STORMWATER HARVESTING AS A WATER SOURCE FOR SOUTH EAST QUEENSLAND
"Assessment demonstrates that stormwater harvesting is a feasible alternative"

Author/s:
Mr Chris Tanner, Director, Bligh Tanner Pty Ltd
Mr Shaun Leinster, Director, DesignFlow
Mr Damian Hamlyn-Harris, Director, Bligh Tanner Pty Limited

ABSTRACT

Recent droughts in South-East Queensland (SEQ) and other Australian cities have driven investigations into alternative sources of supply to assist with water security. The capture and use of stormwater is one source that can be used to replace potable supplies and thereby take pressure off central supplies. At the same time the environmental impact of urban run-off has lead to improved stormwater management practices. These two drivers are leading to new practices and design approaches for stormwater management.

- To facilitate the uptake of stormwater harvesting the Queensland Water Commission (QWC) commissioned the Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes consultancy.

Through assessment of case studies in SEQ, the consultancy provided:

- Cost and performance details of stormwater infrastructure for key types of greenfield developments to meet supply, quality and flow outcomes
- Analysis of the influence of key variables on cost and performance of infrastructure such as slope, rainfall, development type/intensity, demand, and storage
- Identification of development scenarios where supply volumes beyond the water savings target could be achieved

INTRODUCTION

The Queensland Water Commission (QWC) has released the SEQ Water Strategy, which sets out the means to ensure a secure water supply over the next 50 years, supporting our lifestyles and providing for our water use needs as well as those of the environment. The Strategy includes a water supply guarantee which is to be met by a range of supply infrastructure, such as dams, desalination, purified recycled water and a grid linking them up, as well as an ongoing demand management program.

Following the release of this strategy, and in the light of recent decisions regarding the Traveston Crossing Dam in SEQ, interest in stormwater harvesting as a potential significant decentralised water source has increased. Stormwater harvesting could reduce demand from the major water infrastructure allowing deferral of the necessary investment in that infrastructure.

One key mechanism to improving the security of water supply is the mandating of local supplies to be provided as part of new developments. The Water Savings Target under the Queensland Development Code requires the substitution of town water supplies by alternative sources supplying 70,000 litres per year per house and 42,000 litres per year per townhouse. Alternative sources could include rainwater, stormwater, and recycled wastewater.

Another important policy initiative was the Draft Implementation Guideline No. 7 Water Sensitive Urban Design Objectives for Urban Stormwater Management (SEQ Regional Plan, 2005–2031) released by the Queensland Government Department of Infrastructure and Planning (DIP) in December 2008. This guideline provides the requirements for managing the environmental impacts of stormwater runoff from developments. Guideline No. 7 outlines three criteria:

- Manage stormwater quality: to protect receiving water by reducing the percentage of sediment, phosphorus, nitrogen and litter in stormwater runoff generated by urban development, compared with that in untreated runoff
- Improve waterway stability: to reduce exacerbated in-stream erosion downstream of urban areas by controlling the magnitude and duration of sediment transporting flows
- Manage the frequency of flows: to protect in-stream ecosystems from the effects of more frequent runoff by capturing the initial runoff from impervious areas. In developed catchments, this will ensure that the frequency of hydraulic disturbance will remain similar to what it was before development.

The third criterion is the most significant with respect to stormwater harvesting because it creates the opportunity for capture and beneficial reuse of frequent flow events.

The Queensland Water Commission commissioned Bligh Tanner (sustainable infrastructure) and Design Flow (sustainable water systems) to conduct "The Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes" consultancy. It was commissioned to address the lack of basic information on stormwater harvesting relating to infrastructure needs, cost effectiveness, scheme viability and other considerations for stormwater, such as water quality and flow.

