CRCWSC Research Synthesis

Discussion Paper | CRC for Water Sensitive Cities

SOLUTIONS FOR NORMAN CREEK

CRC for
Water Sensitive Cities

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Solutions for Norman Creek

Publisher

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About this Discussion Paper

This Discussion Paper proposes flood resilience initiatives for Norman Creek, Brisbane. It compiles ideas generated during a research synthesis workshop hosted by the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) and Brisbane City Council on the 16th and 17th August 2016. The workshop participants gathered to develop innovative flood management ideas and to consider how they might be applied in Norman Creek. The ideas were developed as part of an innovation process and have no formal status; further analysis and evaluation will be required before any are adopted.

The need for Solutions for Norman Creek

Brisbane is a city built on a flood plain. Floods are a familiar, if not necessarily welcomed, part of life. Recognising this, Brisbane aspires to be a city that 'lives well with flooding'. Brisbane's community has also experienced drought, and understands that flood resilience, water security and liveability are linked concepts that make up Brisbane's water story.

These aspects of Brisbane's water story reflect the changing nature of water in cities more broadly – the need to manage for a changing climate, growing urban population and a desire to harness water's ability to create more liveable places in which to live and work.

Norman Creek, as one of the most urbanised catchments in Brisbane, acutely represents these opportunities and can showcase solutions that can be replicated across the city. In addition to the challenges of flood management and drought security, there is also a strong desire to re-connect the community with the catchment in which it lives and to facilitate sustainable urban development. Taking these leads, workshop participants were invited to reconsider the issue of flooding in Norman Creek by:

- expanding the definition of the problem
- exploring new options that intentionally differ from traditional approaches
- considering future scenarios in which these options would be economically and practically viable, to understand when and how they might be implemented.

The result is Solution for Norman Creek.

Figure 1 – Flood resilient cites create temporary spaces for stormwater and harness flood infrastructure to improve liveability. Adventure corridors (see pg 34) apply these principles and can be created along overland flow paths in Norman Creek in areas of high density redevelopment. (Image credit - Realm Studios)

Key Findings

The problem

Norman Creek is an urbanised catchment that experiences regular flooding. Flooding caused by overland flows is of particular interest as this affects more properties than river flooding or other sources. The catchment itself is subject to ongoing urban development. Whilst development controls ensure new development protects life and property and does not exacerbate current flood risks, densification can still alter the area of impermeable surfaces across the catchment.

Proposed strategy

A new whole-of-catchment flood strategy can support existing drainage infrastructure by restoring some of the permeability and flow paths of the catchment. This whole-of-catchment approach recognises that flooding doesn't distinguish between **public** and **private** spaces, and builds flood resilience by harnessing local-scale open space opportunities across both realms. The solutions themselves build upon this by achieving two outcomes: **retention of stormwater locally** and/or the **provision of safe passage for overland flows**. This strategy, and the solutions, are shown in Figure 2.

The strategy harnesses the community value of open space as a basis for investment, placement and design of flood management elements. These spaces can be designed to be multifunctional – to store or infiltrate stormwater, whilst also offering other amenity, recreation or sustainability outcomes.

Business case

Whilst a full business case is beyond the scope of this Discussion Paper, it is possible to articulate the rationale and benefits of the proposed solutions. Initial analysis shows the solutions are achievable, deliver measurable reductions in runoff are net present value (NPV) positive and deliver additional community benefits such as a reduction in the urban heat island effect.

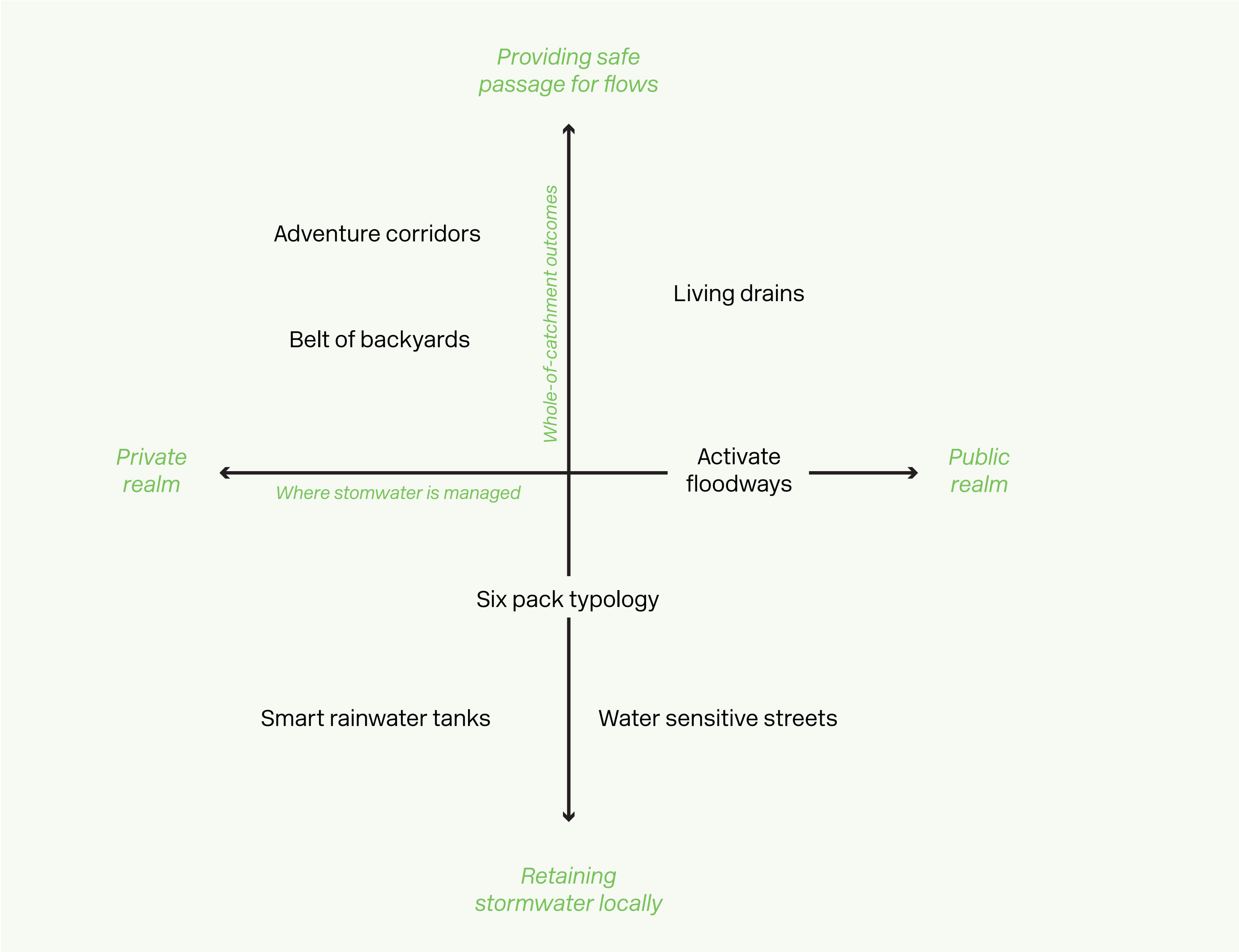


Figure 2 – Overview of the strategy and solutions

Context

Norman Creek[1]

The Norman Creek catchment includes the suburbs of Annerley, Norman Park, East Brisbane, Woolloongabba, Greenslopes, Coorparoo, Camp Hill, Holland Park, Holland Park West, Mount Gravatt, Mount Gravatt East and Tarragindi.

The catchment is approximately 29.8 km² in area and includes the waterway of Norman Creek and its tributaries. The topography varies considerably, with the upper reaches being steep and hilly, while the lower catchment is relatively flat. The watercourses are highly modified, with many being channelled, piped, concreted or realigned.

The catchment is home to almost 9.5% of the population of Brisbane. As a result it is highly urbanised, with the dominant housing type in the catchment being the single detached house, and only 2% of the area is undeveloped. There are few areas of original vegetation remaining and impervious surfaces, including roads and roofs, cover between 28-58% of the catchment.

The population within the Norman Creek catchment is expected to increase by approximately 5.7% to 106,996 persons by 2031. The statistical local area that will accommodate the greatest growth from 2011 to 2031 is Woolloongabba, with an expected growth of 177%. The statistical local areas of Greenslopes (28%), Coorparoo (22%), East Brisbane (12.5%) and Annerley (6.9%) are also the higher population growth areas in the Norman Creek catchment. The statistical local areas of Holland Park, Holland Park West, Tarragindi, Mount Gravatt, Mount Gravatt East, Camp Hill and Norman Park will experience little change in population between 2011 and 2031.

Figure 3 – The Norman Creek Catchment (Image credit – Brisbane City Council)

[1] *Adapted from BCC (2017)*

How flooding affects Norman Creek

Understanding the source of flooding is an important first step in designing solutions. As the responses to each may vary, it can be useful to describe these different types:

- Fluvial (creek and river) flooding - when water breaks out of a waterway following rain across a large catchment.
- Pluvial (overland) flooding - overland flows generated by rain falling in a local area.
- Coastal/storm tide flooding - storm surges and waves generated by severe storms.
- Groundwater flooding - when groundwater rises above the ground surface.

Figure 4 shows the extent of these flooding types in the Norman Creek region (an area that includes Norman Creek, South Bank and West End). It shows that more properties are affected by overland flows than any other source of flooding. This Discussion Paper recognises these impacts and the problems potentially faced in a denser future city when even small storms will generate overland flows and potential flooding.

