INNOVATIVE SOLUTIONS TO MULTIPLE PROJECT CHALLENGES – CONNECTING A SATELLITE WASTEWATER SYSTEM

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ABSTRACT

Currently, wastewater from Ashhurst is treated at the Ashhurst wastewater treatment plant and then discharged into the Manawatu River. With the discharge consent of this plant expiring shortly, Palmerston North City Council identified efficiencies in diverting the Ashhurst wastewater system to the Palmerston North wastewater treatment plant. An additional advantage to this connection is that it will pass through and could provide service to the Whakarongo residential growth area, located 8 km from Ashhurst.

This paper looks at the challenges faced in designing the connection between the two systems and the innovative design implemented to overcome these challenges. By making use of existing Ashhurst oxidation pond infrastructure, risks associated with multiple design issues were mitigated.

In undertaking the design, three key variables were identified, each having multiple options. The variables were the route of the proposed rising main, the Ashhurst pumping regime and how the system incorporates the Whakarongo growth area. This resulted in a total of 18 combined options which were assessed using the Net Present Value method. Considering the existing ponds at Ashhurst, the new pump station and also the delivery pipeline as a single system instead of individual components allowed the team to select a design that best suited the community's needs at the lowest whole of life cost.

KEYWORDS

Wastewater, Pressure Mains, NPV

1 INTRODUCTION

Ashhurst is a small township of approximately 2,500 people located 10 km northeast of Palmerston North. Wastewater from Ashhurst is currently treated at the Ashhurst Wastewater Treatment Ponds located south of the town. From there, the treated wastewater is discharged a short distance away into the Manawatu River.

With the discharge consent for this plant soon to expire, Palmerston North City Council (PNCC) identified efficiencies in diverting the Ashhurst wastewater system to the Palmerston North Wastewater Treatment Plant. An additional advantage to this connection is that it will pass through and could provide service to the Whakarongo residential growth area. Illustrated overleaf is a map showing the proximity of each of these systems.

Due the elevation differences it was obvious that the Ashhurst to Palmerston North connection would consist of a new rising main and pumpstation. The Palmerston North WWTP is located on the opposite side of the city to Ashhurst. It was therefore desirable to make use of Palmerston North's existing wastewater network to convey Ashhurst's wastewater through the city where possible.

