ABSTRACT

Wastewater treatment processes have been driven to reduce nutrient concentrations over the past couple of decades to improve receiving water quality particularly in inland waterways. This has led to the installation of complex and often energy intensive processes. Recently focus has been on optimising existing treatment processes both in terms of energy usage and plant performance to maximise performance, capacity and operation of the plants.

This paper discusses investigations by Sydney Water through assessment of the performance, operation and maintenance of the treatment processes to establish the process capacity and capability of water and wastewater treatment assets. In addition it assesses their ability to treat the effluent discharge standards both now and in the future whilst optimising operational costs and allowing efficiencies to be gained throughout the Corporation’s entire operation with the aim of leading to the following:

- Operations are standardised where possible on good practice to optimise maintenance requirements
- Consistently comply with effluent and biosolids land application guidelines/standards
- Improvement in biosolids and effluent quality
- Improvement in operational efficiency so Sydney Water customers get better value for money

INTRODUCTION

Wastewater treatment processes have been driven to reduce nutrient concentrations over the past couple of decades to improve receiving water quality particularly in inland waterways. This has led to the installation of complex and often energy intensive processes. Recently focus has been on optimising existing treatment processes both in terms of energy usage and plant performance to maximise performance, capacity and operation of the plants.

On this basis, Sydney Water commenced a program of work in 2011 with Aurecon to audit 11 anaerobic digestion facilities. Following successful results from this program Sydney Water has initiated a program to assess the capacity and capability of their water and wastewater facilities focusing on the performance of the system and operation and maintenance. From the outcomes, combined with an assessment of asset condition a long term view on capacity and performance limits of the facility can then be formed to optimise asset performance and understand the maximum capacity to service growth and provide the required environmental outcomes therefore leading to more accurate strategic planning.

This program involves an integrated team approach using a number of consultants and Sydney Water to provide consistency across all plant outcomes and investigations and make sure all facilities are assessed on the same basis and with the same outcomes.

METHODOLOGY

A standardised methodology, developed as part of the anaerobic digestion audits, is being used in the assessment of the capacity and capability of all of Sydney Water’s water and wastewater facilities. The approach includes the following

- Assessment of performance of individual process units against design specifications and industry standards
- Assessment of operational practice against design. Recommendation of pragmatic changes to operation practice that could be implemented quickly to achieve immediate improvements.
- Identification of areas where equipment reliability and performance is impacting process performance.

Specifically the process involves collecting and reviewing design and operational information using a process unit assessment template; identifying information gaps as well as deviations between expected and actual performance and developing a
mass balance for the current plant status and operation.

Following this, process modelling is completed to predict consequences of process changes/ modifications, developing and generating an action list. The commercially available BioWin™ process simulator is used for plant modelling to enable an overall plant mass balance and performance assessment to be completed and Sydney Water to update the models as new operating data becomes available.

Performance Audit: Data Review

The first step in the audit methodology involved collecting and reviewing design information and identifying information gaps as well as deviations between expected and actual performance.

Site data was assessed to understand current operation versus the original design intent and industry practice. A review of the available monitoring data for the plant (influent, effluent, inter process data and biosolids production), odour emission potential and biogas production was completed to gain an overview of the plant and its capacity.

In addition to already available routine plant monitoring data an intensive sampling program was carried out to gain further understanding of current performance and loads. In this program both weekday and weekend data is collected using both composite and diurnal sampling. Through analysis of a number of plants, and especially where trade or visitor loads are prevalent, but also in commuter areas of Sydney week day profiles can be significantly different to weekend profiles in terms of both flow and load.

An example of such a profile can be seen below.

![Figure 1: Typical week day and weekend day flow profile changes](image)

In addition peak loads throughout each day can be analysed to establish any differences between time based composite sampling and flow based, which for some plants was found to be up to 14% different.

![Figure 2: Flow Paced versus Time Based Influent Data Comparison](image)

This load analysis was also then used to understand peaking factors and hence process capability.