The consultancy considered two case studies in SEQ, however the methodology and outcomes are thought to be applicable across Australia. Rainfall in SEQ follows a subtropical pattern, with a well defined wet season between October and March, followed by a drier season. It could be expected that regions with a less seasonal rainfall pattern may experience an increased yield from stormwater harvesting schemes, and better reliability of supply (Figure1)

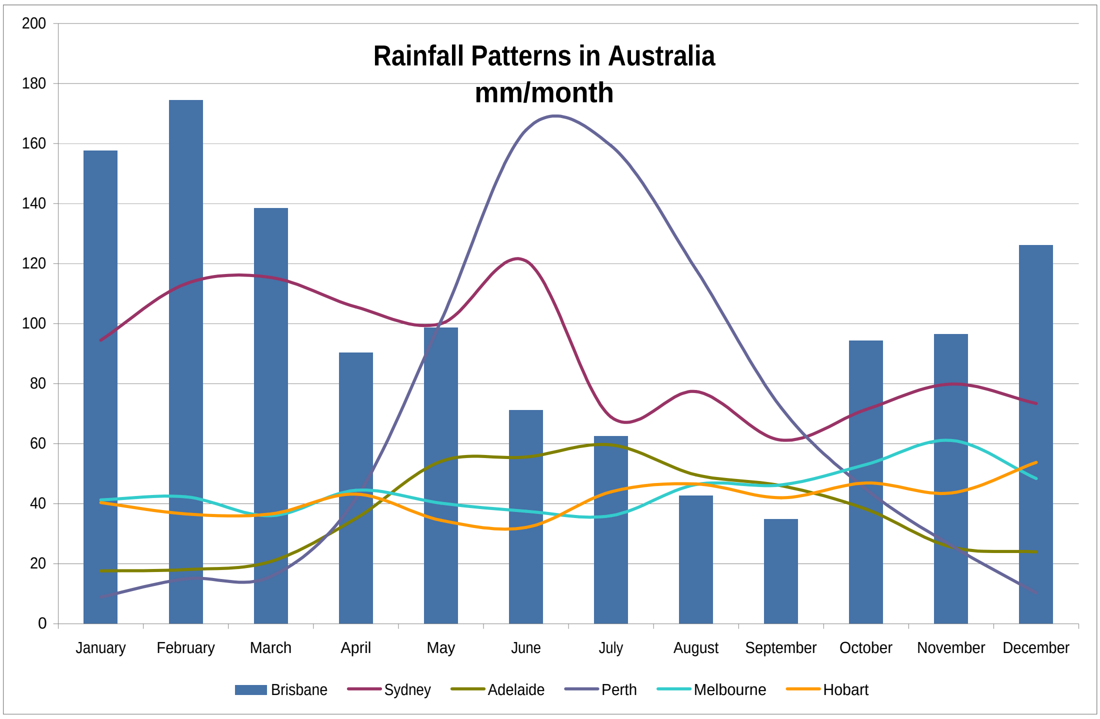

Figure 1. Rainfall Patterns in Australian cities.

METHODOLOGY

Selection of development sites

The consultancy identified and assessed stormwater infrastructure options for new broad scale developments, based on case studies for real sites at North Lakes and Sippy Downs in Queensland (refer to Figure 1).

- **North Lakes** - Large greenfield development site north of Brisbane situated on moderate topography (rolling hills). Most of the development has been designed and constructed. Within the development site the following development parcels were selected for case study assessment:
  - 20ha low density residential, 11-12 dwellings per ha
  - 100ha low density residential, 11-12 dwellings per ha
  - 500ha low density residential, 11-12 dwellings per ha
  - 20ha industrial

- **Sippy Downs** – Medium density development proposed for the Sunshine Coast. The layout and infrastructure associated with the development has been designed and implementation is progressing at the time of this assessment. The following case study options were assessed:
  - 40ha residential, 100 dwellings per ha
  - 40ha residential, 40 dwellings per ha

These developments were selected for case study assessment for the following reasons:

- they provide a representative mix of land use, scale, density and topography
- they provide a mix of alternative stormwater infrastructure
- the developments are considered to be representative of the bulk of development that will occur in SEQ
- they address greenfield and infill development