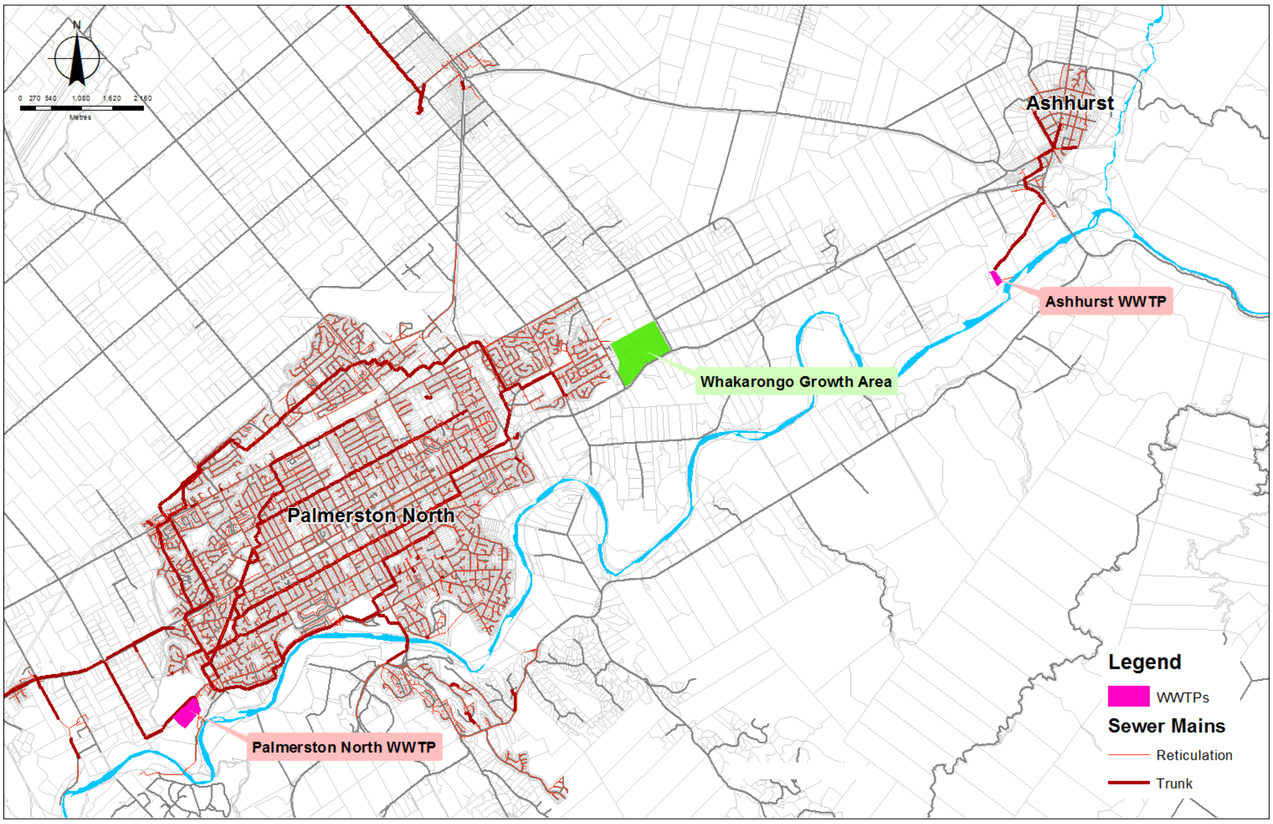

Figure 1: Location Overview

Below is a map showing the existing Palmerston North trunk sewer mains. From this it can be seen that the section of trunk sewer nearest to Ashhurst is the top end of the Fergusson Trunk near the intersection of Roberts Line and Rosalie Terrace. Under a separate project, a hydraulic model was used to show that the Fergusson Trunk Main had sufficient capacity to receive the Ashhurst flows. This was therefore the logical location to connect Ashhurst into the Palmerston North network.

