STORMWATER REUSE AND THE EFFECTS ON RECEIVING WATERS

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ABSTRACT

Harvesting stormwater from drainage pipes or waterways for reuse is an increasing practice in Melbourne, as the impacts of prolonged reduced rainfall promotes investigation into innovative ways of reducing demand for potable water.

The open waterways that receive the outflow from Melbourne's drainage systems are also an important community asset and are generally areas of abundant flora and fauna species. In recent times community groups and drainage authorities have made great inroads into improving waterway health.

In some cases there are concerns about reduced flows and poor water quality for major waterways as a result of reduced rainfall. Diverting stormwater from drainage systems for reuse, if not managed correctly, can exacerbate this problem for waterways. Maintaining flows is critical for healthy waterways, given that 99% of the runoff volume occurs in rainfall events with Average Recurrence Intervals (ARI) of less than one year (Wong 2000).

This paper outlines a method to assess a stormwater harvesting and reuse scheme to minimise the effects on downstream waterways; it includes a case study from Melbourne where it has been applied; and describes how such schemes can be regulated in the future.

The assessment is in two stages:

1. Understanding the background of the catchment and receiving waterway.
2. The potential effects of applying the scheme to the receiving waterway.

Stage one includes:

- past modifications made to receiving waterway
- flow regime and the effects of recent reduced rainfall
- environmental considerations
- development within the catchment
- options for diversion locations in the catchment.

Stage two includes:

- meeting target extraction demands
- effects on flow duration in the creek based on scheme implementation
- percentage of flow taken from catchment.

INTRODUCTION

Melbourne has invested heavily in remediation works and initiatives to improve the quality of its waterways in some urban areas. This is an attempt to rehabilitate highly modified drainage channels where these systems were not appreciated for their natural value and amenity but instead engineered to convey polluted stormwater away from growing urban areas.

Melbourne's average rainfall in the past 10 years has reduced by 116 mm from the long-term average. In some areas the change has placed stress on waterways due to changes to the historical flow regime and resulting impact on waterway health and ecology.

Changes in climatic conditions have resulted in water restrictions that have led to Melbourne and other Australian cities becoming more conscious of their water usage. Alternative water supplies, such as stormwater runoff, have been considered for non-potable applications.

As these schemes become more common in urban catchments, greater consideration is given to the individual, and in some cases multiple, scheme(s) in catchments and how they will affect the immediate downstream waterway and the larger receiving waters.

Guidance provided for stormwater reuse schemes limits extraction to 50% of stormwater runoff discharging into a downstream waterway (CRSWS 2006). However, stormwater harvesting schemes also need to consider other significant factors as outlined as Index of River Condition (IRC) in the Regional River Health Strategy. These include:

- hydrology or flows — the quantity and timing of existing flows compared to natural conditions
- physical form — condition of waterway bed and banks and available aquatic habitat
- streamside zone — type and extent of vegetation
- water quality — the physical and chemical makeup of the water
- aquatic life — the diversity and quantity aquatic life within the waterway.

Of these factors, the waterway's flows or flow regime are strongly linked with the remaining four indices because:

- A consistent flow regime provides for vegetation health within the streamside zone, which is a major contributor to stabilising the creek and its banks to prevent erosion.
- Reduced flow in a waterway can contribute to poor water quality.

- Aquatic life and vegetation are reliant and have adapted to the existing flow regime within the waterway.
- Habitat is reliant on healthy vegetation and flow within a waterway. Vegetation provides refuge for fauna.

This paper presents an impact assessment method using the IRC outlined above and available flow data for a waterway, to determine the effects of a stormwater harvesting and reuse scheme.

The impact assessment is aimed at providing guidance on the potential maximum stormwater volume extraction, as well as informing the design and location of diversion and storage structures for the scheme.

This method is outlined using an example case study for a stormwater harvesting and reuse scheme in the Melbourne suburb of Keilor Park.

