IMPORTANCE OF INUNDATION FREQUENCY ANALYSIS FOR CONSTRUCTED WETLANDS

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ABSTRACT (200 WORDS MAXIMUM)

Constructed wetlands play a vital role in Australia to reduce the environmental impacts of urbanisation. They also provide habitats for wildlife, provide people with places for recreation, and help make people be more aware of the environment around them.

Wetlands in Australia are typically designed to treat the 3 month ARI peak storm events over a 72 hour detention time. Urban development has forced wetlands 'online' which effectively treat flows from the whole of catchment. Wetlands placed downstream of other water quality treatments, retarding basins, large catchments and coupled with successive rainfall events, generate base flows for extended periods. This causes increased frequency of inundation and detention times in excess of 72 hours. Additional stress on vegetation and treatment performance therefore occurs, especially during establishment periods.

This paper takes a case study from one of Melbourne's northern growth area where a constructed wetland's vegetation partially died due to increased inundation times during establishment. A holistic catchment analysis was carried out utilising Continuous Rainfall Simulation (using MUSIC) in order to determine the frequency of inundation of vegetation over a 10 year period and the effects of urban hydrology. The paper recommends design considerations and techniques for 'online' wetlands.

KEYWORDS

Inundation, Frequency, Constructed Wetlands, WSUD,

PRESENTER PROFILE

Leigh is a qualified Civil Engineer and Project Manager with over 8 year's professional experience Leigh currently manages Spiire Australia's Water and Landscape Team. Leigh's expertise lies within urban stormwater management and is determined to make a difference in the water industry with his strong focus on creating livable cities.

1 INTRODUCTION

Constructed wetlands play a vital role in Australia to reduce the environmental impacts of urbanisation. They also provide habitats for wildlife, provide people with places for recreation, and help make people be more aware of the environment around them.

Wetlands in Australia are typically designed to treat the 3 month ARI peak storm events over a 72 hour detention time. Urban development has forced wetlands 'online' which effectively treat flows from the whole of catchment. Wetlands placed downstream of other water quality treatments, retarding basins, large catchments and coupled with successive rainfall events, generate base flows for extended periods. This causes increased frequency of inundation and detention times in excess of 72 hours. Additional stress on vegetation and treatment performance therefore occurs, especially during establishment periods.

The paper will examine a 1400ha catchment in Melbourne's Northern residential growth area where a wetland was constructed and failed during its plant establishment phase due to the excessive inundation of this system

2 BACKGROUND

The particular wetland analysed in this paper (referred to from here on in as 'WL3') is located within Laurimar, 40km north of Melbourne. The catchment is approximately 1400ha and large portion of the catchment is and will be developed. The mean annual rainfall within the vicinity of this area is approximately 600mm/year.

In Victoria, Melbourne Water (MW) is the caretaker of rivers, creeks and drainage systems within Melbourne's catchments and for this particular catchment MW formulated a drainage scheme to ensure drainage infrastructure that dealt with quality and quantity issues was implemented in a coordinated and equitably manner across all land holders.

With respect to quality systems the scheme adopted a number of wetland systems (online and off-line) to treat the majority of the catchment. WL3 had five wetland systems upstream of it, where one large upstream wetland also doubled as a retarding basin. All flows discharged downstream into a drainage reserve, where WL3 diverted these flows into its system via a weir system within the drainage reserve.

Following record drought periods between 2001-2010, In 2011 and 2012 the area received verging on record high annual rainfalls (in excess of 800mm/yr). WL3 was within it's establishment phase within the period of 2011-2012 and it was evident during this time that the base flow conditions within this drainage reserve was running for multiple days after a rainfall event. As a result the wetland was operating well above normal operating levels for much of this period. Consequently much of the vegetation within the wetland other than one particular species died due to the frequency of inundation.