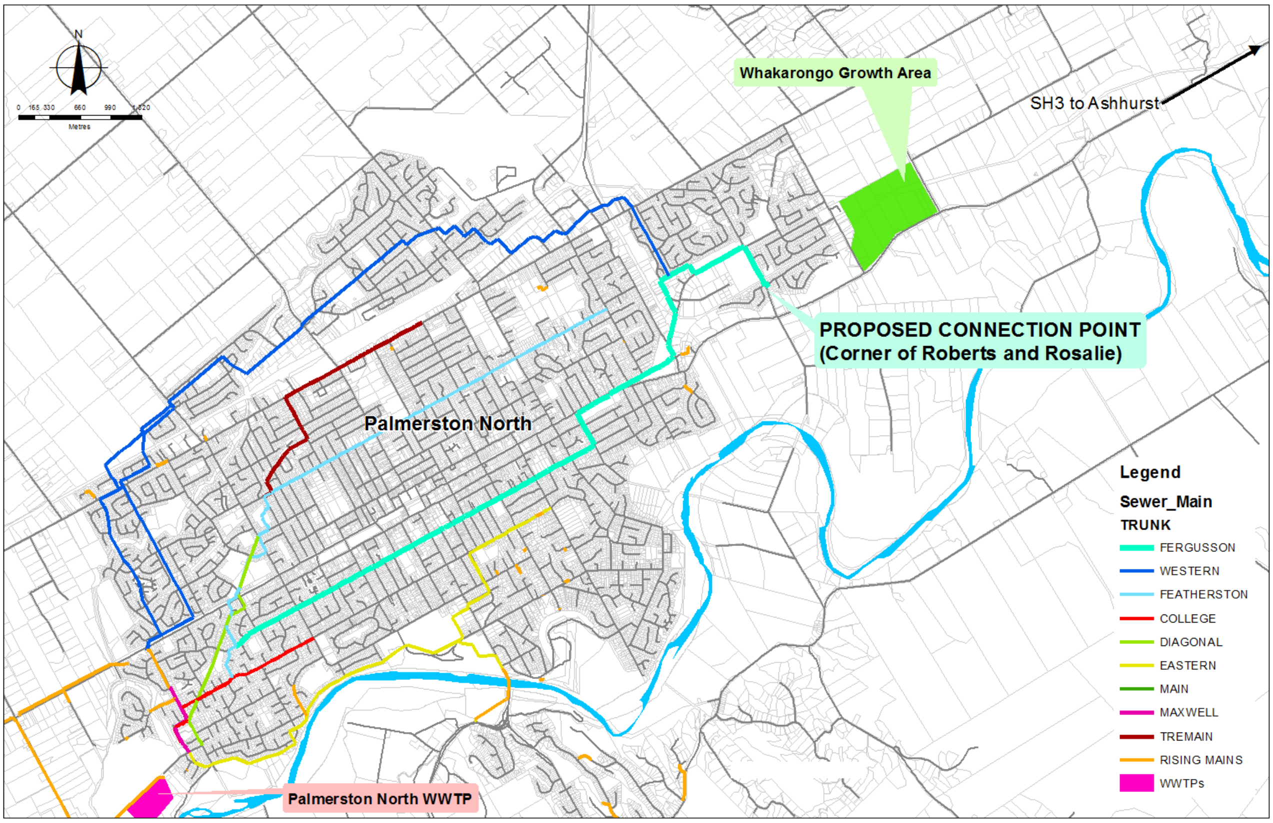

Figure 2: Proposed Connection Point

In order to select a design that best suited the community's needs, an options investigation was carried out.

At the beginning of the options investigations three key challenges were identified as listed below.

- The long rising main required (approximately 10 km) – odour, corrosion & pumping costs are typical issues often associated with this.
- High wet weather peak flows in Ashhurst – 5.3 times average dry weather flow (ADWF) – typically results in large and expensive wetwells, pumps and rising mains.
- Limited capacity in the Palmerston North wastewater network to cater for future growth.

Additional to these challenges three design variables with multiple conceptual options were also identified as listed below.

- Rising main route
- Ashhurst pumping regime
- How to allow for the future connection from the Whakarongo growth area.

This paper outlines the process used to mitigate these issues and discusses the advantages of the innovative solution selected.

2 DISCUSSION

2.1 EXISITING ASHHURST WASTEWATER INFRASTRUCTURE

As illustrated in Figure 3 below, the Ashhurst Wastewater Treatment Ponds are located at the end of Hacketts Road, Ashhurst. A normal gravity wastewater network collects Ashhurst's raw wastewater and conveys it to the ponds where it is treated. From there, the treated wastewater is discharged a short distance away into the Manawatu River.