BACKGROUND

The Keilor Park Recreational Reserve (KPPR) is a 68 ha site located in the north-western Melbourne suburb of Keilor Park. It is the location for the Brimbank City Council Operational Centre, as well as multiple recreational facilities that include:

- tennis courts and club rooms
- one AFL oval
- four soccer fields and one club room
- basketball stadium
- one baseball field
- athletics track.

Figure 1 shows the reserve.

The site's irrigation demand has been estimated at approximately 60 ML/year. As part of Brimbank City Council's (BCC) ongoing planned and implemented water conservation measures, it is expected this estimated usage will be further reduced to a target of 45 ML/year demand.

A stormwater harvesting and reuse scheme was considered a feasible option to replace potable water for irrigating the KPRR site. Stormwater options investigated included diversions from drains discharging to Steele Creek and a diversion from Steele Creek.

Steele Creek is a major waterway located along the eastern boundary of the KPRR. The creek has a total catchment of 25 km² and forms part of the larger Maribyrnong River catchment. The Maribyrnong River has a total catchment area of 143 km² and its outfall is directly into Port Phillip Bay.

Since the 1920s, Steele Creek has been largely modified by the increase of industrial development in the catchment. In the 1940s, Niddrie quarry was established adjacent to Steele Creek and mined for basalt. It operated for several decades until residential development increased in the area between 1960 and 1970. Melbourne Airport was established in 1970, which resulted in increased stormwater flows and water quality issues. The catchment is now typically urban and industrial.

The creek corridor is generally narrow with sections that have steep escarpments. Its lower reaches are open grasslands that act as a flood plain and connection into the Maribyrnong River.

In accordance with the Melbourne Water Regional River Health Strategy (RRHS), Steele Creek has been categorised as a stream in poor condition. This is based on an overall assessment of attributes, including water quality, aquatic life, habitat and stability, vegetation and flow.

Pollution spills in the creek have contributed to its poor water quality, which is a major consideration within the waterway.

The majority of its length has been subject to modifications made to accommodate urban development. Changes to the creek include piping, concrete lining as shown in Figure 2 and straightening, which can cause impediments to the movement of aquatic fauna. Erosion and weed issues have also been a concern in sections of the creek.

Parts of the creek has been remediated as shown in Figure 3 and further works are planned as part of a masterplan for the creek and habitat improvements.

In the location of the KPRR site the creek is engineered, with a low to medium flood flow pipe conveying flows up to the 10 year ARI. Larger flood flows are conveyed within the grass-lined channel.

EXISTING CONDITIONS STEELE CREEK

As part of developing the KPRR stormwater reuse and harvesting scheme, an initial background assessment was completed to understand the existing conditions of Steele Creek using the IRC. This allowed a scheme to be developed for KPRR that where possible, would mitigate any potential risks and improve these areas of interest.

Hydrology

Given the large extent of urbanisation in the catchment the hydrology of the catchment is highly modified from natural conditions. However, the creek's existing conditions have and will further adapt to these modified conditions.

The flow regime in the creek is measured by a daily stream flow gauge located approximately 2 km downstream of the KPRR site at Rosehill Road. The stream flow gauge has mean and peak daily flow information for 1998–2008, which represents the recent drought period.

A flow duration curve best represents a waterway's flow regime. The mean daily flow information from the Steele Creek gauge was used to create a flow duration curve for existing conditions.

The total flow volume in the creek has also been calculated at the flow gauge and the KPRR site as 2,834 ML/year and 397 ML/year respectively.

Physical Form

As mentioned previously, Steele Creek is a highly modified waterway. Major sections of the creek have been engineered. Where the waterway was once a wider flood plain it is now restricted by a pronounced channel and banks in most areas due to urban development. Other lengths of the creek have and will be remediated over time.

The Steele Creek masterplan has outlined proposed works to the creek to improve its physical form and to link existing habitat zones.

Streamside Zone

The existing aquatic habitat is formed from a large range of native and introduced species of vegetation. The macrophyte and riparian species are spread across the bed and banks of the creek along segmented lengths of the waterway.

Water Quality

The water quality within Steele Creek is controlled by catchment runoff and freshes flow. Freshes flow are defined as short pulses of water into a waterway system to maintain and improve water quality (Nathan 2002).

