be used to provide SMAF hydrological mitigation for roof areas. If rainwater tanks are placed below ground, SMAF hydrological mitigation can also be provided for impervious surface areas.

Table 7: Advantages and Disadvantages of On-Lot SMAF Rainwater Tanks

Advantages	Disadvantages
Reduction in non-potable water use from the public water supply network.	When an above ground tank is used, retention and detention for runoff generated from impervious surface areas must be provided using another stormwater management device.
Above ground tanks can be used to provide retention and detention for runoff generated from the roof area.	Where rainwater tank are to provide retention through reuse, the asset owner must commit to using the retained volume.
Below ground tanks can be used to provide retention and detention for runoff generated from the roof and impervious surface areas.	The rainwater tank cannot be used for potable water supply. If this is required, extensive treatment processes may be required.
	For detention only rainwater tanks, a minimum tank size of 1,000 Litres is required. Dual purpose rainwater tanks require a minimum storage volume of 4,500 Litres. For smaller residential lots, the minimum tank size may be excessive compared to the required stormwater mitigation volumes, making it an infeasible option on small lots.
	Above ground rain tanks should be placed in locations where they can be easily access for maintenance, which limits the flexibility of locating the device.
	If possible, above ground rainwater tanks should be placed on the southern side of buildings (to reduce exposure to sunlight).
	Rainwater tanks should not be placed inside the drip line of a tree canopy to prevent damage to the tank from the roots.
	Above ground tanks located next to the site boundary should be less than 1.8m high.
	Rainwater tanks are perceived as having poor ascetics. Therefore, it is difficult to incorporate rainwater tanks into the landscape and architectural design of the lot.
	A geotechnical assessment should be carried out when locating a rainwater tank in geotechnical unstable areas or close to a retaining wall or on slopes. This may reduce the feasibility of the device depending on the development and site constraints.

4 CONCLUSIONS

4.1 DEVELOPMENT DESIGN AND CONSENTING PROCESS

In many cases, WSD considerations are addressed at the project outset, then ignored throughout much of the earthworks and resource consenting stages. Contrary to this, GD 04 Water Sensitive Design for Stormwater states that WSD aims to reduce or minimise negative effects on the environment through the appropriate location, layout, and design of the development in its context within the broader catchment and region.

A direct result of the decision to exclude stormwater management from the development design is that communal devices, and more so on-lot devices, are often the last aspect of the development to be given appropriate consideration. Early consultation with water resources designers would in many cases lead to developments that better mimic the natural hydrology of the pre-development site. Cross-benefits of this alternative way of working would be realised by improved stream health and improved amenity values within the development.

4.2 DEVICE LIMITATIONS

The physical limitations of on-lot SMAF devices are generally well understood by water sensitive designers. The majority of physical limitations are related to structural stability, slope stability, geotechnical considerations, and subsoil drainage capacity.

There are very few practical recommendations to be made regarding physical limitations.

On development sites where vacant lots are sold to private lot developers it is often difficult to locate stormwater management devices in the front yard due to offset requirements from wastewater connections.

Additionally, minimum dual-purpose rainwater tank size requirements introduced under recent guidelines can be challenging to implement. The requirement to provide such large tanks, which are often close to two metres high and three metres long, has a profound effect on urban design and landscaping aspects of the projects including shade studies.

4.3 SETTING FLEXIBLE WATER SENSITIVE DESIGN REQUIREMENTS

Although the WSD approach relates to management of the total water cycle, its use in Auckland is generally restricted to a stormwater management scope. Successful application of WSD principles will approximate, as far as practicable, the natural hydrology of the undisturbed, pre-development site.

A prevalent misconception exists that WSD should prioritise infiltration of runoff as a means of recharging groundwater and protecting stream baseflow, regardless of the site's geotechnical, topographical and hydrological features. Water Sensitive Design objectives should however be tailored to mimic the function of the pre-existing landform rather than meeting a predetermined objective.

We would argue that in areas with relatively high subsoil drainage rates and reasonable stream health, retention through non-potable reuse should be prioritised over retention through infiltration. In this case a high level of groundwater recharge will be achieved through infiltration in pervious areas, supplemented by the volume reduction achieved by non-potable reuse.

Similarly, retention through infiltration should be prioritised over retention through non-potable reuse on development sites with poor pre-development subsoil drainage properties. In this case it is unlikely that stream baseflow would be preserved if retention through non-potable reuse was used throughout the catchment.

Finally, in cases where residential lots are so constrained that infiltration cannot be provided at a level normally required by SMAF retention, concessions for partial fulfilment of retention quota should be considered in recognition of the cross-benefits to stream ecology offered by infiltration opposed to non-potable reuse. This style of approach aligns well with a core concept of WSD: promoting land use planning practices that balance land development with the ecosystem services necessary to support it.

5 RECOMMENDATIONS

- Stormwater management design needs to be initiated at an earlier stage in the development process. This could be achieved by requiring a greater level of detail at the resource consenting stage. This recommendation aligns with the WSD principle of promoting inter-disciplinary planning and design and may lead to the use of a more diverse range of stormwater management solutions.
- The methodology used to determine minimum sizes of dual-purpose rainwater tanks (GD 01) needs to factor in the size of the lot and the impervious catchment area draining to it. It is often difficult to incorporate the tanks into small terraced or duplex lots due to spatial restrictions.
- Concessions for partial fulfilment of retention quota should be considered in extreme cases where the site-specific constraints are prohibitive to achieving SMAF retention through infiltration.

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