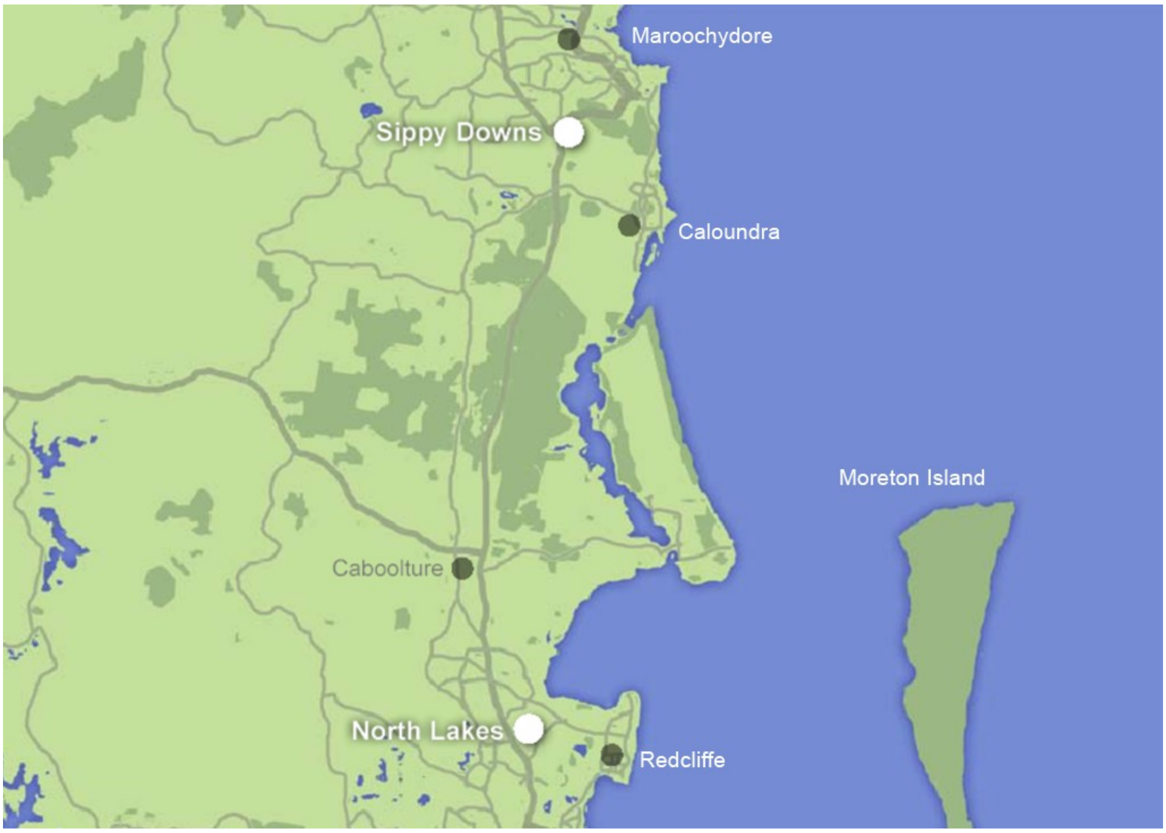

Figure 1: Case Study Locations

Stormwater infrastructure scenarios

Each of the case studies was investigated across a range of stormwater scenarios. The scenarios represent the range of possible approaches to stormwater from the traditional focus on flow conveyance and flood mitigation to the contemporary best practice incorporating water sensitive urban design (WSUD) and stormwater harvesting. General descriptions of these are provided in Table 1.

Table 1 Stormwater Scenarios

Scenario	Name	Stormwater Management Measures
1	Traditional	• Normal Conveyance • Flood Flow Rate Mitigation
2	Current	• Traditional, PLUS • Queensland Development Code: Water Savings Target • Stormwater Quality Management Measures
3	WSUD	• Current, PLUS • SEQ Draft Implementation Guideline No 7[1]
4	Stormwater Harvesting at Allotment Scale	• WSUD, PLUS • Stormwater Harvesting at an Allotment Scale • Only investigated for Sippy Downs and reuse was for irrigation only
5	Stormwater Harvesting at Catchment Scale	• Same as no 4, but catchment scale stormwater harvesting • Sippy Downs included rainwater tanks and reuse was for irrigation only • North Lakes considered 3 sub-scenarios: o No rainwater tanks, dual reticulation to allotments only o No rainwater tanks, dual reticulation to allotments and public open space o Rainwater tanks and public open space irrigation
6	Stormwater Harvesting to an External Demand	• Catchment scale stormwater harvesting with a connection to an external demand equivalent to collection and reuse of the runoff from rainfall events up to 15mm • Similar to the above the Sippy Downs scenario included rainwater tanks and North Lakes did not.