In the Australian climate, an upper limit of 30 days of no flow in between freshes flow should be applied as a general precaution for water bodies to prevent algal blooms. (Melbourne Water 2005).

From the anecdotal information available, Steele Creek's poor water quality is a result of industrial and urban runoff rather than algal blooms from lack of flow.

Recent efforts have been made to improve the water quality in the creek through tighter regulation of industrial polluters and applying water sensitive urban design (WSUD) in the catchment.

Aquatic Life

An aquatic fauna assessment of Steele Creek (Biosis 2009) found aquatic species, such as native and exotic fish, native crustaceans and vertebrates, have been sighted along the creek up to the KPRR site.

Sections of the creek form barriers or impediments to the movement of aquatic fauna during flow events. One such structure — a pipe and overflow culvert arrangement — exists directly downstream of the KPRR site, as shown in Figure 4.

Works on the creek to promote the movement of aquatic fauna have been outlined in the masterplan for the creek corridor, which will assist in removing these restrictions.

<u>KPRR STORMWATER HARVESTING AND SCHEME DESIGN</u>

The scheme's design components were based on set design limitations and water balance modelling.

Design limitations included ensuring that:

- Diversion structures and storages do not create a blockage or impediment to the movement of aquatic fauna in Steele Creek.
- A low flow into the downstream section of creek is maintained at the diversion.
- The total diversion quantity does not exceed the total site water demands.

Water Balance modelling used the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). The information input into this model included:

- Ten years of mean daily flow information (1998–2008) that was disaggregated from the flow gauge location at Rosehill Road and based on catchment area and imperviousness to estimate the flows at the KPRR.
- Total demand quantities for the KPRR site in proportion for each month.

The water balance model included diversion options from Steele Creek and a main drain discharging into Steele Creek, the Translink Business Park (TBP) main drain. Various storage sizes and stormwater diversion proportions were modelled to create the best possible scheme.

The design selected involved a proposed diversion from the TBP main drain. Figure 5 shows the storage and diversion structure.

Diversion from the main drain rather than directly from the creek had a number of advantages in terms of design and constructability; but also had considerable habitat and aquatic benefits as it avoids modification and disturbance of the existing conditions in the creek.

<u>FUTURE IMPACTS ON STEELE CREEK</u>

Several assessments were completed to determine the effects of the proposed stormwater reuse and harvesting scheme on the existing IRC of Steele Creek, they included:

- Flow duration assessment, which is used to assess the flow or hydrology.
- Creek water level and flow volume assessment, which is used to gauge the variance in water inundation that sustains aquatic and riparian plant health, as well as water levels in varying flows that provide a means of transport within the waterway for aquatic life. (These are essential for understanding the effects on the waterway IRC of physical form, streamside zone and aquatic life.)
- Spell analysis assessment, which is used to determine the potential for prelonged periods of

limited flow in the creek and is crucial for understanding the IRC of water quality.

Flow Duration Assessment

Based on the output of the water balance modelling and the existing flow data, flow duration curves were developed for Steele Creek at the KPRR site and Rosehill Road flow gauge location, as shown in Figures 6 and 7 respectively.

These flow duration curves show the effects on the flow regime at KPRR site are more pronounced than at Rosehill Road. This is because the contributing catchment to the waterway, Rosehill Road, is approximately 6.5 times larger than the KPRR catchment.

The flow duration curves illustrate that during irregular events (with a 10% exceedance probability), flows will be reduced by approximately 5 L/s and during regular events (with a 75% exceedance probability), flows will be reduced by less than 0.4 L/s.

Water Levels and Flow Volume

The change in flow regime results in changes to the water level downstream of the KPRR site, as outlined in Table 1.

Based on these results, a flow in Steele Creek of 10% exceedance probability would experience a reduction in water level of approximately 1 mm as a result of the scheme. A change in water level of this amount for the given event would have negligible effects on the inundation of aquatic and ephermeral plants and would not disturb aquatic fauna that use such flows to migrate between sections of habitat.

