University of Southern Queensland

Faculty of Engineering and Surveying

Optimized Scheduling of Water Distribution Network to Reduce Energy Costs

A Dissertation submitted by

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in fulfilment of the requirements of

ENG4112 Research Project

towards the degree of

Bachelor of Engineering (Honours) (Civil)

October 2015

ABSTRACT

Energy costs for water utilities have increased significantly over recent years, primarily due to expanding water supply systems and increases in electricity charges. The impact of rising energy costs is being felt by Rous County Council (Rous Water) who own and operate the bulk water supply system for the Northern Rivers region in NSW. There is currently a strong drive within Council to reduce our energy costs.

This dissertation investigates options to reduce energy costs of the bulk water supply system owned and operated by Rous Water. The focus of this dissertation is on controlling the filling schedule of the reservoirs in the water distribution network to enable the high energy demand Nightcap Water Treatment Plant (WTP) to take advantage of Time of Use (TOU) electricity metering.

Investigation of current energy usage identified a number of possible control options to schedule the operation of the WTP into lower cost electricity tariff periods. The control options to schedule operation of the water distribution network were developed using the existing functionality of the SCADA control system to minimise costs. Modelling of the control options was able to demonstrate that the avoidance of peak tariff energy use can be achieved with only minor modifications to the SCADA control system. The estimated energy cost savings from the implementation of this project recommendations are approximately 10% of Council's total energy costs.

This dissertation has shown that there are significant savings available for water utilities by taking advantage of TOU electricity tariff structures. Scheduling the operation of high energy demand equipment into less expensive tariff periods can be achieved using existing SCADA based control systems.

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ACKNOWLEDGEMENTS

This dissertation was carried out under the principal supervision of Dr. Les Bowtell. Thank you for your assistance in helping me to get started in the right direction and your continued support and enthusiasm for the subject matter.

Thank you to my employer, Rous Water, for providing me valuable time, access to the required resources and programs and continued support throughout my degree.

I would also like to thank my loving wife and family for their unyielding support and encouragement.

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1. CHAPTER 1 – INTRODUCTION

1.1. Introduction

Energy costs for water utilities have increased significantly over recent years. This is primarily due to three factors; increased water demand from growing populations, improvements to the quality of water produced and increases in electricity charges. The production and supply of potable water requires large pumps and other energy hungry equipment. The impact of rising energy costs is being felt by Rous County Council (Rous Water) who own and operate the bulk water supply system for the Northern Rivers region in NSW. Energy costs account for around 10% of Rous Water's annual operating budget of $15 million.

Rous Water has significant energy consumption and energy demand at a number of large sites with the highest energy costs being attributed to the primary Water Treatment Plant (WTP), Nightcap WTP. This facility has historically been run to meet the demand in the water distribution network without consideration for optimizing the operating times to take advantage of lower cost electricity tariff periods.

The objective of this dissertation is to investigate the current electricity usage at Nightcap WTP and determine if and how water production can be shifted into lower cost electricity tariff periods. A proposed method to achieve this objective with minimal required capital cost is modelled for the water distribution system. The results of the modelling are discussed and a proposed implementation plan is detailed in the conclusion.

1.2. Background

Rous Water is a bulk water supply special purpose County Council operating under the Local Government Act. Rous Water is responsible for the supply of bulk drinking water to Ballina Shire Council, Byron Shire Council, Lismore City Council and parts of the Richmond Valley Council area. The water is transferred to the aforementioned Councils who reticulate the water around the urban areas. The point of supply is typically into a storage reservoir however there are some areas where water is supplied direct into the reticulation network. Rous Water also supplies water to roughly 2000 retail customers direct of the trunk mains. These include customers in rural properties and small villages.

The primary water storage is Rocky Creek Dam at Dorroughby, NSW. Water is extracted from Rocky Creek Dam and treated at Nightcap Water Treatment Plant (WTP) before it is distributed almost completely by gravity to the distribution network.

Over the last 10 years Rous Water has commissioned significant capital upgrades to the bulk water supply system to improve the quality and security of potable water for the region. These upgrades include a membrane filtration water treatment plant, a wastewater treatment plant for handling of solids from the water treatment process, an ozone and biologically activated carbon filtration plant for tertiary treatment of the potable water and a river water pump station to supplement surface water supplies.

1.3.Scope and Limitations

This aim of this project is to investigate a suitable method to enable the WTP to produce water in the lower cost electricity tariff periods.

It should be noted that this project is not considering reducing energy consumption or energy demand at the WTP, rather it is focussing on shifting that consumption and demand into a lower cost electricity tariff period.

1.4.Project Objectives

The primary objective of this project is to reduce energy costs at the Nightcap WTP. It is proposed to achieve this by optimizing the schedule of filling reservoirs in the water distribution network to avoid producing water at the WTP in peak electricity tariff periods.

Since the plants construction in 1992, process optimization and energy efficiency measures have been implemented successfully, however optimization of the distribution system to control operation of the WTP has not been investigated previously.

The average annual electricity consumption for the Nightcap WTP is 3000MWh, which includes electricity consumption from two separately metered electricity supply points. One supply point is for the WTP (excluding waste treatment) and the other supplies power to the Raw Water (Dam) Pumps and the Waste Treatment Plant

Based on this high energy consumption the Nightcap WTP is a contestable electricity site which requires electricity retailers to bid for the electricity contract for this site. The site has recently been signed to a new 30 month electricity supply contract. The retailer has offered a Time of Use (TOU) energy consumption tariff for this site. Peak and Shoulder energy usage are at the same rate while Off-peak energy usage is considerably less.

The electricity distributor for this site is Essential Energy. The network electricity tariff is BLND3AO LV TOU Demand 3 Rate. This network tariff has a demand charge for each TOU tariff period. The demand charge is based on the highest recorded energy demand recorded at the WTP during the month. The Peak and Shoulder monthly maximum demand is charged at the same rate with Off-peak demand charges being considerably less. This network tariff also has TOU charges for electricity consumption. Again, the Peak and Shoulder consumption charges are charged at the same rate with Off-peak charges being considerably less.

All charges are adjusted for losses in the distribution and transmission lines and generally add 10% to the contract rates. A summary of all loss adjusted electricity charges at the Nightcap WTP is provided below in Table 1.1 (2014/15 figures):

Charge Description	Charge Type	Amount
Peak Energy	Consumption	$0.1004/kWh
Shoulder Energy	Consumption	$0.1004/kWh
Offpeak Energy	Consumption	$0.0654/kWh
Peak Demand	Demand	$14.955/kVa
Shoulder Demand	Demand	$14.955/kVa
Offpeak Demand	Demand	$3.4182/kVa
Market Charges/Levies (AEMO, SRES, etc.)	Consumption	$1.4936/kWh
Network Access Charge	Daily	$13.613/Day
Meter charge, retail fee	Daily	$5.10/Day

Table 1.1 Nightcap WTP Electricity Charges

The Nightcap WTP is currently operated to meet the demand of the water distribution network. The average energy consumption rate for the WTP during normal operation is approximately 283kWh/Mega litre (ML). This project is not looking at reducing the energy consumption per ML but rather shifting the energy usage into a lower cost TOU tariff period.

The TOU tariff periods for the Nightcap WTP are a common arrangement as shown in Figure 1.1 below. Note these tariffs only apply to weekdays. Weekends are completely off peak.

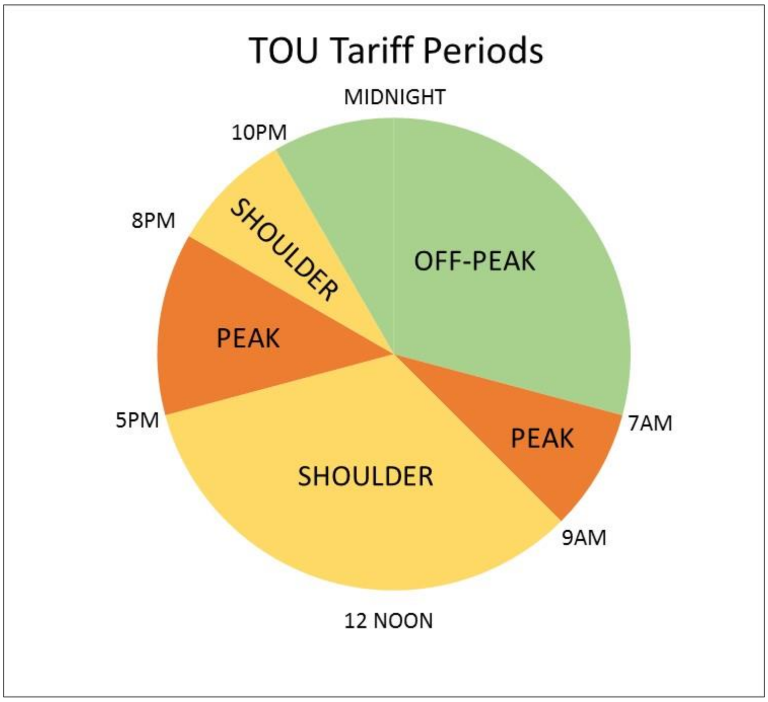

Figure 1-1 TOU Tariff Periods (Weekdays only)

Scheduling the WTP energy usage and demand into a lower cost TOU tariff period (or shifting all usage into two rather than three TOU tariff periods) will result in significant energy cost savings.

1.5.Methodology

The methodology used in this project was that of investigation and modelling. A preferred option was identified that would achieve the project objective. Further work includes a business case to Council to secure funding and implementation of the project recommendations.

Investigation

The first stage is to investigate the current energy usage within the Nightcap WTP and water distribution network to determine the constraints for the project and the best opportunities to reduce energy costs. Investigations into potential options to achieve the project objective were undertaken in this stage. An energy audit was conducted to analyse the energy usage patterns of the Nightcap WTP.

The investigation stage focussed on existing functionality within the system that may be able to assist in achieving the project objective as well as determine the potential energy savings to help in preparing the business case for any potential solutions.

Investigation was primarily desktop based and involved developing a thorough understanding of the operation of both the WTP and the distribution system, extensive data collection and analysis. A literature review was undertaken to determine the current research done in this area and to provide a starting point for this work.

Modelling and Validation

Various models of the distribution system were developed in Excel to enable possible solutions to be tested to review if the project objective could be achieved without detriment to operation of the network.

This modelling of the potential solutions was able to validate and confirm the viability of the options.

Business Case

A business case will be prepared for presentation to Council to request approval to proceed and potential funding for implementation of the preferred solution. This will involve justifying the project to Council through demonstration of the potential savings and improvements to operations. The investigation of this project was initially requested by Council so it is likely that future funding should be available.

Design and Implementation

The preferred option will have a detailed design and specification prepared combined with an implementation plan. Depending on the funding required the implementation may be able to proceed prior to completion of a business case to Council.

Field optimization of preferred option

The implemented option will no doubt undergo further refinement and optimization in the field to identify the best possible configuration that will satisfy the operating rules and allow the most flexibility in operating the system, such as adapting to unplanned shutdowns and required maintenance activities.

1.6.Project Viability

To demonstrate the viability of shifting the electricity usage and demand into lower cost or fewer electricity TOU tariff periods, analysis of Nightcap WTP water production data for the last seven years was undertaken to determine the average and peak day demands.

Analysis of Nightcap WTP production data from the last seven years returned an average daily production of 29.5ML and a peak daily production of 44.8ML. WTP run hours can be calculated roughly by dividing the daily production by the typical production flowrate. The typical production flow rate for the Nightcap WTP is 600L/s which is running two raw water (dam) pumps.

Table 1.2 below shows the WTP run hours to produce the average and peak production quantities.

	Average Day	Peak Day
Water Production (ML)	29.5	44.8
WTP Run Time (Hrs)	13.7	20.7

Table 1.2 WTP Run Hours for Average and Peak Day Demand

The total hours for each TOU tariff period in the above TOU structure are:

- Peak: 5 hours
- Shoulder: 10 hours
- Off Peak: 9 hours

Based on the required WTP run hours to produce the average and peak day demands it is clear that the average day demand can easily be met without using energy during the peak tariff period however the peak day demand would require energy to be used in all TOU tariff periods. There is scope to run the WTP at an increased flowrate thereby reducing the required run hours but this has other issues and is discussed in a later section.

In regards to energy demand costs these are charged based on the maximum demand for the month for each TOU tariff period so running the WTP once during the month in the Peak power period will incur the full Peak demand charge.

The maximum day demand that can be produced by the WTP in only Offpeak and Shoulder TOU tariff periods (19 hours combined) is approximately 41ML. This is based on a constant 600L/s flowrate. As indicated by the dashed line in Figure 1.2 below, over 99% of all daily production records from the last 7 years are less than 41ML and can theoretically be produced by the WTP without using energy in the Peak TOU tariff period.

Note this viability check is only considering the current WTP flowrate of 600L/s. As previously mentioned the WTP may be able to be operated at higher flowrates which would increase the daily water production capacity and increase the viability of this project. However there would be a significant cost penalty imposed by high electricity demand charges when running the plant at higher capacities. Discussion on running the WTP under different operating scenarios is included in a later chapter.

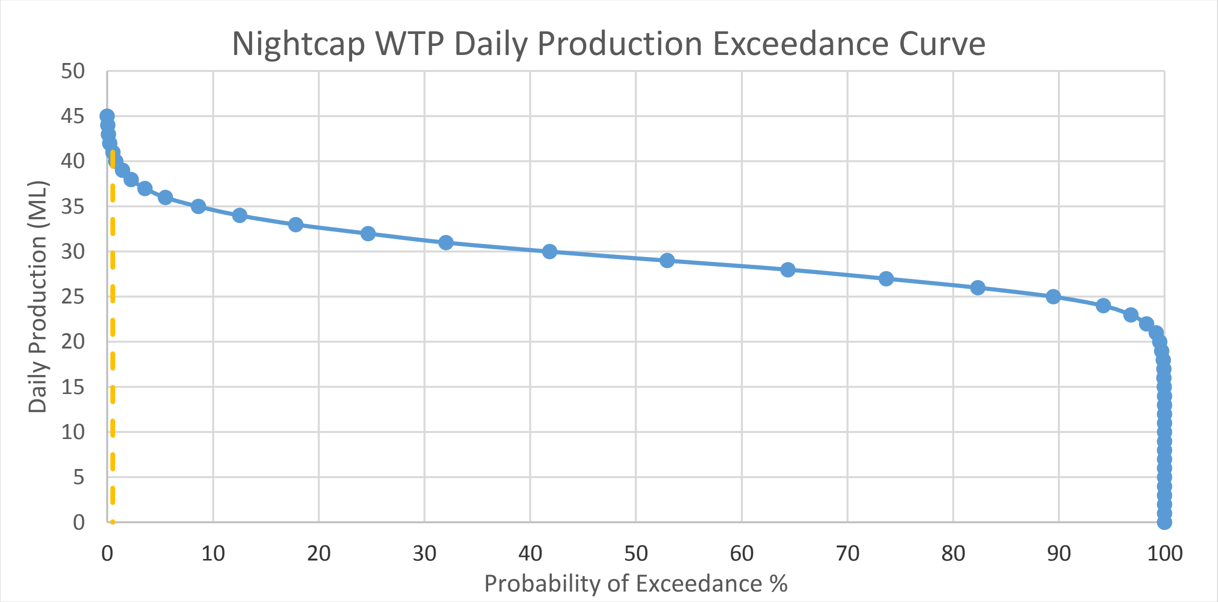

Figure 1-2 Nightcap WTP Daily Production Exceedance Curves

Taking advantage of TOU metering at the WTP will result in a significant saving in energy demand charges. Evaluation of the energy cost savings is assessed in a later section.

2. CHAPTER 2 – BACKGROUND

2.1. Description of Nightcap WTP

Nightcap WTP is a 70ML/day Dissolved Air Filtration Flotation (DAFF) plant. The operation of the plant is fully automated and controlled by a Supervisory Control and Data Acquisition (SCADA) system.

The plant is automatically started when the water level in the CWSR drops to the low level set point and the plant stops when the water level in the CWSR reaches the high level set point. The plant operates on a continuous flow of 600L/s however some processes within the plant occur on a regular cycle such as backwashing of the filters.

The Nightcap WTP primarily extracts water from the adjacent Rocky Creek Dam however water can also be delivered from the Wilsons River which is used a secondary supply.

An aerial view of Nightcap WTP highlighting the treatment trains is shown as Figure 2.1.

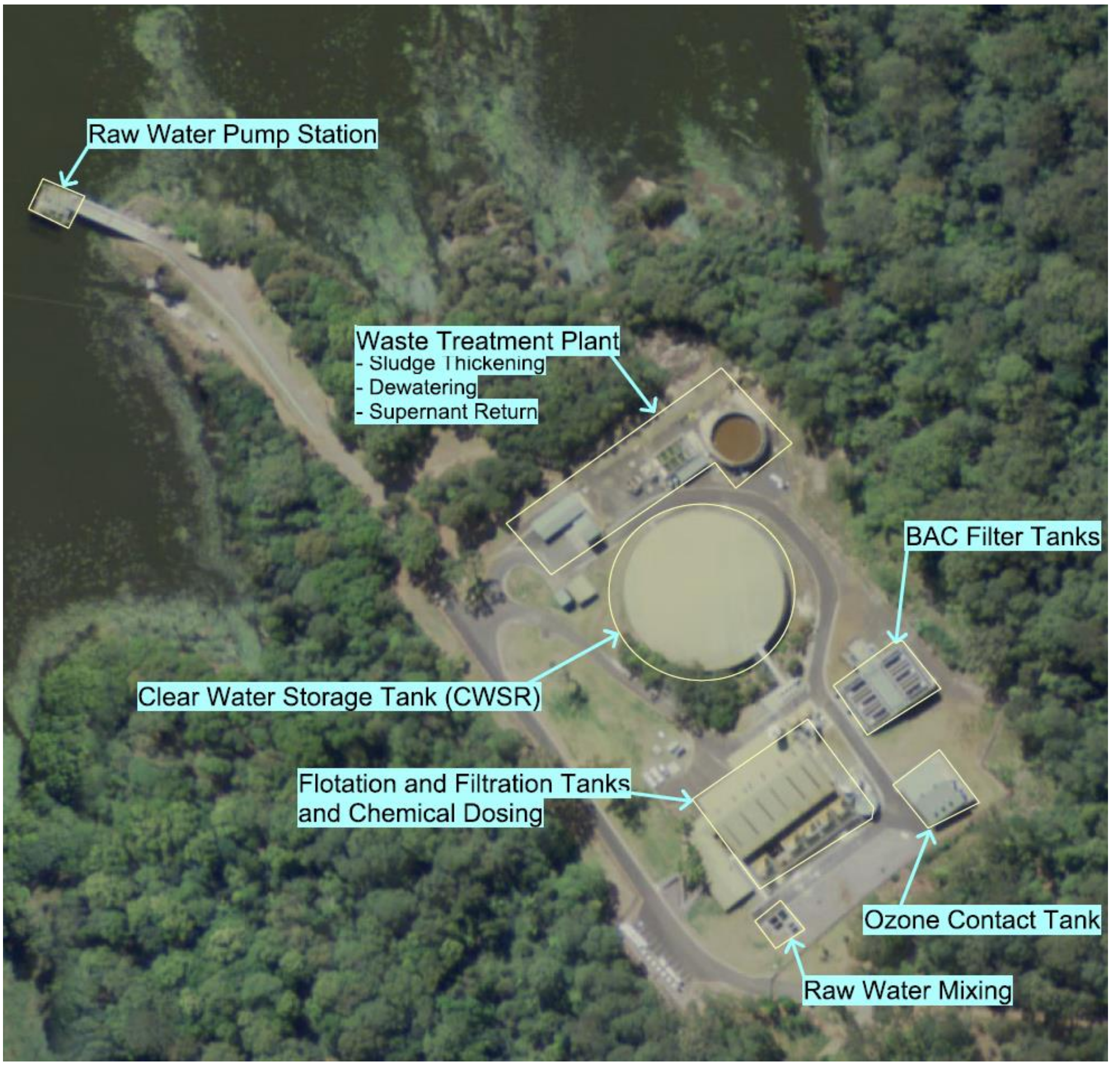

Figure 2-1 Nightcap WTP - Aerial View

2.1.1. Nightcap WTP Process Overview

The original WTP was constructed in 1992. The WTP was upgraded in 2006 to include a Waste Treatment Plant for the water treatment solids. The WTP was again upgraded in 2008 to introduce the alternative source water of the Wilson River and construct an Ozonation and Biologically Activated Carbon (BAC) Filter for tertiary treatment of the potable water.

To give the reader an appreciation of the treatment process at the Nightcap WTP the process is described below following the flow of water through the plant.

Raw Water Delivery

Raw (untreated) water is delivered to the head of the WTP from either the Rocky Creek Dam raw water pumps or the Wilson River high lift pumps.

The WTP is run at approximately 600L/s by running either two raw water pumps or a combination of one raw water pump with the Wilson River high lift pumps.

Raw Water Mixing

Lime is added to the water to increase the alkalinity and CO2 is added to decrease the pH to achieve optimum coagulation. Lime and CO2 also react to form calcium bicarbonate which buffers the water against changes in pH.

Coagulants (Aluminium Chlorohydrate and polyelectrolyte) are added to the water to suspend and clump the solids particles in the next process. The water passes through a series of baffles and weirs to hydraulically mix the chemicals into the water.

Flocculation

The water is passed in flocculation tanks where slow speed mixers assist the coagulants to bind together lightweight solid particles in the water to form heavier “flocs”.

Flotation and Filtration

Dissolved air is pushed through the water to float the flocs to the surface forming a sludge which is periodically skimmed off and recycled through the waste plant. The water is then filtered through sand filters to remove any residual coagulant chemicals and floc particles which were not floated off.

Ozonation

Filtered water is then pumped through the ozone contact tank where primary disinfection occurs. Ozone is manufactured on-site using generators which convert oxygen (O2) to ozone (O3). Ozone breaks down any organic material that may be present (such as taste and odour causing compounds, algal toxins, pesticides and herbicides) into biodegradable compounds.

Biologically Activated Carbon (BAC) Filters

The water is then filtered through BAC filters, where the microbiological action in the filters consumes and removes the compounds.

Residual Disinfection and pH Correction

The treated water is then dosed with Lime to increase the pH to drinking water standards. Chlorine is added as a residual disinfectant to protect the water from disease causing organisms from the treatment plant to the consumers tap.

Fluoridation

Fluoridation of the water is only required for three of the four Constituent Councils supplied from the Rous Water bulk system. The fluoridation plants are therefore located at downstream locations on the distribution network.

Wastewater Treatment

Wastewater from the filtration process is thickened in settlement tanks before passing to the centrifuge for dewatering. Separated clear water from the process is returned to the head of the WTP while the dewatered sludge is taken off site for disposal.

Figure 2.2 below is a process schematic of the Nightcap WTP.

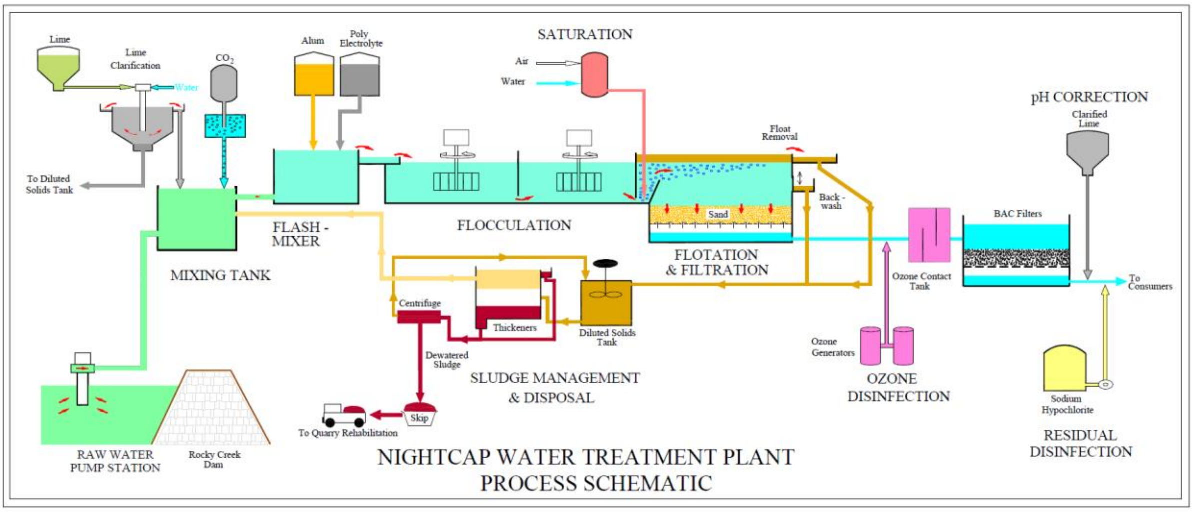

Figure 2-2 Nightcap WTP Process Schematic

2.1.2. Energy Usage at Nightcap WTP

There are two electricity metering points at Nightcap WTP with separate National Meter Identifiers (NMI):

- Raw Water Delivery + Waste Treatment Plant (NMI: NFFFNRKJ61)

- Water Treatment Plant (NMI: NFFFNRKJ60)

2.1.2.1. Raw Water Pumps +Waste Treatment Plant

At the raw water pump station there are four fixed speed centrifugal pumps each rated at 110kW however the current water demand only requires the WTP to operate on two pumps with two standby.

The majority of processes at the WTP are designed for 70ML/day production and current average day demand (ADD) in the distribution network is less than 30ML/day. This ADD can be achieved in approximately 14 hours of WTP run time by running only two raw water (dam) pumps which produce a flow rate of approximately 600L/s.

This electricity metering point also includes power supply to the Waste Treatment Plant. The Waste Treatment Plant was added to the Nightcap WTP in 2006 and is a continuous flow process for thickening and dewatering the water treatment solids for disposal off site. The Waste Treatment Plant accepts all waste water from the WTP.

A summary of the energy using equipment at this electricity metering point when the plant is running is presented in Table 2.1 below.

Equipment	kW Rating	Usage
Raw Water (Dam) Pump x 2	110kW each	Continuous when WTP running
Waste Recycle Pump x 2	30kW each	Continuous when WTP running
Centrifuge	15kW	Continuous when WTP running
Supernatant Pump	11kW	Continuous when WTP running
Diluted Solids Holding (DSH) Pump	11kW	Continuous when WTP running
Other Equipment - Combined	26kW	Continuous when WTP running

Table 2.1 High Energy Using Equipment (Raw Water & Waste: NFFFNRKJ61)

2.1.2.2. WTP (excluding Waste Treatment)

The WTP is operated on a continuous flow and thus most the equipment within the WTP processes is operated on a fixed speed. Therefore the energy demand in the WTP is fairly steady and predictable when the WTP is running. The major use of energy in the WTP is pumping water through the treatment processes and generation of ozone gas.

Each of the six sand filters are backwashed once for every 25 hours of WTP operation. Each of the six BAC filters are backwashed once for every 90 hours of WTP operation. The backwash process involves pushing large amounts of water and air through the bottom of the filters to clean the filter media. Backwashing of the filters causes occasional spikes in energy demand.

A summary of the energy using equipment at this electricity metering point when the plant is running is presented in Table 2.2 below:

Equipment	kW Rating	Usage
Air Compressor Ozone Train x 2	77kW each	Continuous when WTP running
Ozone Generator x 2	73kW	Continuous when WTP running
Air Blower	75kW each	Batch. 12min every backwash
Backwash Pump	55kW each	Batch. 14min every backwash
Dunoon Pump	55kW	Batch. 5hrs every day
Recycle Pump x 2	45kW	Continuous when WTP running
Relift Pump x 2	30kW	Continuous when WTP running
Main Air Compressor	18kW	Continuous when WTP running
CO2 Service Water Pump	15kW	Continuous when WTP running
Lime Service Water Pump	11kW	Continuous when WTP running
Other Equipment - Combined	53kW	Both continuous and batch

Table 2.2 High Energy Using Equipment (WTP: NFFFNRKJ60)

2.1.3. Operating Scenarios for Nightcap WTP

The normal operating scenarios for Nightcap WTP are to run either two dam pumps or a combination of one dam pump and the Wilson River high lift pumps. Both these operating scenarios produce a WTP flowrate of roughly 600L/s. The WTP can be operated with higher inflows however the operations staff at the Nightcap WTP report higher flows through the plant will cause overloading of some of the treatment processes, namely the waste treatment plant and lime dosing system (Hildebrand, B 2015, pers. comm., 21 May). The affected processes may either be undersized or require further process optimization to provide effective treatment for the increased flowrates.

The existing dam pumps have fixed speed drives and currently run at around 90% load. One potential option is to install Variable Speed Drives (VSDs) onto the pumps to allow pumping at variable flowrates which may assist to optimize the WTP run times.

The different operating scenarios are presented in Table 2.3 below each with its own pros and cons in regards to energy costs and ability to assist in WTP run time optimization.