![Figure 3: Diurnal Load Variation](image)

Performance Audit: Process Performance Assessment

The first stage in the audit process is an assessment of performance data against design specifications and identification of root causes of any performance gaps.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing Design</th>
<th>Current Performance</th>
<th>Benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Opening</td>
<td>3</td>
<td>3</td>
<td>3 / 1</td>
</tr>
<tr>
<td>Screen Opening Type (e.g. slot/perf)</td>
<td>1d slot (step)</td>
<td>1d slot (step)</td>
<td>2D</td>
</tr>
<tr>
<td>Screening Solids production</td>
<td>10-20 kg/ML</td>
<td>4.7 kg/ML.</td>
<td></td>
</tr>
<tr>
<td>Dewatered Screening Solids Solids Content</td>
<td>&gt;40</td>
<td>30.3</td>
<td>40</td>
</tr>
<tr>
<td>VS</td>
<td>&lt;20%</td>
<td>25%</td>
<td>&lt;10%</td>
</tr>
</tbody>
</table>
Performance Audit: Biowin Modelling

From this analysis, a mass balance was developed for the current plant operation and process modelling used to predict consequences of process changes/modifications.

Operations Audit

The next stage of the audit involves investigation into the operation of the plant including an assessment of any deviations from the original design with links back to the data reviewed in the performance audit. This gives further understanding of the data and plant performance and allows any lessons learnt and good practices to be applied across all processes. Specifically, this included:

- A review of operations practice including operation staff training, process monitoring for the sludge system and control systems. This involves a site visit and operator interview to understand the operational limitations and opportunities.
- Assessment of the current practice against design specifications, Unit Process Guidelines or original design intent and industry standards.
- Recommendation of practical changes to operation practice that can be implemented quickly to achieve immediate improvements including additional sampling and analysis.

Maintenance Audit

The third stage of the assessment was based on a review of the maintenance practices and reliability of the system. This was then linked to the operational assessment as often a lack of reliability will alter operational practices to ensure overall system reliability. The maintenance audit included the following:

- A review of the condition and maintenance records for key equipment.
- Identification of equipment reliability and operation which is impacting process performance.
- Recommendation of practical changes to maintenance practice to achieve immediate improvements.

Finally the audit combined all three reviews developing and prioritising recommendations to enhance performance, generating an action list. These recommendations range from operational enhancements in the short term through to potential capital upgrades in the medium to long term.

RESULTS

Several optimisation recommendations were made for each plant during the anaerobic digestion audits in terms of an understanding of bottlenecks on each plant and rectification of these, implementation of processes to prevent operational issues such as sludge screening and its interaction with digester mixing and optimisation of the anaerobic digestion process through recuperative thickening.

Implementation of recuperative thickening at one site has increased gas production significantly and reduced biosolids output and polymer usage.

Following on from this, the PCA program has generated some overall plant learnings:

- Careful characterisation of the influent of each plant to understand both liquid and solids stream process technologies is important and flow paced sampling can provide a better insight into actual loads to the plant and a good understanding of performance and capacity.
- Understanding of recycle streams is critical. The mixed liquor concentration in some liquid stream processes has been found to vary significantly (taking up to 20% of capacity) by poor capture in thickening and dewatering processes. This has additional knock on effects such as clarifier performance, high costs of sludge pumping and additional polymer use.
- Understanding of location of return streams and influent sample points and other factors which may affect sampling such as septage receival is critical in understanding overall plant loads.
- Good screenings and grit removal is key in process performance. Grit and screenings in downstream processes cause inefficiencies, poor aeration control and maintenance issues resulting in a loss of treatment capacity.

In addition, the recommendations for the plants have ranged from operational practices to capital investment. Understanding the true capacity of the plant allows processes such as recuperative thickening to be installed or balancing of high peak loads to maximise the capacity of the downstream biological treatment and aeration systems.

Examples of process recommendations to optimise the secondary treatment include:

- Addition of load balancing tanks to reduce ammonia breakthrough in intermittent processes
- Optimisation of cycle times throughout the day in intermittent processes lengthening aeration times to achieve nitrification in peak load times whilst reducing aeration times and hence energy usage at low load periods.
ALTERATIONS TO PLANT CONFIGURATION AND
COMPARTMENTS TO IMPROVE NITROGEN REMOVAL
PROCESSES, OPTIMISE AERATION SYSTEMS WITH
PROCESS CONTROL SYSTEMS

EFFECT OF WET WEATHER FLOWS ON TREATMENT
PERFORMANCE AND RECOMMENDATIONS FOR WET
WEATHER FLOW TREATMENT THROUGH SECONDARY
TREATMENT SIZING, OPERATION (LONGER SETTLE TIMES
IN INTERMITTENT PROCESSES) AND CHANGE IN
BACKWASH TIMES IN DOWNSTREAM FILTERS.