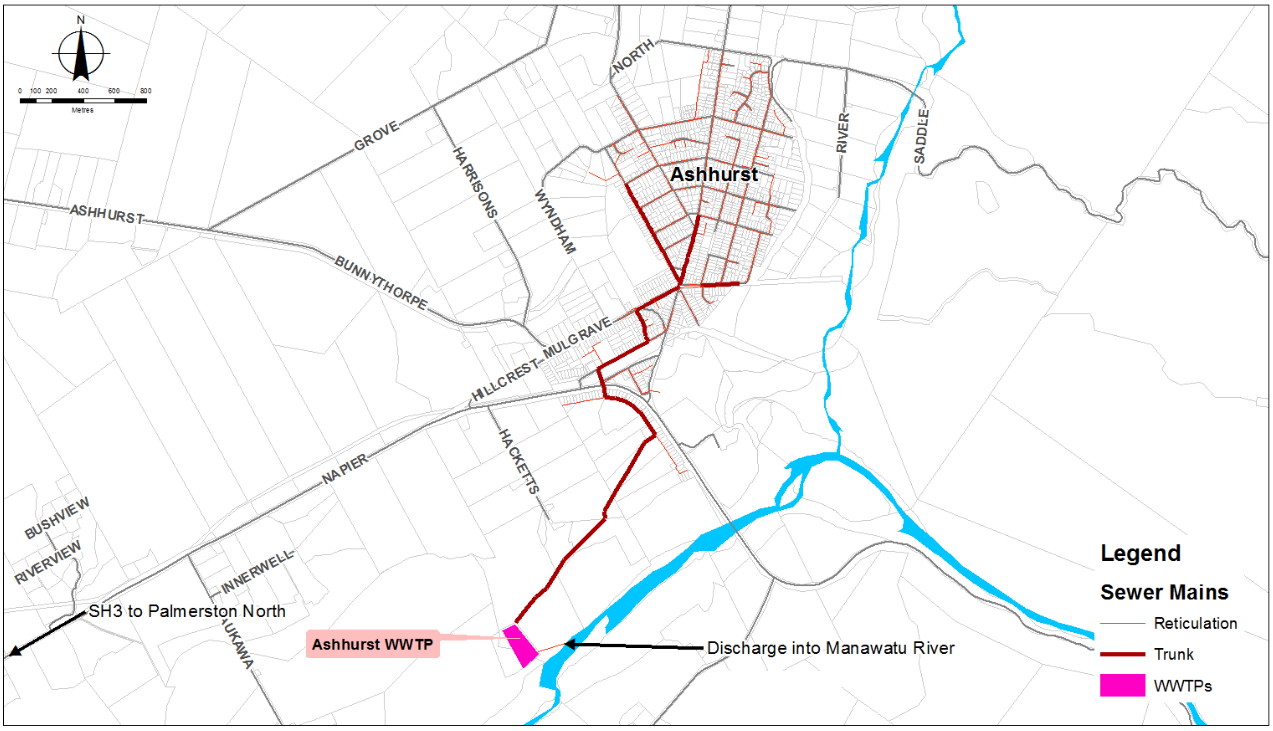

Figure 3: Ashhurst Wastewater System

Through liaison with the client, it was decided that the new pump station and rising main should be sized to cope with a maximum of a 1:2 flow event allowing for 20 years of population growth. Analysis of eight years of historical flow data showed that the Ashhurst system had a 1 in 2 year peak flow of 3333 m^3/d. This was scaled up to 3,600 m^3/d based on a l/h/d ratio using council's population projections for 2031.

The existing Ashhurst Treatment Ponds consist of two ponds in series. The first, being the facultative pond, has a volume of approximately 18,000 m^3. The second, being the maturation pond, has a volume of approximately 6,000 m^3. Both ponds are approximately 1.5 m deep at normal water level. It was identified that there could be significant benefits in retaining these ponds as discussed below.

2.2 BENEFITS OF RETAINING THE ASHHURST PONDS

By utilising the existing ponds for flow buffering and pretreatment, the issues associated with all three of the key challenges identified in Section 1 would be mitigated. Flow buffering would reduce the peak flow, reducing the required size of the pump station and rising main as well as minimizing the impact on the receiving Palmerston North wastewater network and WWTP. Pretreatment would reduce the solids and BOD content of the wastewater minimizing the risk of corrosion and odour associated problems.

Sections 2.1.1 to 2.1.3 below detail this innovative concept which was carried forward to the options analysis phase discussed in Section 2.2.

2.2.1 MATRUATION POND

It was noted that the process performance from the maturation pond would no longer be required as the pathogen reduction function of the pond would become irrelevant when pumping the effluent into the Palmerston North sewer network. It was therefore identified that the maturation pond could be used for buffer storage.