The change in total flow volume was another factor assessed that could alter the health of vegetation and aquatic fauna. Table 2 presents the results of this assessment.

These results show that the application of the stormwater reuse scheme reduces the total average annual flows by 11% annually downstream of KPRR and 2% at Rosehill Road.

Spell Analysis

An assessment was also completed on the effects the proposed scheme would have on freshes flow in the waterway. A spell analysis used the available flow data to determine how many times a year the creek is deprived of freshes flow for more than 30 days in current and future conditions. The assessment concluded that, there are two, 30-day spells in Steele Creek annually for both existing and future conditions. Therefore the scheme does not have any impact on spells of freshes flow in the creek.

CONCLUSIONS

The IRC indices provide the following crucial factors to quantify the health of a waterway:

- hydrology or flows
- physical form
- streamside zone
- water quality
- aquatic life

When developing the design of a stormwater harvesting and reuse scheme and assessing the effects on the downstream waterway, three phases of assessment should be considered:

- quantifying the existing condition of the waterway based on IRC
- scheme design considering constraints from existing conditions
- modelling the scheme to assess the effects on the IRC (flow data is used to complete the flow duration, water level and volume and spell analysis).

MUSIC provides a quantitative means to assess the effects of a stormwater reuse scheme on a downstream waterway applying alternative diversion options. Using real flow data or a calibrated model will provide more reliable results using MUSIC. The assessment criteria and modelling tools are being reviewed by relevant authorities.

General design for stormwater reuse schemes should consider the best diversion option from modelling outputs and the design and location of scheme components. Diversion structures and storages should minimise potential impediments to the movement of aquatic fauna within the waterway. Using existing engineered structures offline from the waterway should be considered as preferred diversion locations to avoid distrubances of the existing natural conditions.

The method in this paper provides a standard impact assessment for a waterway. The assessment results can warrant more detailed investigation, but this was not needed in the KPRR case study.

This method of assessing stormwater harvesting and reuse schemes on downstream waterways using flow information is evolving and being further developed.

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Figure 1: Keilor Park Recreational Reserve

