THE ROSEHILL RECYCLED WATER SCHEME: TWO YEARS ON

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INTRODUCTION

This paper describes the Rosehill Recycled Water Scheme storage and distribution system and how innovative design elements were developed to deal with constraints posed by the requirements for the system, and to address unusual operating conditions.

DESCRIPTION OF THE SCHEME

The Rosehill Recycled Water (RRW) Scheme is a private capital undertaking between Sydney Water Corporation and AquaNet Australia, in which a plant located in the Sydney suburb of Fairfield produces high quality recycled water from secondary treated effluent and a distribution system delivers it to industrial customers in Smithfield and Rosehill. This is the first recycling scheme delivered by private developers under the WICA Act.

AquaNet separately subcontracted the production of the recycled water to Veolia Australia and the storage and distribution of the recycled water to Zinfra Pty Ltd.

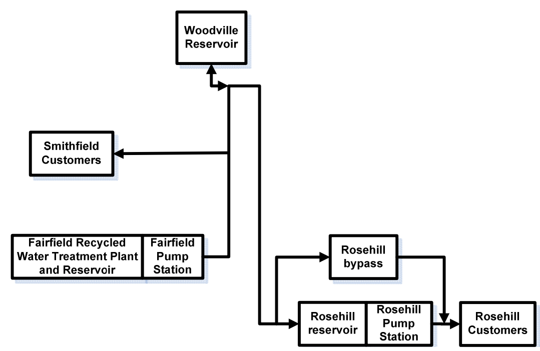
The RRW scheme was a “greenfield” project in that there was no existing recycled water delivered to the recipients, but a “brownfield” in that they were existing, well-established industrial users for whom the recycled water would replace potable water supplied by Sydney Water.

The Scheme comprises both production and distribution assets of recycled water, however this paper covers only the storage and distribution network, which was designed and constructed by Zinfra, and was commissioned into operation by Zinfra in two stages, between 2011 and 2012.

The primary driver for the design of the RRW scheme was the requirements laid down by Sydney Water for availability, quantity and quality of water, the points for delivery, and the quality and location of the source of secondary effluent and return of the brine.

Initial mechanical and electrical design for the network was carried out by Parsons Brinkerhoff, which was further developed and finalised by Zinfra as construction proceeded, to factor in changes from the original design scope. Zinfra and Heuristics Australia refined the control systems design, and the final control systems were implemented by Multiskilled Resources Australia.

The scheme comprises a linear distribution pipeline with two pump stations, a branch pipeline and two reservoirs, which are supplied from one end.



Block diagram of the RRW Scheme

Water is introduced into the Network at Fairfield, downstream of the water treatment plant. Veolia operates the RO plant, with custody transfer of water downstream of the “clean” (recycled) water tank. Veolia’s plant performs ultrafiltration and reverse osmosis treatment of secondary effluent derived from Sydney Water’s Liverpool to Ashfield Pipeline.

Recycled water is introduced into the clean water tank, and pumped into the network via the Fairfield Pumping Station.

From Fairfield, the pipeline follows an ascending grade to a surge tank at Woodville, which is located at the highest point on the route. Approximately midway, the pipe branches off to a lateral supplying a cluster of industrial customers in the Smithfield area.

The Woodville surge tank’s role is twofold:

1. It provides the master control objective for the operation of the scheme, namely level control of the reservoir, and
2. It provides a limited source of stored recycled water for the Smithfield area, in the event of a loss or outage of the Fairfield Pumping Station.

From Woodville, the pipeline follows a downhill grade to a reservoir and pump station at Rosehill. The Rosehill facility supplies another cluster of industrial customers in the Rosehill/Camellia area.

A significant constraint is the absence of an alternative supply of recycled water. This presents design, engineering and operational challenges. The ultimate (albeit expensive) fallback in the event of supply curtailment or loss is the use of potable water to top up reservoirs, and/or to back up the recycled water supply to individual customers.

A detailed technical description of the scheme may be found in Ypsilantis *et al* (2013).

DESIGN AIMS, CONSTRAINTS AND SOLUTIONS

A number of innovations were incorporated in the design to minimise capital and operating costs, minimise the requirements for active operator involvement in controlling the network, and maximise reliability of both quality and quantity of delivered water.