Operating Scenario	Flowrate (L/s)	Pros	Cons
2 x Raw Water (Dam) Pumps	600	• WTP processes are proven for this flow rate • Lowest energy consumption	• Long WTP run time to produce daily consumption
1 x Raw Water (Dam) Pumps + Wilson River	600	• WTP processes are proven for this flow rate	• Long WTP run time to produce daily consumption • High energy consumption
3 x Raw Water (Dam) Pumps	900	• Short WTP run time to produce daily consumption	• Would exceed capacity of some WTP treatment processes • Processes not currently optimized for this flowrate • Moderate energy consumption
2 x Raw Water (Dam) Pumps + Wilson River	900	• Short WTP run time to produce daily consumption	• Would exceed capacity of some WTP treatment processes • Processes not currently optimized for this flowrate • High energy consumption
Raw Water (Dam) Pumps + VSDs	Variable	• Short WTP run time to produce daily consumption • WTP could be run with varying flowrates to match demand	• Could exceed capacity of some WTP treatment processes depending on flowrate • High cost to implement VSDs • Moderate energy consumption

Table 2.3 Nightcap WTP Operating Scenarios

2.1.3.1. Increased WTP Flowrate

The main benefit of using an increased flowrate through the WTP is to reduce the required WTP run hours needed to meet the demand of the distribution network. This in turn would allow more flexibility in scheduling the WTP run times to avoid peak tariff periods. The obvious downside is that increasing the flowrate requires increasing the energy usage of the pumps and other equipment which may offset any potential savings gained by avoiding Peak power demand charges.

The main equipment that would contribute to the increased demand are as follows:

- Raw water (dam) pump – extra pump required
- Ozone compressors and generators – flow paced operation
- Relift pumps – flow paced operation
- Chemical dose pumps – flow paced operation
- Waste Treatment Plant – flow paced operation

All other equipment in the WTP would either:

- Maintain current demand - for continuous duty
- Increased frequency of operation – for batch duty

Increasing the flowrate through the WTP will present operational issues because it is known some of the treatment processes do not function well with the higher flowrate. In particular the lime and CO2 dosing systems are near capacity and the Waste Treatment Plant is near capacity. The treatment processes would require upgrading or extension if the WTP was regularly operated under increased flowrates.

The estimated increase in energy demand to run the three dam pumps is approximately 220kW. This extra energy demand largely offsets any potential savings from avoiding peak electricity tariff period. For this reason and because of the identified operational issues, the three dam pump operating scenario will not be investigated further in this report.

2.1.3.2. Wilson River Operating Rules

Another point that should be raised here is the operating rules regarding extraction of water from the Wilson River. The operating rules are designed to ensure Rous Water’s water reserves are in the best possible situation should the region enter into an extended dry period while also maintaining water availability for downstream environments. The operating rules may call for or prohibit use of the Wilson River. These rules will generally take precedence over energy cost considerations.

The primary operating rule is to conserve the water in Rocky Creek Dam to be in the best possible situation in the event of an extended dry period. To achieve this Rous Water can supply water from the Wilson River to Nightcap WTP to lower the required extraction from Rocky Creek Dam. Note that the Wilson River can supply approximately half of the required raw water flowrate to Nightcap WTP so one raw water (dam) pump is run in conjunction with the Wilson River supply.

The second rule is from the Wilson River extraction license and requires that Rocky Creek Dam must be below 95% before water can be extracted from the Wilson River.

The third operating rule is also from the extraction license for the Wilson River. Water can be extracted if there is sufficient environmental flow in the river. The extraction allowance is based on a sliding scale which has different extraction allowances for summer and winter.

2.1.3.3. Wilson River Energy Costs

In assessing the available operating scenarios it was shown that all scenarios that included running the Wilson River had "high energy consumption" in the negative column. The high energy consumption is due to the large distance and elevation that the water from the Wilson River must be pumped to Nightcap WTP.

The operating data for the Wilson River pumps is compared against a raw water (dam) pump at Nightcap WTP to highlight the large difference in energy usage as shown in Table 2.4 below. One raw water (dam) pump can deliver equivalent water as the Wilson River pump system.

	Wilson River	Raw Water (Dam) Pump x 1
Flowrate (L/s)	300	300
Maximum Demand (kW)	743	103
Average kWh/ML	1056	84
Average $/ML	231	23

Table 2.4 Wilson River vs. Raw Water Pump Energy Cost

The above figures were derived from monthly electricity invoices and water production data collected by Rous Water with some adjustments made to account for the Waste Treatment Plant which is also supplied electricity on the same NMI as the raw water (dam) pumps.

2.2.Description of Distribution Network

The Rous Water distribution network conveys water to four Local Government Areas in the Northern Rivers region of NSW. The Councils are Lismore City Council, Ballina Shire Council, Byron Shire Council and Richmond Valley Council.

The network is comprised of:

- 254km of trunk mains
- 153km of reticulation mains
- 36 reservoirs (total capacity 140ML)

Figure 2.3 below is shows the Rous Water distribution network extending into the four local government areas.

Figure 2-3 Rous Water Distribution Network

2.2.1. Operation of the Distribution Network

The reservoirs in the Rous Water network are generally operated to achieve the following objectives.

- Maintain sufficient supply in the reservoirs at all times – in the event of unanticipated high demand or emergency.
- Maintain water quality by minimising water age and thus increasing turnover of the reservoirs
- Avoid frequent inlet valve movements or pump starts
- Encourage mixing in the reservoir by having a sufficient cycle depth

Some reservoirs in the network also have extra considerations as follows

- Maintain high water level in reservoir to maintain pressure to high zone customers on reservoir outlet
- Maintain sufficient supply for fire flows
- Maintain sufficient supply to provide structural integrity in event of severe storm

Operation of the distribution network is based on high and low set points for each reservoir[1]. For the majority of reservoirs in the Rous Water network the filling of the reservoirs is via gravity feed. As the reservoir drains it will reach the low set point which will open an inlet control valve and the reservoir will feed under gravity flow. As the reservoir fills it will reach the high set point which will close the inlet control valve.

There are a few reservoirs which require pumps to increase the energy of the water above the reservoir inlet. The high and low set points in this case operate the starting and stopping of a pump station.

The reservoir at the head of the Rous Water distribution network is located at the Nightcap WTP and is known as the Clear Water Storage Reservoir (CWSR). This reservoir is fed from the Nightcap WTP and has high and low set points which act to start and stop the operation of the WTP.

The normal operation of the distribution network is automated by a Supervisory Control and Data Acquisition (SCADA) system. Rous Water operations staff input rules to the system such

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[1] Reservoir is used to mean a water retaining structure (such as a concrete tank or steel tank) rather than a raw water storage such as a dam

as reservoir set points for fill control, alarm limits and pump loops. The SCADA system monitors reservoir levels and system flows and has the ability to send signals to open and close valves or start pumps as required by the operating rules.

For sites without valve or pump control, Rous Water uses hydraulic control valves which operate off the head in the reservoir to control the water level. The SCADA is able to monitor these sites to detect abnormal operation.

2.2.2. Distribution Network Control

The filling of all reservoirs in the distribution network is controlled by one of four methods:

1. Hydraulic Control Valve (HCV)
2. Hydraulic Control Valve with Remote Input (HCV-R)
3. Actuated Control Valve (ACV)
4. Pump Loop

Each of these methods is described in more detail below including any specifics regarding how they work in the Rous Water water supply system.

Hydraulic Control Valve (HCV)

Approximately half of the reservoirs in the Rous Water network are controlled using a Hydraulic Control Valve (commonly referred to as an ‘Auto-Valve’ or ‘Altitude Valve’). A typical HCV is shown below as Figure 2.4.

These valves work off the water level in the reservoir and use a series of pilot lines and springs to open and close the valve. The springs can be adjusted to set the open and close points of the valve as required to meet the operational objectives mentioned above.

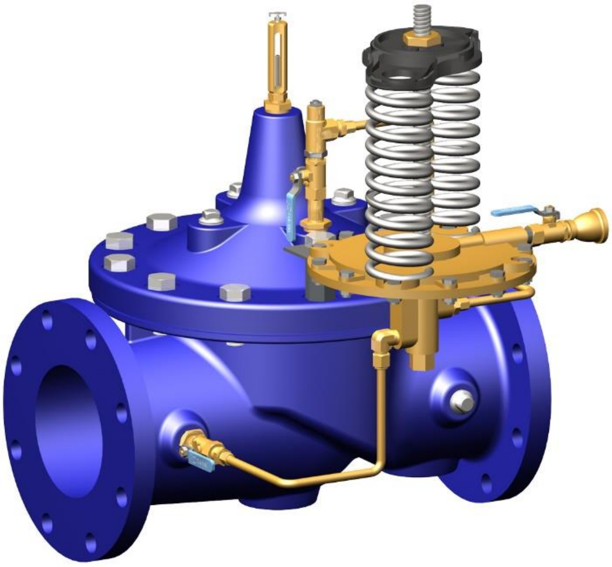


Figure 2-4 - Hydraulic Control Valve (Source: Cla-Val)

Hydraulic Control Valve with Remote Input (HCV-R)

A number of the hydraulic control valves are fitted with solenoid valves on the pilot pressure lines. The solenoid valves are able to be remotely activated to open and close the pilot lines and manipulate the operation of the hydraulic control valve. These valves can operate in the same way as actuated control valves.

Actuated Control Valve (ACV)

A number of ACVs have been installed on reservoir inlets in the Rous Water distribution network to allow remote operation of the reservoir set points through the SCADA system. The actuated control valves are predominantly butterfly valves which have electric actuators installed onto the valve key. A typical ACV is shown below as Figure 2.5.

As the level in a reservoir drops to the low set point or fills to the high level set point a signal is sent to the SCADA. The ACV then receives a signal from the SCADA to open or close as required to control the water level in the reservoir.

Figure 2-5 - Actuated Control Valve (Site: Water Wheels)

Pump Loop

A few locations in the Rous Water distribution network require pumping to overcome an elevation difference or to increase flowrate to meet demand. Pump loops operate the same way as the ACVs in that a call to start pumping is activated by the receiving reservoir reaching its low set point and a signal to pump being sent through SCADA. The signal to stop pumping is sent once the receiving reservoir's water level reaches the high set point.

A schematic diagram of the water distribution network, including reservoir elevations and capacities is shown as Figure 2.6 on the following page. Reservoirs are colour coded according to their control method.

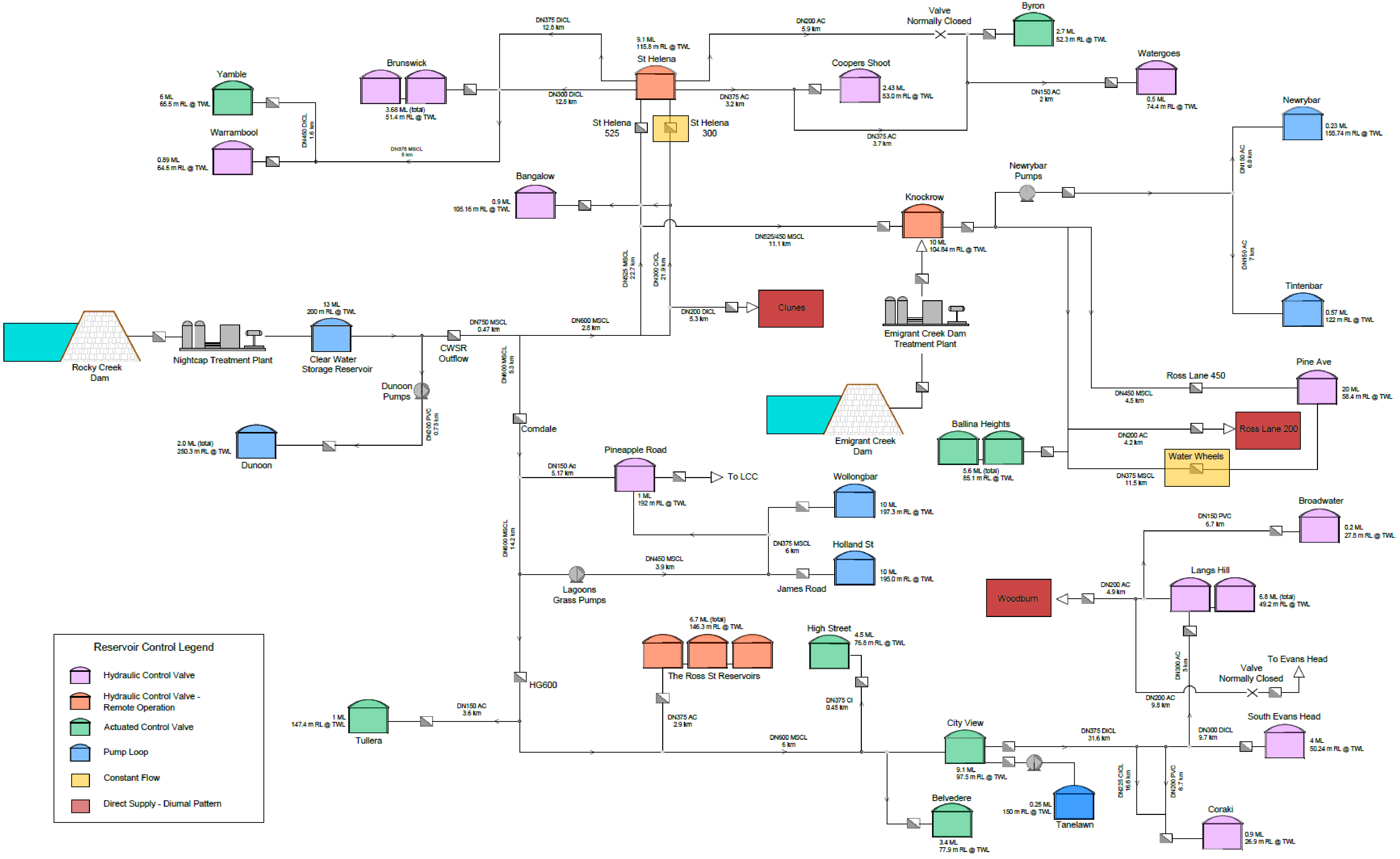


Figure 2-6 Distribution Network Schematic (including Control Method)

2.2.3. SCADA Control Functionality

The SCADA system used in the Rous Water distribution network also has additional controls that can override the reservoir filling control signals. Some of these functions may assist in scheduling the reservoir fill times to achieve the project objectives. The override controls are discussed below.

2.2.3.1. Remote Close

Although the HCVs are not directly controlled by the SCADA, many of these valves have a ‘remote close’ function. The ‘remote close’ function allows Rous Water operational staff to remotely activate a solenoid valve on the HCV to force it to close regardless of its current position. The ‘remote close’ is activated through the SCADA system.

2.2.3.2. Tariff Timers

The SCADA system has built in functionality to effectively ‘lock out’ the filling of reservoirs by inhibiting calls for water generated by the low level set points. The tariff timers are set to user defined hours of the day to inhibit operation during this time. For example setting a tariff timer from 7am to 9am will inhibit filling of the reservoir during this time.

Each reservoir with an actuated control valve or pump loop can have up to two tariff timers lock out periods per day. Some of the hydraulic control valves in the network have also been fitted with solenoid control which can effectively control the reservoir water level remotely through manipulation of the hydraulic control valve pilot system. These modified hydraulic control valves are also able to have tariff timers enabled.

Scheduling of the tariff timers could be used to reduce the water demand in the distribution network during the peak tariff period thereby reducing the requirement for the WTP to produce water.

If tariff timers are to be used care should be taken to avoid having a reservoir run dry or drop below required emergency or fire flow storage. The SCADA system has an in built emergency override that will cancel the tariff timer if the water level in a reservoir drops to or the low low level alarm point. This function is called ‘Ignore Tariff When Low’. The low low level alarm set points for each reservoir would be determined on a case by case basis with regards to the distribution system operating rules such as emergency storage and storage for fire flows.

After the ‘Ignore Tariff When Low’ command has been activated the tariff inhibit times will re-enable if any of the following conditions are met (SAFEgroup, 2014):

- ‘Ignore Tariff When Low’ command is disabled
- Outside tariff times has been reached
- Reservoir level reaches the duty stop level
- Valve close override command has been activated

2.2.3.3. Force Fill

Another feature of the SCADA system is to ‘force fill’ reservoirs. This functions allows an overriding signal to be sent through the SCADA to an actuated control valve or pump loop to open and fill the reservoir to the high level set point. This function will force a reservoir to fill regardless of whether the reservoir is currently draining or filling.

Again this function can only be applied to actuated control valves, pump loops and hydraulic control valves with solenoid operation.

3. CHAPTER 3 - LITERATURE REVIEW

Optimizing the scheduling of a water distribution network to minimize energy costs is not a new concept. There are a number of papers available with varying methods on implementing an optimization program as well as proprietary software for this exact task.

3.1. Water Distribution Network Optimization Concept

The basic concept of water distribution system control is presented in a paper entitled '*Optimal control of a water distribution network in a supervisory control system*' by Cembrano. et al. (2000). The concept comprises three main components required for optimized control.

- SCADA – interface for monitoring and controlling of water distribution network valves, pumps and other variables.
- Demand Prediction Model – models and predicts future demand in the network based on process variables received from the Optimal Control. Sends predicted demand model to Optimal Control program.
- Optimal Control – Solution finding program which takes inputs from SCADA and the demand prediction model and determines best schedule for valve operations and pumping. Communicates the schedule to the SCADA for communicating to the water distribution network.

Figure 3.1 below shows the conceptual control system defined by Cembrano.

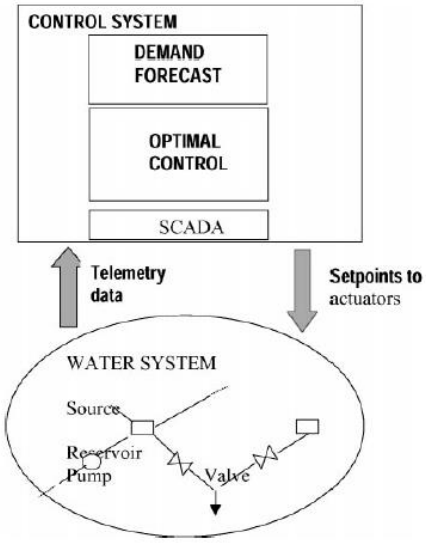


Figure 3-1 - Dynamic Schedule Optimizer (Source: Cembrano (2000))

Cembrano. et al. (2000) and Moreira and Ramos (2013) both use genetic algorithms for the Optimal Control.

However Lopez-Ibanez, Prasad and Paetcher (2008) adopted Ant Colony Optimization (ACO) techniques, which attempts to mimic the technique used by real ants for optimizing the path between the nest and source of food.

Ideally the Rous Water optimization system will be far less complex and utilise existing functions within the SCADA however as there is significant energy costs savings as a result of achieving optimization this may justify investigating more complex optimization methods such as those mentioned above.

3.2. Optimization Considerations

Lopez-Ibanez, Prasad and Paetcher (2008) elaborate on Optimal Control to define it as finding an optimum in a search space whose size is exponential to the number of decision elements. Ideally finding a global optimum but occasionally finding a local optimum. Applying this concept to the optimizing of a water distribution network, each point on the search space represents a decision variable i.e. pump on/off, valve open/close, etc. The demand prediction model (typically a hydraulic model) must produce a solution for each point on the search space until an optimum solution is achieved. Each hydraulic model evaluation takes considerable computational processing power.

When investigating options for optimization of the Rous Water network, it was important to consider the simplicity of the system and the amount of resources required.

Cembrano. et al. (2000) states the main difficulty in optimizing control of a water distribution network is the unknown future demand in the network. A demand prediction model should be included as part of the optimization to provide a fair estimate of the future demand.

To be able to predict demand in the Rous Water network this could be achieved by running the hydraulic model or applying typical diurnal patterns of consumption to the network. However this style of optimization has been attempted before on the Rous Water network, albeit without using real-time distribution system monitoring data, and was unsuccessful. It is proposed to find a simpler solution to the problem by manipulating the feed times of reservoirs and production at the WTP.

Cembrano. et al. (2000) also stresses the importance of maintaining supply pressures within the network. This requirement will be considered when determining the most appropriate way to optimize the scheduling of the reservoirs for the Rous Water network. It is prudent to conduct an operational risk assessment, perform simulated modelling of any proposed solution and implement failsafe measures to reduce the risk of creating an operational failure in the system (such as a reservoir draining while locked out).

Pegg S (2000) explains how a proprietary scheduling optimization system (Derceto Aquadapt) handles unusual events such as telemetry failure or lighting strikes by adopting the last optimized solution until the failure is rectified and a new optimized solution can be found.

This functionality highlights the importance of having failsafe measures in the final adopted solution. Some things to consider would be implications of losing power or communications to a site, unusual demand in the network, etc. and how these occurrences would affect the scheduling optimization process.

3.3.Previous Implementation of WTP Control

As mentioned there has been a previous attempt to implement some control over the running of the Nightcap WTP to reduce peak tariff energy usage. The previous attempt was limited only to the WTP and was implemented using an algorithmic code to run the WTP prior to peak tariff to ensure the storage reservoir was full. The code also had an option to start a third raw water (dam) pump to increase production prior to the peak tariff. The algorithmic code was based on the rate of drop in the clear water storage reservoir.

However as the monitoring did not extend to the water distribution system calls for water were received from the downstream reservoirs which would drain the treated water tank to a low low level alarm and override the tariff timer which would then start the WTP and any energy demand charges savings for the month were then lost.

The other issue was the running of the third pump. The WTP Operators report the third pump would occasionally turn on around midnight. This would cause operational issues in some treatment processes of the WTP, which as previously mentioned, may be undersized or uncalibrated for the higher flows.

This algorithmic code was implemented into the WTP SCADA system but is currently disabled as it was causing unnecessary after hours call outs.

3.4.Review of Alternative Methods

A number of different methods to achieve the project objective of reducing Nightcap WTP peak energy usage were identified. The list presented below is in order of increasing complexity and generally in order of increasing cost to implement also.

3.4.1. WTP Control

This method involves implementing control of the WTP run times in isolation from the water distribution system. As mentioned in the previous section this was previously implemented however the control method did not work to regularly avoid peak energy usage. There is scope to revisit this approach without including the option to bring a third dam pump on-line.

3.4.2. Tariff Timers on Distribution Network

The functionality already exists in the distribution system SCADA system to allow tariff timers to be activated on a large number of reservoirs. There are some reservoirs however that do not have this function due to the type of inlet control valve installed at the site.

If tariff timers could be implemented on the critical reservoirs in the distribution network then the timers could be staggered around the peak electricity tariff times to conserve water in the reservoirs, maintain system pressures and not create excessive flows in the network when all reservoirs subsequently open. The critical reservoirs are immediately downstream of the Nightcap WTP and are critical in terms of conserving water in the network and avoiding running the WTP. There are a small number of low capacity reservoirs immediately downstream of Nightcap WTP however control of these is of no advantage due to their low turnover.

3.4.3. Force Feed Control

The functionality already exists in the SCADA system to command a reservoir to force fill. Again this can only be applied to reservoirs with actuated inlet control valves or operated on a pump loop.

Force feed control could be used in conjunction with the tariff timers to fill the critical reservoirs prior to locking them out during peak electricity tariff periods.

3.4.4. Time Based Reservoir Set Points

An idea was raised by the WTP Operators to implement time based reservoir set points. This would mean the reservoirs could have a higher and narrower pair of set points in the hours before peak electricity tariff periods to effectively maintain a higher water level in the reservoirs.

For example a reservoir that normally has low level set point at 40% and high level set point at 80% could be adjusted to have low and high set points of 80% and 90% respectively in the hours before the peak electricity tariff periods.

This option would require significant SCADA programming to implement.

3.4.5. Dynamic Optimization Models

There is potential to implement a series of linked programs to perform the necessary dynamic optimization functions to prepare an optimum operating schedule for the water distribution network. This method was identified in the literature review however no examples were found where this method had been trialled or implemented on an actual water supply system. The required linked programs would be as follows:

- Hydraulic Model
    - receives trial parameters from Optimization Controller
    - outputs modelled projections to Optimization Controller
- Optimization Controller
    - receives real-time operational data from SCADA
    - outputs real-time operational data to Hydraulic Model
    - receives modelled projections from Hydraulic Model
    - cycles different decision elements through Hydraulic Model to find optimum
    - outputs optimum decision elements to SCADA
- SCADA
    - receives real-time operational data from Water Distribution Network
    - outputs real-time operational data to Optimization Controller
    - receives optimum decision elements from Optimization Controller
    - outputs optimum decision elements to Water Distribution Network

This method of control is very complex and may not be required to achieve the project objective.

3.4.6. Proprietary Dynamic Optimization Software

There is software available on the market that is able to communicate directly with the SCADA system and run the optimization automatically while using a hydraulic model such as EPANET to perform the network simulation. These systems are built for this purpose and would be easier to implement than the ‘build your own’ option presented above but could be more costly.

3.5.Summary of Literature Review

Lopez-Ibanez, Prasad and Paetcher (2008) define the water distribution network optimization problem as finding the best pump/fill schedule over a typical operating cycle such that total operational costs are minimised and operational constraints are maintained (such as available system pressures). The optimization of the Rous Water water distribution network is to be based on this same definition.

Much of the literature is focussed on optimized scheduling of water distribution pumping stations, and understandably so, as pump stations consume large amounts of electricity. The Rous Water distribution network is somewhat unique in that the large majority of reservoirs are supplied by gravity flow and there are only two water distribution pump stations in the network. These pump stations are known as the Newrybar Pumps and Lagoons Grass Pump Station. It should be noted also that the Lagoons Grass Pump Station is already controlled to only operate in off-peak tariff periods.

It is also important to note that these distribution pump station sites only have energy consumption charges and no energy demand charges, thus any savings will be considerably less than what can be achieved at the Nightcap WTP. The difference between possible savings from shifting energy consumption into lower cost tariff periods against avoiding peak energy demand is highlighted in Section 4.2.7.

The literature review shows that this project can be approached in multiple ways. The simplest option for achieving the project objective of reducing energy costs at Nightcap WTP is to utilise existing SCADA rules and functions. These rules and functions can be manipulated to set a rigid schedule of prioritised force filling of reservoirs followed by lock outs applied through tariff timers to avoid draining the reservoirs during the peak electricity tariff periods and effectively avoid starting the WTP. Also this method would not be dynamic and as such will not be able to adapt to unexpected events such as high water demands or power outages.

The second option, which is more complex, is to implement a dynamic optimization scheduler similar to those concepts presented by Cembrano. et al. (2000), Moreira and Ramos (2013) and Lopez-Ibanez, Prasad and Paetcher (2008). These systems can be built in house by linking a string of programs to perform each function such as EPANET-Matlab-SCADA in the roles of Demand Prediction Model-Optimization Control-SCADA. Matlab would be required to be programmed to perform the optimization and transfer of data to and from the other programs. Alternatively there are products available on the market which link directly to the SCADA and perform the optimization automatically such as Derceto Aquadapt and H2OMAP-Scheduler.

It is proposed to attempt the simpler, lower cost method of achieving the project objective, that being the scheduling of reservoirs and WTP production using the existing SCADA controls. The more complex and costly methods could be investigated in future if this simpler method is unsuccessful.

4. CHAPTER 4 – SYSTEM ANALYSIS AND MODELLING

4.1.Nightcap WTP Energy Audit

An energy audit was conducted for the Nightcap WTP to gain an understanding of the energy usage and the operation of plant and equipment at this facility.

The conducting of the energy audit followed the guidelines in Australian Standard 3598.2-2014. Further guidance in the process for conducting an energy audit was found in a paper entitled 'Improving Industrial Energy Audit Analyses' written by Barney and Lynne Capehart. This paper provided background on motor load factors and the difficulty in auditing their energy usage.

The energy audit process that was used for the Nightcap WTP is as follows:

- Site visit to Nightcap WTP
    - Record nameplate kW ratings of all significant pumps and equipment
    - Identify which pumps and equipment work on duty/standby arrangement. This will identify how many pumps and equipment are active during WTP operation.
    - Determine operating hours for the pumps and equipment through discussions with the WTP Operators
    - Identify pumps and equipment with known energy demand
    - Identify other energy using equipment at the WTP (eg: lights, air con, etc.) and approximate operating hours.
- Use data in Council asset register to identify kW ratings of pumps and equipment that were unable to be collected during site visit (eg: submersible pumps)
- Develop energy balance (audit) in spreadsheet including motor load factors and consideration of operating hours.
- Determine WTP energy demand (kW) and daily energy consumption (kWh) from energy balance and compare to actual average values.

The WTP staff who regularly operate and maintain the plant and equipment were able to identify a few items of equipment with known operating load and energy consumption. This information was also found on the remote touchscreen displays of the Variable Speed Drives (VSDs). The major item that had known electricity demand was the raw water (dam) pumps which had confirmed running at 90% load or 100kW each.