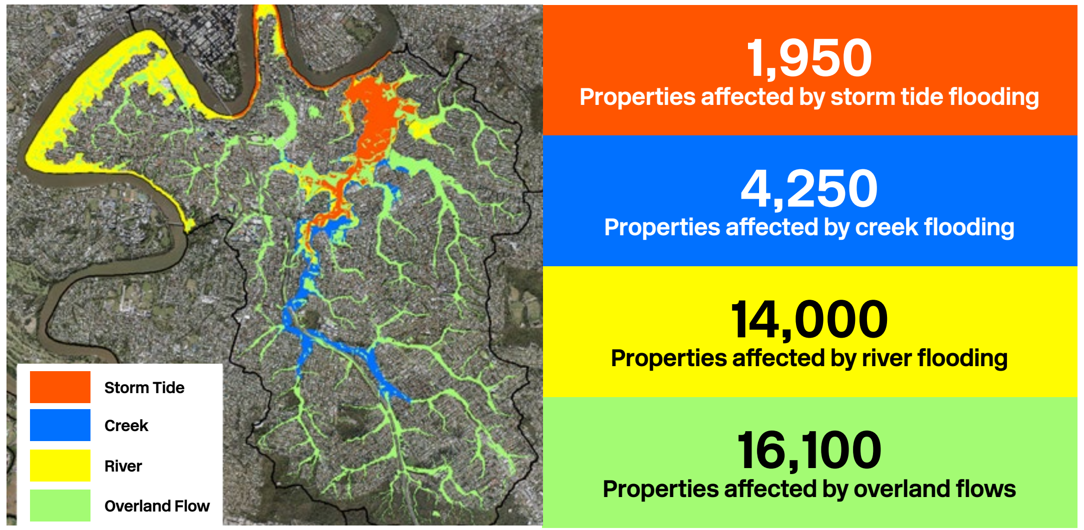


Figure 4 – The impact of different sources of flooding in the region (an area including Norman Creek, South Bank and West End)[2] (Image credit – GHD).

[2] *The approximate number of properties affected by a nominal flood event, intended to show the relative impacts of different flood sources. These figures are derived from separate studies conducted using different methods, and are not an official estimate.*

Flooding at the river basin scale: the urban response

The Solutions for Norman Creek form part of a broader, catchment scale approach to flood resilience in Brisbane and South East Queensland.

In 2016, James Davidson Architects hosted a Water Futures Design Charrette to develop a catchment-scale flood resilience framework for South East Queensland: a "Fluvial Transect" (Figure 5). The workshop was initiated in response to the 2011 Brisbane River floods and its outputs highlight the specific opportunities in the "River City" zone:

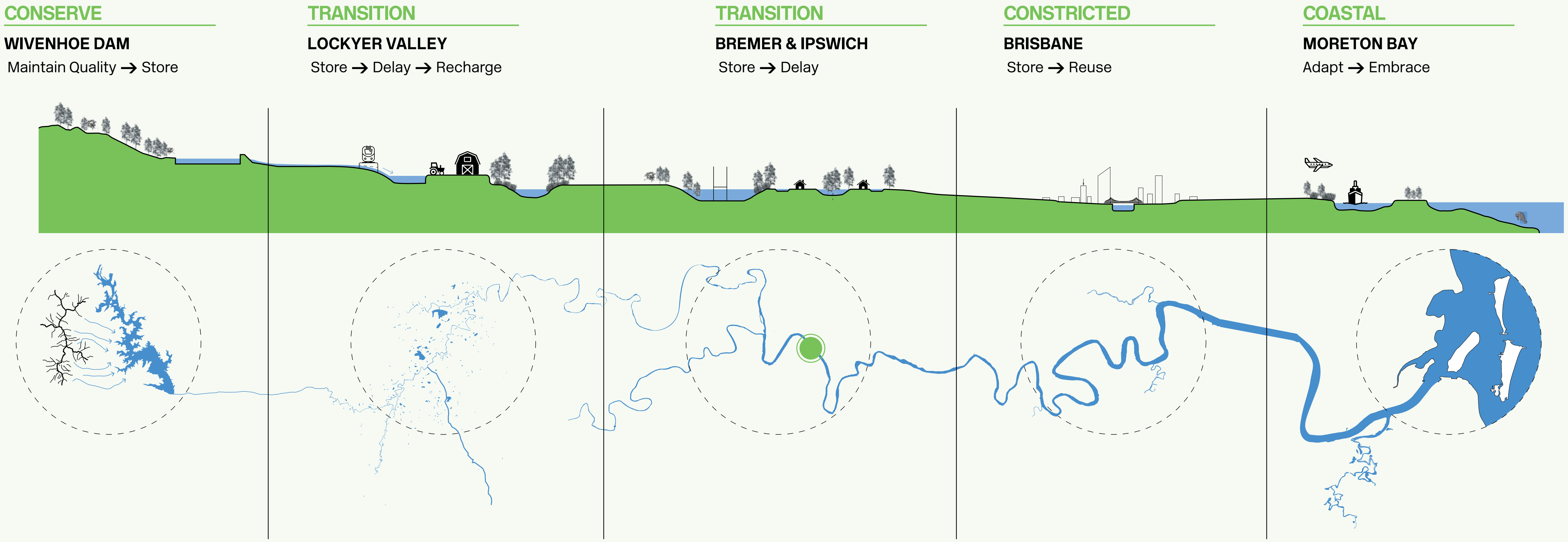
> "Existing development in Brisbane restricts flood mitigation opportunities, requiring a localised approach including:
>
> - Sponge urbanism strategies: retention parks, permeable surfaces, and architectural design solutions along local creeks,
> - Adapt and protect legacy sites through water sensitive urban design".
>
> (James Davidson Architect, 2017)

A sponge urbanism approach is designed to absorb, treat and slowly release rainwater to reduce the impacts of flooding. It achieves this using drainage systems that incorporate permeable surfaces (such as raingardens and wetlands) and stormwater harvesting to retain, infiltrate or harvest rainwater across the urban catchment. This in turn reduces overland flows and the volume of stormwater reaching conventional drains and waterways. The solutions outlined in this Discussion Paper align well with this work and provide a more granular expression of this approach and its implementation in an existing urban area.

Figure 5 – A Fluvial Transect framework for South East Queensland (Image Credit - James Davidson Architects, 2017)

THE FLUVIAL TRANSECT

Everyone living in the greater Brisbane River Catchment is linked via catchments and watersheds in one way or another. By taking an integrated water management approach, we are able to better address the issues and opportunities within local communities, and each factor in the fluvial transect is aware, and considerate of, the other. With this in mind, the Charrette established the following principles:



Developing ideas

The workshop participants identified a series of design challenges for Norman Creek. These challenges are borne out of an understanding of the catchment, its community, and the nature of flooding. These challenges were framed as questions and guided the development of the ideas for Norman Creek.

Design challenges: how might we ....?

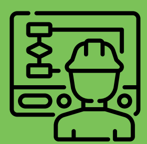
... create multiple outcomes: improve liveability, enhance biodiversity, improve water security and reduce flood risk?

... apply an *adapt*, *defend* or *retreat* flood management strategy to the challenge of overland flooding in a densifying catchment?

... build flood literacy and a flood resilient community?

... make flood resilience commercially attractive and a sought-after outcome by communities?

... harness the planning scheme to create flood resilience?



... operationalise the ideas and help Council to deliver them?

Solutions: eight ways to make Norman Creek more flood resilient

The following eight ideas are a response to the design challenges. They propose innovation in urban development, a redefinition of the 'grid' of flow pathways in an urban landscape, and new designs for flood assets to ensure they are multifunctional.

Business cases

1. An investment framework

Multi-functional assets

2. Flood resilient street typologies
3. Smart rainwater tanks

Private and public open space

4. Living drains
5. Activate existing flood ways
6. A green belt of backyards

Development typologies

7. Six pack redevelopment typology
8. Adventure corridors

Idea 1. An investment framework

Reframe business cases for flood management projects from 'efficiency in providing flood infrastructure' to 'investment in the catchment and community', thus enabling more integrated projects that deliver multiple Council objectives and strategies.

A 'conventional' business case that narrowly defines the problem in (only) flooding terms will not deliver the aspirational outcomes described by Council's various strategies and by the community. However, individual business cases proposing novel integrated solutions are at risk of failure unless there is an overarching investment framework that can recognise and assess the net benefits and returns on the investment being made.

How?

Develop investment principles and an investment framework that captures non-market values in decision making. Examples may include community willingness to pay for healthy waterways or to reduce the local impacts of the urban heat island. The implementation of the ideas in this Discussion Paper could initiate this by proposing principles for an investment framework that is not restricted to flood management outcomes. This can be supported with exemplars of the types of investments the framework will deliver based on the Norman Creek focus areas of Hanlon Park (idea 5), Kingfisher (idea 4) and Greenslopes (idea 7).

The framework will require endorsement from decision makers and regulators. These stakeholders should be involved in the framework development from the early stages.

Next steps

1. Identify the key decisions makers. Given the scope of the solutions, the investment framework case will require the support of the Lord Mayor, Council, Cabinet and State Government.
2. Work with the advisors of these decision makers to craft the arguments and align them to strategic agendas and opportunities. Informal advisors will include residents, community groups and the development industry.
3. Highlight the magnitude of the overland flooding problem and the need for a novel solution. The decision makers will require evidence-based business cases supported by financial, technical and social arguments.
4. Demonstrate the potential community, economic and strategic benefits of a multiple outcomes approach. These benefits are summarised in Table 1.
5. Quantify these benefits. Suggested approaches are provided in Table 2 using Norman Creek as an example.

Table 1. The potential community, economic and strategic benefits for Norman Creek

Benefit	Description
Economic development	• Remove overland flooding constraints to increase the amount of developable land in the catchment. • Increase economic activity through place making outcomes delivered by flood management initiatives.
Reduced impacts on private property	• Creating a safe, confident and flood-resilient community. • Flood damages and complaints avoided.
Enhanced liveability	• Meet the increasing community demand for parks and open space. • Improved access to open space. • Improved community health and wellbeing by increasing the quality of open / green space. • Improved ecological health of Norman Creek by reducing stormwater runoff. • Mitigating the impact of heatwaves by creating shade and networks of cooler green spaces.
Alignment with the Brisbane 'brand'	• Norman Creek as a catchment example of how New World City solutions are showcased. • Norman Creek as an exemplar of integrated project delivery across Council functions.
Development of new partnering models that will improve the functioning of the city	• Developing innovative solutions in partnerships with industry, government and research organisations. • Sister city partnerships to align aspirations and processes, and leverage innovation and brand through strategically valuable relationships. • Leveraging added value from other cities with similar challenges.

Table 2. Approaches to quantify some of the novel liveability and economic benefits

Benefit	Quantify by Metric
Increased developable land / yield	Use Council flood maps to compare the developable area in the catchment before and after the strategy. Value the economic uplift associated with the additional developable land / yield.
Flood damages	Model reductions in overland flooding extent and calculate changes in average annual damages.
Improved ecological health of Norman Creek	Model the stormwater flow and pollutant reduction of catchment-wide adoption of green infrastructure. Calculate the area of natural vegetation to be created through a living streams approach. Document the support from community groups for waterway improvements.
Heat mitigation	Show the predicted frequency and severity of future heatwaves, and the links to human health. Model the predicted ground temperature across the catchment on hot days with and without the proposed solutions.