Figure 2: Modified Section of Steele Creek

Figure 3: Remediated Section of Steele Creek

Figure 4: Existing structure downstream of Keilor Park Recreational Reserve Site

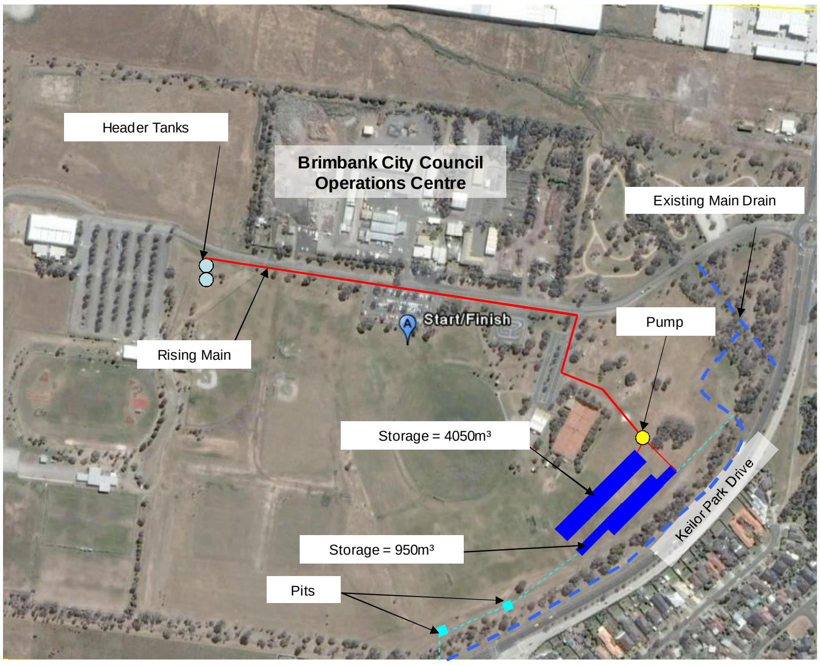

Figure 5: Keilor Park Recreational Reserve Stormwater Harvesting Scheme Design

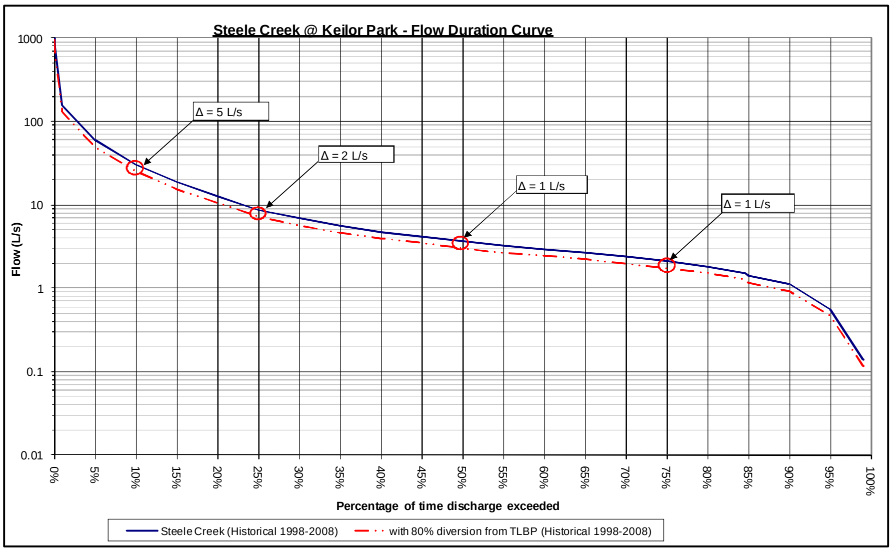

Figure 6: Flow duration curve at KPRR

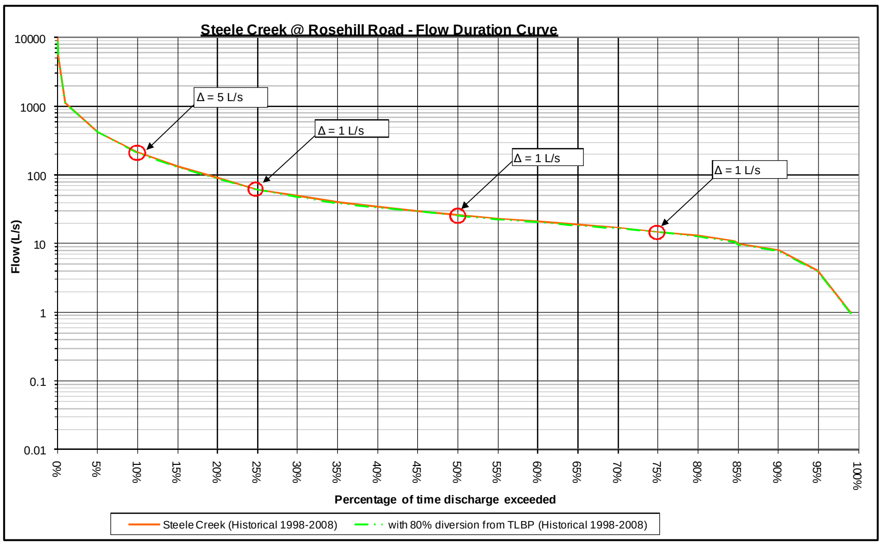

Figure 7: Flow duration curve at Rosehill Road

Table 1: Steele Creek – flow reduction and water levels at Keilor Park Drive

Percentile flow	Reduction in flow (L/s)	Existing water depth (mm)	Future water depth (mm)	Change in water depth (mm)
10	5.2	24	23	1
50	0.6	7	6	1
75	0.4	5	4	1

Table 2: Average annual flow volume in Steele Creek

Location	Condition	Average yearly flow (ML/year)
KPRR	Existing	397
KPRR	Future	352
Rosehill Road	Existing	2834
Rosehill Road	Future	2789