Based on advice given by Capehart & Capehart an efficiency for all other pumps and equipment where the energy demand was undetermined was selected as 40%.

The energy audit detail is included in Appendix B.

4.1.1. Batch and Continuous Duty Equipment

The majority of pumps and equipment at the WTP run continuous when the WTP is operating. The exception to this is pumps and equipment associated with batching of chemicals and backwashing of the filters. The batch time and frequency of these processes was determined through discussions with the WTP operators.

The energy consumption for batch duty equipment was calculated using the equipment kW rating, load factor, batch time, batch frequency and plant run times. The calculation for energy consumption for batch duty equipment is shown below through use of an example:

Equipment: **Backwash Pump 1 (55kW)**

Load Factor (LF): **40%**

Batch Time (BT): **13 minutes 40 seconds**

Batch Frequency (BF): **1 backwash every 3 hours 15 minutes plant run time (6 sand filters backwash every 25hrs, 6 BAC filters backwash every 90hrs)**

Plant Run Time (PRT): **14.35hrs per day (average)**

Energy Consumption = kW x LF x BT x PRT/BF

= 55kW x 0.4 x 0.228hrs x 14.35hrs / 3.25hrs

= **22.15kWh/day**

The calculation for energy consumption for continuous duty equipment is shown below through use of an example:

Equipment: **Raw Water Pump 1 (110kW)**

Load Factor (LF): **90%**

Plant Run Time (PRT): **14.35hrs per day (average)**

Energy Consumption = kW x LF x PRT

= 110kW x 0.9 x 14.35hrs

= **1420.65kWh per day**

4.1.2. Duty/Standby Equipment

The majority of large plant items at the WTP are designed with a duty/standby arrangement to allow redundancy for maintenance activities or breakdowns. Duty/standby is generally achieved by having two pumps installed when only one is utilised at a time. The current duty/standby arrangements for each set of pumps or drives was determined through discussions with the WTP operators.

4.1.3. Energy Audit Results

The results of the energy audit are shown below in Table 4.1 compared against average actual energy demand and consumption.

Demand		**Daily Consumption**	
kW-Audit	kW-Actual	kWh-Audit	kWh-Actual
655	645	8499	9441

Table 4.1 Energy Audit Results

The energy demand calculated from the audit is very close to the actual demand however the consumption is about 10% less. This is most likely a result of the broad assumption of pumps and equipment running at 40%.

The outcome of this energy audit was a better understanding of the WTP operation and major energy using equipment. A significant energy demand at the WTP is the operation of the Ozone/BAC system which accounts for around 150-200kW of the Nightcap WTP energy demand. The operation of the Ozone/BAC system should be reviewed to determine if there is an opportunity to reduce running of this treatment process however this is outside the scope of this project.

The energy audit also provides a base dataset of pumps and equipment energy ratings to allow potential modelling of other WTP operating scenarios such as running a third raw water (dam) pump.

The following sections provide a description of the energy usage at the Nightcap WTP.

4.2. Nightcap WTP Energy Analysis

Electricity data from the entire Nightcap WTP (including the Raw Water (Dam) Pumps and Waste Treatment Plant which are separately metered) has been analysed to determine the potential energy cost savings of achieving the project objectives. These estimated cost savings will also form part of the business case analysis when considering options to achieve the project objective.

The distribution (DLF) and transmission (MLF) loss factors for this site are currently 1.0912 and 1.0204 respectively.

4.2.1. Average Energy Demand

The average energy demand for the Nightcap WTP was determined by analysis of the daily maximum demands for the period from October 2012 to June 2013. The maximum daily energy demands for the combined meters at the Nightcap WTP are plotted on Figure 4.1 below.

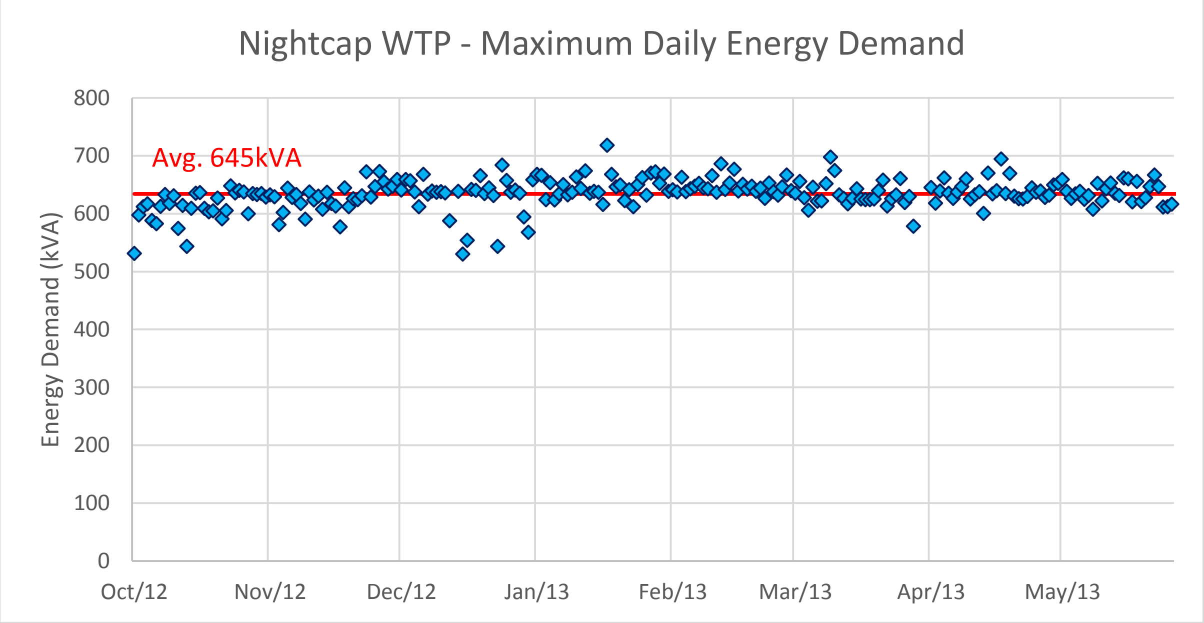


Figure 4-1 Nightcap WTP Maximum Daily Energy Demand

As the WTP has a continuous flow and fairly steady energy usage whilst in operation it is fair to draw the conclusion that the average maximum demand is reached frequently and is very likely to occur within every TOU tariff period during a month.

The average monthly maximum energy demand is 645kVA.

4.2.2. Base Energy Demand

The base energy demand for the Nightcap WTP was determined through inspection of daily kW demand trends.

The minimum daily energy demands for the combined meters at the Nightcap WTP are plotted on Figure 4.2 below.

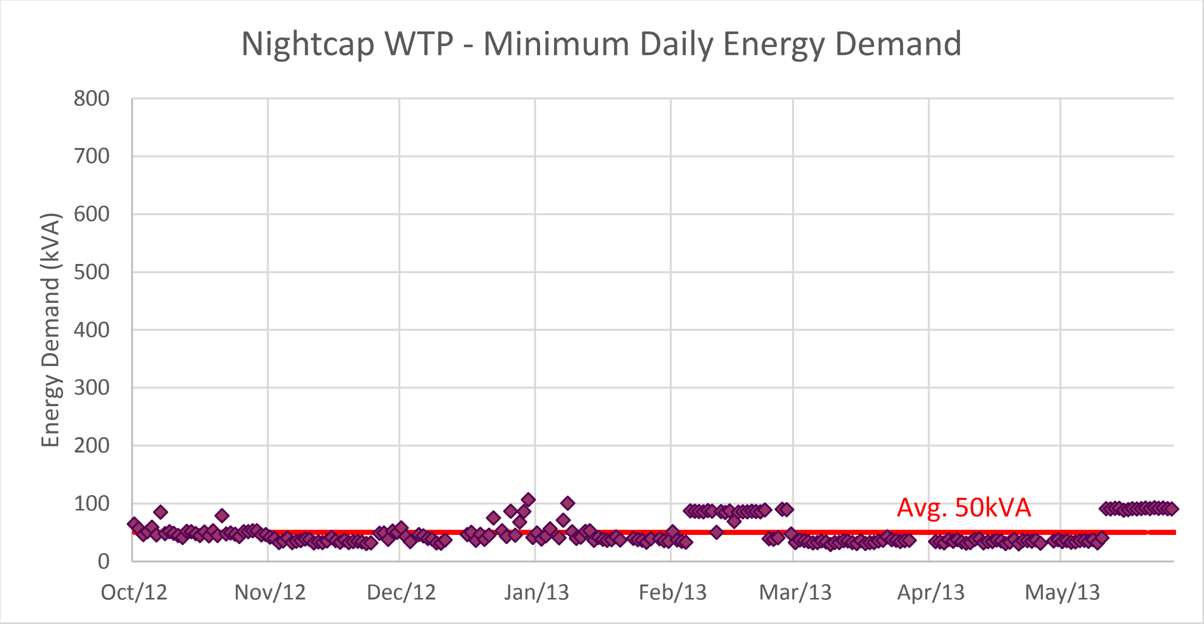


Figure 4-2 Nightcap WTP Maximum Daily Energy Demand

The average base energy demand of the combined meters for the Nightcap WTP is 50kVA.

4.2.3. Power Factor Analysis

The power factor (PF) is the relationship between real and apparent power. Power factors below unity result in higher kVA demand to maintain the required supply of energy. Power Factor Correction (PFC) units are installed on the majority of plant and equipment at the Nightcap

WTP. Figure 4.3 below shows the typical PF for both the WTP and the Raw Water Pumps/Waste Plant.

The average PF when the WTP is running is unity.

The average PF when the Raw Water pumps are running is 0.96.

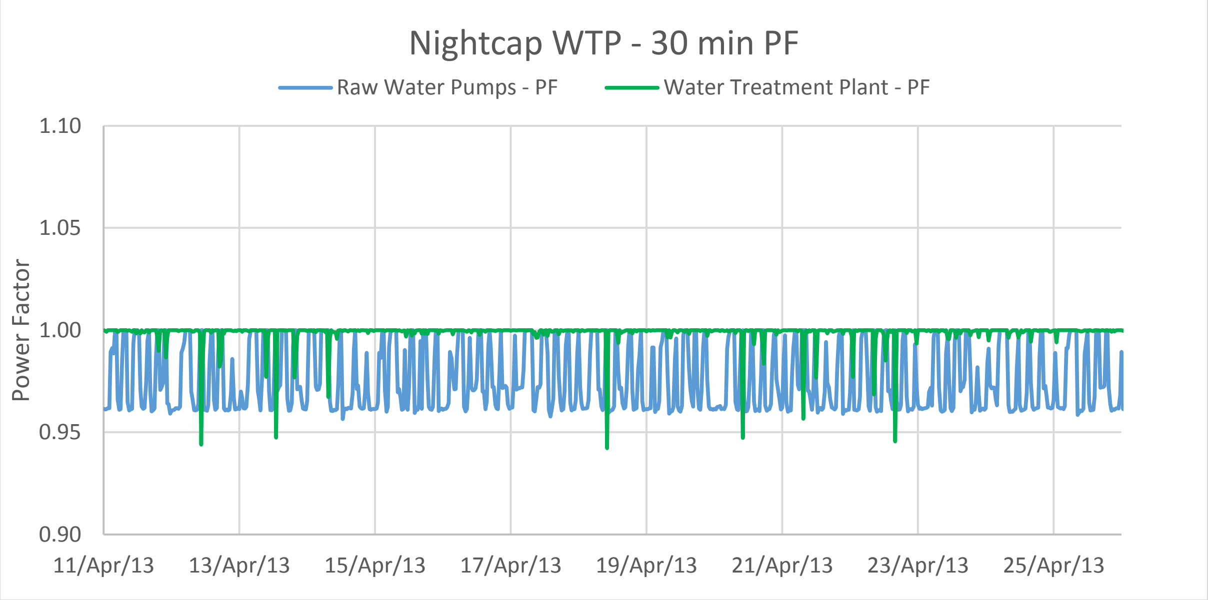


Figure 4-3 Nightcap WTP 30 Minute Power Factor

4.2.4. Daily Energy Usage Patterns

The WTP is automatically started when it receives a signal to fill the clear water storage reservoir. The filling of the reservoir is based on adjustable high and low set points. As such the WTP operates as required based on demand in the water distribution network.

Typical trends of daily energy demand are shown below as Figures 4.4 and 4.5. The TOU tariff periods have been overlaid onto the graphs.

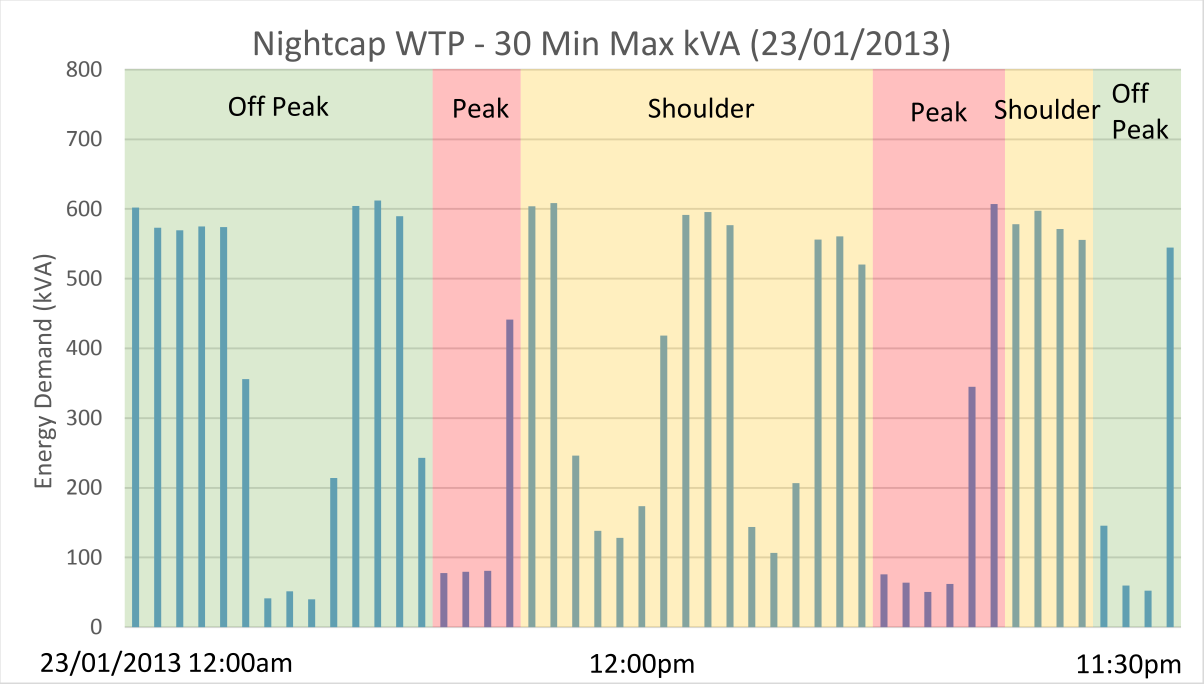


Figure 4-4 – 30 Minute Max kVA demand (23/01/2013)

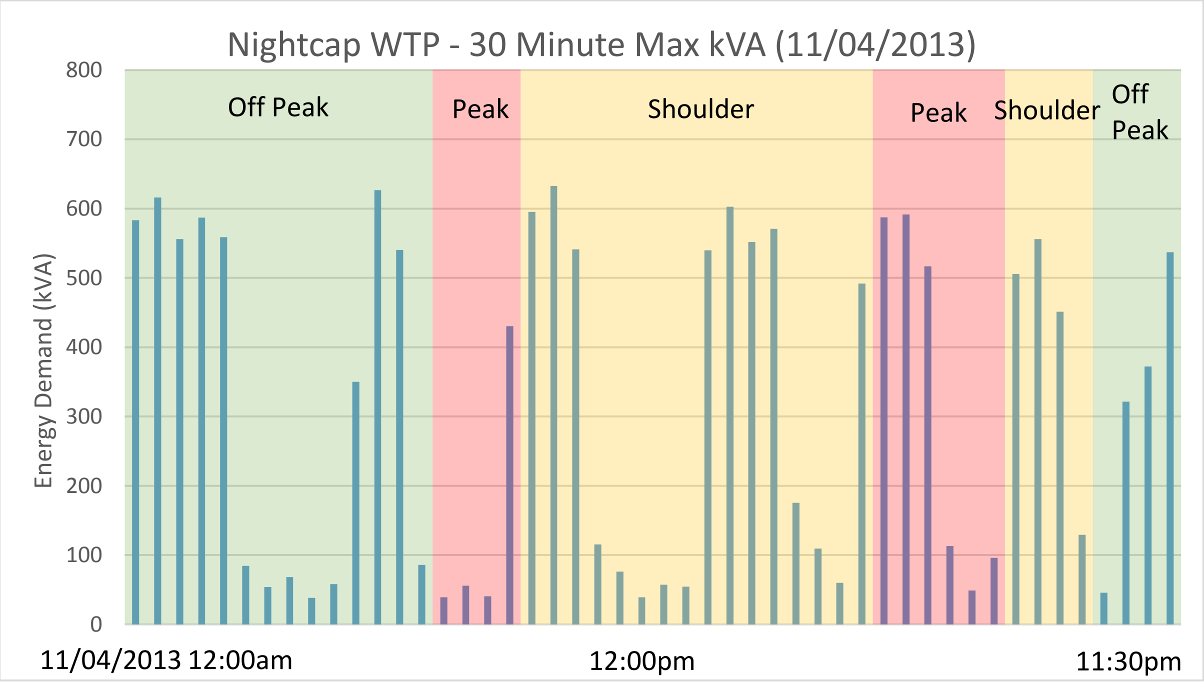


Figure 4-5 - 30 Minute Max kVA demand (11/04/2013)

The typical daily energy demand trends presented above show a regular cycle of operation of the WTP. The typical energy demand is aligned to WTP operation of 2 hours on and 2 hours off. It is clear the WTP is currently operated as required without consideration of the TOU tariff periods and the potential cost savings.

There is a noticeable larger run at midnight of around 2.5-3 hours. This is due to a large demand in the network as some reservoirs are controlled to fill at this time to avoid very high flows in the network which would affect consumer pressures.

The 30 min energy demand trends also show that when the WTP is running the energy demand is fairly constant. The trends appear to show ramp up and ramp down times at the WTP however this is misleading and is a consequence of the 30 min aggregated data.

4.2.5. Average Daily Energy Consumption

The average daily energy consumption for each of the TOU tariff periods was determined through analysis of the 30 minute kWh interval data. Electricity consumption from the weekends was excluded from the analysis as this is only charged at off-peak rates.

The average daily energy consumption for each TOU tariff period is shown in Table 4.2 below.

Tariff Period	**Avg. Daily kWh Consumption**
Off-peak	3655
Shoulder	3731
Peak	2055
TOTAL	9441

Table 4.2 Average Daily kWh Consumption

The proportions of energy usage for each tariff period are in line with the number of hours of each tariff period in a day and again shows the WTP is currently run to meet demand without consideration of the tariff periods.

4.2.6. Constraints for Estimating Cost Savings

As previously mentioned, the Nightcap WTP can accept water from both Rocky Creek Dam and the Wilson River. Energy costs to extract water from the Wilson River are significantly higher than extracting water from Rocky Creek Dam due to the distance and elevation difference. As discussed in Section 2.1.3.2, a condition of the Wilson River extraction license prohibits extraction of water unless Rocky Creek Dam is less than 95%.

Whether the water is sourced from Rocky Creek Dam or the Wilson River makes no difference to the optimized scheduling of the WTP run times. There are greater potential savings if the water is being sourced from the Wilson River because the energy demand for this site is very high and the energy consumption per ML is also very high as described in Section 2.1.3.3. For the purposes of this analysis the energy consumption and potential savings are based only on pumping from Rocky Creek Dam.

It should be noted that if the raw water is extracted only from Rocky Creek Dam without supplementing with water from the Wilson River, the raw water is generally of sufficient quality that the WTP can be operated without the Ozone/BAC. Not running the Ozone/BAC treatment process reduces the energy demand of the WTP considerably – approximately by half. However the WTP Operators advised that running the Ozone/BAC improves the retention of the chlorine residual through the network and reduces the organics in the water which reduces the biofilm build-up on the walls of the pipes in the water distribution network.

For the purposes of this analysis the energy consumption and potential savings will include running of the Ozone/BAC.

4.2.7. Calculation of Estimated Cost Savings

Using the average data for the electricity usage at Nightcap WTP the cost savings were estimated using the contract energy rates being offered by the electricity retailer and the network rates offered by the distributor.

Two calculations were performed to provide a sensitivity analysis. The first calculation was based on the WTP producing water in 100% of the available Off-peak hours with the remaining consumption in the Shoulder period. The second calculation was based on the WTP producing half the water in Off-peak and the other half in Shoulder.

It should be noted also that any savings realised by shifting energy consumption to a lower cost tariff period is limited to weekdays only as weekends are currently charged only at Off-peak.

Table 4.3 below details the calculations to derive the maximum possible cost savings.

Calculations – Maximum Possible	**Offpeak**	**Shoulder**	**Peak**
Available TOU tariff period hours	9	10	5
Current WTP hours for average day *(avg. day kWh/avg. kW demand)*	5.26	5.37	2.96
Current utilisation for average day *(current hours/available hours)*	58%	54%	59%
Optimized WTP hours for average day *(100% offpeak, remainder in shoulder)*	9	4.59	0
Changes to TOU tariff period hours *(+increase, -decrease)*	+3.74	-0.78	-2.96
Changes to daily kWh consumption *(TOU hours changes/avg. kW demand) (+increase, -decrease)*	+2598	-543	-2055
Loss adjusted kWh consumption charges *(combined retailer and distributor)*	$0.0654	$0.1004	$0.1004
Daily energy consumption savings *(consumption charges*changes to daily consumption) (+saving,-expense)*	-$169.92	+$54.49	+$206.36
Total Energy Consumption Savings/Month *(note: savings only realised on weekdays)*	**$1,976.12**		
Changes to kVa demand *(avg. kW demand*PF – base load kW*PF) (+increase, -decrease)* *(note: any run hours of the WTP will generate the average kW demand)*	0	0	-595
Loss adjusted kVa consumption charges *(combined retailer and distributor)*	$3.418	$14.955	$14.955
Demand charge savings *(demand charges*changes to kVa demand) (+saving,-expense)*	0	0	+$8,898.23
Total Energy Demand Savings/Month	**$8,898.23**		
TOTAL POTENTIAL SAVINGS/MONTH	**$10,874.35**		

Table 4.3 Potential Energy Cost Savings - Maximum

Table 4.4 below details the calculations to derive the typical cost savings.

Calculations – Typical Savings	**Offpeak**	**Shoulder**	**Peak**
Available TOU tariff period hours	9	10	5
Current WTP hours for average day *(avg. day kWh/avg. kW demand)*	5.26	5.37	2.96
Current utilisation for average day *(current hours/available hours)*	58%	54%	59%
Optimized WTP hours for average day *(50% offpeak, 50% shoulder)*	6.79	6.79	0.00
Changes to TOU tariff period hours *(+increase, -decrease)*	1.53	1.42	-2.96
Changes to daily kWh consumption *(TOU hours changes/avg. kW demand) (+increase, -decrease)*	+1065	+990	-2055
Loss adjusted kWh consumption charges *(combined retailer and distributor)*	$0.0654	$0.1004	$0.1004
Daily energy consumption savings *(consumption charges*changes to daily consumption) (+saving,-expense)*	-$69.62	-$99.37	+$206.29
Total Energy Consumption Savings/Month *(note: savings only realised on weekdays)*	**$810.26**		
Changes to kVa demand *(avg. kW demand*PF – base load kW*PF) (+increase, -decrease)* *(note: any run hours of the WTP will generate the average kW demand)*	0	0	-595
Loss adjusted kVa consumption charges *(combined retailer and distributor)*	$3.418	$14.955	$14.955
Demand charge savings *(demand charges*changes to kVa demand) (+saving,-expense)*	0	0	+$8,898.23
Total Energy Demand Savings/Month	**$8,898.23**		
TOTAL POTENTIAL SAVINGS/MONTH	**$9,708.49**		

Table 4.4 Potential Energy Cost Savings - Typical

The above calculations highlight the possible savings that would be realised by achieving the project objectives. The energy demand charge is the largest component of the savings calculations, so long as the WTP is run outside of the Peak TOU tariff period hours the savings per month will be approximately $10,000. This figure will be used in preparation of a business case to seek funding for this project if required.

4.2.8. Power Outages

The Nightcap WTP is located at Dorroughby NSW on the edge of the Nightcap National Park. The closest town is Lismore approximately 30km south. The power supply to the WTP is subject to a lower service level than what would normally be available in more densely populated areas. The likelihood of power outages is high although the energy distributor in the area has provided dual incoming power supply points to minimise the frequency and length of power supply interruptions.

Power supply interruptions are generally caused by severe storm events or otherwise planned maintenance on the electricity distribution network and on average occur 3-4 times per year, particularly in summer during the storm season. In the case of planned maintenance, there is generally ample time to manually force fill the distribution system to avoid impacting the ability to supply water.

Interruptions to the power supply result in the WTP being unable to produce water. This will also result in the WTP having to catch up the water supply requirements when the power supply is reinstated. Energy outages are therefore likely to require the WTP to produce water during the peak tariff periods thereby negating the energy demand saving for the month in which this occurs.

4.2.9. Emergency Generators

Rous Water is currently investigating the use of generators at the Nightcap WTP to provide backup power supply in the event of a network power supply interruption. The generators will have sufficient capacity to run the WTP at normal flow rates until power supply is reinstated – except for extended outages. The generators will be required to be run periodically for maintenance and to ensure they are in working order in case of an emergency event.

It is possible that peak water demands from the water distribution network will require the WTP to run for longer periods than normal and run into peak electricity tariff periods. It may be possible to utilise the emergency generators to run the WTP during the peak electricity tariff periods thus avoiding the use of network power. The use of the generators in this way will likely achieve a higher success rate in avoiding peak energy usage from the electricity network – in particular in the summer months when peak water demands and severe weather power outages are expected to occur.

The use of generators will be investigated further following their installation and commissioning in the coming years.

4.3. Water Distribution System Analysis

Water distribution networks are typically complex dynamic systems which operate in response to consumer demand. Modelling of these systems allows for prediction and evaluation of the effects of specific changes in the actual network. The modelling task is normally undertaken by proprietary computer modelling software such as EPANET or H2OMAP. These systems are capable of modelling flows and pressures in the system over long periods of time and can take into account different reservoir control methods, valves, pumps and rule based controls such as timers.

To determine the changes required in the water distribution network to achieve the project objectives the Rous Water system was modelled in both Microsoft Excel as the H2OMAP program was unavailable at the time. Further validation of the preferred option will be conducted in H2OMAP in the future.

The modelling was performed using the average daily demand. The Peak:Average ratio in the Rous Water bulk supply network is approximately 2.5 (Campbell, 2012). It is expected that Peak day demands will deplete the reservoir storage capacities in the Rous Water network and will require the WTP to operate in peak electricity tariff periods. Peak day demands typically occur during the warmer summer months or in the event of a major pipe burst. An estimation of these occurrences and subsequent reduction in viability will be taken into account in the conclusion of this project.

To enable accurate modelling of the bulk water distribution system sufficient information must be known about the system. The required data includes:

- average day demand for all supply points
- typical flow rates
- reservoir control systems
- reservoir capacities and set points
- advanced system controls (city view timer, lagoons grass pump timer)
- retail consumers on the bulk supply system

4.3.1. Average Day Demand

The existing average day demand (ADD) for both the entire water distribution system and individual supply points was determined from analysis of daily consumption data from 2001-2015. Daily demands vary due to changes in customer demand and reservoir set points. Some reservoirs in the Rous Water network feed multiple times per day where others feed once every couple of days.

Some example sites are shown below as Figures 4.6 and 4.7.