3 WSUD IN AUSTRALIA

Although water Sensitive Urban Design (WSUD) in Australia is still an emerging practice, constructed wetlands have been implemented throughout Australia for over 20 years. Wetlands are recongnised for their ability to improve water quality, provide habitat for fauna and amenity for the community. Water quality standards in Australia are generally in accordance with the Best Environmental Practice Management Guidelines for urban Stormwater, where the following objectives are recommended:

- 45% reduction in Total Nitrogen (TN) from typical urban loads
- 45% reduction in Total Phosphorus (TP) from typical urban loads
- 80 % reduction in Total Suspended Solids (TSS) from typical urban loads
- 70% reduction in Litter from typical urban loads
- Maintain discharges for the 1.5 year ARI event at pre-development levels

Melbourne Water has been working with developers and local council to incorporate more water-sensitive interventions, including the construction of wetlands, into the planning and development of new urban areas. Through this process they developed the Constructed Wetlands Guidelines in 2010.

In Melbourne it is preferred to construct offline wetland systems for stormwater treatment, however online wetlands may be permitted if they meet a number of criteria setout by Melbourne Water (MWC). These 'online' wetlands are sometimes placed downstream of other water quality treatments, retarding basins and within large catchments, all of which contribute to longer durations of base flows. This coupled with successive rainfall events causes increased frequency of inundation and detention times in excess of designed detention times. Additional stress on vegetation and reduced treatment performance therefore occurs, especially during establishment periods.

The Melbourne Water Constructed Wetland Guidelines depict the need to carry out inundation frequency analysis; however this is only on the basis of if the extended detention depth is greater than 500mm or in high rainfall areas (above 800mm/yr). This criteria doesn't take into account the scale of the catchment or associated upstream drainage infrastructure which would affect the hydrologic response of the catchment.

Based on the experiences described in section two this paper will aim to depict the importance of inundation frequency analysis and a procedure of how to design wetlands with respect to a whole of catchment approach. Utilising the Melbourne Water guideline criteria this paper will adopt the following criteria for determining an appropriate inundation frequency.

- Water depth within the wetland should not exceed half the design plant height for more than 20% of the time.

4 THE CONTINUOUS SIMULATION MODEL

In Australia, MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is an industry standard tool for aiding decision-making for stormwater management projects. MUSIC provides the ability to simulate both quantity and quality of runoff from catchments ranging from a house up to many square kilometres, whilst determining the effect of a wide range of WSUD outcomes with respect to runoff downstream. MUSIC has adopted continuous simulation modelling as it is recommended in modelling stormwater management systems as in the case for stormwater pollutants delivered to receiving waters from many small storm events, it can make up in excess of 90% of the annual loads discharged from the catchment. Based on this it is vital that we examine the hydrologic performance of treatment systems over a range of climatic conditions. The below figure represents the Rainfall-Runoff model adopted for MUSIC.

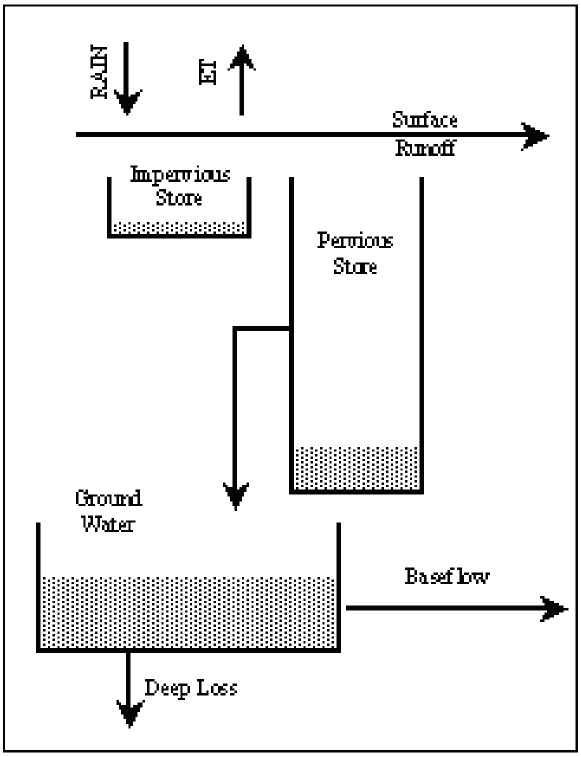


Figure 1: MUSIC rainfall-runoff algorithm

For the purposes of this paper MUSIC has been adopted as the preferred Continuous Simulation model, however other models could be used to carry out the analysis within this paper.