Design Impact on Construction Costs

It was necessary to minimise construction costs, project duration and disruption to community in a densely populated part of Sydney, particularly to minimise the need for roads openings with associated traffic controls, permits etc. in heavily trafficked roads such as Woodville Road. This in turn has a beneficial flow on effect on project risk.

Pipe bursting technology was employed where available, including Woodville Road, to make use of abandoned pipe assets. These techniques are outlined in Appendix 1 to this paper.

A key design decision was made that sacrificed a small amount of construction cost for considerable advantages in constructability and longevity. The nature of the recycled water excluded conventional cement lined or unlined pipe for stations. The choice essentially came down to lined ductile iron or stainless steel, stainless steel being estimated to be marginally more expensive. The decision was made in favour of stainless, on the grounds that

a) any subsequent re-work of stainless piping on account of remediation would not require high reliability lining repairs, and
b) there would be no piping failures resulting from minor, possibly undetectable, lining flaws.

Energy Usage

A key design aim was to minimise energy usage during network operations, arising from pipe losses and customer delivery requirements. This comprises the largest operating cost for the network and therefore has a significant contribution to revenue for the asset owner and operator.

This was addressed by implementing a load matching control strategy based on variable speed pumps, in lieu of a conventional “diurnal” reservoir level control strategy. A comparison of estimated energy usage for these control strategies may be found in Appendix 2 to this paper.

System Reliability and Availability

The design included provisions to maximise system reliability and availability. This in turn reduces operational risk and cost associated with planned and unplanned outages of the network or its individual components.

The design addressed this as follows:

a) one standby pump run was incorporated at each pump station, identically sized with the other runs, i.e., to provide 50% of the rated maximum output of the station,
b) bypass facilities were constructed at the Rosehill site,
c) materials suitable for use and compatible with the chemistry of the recycled water were selected for the plant and pipelines, and
d) a robust control and communications system was designed

Water Quality and Effects on Network Infrastructure

A key operational requirement is the maintenance of very high quality recycled water (compliant with contracted specifications) from receipt at Fairfield to delivery at the customer receipt points. In some cases, the incentive for customers to adopt recycled water is that less pre-processing (e.g., demineralisation) of is required in comparison with potable, before introduction to the customers’ plant. Adherence to the contract water quality specification is therefore critical for the asset owner and operator.

An important related issue is the effect that the recycled water can have on the pipe infrastructure. Recycled water, by virtue of its chemistry, has relatively aggressive effects on pipework in comparison to potable water, and the design needed to take this aspect into account.

The design addressed this requirement as follows:

a) Appropriate materials were selected for the plant and pipelines, including stainless steel piping at pump stations, PVC and PE pipe for pipelines, and epoxy lined reservoirs and pumps,
b) Provision was made in the controls design for all reservoirs to be regularly flushed, and
c) Water quality monitoring points were designed and provisioned, to allow monitoring at the network inlet and at groups of delivery points.

Contingency for Significant Outages

Certain contingencies, e.g., extended outages of the Veolia treatment plant, cannot be managed by the network or control systems alone. Additional provisions were therefore required to provide back up for planned and unplanned outages of treatment plant, pumps, reservoirs and pipelines.

A hierarchy of contingency management was designed for this purpose. The actions are summarised (in order of decreasing desirability) as follows:

a) The maintenance of sufficient storage in the Fairfield (Veolia), Woodville and Rosehill reservoirs to provide security of supply against short outages of plant,
b) Provision of bypass facilities at Woodville and Rosehill to allow continuity of operations in the event that the Woodville Reservoir, the Rosehill Reservoir or Pump Station is unavailable,
c) Provision of top-up connections via the local potable water at all reservoirs, to allow continuity of supply within certain constraints, and
d) Provision of back-up connections to the local potable water supply at all customers.

Smithfield's sensitivity to Fairfield pump station stoppages

The network topology renders the Smithfield area prone to transient pressure drops whenever the Fairfield pump station shuts down. These pressure drops had the potential to drop delivery pressure below contracted low limits for the group of Smithfield customers. (This issue and exposure was subsequently confirmed during commissioning).

The design caters for the control of the Fairfield pumps to continually maintain Woodville reservoir levels against a desired (settable but otherwise fixed) target level. This, in turn, results in mitigating the risk of breach of the Smithfield customer supply contracts in regard to delivery pressure.