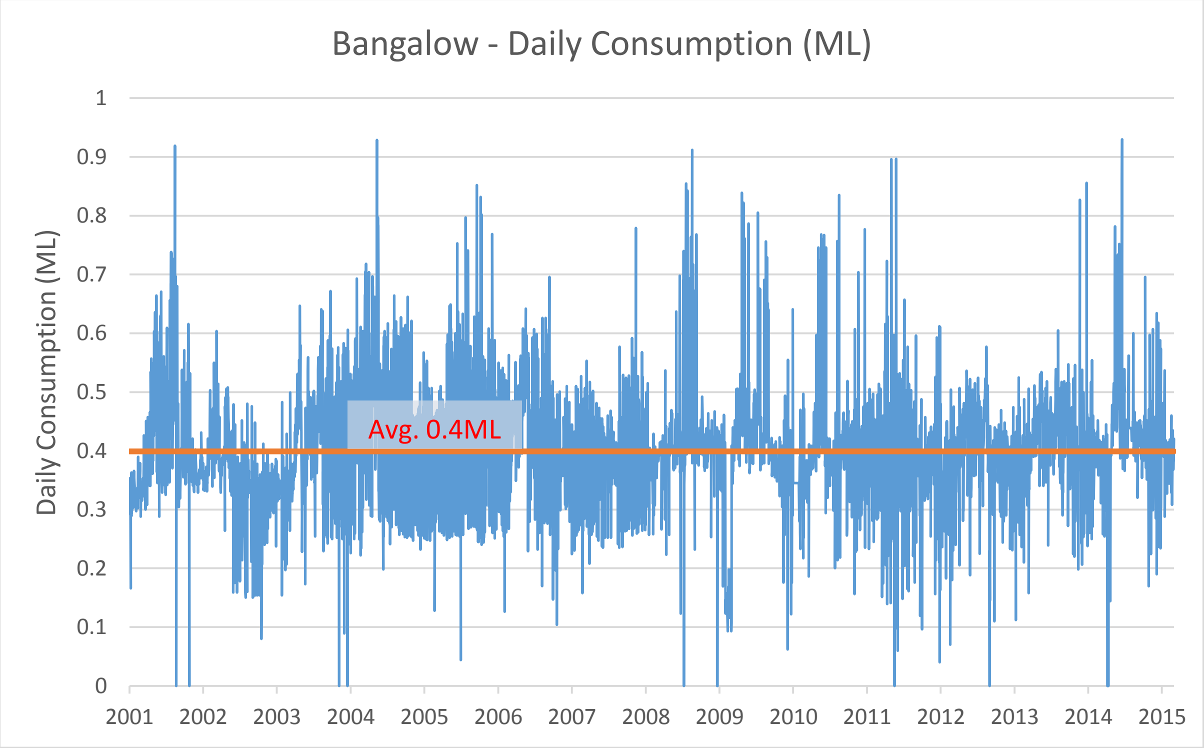


Figure 4-6 Daily Water Consumption - Bangalow

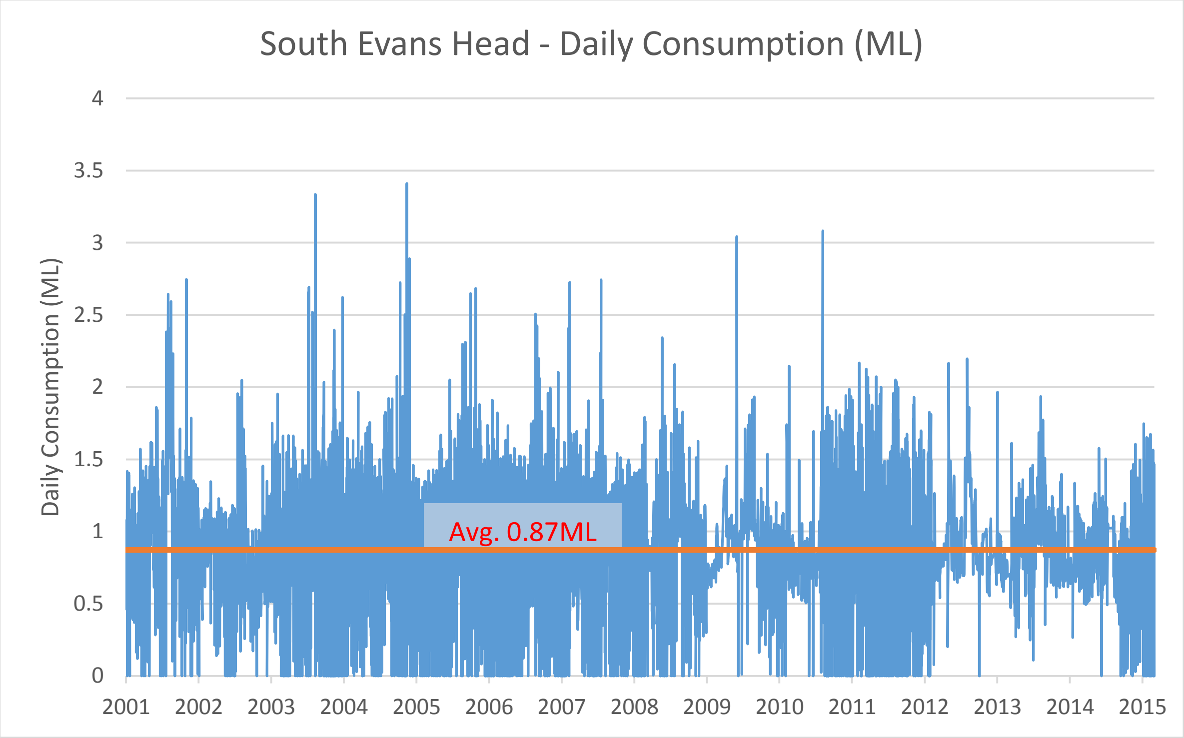


Figure 4-7 Daily Water Consumption - South Evans Head

The ADD of all reservoirs and direct supply points in the water distribution network are shown in Table 4.5. The reservoirs in italics are balance tanks and their average daily demand is passed through to downstream dependent reservoirs and Rous Water retail connections.

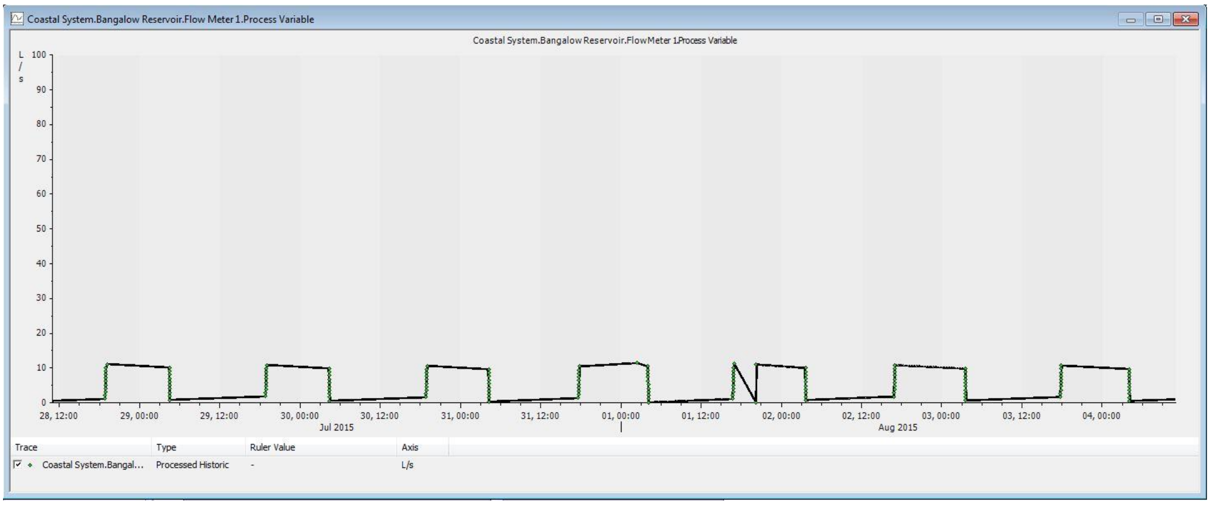
Reservoir/Supply Point	**Avg Daily Demand (ML)**
Nightcap CWSR	*28.653*
Dunoon	0.421
Clunes	0.146
Bangalow	0.399
St Helena	*6.853*
Coopers Shoot	2.491
Wategoes	0.137
Patterson St (Byron Bay)	1.491
Brunswick	0.592
Yamble	1.116
Warrambool	0.336
Knockrow	*6.864*
Newrybar/Tintenbar	0.281
Ballina Heights	0.424
Ross Lane 200	0.110
Ross Lane 450 (Pine Ave)	5.086
Water Wheels	2.557
Pineapple Rd	0.016
Holland St	1.342
Wollongbar	1.773
Ross St	2.557
Tullera	0.101
High St No.4	1.510
Belvedere No.9	2.718
City View Drive	*2.203*
Tanelawn	0.174
Coraki	0.340
Langs Hill	*0.449*
Woodburn Retic	0.193
Broadwater	0.269
Sth Evans Head	0.871

Table 4.5 Distribution Network Average Day Demand

4.3.2. Typical Inflows

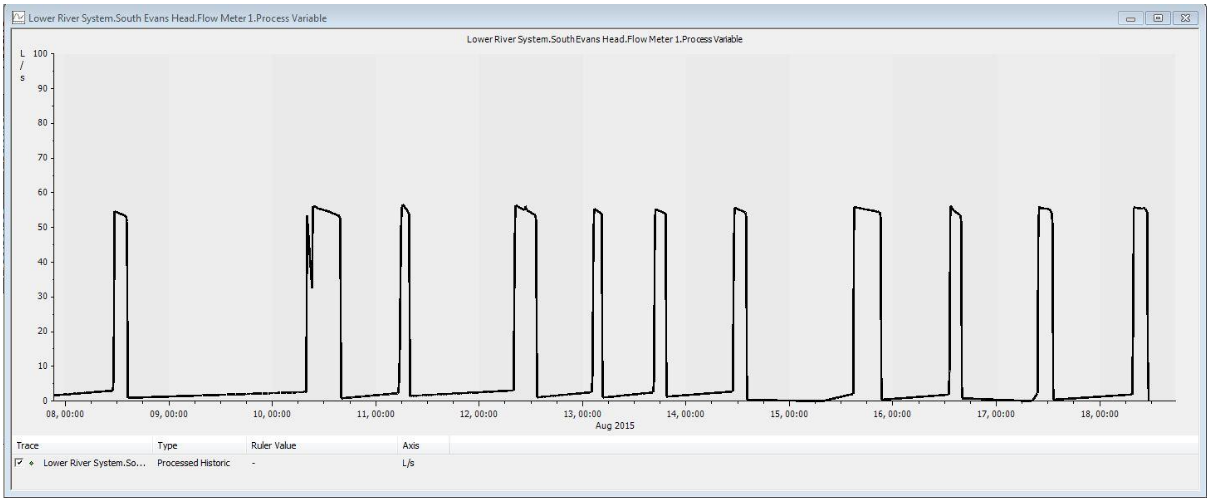
The Rous Water distribution network is predominantly a bulk water supply system. Operation of the network is based on reservoir set points which open and close the bulk supply pipelines to fill the reservoirs. Therefore flows in the network are fairly constant and not subject to varying consumer demand. There are roughly 2000 retail connections on the bulk water supply network however these have minimal impact on the normal flow rates through the system.

Figures 4.8 and 4.9 below are screenshots taken from the SCADA system of the actual inflows to Bangalow and South Evans Head Reservoirs respectively. The graphs show when the reservoirs are feeding the flows are constant. Consistent inflow rates are typical of the entire water distribution network.



Trace	Type	Ruler Value	Axis
☑ Coastal System.Bangal...	Processed Historic	-	L/s

Figure 4-8 Typical Inflows - Bangalow



Trace	Type	Ruler Value	Axis
☑ Lower River System.So...	Processed Historic	-	L/s

Figure 4-9 Typical Inflows - South Evans Head

The typical inflow rate for modelling of all reservoirs and direct supply points in the water distribution network is shown in Table 4.6.

Reservoir/Supply Point	**Typical Inflow Rate**
Nightcap CWSR	600
Dunoon	34
Clunes	diurnal
Bangalow	11
St Helena	170(+50 constant)
Coopers Shoot	150
Wategoes	25
Patterson St (Byron Bay)	64
Brunswick	18
Yamble	30
Warrambool	22
Knockrow	260
Newrybar/Tintenbar	9
Ballina Heights	25
Ross Lane 200	diurnal
Ross Lane 450 (Pine Ave)	70
Water Wheels	32 (constant)
Pineapple Rd	7.5
Holland St	75
Wollongbar	140(+10 constant)
Ross St	200
Tullera	18
High St No.4	410
Belvedere No.9	175
City View Drive	200
Tanelawn	22
Coraki	10
Langs Hill	50
Woodburn Retic	diurnal
Broadwater	8
Sth Evans Head	55

Table 4.6 Distribution Network Typical Inflows

A number of sites have a constant flow at all hours of the day. The Water Wheels site has been throttled to provide a constant flow of 32L/s to maintain chlorine residuals and reduce management of the site for water age issues.

St Helena site has a constant flow from a secondary supply pipeline of 50L/s. The secondary pipeline is in poor condition and flow is maintained to lower the pressure in the pipeline thus reducing pipeline break frequency and intensity. This constant flow is insufficient to maintain the required water level in the reservoir and the primary bulk supply pipeline opens and supplies water to the reservoir at approximately 170L/s.

The Wollongbar site is supplied by gravity flow throughout the day at approximately 10L/s however this is insufficient to maintain the required water level in the reservoir. A distribution pump station is operated as required to boost the supply to this reservoir to 150L/s.

4.3.3. Reservoir Control Systems

Rous Water reservoirs are operated by the control systems described in Section 2.2.2. The identification of control system is important to this project as the modelling will first be conducted on the available control functionality before investigating additional control functionality. Table 4.7 below presents a description of the different control systems.

Control System	Description
Hydraulic Control Valve	Mechanical valve operated on reservoir high and low set points via pilot lines and springs
Hydraulic Control Valve - Remote	Mechanical valve operated on reservoir high and low set points via pilot lines and springs. With remote open and close functionality via solenoid valves
Actuated Control Valve	Electrically actuated valve operated on reservoir high and low set points
Pump Loop	Pumped flow operated on reservoir high and low set points
Direct Supply - Diurnal	Supply direct into reticulated network which exhibits diurnal demand pattern
Constant Feed	Constant flow through supply point

Table 4.7 Reservoir Control System Descriptions

The control systems for each reservoir to be modelled are shown below in Table 4.8.

Reservoir/Supply Point	Control System
Nightcap CWSR	Pump Loop (WTP)
Dunoon	Pump Loop
Clunes	Direct Supply - Diurnal
Bangalow	Hydraulic Control Valve
St Helena	Hydraulic Control Valve - Remote
Coopers Shoot	Hydraulic Control Valve
Wategoes	Hydraulic Control Valve
Patterson St (Byron Bay)	Actuated Control Valve
Brunswick	Hydraulic Control Valve
Yamble	Actuated Control Valve
Warrambool	Hydraulic Control Valve
Knockrow	Hydraulic Control Valve - Remote
Newrybar/Tintenbar	Pump Loop
Ballina Heights	Actuated Control Valve
Ross Lane 200	Direct Supply - Diurnal
Ross Lane 450 (Pine Ave)	Hydraulic Control Valve
Water Wheels	Constant Feed
Pineapple Rd	Hydraulic Control Valve
Holland St	Pump Loop
Wollongbar	Pump Loop
Ross St	Hydraulic Control Valve - Remote
Tullera	Actuated Control Valve
High St No.4	Actuated Control Valve
Belvedere No.9	Actuated Control Valve
City View Drive	Actuated Control Valve
Tanelawn	Pump Loop
Coraki	Hydraulic Control Valve
Langs Hill	Hydraulic Control Valve
Woodburn Retic	Direct Supply - Diurnal
Broadwater	Hydraulic Control Valve
Sth Evans Head	Hydraulic Control Valve

Table 4.8 Distribution Network Control Systems

4.3.4. Reservoir Capacities and Set Points

The low and high water level set points for each reservoirs are based on 0% being empty (outlet pipe invert) and 100% being full (overflow pipe invert). As described in Section 2.2.1 reservoirs are operated to achieve a number of often competing objectives. As a result of these operational objectives the water level in the reservoirs is controlled within a smaller range than the full 0-100% span.

Table 4.9 below is a summary of the reservoir capacities and set points for use in modelling. The set points can be changed by Rous Water operations staff to achieve different operational objectives however the set points identified in the table below are typical of the normal set up for the bulk water supply system. These are the current SCADA set points as of 18/08/2015.

Reservoir/Supply Point	Capacity (ML)	Low Set Point	High Set Point
Nightcap CWSR	13.00	72%	88%
Dunoon	2.00	50%	55%
Clunes	direct		
Bangalow	0.90	61%	95%
St Helena	9.10	50%	75%
Coopers Shoot	2.43	72%	87%
Wategoes	0.50	69%	74%
Patterson St (Byron Bay)	2.70	80%	85%
Brunswick	3.68	79%	82%
Yamble	6.00	45%	50%
Warrambool	0.89	78%	82%
Knockrow	10.00	65%	81%
Newrybar/Tintenbar	0.23	50%	90%
Ballina Heights	5.60	45%	55%
Ross Lane 200	direct		
Ross Lane 450 (Pine Ave)	20.00	88%	98%
Water Wheels	direct		
Pineapple Rd	1.00	89%	94%
Holland St	10.00	89%	96%
Wollongbar	10.00	70%	90%
Ross St	6.70	70%	89%
Tullera	1.00	60%	65%
High St No.4	4.50	75%	87%
Belvedere No.9	3.40	75%	85%
City View Drive	9.10	81%	88%
Tanelawn	0.25	50%	80%
Coraki	0.90	81%	95%
Langs Hill	4.50	50%	70%
Woodburn Retic	direct		
Broadwater	0.20	53%	73%
Sth Evans Head	4	70%	92%

Table 4.9 Reservoir Capacities and Set Points

4.3.5. Existing System Controls and Constraints

To manage specific issues within the Rous Water bulk water supply system existing controls are already in place as described below.

4.3.5.1. City View Drive Reservoir Lockout

The City View Drive reservoir in Lismore NSW is a key balance tank for supply to the lower river reservoirs. The average daily throughput of this reservoir is 2.2ML and the typical inflow rate is 200L/s (this figure has been calculated by water balance and reservoir drop test as the inflow is currently unmetered).

City View Drive reservoir is dependent on the Nightcap CWSR. A number of other large reservoirs with high inflows are also dependent on the Nightcap CWSR. For this reason the actuated inlet valve to the city view drive reservoir has a tariff timer lockout applied to allow other reservoirs a chance to feed without reducing system pressures to unacceptable levels.

The tariff timer lockout prevents the valve from opening during the following times:

6:00 AM - 12:00 PM
and
3:00 PM - 12:00 AM

4.3.5.2. Lagoon Grass Pump Station Lockout

Lagoon Grass Pump Station supplies water to Wollongbar and Holland St Reservoirs. The pump station is operated to boost the supply to these reservoirs to meet demand requirements. As was the case for City View Drive reservoir, this pump station has a tariff timer lockout applied to prevent reducing system pressures to unacceptable levels during hours when residents are likely to be awake.

The tariff timer lockout prevents the pumps from operating during the following times:

7:00 AM - 10:00 PM

An additional benefit of this tariff timer lockout is that it prevents the operation of the pumps during peak and shoulder electricity tariff periods thereby reducing energy costs for this site.

For the modelling and implementation phase of this project these existing controls will be left in place unless there is sufficient justification to remove them.

4.3.6. Rous Water Retail Customer Consumption

On the Rous Water bulk water supply system there are approximately 2000 retail connections. These connections supply a range of consumers including rural properties, rural residential subdivisions and small villages.

To determine an average daily consumption for the Rous Water retail connections the last three years total retail consumption was averaged across the number of connections. This is shown below in Table 4.10.

Financial Year	Total Retail Consumption (kL)
2012/13	737530
2013/14	786484
2014/15	767164
Average Consumption	**763726**
Average per Connection	**1.0462**

Table 4.10 Rous Water Retail Customer Average Daily Consumption

The average daily consumption for the Rous Water retail connections is approximately 1kL/connection/day. This figure is higher than the standard 630L/equivalent tenement/day figure determined by the NSW Water Directorate (BSC, 2007). The higher consumption is attributed to the majority of the rural connections which also supply troughs and outbuildings and have long private service lines with higher undetected leakage.

Generally the custody of the bulk water is transferred from Rous Water to the Constituent Councils at the inlet or outlet of a reservoir. In these case the consumption of the downstream residents is captured by the inflow or outflow of the reservoir.

Where the reservoir is a balance tank the outflow also includes the consumption of the Rous Water retail connections between the balance tank and its downstream dependent reservoirs.

Table 4.11 below lists the number of retail connection and their consumption contributing to the outflow of the Rous Water balance tanks.

Balance Tank	D/S Retail Connections	D/S Retail Consumption (ML)
Nightcap CWSR	825	0.863
St Helena	408	0.427
Knockrow	121	0.127
Newrybar	269	0.281
City View Drive	370	0.387
Langs Hill	30	0.031

Table 4.11 Rous Water Retail Customer Distribution

4.4. Water Distribution System Modelling

4.4.1. Model Development – Microsoft Excel

A significant feature of the Rous Water distribution network is that the reservoirs generally feed at a constant flow rate when filling. For example, when Bangalow Reservoir is calling for water the inflow rate is 11L/s and this flow rate is largely independent of what else is happening in the network.

The Rous Water distribution network was modelled in Microsoft Excel using a water balance model based on a 15 minute time step. At each time step inflows and outflows were recorded for the reservoirs (including Rous Water retail consumers) to determine the new reservoir level.

4.4.1.1. Modelled Water Demand

Demand in the water distribution network was modelled using a standard diurnal pattern. The pattern selected is the standard diurnal demand pattern used by Rous Water for hydraulic modelling purposes. The diurnal water demand pattern is shown below as Figure 4.10. There is a large morning peak demand at 7:00am and an afternoon peak at 7:00pm which reflect typical household demand. The saddle between morning and peak demands is fairly high and is representative of business and industrial water use. It also captures the background usage through the night which is predominantly attributed to system leakage. As this diurnal pattern represents both residential and commercial use of the water the modelling task is simplified.

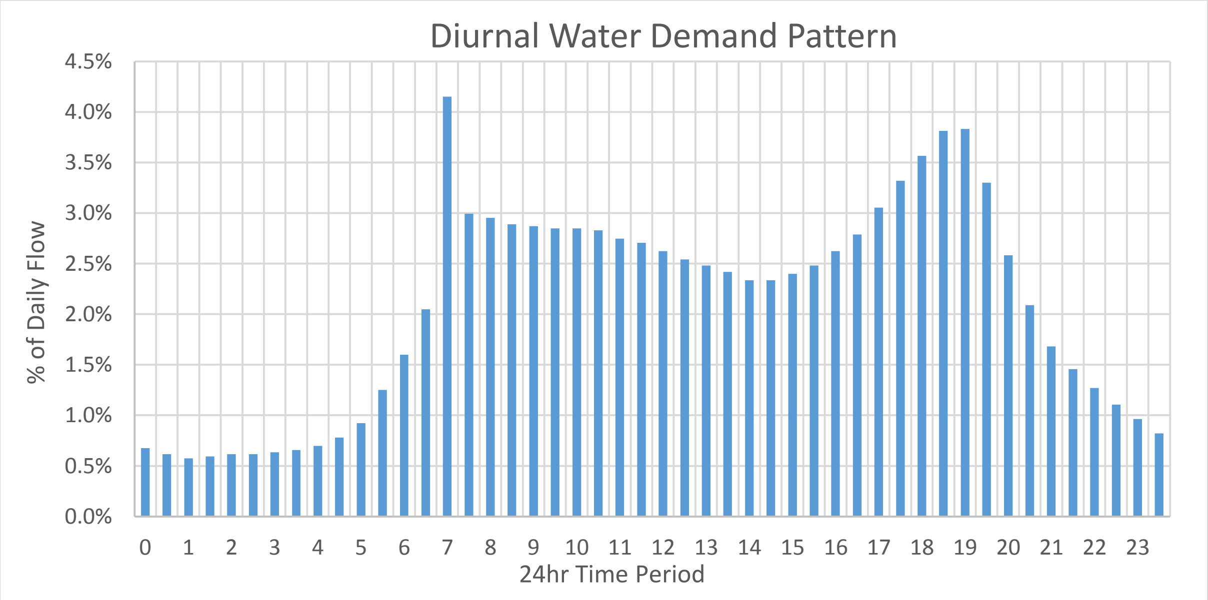


Figure 4-10 Rous Water Diurnal Water Demand Pattern

4.4.1.2. Reservoir Modelling

The inflow to the reservoirs is controlled by reservoir inlet control valves which are opened and closed depending on the reservoir set points. For example Bangalow Reservoir has an open set point at 63% and a close set point at 95%. A graph of this reservoir modelled over 10 days is shown below as Figure 4.11.

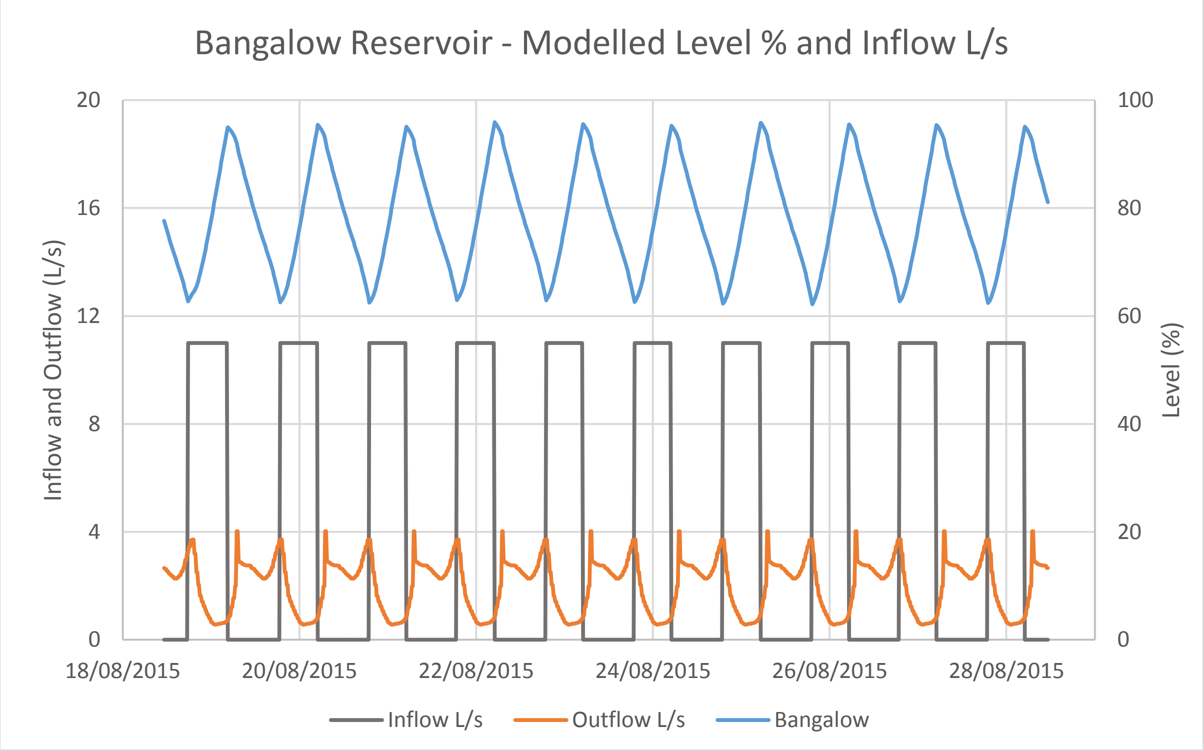


Figure 4-11 Example Modelled Reservoir Levels (Bangalow)

Outflows from most reservoirs are derived from end point user consumption such as supply to towns and industrial areas. The outflow from these reservoirs is based on current diurnal demand patterns used by Rous Water for hydraulic modelling.

The outflow from reservoirs supplying end point consumers only has been modelled by distributing the Average Daily Demand (ADD) according to the diurnal pattern shown in Figure 4.10. For example Bangalow Reservoir has an average daily outflow demand of 399kL. This has been distributed by the diurnal pattern as shown below in Figure 4.12.