Storage

Storage is required to buffer the episodic nature of stormwater runoff and ensure end use demands are met. The size of storage is dependent on reuse demand and the desired water supply reliability. In the past, the storage size required to attain a high reliability has been viewed as a major constraint to the widespread application of stormwater harvesting. However, in the urban context, stormwater harvesting may be adopted to supply non-potable end uses using modest storage sizes to achieve moderate water supply reliability, with mains supply as a back-up if necessary.

A large constant demand delivers the most cost efficient stormwater harvesting scheme with the highest yield. This is because the higher the demand for stormwater, the more rapidly the storage is drained, thereby creating space to capture the next rainfall event. The volume of the storage for each case study and scenario was established based on the economic limit of performance of the storage (i.e. the diminishing rate of return on the storage versus demand met curve).

MITZI Footnote to be placed under the table [1] Since completion of this investigation, the Queensland Government has released the State Planning Policy for Healthy Waters and the SEQ Implementation Guideline No 7. These guidelines confirm the requirement for managing the environmental impacts of stormwater runoff from developments.

Treatment for reuse

The existing draft Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse (Phase 2) (EPHC, NHMRC, & NRMMC 2008b) do not define specific water quality classes for stormwater uses. Instead, the guidelines provide Log Reduction targets for various uses for virus, parasite and bacteria concentrations. To assist in defining treated water quality requirements, the following quality levels have been defined (Draft Stormwater Harvesting Guidelines, Healthy Waterways Partnership 2009):

1. Primary Contact (PC) – for uses such as community swimming pools
2. Non-Potable High Contact (NPHC) – for uses where there is a high probability that people will come into contact with the water during use, eg toilet flushing, private garden watering, high use public facilities
3. Non-Potable Medium Contact (NPMC) - for uses where there is a moderate probability of contact during use, eg low use public facilities or dust suppression
4. Non-Potable Low Contact (NPLC) - for uses where there is a low probability of contact, eg industrial uses or where public access is effectively restricted during irrigation

In general, with appropriate levels of treatment, harvested stormwater is considered to be suitable for all uses which could be supplied by treated recycled water, including toilet flushing, garden / landscape watering, general maintenance and car washing.

RESULTS

Select results are presented in the following charts. The charts have been formulated as follows:

- **"WSUD/Current"** represents Scenarios 2 and 3
- **"SWH to Site"** represents Scenarios 4 and 5
- **"SWH to Ext"** represents a yield generated by collecting and reusing the whole of the frequent flow objective to capture and reuse the runoff from impervious areas and all rainfall events up to 15mm
- Bars represent the highest and lowest values estimated
- Dots represent the median of the values estimated

Yield estimates from the various scenarios are shown in Figure 2. The following observations can be made:
1. The progression from **WSUD/Current** to **SWH to Ext** shows a steady rise in the median yield
2. The median yield is 3.6 kL/ha/day for **SWH to Site**, and 9 kL/ha/day for **SWH to Ext**

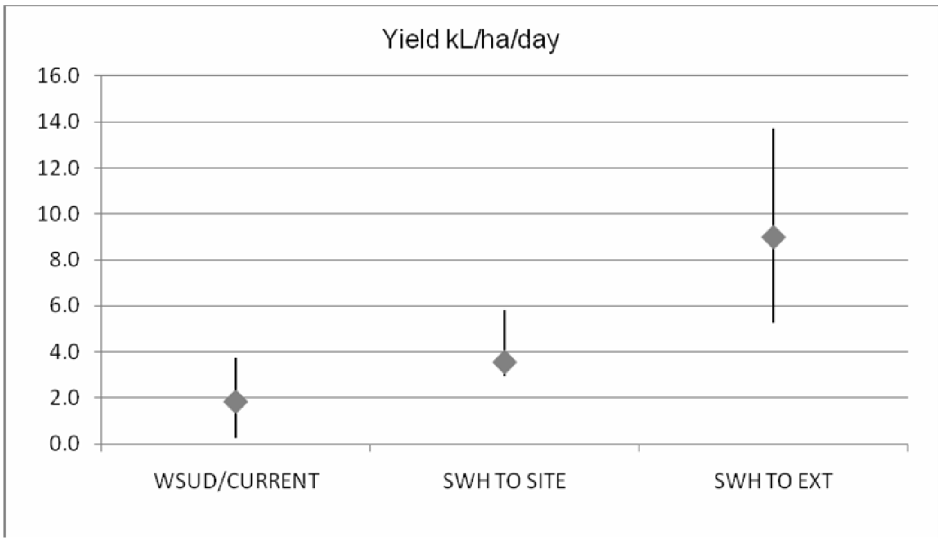

Figure 2: Stormwater Harvesting Yield (Average)