To avoid weed growth on the bottom of the maturation pond it was recommended that a minimum wastewater depth of 900 mm was maintained in the ponds at all times. At this depth the amount of light that reaches the bottom of the pond is minimal suppressing weed growth. The remaining 600 mm depth of the total 1,500 mm was therefore available for flow buffering which equated to about 4,000 m^3. This is more than 24 hrs storage at daily design flow of approximately 3,600 m^3/day.

For added risk reduction it was decided that the maturation ponds would only be used to buffer the diurnal peaking factor. Assuming a diurnal peaking factor of 2, this could allow the pumpstation and rising main design flow rate to be halved from 83.0 l/s to 41.5 l/s.

A further opportunity to ultilise the maturation pond for flow buffering was identified. It was recommended that a time and level based pump station control philosophy be used that favoured night time (off peak) pumping. The key benefit of this is that it would help smooth the diurnal peaking at the Palmerston North WWTP resulting in a more stable and effective treatment process.

2.2.2 FACULTATIVE POND

Theoretically the facultative pond could also be used for flow buffering, however this will affect the performance of the pond in terms of BOD and suspended solids reduction. This is important function as a lower BOD and suspended solids loading reduces the risk of the wastewater becoming septic in the long rising main, mitigating the risk of oduor and corrosion.

As the maturation pond is sufficiently sized to buffer 24 hrs of peak flow it is not necessary to utilise the facultative ponds for flow buffering for anything other than extreme wet weather events greater than the 1 in 2 year design event. To allow the maturation pond levels to vary without the effecting the levels in facultative pond a weir on the connection between the facultative and maturation ponds will be required.

2.2.3 OVERFLOW

As with any contained system, overflow of these ponds could occur in the most extreme events or following prolonged pump failure. There is 1 m of freeboard above the current normal water level in both ponds. While this freeboard allows for significantly more emergency storage making overflow in extreme events even more unlikely, it is still theoretically possible. To cater for this it was recommended that an overflow weir be constructed on the inlet to the existing outlet main and the existing outlet main to the Manawatu River be retained as an overflow main. This facility would only be used in extreme, unforeseen events and, depending on the Regional Councils legislation, may not require a consent.

2.3 OPTION SELECTION

As discussed in Section 1, multiple conceptual options for the following three variables were identified:

- Rising Main Route
- Ashhurst Pumping Regime (including the concept to retain the Ashhurst Ponds)
- How to allow for the future connection from the Whakarongo growth area.

The details of the options for each of the three variables are discussed below:

2.3.1 ROUTE SELECTION

The route between the Ashhurst ponds and Palmerston North was divided into the following three logical sections:

- Ashhurst Ponds to Napier Road / State Highway 3 (SH3).
- SH3.
- SH3 to discharge location.

For maintenance and access reasons the routes were selected to generally make use of road corridors where possible. The two route options identified are illustrated in Figure 4 below.