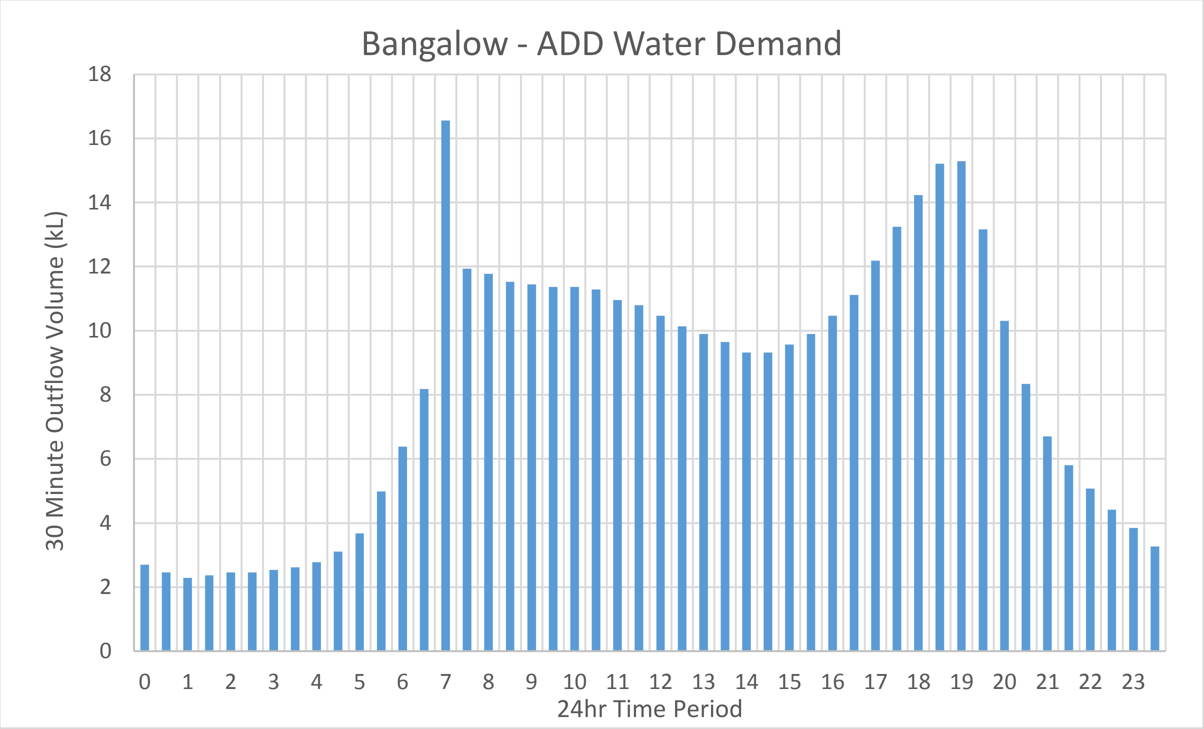


Figure 4-12 Example Modelled Diurnal Water Demand (Bangalow)

A number of reservoirs in the Rous Water network also supply downstream dependent reservoirs. Reservoirs with downstream dependency are known as ‘balance tanks’. Balance tanks are only located within the Rous Water network and are not a point of supply to the constituent councils. The outflow from Rous Water balance tanks is a combination of supply to the downstream dependent reservoirs and consumption by the Rous Water retail customer connections.

As an example City View Drive Reservoir has four downstream dependent reservoirs and 400 downstream Rous Water retail connections. The retail connection demand is distributed according to the diurnal pattern however the downstream dependent reservoirs demand is generated by the downstream reservoirs according to their outflow and level set points. Figure 4.13 below shows a typical balance tank outflows.

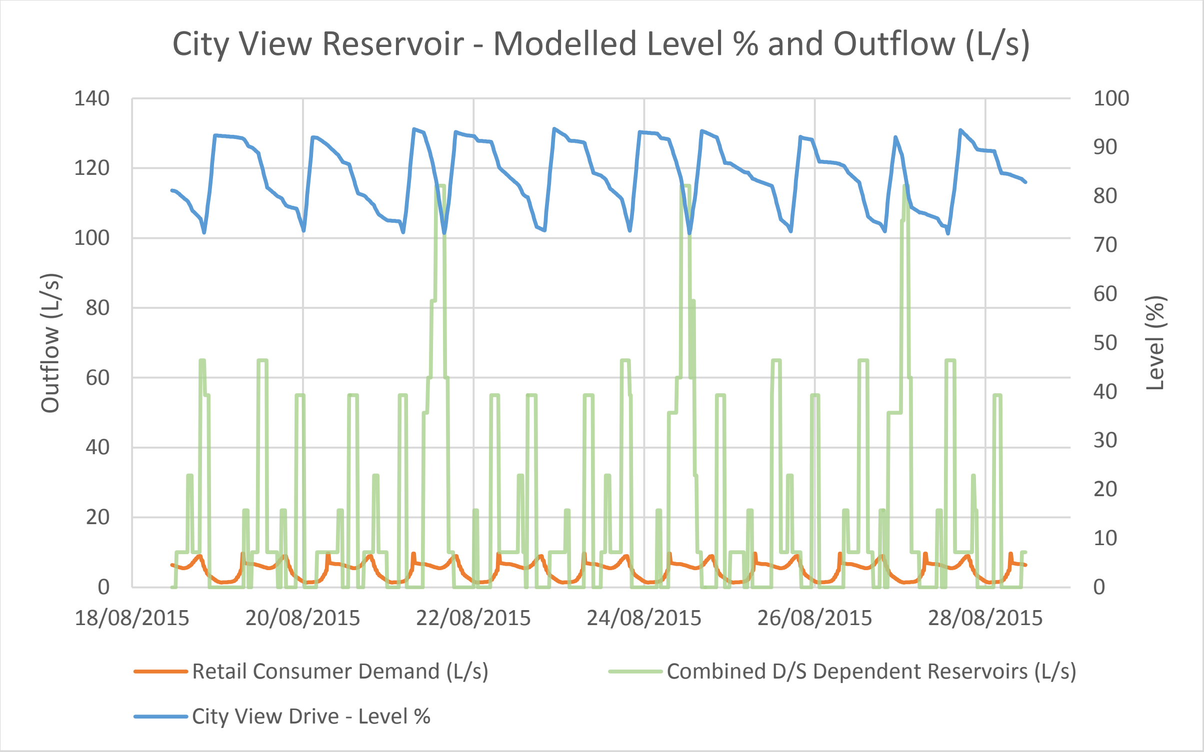


Figure 4-13 Example Modelled Reservoir Levels (City View Drive)

In addition to the reservoirs there are a small number of direct supply points in the network where the water is distributed directly into the reticulated water network of the constituent councils. The direct supply points are simply modelled by distributing the ADD over the diurnal pattern as was the case for the reservoir with only end point user consumption.

4.4.1.3. Initial Reservoir Water Levels

Ultimately the water levels in the reservoirs drive the opening and closing of the water distribution network and the operation of the WTP to produce water. The model was initiated using a snapshot of reservoir water levels in the Rous Water distribution network reservoirs at 11.15am on 18/08/2015. The filling status of the reservoir was recorded at the same time as recording the reservoir water level. The levels and filling status were obtained from the ClearSCADA system and are shown in Table 4.12.

Reservoir/Supply Point	Initial Reservoir Water Level (%)	Filling?
Nightcap CWSR	82.19	No
Dunoon	54.75	No
Clunes	direct	
Bangalow	77.68	No
St Helena	65.71	No
Coopers Shoot	75.38	No
Wategoes	70.99	No
Patterson St (Byron Bay)	84.86	No
Brunswick	79.8	Yes
Yamble	47.25	Yes
Warrambool	77.71	Yes
Knockrow	66.93	Yes
Newrybar/Tintenbar	53.86	Yes
Ballina Heights	51.08	No
Ross Lane 200	direct	
Ross Lane 450 (Pine Ave)	93.43	Yes
Water Wheels	constant	
Pineapple Rd	89.09	Yes
Holland St	97.04	No
Wollongbar	84.31	No
Ross St	78.49	No
Tullera	59.89	No
High St No.4	86.63	No
Belvedere No.9	79.59	No
City View Drive	81.19	No
Tanelawn	65	No
Coraki	83.04	No
Langs Hill	62.27	No
Woodburn Retic	direct	
Broadwater	71.94	No
Sth Evans Head	92.65	No

Table 4.12 Modelling - Initial Reservoir Water Levels

4.4.1.4. Timestep Example

The Microsoft Excel model is based on a 15 minute water balance. At each timestep inflows and outflows are calculated for each reservoir/direct supply point in the water distribution network.

Outflows are generated by Rous Water retail consumer demand and downstream dependent reservoir feeds. Inflows are either constant or controlled through the reservoir high and low set point controls.

The best way to describe the water balance model is through use of an example. The example will show an arbitrary timestep of the St Helena reservoir. This reservoir is a key balance tank in the Rous Water network and was selected for the example as it has all forms of inflow and outflow.

ST HELENA RESERVOIR

Low Set Point (LSP): 50% **High Set Point (HSP):** 75%

Typical Inflow (TI): 170L/s **Constant Inflow (CI):** 50L/s

Reservoir Capacity (RC): 9.1ML **Retail Consumer Demand (RD):** 0.427ML

Timestep: 18/08/2015 4:45 PM **Reservoir Level (RL):** 55.153%

Previous Timestep Inflow (PTI): 50L/s

Inflow = Constant Inflow + Control Based Inflow

Constant Inflow = *CI* = 50L/s

Control Based Inflow = IF(PTI<=CI,IF(RL<(LSP),TI,0),IF(RL>(HSP),0,TI))+CI

= IF(50<=50,IF(55.153<(50),170,0),IF(55.153>(75),0,170))+50

= 50L/s

Inflow = 50L/s

Total Inflow Volume (15min) = 50L/s x 900sec/1000000 = 0.045ML

Outflow = Retail Consumer Demand + Inflows of Dependent Reservoirs

Retail Consumer Demand = RD x % of Daily Flow at Timestep (Diurnal Pattern)

= 0.427ML x 1.39% = 0.0059ML

Inflows of Dependent Reservoirs at timestep:

Brunswick Reservoir = 0L/s
Coopers Shoot Reservoir = 150L/s
Paterson St (Byron Bay) Reservoir = 64L/s
Warrambool Reservoir = 0L/s

Wategoes Reservoir = 0L/s

Yamble Reservoir = = 0L/s

Sum of Inflows of Dependent Reservoirs = 214L/s

Dependent Reservoir Outflow Volume (15min) = 214L/s x 900sec/1000000 = 0.1926ML

Total Outflow Volume (15min) = 0.0059ML + 0.1926ML = 0.1985ML

Water Balance of Inflows and Outflows

New Reservoir Water Level = RL + (Inflow Volume – Outflow Volume) / RC

= 55.153% + (0.045ML – 0.1985ML) / 9.1ML x 100

= 53.466%

Timestep: 18/08/2015 5:00 PM **Reservoir Level (RL):** 53.466%

4.4.1.5. Model Validation

Validation of a water distribution model against actual operation is highly unreliable as the model is developed using average day demand and average diurnal patterns. Comparisons may be able for a period up to 24 hours if the actual demand of the system is close to the average day demand used in the model.

Hydraulic model validation is normally performed by checking modelled flows against measured system flows and modelled pressures against measured system pressures. As the hydraulic model has been developed using flow rates of the actual network this validation method is not applicable. The model will be validated by comparing the modelled operation of the Nightcap WTP against the actual operation over a few days. Figure 4.14 on the following page shows the modelled WTP production against the actual WTP production over the modelling period.

The water production of the modelled WTP is comparable to the actual production particularly over the first 24 hours. The modelled WTP production times occur slightly before the actual which is likely due to using the average day demand of 28.65ML whereas the actual production on the 18/08/2015 was 26.10ML.

Figure 4.15 on the following page shows the modelled WTP reservoir level against the actual WTP level over the modelling period. The modelled WTP reservoir level again is comparable to the actual reservoir level including following the actual reservoir level well below the 72% low set point in the first hours of the modelling period. This drop below the low set point was caused by significant downstream demand in the distribution network. The modelled level change amplitude is very similar to the actual because the model was developed using the actual low and high set points however the timing of the peaks and troughs becomes offset after 24 hours. Any analysis beyond this point is unreliable.

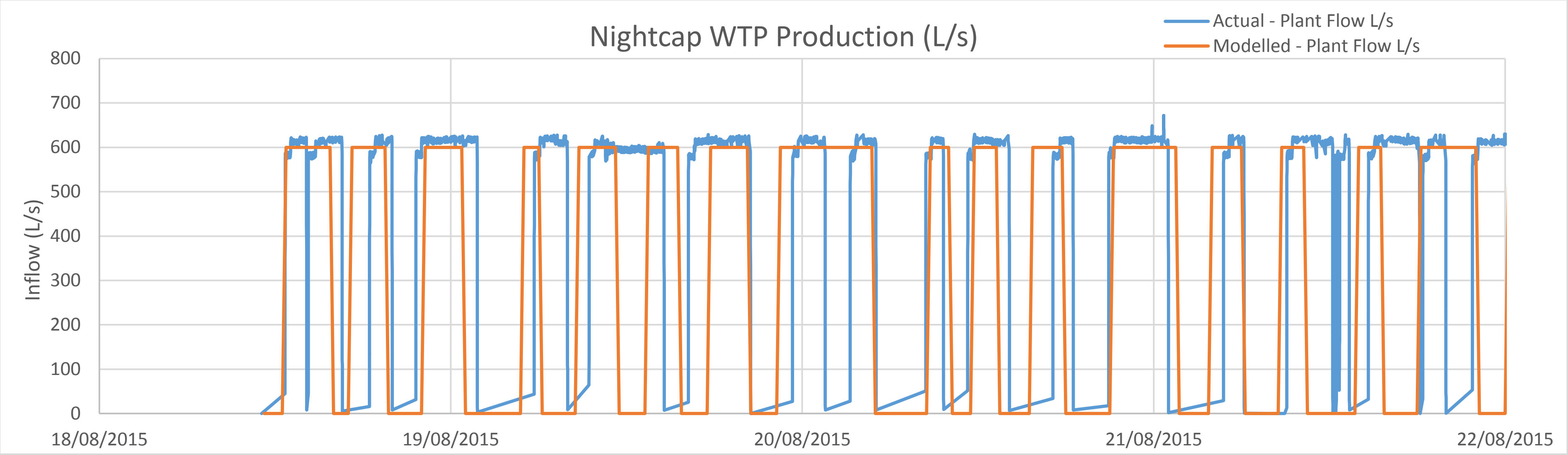


Figure 4-14 Nightcap WTP Flow - Actual vs Modelled

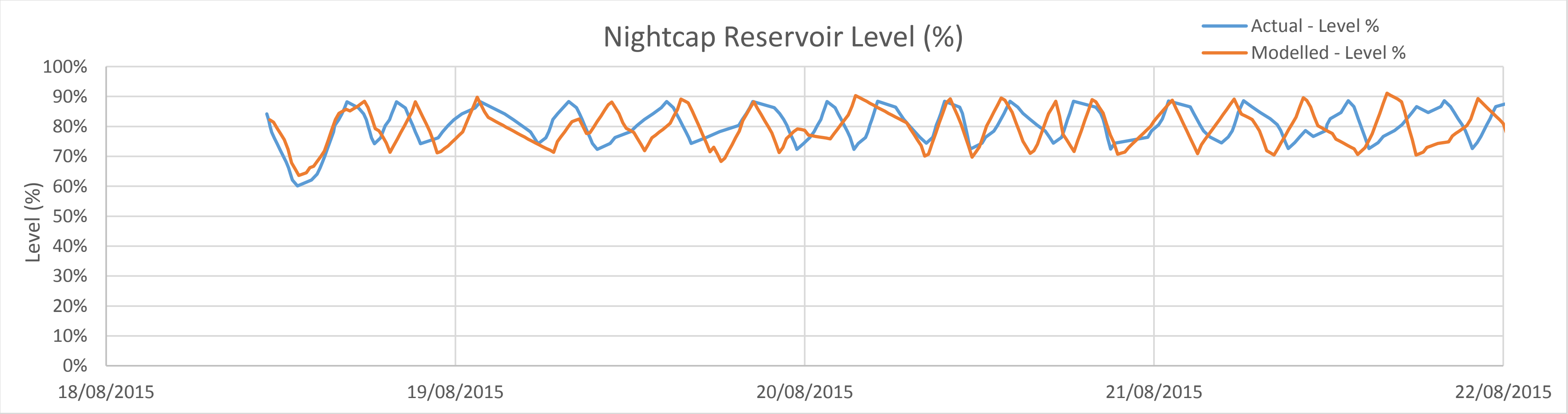


Figure 4-15 Nightcap WTP Reservoir Level - Actual vs Modelled

The above figures demonstrate the Microsoft Excel model is able to simulate operation of the water distribution network. However due to the use of an average day demand and average diurnal pattern the model is unable to mimic the actual operation of the water distribution network beyond any more than 24 hours.

Given these limitations the excel model is still a useful tool to analyse options for control of the reservoir feeding times. The conclusion can be drawn that if modelled control methodologies achieve the project objectives in the model, which is based on average day demand then it is feasible they will work in the field which has daily variations in demand.

It is expected that high demands will be experienced in the water distribution network, especially during the summer months, and the system must be operated to meet these demands without adverse impact on the network or on Rous Water's level of service to our customers. Time based controls adopted into the actual network may work for average day demand but may have negative impacts during high demand periods. For this reason any proposed time based control must have an automatic override if reservoir water levels reach critical limits.

4.4.1.6. Modelling Scenarios

The primary objective of this project is to reduce energy costs at the Nightcap WTP. The best way to achieve this objective is to avoid operating the WTP during peak electricity tariff periods as was determined by the energy analysis in Section 4.2.

The base model is the 'do nothing' scenario and will be a benchmark to assess the modelling scenarios.

Scenarios were identified for modelling that have potential to achieve the project objective of avoiding peak electricity tariff periods. The scenarios are as follows:

- **1. Nightcap WTP Control Only** – this scenario models the impact of imposing tariff timer, force fill and low level override controls only on the Nightcap WTP
- **2. Distribution System Control** – this scenario models the impact of imposing tariff timer, force fill and low level override controls on strategic reservoirs in the Rous Water distribution system
- **3. Combination of Scenarios 1 and 2**

- **4. Time Based Reservoir Set Points** – this scenario models the impact of variable reservoir level set points on strategic reservoirs in the Rous Water distribution system

To achieve the project objective of reducing energy costs, the WTP must not run at all during the peak electricity tariff periods. A single run in peak during the monthly billing cycle will result in a high peak energy demand charge which is the major contributor to energy cost at the WTP.

A successful scenario will show no WTP operation during peak tariff periods and will not adversely affect reservoir water storage levels. As a general measure, reservoirs that drop 10% below their low set point were highlighted for each modelled scenario.

The scenarios were run through the Microsoft Excel model over an extended period of 10 days to analyse the operation of the system. The development of the scenarios and the modelled results will be described in detail in the following sections.

4.4.2. Base Model

The existing system has been modelled with current reservoir set points and existing lockout controls on selected reservoirs. The development of this model has been documented in the preceding sections.

The current operation of the WTP is run to meet the water distribution network demand without consideration of electricity tariffs. The WTP operation is controlled by the CWSR high and low level set points. A low level triggers the WTP to run, a high level triggers the WTP to stop.

Figure 4.16 below is a chart of the modelled Nightcap WTP operation for the base model. The WTP run times that occur in peak electricity tariff period are highlighted red. The number of WTP starts during the modelling period for the base model was 43.

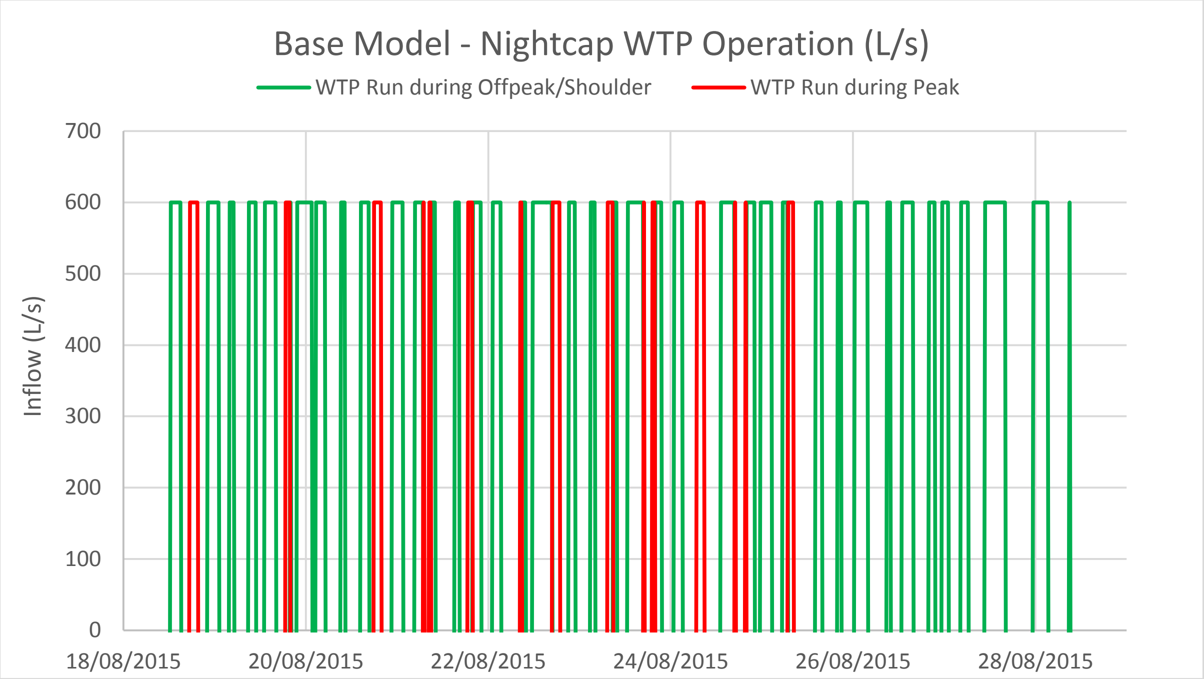


Figure 4-16 Base Model - Nightcap WTP Operation

The current operation of the WTP means that it regularly runs during the peak electricity tariff period as there is no control applied.

Figure 4.17 below is the water level in the Nightcap WTP CWSR modelled over 10 days. Generally the reservoir water level is within the high and low set points except for one notable decline in water level on the 22/08/2015. This drop in level was caused by multiple downstream dependent reservoirs calling for water at the same time which exceeded the WTP production. This does occur in the actual water distribution network at times and is an acceptable occurrence.

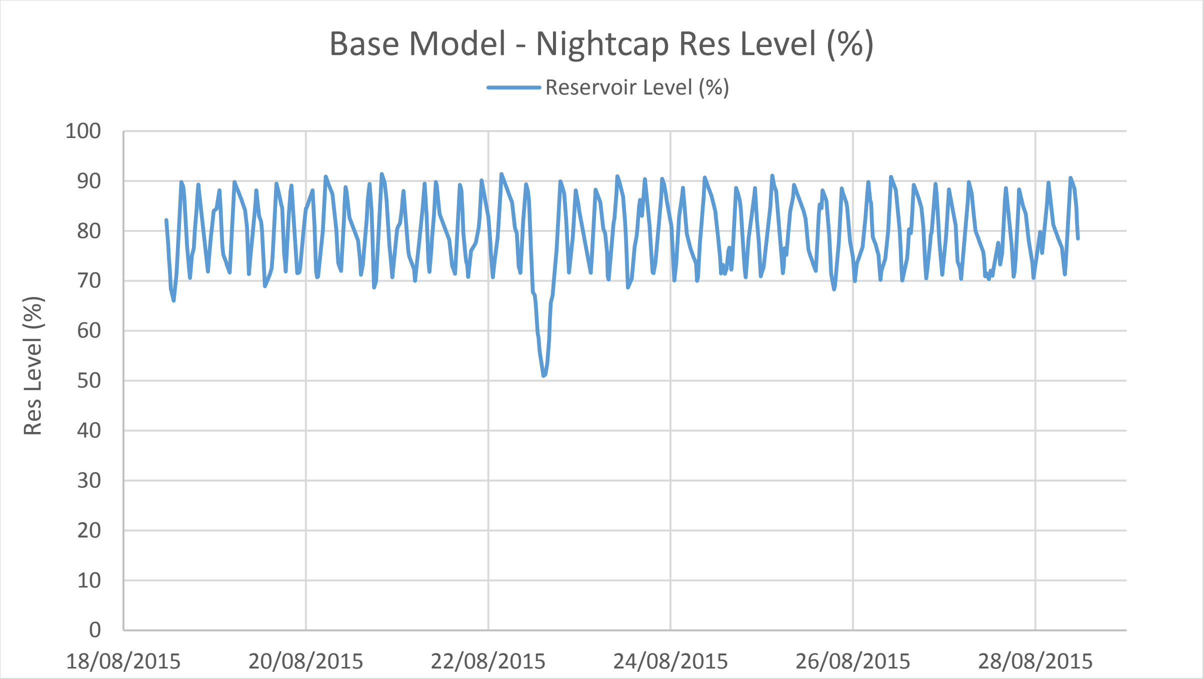


Figure 4-17 Base Model - Nightcap Reservoir Level

4.4.3. Modelled Scenario 1 – Nightcap WTP Control Only

This modelling scenario examines the effects of implementing SCADA controls to manipulate the operation of the Nightcap WTP only. The remainder of the water distribution network will continue to operate on the existing reservoir controls.

The selected controls include:

- Low Level Override – a low alarm set point that will override any other controls and force operation of the WTP
- Tariff Timer – to prevent operation of the WTP during the tariff time period
- Force Fill – to force operation of the WTP during the force fill time period
- Inhibit Fill – to inhibit a force fill call if the reservoir is near full level to prevent short WTP run times

To ensure efficient operation of the WTP and an acceptable level of water is stored in the reservoirs at all times a priority order is applied to the controls.

The priority order of controls for the Nightcap WTP CWSR is described below. Noting that a higher priority control will override a lower priority control.

1. **Low Level Override** (If res level<low level override, then WTP Run to High Set Point)

   Low Level Override set to 30% for the Nightcap WTP

2. **Tariff Timer** (Inhibit WTP Run between tariff timer periods)

   Tariff Timer Period 1: 7:00am – 9:00am

   Tariff Timer Period 2: 5:00pm – 8:00pm

3. **Inhibit Fill** (Inhibit Fill control if reservoir recently full)

   Inhibits Fill activation IF reservoir not currently filling and within 1 hour of tariff timer lockout

   Inhibit Timer Period 1: 6:00am – 7:00am

   Inhibit Timer Period 2: 4:00pm – 5:00pm

4. **Force Fill** (Force WTP Run between force fill periods to High Set Point)

   Force Fill Period 1: 4:30am – 7:00am

   Force Fill Period 2: 3:00pm – 5:00pm

5. **Reservoir Level Control** (Basic operation via high and low set points)

   Low Set Point: 72%

   High Set Point: 88%

The time periods shown above were determined through trial and error as giving the acceptable results for this modelled scenario. Further optimization of the control time periods would be undertaken in the actual distribution system following successful implementation of a preferred option.

Figure 4.18 below is a chart of the Nightcap WTP operation for Modelled Scenario 1. It is noted that the WTP does not run during the peak electricity tariff periods.

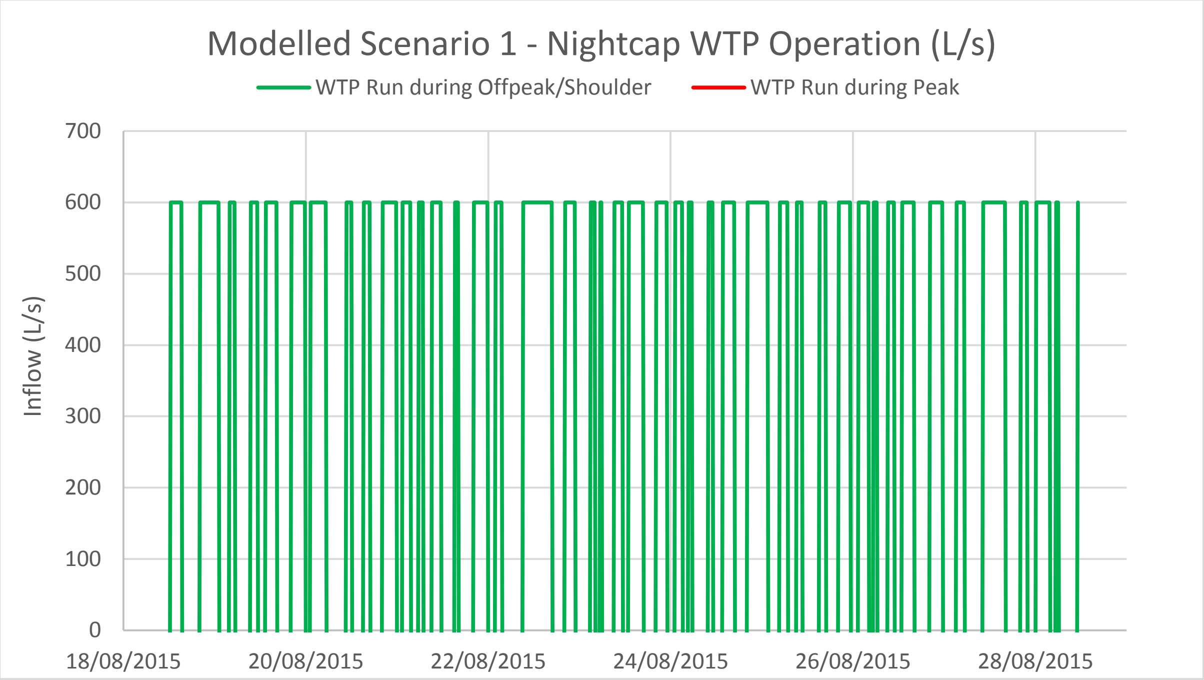


Figure 4-18 Modelled Scenario 1 - Nightcap WTP Operation

Figure 4.19 below is the water level in the Nightcap WTP CWSR modelled over 10 days. As compared to the base model there are and increased number of excursions outside the high and low set points due to the extra layers of control. The lowest reservoir level recorded by the model for this scenario is 48.7% which is acceptable for normal operations. This low level was caused by the Tariff Timer lockout. The number of WTP starts during the modelling period for this scenario was 42.

