When to Slow and When to Flow – A Case Study of the Interaction Between Retardation and Water Quality

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Biography

Chris has over nine years of experience in a wide range of water related and civil construction projects, providing project management experience and specialist technical skills. Chris has completed a Bachelor of Environmental Engineering (Honours), a Master of Engineering Science (Project Management) at UNSW and a Graduate Diploma in River Health Management. Coming from a Council background, Chris understands the unique design, and in particular maintenance requirements that these projects provide. Previous projects include the modelling, design, and documentation of stormwater networks, Council assets and urban floodways. Chris has recently been involved as Project Director for a number of Melbourne Water projects including the Brockhoffs MD and Damper Creek Flood Mapping as well as the Shire of Yarra Ranges Flood Management Plan. Chris also Project Managed the City of Casey Flood Management Plan. Chris has significant hydrologic and hydraulic modelling experience through the use of RORB, HEC-RAS, SWMM, TUFLOW and MIKE. Over the past 2 years Chris has lectured the Melbourne University 3rd year hydraulics assignment, based in HEC-RAS.

Abstract

Current Victorian stormwater quantity management practice requires the retention of post development subdivisional flows to match the pre development flows for the 100 year ARI storm. Current stormwater quality management requires the reduction of post development nutrients back to best practice guidelines. In the interest of efficient use of space these two requirements outcomes are located in the same area, more often than not with the storage above the water quality. However in some locations the retention of flows is not only difficult, but may result in the increase of flows downstream of the site. In these cases, the use of storage above wetlands needs to be evaluated for the best use for the catchment. In these cases the evaluation of the full predevelopment hydrologic regime can be assessed against a post development regime and matched to provide the best outcomes for the catchment.

This paper explores some of the situations when this may occur, the changes in hydrological regime and some of the methods used in finding a matching hydrological regime. The main case study involves a
medium to large subdivision spanning two sides of a valley. Six separate large wetlands are required to meet the water quality requirements. Traditional retardation of flows would result in a delaying of subdivisonal flows until the main stream peak reaches the site. As such a different approach is called for allowing for the analysis of other important flow related water way influences including geomorphic and ecological responses to changed regime. These changes are explored through a series of model results and discussion of their impact entered into.

**Introduction**

Urbanization of our catchments has led to major changes in the system hydrology as a result of an increased impervious fraction. The resultant hydrology has an increased flow frequency and magnitude, which has prompted the Catchment Management Authorities to require 100 year flow retention for new developments. Historically this approach has primarily been undertaken to reduce the possible effects of flooding downstream of any given development. More recently a significant amount of research has gone into some of the affects of the increased frequency of flows, in particular the increased frequency at lower magnitudes.

Over the last decade the CRC for Freshwater Ecology and others have committed to research on the affects of urbanization on streams. Through this research the concepts of “effective impervious area” (EI) or a measure of the directly connected impervious areas to a given receiving water (Walsh. C, et al.,2004). It has been found that as EI increases stream base flow decreases, peak flows become “flashier”, and small moderate flows in the stream become more frequent, this can be seen in Figure 1 . All of these affects can be attributed to the direct transportation of flows from impervious surfaces to the stream in an efficient manner. Some of the direct affects of this changed hydrological regime include:

- Associated changes in stream geomorphology or stream dimensions
- Impacts on flora and fauna communities
- Disruption of fish migrations, habitat and spawning
- Changes in stream sediment balance resulting in aggradation or bed and bank erosion
- Changes in floodplain engagement and associated floodplain health degradation

(DSE,2007)
It has been found that these affects are particularly prevalent up to the 1.5 to 2 years Average Recurrence Interval (ARI). Associated with this low end range of flow events are also the changes to catchment water quality associated with urbanization. Research has been undertaken into the design flow treatment of water through water sensitive design features. As a result of this, treatment designs are typically sized for the 0.25 year ARI, though as shown in Figure 2 removal rates continue to increase up to the 1.5 year ARI (CSIRO, 1999). Given these two major catchment influenced changes to our streams (stream hydrology and stream water quality), it could be argued that analysis and treatment of the sub 2 year ARI flow is of upmost importance to the health of our streams.