Conventional pump/reservoir control systems employ switches that switch pumps on and off at full flow between pre-set high and low reservoir levels. However, where there is a significant length of up-hill pipeline between pump and reservoir as is the case for Fairfield-Woodville, pump shutdowns result in significant pressure surges. The solution was to install continuously variable speed pumps at Fairfield Pump Station to allow station outflow to be instantaneously matched with demand, thus avoiding the need to switch the pumps on and off several times a day.

Robustness of Master Control Variable

The control strategy for the Fairfield Pump Station is heavily reliant on the reservoir level telemetry at Woodville. As this site is remote to Fairfield, a number of issues and exposures exist in regard to loss of this signal. For example, communications may drop out resulting in short- or long-term loss of this signal at Fairfield.

The controls and communications design addressed this issue in three ways:

a) dual redundant level transmitters were used, with a soft and automated failover between them, facilitating continuity of availability of reservoir level,
b) dual diverse communications paths were designed, so that a single communications outage would not result in a complete loss of telemetry at Fairfield, and
c) robust control logic was designed at Fairfield, specifically using cascaded control loops. This allowed the managed and automated fall-back to, and restoration from, pump station outlet pressure control if the level signal from Woodville is lost.

Allow for continuity of supply out of the Rosehill site, whenever the pump station is shut down

It is essential that the Rosehill site continue to deliver at times where the pump station is idle or the reservoir off line, e.g., for maintenance, or under low load conditions.

The design leveraged the station and reservoir bypass. The inlet isolation valve was designed and fitted with a modulating actuator, and a pressure control strategy devised to coordinate the operation of the bypass and the pump station, in conjunction with the bypass' non-return valve.

At times when the pump station is operating, the pressure set point for the inlet isolation valve is set to track marginally below pump outlet pressure, which results in the non-return valve being held closed.

When the pump station stops (i.e., the pumps fail or are turned off) the check valve opens as outlet pressure falls and the outlet flow switches from pump to the inlet pipeline. Simultaneously, the control system raises the setpoint for the inlet isolation valve to the district pressure required for the Rosehill area, thus restoring the district pressure to the normal level defined by the setpoint.

Note that this strategy only works up to the capacity of the inlet main, which is less than that of the reservoir/pump station combination. It follows that there will be times where the pump station must operate in order to meet load in the Rosehill area.

Zero turndown of Rosehill delivery flow whilst maintaining contract network pressure

A contractual requirement for operations is that the outlet pressure of the Rosehill site be maintained at a value up to approximately 60 m, for zero to maximum design flow rate.

One possible (conventional) design option was to locate the Rosehill reservoir with sufficient elevation to allow supply under gravitation at lower flows, and to operate the pump station only as required to boost pressure under increased load. However, the required elevation was not available at this site, or for any feasible alternative site upstream of Rosehill

This requirement therefore had to be addressed by designing the pump station to operate down to zero flow.

A conventional design for this employs a pump station recirculation valve that switches fully open/closed under some fixed condition. This can result in potentially excessive power wastage.

An enhanced solution for low demand was designed in two complementary parts:

a) a modulating actuator was used on the recirculation valve, with a control strategy which modulates the valve position according to metered station outlet water flow, so as to approximate matching against the pump curves, and
b) the station control strategy included an automated transition from pump operation to station bypass operation, to supply outflow directly from the incoming pipe for low to moderate flows and shut down the Rosehill Pump Station. This results in the indirect use energy from Fairfield Pump Station to supply Rosehill customers under low load conditions.

Systems Integration

A common risk on such projects is systems integration between major items of equipment or major subsystems. In particular, it was recognised that the integration risk for the variable speed pumps and drives was relatively high.

This issue was resolved via a policy to procure pump motors and VSDs from the one supplier.

Summary of Design Features

The final design exhibited the following key features and benefits:

a) Enhanced reliability and availability for the network and associated plant,
b) Maintenance of water quality and delivery parameters (pressure) from receipt to customer,
c) Reduced energy consumption for network operations,
d) Reduced construction cost and project duration,
e) Compliance with the requirements of customer contracts, and
f) Reduced potential for asset deterioration.

COMMISSIONING EXPERIENCE

The efficacy of any engineering design is initially evident during commissioning. The following summarises commissioning activities and issues encountered on this project.

Overall, the experience was positive and resulted in project and operations staff acquiring a high level of confidence in the system during the course of commissioning.