Idea 2. Flood resilient street typologies

Streets are an integral part of the drainage network. They carry the smaller floods and storms within the street profile and convey these flows to the underground drainage networks. This idea increases the capacity of the existing street network by:

- Replacing a part of the hardscape areas in wide streets with appropriate, nature based stormwater treatment.
- Introducing a second curb to increase extended detention capacity.

Different designs can mix these elements to create a hierarchy of flood resilient streets for Norman Creek. This can also help retain water in the urban landscape, support street trees and thus increase local tree canopy cover.

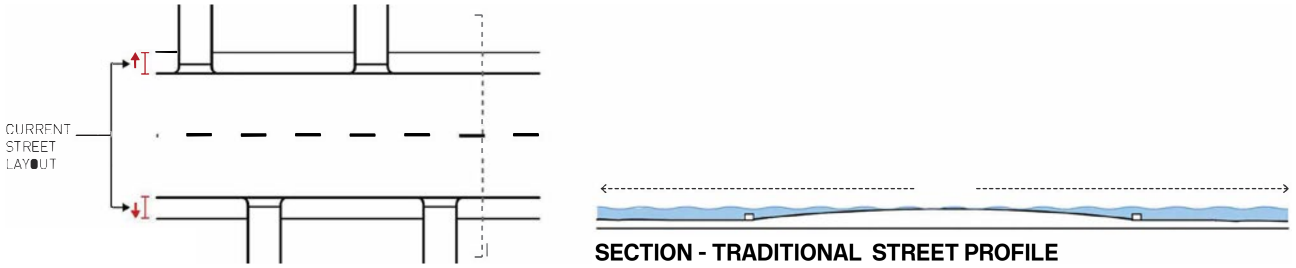


Figure 6 – Traditional street design (Image credit - University of Queensland)

Where?

These approaches can be tested in Greenslopes which has wider streets (Figure 7).

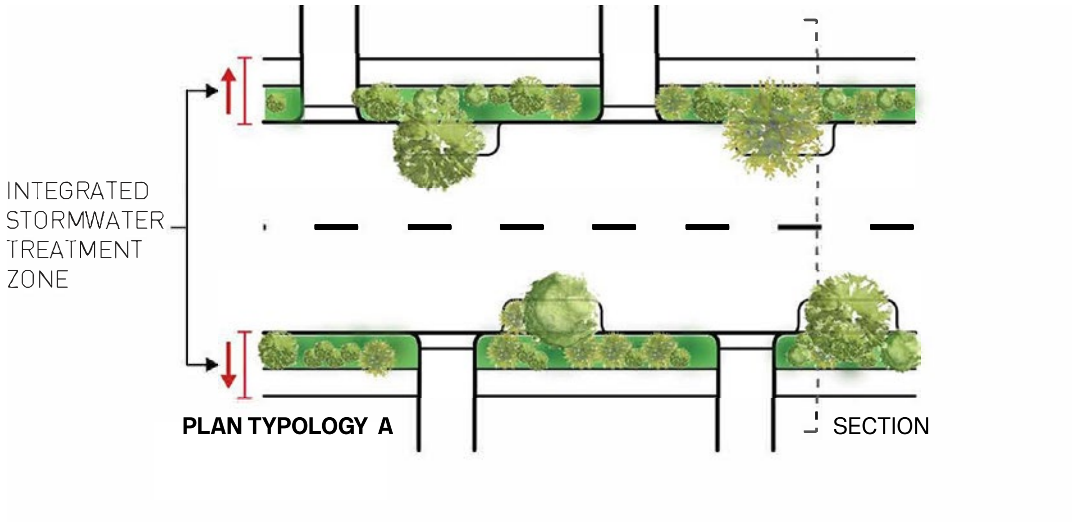
Figure 7 – Typical Greenslopes streetscape

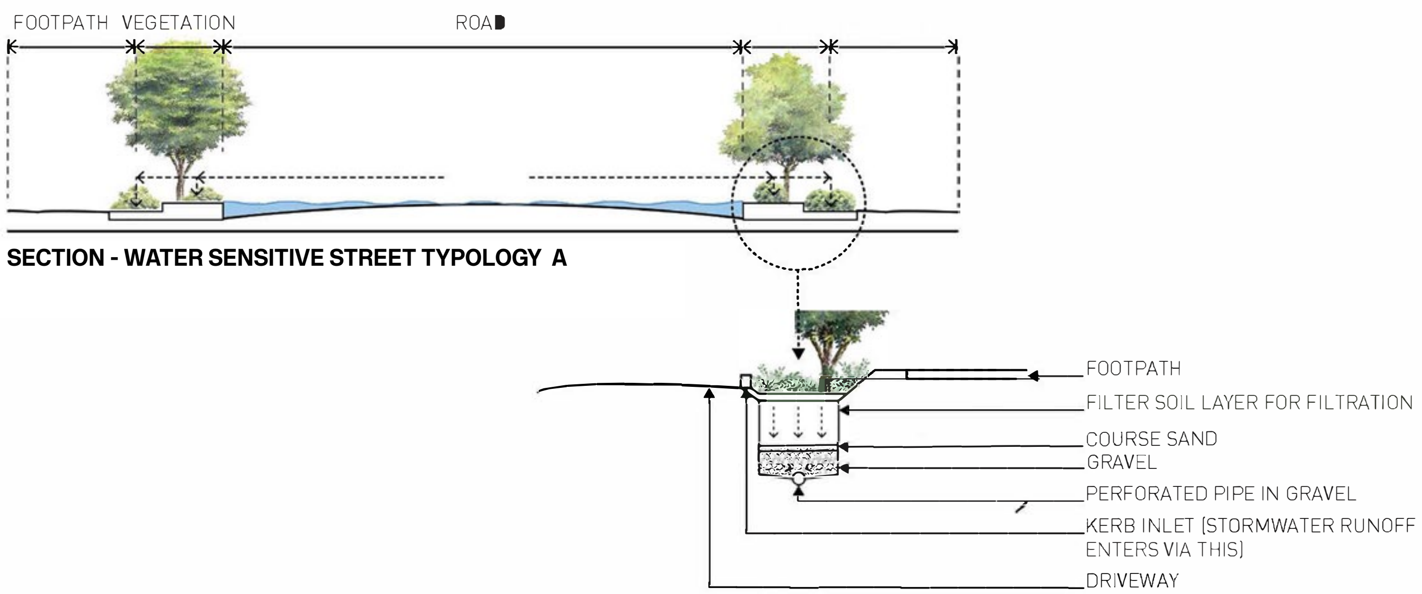
How?

This idea is suited to wider streets in lower density areas where the community is less likely to be disrupted by the replacement of car parking areas with green areas. In high density development areas, this solution may also have merit in providing street scale amenity and tree canopy, provided car parking issues can be resolved.

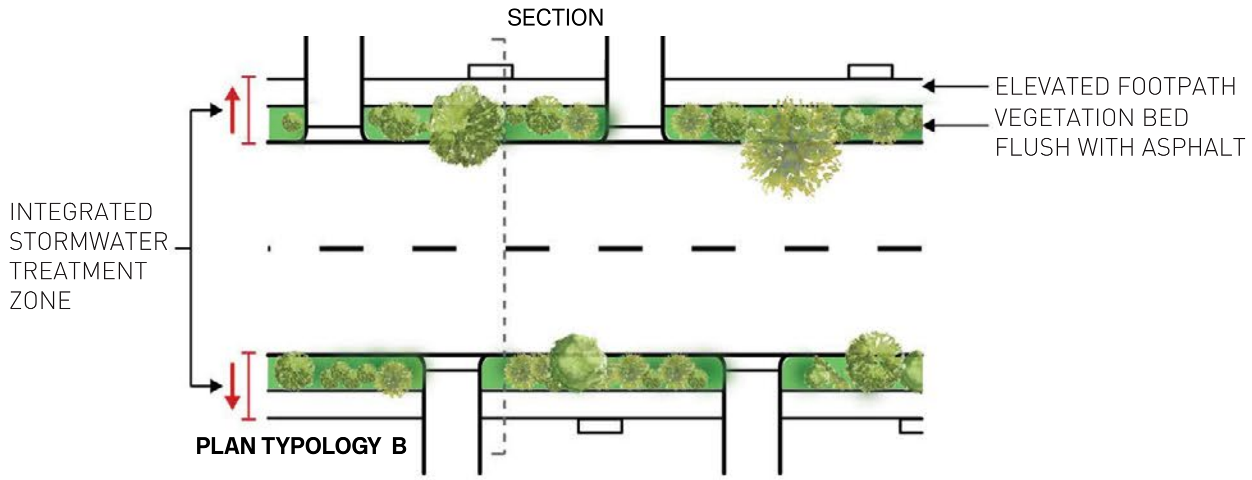
Next steps

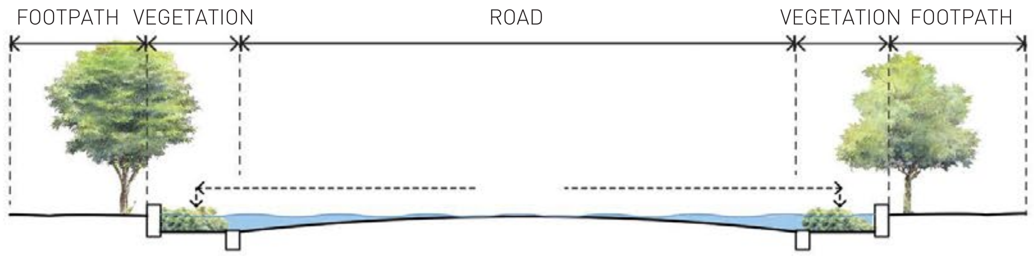
- Catalogue the water sensitive street profiles and develop specifications for each.
- Audit the current street network to identify potential locations for street upgrades. Initial suggestions include streets with localised flooding that also include wide grassed centre medians or extra wide verges such as:
  - Glindemann Drive
  - Murton Avenue / Blacha Street
  - Cavillon Street
  - Gaynesford Street
  - Kanumbra Street
  - Ferguson Road
  - Majestic Outlook
  - Morven Street
- Determine the relevant zoning that would facilitate this approach.
- Incorporate these outcomes in relevant Council Road Corridor Initiatives.