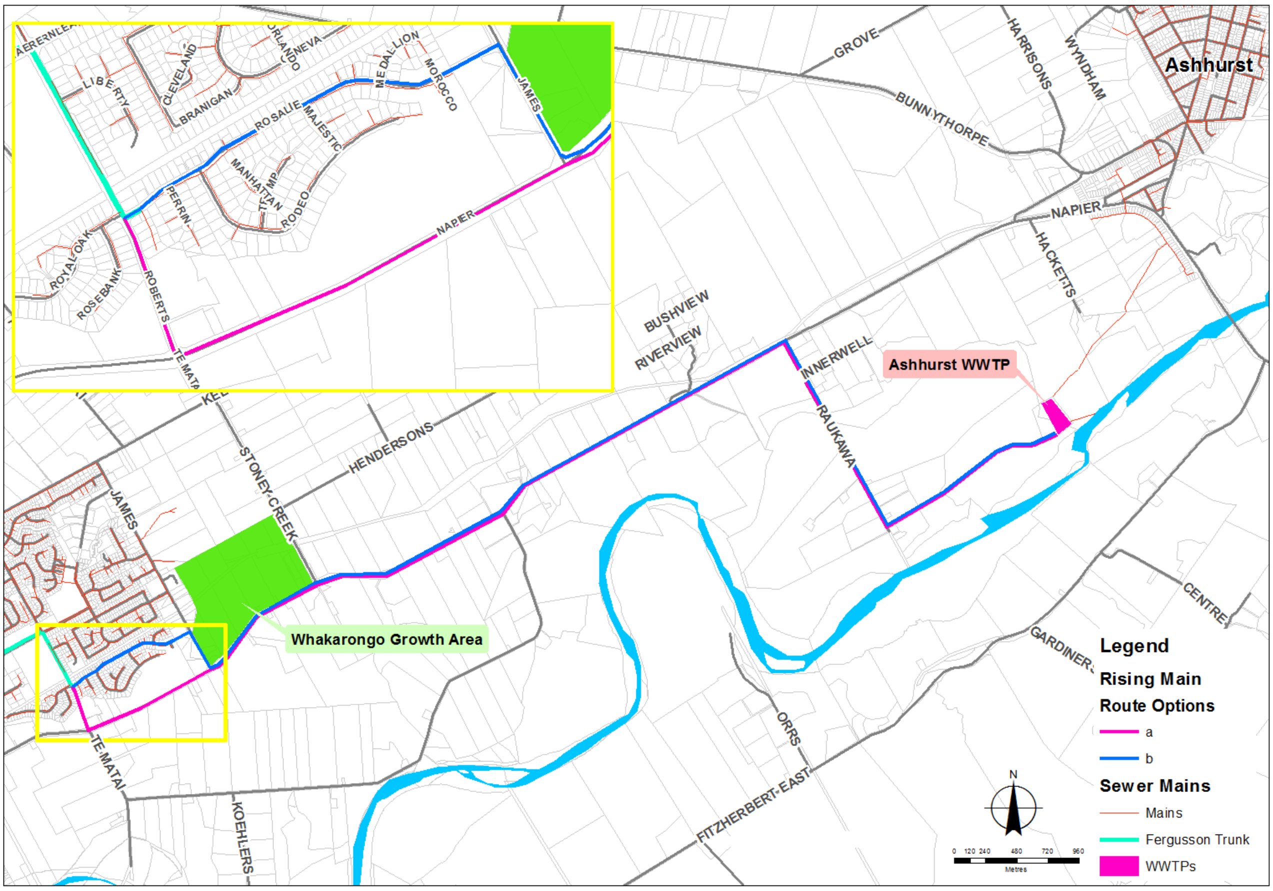

Figure 4: Route Options

The Ashhurst Ponds are landlocked relative to road corridors. This means that the proposed rising main must cross private land prior to reaching a road corridor. The route for this section was selected through liaison with the affected land owner as such only one option was available for this section.

Between Raukawa Road and the outskirts of Palmerston North city, the only logical route was to follow SH3. No other roads provide a direct route in this vicinity.

Two route options were identified between SH3 and the proposed discharge location at the intersection of Roberts Line and Rosalie Terrace as illustrated above.

Option a was the most obvious option, running along SH3 and Roberts Line to the proposed discharge point. As there is a significant rise between SH3 and the proposed discharge location, the entire main would have to be a pressure main. For this option it is proposed that wastewater from the entire Whakarongo area will discharge into a pump station located near the intersection of SH3 and James Line.

Option b was a more innovative option that ran up James Line, across a short section of private land and along Rosalie Terrace. This section of private land had been identified by council for a future extension of Rosalie Terrace to connect into James Line. Due to the nature of the topography, it is possible that the section of the proposed sewer main between James Line and Roberts Line be laid as a gravity main. This enables wastewater from the Whakarongo upper terrace to be conveyed into the existing network by gravity meaning that only flows from the lower terrace would have to be pumped. Refer to Figure 5 below.

