2013

Reliability and effectiveness in water quality control ponds

Andrew Thomas  
Wollongong City Council, aot01@uowmail.edu.au

R John Morrison  
University of Wollongong, johnm@uow.edu.au

Philomena Gangaiya  
Wollongong City Council, philomen@uow.edu.au

Tony Miskiewicz  
Wollongong City Council

Murray Powell  
Optimal Stormwater

See next page for additional authors

Publication Details

Reliability and effectiveness in water quality control ponds

Abstract
Poster that was presented at the 2013 Stormwater NSW Conference, 17-19 September, Leura, NSW.

Disciplines
Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

Authors
Andrew Thomas, R John Morrison, Philomena Gangaiya, Tony Miskiewicz, Murray Powell, and Ray Chambers

This conference paper is available at Research Online: http://ro.uow.edu.au/smhpapers/2126
Use of wetlands to improve water quality was initially developed about 40 years ago.

By the 1990s, the use of constructed wetlands for water treatment had become popular in NSW.

But how well are they really doing their job?
Masters Thesis.

- Postgrad Study supported by Wollongong City Council and the University of Wollongong
- Original aim:

  Assess the “Priority Pollutant” (TN, TP and TSS) reduction capacity of the WQCP “ROB1”

- Put simply: Pollutant load in vs. Pollutant Load out.
Review of Similar Studies

- Purpose: Identify suitable method
- UoW Search engines: Summons, Scopus and Web of Science b/w 2000 and 2011
- 182 Studies identified of which 10 closely mirrored the intent of this study
Significantly different results between Studies for TN and TSS removal (13% to 96%)

Removal efficiencies for TP were even more variable (86.5% to two fold export!!)

Causes?

• Wetland design
• Treatment water sources (e.g. urban runoff, treated or untreated sewage)
• Climatic conditions
Review of Similar Studies

Methodologies applied in each study varied, often significantly in terms of:

• Data collection (method and sampling frequency)
• Load calculation
• Application of statistics (some of which is questionable)

……... Something else far more fundamental emerged:
Findings of Review – Implications

• Comparison of removal efficiencies reported is inappropriate
• General confidence in all removal efficiencies for all studies is questionable
• None considered suitable!
ROB 1 – The Subject Site
Water Quality Monitoring Stations - WQMS
Data Collection

Periodic automatic sample collection

• Flow triggered
  • Inlets = every 10 minutes first hour, then every half hour thereafter
  • Outlet = every 10 minutes first hour, then every hour thereafter
• Total Nitrogen (TN)
• Total Phosphorus (TP)
• Total Suspended Solids (TSS)

Every 5 minutes

• Flow
• Temp
• Turbidity
• Conductivity
• Rainfall
Data Collection

- Six rain events over 11 months
- Some issues:
  - Program update with faulty code (Event 2)
  - Fried CPU in auto sample = distributor arm failure (Event 2 and 3)
  - Couple of FloPro software freeze ups
  - Peristaltic pump tubing split (Event 3)
  - Also a wee bit expensive,
- But.......
Data Collection

Inlet H1 - Event 1 (October 2009) - 42.5 mm Rain in 22.5 hours

- Sub-event a
- Sub-event b
- Sub-event c
Needed a way to use data to reliably estimate TN, TSS and TP using high resolution monitoring data

Tested simple correlations b/w things like TP and Turbidity

.........Fail

Simply too Poor / unstable.

Needed something more powerful:
Estimating Load Balances

Constructed two multi-variable statistic models using standard least squares procedures.
Estimating Load Balances

START

Each of five WQMS

Water Samples

Laboratory (NATA)

TN, TP and TSS

CSV files
- Flow (L/s)
- Turbidity
- Conductivity
- Temperature

Excel – cleaned up and sorted.

Derivation of additional parameters
- Event
- Sub-event
- Cumulative flow

Estimating Load Balances
Fitting the Predictive Model

Import into JMP
- TN, TP, TSS
- Associated monitoring data
- By event, WQMS and Sub-event

natural Log transformations for skewed data sets.