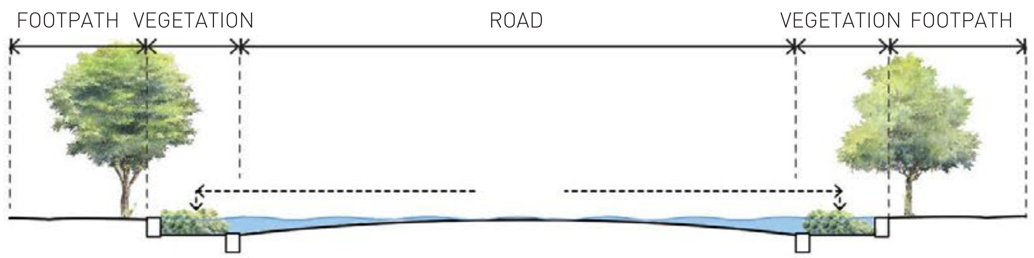
SECTION - WATER SENSITIVE STREET TYPOLOGY A





SECTION - WATER SENSITIVE STREET TYPOLOGY B

OPTIONS B1: CURB RAISED ABOVE FOOTPATH



SECTION - WATER SENSITIVE STREET TYPOLOGY B

OPTIONS B2: CURB LEVEL WITH FOOTPATH

Figure 8. Example water sensitive street typologies A and B (Image credit – University of Queensland)

Idea 3. Smart rainwater tanks

Increase the adoption of rainwater tanks to create a large, virtual flood storage for the catchment. This will reduce rainwater runoff from roofs following storms, as well as providing an additional water source to improve water security and/or to maintain a lush, green urban environment.

This idea can be optimised using smart rainwater tanks. Smart rainwater tanks use technology to act as both water supply and flood mitigation infrastructure. This is particularly useful in flood prone catchments: storm predictions can be received via a communications link to the Bureau of Meteorology and if rainfall is expected, the tanks will anticipate that draining is required to provide capacity to capture the rainwater. As varying roof and tank combinations react differently to the volume and intensity of a downpour, the software behind this system can analyse how successful the capture of rainwater was and adjust accordingly for future events (South East Water, 2014).

How?

This technology has been developed by South East Water and is planned for use in the Aquarevo development in Melbourne. All homes in this development will be fitted with smart rainwater tanks

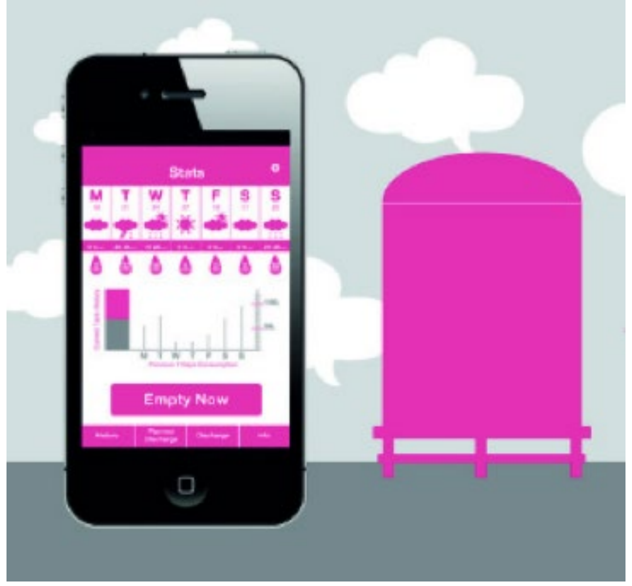


Figure 9 - South East Water is introducing smart rainwater tanks into all houses in its Aquarevo development. (Image credit – South East Water)

to create a 1 million litre virtual storage that will reduce peak stormwater runoff by 25% and reduce potable water demand by approximately 35% (CRCWSC, 2017).

The installation of tanks can be voluntary, incentivised by Council or relevant water authorities such as Seqwater or Queensland Urban Utilities, or linked to development controls that are already designed to maintain flood risk at current levels.

Next steps

Investigate specific rainwater tank implementation mechanisms through City Plan provisions for multiple dwellings, Queensland Development Code plumbing provisions and building regulations for new dwelling houses, and grants and rebates for existing dwelling houses.

Quantifying the benefits of rainwater tanks

The effect of rainwater tanks on flooding across the whole catchment was modelled as part of this project (Appendix One). The conclusions are summarised below.

1. Harvesting rainwater will reduce rainfall runoff. Reducing runoff by more than 10% requires more than 50% of households to install a rainwater tank. This is consistent with other research which shows that widespread installation of tanks can reduce overland flooding risk by up to 30% for minor flooding events (e.g. Urich et al., 2013, or Löwe et al., 2017).

2. Norman Creek is undergoing increased densification and if no action is taken, it is anticipated that flooding will increase as a result of the increase in impervious area. Rainwater tanks are an effective solution to incremental densification if the number of tanks can progressively increase each year in sync with development. A 1% per annum uptake of tanks can offset this densification impact (i.e. no net increase in flood risk over time), while a ≥3% uptake will reduce existing (2016) flooding risk (i.e. flood risk will decrease over time).

3. If a ≥3% per year uptake of tanks can be achieved, this will also:

    a. Conserve water by reducing potable water demand by almost 10%

    b. Reduce the impact of stormwater on local waterways (Stream Erosion Index will be reduced by 1%-2% from a typical catchment which has a rating of 5%-7%)

    c. Reduce the urban heat island effect. A lush, green landscape maintained through irrigation by a secure alternative water source will reduce extreme ground temperatures during heatwaves by 1°C-1.5°C from the current average of 58.72°C.

These results show that harvesting rainwater is an important part of the solution because it can

- Be distributed throughout the catchment
- Be implemented through the planning scheme so that all redevelopments trigger an opportunity to introduce rainwater harvesting to achieve a minimum 3% per annum uptake
- Reduce waterway pollution, extreme surface temperatures and conserve water supplies.

Idea 4. Living drains

Create new 'waterway features' in urban areas by daylighting[3] existing drainage culverts to create surface drains. These surface drains can run parallel to underground drainage culverts and be landscaped to mimic ephemeral, natural creeks. They will be designed as a low flow channel to capture smaller overland flows, and be connected to the culverts to provide drainage for larger flows.

Figure 10 – Proposal for a living drain along Kingfisher Creek. (Image credit – University of Queensland)

Where?

This idea is well suited to the Kingfisher Creek area where overland flooding is an existing issue and local streets are often impassable following heavy rain. There is also a growing demand for high quality open space as the existing light industry progressively makes way for cafes and gymnasiums that draw the residents from new urban infill development into the area. Living drains located along existing corridor links in the Kingfisher Creek area could transform these areas, mitigating localised flooding issues and establishing a connection from Norman Creek to the centre of Woolloongabba by linking council land and existing open spaces such as Rotary Park (Figures 10 and 11).

Figure 11 – Examples of existing open space corridors and associated drainage culverts that provide Living drain opportunities at Kingfisher

[3] *Daylighting refers to the uncovering of previously covered or buried waterways or drains to create open air waterways, usually with the introduction of landscape features that create a more natural state (American Rivers, 2016).*

How?

Daylight flood culverts to create a parallel surface channel to carry flows up to the 3-month event. Low flows are diverted to this surface drain, with higher flows continuing to be carried by the culvert (Figure 12).

This combined system of surface drain and underground culvert provides additional capacity for overland flows and ensures that rainwater from minor storms no longer disappears underground; instead rainwater will flow at surface level with runoff from larger storms continuing to be carried by the culverts.

The surface drains will have a narrow width and shallow depth, allowing them to be easily incorporated into open space and streets. The design will also mimic a natural waterway by introducing swales and raingardens along the easement to make them 'living drains'. Research shows that the creation or restoration of such systems creates amenity that increases the value of adjacent housing. (e.g. Payne et al., 2015; Polyakov et al., 2017).

The landscape design can also facilitate community engagement with flood resilience concepts. It can achieve this by integrating features that engage people with water, highlight the features of a well-integrated green space, showcase Brisbane's wet and dry seasons and encourage nature-based play.

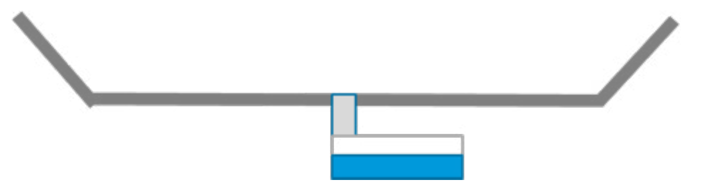
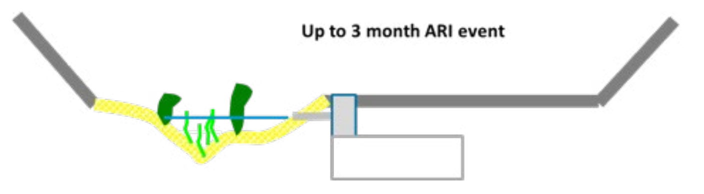
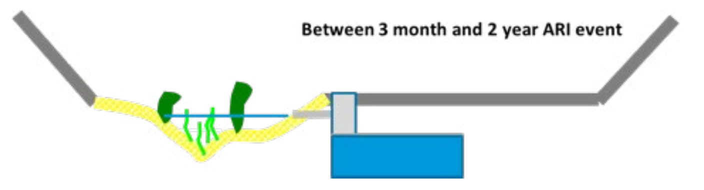
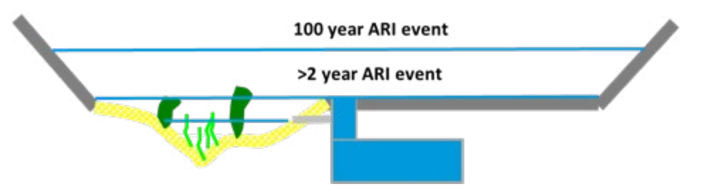
	1. Existing flood culverts carry flood flows below ground.
	2. A parallel surface waterway – within the floodway – can carry flows up to the 3 month event. This can be landscaped to create a living drain.
	3. Flows that exceed the capacity of the living drain will spill into the culvert.
	4. The larger flows will utilise the design capacity of the floodway.

Figure 12 – The design and functioning of a living drain (Image credit – Tony Wong)

Next steps

Undertake technical investigations to determine the feasibility at Kingfisher, particularly given low ground levels and the risk of salt water intrusion as well as the potential presence of acid sulphate soils or old landfills.

Once feasibility has been determined, commission master planning to explore different living drain designs and allocate space for living drains in areas with contested public space.