Costs were determined on a stand-alone basis for all the stormwater and rainwater harvesting options (marginal costs), as well as including all stormwater costs (gross costs). The stand-alone basis is presented first, as this represents the marginal costs of stormwater and rainwater harvesting.

Figure 3 shows the levelised marginal cost per megalitre of water supplied.
Table 2 provides the same costs per dwelling served. The following observations can be made:

1. The levelised marginal cost of stormwater (based on capex + O&M) for **WSUD/Current** is $5,595/ML, for **SWH to Site** is $5,631/ML, and for **SWH to Ext** is $2,535/ML
2. Costs of any of the stormwater harvesting options on a per dwelling basis are significantly lower for the medium density cases, ie at Sippy Downs, than for the low density development at North Lakes
3. Medium density cases only represent a relatively small cost increase over and above the **Current/WSUD** options

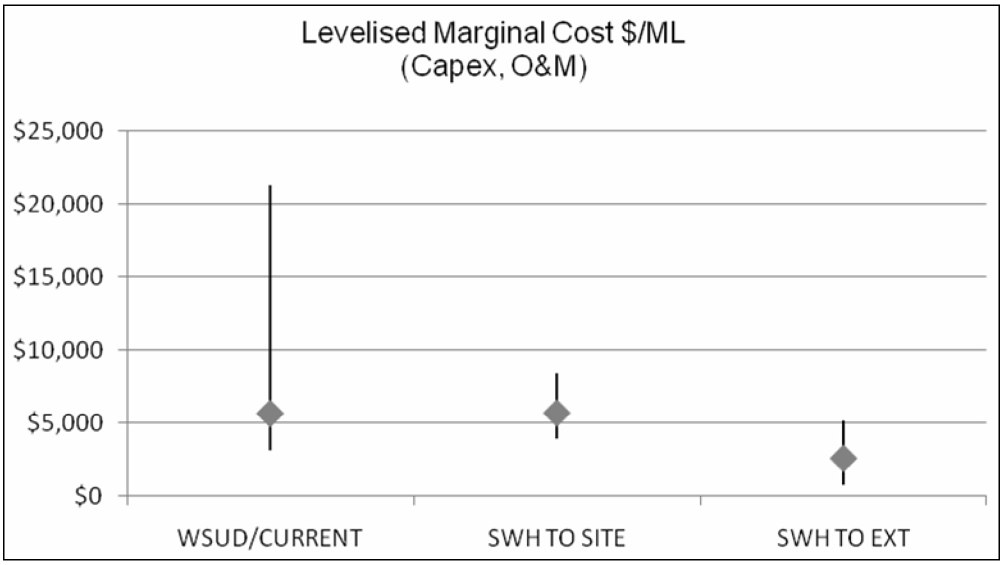

Figure 3: Levelised Marginal Cost of Stormwater

Table 2: Marginal Cost (capital and ongoing) of Stormwater Harvesting per Dwelling

Scenario	Description	Capital and Ongoing Cost (incl Land) $NPV/dw				
		Sippy Downs 100 dw/Ha	Sippy Downs 40 dw/Ha	North Lakes 20Ha Res	North Lakes 100Ha Res	North Lakes 500 Ha Res
1	Traditional					
2	Current	$500	$800	$4,400	$4,500	$3,500
3	WSUD	$500	$800	$4,400	$4,500	$3,500
4	WSUD + SWH (Allotment Scale)	$1,200	$2,400			
5a**	WSUD + SWH (Catchment Scale, Dual Retic to Lots)	$1,200	$2,300	$8,800	$6,300	$5,900
5b**	WSUD + SWH (Catchment Scale, POS irrigation, Dual Retic to Lots)			$9,100	$6,800	$6,100
5c*	WSUD + SWH (Catchment Scale, POS irrigation only)			$8,600	$6,500	$5,100
6**	WSUD + SWH to External	$1,300	$2,700	$9,600	$5,200	$2,600
*RWT all cases, ** Sippy Downs RWT were allowed, at North Lakes RWT were not allowed						

To provide context for the above, the total costs of all stormwater conveyance, peak flow mitigation, water quality management, rainwater and stormwater harvesting have also been estimated (Figure 4).