Figure 2 Treatment of mean annual flow against Average Recurrence Interval (CSIRO, 1999)
Additional to these concerns, there is still however an imperative to retain existing 100 year ARI flood flows from a flooding perspective. Peak 100 Year ARI flows resulting from a development are required to be no higher than the existing conditions through the use of mitigation structures. The mitigation can occur throughout the development or at an end of line treatment such as a retarding basin. The two main objectives for flow retardation, as defined in the Melbourne Water Land Development Manual (2012), are to:

- Minimise the impact on waterways from urban development (through changes to flow regimes, flood frequency and runoff volume, frequency and velocity)
- Ensure no adverse impacts on downstream properties as a result of the development

Flow retardation is often achieved within a retarding basin which may also incorporate WSUD features.

While the current regulations prevent any additional flooding of downstream properties in the 100 Year ARI event, often the lower ARI events (above the 0.25y ARI treatment flows) are not considered when designing these structures. Whilst there is a requirement for 1.5 Year ARI retardation to protect the waterways from additional flow in more frequent events, it is often a secondary concern and not strictly enforced.

Finally, often flood retention is undertaken with only the site in mind and no consideration of the greater catchment. Timing of the flows can often significantly impact on the overall peak flow for the catchment, particularly in cases where retained developed flows coincide with large rural catchment flows.

This paper looks at a case study of a residential subdivision where the conventional flow retardation was not the optimum solution for the site. With only minimal flood retention the 100 year peak flows for the catchment were staged, while still providing some retention of smaller events. This solution provided a hydrologic system which more accurately reflected the natural conditions. The main objectives of this paper are to:

- Hydrologically model and report a catchment where retardation of flows in line with Victorian practice is contrary to the flood objectives for the catchment
- Model and report the possible hydrologic flow regime changes by the manipulations of storage associated with the water quality devices
- Discuss the implications of flow regime changes with relation to the possible storage manipulations of the water quality devices
Method

A stormwater management strategy for a new development generally consists of:

- A review of the site for opportunities and constraints
- Development of a hydrology model to assess the onsite flows for existing and developed conditions
- Sizing of a retarding basin to reduce peak 100 Year developed flows back to existing
- Modeling and conceptual design of any water quality features (often co-located with the retarding basin)
- Flood modeling to ensure no offsite impacts on neighboring properties and flood safety criteria within site are met
- Consultation with Council / CMA to discuss the findings

Often these investigations are predominantly focused on the study site and the impact of the development on the receiving water’s hydrology is not considered unless proposed features are online. This can lead to the flood retention features actually worsening the downstream flooding as the mitigated flows coincide with greater catchment peak flows.

This paper will consider the catchment and subdivision flows using the modeling program RORB, showing the influence of the storages on downstream flows. MUSIC modeling of the catchment and subdivisional flows will then be undertaken to display the change in flow probability exceedence through the addition of the subdivision on the catchment. The regime changes will then be compared to literature.

The Site

Water Technology developed functional design’s for a stormwater treatment system for the proposed development of the Brookfield Lakes, Bairnsdale (Figure 3). This study follows from the Stormwater Management Plan prepared by Water Technology (2007). The functional design will consists of major waterway improvement for the Goose Gully Creek within the study site, 3 offline wetlands, 3 sedimentation ponds and 1 online lake. This design meets both the CMA’s and Council’s requirements and follows Melbourne Water’s design guidelines.
The major waterway for the study area is Goose Gully Creek, intersecting the site in a north-south direction and is characterized by significant topographical relief on either side of the gully. Goose Gully Creek is an ephemeral stream, with little summer flow. Goose Gully Creek receives flow from a predominantly agricultural upstream catchment, with an approximate catchment area of 700 hectares upstream of the proposed site. A typically view of the gully can be seen in Figure 4.
The Creek is currently in a moderate to poor condition. A small section of the creek maintains pre-existing vegetation and stream geomorphology (and has been included as an exclusion zone). In general however, the stream has suffered generations of agricultural use and displays signs of erosion, exotic species domination and poor water quality (Figure 5). There is little to no defined creek channel through the proposed development site. The channel, in most cases, would be best described as a grassed swale with a wide floodplain comparative to the catchment size.