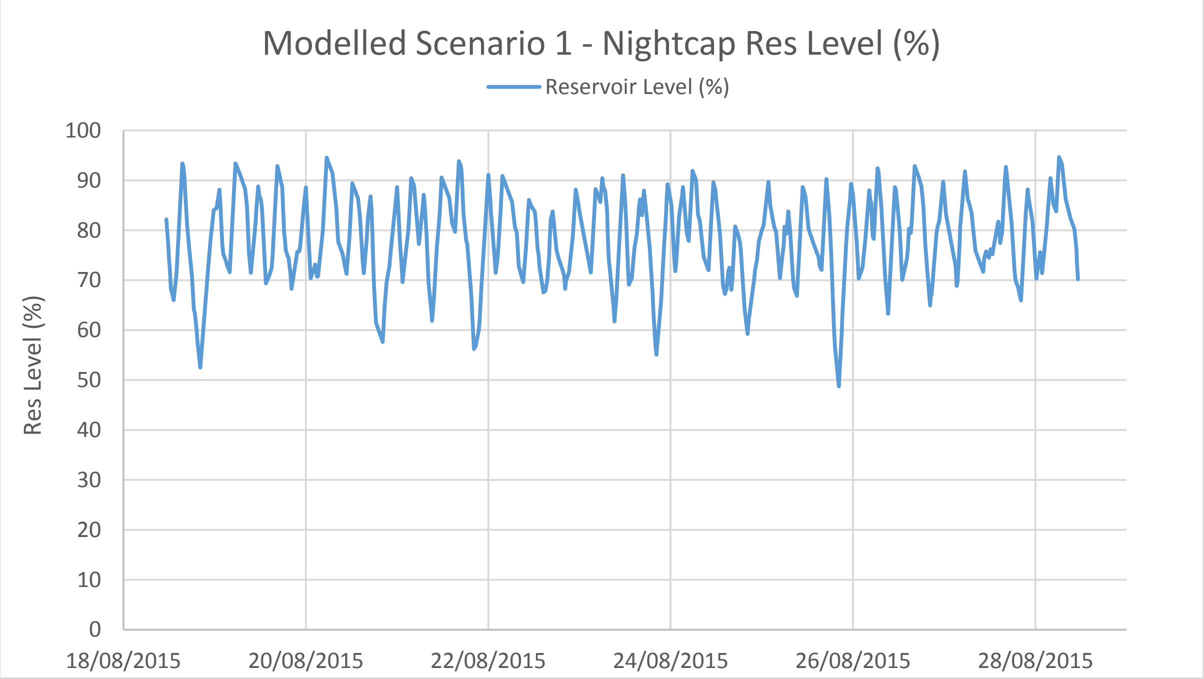


Figure 4-19 Modelled Scenario 1 - Nightcap Reservoir Level

It should also be noted that the City View Drive reservoir which is downstream of Nightcap CWSR recorded a low level of 65.2% which is below its low set point of 81%. This was caused by the existing City View Drive Tariff Lockout described in Section 4.3.5.1

Force Fill and Inhibit Fill controls were required to ensure sufficient water was stored in the Nightcap CWSR prior to the Tariff Timer Lockout. This was particularly important for this scenario as the distribution system was operating on reservoir level control only. This meant there was no control over the potential for high water demands during or just before the peak electricity tariff period.

To implement this modelled scenario into the WTP would require modifications to the WTP SCADA control system to enable the priority order controls.

4.4.4. Modelled Scenario 2 – Distribution System Control Only

This modelling scenario examines if controls placed onto the distribution system are able to achieve the project objective of avoiding peak electricity tariff periods while maintaining sufficient stored water in the distribution system. The only control at the WTP in this scenario will be reservoir level control.

The controls applied to distribution system in this scenario will only include Low Level Override, Tariff Timer Lockout and Reservoir Level Control. These controls were selected as they are the only controls currently available at most sites and thus only minor configuration would be required to implement this scenario.

The priority order of controls for the distribution system is described below. Noting that a higher priority control will override a lower priority control.

1. **Low Level Override** (If res level<low level override, then fill to High Set Point)
2. **Tariff Timer** (Inhibit WTP Run between tariff timer periods)
3. **Reservoir Level Control** (Basic operation via high and low set points)

Tariff Timer control of all reservoirs in the network is unnecessary to achieve the project objective as many only have small daily demands or are not directly downstream of the Nightcap CWSR. Table 4.13 below is the prioritised list of reservoirs based on average daily ML demand (or throughput in the case of balance tanks).

Reservoir/Supply Point	Dependence	Avg Daily Demand (ML)	Priority Control
Nightcap CWSR		28.653	1
Knockrow	Nightcap CWSR	6.864	2
St Helena	Nightcap CWSR	6.853	3
Belvedere No.9	Nightcap CWSR	2.718	4
Ross St	Nightcap CWSR	2.557	5
Ross Lane 450	Knockrow	2.543	6
Coopers Shoot	St Helena	2.491	7
City View Drive	Nightcap CWSR	2.203	8
Wollongbar	Nightcap CWSR	1.773	9
High St No.4	Nightcap CWSR	1.510	10
Patterson St (Byron Bay)	St Helena	1.491	11
Holland St	Nightcap CWSR	1.342	12
Yamble	St Helena	1.116	13
Sth Evans Head	City View Drive	0.871	14
Brunswick	St Helena	0.592	15
Langs Hill	City View Drive	0.449	16
Ballina Heights	Knockrow	0.424	17
Dunoon	Nightcap CWSR	0.421	18
Bangalow	Nightcap CWSR	0.399	19
Coraki	City View Drive	0.340	20
Warrambool	St Helena	0.336	21
Newrybar/Tintenbar	Knockrow	0.281	22
Broadwater	Langs Hill	0.269	23
Tanelawn	City View Drive	0.174	24
Wategoes	St Helena	0.137	25
Tullera	Nightcap CWSR	0.101	26
Pineapple Rd	Nightcap CWSR	0.016	27
Clunes	Nightcap CWSR	direct	n/a
Ross Lane 200	Knockrow	direct	n/a
Water Wheels	Knockrow	direct	n/a
Woodburn Retic	Langs Hill	direct	n/a

Table 4.13 Distribution Network Priority Control

Tariff control was only applied to reservoirs dependent on Nightcap CWSR with an average daily demand greater than 2ML. Additional controls could be implemented on other reservoirs as required to achieve the project objective.

The selected reservoirs for modelling of the additional controls include: Knockrow, St Helena, Belvedere, Ross St and City View. These reservoirs are shown on the following page as Figure 4.20. Plots of the modelled inflows to each reservoir from the base model are shown in Figures 4.21 to 4.25. The plots display the daily feed frequency and feed length which can be used to develop a schedule of Tariff Timer lockouts.

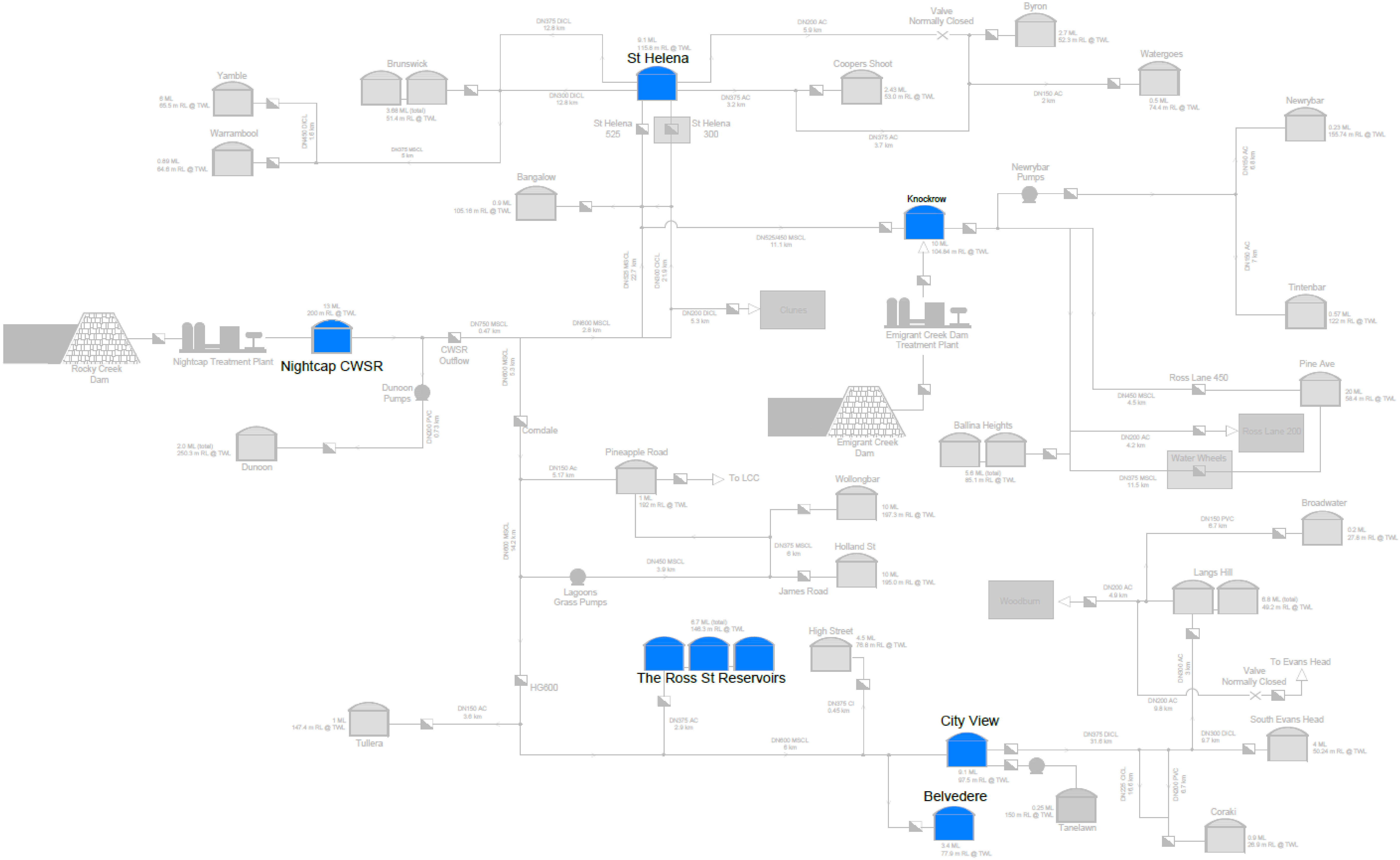


Figure 4-20 Selected Reservoirs for Tariff Timer Control

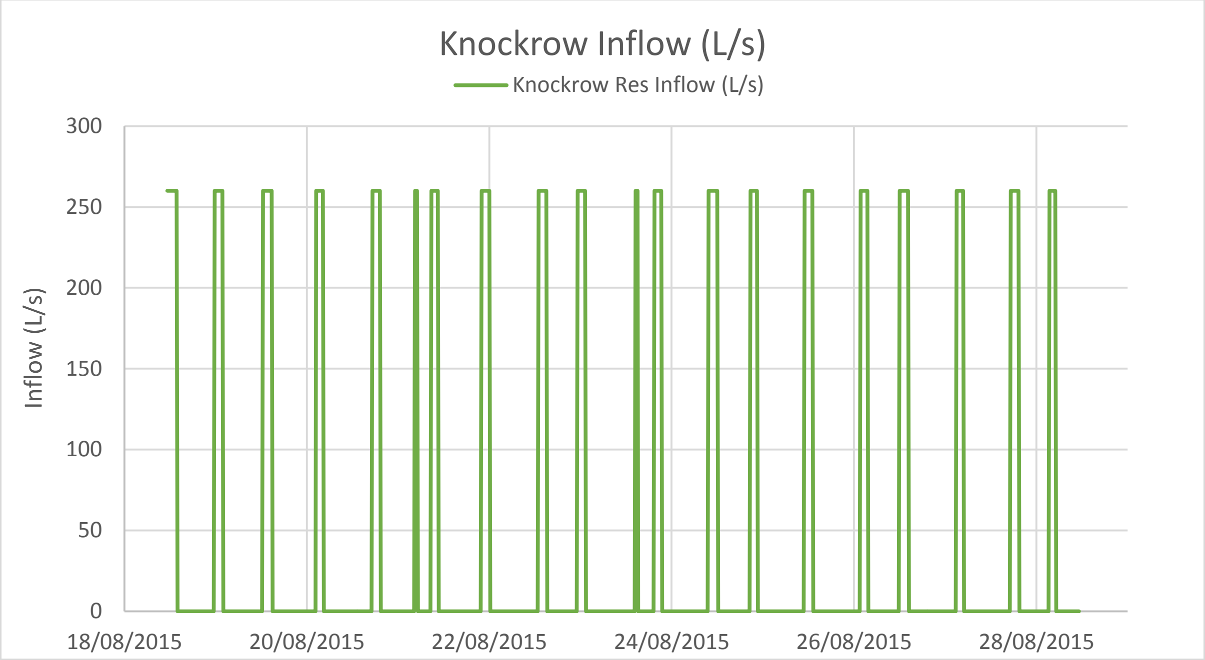


Figure 4-21 Modelled Inflow - Priority Reservoir 1 (Knockrow)

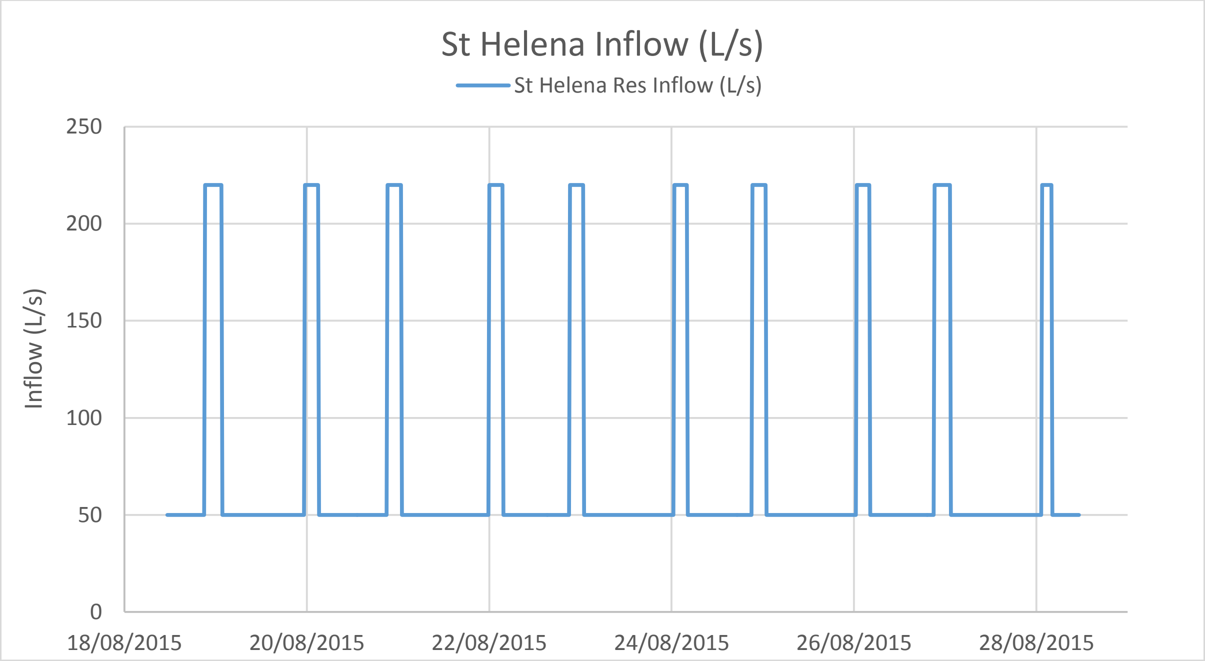


Figure 4-22 Modelled Inflow - Priority Reservoir 2 (St Helena)

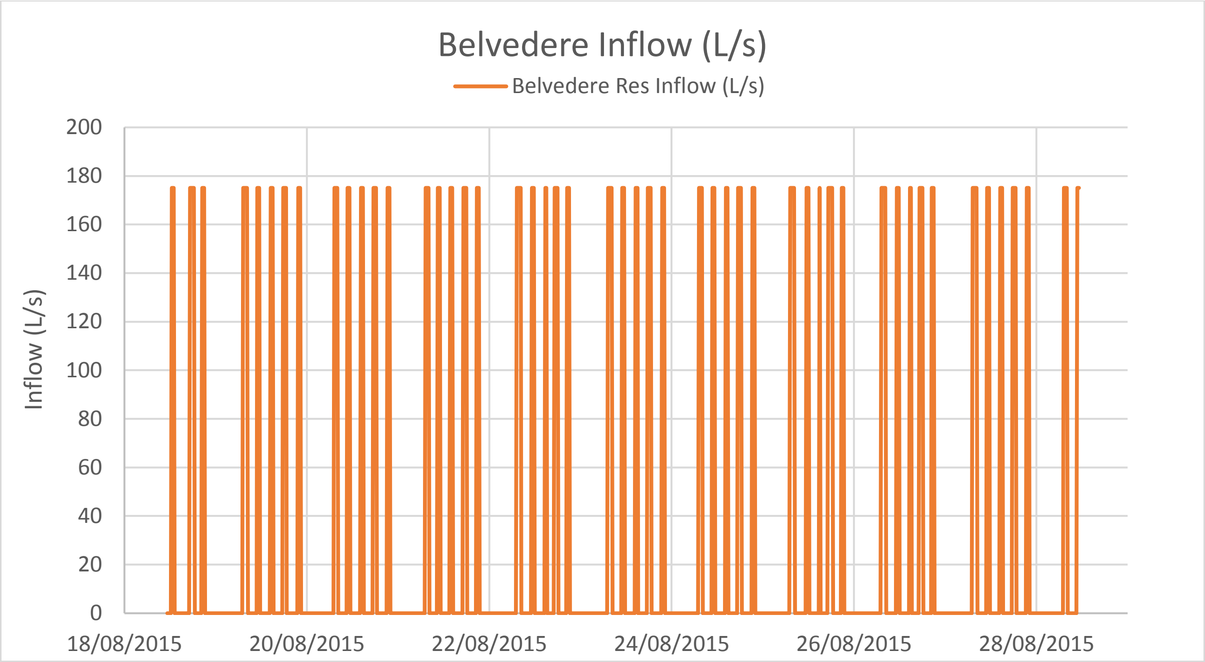


Figure 4-23 Modelled Inflow - Priority Reservoir 3 (Belvedere)

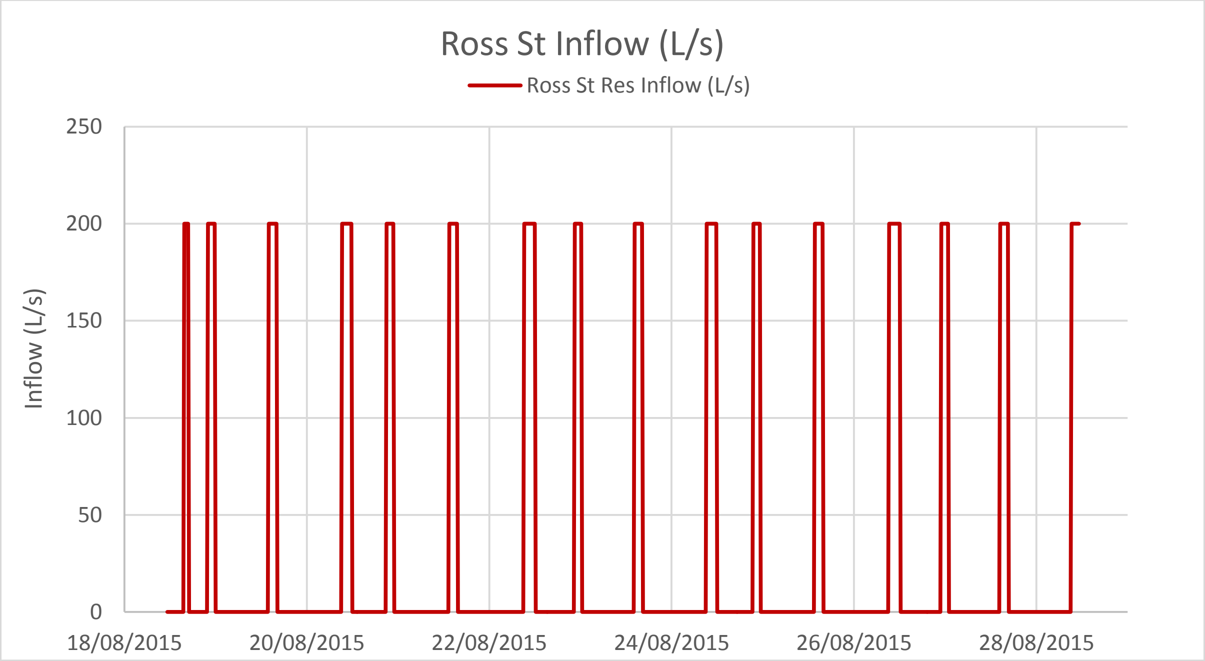


Figure 4-24 Modelled Inflow - Priority Reservoir 4 (Ross St)

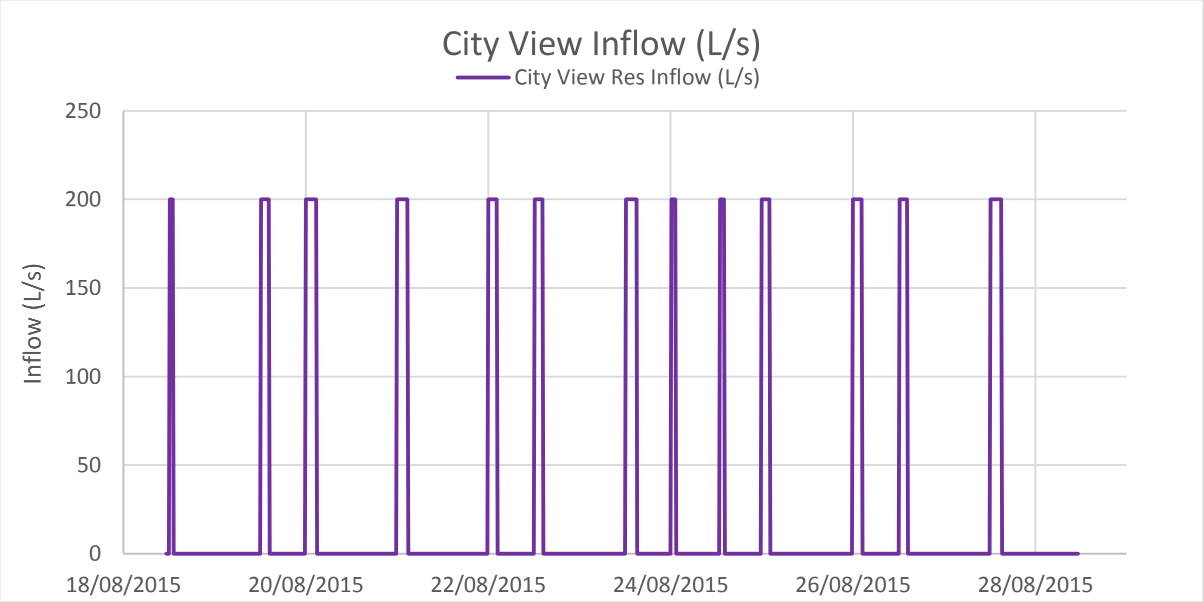


Figure 4-25 Modelled Inflow - Priority Reservoir 5 (City View Drive)

Figures 4.20 to 4.25 show the inflows to the priority reservoirs taken from the base model which has no additional control. The frequency and length of inflows to each priority reservoir is determined from the charts and shown below.

- St Helena – 1 feed/day. Approximately 4.5 hours feed time
- Knockrow – 2 feeds/day. Approximately 2 hours feed time
- Belvedere – 5 feeds/day Approximately 1 hour feed time (high level must be maintained to supply high zone customers)
- Ross St – 2 feeds/day. Approximately 2 hours feed time
- City View – 1 feed/day. Approximately 2.5 hours feed time

Based on the above information the Tariff Timer controls were modelled for this scenario. The selected controls are shown in Table 4.14 below.

Reservoir	**Low Level Override (%)**	**Tariff Timer Period 1**	**Tariff Timer Period 2**	**LSP**	**HSP**
Knockrow	40	5:00am – 7:00am	3:00pm – 5:00pm	65	81
St Helena	40	4:00am – 9:00pm		50	75
Belvedere No.9	40	5:00am – 7:00am	3:00pm – 5:00pm	75	85
Ross St	40	7:00am – 5:00am	9:00pm – 8:00pm	70	89
City View Drive*	40	6:00am – 12:00pm	3:00pm – 12:00am	81	88
Wollongbar*	0	7:00am – 10:00pm		70	90
Holland St*	0	7:00am – 10:00pm		89	96

*as per existing control

Table 4.14 Modelled Scenario 2 - Selected Reservoir Controls

The time periods shown above were determined through trial and error as giving acceptable results for this modelled scenario. It is expected that further optimization of the control time periods would be undertaken in the actual distribution system following successful implementation of a preferred option.

Figure 4.26 below is a chart of the Nightcap WTP operation for Modelled Scenario 2. It is clear that controlling only the distribution network without control of the WTP results in the WTP having multiple runs in peak electricity tariff period. The number of WTP starts during the modelling period for this scenario was 43.

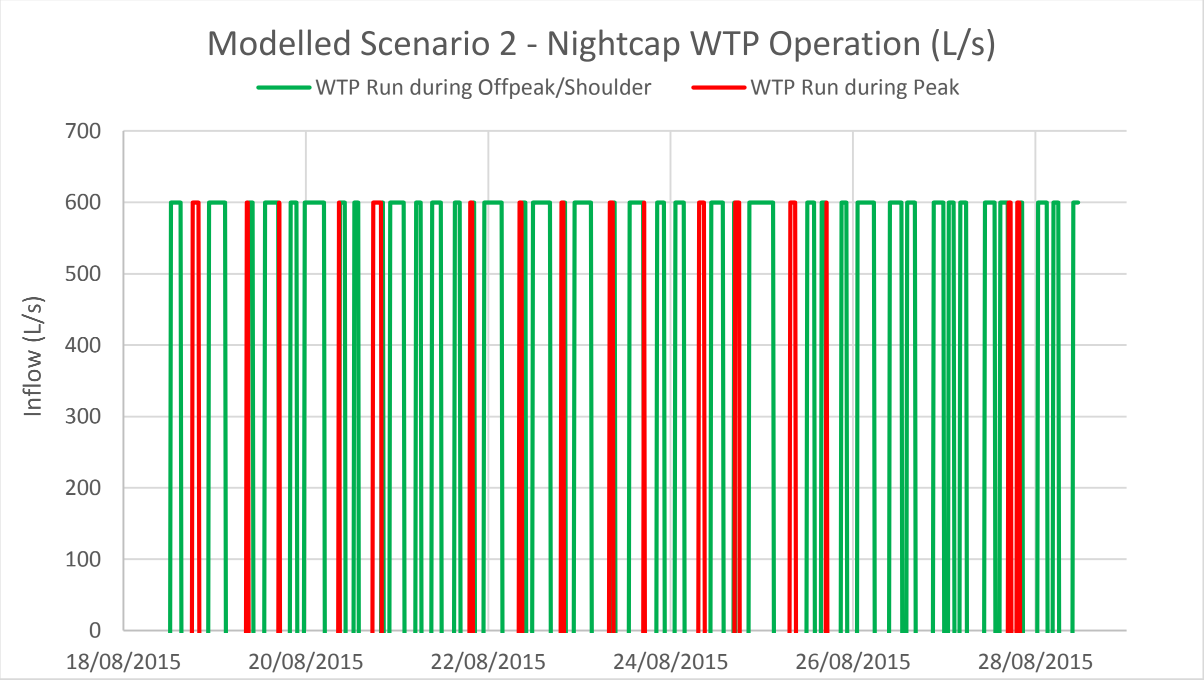


Figure 4-26 Modelled Scenario 2 - Nightcap WTP Operation

Figure 4.27 below is the water level in the Nightcap WTP CWSR modelled over 10 days. Again, when compared to the base model there are some excursions outside the high and low set points due to the extra layers of control however not as many as in Modelled Scenario 1.