These results suggest the following:

1. The **WSUD/Current** scenario shows a wide spread of costs, due to the low demands and yields for the industrial estate case study
2. The median value of the cost decreases consistently for the three groupings from $23,000 per ML, to $15,000 per ML, to $5,000 per ML

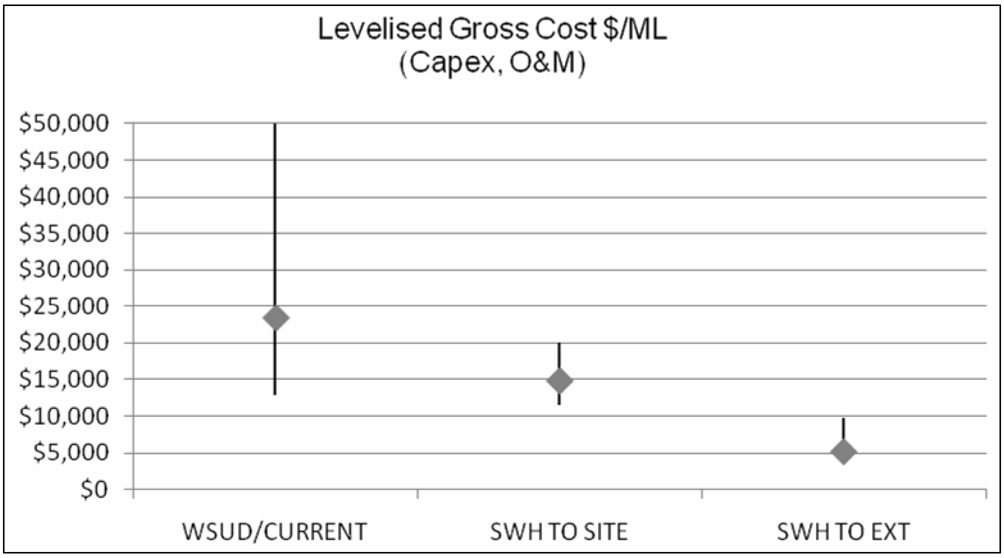

Figure 4: Levelised Gross Cost Stormwater Infrastructure

DISCUSSION

The yields from the schemes investigated provide a range for stormwater harvesting to site uses of 4 to 5 kL/ha/day. Where there is a large external demand the yield is about double this, i.e. 8 to 10 kL/ha/day. This indicates that if stormwater harvesting was adopted on a significant scale in SEQ, it may have the potential to reduce the demand on current or other planned infrastructure.

The assessment has found that stormwater storages vary in size depending on the reuse situation but remain relatively small to achieve a yield of approximately 70-75% of total demand. For stormwater harvesting within a site (i.e. capture stormwater from a catchment to supply demand within the same catchment) the storage size is around 60-80 kL/ha and to an external demand is around 90 kL/ha.

The investigation has confirmed that stormwater harvesting can play a role in protecting downstream aquatic ecosystems. The introduction of impervious surfaces can lead to significant changes to hydrology and increased pollution, which in turn can result in irreversible impacts on sensitive aquatic ecosystems.

Stormwater design objectives have been established to manage the impact of these changes as outlined in the Implementation Guideline No 7 Water Sensitive Urban Design (SEQ Regional Plan 2009-2031). The water balance assessments confirmed that the pre-development hydrology is preserved for Scenario 6 where the first 15mm of flow from impervious surfaces is captured and reused (i.e. strict compliance with frequent flow objective). The other stormwater harvesting scenarios (Scenarios 4 and 5) go some way towards re-establishing the pre-development hydrology, however, the smaller demand associated with reusing water within the catchment means reuse of the full 15mm of stormwater from impervious surface is not achieved.