Fit model to data derived from all four inlet WQMS

Inlet Predictive Model
IPM

Fit model to data derived from the outlet WQMS

Outlet Predictive Model
OPM
Now possible to estimate TN and TP loads entering and leaving ponds on an event basis.

Each event, import explanatory variables into the IPM.
- Turbidity
- Conductivity
- Flow rate
- Cumulative flow rate
- Water temp
- Rain event
- Sub-event

Model predicts TN and TP for each five minute interval based on above.

Export results into excel spreadsheet containing hi. res. data for given event.
- Converts log TN and log TP.
- Based on flow volume per 5 minute timeslot, multiply up concentrations and sum to give total inlet load for TN and TP for the given event.

Do the same for the outlet using the OPM.

Estimate load balances by taking the estimated event load leaving for the pond via the outlet as a percentage of the estimated load entering the pond via the inlets.

Simple, right!?
And the Answer is…….

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated pond volume at start of the event (kL)</td>
<td>Inflow (kL)</td>
<td>Outflow (kL)</td>
</tr>
<tr>
<td>EVENT 1 (25 October 2009)</td>
<td>42.5 mm (in 22.5 hours)</td>
<td>22,247 kL</td>
<td>12,069 kL</td>
</tr>
<tr>
<td>EVENT 2c (12 February 2010)</td>
<td>54.5 mm (in 43 hours)</td>
<td>22,836 kL</td>
<td>24,575 kL</td>
</tr>
<tr>
<td>EVENT 5 (2-4 September 2010)</td>
<td>25.5 mm (in 74 hours)</td>
<td>21,905 kL</td>
<td>8,416 kL</td>
</tr>
<tr>
<td>EVENT 6 (14-15 September 2010)</td>
<td>132 mm (in 21.4 hours)</td>
<td>22,030 kL</td>
<td>32,907 kL</td>
</tr>
</tbody>
</table>
Is it Real, or is it Really Unreal?

- In short, not 100% sure – validation is required
- But.....
- Statistical diagnostics indicate high probability that model predictions are not random

Summary of fit and analysis of variance indicators generated by the IPM when applied to predicting Log TN

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R² response coefficient</td>
<td>0.89</td>
</tr>
<tr>
<td>Root Mean Squared Error (RSME)</td>
<td>0.2737</td>
</tr>
<tr>
<td>Observations</td>
<td>660</td>
</tr>
<tr>
<td>Outliers excluded</td>
<td>2</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>64</td>
</tr>
<tr>
<td>F ratio</td>
<td>73.4</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
Is it Real, or is it Really Unreal?

Actual by Predicted plot (left) and Residual by Predicted plot (right) generated by the IPM when applied to predicting log TN.
What Happened to TSS?

Actual by Predicted plot (left) and Residual by Predicted plot (right) generated by the IPM when applied to predicting log TSS. TSS levels too low for measuring by automated meters.
In Conclusion – Performance of ROB1

- Ponds appear to be working but could larger events effectively be negating pollutant reduction achieved during smaller events (i.e. Flushing)?, very Likely YES. TN 71% to -58%. TP 75% to -9%

- Basic design of pond may be contributing to this
  - No high flow bypass
  - Poor inlet structures
  - Absence of effective pre-pond sediment settling / retention
  - Very basic gross pollutant traps

- Lack of maintenance – GPTs, veg in pond, sedimentation. Must remove.

- Do we really understand how pond performance changes as such infrastructure matures and ages?

- And what about pond chemistry during low flow periods? What sort of pollutant losses occur then?
In Conclusion – Methodology

For the negative

- Expensive
- Complex integration of technology
- Data processing and collation time consuming
- Statistical modelling is not straightforward

For the affirmative

- Data capture is extremely good
- While not proven, diagnostics strongly suggest that potential is high
- The trail has been blazed (therefore risks are less and probability for success is higher)
- Ample opportunity for streamlining and reducing cost
Thank you

Questions?

Acknowledgements:
• Murray Powell (Optimal Stormwater)
• Thomas Withers (Aurecon)
• Greenspan Technology