To improve the stream health in line with the principals previously discussed a range of measures were proposed and incorporated into the design, these are outlined in
Table 1. Critical to the success of the project however was the incorporation of additional storage to each of the wetlands. This is outlined below.

**Table 1  Challenges and mitigation measures**

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Ameliorative measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Long term the stability of the macro channel</strong></td>
<td>Will be ensured through the incorporation of the rock chutes.</td>
</tr>
<tr>
<td><strong>Construction stability of the macro channel</strong></td>
<td>The introduced grasses will be removed during the construction. Whilst in the long term they are undesirable they do provide a valuable stability measure. It is recommended that the topsoil be scraped stored and reinstated, with the grass seed bank, to provide a short term stable substrate. This area is to be planted with the full suite of natives as soon as practical after disturbance.</td>
</tr>
<tr>
<td><strong>Potential development of an erosion head at Eastwood Road, outside the boundary of the development. The informal rock chute that has been built in this area is insufficient to cater for the flows into the long term.</strong></td>
<td>A redesigned rock chute in this location is recommended, liaison with Vic Roads will be required.</td>
</tr>
<tr>
<td><strong>Stability of the low flow channel</strong></td>
<td>The low flow channel has been designed as a formal trapezoid, this is unlikely to persist. It is anticipated that there will be minor erosion within this channel that will naturally develop into a stable, geomorphically diverse, scour and depositional channel. Structures will prevent material being exported from the site.</td>
</tr>
<tr>
<td><strong>Control of the weed grasses, short term.</strong></td>
<td>The persistence of the introduced grasses will inhibit the growth of the planted trees. It is proposed that introduced grass is sprayed with herbicide prior to planting and re-sprayed every six months after planting until established to a height of 1.5m as a minimum.</td>
</tr>
<tr>
<td><strong>Control of weed grasses, long term</strong></td>
<td>The long term objective is for a forest on the slopes and a riparian forest on the floodplain. The introduced grasses will not thrive in a shaded environment which the canopy trees and shrub layer will provide. It is acknowledged that there</td>
</tr>
</tbody>
</table>
There will always be some weed species in the groundcover.

<table>
<thead>
<tr>
<th>Damage to the area with protected vegetation</th>
<th>This area is to be fenced off prior to the start of the works and</th>
</tr>
</thead>
</table>

As a result of waterway improvement, wetlands and sedimentation ponds construction approximately:

- 7300 m$^3$ of floodplain storage was provided
- Over 14,000 m$^2$ of water quality treatment
- More than 2000 m$^2$ of high quality stream was protected
- Over 60,000 m$^2$ of riparian vegetation will be planted

An overview of the design is shown in Figure 6.

**Additional storage**

In addition to a 300mm freeboard, an additional 300mm above the TED level for each wetland has been included in the design. The storage is considered to provide low ARI (<5yARI) flood attenuation storage and reduce the runoff frequency (Table 2).