4.1 Rainfall Data

The rainfall data set which best represents the rainfall patterns for this area is Melbourne City and has a mean annual rainfall of 650mm. The data was in converted from 6min time step to daily time step for the purposes of this investigation. For this paper it was decided to evaluate the frequency inundation over recent years (2001-2010) as it represented a lower rainfall period of just less than 500mm per annum. The rational to model over a drought period was to understand how the system behaved in lower rainfall periods and therefore assess if the system would work in climatic periods. It was also thought to run the analysis over a longer period to enable a variety of different rainfall patterns i.e. successive days of rainfall.

4.2 WL3 Parameters

Wetland WL3 is a 6500m^2 system and in its current configuration has the following design parameters:

- 0.5m extended detention depth
- 72hour detention time

5 INUNDATION FREQUENCY ANALYSIS

An inundation frequency analysis ascertains the portion of time the wetland water level exceeds normal operating levels. A graphical representation of this analysis can be derived by comparing the water level over time and the percentage of time the system operates at these levels. As mentioned earlier the criteria for assessing the level of acceptance within a wetland is as follows:

- Water depth within the wetland should not exceed half the design plant height for more than 20% of the time.

5.1 Method

Using MUSIC to depict the various catchment types, treatment systems and flow paths a model was setup to best represent these various attributes. Parameters of the model were setup as per the Melbourne Water MUSIC guidelines and all treatment system sizes, volumes and detention times were obtained from Melbourne Water.

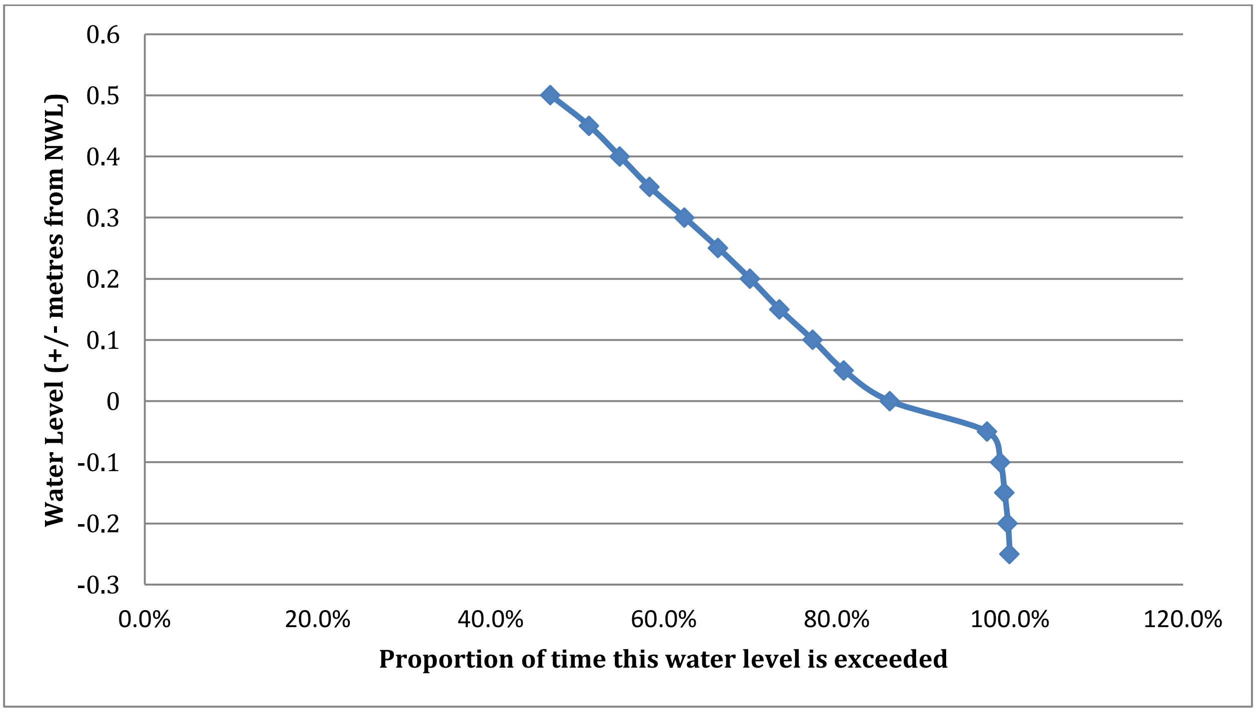
Water balance results are exported to excel and setup to extract percentage of times a certain water level was at. A graph could be plotted to depict the water level versus percentage of time this water level was exceeded.