Idea 5. Activate existing floodways

Existing floodways such as Hanlon Park are important flood management assets but may be otherwise underutilised spaces. Transform these areas into valued public spaces by activating the drainage channel and adjacent floodway, and linking these elements with the surrounding streetscapes to encourage visitation. This can be achieved by:

- remodelling the channel and incorporating stormwater management elements.
- incorporating place making features and addressing boundary effects between parks and surrounding streets and houses.


Figure 13 – Views of Hanlon Park showing the current channel form, floodplain and associated open space values, as well as the adjacent urban development.

Where?

Hanlon Park.

How

At present Hanlon Park is: divided into two sections; not able to meet the demands of a growing community; and disconnected from adjoining land uses, which face away from the park.

A new design could:

1. **Improve flood capacity** by lowering the surface profile of the Park to provide additional flood storage. Flood discharge is also constrained by an existing weir. To counteract the flooding impacts of new amenity features that increase hydraulic roughness, improve the spillway capacity by reshaping it as a curved retaining wall with a lower profile.
2. **Bring people into the park (when it is not flooding) through landscape design.** The Park will become the 'backyard' for the Stones Corner development. Introducing a series of terraces will address the existing difference in levels along the park. These terrace spaces can be used by pedestrians and cyclists to bridge the distance and bring people down to the park (Figure 14).

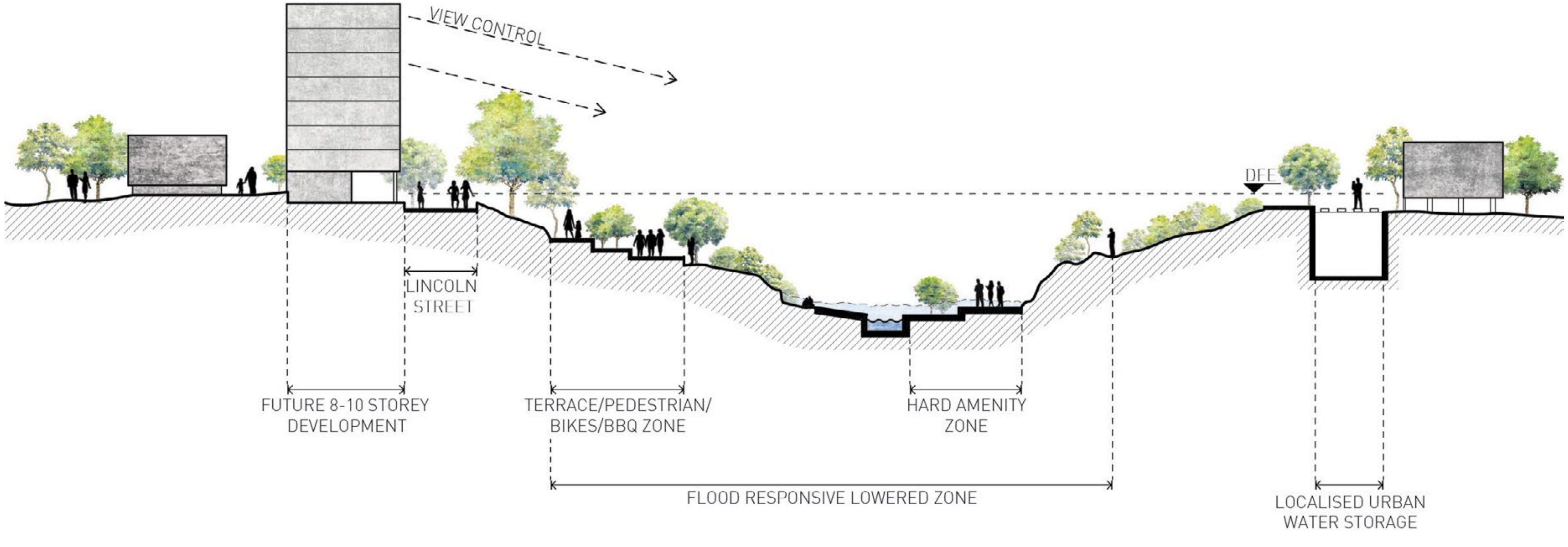


Figure 14 - Hanlon Park cross section. (Image credit – University of Queensland)

3. **Improve waterway health.** The terraces can incorporate other stormwater management features such as occasionally inundated water squares or small water quality treatment systems to retain and/or cleanse stormwater before it reaches the waterway.

4. **Connect the park with surrounding precincts and destinations.** Encourage visitors to the park and improve linkages to the Logan Road commercial area by extending the park vegetation plan into neighbouring street corridors (Figure 15).

Next steps

The planned high density development at Stones Corner will increase demand for open space and provides a catalyst for local master planning and investment. There is an opportunity to align a series of existing but otherwise disconnected capital investments planned for this area, including replacement of the Stones Corner roundabout, high density development, drainage and sewer upgrades, and existing Council funding to upgrade amenities.

Figure 15 - Hanlon Park plan view. (Image credit – University of Queensland)

Idea 6. A green belt of backyards

In this solution, the existing grid of suburban backyards is recognised as a second network of spaces for managing overland flows. This idea challenges the notion that the street grid (idea 2) and major floodways (ideas 4 and 5) are the only networks available to flood planners, and offers a coordinated plan to safely manage overland flows that already occur on private property.

Where?

Greenslopes.

How?

This is a voluntary measure that encourages property owners to manage existing flow paths through backyards in sympathetic ways. Implementation may include:

- An awareness campaign to highlight the backyard as important flood management 'infrastructure' that requires consideration of safety and functionality.
- Guidelines on the use of trees and backyard vegetation to increase hydraulic roughness and slow overland flow velocities.
- An incentive scheme (such as rate relief) for property owners that encourages the installation of low impact fences and appropriate vegetation to create a contiguous green belt.
- Planning approvals to consider the siting and design of structures within these belts.

Next steps

- Map the natural flow paths to identify which backyards are critical to safe flow pathways.
- Consultation on this concept with the aim of building it into the planning scheme. Develop a communications strategy to promote the new typologies.
- Test this idea through a future review of City Plan's multiple dwelling code.

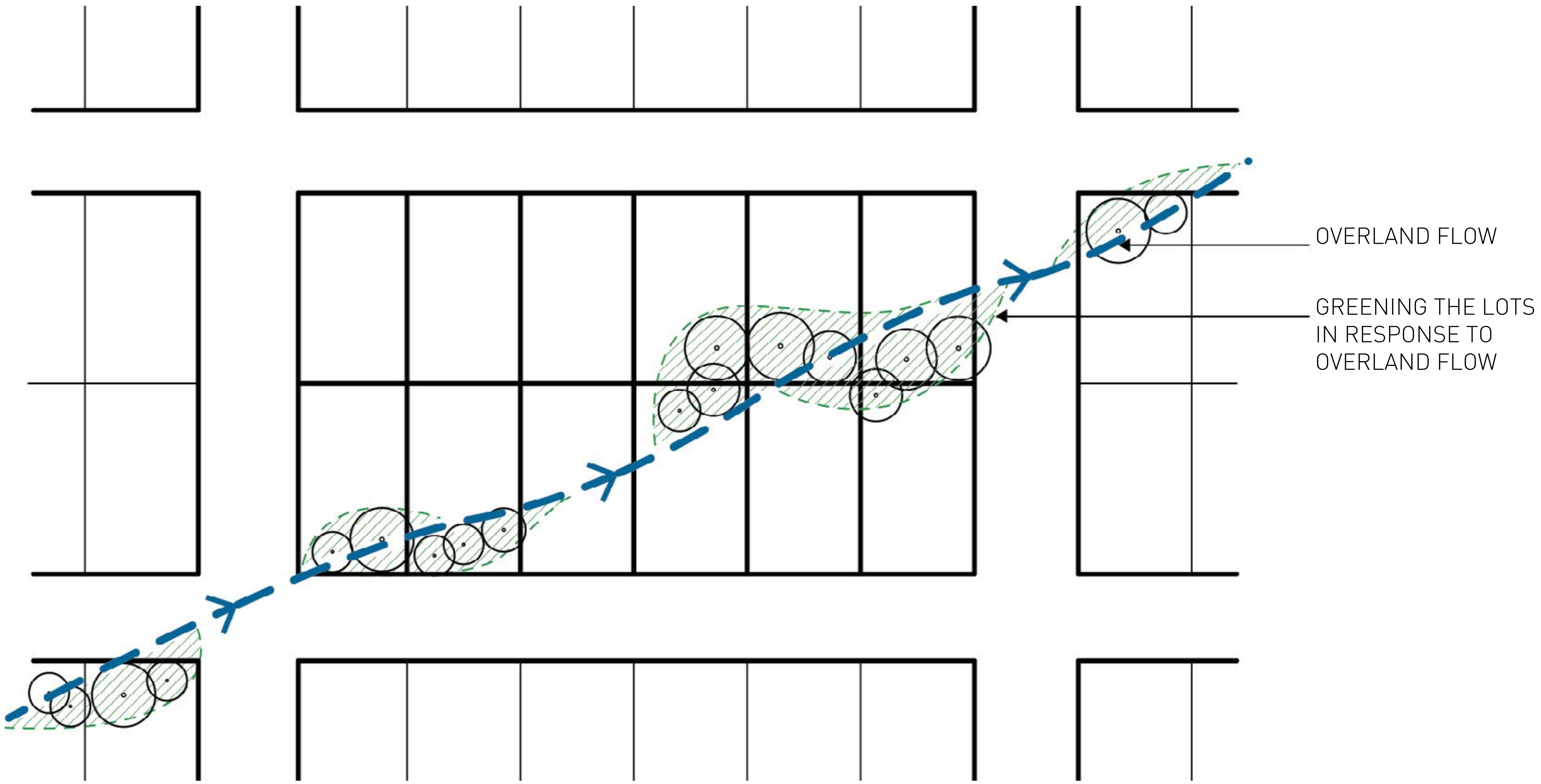


Figure 16 – Brisbane Backyards. (Image credit – University of Queensland)

Idea 7. Six pack redevelopment typologies

This idea is suited to areas undergoing medium density redevelopment. By employing a variation of the six pack development, corridors and flow paths can be created to mitigate the loss of private open space and overland flow pathways otherwise caused by the conversion to medium density development (Figure 18).

Where?

This approach suits long blocks in areas such as Greenslopes where the low point is often the space between blocks that is shared between private owners.