CASE STUDY – LIVERPOOL WRP

PLANT DESCRIPTION

One of the plants that have been audited to date is
Liverpool Water Recycling Plant (WRP). The plant
 treats wastewater from the South Western Suburbs
of Sydney around Liverpool.

The plant consists of an inlet works, primary
sedimentation and secondary treatment in a
conventional activated sludge plant. The plant was
previously designed for carbonaceous removal for
discharge to the SWSOOS; however in 2009 the
Liverpool Ashfield Pipeline (LAP) was constructed
to transfer flows to a new recycled water plant at
Rosehill. This caused the effluent quality
parameters to change including a requirement for
ammonia removal. Wet weather flows are
discharged to the Georges River.

The solids processing facilities at the Liverpool
Water Recycling Plant (WRP) have had several
upgrades since their first construction, the last
major upgrade being commissioned in 2006. It
consists of WAS thickening in centrifuges, two
anaerobic digesters and centrifuge dewatering.
The thickening and dewatering centrifuges are
colocated in one building. There are three
centrifuges, one designated for thickening, one for
dewatering and the third as a common standby.
The biosolids are stored in a cake building and
taken off-site periodically for beneficial reuse.

The outcomes of this calibration exercise can be
seen in Table 2. Data from a wastewater treatment
plant can have some inaccuracies and the mass
balance can highlight these. Specifically one
challenge was in the grab samples taken from
solids streams. Further investigation was
completed with site operations were carried to
understand where inaccuracies may occur.

The plant has been designed such that there is the
ability to co-settle the WAS and the thickening and
dewatering feeds to / from the digesters are all
located in one gallery. This has given the flexibility
for a trial to be initiated on-site.

AUDIT OUTCOMES

The Liverpool WRP audit and BioWin™ modelling
identified a number of short, medium and long term
modifications to improve digester performance.
This paper concentrates on specific recommendations regarding digester operation and
performance however other solids stream
recommendations were made including flushing of
raw sludge lines to increase reliability of the feed,
modifications to gas pipework, optimisation of the
polymer system and a number of other small
modifications.

For all sites examined in the audits, the following
approach was taken to examine optimisation of the
digestion process:

- Increase SRT by addition of recuperative
thickening. The digesters at Liverpool WRP
were being operated at approximately 1.2%DS
and 20 days SRT therefore scope was
available for this to be increased
- Increase digester temperature to 38°C
- Reconfiguring of the digesters to series
operation to reduce short circuiting
(acknowledging the need to prevent acid phase
occurring in the first stage).

The modelling showed that recuperative thickening
had the largest effect on increasing the SRT within
the digesters, increasing gas production and
decreasing solids however there were also
improvements if the temperature is increased within
the digesters to 38°C and by changing the
configuration of the digesters to primary/secondary
mode.

The results of the audit outcomes in terms of
digestion performance can be seen in Table 3.

The low solids concentration in the digested sludge
at the site was a function of no primary sludge
thickening and the WAS thickening performance
being variable therefore there was scope for
optimisation of the system.

Figure 1: BioWin™ Process Flow Schematic for
Liverpool WRP

BioWin 3.1 was used to calibrate the model based
on a mass balance and compared to existing site
data. This approach allows calculation of the effect
of recycle streams throughout the process in terms
of solids and nutrients.
Liverpool WRP is unique in that the plant has large primary sedimentation capacity for dry weather flows. Of the eight primary sedimentation tanks, the plant operates four in dry weather flows. In addition, given that pipework exists for the waste activated sludge to be sent to the primary sedimentation tanks for co-settlement, this was examined in conjunction with reconfiguring the thickening centrifuges to operate in recuperative thickening mode.

Whilst co-settlement reduced the concentration of the raw sludge slightly, it allowed investigation into the effect of the increased solids retention time within the digesters by using the centrifuges for recuperative thickening. In addition, it reduced the issues with fat build-up in the raw sludge pipework increasing reliability of the sludge feed.

The site had already increased digester temperature to from 35°C to 36.5°C prior to the audit and the gas production had increased from 3700kg/d to 3926kg/d (6% increase) as seen in Figure 3. Therefore further increase in temperature may be beneficial.