The analysis review several scenarios to understand the impact of WL3 as follows:

- Current System
- Reduced extended detention times for upstream wetlands
- Remove wetlands upstream of WL3
- Convert WL3 to offline system with 100ha catchment
- Retrofit Low flow Bypass

5.2 Results

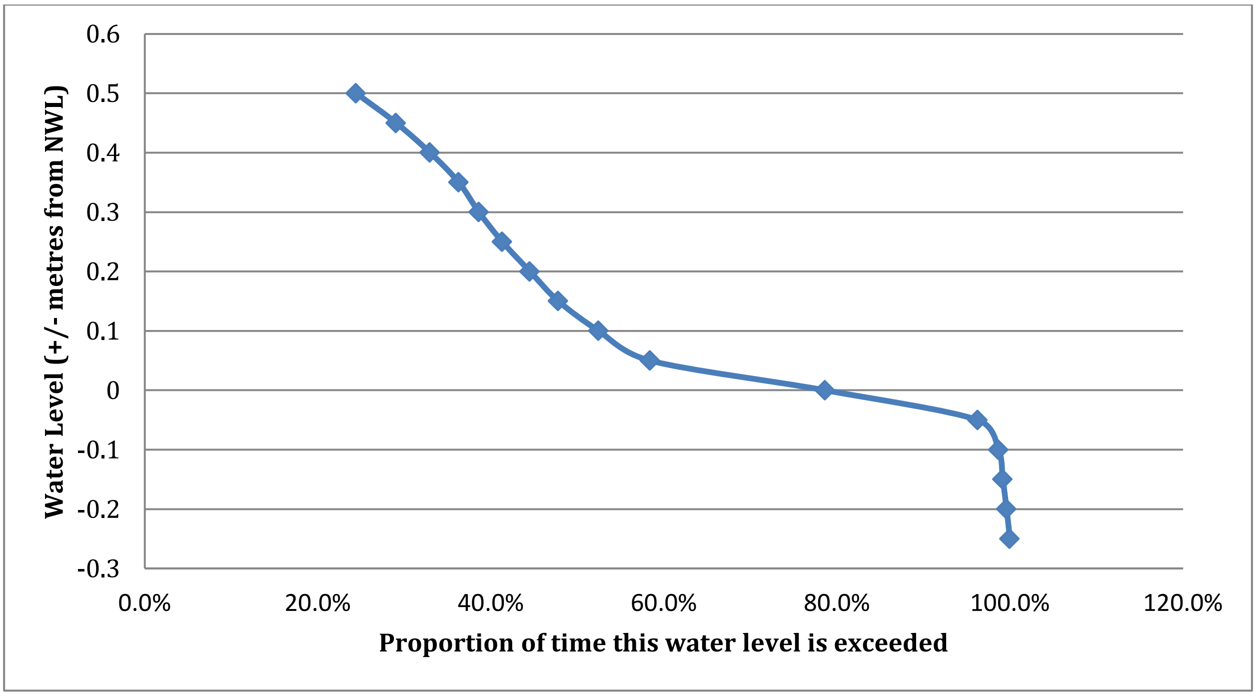
5.2.1 CURRENT SYSTEM



Based on the current configuration the frequency inundation analysis showed that