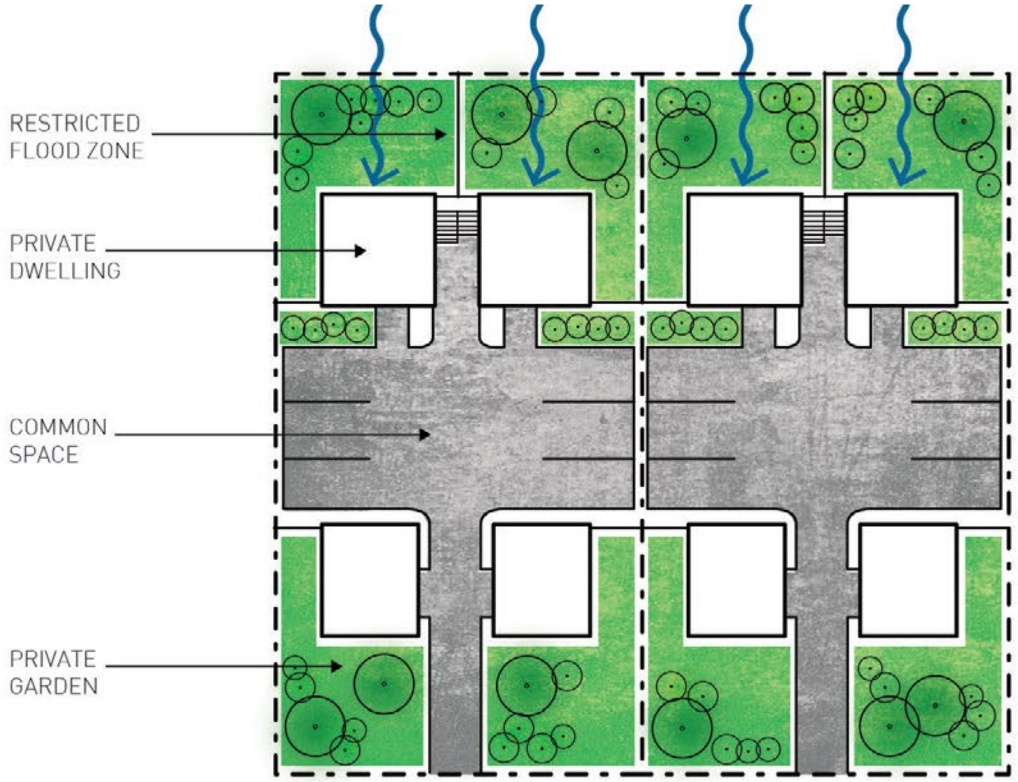
Figure 17 – Old and new housing at Greensopes showing the replacement of undercroft areas and private green space with impervious areas

How?

Comparing a traditional six pack urban form with modern development patterns shows the effect on private garden space (Figure 18). Six pack designs allow more room for garden space and shared public amenity across the side and back of blocks. By offsetting six pack developments face-to-face on opposing blocks, it is possible to create a central open space at the allotment level that provides a connected flow path.

Next steps

This idea requires the development of a building form that faces the street to ameliorate design issues of the conventional six pack design.



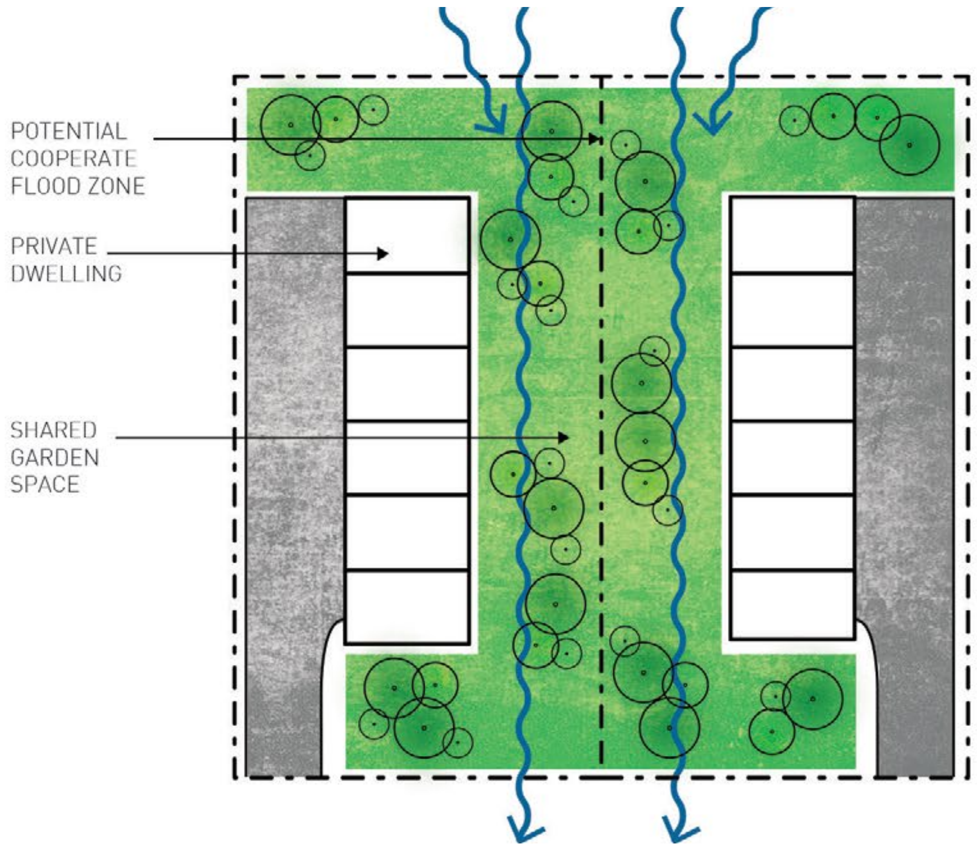


Figure 18 – A comparison of the garden space and flow pathways of alternative development patterns. (Image credit – University of Queensland)

Idea 8. Adventure corridors

Retrofit (or protect existing) green corridors in higher density areas using new development typologies that create linear, connected green corridors. These corridors can function as ephemeral stormwater channels, and can be designed and landscaped with extended detention and infiltration areas, along with vegetation features designed to slow flow. In periods between flooding they can also support active transport, recreation and amenity. Variations could include plazas (e.g. 'mini Coorparoo Creek Parks') that create localised stormwater soaks.

Where?

This idea is suited to areas with higher density development and where corridors can link public transport and commercial nodes.

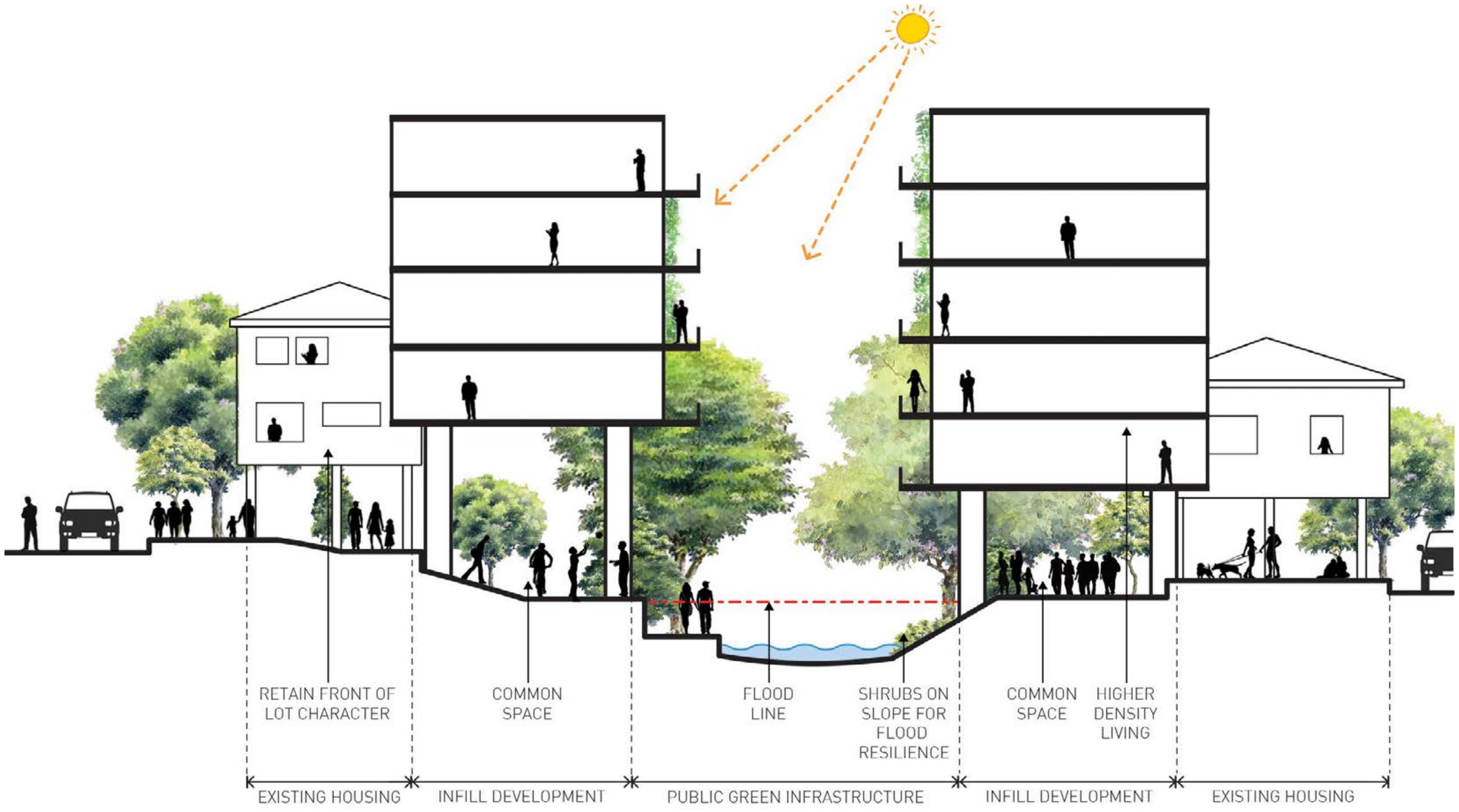


Figure 19 – Raised houses section. (Image credit – University of Queensland)

How?

The placement of Adventure corridors can be incorporated into the long-term planning of the city by identifying future high density areas, transport corridors and commercial nodes; and investigating groups of streets just outside these areas to find locations with existing flooding problems and the right orientation for corridors.

Adventure corridors can then be enabled through bigger block scale redevelopment rules that provide incentives if land is provided for water and public space.

Next steps

This is a long-term solution requiring further policy evaluation before implementation. In the first instance it may be appropriate for Council to review the role it should play. The most appropriate role may be as facilitator rather than the sole provider of these solutions.