A number of factors can have a significant influence on the costs of a stormwater harvesting scheme. The obvious ones are things like conveyance costs, storage costs, environmental mitigation costs, treatment and distribution costs. This study has found that the opportunity cost associated with the use of land for stormwater harvesting uses, and in turn whether or not stormwater harvesting infrastructure is above or below ground has a significant influence on cost. Additionally, at a small scale, treatment (filtration and disinfection) requirements tend to dictate cost whereas at a large scale the distribution network dictates costs.

To satisfy the provisions of the Queensland Development Code most developments implement rainwater tanks. To reflect this practice all scenarios except the Traditional, North Lakes Scenarios 5a and 5b and Scenario 6 included rainwater tanks. The North Lakes scenarios 5a and 5b do not include rainwater tanks because it was considered that if stormwater harvesting was to provide source substitution in accordance with the Queensland Development Code, and a dual reticulation system back to allotments was provided then rainwater tanks would essentially be doubling up on infrastructure at a significant cost.

The results suggest that the levelised cost of harvested stormwater is around $1,000 to $5,000 per ML, which is at the lower end of the range of costs presented for rainwater tanks. Stormwater harvesting appears to be comparable in costs to other options such as Purified Recycled Water and Dual Reticulation Recycled Water, slightly higher in cost than the water from the Gold Coast Desalination Facility, and significantly higher in cost than those anticipated for water from the Traveston Crossing Dam. All of these options have different drivers, advantages and disadvantages, and it is not the purpose of this study to make in-depth comparisons between the options. The key difference is that stormwater and rainwater do not provide the same level of reliability.

CONCLUSIONS

The findings of the study provide insight into when stormwater harvesting is a viable water supply option, and the key factors affecting this viability.

Supply/Yield

- Yield is maximised when there is a large demand (or large storage such as aquifers) which allows for storages to be drawn down and readily fill at the next rainfall event
- This reduces the levelised cost of the water, and reduces the environmental impact of stormwater flows
- To achieve this in practice it will be necessary to have high density development, or a large external water user
- A supply reliability of 70-75% has been designed for: improved reliability can be achieved through larger storage size but this leads to a worsening cost to supply ratio
- The yields from the schemes investigated provide a range for stormwater harvesting to site uses of 4 to 5 kL/ha/day
- Where there is a large external demand the yield is about double this, i.e. 8 to 10 kL/ha/day

Cost

- The ‘add on’ costs for stormwater harvesting are not large compared to overall infrastructure costs
- Stormwater harvesting has the potential for greater water supply yields at lower costs than rainwater tanks, particularly for large developments, or where high water demands can be supplied
- A key cost issue is the cost of land for stormwater infrastructure (and in particular storage), where infrastructure leads to reduced lot yield the cost increases significantly
- Storage in an existing drainage reserve or a suitable aquifer for storage greatly reduces the cost of stormwater harvesting
- Draining catchments to a single location (or smaller number of discharge points) results in lower costs of storage, treatment and distribution of stormwater. This can readily occur in moderate to steep catchments (2 - 10% slopes) rather than flat sites where catchments are typically split to avoid large pipe drainage infrastructure
- Larger scale development appears to reduce the costs on a levelised and per ha basis. The minimum scale that should be considered is around 20 ha, but 100 ha or more is desirable

- Low density development provides a lower levelised cost per ML for water, but higher density development provides a lower cost per dwelling for water

Environmental

- A stormwater harvesting scheme with a high yield has the potential to significantly contribute to improvement in downstream aquatic ecology

Factors for successful stormwater harvesting

The following factors were identified as contributing to a successful stormwater harvesting scheme:
- Large scale development
- High demands (from high density)
- Moderate slopes which drain to single/few points
- Cheap storage

It is stressed that this study has found a significant spread in the results, albeit with some clear trends. This indicates that there is wide variability in the way a stormwater harvesting scheme should be conceived and implemented, so every harvesting system should be considered on its merits and optimised to suit the situation in hand.