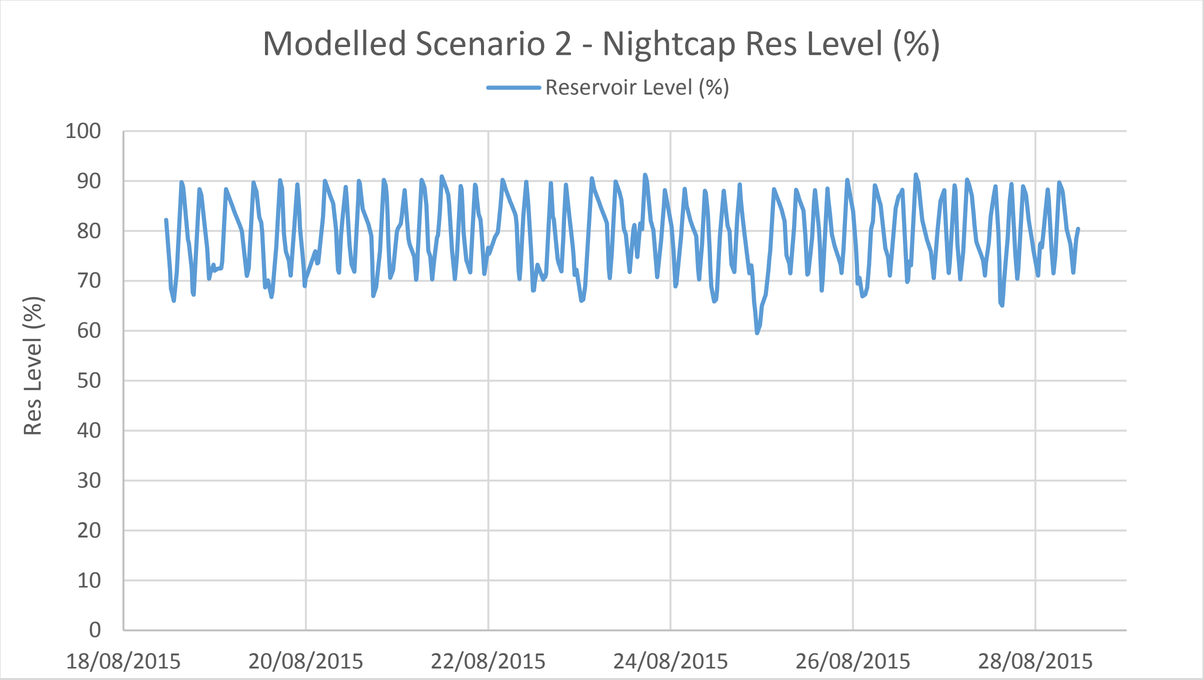


Figure 4-27 Modelled Scenario 2 - Nightcap Reservoir Level

This modelled scenario was not able to achieve the project objective of negating the need to run the WTP during peak electricity tariff periods.

This scenario has established that, as a minimum, control of the WTP must be implemented to avoid running the WTP during peak electricity tariff periods.

4.4.5. Modelled Scenario 3a – Distribution System + WTP Tariff Control

To further examine if distribution system control is advantageous to achieving the project objective, this scenario includes Tariff Timer control on the WTP in combination with the Scenario 2 distribution system control.

The Tariff Timer control applied to the WTP is as follows:

Tariff Timer (Inhibit WTP Run between tariff timer periods)

Tariff Timer Period 1: 6:45am – 9:00am

Tariff Timer Period 2: 4:45pm – 8:00pm

Figure 4.28 below is a chart of the Nightcap WTP operation for Modelled Scenario 3a. It is noted that the WTP does not run during the peak electricity tariff periods. The number of WTP starts during the modelling period for this scenario was 36 which is more efficient than the base model.

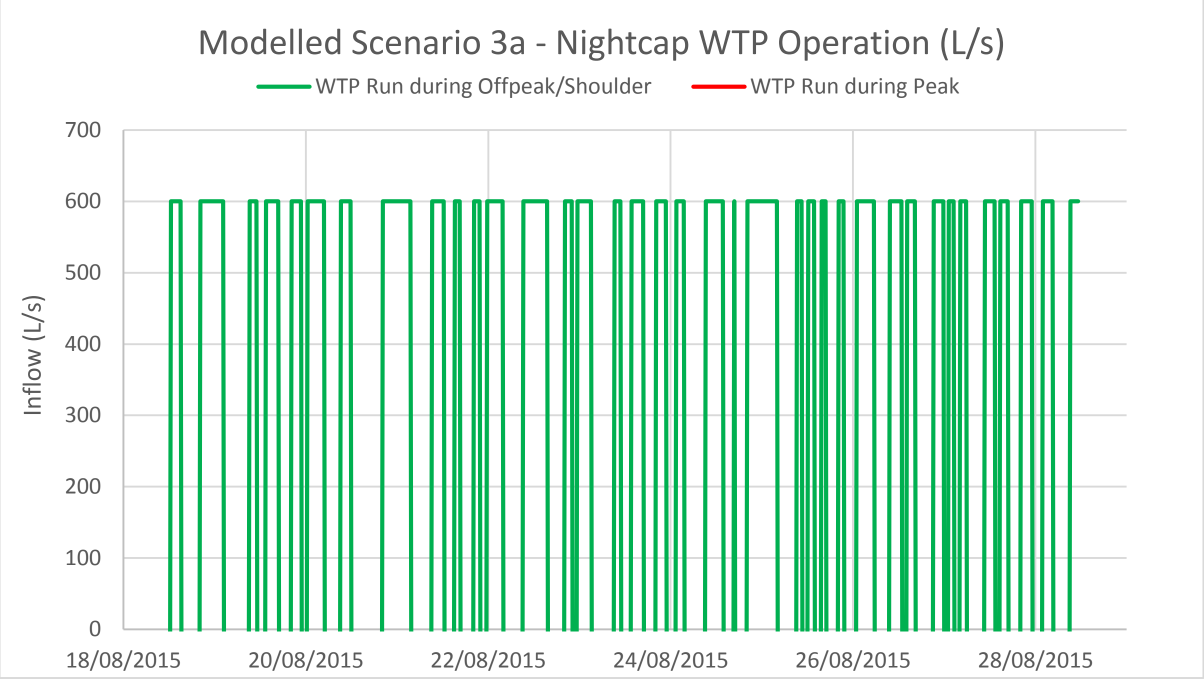


Figure 4-28 Modelled Scenario 3a - Nightcap WTP Operation

Figure 4.29 below is the water level in the Nightcap WTP CWSR modelled over 10 days. As compared to the base model there are an increased number of excursions outside the high and low set points due to the extra layers of control. The lowest reservoir level recorded by the model for this scenario is 41.0% which is acceptable for normal operations. This low level was caused by the Tariff Timer lockout.

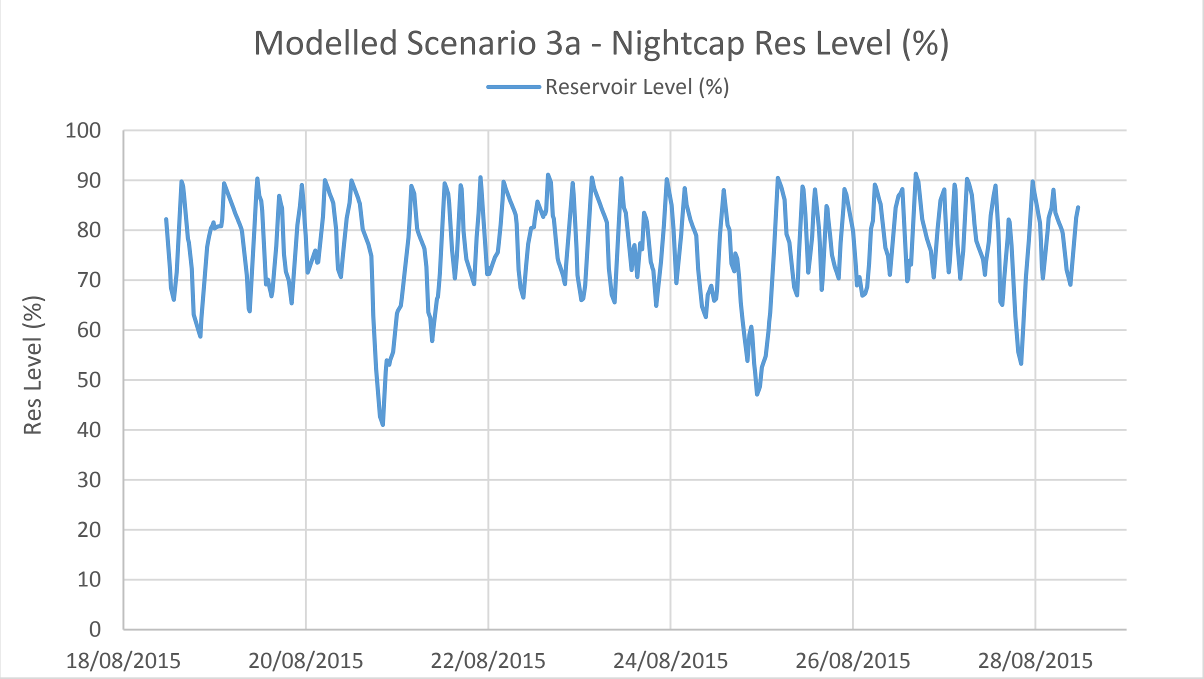


Figure 4-29 Modelled Scenario 3a - Nightcap Reservoir Level

During the modelling period, St Helena reservoir has a low level of 42.1% which is greater than 10% below the low set point for this reservoir however still within acceptable operating limits.

It should also be noted that the City View Drive reservoir which is downstream of Nightcap CWSR recorded a low level of 65.2% which is below its low set point of 81%. This was caused by the existing City View Drive Tariff Lockout described in Section 4.3.5.1

Therefore combing WTP control with distribution system control can achieve the project objective of avoiding WTP run during peak electricity tariff periods while maintaining sufficient storage water in the reservoirs.

This scenario is very simple to implement as the Tariff Timer functionality already exists on the majority of the identified sites and only minor programming of the WTP SCADA system would be required.

4.4.6. Modelled Scenario 3b – Distribution System + WTP Full Control

To examine if there is further gains to be made by including additional controls on the WTP, this scenario combines the distribution system control of Scenario 2 with the full WTP control of Scenario 1 including Tariff Timers, Force Fill and Inhibit Fill control.

Similar to Scenario 3a, this scenario achieves the project objective of not running the WTP during peak electricity tariff periods. The number of WTP starts during the modelling period for this scenario was 40.

Figure 4.30 below is the water level in the Nightcap WTP CWSR modelled over 10 days. As compared to the base model there are an increased number of excursions outside the high and low set points due to the extra layers of control. The lowest reservoir level recorded by the model for this scenario is 56.55% which is acceptable for normal operations. This low level was caused by the Tariff Timer lockout. This low level is not as low as in Scenario 3a indicating that combining full WTP control with the distribution system control is advantageous.

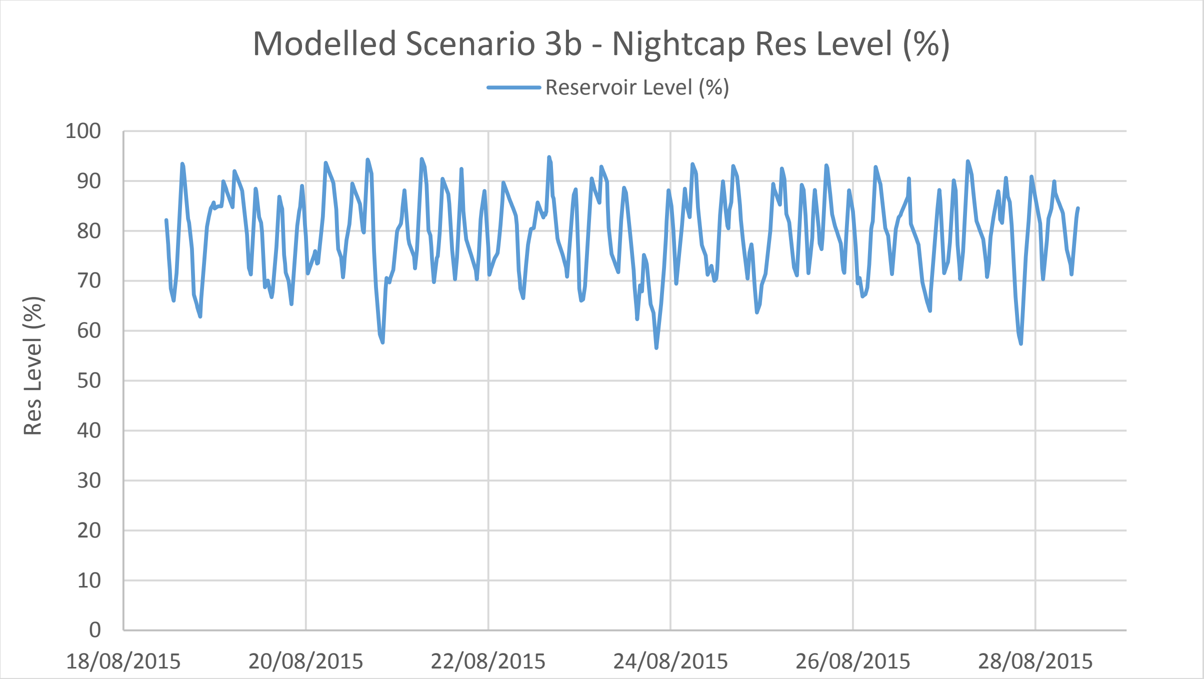


Figure 4-30 Modelled Scenario 3b - Nightcap Reservoir Level

Again St Helena reservoir has a low level of 42.1% and City View Drive reservoir has a low level of 65.2% but these are within acceptable operating limits.

This scenario would require more significant control modification at the Nightcap WTP as has been described in Scenario 1.

4.4.7. Modelled Scenario 4 – Time Based Reservoir Set Points

This scenario has been modelled to examine the impact of variable reservoir level set points on strategic reservoirs in the Rous Water distribution system. The concept is to have high water levels in strategic reservoirs in the network before and during the peak electricity tariff periods. To achieve this the reservoir level control set points will be raised in the hours preceding the peak tariff periods.

The same strategic reservoirs that were identified in Scenario 2 will have this control applied. The control will be applied by lifting the low set point only. It is assumed that the existing high set points have been set at the maximum that the reservoir can fill to (i.e. for an operational need or to prevent overflow).

Table 4.15 below is a summary of time based reservoir level set points that were modelled:

Reservoir	Adjusted Set Point Timer 1	Adjusted Set Point Timer 1	Adjusted LSP	HSP
Knockrow	3:00am – 7:00am	1:00pm – 5:00pm	75	81
St Helena	3:00am – 7:00am	1:00pm – 5:00pm	70	75
Belvedere No.9	3:00am – 7:00am	1:00pm – 5:00pm	80	85
Ross St	3:00am – 7:00am	1:00pm – 5:00pm	85	89
City View Drive	3:00am – 7:00am	1:00pm – 5:00pm	84	88

Table 4.15 Time Based Adjusted Set Points and Timers

The adjusted low set points for these reservoirs will activate during the timer periods shown above. This will force the reservoir to maintain a higher water level than normal. The timer is removed at the start of the peak electricity tariff periods so the reservoirs can drain back to their normal low set points levels and not place water demand on the WTP storage.

All the reservoirs in the table above are fed by gravity from the Nightcap CWSR. Therefore more frequent fill times in the hours preceding peak tariff periods will only result in more frequent valve openings. Time based reservoir level set points would not be suitable for pumped systems as frequent stopping and starting of the pumps is undesirable.

To ensure the Nightcap WTP does not run during the peak electricity tariff periods, the Tariff Timer control has been modelled on the Nightcap CWSR. The Tariff Timer periods used are shown below.

Tariff Timer (Inhibit WTP Run between tariff timer periods)

Tariff Timer Period 1: 7:00am – 9:00am

Tariff Timer Period 2: 5:00pm – 8:00pm

Figure 4.31 below is a chart of the Nightcap WTP operation for Modelled Scenario 4. It is noted that the WTP does not run during the peak electricity tariff periods. However the below chart shows that the Nightcap WTP has more starts during the modelling period compared to the previous scenarios which is undesirable. The number of WTP starts during the modelling period for this scenario was 44. Multiple starts may result in high energy consumption as the direct start pumps take large energy draws more frequently, increased wear and tear on the pumps and other WTP equipment and difficulty in achieving water quality targets at the WTP.

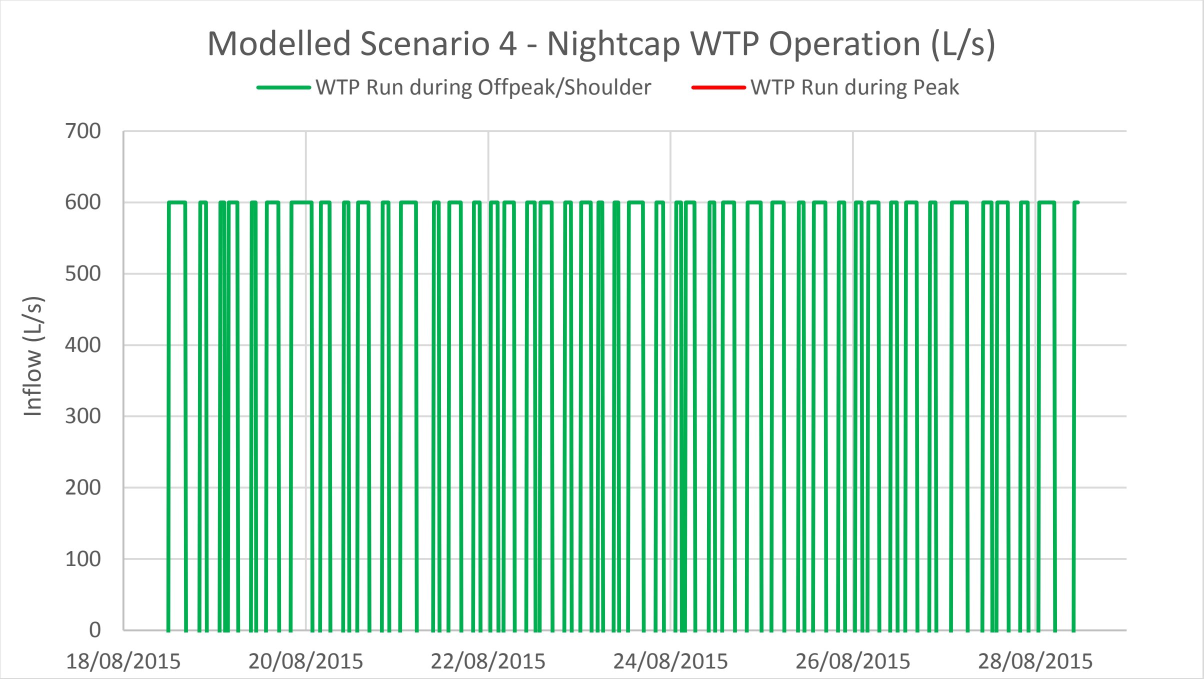


Figure 4-31 Modelled Scenario 4 - Nightcap WTP Operation

Figure 4.32 below is the water level in the Nightcap WTP CWSR modelled over 10 days. As compared to the base model there are an increased number of excursions outside the high and low set points due to the extra layers of control. The lowest reservoir level recorded by the model for this scenario is 43.4% which is acceptable for normal operations. This low level was caused by the Tariff Timer lockout.

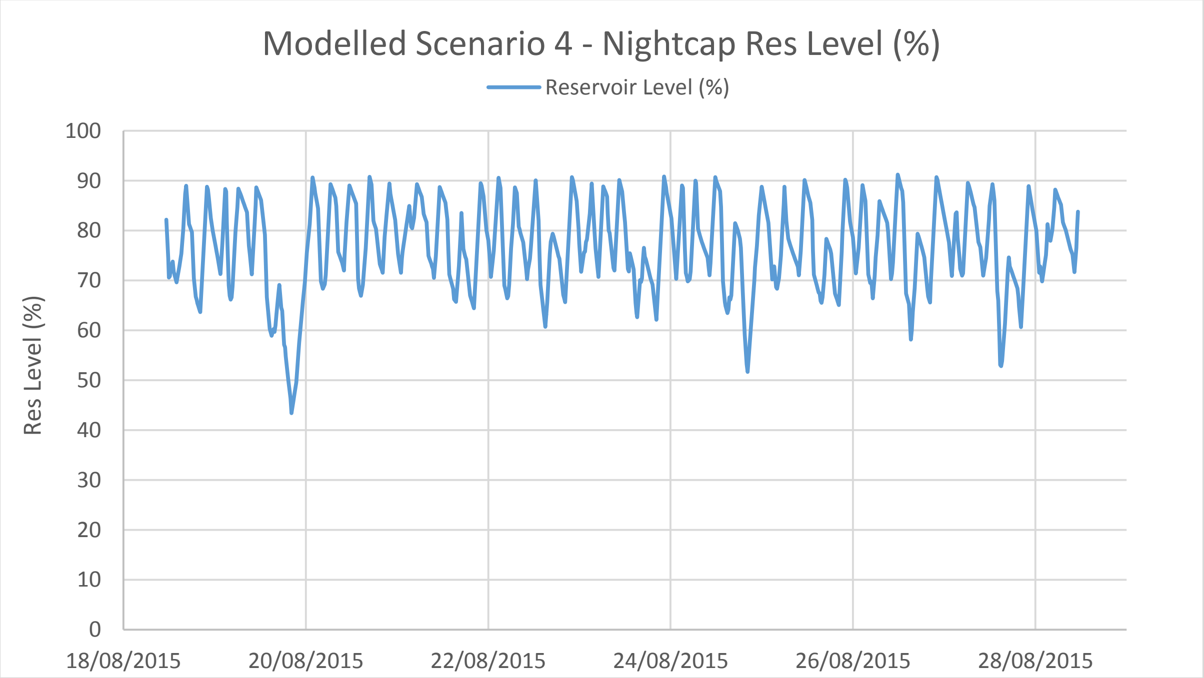


Figure 4-32 Modelled Scenario 4 - Nightcap Reservoir Level

4.4.8. Summary of Modelling Scenarios

Table 4.16 below is a summary of the modelling scenario's performance. This summary information will be used to develop the recommendation and select the preferred option for validation modelling and implementation.

Modelling Scenario	**WTP run in Peak?**	**CWSR Lowest Level**	**WTP Starts**	**Implementation Cost**
Base Model	Yes	50.97%	43	Nil
S1.WTP Control Only	No	48.70%	42	Medium
S2. Distribution Control Only	Yes	59.51%	43	Low
S3a. Distribution + WTP Tariff	No	41.00%	36	Low
S3b. Distribution + WTP Full	No	56.55%	40	Medium
S4. Time Based Set Points	No	43.42%	44	High

Table 4.16 Summary of Modelling Scenarios Performance

5. CHAPTER 5 – DISCUSSION

5.1.Modelling Discussion

The modelling results show that it appears possible to implement additional SCADA based controls onto the water distribution network and WTP that will achieve the project objective of avoiding the operation of the WTP during the peak electricity tariff period and thereby reduce energy costs.

The base model clearly shows that without any additional controls the WTP regularly operates during the peak electricity tariff period. The base model reflects accurately what happens in the actual system.

Each modelled scenario was assessed to determine its ability to achieve the project objective, the impact on reservoir water storage levels and the impact on the WTP in terms of frequency of starts. Scenarios unable to achieve the project objective were not considered as possible alternatives. Scenarios which maintain higher water levels in the reservoirs (in particular the WTP storage tank) are favoured over those that cause significant drops in reservoir water storage levels. Scenarios that minimise the number of WTP starts during the modelling periods are preferred as this decreases the wear on the WTP assets and reduces the running costs of the WTP.

5.1.1. Modelled Scenario 1 Discussion

Scenario 1, which modelled additional controls on the WTP only, was able to achieve the project objective. This result was not expected. Prior to starting this project it was expected that additional controls would also be required on the distribution network to avoid placing large water demands on the WTP.

The controls modelled in this Scenario 1 effectively locked out the WTP from operating during the peak electricity tariff period and attempted to run the WTP immediately before the peak tariffs to ensure the water storage at the WTP was as high as possible whilst the WTP was locked out. There were instances in this modelled scenario where the water storage level at the WTP dropped to around 50% which is below normal levels however the storage level was able to recover once the peak tariff lockout had ended.

A further benefit of Scenario 1 is that it places no constraints on the distribution system and allows it to operate as it has been to meet demand. To implement Scenario 1 requires the modelled controls to be implemented on the SCADA control system at the WTP

The current control program for the WTP is written in CitectSCADA. The additional controls mentioned in this report including: ‘Tariff Timers’, ‘Force Fill’, ‘Inhibit Fill’, etc. were in reference to ClearSCADA but similar functions may be available in CitectSCADA or could be programmed.

As referred to earlier, there is an existing control code, known as the ‘Nightcap Algorithm’, written into the control program which was designed to achieve the same objective of avoiding peak electricity tariff periods. The Algorithm was fairly complex and attempted to predict future demand of the network and run the WTP as required to produce sufficient water storage to meet this demand. The Algorithm did not link to the distribution system control and was unable to control high network demands. This Algorithm included running a third dam pump as required to increase production prior to the peak tariffs. This method somewhat negated the energy demand savings and regularly caused overflows and water quality alarms in the WTP as a number of processes are either undersized or not optimized for the higher flows. WTP operators were regularly called out after hours to reinstate the WTP and the expected energy cost savings were not realised. The Algorithm was subsequently ‘turned off’ by bypassing that section of the control code. It may be possible to utilise parts of this code, such as the peak tariff time inputs and lockouts to develop a new code based on Scenario 1.

Implementation of Scenario 1 is likely to be low cost especially if the existing Algorithm code could be utilised.

5.1.2. Modelled Scenario 2 Discussion

Scenario 2, which modelled additional controls on the distribution system reservoirs only, was unable to achieve the project objective. Although the distribution system reservoirs were controlled to feed at strategic times to minimise the impact on the WTP storage during the peak tariffs, the varying demand in the system and the lack of direct control of the WTP meant that the WTP ran numerous times during the peak electricity tariff in the modelling period.

It may be possible to adjust the scheduling of reservoir lockout times to attempt to improve the storage at the WTP and reduce the peaks in the downstream demand however because the demand varies every day it is unlikely that control of only the distribution network would be able to avoid running the WTP during the peak tariffs for the entire month.

The functionality modelled in Scenario 2 is already available in the ClearSCADA system and combining this existing functionality with lockout of the WTP is advantageous as shown in Scenarios 3a and 3b.

5.1.3. Modelled Scenario 3a and 3b Discussion

Scenarios 3a and 3b both combine WTP controls with distribution system controls. Scenario 3a only has lockout control at the WTP with the distribution system controls of Scenario 2. Scenario 3b has the full WTP controls of Scenario 1 with the distribution system controls of Scenario 2.

As predicted these scenarios were able to achieve the project objective as they both employed lockout of the WTP during the peak tariff periods which is the critical control. These scenarios were modelled to test if further improvement could be made on Scenario 1 by also controlling the feed times of strategic reservoirs in the distribution network. Further improvement is defined by maintaining a higher water level in the WTP storage throughout the modelling period.

Interestingly Scenario 3a performs worse than Scenario 1 as the WTP storage tank level drops to a lower level. This is likely caused by two factors. In Scenario 3a the only control at the WTP is tariff lockout whereas in Scenario 1 the WTP has additional controls to run the WTP and fill the storage tank prior to the lockout. The other factor is the lockout of the distribution system reservoirs in Scenario 3a means that it is possible that multiple reservoirs will call for water immediately after being locked out placing a large demand on the network. It may be possible to better stagger lockouts on the distribution system reservoirs to avoid this but this has not been investigated in this report.

Scenario 3b performs better than Scenario 1 as it maintains a higher water storage level at the WTP throughout the modelling period as well as decreasing the number of WTP starts. This was expected as Scenario 3b employs the same WTP control as Scenario 1 with the addition of the distribution system reservoir control. Although Scenario 3b improves on Scenario 1 it adds additional complex controls onto the network at additional cost while it is not strictly required to achieve the project objective.

5.1.4. Modelled Scenario 4 Discussion

Scenario 4 is fundamentally different to the other models. This scenario attempts to achieve the project objective by using time based variable reservoir set points to essentially increase the stored water in the distribution system prior to the peak tariff periods. The only additional control applied to the WTP is the tariff lockout as it was previously shown in Scenario 2 that this control is critical to achieving the project objective.

This scenario is able to achieve the project objective however there are low water storage levels at the WTP during the modelling period and the higher set points increase the number of WTP starts. The functionality required to implement this scenario is not currently available in ClearSCADA and would require significant capital cost to implement.

5.2. Consequences

A review of the consequences of implementing the proposed additional controls onto the WTP or the distribution system was undertaken to understand the potential impacts on Rous Water operations.