The initial changes resulted in improvements to biosolids product quality and a reduction in operating costs. The installation of recuperative thickening increased gas production up to 4800kg/day (30% increase) due to increasing digested sludge TSR from 1.3%DS to 2.0%DS and therefore increased the SRT to 31 days.

Following on from the initial success, between October and early 2014 the recuperative thickening has been optimised on-site to stabilise the thickening performance and hence the digester operation within the limits of the existing equipment.

Gas Production

It can be seen in Figure 4 that performance at the plant in terms of gas production has continued to improve since the optimization. The overall increase in gas production has continued to 4,800kg/d which is an increase of 30%. This is in excess of that predicted within the audit.

The additional gas production cannot be fully utilised for additional energy production as the maximum capacity of the cogeneration engine currently on-site has been reached, however there is an increased reliability of the engine as it can be run at 100% and potential scope for additional
energy production if additional generation capacity is installed on-site in future upgrades.

Cake Transportation

The biosolids wet cake production at Liverpool is difficult to measure over a short period as it is removed approximately every six weeks. However, on the basis of this gas production increase, the overall cake production can be assumed to have decreased from 10.3 wet tonnes per day to 7.2 wet tonnes per day which translates to a saving of approximately $96,000 per annum in transportation and beneficial disposal costs. Results from site indicate this may be as low as 5.5 wet tonnes per day over the longer term.

Polymer Consumption

In addition to the savings in cake transportation, the overall polymer consumption has decreased at the site. Whilst additional polymer is used in the recuperative thickening this has been optimised to 3kg per tonne dry solids whereas the dewatering polymer is 13kg per tonne dry solids. Therefore the increased volatile solids destruction and the subsequent reduction in digested sludge significantly outweighs that used in the recuperative thickening. The initial polymer consumption was 48kg/day, and the latest site operational data shows an average of 22kg/d (overall, including that used in the recuperative thickening). This results in a saving of $52,000 per annum.

CONCLUSION

The auditing process as applied to Sydney Water treatment plants allows understanding of influent characteristics, overall plant mass balance and process unit performance. Examination of these, alongside operations and maintenance practices and comparison to good practice can lead to optimisation of treatment facility assets and maximising available treatment capacity.

In turn this can have tangible benefits as has been seen at Liverpool WRP and reduce operational issues, operator input requirements and maintenance.

The PCA program of works allows a comprehensive examination of each Sydney Water facility and aims to optimise operation and understand the use of existing assets and the need for wise capital investment.

ACKNOWLEDGMENT

The Sydney Water team involved in the anaerobic digestion audits and the integrated team involved in the PCA (consisting of AECOM Aurecon Joint Venture, ENSureJV and Sydney Water) were involved in the data collection and analysis contained within this paper.
### Table 2: Liverpool WRP Calibration Data

<table>
<thead>
<tr>
<th>Location</th>
<th>Parameter</th>
<th>Unit of measurement</th>
<th>Median of Plant Data</th>
<th>Calibrated Model</th>
<th>% Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Influent</strong></td>
<td>Flow</td>
<td>m³/d</td>
<td>29,650</td>
<td>29,650</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>mg/L</td>
<td>605</td>
<td>605</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>cBOD</td>
<td>mg/L</td>
<td>272</td>
<td>302</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td>TSS</td>
<td>mg/L</td>
<td>255 (300 from site data)</td>
<td>299</td>
<td>17% (0% based on site data)</td>
</tr>
<tr>
<td></td>
<td>VSS</td>
<td>mg/L</td>
<td>229</td>
<td>266</td>
<td>16%</td>
</tr>
<tr>
<td><strong>Primary Effluent</strong></td>
<td>Flow</td>
<td>m³/d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>mg/L</td>
<td>291</td>
<td>334</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>TSS</td>
<td>mg/L</td>
<td>103</td>
<td>104</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Mixed Liquor</strong></td>
<td>MLSS</td>
<td></td>
<td>2380</td>
<td>2100</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Effluent</strong></td>
<td>Flow</td>
<td>m³/d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>mg/L</td>
<td>33</td>
<td>36</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td>TSS</td>
<td>mg/L</td>
<td>8.0</td>
<td>7.2</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Raw Sludge</strong></td>
<td>Flow</td>
<td>m³/d</td>
<td>166¹</td>
<td>182</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>%</td>
<td>3.3</td>
<td>2.9</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>VS/TS</td>
<td>%</td>
<td>86.3</td>
<td>87.7</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Waste Activated Sludge</strong></td>
<td>Flow</td>
<td>m³/d</td>
<td>516</td>
<td>485</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>mg/L</td>
<td>3948</td>
<td>3751</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>VS/TS</td>
<td>%</td>
<td>83</td>
<td>73</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Digested Sludge</strong></td>
<td>Flow</td>
<td>m³/d</td>
<td>261</td>
<td>248</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>%</td>
<td>1.5</td>
<td>1.4</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td>VS/TS</td>
<td>%</td>
<td>71.5</td>
<td>73.1</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Digesters</strong></td>
<td>Gas</td>
<td>kg/d</td>
<td>3700³</td>
<td>3695</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Cake</strong></td>
<td>Mass</td>
<td>Dry T/d</td>
<td>2.5¹</td>
<td>3.1</td>
<td>24%</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>%</td>
<td>24.6</td>
<td>24.1</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>VS/TS</td>
<td>%</td>
<td>71.5</td>
<td>73.1</td>
<td>2%</td>
</tr>
</tbody>
</table>