the wetland system was likely to exceed extended detention times up to 50% of the time.

The number of consecutive days above EDD: 45

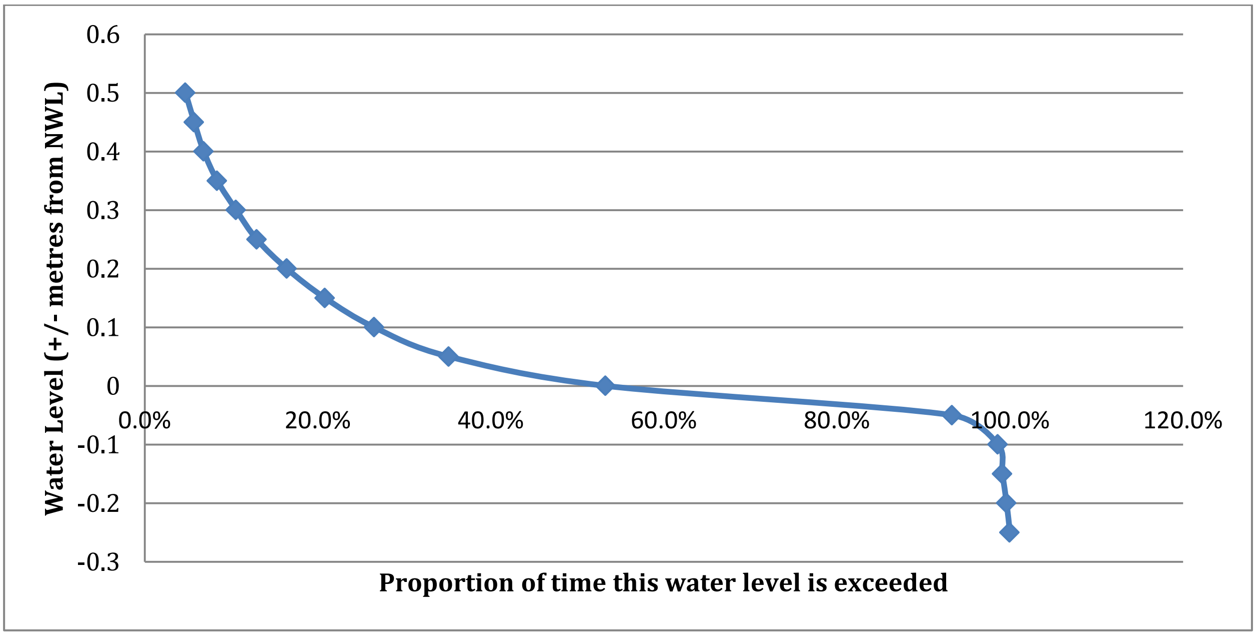
5.2.2 REDUCED EXTENDED DETENTION TIMES FOR UPSTREAM WETLANDS



By reducing upstream detention times the inundation of the wetland system was reduced however the results show there was still more than 50% of the systems time above normal water level.