Commissioning connection to the LAP

In order to facilitate the commissioning and performance testing of the Veolia plant and the

Fairfield Pumping Station, a temporary connection was made from the outlet of the Fairfield Pump Station to the Liverpool to Ashfield Pipeline (LAP).

Construction of this temporary connection was concluded successfully and with minimal issues, and allowed the demonstration of compliance of the treatment plant and pump station with client performance requirements, in particular the performance test at maximum design loads.

Commissioning of Pipeline Segments

Of the pipelines, no major failures were encountered during commissioning, but there were some issues in regard to the presence of construction debris in the system. This manifested in the transfer of this debris into the reservoirs and customer connection points, which subsequently required remedial action.

Commissioning of Reservoirs

Minor lining problems were discovered during commissioning of the reservoirs. These manifested as corrosion marks after the first fill/drain and subsequent examination.

Commissioning of Pumping Stations

At the Rosehill pump station, construction debris was washed into station piping during commissioning, particularly into the DN150 recirculation line, and an instance of noise and inadequate performance in one pump run was observed. The latter was subsequently found to be caused by construction debris lodged in the impeller inlet. Both issues were promptly remediated and resolved during commissioning, with minimal disruption to the commissioning schedule and no compromise of the assets.

There was an incident where one of the VSDs at Rosehill developed a fault during commissioning. The VSD vendor promptly resolved this issue on site.

Underfloor flooding was observed at the Fairfield and Rosehill pump station buildings, following a period of heavy rain during the commissioning period. This was subsequently found to be due to inadequate sealing of cable duct penetrations, and was promptly resolved.

EXPERIENCE OVER THE FIRST TWO YEARS OF OPERATION

Aquanet (a subsidiary of Jemena) uses Jemena's Osi Pi historian as a repository of data to support long term planning and asset management. This has proven to be an invaluable tool in the case of the Rosehill Recycled Water Project, not the least because of the availability of high-resolution base data.

Osi Pi can provide valuable analytics, which in turn support informed decisions in regard to asset planning and management. This was particularly useful in the immediate post-commissioning period, as it allowed the various control systems to be fine-tuned in a convenient, efficient and timely manner.

Operations staff was consulted recently in regard to operational experience since handover. Considering that this was the first water asset to be brought under the supervision of the Jemena Control Room at Sydney Olympic Park, feedback was very positive. Staff particularly highlighted the ease of supervision of the network, which confirmed a primary aim for a high level of automation to implemented at each of the main remote sites.

Of particular note, the operations staff interviewed advised that the facility has operated autonomously and well from day one, with no major unplanned outages. This is important because the Rosehill scheme is a new type of asset which is managed from this control room. The operations staff were appreciative of the level of automation and system reliability, as it allowed them to become familiar with the asset and its characteristics at a comfortable pace, without compromising other (gas network) operations conducted from the same control room.

There were a few excursions in water quality as monitored over this period. However, these were not unexpected, and were appropriately managed in each case.

Significantly, there were no incidents that required customers to fail over to backup potable water. The controllers interviewed noted that there was one instance where reservoir potable top up was used, for a scheduled but extended outage of the Veolia plant.

A survey of typical energy intensities expected for pumped water systems yields figures in the vicinity of 0.5 to 1.2 kWh/kl. (SAIC (2006), Dalby (2008)). Of particular note, a CSIRO report notes that Sydney Water achieves approximately 0.26 kWh/kl for water delivery in the Sydney area

(Kenway *et. al.* (2008)), which compares well in regard international practice.

In comparison, calculations based on data available to date for the Rosehill Recycled Water Scheme indicate an energy intensity of 0.09 – 0.12 kWh/kl for the Fairfield and Rosehill Pumping Stations, or less than 40% of the energy used in other systems. The authors believe that the savings are largely attributable to the load matching control scheme at Fairfield, the low flow bypass arrangement at Rosehill, and the pipeline design.

CONCLUSION

The Rosehill Recycled Water scheme presented a number of engineering challenges in the design, construction and commissioning, as well as constraints in regard to operations.

Innovation throughout the engineering process ensured that the project was delivered in an effective manner, and that the delivered asset met all of the requirements expressed by the end client.

Experience to date vindicates the engineering and design decisions made over the course of the project. In particular, the scheme operates as envisaged by the design, especially in regard to ease of operation, reliability and energy efficiency.