1. The raw sludge flow-rate is measured as 233m³/d at the pumps and 166m³/d at the digesters. Further analysis of this data, the digested sludge flow-rate and the centrifuge feed flow rate suggests that the digested sludge flow-meter is more accurate and therefore raw sludge has been determine from subtraction of the WAS flow from the digested sludge flow (as agreed with the plant operations team 24th April 2013).
2. The influent suspended solids concentration is measured more frequently in PDMS than in EKAMS. Further analysis of this data shows that on comparable days the PDMS data is approximately 30mg/L higher than EKAMS data. Therefore a suspended solids concentration has been chosen to reflect this.
3. The gas production is 3771kg/d however the gas consumption is 3900kg/d. Gas consumption is deemed to be, in general, more accurate as the gas is cleaner and contains less water.
4. Liverpool has cake storage bays and cake is kept for a number of weeks, it is likely that further water is evaporated within this time and weight is measured in wet tonnes. It is has been assumed that the cake reaches 27% which would give a dry weight of 2.75tonnes/day.
### Scenario 3: Liverpool WRP Outputs from BioWin Modelling Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Digester Configuration</th>
<th>Operating Conditions</th>
<th>Model Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Table 3: Liverpool WRP Outputs from BioWin Modelling Scenarios

<table>
<thead>
<tr>
<th>#</th>
<th>No of 1°</th>
<th>No of 2°</th>
<th>Recuperative thickening</th>
<th>Increased temp</th>
<th>Co-settle</th>
<th>VSR (%)</th>
<th>SRT (days)</th>
<th>Total Gas Production (m³/d)</th>
<th>Cake VS (%)</th>
<th>Cake Dry Solids Conc (%)</th>
<th>Wet Tonnes/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>0</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>57%</td>
<td>20.2</td>
<td>3699</td>
<td>73%</td>
<td>24%</td>
<td>12.7</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>46%</td>
<td>10.1</td>
<td>3051</td>
<td>77%</td>
<td>24%</td>
<td>15.2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>68%</td>
<td>61.8</td>
<td>4305</td>
<td>67%</td>
<td>24%</td>
<td>9.5</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>59%</td>
<td>20.2</td>
<td>3837</td>
<td>72%</td>
<td>24%</td>
<td>12.3</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>70%</td>
<td>66.7</td>
<td>4315</td>
<td>67%</td>
<td>24%</td>
<td>9.0</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>64%</td>
<td>20.2</td>
<td>4069</td>
<td>70%</td>
<td>24%</td>
<td>11.2</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>72%</td>
<td>61.0</td>
<td>4392</td>
<td>65%</td>
<td>24%</td>
<td>8.8</td>
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<tr>
<td>8</td>
<td>2</td>
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<td>Y</td>
<td>Y</td>
<td>N</td>
<td>69%</td>
<td>61.0</td>
<td>4457</td>
<td>67%</td>
<td>24%</td>
<td>9.6</td>
</tr>
</tbody>
</table>

1. Raw sludge thickening assumes 3 kg/dT polymer
2. RT = Recuperative thickening. Set to achieve target of 3% TS in the primary digester
3. SRT is different to that calculated on site due to the difference in modelled and actual digested sludge flow
4. Cake dry solids assumed constant - some improvement likely with RT due to thicker feed solids and lower volatile solids content