The number of consecutive days above EDD: 29

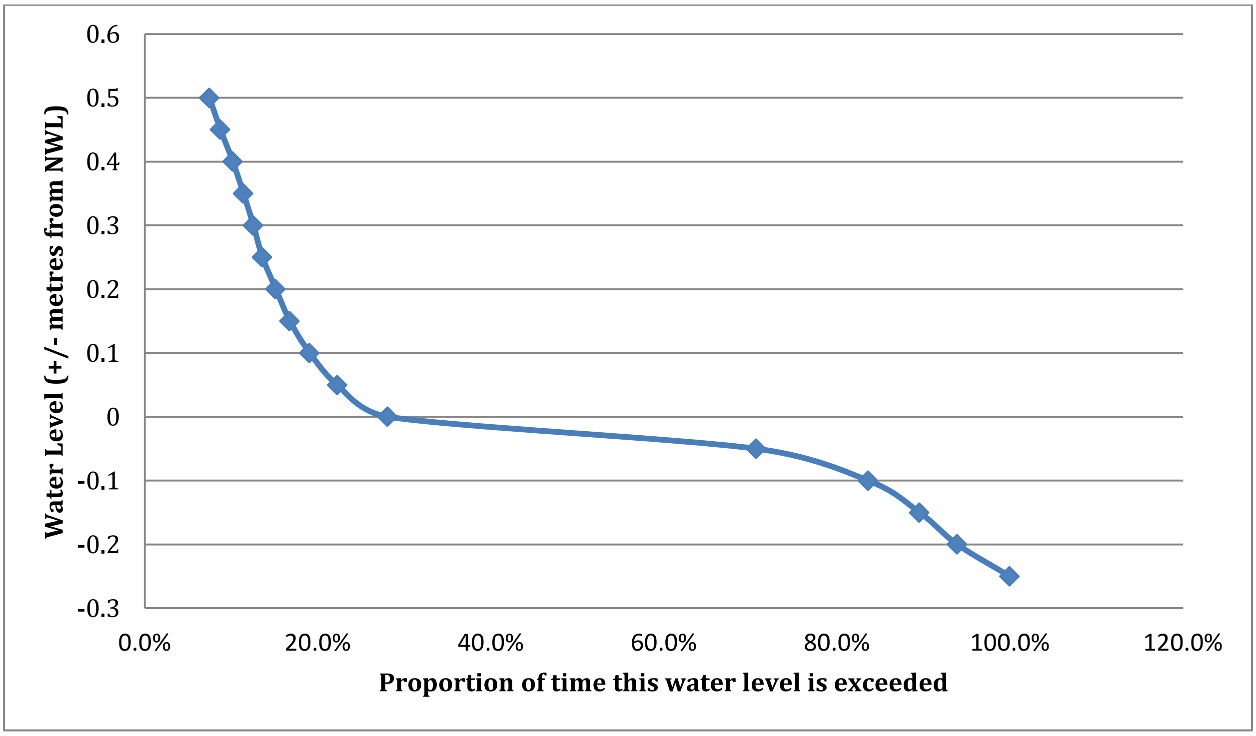
5.2.3 CONVERT WL3 TO OFFLINE SYSTEM WITH 100HA CATCHMENT



By changing the upstream catchment the impacts are evident as only 20% of the time the wetland is just above normal operating levels.

The number of consecutive days above EDD: 4

5.2.4 RETROFIT LOWFLOW BYPASS



Retrofitting a low flow also considerably impacts the hydrological regime of the wetland where for only 20% of the time the wetland is only slightly above normal operating levels. The results from this scenario may show that too much water has been bypassed as operating levels drop below normal operating conditions more frequently.

The number of consecutive days above EDD: 18

6 DISCUSSION

Based on this case study it has shown how important it is to understand the hydrological impacts on wetlands system. Wetlands can be very sensitive to hydrological changes within the catchment and if not designed correctly will fail especially during the establishment phases.

The scenarios modeled showed that a modification to upstream treatments, retrofitting low flows or even converting too off line system can play a large role in changing the operation of the subject wetland. To further understand the sensitivity of this wetland system further modeling could be carried out as follows:

- Model wet year vs. dry year
- Model finer time-step increments
- Model seasonal influences (i.e. Summer, Winter Spring and Autumn)
- Model different diversions scenarios

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