Once roles have been defined, a master plan will be required to establish the number, size and location of Adventure corridors in the catchment. This will be followed by the development of specifications for individual corridors.

Conclusions

Norman Creek provides an opportunity to prototype new approaches to flood resilience. The approaches outlined in this Discussion Paper target the problematic overland flows that generate a large number of complaints across the catchment, and simultaneously deliver a range of other benefits. Eight ideas are presented that achieve this by harnessing a strategy of managing rainfall runoff close to its source. The resulting mosaic of localised solutions will:

- Retain and infiltrate rainfall locally.
- Provide safe passage for overland flows that do eventuate.
- Provide a consistent response across public and private spaces, and activate these spaces in the process.

An initial evaluation of these solutions shows that there is a prima-facie case for a more detailed evaluation and discussion. Specifically, these solutions are anticipated to provide a measurable flood risk benefit, albeit not a complete solution, that will eliminate flooding. These solutions can therefore play a role in diversifying Council's portfolio of flood management responses and help to deliver a range of its other strategies for Norman Creek. These solutions can then be tested and evaluated before being scaled up to provide a larger scale flood resilience response for Brisbane.

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Appendix 1 - Testing the solutions

Introduction

This section summarises the evaluation of selected solutions for Norman Creek. This evaluation focused on the impact and business case of a subset of workshop ideas: rainwater tanks, water sensitive street typologies and adventure corridors. The evaluation was conducted as a first pass assessment to establish whether these ideas have merit. It is not a definitive nor exhaustive assessment of these ideas.

About the analysis

Selected solutions were tested by GHD and the CRCWSC to quantify their effectiveness. This testing applied a "whole-of-water cycle" approach using two models and an understanding of expected future development. The framework and tools for this evaluation are shown below.

Solutions tested:

- Rainwater tanks
- Flood resilient street typologies
- Adventure corridors

Tools used:

- TUFLOW to assess the flood mitigation performance
- Design Platform to test the integrated performance of the water system including economic costs and benefits.

What was tested:

- The impact on flooding
- Multiple benefits
- The business case

Scenarios tested:

- Different levels of uptake
- Different combinations of solutions
- Current and future development

Figure 1 – Overview of the analysis approach

Assumptions

- For the purposes of analysis, passive rainwater tanks were modelled rather than smart tanks. Water sensitive streets and adventure corridors were modelled together as bioswales in public spaces and along flow paths (respectively), based on the area of catchment being treated.
- The results consider future changes in development and compare land use plans with and without these tanks and bioswales (Figures 2 and 3). This redevelopment has been modelled over time based on current development codes. The modelling therefore uses assumptions about redevelopment that are suitable for this initial feasibility testing, but may require refinement during detailed evaluation.
- Different levels of uptake, and different combinations of solutions were modelled. The combinations are henceforth referred to as 'options' and include different mixes of rainwater tanks (from 0% to 100% of properties using 2, 5 or 10 KL tanks) and the combination of 5 KL tanks (again at 0% to 100% uptake) with additional implementation of bioswales with a 300 mm extended detention to treat 10 to 50% of the connected impervious area.
- The Design Platform modelled minor floods (AEP>20%) and the TUFLOW analysis considered the following storm events:
    - 2-year ARI 60-minute duration storm – 47 mm total rainfall depth
    - 10-year ARI 60-minute duration storm – 70 mm total rainfall depth
    - 50-year ARI 60-minute duration storm – 98 mm total rainfall depth
- The analysis considered both:
    1. the impact of these solutions on flooding, and
    2. the business case, considering lifecycle costs and intangible benefits.
- The life-cycle costing considered construction, maintenance and the value of water savings and calculated the net present value (NPV) using a discount rate of 3% over 20 years. These calculations do not include flood costs (such as average annual damages) meaning the results are conservative. It should also be noted that the NPV results combine the perspective of Council and community – meaning that only a part of these savings can be directly captured by Council.
- The intangible benefits are presented as a 'community preference' rating based on willingness-to-pay research (e.g. CRCWSC, 2016). Options with a preference of "0" indicate that there is no significant improvement in stream health, heat reduction and/or water savings and thus no benefit to householders living in the catchment. A preferment of "1" represents a significant improvement.

Figure 2 – 2016 (blue) and 2030 (yellow) building footprints used in the TUFLOW model

Figure 3 – Design Platform assessed the performance of urban development in 2030, with and without water sensitive streets and adventure corridors. The placement and size of green corridors is for modelling purposes only

Results

Impact on flooding

The evaluation provides three insights:

1. On their own, solutions such as rainwater tanks have a measurable but modest impact on flooding in Norman Creek (Table 1). The effectiveness of rainwater tanks is constrained by the high rainfall intensity in Brisbane and the total area of the catchment (i.e. roofs) that can be serviced by tanks.

Table 1 – Flood risk reduction benefits for rainwater tanks for a 2 year ARI storm

Development scenario	Rainwater tank scenario	Typical reduction in peak flood level compared to no rainwater tanks
Current	5 KL	5.4 mm
	10 KL	11.8 mm
2030	5 KL	5.5 mm
	10 KL	12.5 mm

2. Combining solutions increases the impact and feasibility. A 30% runoff reduction in minor flooding events is feasible if stretch targets for the adoption of 5 KL rainwater tanks and flood resilient streets/Adventure corridors are adopted (Figure 4). For instance, 50% uptake of rainwater tanks, together with a 10% coverage of the catchment by flood resilient streets/adventure corridors will reduce runoff by ~30%.

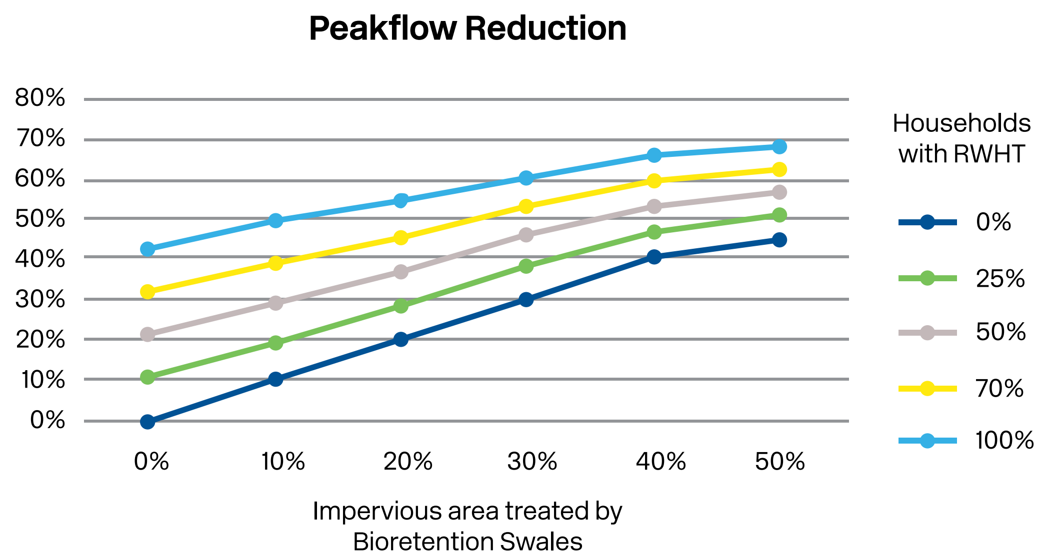

Figure 4 – The combined impact of rainwater tanks and water sensitive streets/ adventure corridors on runoff.

3. This level of uptake may be achievable by 2030 if a progressive implementation approach linked to redevelopment is used (see for example Figure 5). This also shows that rainwater tank uptake need only exceed 1% p.a. if the goal is to ensure flooding does not worsen as the catchment densifies to 2030.

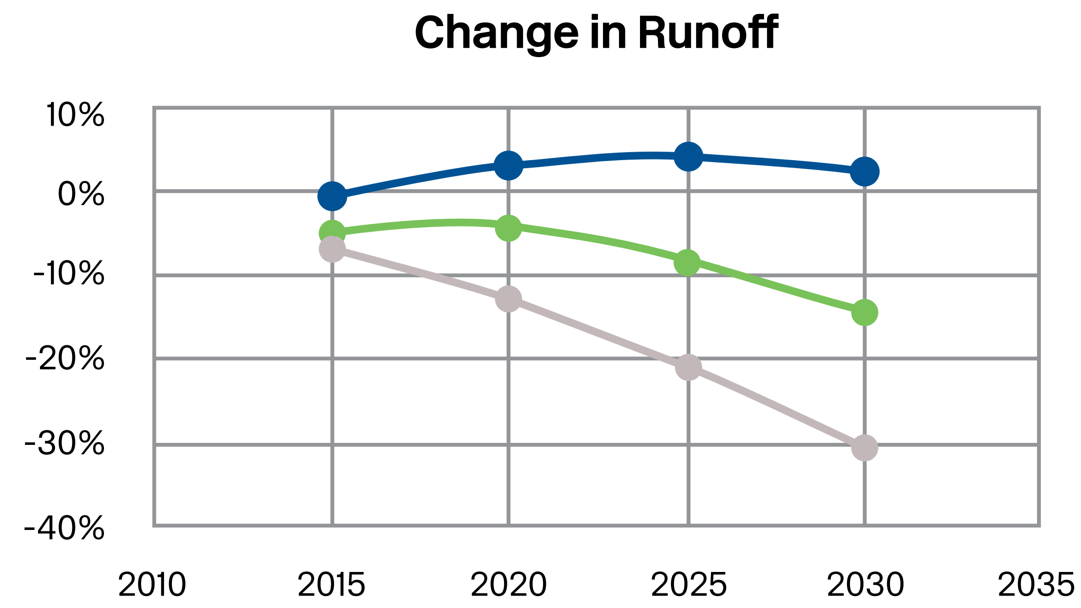

Figure 5 – The effectiveness of rainwater tank uptake in reducing runoff in a high population growth scenario (1.2% per annum).

Quantifying the multiple benefits

In addition to reducing runoff, the modelling shows that these solutions will:

1. Conserve water by reducing potable water demand by almost 10%.
2. Reduce the impact of stormwater on local waterways. Pollution removal and the stream erosion index (Brookes and Wong, 2009) are used as a proxy for stream health. For example, stream erosion index will be reduced by 1%-2%, compared with a typical catchment which has a rating of 5%-7%.
3. Reduce the urban heat island effect. A lush, green landscape will reduce ground temperatures across the study area during heatwaves by 1°C-1.5°C from the current average of 58.72°C (Figure 6).