**Table 2**  
**Additional storage in the wetland systems**

<table>
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<tr>
<th>Wetland 1</th>
<th>Wetland 2</th>
<th>Wetland 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage above NWL</td>
<td>2474</td>
<td>2120</td>
</tr>
<tr>
<td>Storage above TED</td>
<td>1040</td>
<td>851</td>
</tr>
</tbody>
</table>
To review the hydrological impacts of the design, a RORB model was developed for the catchment and study site as shown in Figure 7. The study site is in the lower portion of the model, within subareas Y, Z, AB, AC, AD & AE. The RORB model was run for all events and durations to determine the peak flows for the greater catchment, and study site under existing and developed conditions. Results are shown in Figure 8.
Figure 7 RORB Model Layout
As can be seen above, the critical 100 year ARI duration for the external catchment is the 9 hour event. The peak flow is $24.3 \text{m}^3/\text{s}$ after 6.5 hours (Figure 8). The timing of the peak for the external catchment is similar to the study site, although the flows vary in magnitude. In developing the site, the peak flow increases from existing flow, however the timing is much faster (flashier) than the existing conditions due to a higher impervious area. Most notably the developed flow has passed before the catchment flow enters the site. This offset of peaks means there is no downstream impact on the catchment peak flow. It is therefore more beneficial to allow the flow to enter the creek directly rather than delay the peak by the use of a retarding basin.

In addition to the 100 Year flow the 1.5 Year ARI is a critical event in which geomorphology and ecology can be impacted. The aim is to maintain the 1.5 Year ARI event hydrology in existing and developed conditions in order to avoid habitat disturbance. For ease of calculation, the 1 Year ARI events have been considered to assess if the flows were significantly larger in developed conditions. Figure 9 depicts the peak flow for the developed site is $2.6 \text{m}^3/\text{s}$ compared to $1.8 \text{m}^3/\text{s}$ in existing conditions. With the additional 300mm of storage above the wetlands however the flow is reduced back to the original $1.8 \text{m}^3/\text{s}$ with a hydrograph much closer to the pre-development shape.
Finally a runoff frequency analysis was conducted in MUSIC to check what impact the additional flows had on the frequency of runoff. The analysis, as shown in Figure 10, shows that only negligible increase of runoff frequency is likely occur due to the development, and mostly the increases are for the flows less than 0.2 m$^3$/s. The days with flow increased by 2% once the WSUD features were included in the model. This is considered negligible for ecosystem disturbance.
These results show that:

- In this occasion the standard sub divisional stormwater management results in less than ideal outcomes as it allows the peaks to match up in the 100 Year event, providing flooding implications downstream.
- With the WSUD features included the smaller flows can be suitably mitigated to prevent a substantial increase in flow days.
- It is possible to alter the flow regimes through the manipulation of water treatment storages.
- An additional 300mm of storage on top of the Total Extended Detention (TED) resulted in improved ecosystem flows, a closer matching to pre-existing flows for the 1y ARI, and a reduction in flow frequency disturbance.

**Discussion**

Moving away from a non-traditional design has allowed the site to better meet the requirements of the creek and the greater catchment. The design as shown in Figure 6 has enabled the development to meet all statutory and waterway management objectives including:

- Providing no offsite flooding impacts,
- Best practice stormwater treatment for water quality purposes,
- Approximating the pre-existing 1.5 Year ARI hydrology

This matching of the existing conditions hydrology for the 1.5 Year ARI event has significant improvements to the geomorphic and ecological responses compared to a developed regime without any retention, or retention of the 100y ARI flows only.

Through this example it can be seen that considering site 100 year retention only may not only be a false objective, but may also result in increased downstream flows, and detrimental increases in high frequency flows. In this location a relatively minor addition of storage to the proposed stormwater quality devices has resulted in achieving all best practice objectives. This serves as a lesson to future developments to look outside of the standard paradigms and search for a best of catchment approach.

**Conclusion**

This project discusses the implications of blanket subdivisional approval rules and their application in practice. Hopefully it incites debate about the best way to manage flows from development on a case by case basis.

When the peak flow of the external catchment aligns with the onsite mitigated flow the effects downstream can be exacerbated. Allowance of the flows to enter the system at different times within
the event often helps to mitigate the overall peak flow. Reviewing the storage requirements, and using them inventively can also achieve much greater stream health objectives.

References


Department of Sustainability and Environment (2007), *Technical Guidelines for Waterway Management*, Department of Sustainability and Environment, Victoria