General

- Stormwater infrastructure can achieve a number of outcomes (e.g. water quality, supply and environmental flow) and therefore cost efficiencies do occur
- In a number of development scenarios stormwater harvesting can deliver water supply to meet and exceed the water savings target at a cost comparable to rainwater tanks, and in some cases cheaper
- Stormwater harvesting should be the means of meeting the Water Savings Target under the Queensland Development Code for certain developments
- There are likely to be many areas identified for development in the SEQ Regional Plan 2009-2031 that will be suitable for cost effective implementation of stormwater harvesting
- If wide uptake of stormwater harvesting to exceed the water savings target occurs further reductions in demand on central supplies may be achieved, further delaying the need to build new infrastructure

Future work

A range of other factors requires consideration in the implementation of stormwater harvesting systems. These are not the subject of this study, but nevertheless, a list of these issues has been compiled to provide some context to this work. Issues for further consideration are as follows:

- Developing the information from this consultancy and other documents (such as the Healthy Waterways Partnership Draft Stormwater Harvesting Guidelines) into information products and workshops for local government and developers
- The findings of this study could be applied to future development areas identified under the SEQ Regional Plan to map areas where viable stormwater supplies can be harvested
- Further analysis will allow for an estimation of stormwater supply volumes
- How the costs of stormwater harvesting are assigned is a key question – for example charging on a volumetric basis would lessen the cost burden on house price (currently the costs of rainwater tanks are incorporated into the house price)
- Who owns and manages a scheme needs to be addressed to ensure efficient and effective operation and to inform pricing frameworks
- Incentives for stormwater harvesting could be considered (such as reduced developer contribution to supply infrastructure due to the local supply provided)

- Ensure that local and State government legislative approvals are sufficient to ensure schemes are effective but are not overly burdensome
- Clarify the impact of land costs on stormwater harvesting systems
- Review the impact of rainwater tanks on the effectiveness of stormwater harvesting systems
- Identify the advantages and disadvantages of a stormwater harvesting scheme, including community benefits, environmental benefits, water security etc.

Recommendations

This study provides a strong basis over a range of scenarios and development types for the consideration of stormwater harvesting as a source of water for SEQ. The modelling and analyses herein have been undertaken with rigour, providing a set of results that can be used with confidence. The results demonstrate that stormwater harvesting is a feasible alternative to a range of other alternative water sources. It is recommended that the results of this study be used to underpin a study into the broader application of stormwater harvesting in SEQ.

THE AUTHORS

Chris Tanner and **David Hamlyn-Harris** are Directors of Bligh Tanner Consulting Engineers in Brisbane. With a professional background in civil engineering and town planning Chris has a broad grasp of land development issues and a focus on the integration of civil engineering solutions with the environment. David has a particular interest in integrated water management, including rainwater tanks, stormwater harvesting and water recycling. Bligh Tanner is a medium-sized practice with a focus on sustainable urban development and minimisation of the ecological footprint of development. Email: chris.tanner@blightanner.com.au

Shaun Leinster is an Environmental Engineer with DesignFlow with extensive expertise in the fields of urban stormwater management, water sensitive urban design, integrated water cycle management, river and stream hydrology and water resource management. DesignFlow is a team of stormwater professionals who draw heavily from natural systems in their approach to collecting, filtering, reusing, conserving and enjoying water in urban spaces. Email: shaun@designflow.net.au

REFERENCES

Natural Resource Management and Ministerial Council (NRMMC), Environmental Protection and Heritage Council (EPHC) and National Health and Medical Research Council (NHMRC) 2008, The Guidelines for Augmentation of Drinking Water Supplies

Natural Resource Management and Ministerial Council (NRMMC), Environmental Protection and Heritage Council (EPHC) and National Health and Medical Research Council (NHMRC) 2009, The Guidelines for Stormwater Harvesting and Reuse

Healthy Waterways Partnership, Draft Stormwater Harvesting Guidelines 2009

Department of Infrastructure and Planning, Queensland Development Code

Department of Infrastructure and Planning (DIP) 2008, South East Queensland regional plan 2005-2026 Implementation guideline No. 7 DRAFT: Water sensitive urban design – design objectives for urban stormwater management.

Department of Infrastructure and Planning (DIP) 2009, South East Queensland regional plan 2009-2031 Implementation guideline No. 7: Water sensitive urban design – design objectives for urban stormwater management.

Department of Environment and Resource Management (DERM) 2009, Draft State Planning Policy for Healthy Waters