Figure 6 – The reduction in peak land surface temperatures between current (left) and water sensitive (right) strategies. The water sensitive strategy models the widespread adoption of rainwater tanks and bioswales that will create additional irrigated, green space across the catchment.

To deliver these levels of benefits, the solutions need to be widespread throughout the catchment. For rainwater tanks, this translates to uptake rates of 50% or greater (Figure 7).

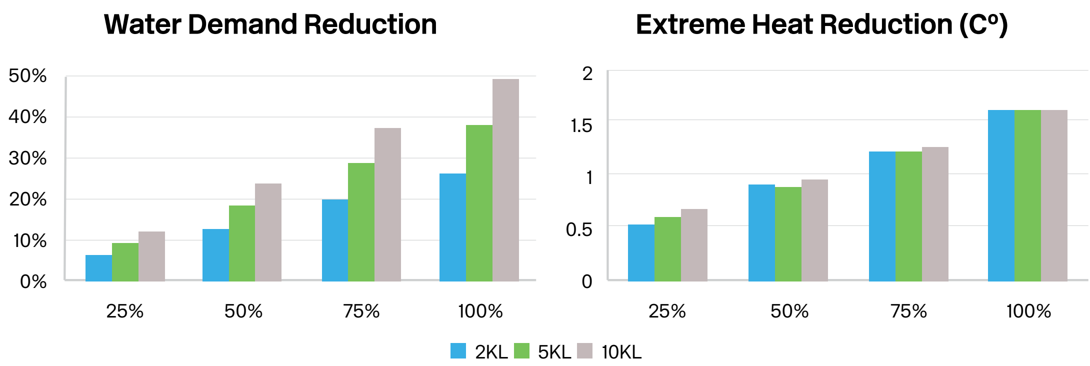

Figure 7 – The multiple benefits delivered by rainwater tanks at different uptake rates

Business case: Evaluating different strategies

A purpose of a business case is to identify the best option for investment. In this part of the assessment, each option incudes a mix of rainwater tanks and adventure corridors/water sensitive streets, but varies the level of uptake of each.

The modelling allows option ranking based on:

- Effectiveness in reducing flood impacts.
- A conventional business case approach (what is the most affordable option, as measured by the net present value (NPV)?)
- An approach that values the multiple benefits delivered by that option. This is measured as a level of 'community preference' based on willingness-to-pay for benefits such as water security, microclimate and stream health improvements.

The options were defined as a level of uptake of rainwater tanks, adventure corridors and water sensitive streets. Different options vary the level of uptake.

When different options were evaluated we found that:

1. Effectiveness in reducing runoff predictably increases in line with the level of uptake. However multiple options achieved a 30% or greater runoff reduction (Table 2).
2. Several options that met the 30% runoff reduction level were also NPV positive.
3. Scoring options based on community preference showed a clear difference, with a distinction between those with a 'high' and a 'low' preference. Options with a high preference were clustered above "0.3" on this scale[4].

Table 2 – Effectiveness – which options reduce peak runoff by ≥30%?

		Percent of properties with a 5KL rainwater tank				
		0%	25%	50%	75%	100%
Percent of impervious catchment treated by bioswales	0%	N	N	Y	Y	Y
	10%	N	N	Y	Y	Y
	20%	N	N	Y	Y	Y
	30%	Y	Y	Y	Y	Y
	40%	Y	Y	Y	Y	Y
	50%	Y	Y	Y	Y	Y

Using these results, three thresholds were established to complete the ranking process (Table 3).

Table 3 – Thresholds for option ranking

Criteria for ranking options	Threshold
Effectiveness – min. level of runoff reduction	30% reduction
Financial – cost effectiveness	NPV positive (greater than 0 NPV)
Economic – community willingness to pay for additional benefits	Preference greater than 0.3

The preferred option(s) must meet all three thresholds. Assuming that we are only interested in options that are effective in reducing runoff (i.e. that meet the effectiveness criteria as shown in Table 3), we can concentrate on the thresholds for NPV and community preference to finalise the ranking. This business case 'decision space' (Luehrman, 1998) can be represented in a matrix[5] with four regions and three colour coded actions (Figure 8).

[4] *This scale is non-dimensional.*
[5] *The alignment of the matrix borders is specific to the Norman Creek results.*

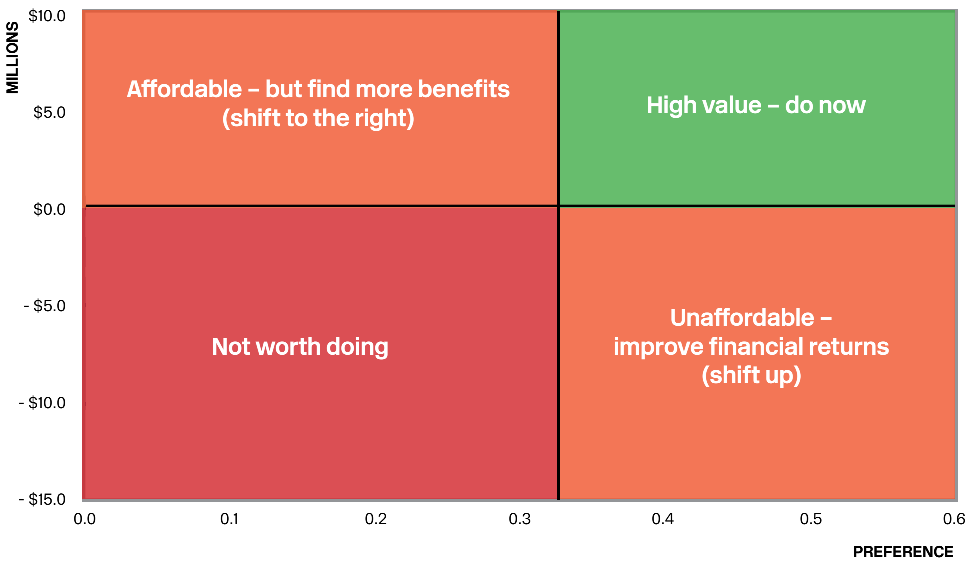

Figure 8 – A potential business case decision matrix that compares NPV (Millions) with community willingness to pay (Preference)

Not worth doing – strategies in this quadrant have an NPV less than $0 and a low preference rating. The business case does not stack up.

Affordable – but find more benefits: Strategies in this quadrant pass the NPV hurdle but offer little additional benefit to the community. Whilst they can be justified, the value is low.

Unaffordable – improve financial returns: The business case for these projects is based on non-market values. Whilst they will enjoy the support of stakeholders, they are unviable without co-investment.

High value – Do now: These strategies have a NPV greater than $0 and are likely to be highly supported by community stakeholders.

The matrix results for all Norman Creek options are shown in Figure 9. The high value options are located in the top right quadrant (the High value quadrant). After eliminating those that are not effective in reducing runoff (Table 2), there is a good business case for a 100% uptake of rainwater tanks, with or without flood resilient streets/Adventure corridors. An option of 75% uptake of tanks, along with a 10% - 30% coverage of flood resilient street/adventure corridors is more realistic and still high value.

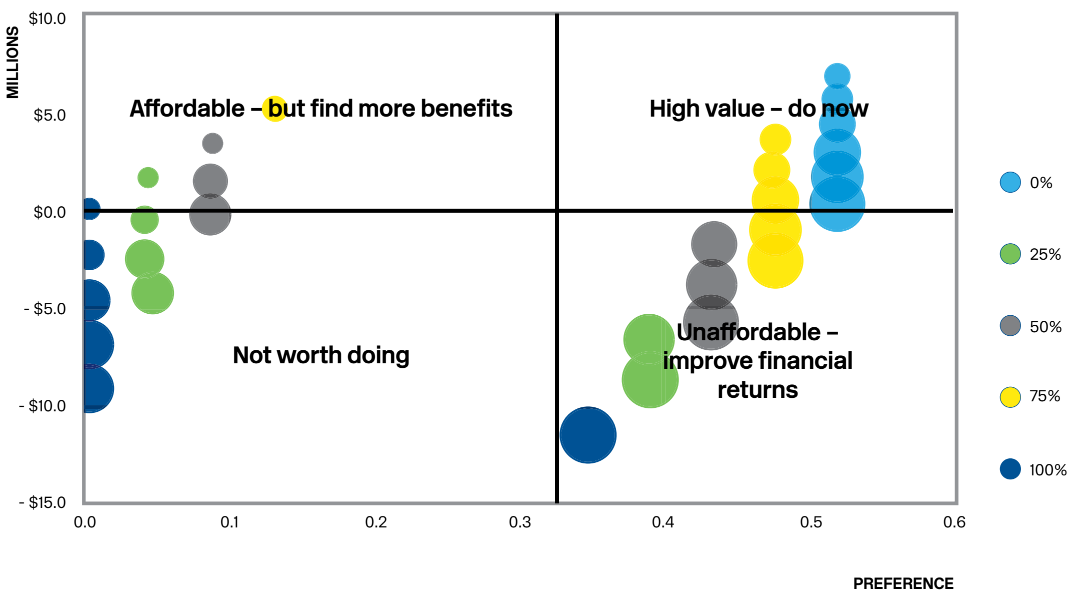

Figure 9 – Business case assessment showing the NPV and community preference results for different options. The colour of the dot represents rainwater tank uptake. The dot size represents water sensitive streets/adventure corridor uptake from 0, 10, 20, 30, 40 and 50% coverage of impervious catchment area.

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About the CRCWSC

The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) was established in July 2012 to help change the way we design, build and manage our cities and towns by valuing the contribution water makes to economic development and growth, quality of life, and the ecosystems of which cities are a part.

The CRCWSC is an Australian research centre that brings together many disciplines, world-renowned subject matter experts, and industry thought leaders who want to revolutionise urban water management in Australia and overseas.

Research synthesis

Research synthesis is key to successful research application and adoption.

A facilitated design process, Research Synthesis brings together the CRCWSC's many research areas and disciplines with government and private industry partners to develop practical "ideas" for addressing specific industry-based challenges.

Research synthesis is a highly effective tool for exploring collaboration and innovation. The open-minded environment of a research synthesis design workshop is founded on science, and no individual organisation leads or owns the conversation. This supports an un-biased dialogue that enables the discovery of new and creative ideas.

CRCWSC Research Synthesis

Discussion Paper | CRC for Water Sensitive Cities

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