5.2.1. Operations

Implementation of additional controls onto the WTP or distribution system to achieve the project objective is likely to have a significant impact on the current operation of the water supply system. It will mean an additional constraint that will have to be considered by staff when undertaking system planning or making operational decisions. For example if this control is implemented the WTP will not be running during the morning peak tariff period between 7am and 9am. The WTP operators start at 7:30am and normally undertake the routine inspections and maintenance on arrival at work. This activity needs the WTP to be operating so will need to be rescheduled. The lockout of the WTP during the peak tariff will also impact on non-routine maintenance activities and troubleshooting that can require the WTP to be operating.

Before any changes to the system occur, extensive consultation with staff must be undertaken to ensure all stakeholders are aware of the changes and how it will impact their work. Normal operation of the water supply system will be disrupted during configuration and commissioning of any control changes.

The additional controls are designed to save significant energy costs at the Nightcap WTP. Operation of the WTP even once during the peak electricity tariff period in any month will incur the peak energy demand charge of nearly $9,000. The WTP operators are required to operate and maintain the WTP and as such currently make the decisions to shutdown or run the WTP as required to perform maintenance or upgrades while minimising impact on the supply of water to the distribution system. If the proposed additional controls are implemented into the system, this means Rous Water, the organisation, has decided it wants to achieve the energy cost savings. When this occurs it is likely that a decision to shutdown or run the WTP that could potentially cause the WTP to run during peak electricity tariff period would need to be made by management as there is a significant cost penalty that is incurred. It is envisaged that appropriate business processes will need to be created once the additional controls are implemented.

This proposed method to achieve the project objective could potentially require additional controls on both the WTP and the distribution system reservoirs. The additional controls include locking out the reservoir from feeding and force filling so there is potential to cause a system failure such as a reservoir running dry, overflowing or a significant pressure drop in the system if control methods not implemented correctly. To mitigate the aforementioned risk, wherever a restrictive control is implemented onto the system it must have an associated failsafe control installed also.

For the force fill function the failsafe control will be that the force fill will deactivate when the reservoir reaches the high water level set point. For tariff timer lockouts the failsafe control is to have low level override functions which will force the reservoir/WTP to fill to the high level set point if a user defined low level alarm is reached. The low level override set point will be different for different reservoirs to allow for fire storage and emergency supply. Further work before any additional controls are implemented will be to consult with the operations staff as to appropriate low level override set points.

Faults and alarms at the WTP are a normal part of operations. The WTP Operators attend to faults and alarms as soon as possible to return the WTP to service. This includes responding to WTP faults and alarms after hours. Faults and alarms are mostly generated when the WTP is running. To achieve the project objective of avoiding operation of the Nightcap WTP during peak tariff periods will result in increased running of the WTP in Off-Peak (10pm – 7am) which could result in more plant faults/alarms being generated after hours (4.30pm – 7.30am) leading to operator fatigue and increased financial impacts of extra overtime payments.

5.2.2. Safety

The potential safety consequences of implementing a more automated system to control the water distribution network is similar to any equipment or facilities that are remotely operated or can be started remotely. There is potential for the automated system to start a pump station or open a valve without notice and not on the normal operating controls. The safety issue arises if a Rous Water staff is in close vicinity to the remotely controlled equipment when it starts.

Rous Water staff operating near this equipment are aware of the remote operation of equipment in the Rous Water distribution network. The staff include this in their risk assessments and implement appropriate controls such as isolation of the equipment and notifying other SCADA users of the works being undertaken. Any additional controls implemented on the control system will need to be include in the risk assessment process.

Implementing a system that has the potential to override the SCADA could introduce safety hazards by starting and stopping equipment and facilities based on a schedule rather than level set points. The hazards arise if operators of the system are unaware of the additional layer of control. This will need to be considered in the design of any possible solution to the project objective and appropriate controls built into the system to allow Rous Water staff to works safely in the vicinity these equipment. Rous Water staff operating the system will need to be trained in the additional control system and its implications on operations.

5.2.3. Customer Impact

Customers will not notice a change in service as the reservoir water storage will generally be kept at the same levels. Customers on pumped supply lines may notice that the changes in pressure that they already experienced as a result of being supplied direct off a pumped supply line will occur at different times of the day.

There are some reservoirs that are operated at a high level to maintain pressure to properties around the reservoir with low hydraulic head pressure. Preventing these reservoirs from filling during the Peak tariff periods may require the reservoirs to be operated with a larger cycle which will force the reservoir water level lower. Where this is the case an assessment should be made as to the minimum water level required in the reservoir to maintain supply to high elevation customers.

6. CHAPTER 6 – CONCLUSIONS

This project was successful in finding a solution to reduce energy costs at the Nightcap WTP. The focus of the project was to take advantage of the Time of Use electricity tariff structure by avoiding running the WTP during the peak tariff.

6.1. Preferred Option

The preferred option is to implement Scenario 1, which is additional controls for the WTP only. This option was selected as it was shown, through modelling, to meet the project objective and has the benefit of not implementing additional controls on the distribution system. Less additional controls are preferred to reduce the required considerations of Rous Water operations and planning staff undertaking their normal work. There is a small capital cost to this solution however the payback period is expected to be less than one year. For ease of reference the additional controls required to achieve the project objective will be referred to as the ‘Algorithm’.

Depending on the performance of the Algorithm in the field, further adjustment of the control configuration may be necessary to regularly achieve the project objective. The benefit of this approach is that this style of control is easily configurable or expandable with low to nil capital cost. For example, the functionality for moving to Scenario 3a or 3b is already available and would simply need to be activated in the ClearSCADA.

6.2. Trial Period

Once the Algorithm has been implemented it is recommended to trial it’s operation and ability to achieve the desired objective. A six month trial period should be conducted with any issues investigated.

It is expected that there will be months where the project objective of avoiding WTP operation during the peak electricity tariff period will not be met. There are a number of occurrences that could require the WTP to run during peak tariff including: peak water demands in the network, pipe burst, WTP malfunction and power outages.

A review of the performance of the Algorithm should be conducted following the trial period. It is expected that the Algorithm would be adjusted and optimized during this trial period in particular the start and finish times for Force Filling and Tariff Lockout periods.

6.3. Implementation Plan

A preliminary implementation plan has been prepared to move this project from the concept/detailed design stage into a capital project and a new functionality of the Rous Water control system.

- Present findings and proposed project to responsible Managers for approval to proceed
- Prepare business case to Council to seek required funding for implementation of Algorithm
- Develop internal business process for operation of the Algorithm including responsibilities, change approval process and operational targets
- Consult with Rous Water staff to make them aware of the changes to control system
- Prepare functional specification for required control functionality
- Engage contractor to implement control functionality into SCADA system
- Commission Algorithm control
- Deliver training to operational staff involved with water supply system operations
- ‘Go Live’ for six month trial period of Algorithm
- Review Algorithm performance and issues during six month trial period
- Following successful trial, continue monitoring performance of Algorithm.

6.4. Applicability of Findings

This project has shown that there are significant savings available for water utilities by taking advantage of Time of Use (TOU) electricity tariff structures by scheduling operation of high energy demand equipment into less expensive tariff periods. It has also shown how this can be achieved using existing SCADA based control systems. This is significant as the current solution to implement an optimized scheduling solution for a water supply system is to implement proprietary software which can be costly.

In this project the focus of energy cost savings was solely on the Nightcap WTP at the head of the system because this is Rous Water’s only site on a TOU tariff structure. There is one significant distribution system pump station however it is already run during the off-peak tariff period.

The exact timings of the scheduled lockouts/force fill controls will be unique to each water supply system however the general concepts presented in this report can be adopted by any water supply system currently controlled via a SCADA system.

6.5. Further Work

There is still an opportunity to improve the Algorithm by supplementing the WTP control with scheduled feeding of the downstream reservoirs to control and reduce the peaks in the water demand. This was attempted in Scenarios 3a and 3b however the modelled scenarios were unable to achieve any significant improvement over Scenario 1 (WTP control only). Further analysis and trialling of different filling schedules would likely produce improved performance of the Algorithm.

The modelling was completed in Microsoft Excel as H2OMAP was unavailable at the time. The scenarios from this project could be further modelled in H2OMAP prior to implementation in the actual system to further validate the operation of the preferred option.

7. References

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8. Appendices

8.1. Appendix A – Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project

PROJECT SPECIFICATION

FOR: Samuel James CURRAN

TOPIC: OPTIMIZATION OF DISTRIBUTION NETWORK FLOWS TO REDUCE WATER TREATMENT PLANT PEAK POWER DEMAND

SUPERVISORS: Dr. Les Bowtell

ENROLMENT: ENG4111 – S1, 2015

ENG4112 – S2, 2015

PROJECT AIM: This project seeks to investigate control of the supply of potable water to the Rous Water distribution network with an aim to significantly reduce peak power demand at the water treatment plant.

PROGRAMME: **Issue A, 18th March 2015**

1. Research background information relating to WTP energy usage and control methodologies for water supply distribution networks

2. Conduct energy audit on WTP and analyse energy demand data

3. Analyse demands, flows and storage capacities through the water supply distribution network

4. Identify control method to reduce peak power demand usage at the WTP

5. Develop a water supply distribution network system model in H2OMAP to enable scenario modelling and validation of control method

6. Design and implement a SCADA-based algorithm to enable control of the water supply distribution network

8.2.Appendix B - Nightcap WTP Energy Audit

Nightcap WTP - Energy Audit

Scenario	**2 pump**
Plant Flow (l/s)	600
Avg. ML Production	32
Avg WTP Run time (hrs)	14.81

Summary Table

NMI	kWh	kW
NFFFNRKJ60	5300	420
NFFFNRKJ61	3466	235
Grand Total	**8765**	**655**

NMI	feature_id	Asset Type	Asset Name	kW	Duty	LF	Continuous/Batch	Batch Time	Batch Freq.	kWh	kW
NFFFNRKJ60	CP2501	Compressor	Air Compressor Ozone Train 1	77	On	80%	Continuous			884	62
NFFFNRKJ60	CP2701	Compressor	Air Compressor Ozone Train 2	77	On	80%	Continuous			884	62
NFFFNRKJ60	CP2901	Compressor	Air Compressor Ozone Train 3	77	Off	80%	Continuous			0	0
NFFFNRKJ60	PF5741	Blower	Air scour Blower 1	75	On	40%	Batch	0.200	4.402	26	30
NFFFNRKJ60	PF5742	Blower	Air scour Blower 2	75	Off	40%	Batch	0.200	4.402	0	0
NFFFNRKJ60	OG2601	Ozone Generator	Ozone Generator Train 1	72.7	On	80%	Continuous			835	58
NFFFNRKJ60	OG2801	Ozone Generator	Ozone Generator Train 2	72.7	On	80%	Continuous			835	58
NFFFNRKJ60	OG3001	Ozone Generator	Ozone Generator Train 3	72.7	Off	80%	Continuous			0	0
NFFFNRKJ60	PF5721	Centrifugal Pump	Backwash Pump 1	55	On	40%	Batch	0.228	4.402	22	22
NFFFNRKJ60	PF5722	Centrifugal Pump	Backwash Pump 2	55	Off	40%	Batch	0.228	4.402	0	0
NFFFNRKJ60	PF5831	Centrifugal Pump	Dunoon Pump 1	55	On	40%	Batch	6.000	1.000	132	22
NFFFNRKJ60	PF5832	Centrifugal Pump	Dunoon Pump 2	55	Off	40%	Batch	6.000	1.000	0	0
NFFFNRKJ60	PV6021	Submersible Pump	Recycle Pump 1	45	On	40%	Continuous			258	18

NFFFNRKJ60	PV6022	Submersible Pump	Recycle Pump 2	45	On	40%	Continuous			258	18
NFFFNRKJ60	PV6023	Submersible Pump	Recycle Pump 3	45	Off	40%	Continuous			0	0
NFFFNRKJ60	PV2301	Centrifugal Pump	Relift pump 1	30	On	40%	Continuous			172	12
NFFFNRKJ60	PV2302	Centrifugal Pump	Relift pump 2	30	On	40%	Continuous			172	12
NFFFNRKJ60	PV2303	Centrifugal Pump	Relift pump 3	30	Off	40%	Continuous			0	0
NFFFNRKJ60	PV2304	Centrifugal Pump	Relift pump 4	30	Off	40%	Continuous			0	0
NFFFNRKJ60	CP6201	Compressor	Main air compressor #1	18.13	On	40%	Continuous			104	7
NFFFNRKJ60	CP6202	Compressor	Main air compressor #2	18.13	Off	40%	Continuous			0	0
NFFFNRKJ60	PV6751	Submersible Pump	CO2 Service Water Pump 1	15	On	40%	Continuous			86	6
NFFFNRKJ60	PV6752	Submersible Pump	CO2 Service Water Pump 2	15	Off	40%	Continuous			0	0
NFFFNRKJ60	PV6621	Centrifugal Pump	Lime Service Water Pump 1	11	On	90%	Continuous			142	10
NFFFNRKJ60	PV6622	Centrifugal Pump	Lime Service Water Pump 2	11	Off	90%	Continuous			0	0
NFFFNRKJ60		Air Con	5.2kW & .45kW	5.65	On	40%	Batch	24.000	1.000	54	2
NFFFNRKJ60	MF6645	Mixer	Lime Clarifier #1 Mixer	5.5	On	40%	Continuous			32	2
NFFFNRKJ60	MF6646	Mixer	Lime Clarifier #2 Mixer	5.5	Off	40%	Continuous			0	0
NFFFNRKJ60	PV2451	Centrifugal Pump	Ozone cooling pump 1	5.5	On	40%	Continuous			32	2
NFFFNRKJ60	PV2452	Centrifugal Pump	Ozone cooling pump 2	5.5	Off	40%	Continuous			0	0
NFFFNRKJ60	PF6502	Air Extractor	Lime silo extractor fan	3	On	40%	Continuous			17	1
NFFFNRKJ60	DR2405	Ozone Destructor	Ozone Destructor	2.55	On	40%	Continuous			15	1
NFFFNRKJ60	PF6814	Centrifugal Pump	Alum dilution water pump	2.2	On	40%	Continuous			13	1
NFFFNRKJ60	PV6605	Progressive Cavity	Lime slurry pump 1	1.5	On	40%	Continuous			9	1

NFFFNRKJ60	PV6606	Progressive Cavity	Lime slurry pump 2	1.5	Off	40%	Continuous			0	0
NFFFNRKJ60		Lighting	50 double fluoros	1.4	On	90%	Batch	24.000	1.000	30	1
NFFFNRKJ60	PF3126	Submersible Pump	BAC filter floor sump pump	1.3	On	40%	Batch	0.083	1.000	0	1
NFFFNRKJ60	PF3150	Submersible Pump	BAC Sample sump pump	1.3	On	40%	Continuous			7	1
NFFFNRKJ60	MF6321	Vacuum Loader	Poly batching unit #1	1.2	On	40%	Batch	0.083	9.568	0	0
NFFFNRKJ60	MF6371	Vacuum Loader	Poly batching unit #2	1.2	Off	40%	Batch	0.083	9.568	0	0
NFFFNRKJ60	MF5110	Flocculator	DAFF 1 - Stage 1	1.1	On	40%	Continuous			6	0
NFFFNRKJ60	MF5210	Flocculator	DAFF 2 - Stage 1	1.1	On	40%	Continuous			6	0
NFFFNRKJ60	MF5310	Flocculator	DAFF 3 - Stage 1	1.1	On	40%	Continuous			6	0
NFFFNRKJ60	MF5410	Flocculator	DAFF 4 - Stage 1	1.1	On	40%	Continuous			6	0
NFFFNRKJ60	MF5510	Flocculator	DAFF 5 - Stage 1	1.1	On	40%	Continuous			6	0
NFFFNRKJ60	MF5610	Flocculator	DAFF 6 - Stage 1	1.1	On	40%	Continuous			6	0
NFFFNRKJ60		Computers	4 computers + servers	1	On	90%	Batch	10.000	1.000	9	1
NFFFNRKJ60	MX448	Mixer	Lime neutralisation tank mixer	0.75	On	40%	Continuous			4	0
NFFFNRKJ60	NZ6505	Bin Activator	Lime Bin Activator	0.75	On	90%	Continuous			10	1
NFFFNRKJ60	PV6910	Dose Pump	Raw water poly pump 1	0.75	On	40%	Continuous			4	0
NFFFNRKJ60	PV6920	Dose Pump	Raw water poly pump 2	0.75	Off	40%	Continuous			0	0
NFFFNRKJ60	PF4150	Progressive Cavity	Dam water sample pump	0.73	On	40%	Continuous			4	0
NFFFNRKJ60	PF5760	Progressive Cavity	Filtered water sample pump	0.73	On	40%	Continuous			4	0
NFFFNRKJ60	PF5820	Progressive Cavity	Treated water sample pump	0.73	On	40%	Continuous			4	0
NFFFNRKJ60	PF2140	Submersible Pump	CO2 Dosing chamber sump pump	0.7	On	40%	Batch	0.083	1.000	0	0

NFFFNRKJ60	PF2150	Submersible Pump	River water flowmeter sump pump	0.7	On	40%	Batch	0.083	1.000	0	0
NFFFNRKJ60	DR6263	Air Dryer	Compressed air dryer #1	0.5	On	40%	Continuous			3	0
NFFFNRKJ60	DR6264	Air Dryer	Compressed air dryer #2	0.5	Off	40%	Continuous			0	0
NFFFNRKJ60	MF5120	Flocculator	DAFF 1 - Stage 2	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	MF5220	Flocculator	DAFF 2 - Stage 2	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	MF5320	Flocculator	DAFF 3 - Stage 2	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	MF5420	Flocculator	DAFF 4 - Stage 2	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	MF5520	Flocculator	DAFF 5 - Stage 2	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	MF5620	Flocculator	DAFF 6 - Stage 2	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	MV6523	Dry Feeder	Lime Screw feeder #1	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	MV6543	Dry Feeder	Lime Screw feeder #2	0.37	Off	40%	Continuous			0	0
NFFFNRKJ60	MX650	Mixer	Permanganate tank mixer	0.37	Off	40%	Continuous			0	0
NFFFNRKJ60	PF2120	Progressive Cavity	River sample pump	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PF2130	Progressive Cavity	Mixed raw water sample pump	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PF2410	Progressive Cavity	Ozone Outlet stream sample pump	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PV6410	Dose Pump	ACH Pump 1	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PV6420	Dose Pump	ACH Pump 2	0.37	Off	40%	Continuous			0	0
NFFFNRKJ60	PV655	Dose Pump	Permanganate Dose Pump 1	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PV656	Dose Pump	Permanganate Dose Pump 2	0.37	Off	40%	Continuous			0	0
NFFFNRKJ60	PV6811	Dose Pump	Alum dose pump 1	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PV6812	Dose Pump	Alum dose pump 2	0.37	Off	40%	Continuous			0	0

NFFFNRKJ60	PV7011	Dose Pump	Ammonia Pump 1	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PV7012	Dose Pump	Ammonia Pump 2	0.37	Off	40%	Continuous			0	0
NFFFNRKJ60	PV7111	Dose Pump	Sodium Hypochlorite Dose Pump 1	0.37	On	40%	Continuous			2	0
NFFFNRKJ60	PV7112	Dose Pump	Sodium Hypochlorite Dose Pump 2	0.37	Off	40%	Continuous			0	0
NFFFNRKJ60	PF150	Centrifugal Pump	Diluted solids sample pump	0.35	On	40%	Continuous			2	0
NFFFNRKJ60	PF317	Centrifugal Pump	Supernatant Sample Pump	0.35	On	40%	Continuous			2	0
NFFFNRKJ60	MF6425	Mixer	Lime batch tank #1 mixer	0.25	On	40%	Continuous			1	0
NFFFNRKJ60	MF6445	Mixer	Lime batch tank #2 mixer	0.25	Off	40%	Continuous			0	0
NFFFNRKJ60	MF6643	Scraper	Lime Clarifier #1 Rake	0.18	On	40%	Continuous			1	0
NFFFNRKJ60	MF6644	Scraper	Lime Clarifier #2 Rake	0.18	Off	40%	Continuous			0	0
NFFFNRKJ60	TK6326	Batching Unit	Polymer #1	0.18	On	90%	Batch	0.083	9.568	0	0
NFFFNRKJ60	TK6376	Batching Unit	Polymer #2	0.18	Off	90%	Batch	0.083	9.568	0	0
NFFFNRKJ60	V5102	Valve	Filter 1 wash water penstock Vlv	0.16	On	40%	Batch	0.017	4.172	0	0
NFFFNRKJ60	V5202	Valve	Filter 2 wash water penstock Vlv	0.16	On	40%	Batch	0.017	4.172	0	0
NFFFNRKJ60	V5302	Valve	Filter 3 wash water penstock Vlv	0.16	On	40%	Batch	0.017	4.172	0	0
NFFFNRKJ60	V5402	Valve	Filter 4 wash water penstock Vlv	0.16	On	40%	Batch	0.017	4.172	0	0
NFFFNRKJ60	V5502	Valve	Filter 5 wash water penstock Vlv	0.16	On	40%	Batch	0.017	4.172	0	0
NFFFNRKJ60	V5602	Valve	Filter 6 wash water penstock Vlv	0.16	On	40%	Batch	0.017	4.172	0	0
NFFFNRKJ60		Fridge	1 fridge	0.05	On	90%	Batch	24.000	1.000	1	0
NFFFNRKJ60		Hot Water	200L	0.05	On	90%	Batch	24.000	1.000	1	0

NFFFNRKJ61	PF4111	Centrifugal Pump	Raw Water Pump 1	110	On	90%	Continuous			1421	99
NFFFNRKJ61	PF4121	Centrifugal Pump	Raw Water Pump 2	110	On	90%	Continuous			1421	99
NFFFNRKJ61	PF4131	Centrifugal Pump	Raw Water Pump 3	110	Off	90%	Continuous			0	0
NFFFNRKJ61	PF4141	Centrifugal Pump	Raw Water Pump 4	110	Off	90%	Continuous			0	0
NFFFNRKJ61	PF1501	Centrifugal Pump	DSH Emergency Pump	55	Off	40%	Continuous			0	0
NFFFNRKJ61	PV1258	Centrifugal Pump	Waste Recycle Pump 1	30	Off	40%	Continuous			0	0
NFFFNRKJ61	PV1357	Centrifugal Pump	Waste Recycle Pump 3	30	Off	40%	Continuous			0	0
NFFFNRKJ61	PV1361	Centrifugal Pump	Waste Recycle Pump 2	30	On	40%	Continuous			172	12
NFFFNRKJ61	CF228	Centrifuge	Centrifuge 1	15	On	40%	Continuous			86	6
NFFFNRKJ61	MF229A	Centrifuge	Centrifuge 2	15	Off	40%	Continuous			0	0
NFFFNRKJ61	PV115	Centrifugal Pump	DSH Pump 1	11	On	40%	Continuous			63	4
NFFFNRKJ61	PV121	Centrifugal Pump	DSH Pump 2	11	Off	40%	Continuous			0	0
NFFFNRKJ61	PV305	Centrifugal Pump	Supernatant Pump 1	11	On	40%	Continuous			63	4
NFFFNRKJ61	PV310	Centrifugal Pump	Supernatant Pump 2	11	Off	40%	Continuous			0	0
NFFFNRKJ61	CP1452	Compressor	Waste plant compressor 2	5.5	Off	40%	Continuous			0	0
NFFFNRKJ61	MX109	Mixer	DSH Tank Mixer	5	On	40%	Continuous			29	2
NFFFNRKJ61	CP1451	Compressor	Waste plant compressor (piston) 1	3	On	40%	Continuous			17	1
NFFFNRKJ61	PV204	Progressive Cavity	WTS Pump 1	3	On	40%	Continuous			17	1
NFFFNRKJ61	PV218	Progressive Cavity	WTS Pump 2	3	On	40%	Continuous			17	1
NFFFNRKJ61	PV219	Progressive Cavity	WTS Pump 3	3	Off	40%	Continuous			0	0
NFFFNRKJ61	PF240	Submersible Pump	Centrate return Pump 1	2.2	On	40%	Continuous			13	1

NFFFNRKJ61	PF241	Submersible Pump	Centrate return Pump 2	2.2	On	40%	Continuous			13	1
NFFFNRKJ61	MF921	Vacuum Loader	WTS poly batching	1.2	On	40%	Batch	0.083	9.568	0	0
NFFFNRKJ61	MX148A	Mixer	WTS Tank A Mixer	0.75	On	40%	Continuous			4	0
NFFFNRKJ61	PF242	Submersible Pump	Skip Drainage Sump Pump	0.75	On	40%	Batch	0.083	1.000	0	0
NFFFNRKJ61	PV555	Dose Pump	DAFT Poly Dose Pump 1	0.75	On	40%	Continuous			4	0
NFFFNRKJ61	PV556	Dose Pump	DAFT Poly Dose Pump 2	0.75	Off	40%	Continuous			0	0
NFFFNRKJ61	SC250	Conveyor	Slewing Conveyor Centrifuge #1	0.55	On	40%	Continuous			3	0
NFFFNRKJ61	SC251	Conveyor	Screw Cross Conveyor 1	0.55	On	40%	Continuous			3	0
NFFFNRKJ61	SC252	Conveyor	Screw Cross Conveyor 2	0.55	Off	40%	Continuous			0	0
NFFFNRKJ61	MF925	Mixer	WTS Poly batch tank mixer #1	0.37	On	40%	Batch	0.083	9.568	0	0
NFFFNRKJ61	MF935	Mixer	WTS Poly batch tank mixer #2	0.37	Off	40%	Batch	0.083	9.568	0	0
NFFFNRKJ61	PV557	Dose Pump	Centrifuge Poly Dose Pump 1	0.37	On	40%	Continuous			2	0
NFFFNRKJ61	PV558	Dose Pump	Centrifuge Poly Dose Pump 2	0.37	On	40%	Continuous			2	0
NFFFNRKJ61	PV559	Dose Pump	Centrifuge Poly Dose Pump 3	0.37	Off	40%	Continuous			0	0
NFFFNRKJ61	DR1455	Air Dryer	WTS compressed air dryer no.2	0.34	Off	40%	Continuous			0	0
NFFFNRKJ61	DR1456	Air Dryer	WTS compressed air dryer no.1	0.34	On	40%	Continuous			2	0
NFFFNRKJ61	SC253	Actuator	Slewing Conveyer Actuator (Rotork)	0.21	On	40%	Batch	0.083	2.000	0	0
NFFFNRKJ61	MF924	Conveyor	WTS poly loading hopper etc	0.18	On	40%	Batch	0.083	9.568	0	0
NFFFNRKJ61	SC1251	Conveyor	Screw Conveyor DAFT Cell #1	0.18	On	40%	Continuous			1	0
NFFFNRKJ61	SC1351	Conveyor	Screw Conveyor DAFT Cell #2	0.18	Off	40%	Continuous			0	0

NFFFNRKJ61	TK902	Batching Unit	Waste Polymer Batching Unit 1	0.18	Off	90%	Batch	0.083	9.568	0	0
NFFFNRKJ61	TK905	Batching Unit	Waste Polymer Batching Unit 2	0.18	On	40%	Batch	0.083	9.568	0	0
NFFFNRKJ61	MF1252	Scraper	Scraper (bottom) DAFT Cell #1	0.12	On	40%	Continuous			1	0
NFFFNRKJ61	MF1352	Scraper	Scraper (bottom) DAFT Cell #2	0.12	On	40%	Continuous			1	0
NFFFNRKJ61	MV1250	Scraper	Skimmer (surface) DAFT Cell #1	0.12	On	40%	Continuous			1	0
NFFFNRKJ61	MV1350	Scraper	Skimmer (surface) DAFT Cell #2	0.12	On	40%	Continuous			1	0

8.3.Appendix C - Project Program

The project program that was used to complete this project is included in the table below. The program is based around the Methodology discussed in an earlier section.

PROJECT PROGRAM				
Project Stage	**Start Date**	**Duration**	**Finish Date**	**Completion**
Investigation				
Energy Audit	Feb 2015	1 month	Mar 2015	100%
Energy Analysis	Feb 2015	2 months	Apr 2015	100%
Flow and Reservoir Analysis	Mar 2015	2 months	May 2015	100%
Control Methodologies	Mar 2015	2 months	May 2015	100%
Literature Review	Feb 2015	4 months	Jun 2015	100%
Modelling and Validation				
Model distribution system – excel	Jun 2015	1 month	Jul 2015	100%
Model distribution system – H2OMAP	Jun 2015	1 month	Jul 2015	100%
Validate model	Jun 2015	1 month	Jul 2015	100%
Optimization of preferred optimization				
Assess viability of optimization methods	Jul 2015	2 months	Sep 2015	100%
Validate and Optimize preferred option	Aug 2015	1 month	Sep 2015	100%
Business Case				
Prepare business case for extra funding if required	Aug 2015	1 month	Sep 2015	TBC
Design and Implementation				
Prepare design documentation	Sep 2015	2 months	Nov 2015	TBC
Implement proposed solution	Sep 2015	2 months	Nov 2015	TBC