Future project activities underway or soon to be commenced include:

a. A facility to allow transfer of water from the Rosehill Reservoir (which has four times the capacity of Woodville) back to Woodville, to make further use of water at Rosehill for security of supply to other customers, and
b. A study and optimisation of target reservoir levels, to address the competing operational constraints (energy use v security of supply) for given customer load patterns. The aim is to facilitate and further improve operational efficiency of the scheme.

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APPENDIX 1: PIPE BURSTING TECHNOLOGIES USED ON THIS PROJECT

A key advantage for construction was the availability of sections of abandoned gas mains under major roads, in particular Woodville Road, a highly trafficked artery in western Sydney.

The aim of pipe bursting is to increase the diameter of pipe that can be inserted into abandoned pipes by first bursting the pipe and expanding the diameter of the hole.

The principle of pipe bursting is to excavate and expose the abandoned pipe at regular intervals determined by the technology, break the pipe and insert a high pressure balloon, and inject fluid at high pressure to burst the pipe along its entire length. The new pipe is then inserted and joined.

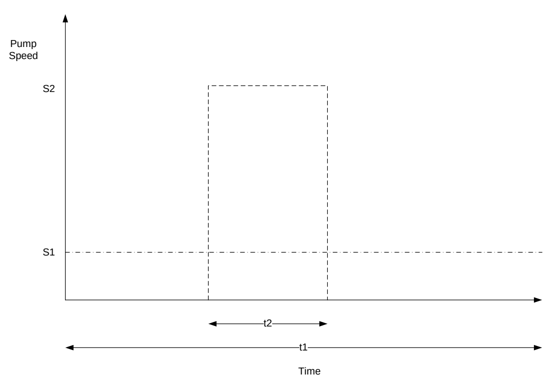
The advantages of pipe bursting include quicker and more economical construction through less excavation, easier covering of excavations for daytime traffic (most works were at night), and less spoil management and restoration.

APPENDIX 2: COMPARISON OF ENERGY PERFORMANCE FOR CONTROL STRATEGIES

Consider the following two scenarios where a constant load is served via a reservoir:

1. A control scheme to regulate the reservoir at a fixed level, thereby matching the reservoir inflow with the load, and
2. A control scheme in which the reservoir is filled to an upper level limit via pumps operating at full capacity, then allowed to drain to a lower level limit before the pumps are switched on again.

Scenario 1 is summarised by the constant speed trace at S_1 in the following diagram, operating over a time period t_1. Scenario 2 is depicted by a diurnal speed trace of S_2, operating over a shorter time period t_2.



For an identical load, it follows that the volume V (proportional to the area under each trace) is equal. In other words,

$$V = k_V S_1 t_1 = k_V S_2 t_2$$

The frictional force experienced by the moving column of water is proportional to the square of the speed v of the column of water:

$$F_{fr} = k_{fr} v^2$$
$$= k_{fr} \left(\frac{V}{t}\right)^2$$

On this basis, the energy required to overcome head loss arising from flow rate, is in each case (noting that the distance travelled by the column of water is proportional to vt):

$$E_1 = k_e \left(\frac{V^3}{t_1}\right)$$

and

$$E_2 = k_e \left(\frac{V^3}{t_2}\right)$$

It follows that

$$\frac{E_1}{E_2} = \left(\frac{t_2}{t_1}\right)$$

noting that

$$t_2 < t_1$$

This can give an estimate of expected energy savings on the basis of head loss, between the two control strategies.

For example, say that the diurnal cycle required for a given load operates the pumps for 2 hours out of every 30 hours. In this case, from the above, the load matching strategy would result in the use of approximately 13% of the energy required for the diurnal strategy (solely for the friction loss).

It is important to note that the greatest savings are achieved where the reservoir capacities are considerably greater than the average load, resulting in slow depletion when inflows are stopped. In situations where the reservoir is depleted relatively rapidly, a diurnal strategy would, by necessity, cycle the reservoir more frequently, and the energy savings would not be as great if a load matching strategy is used.

Following on from the earlier example, if the reservoir is relatively small in comparison with the load, and is, say, charged over 20 hours, for the same 30 hour period, then the energy required for the load matching strategy will then be approximately 67% of that required for an equivalent diurnal strategy.

There are clear advantages in energy conservation, by implementing load-matching strategies in this application.