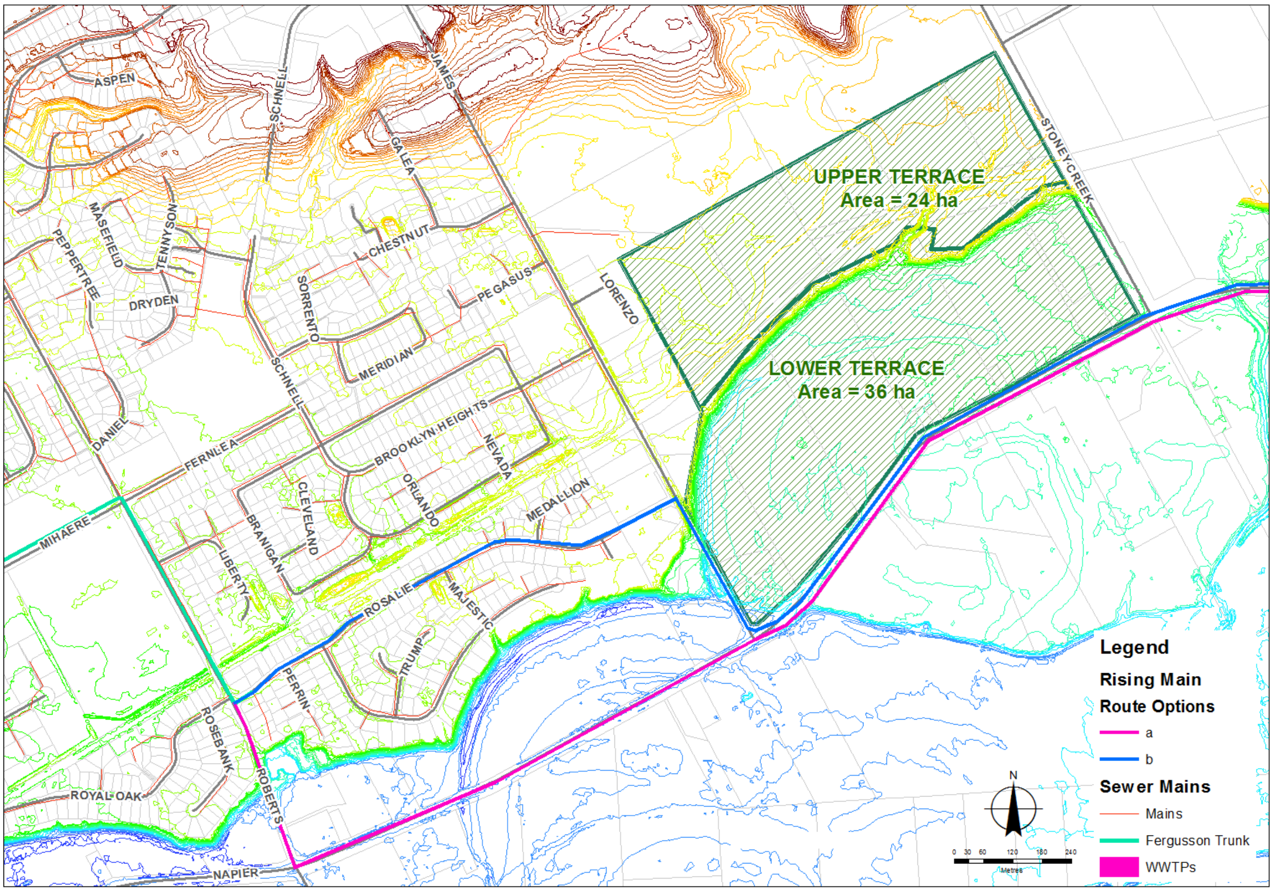

Figure 5: Whakarongo Growth Area

2.3.2 ASHHURST PUMPING REGIME

Three pumping regime options were identified for the proposed Ashhurst Pump Station as listed below:

- Option (A) Typical wastewater pump station not utilising the existing ponds for flow buffering.
- Option (B) Off-peak (night time) pumping only using Ashhurst ponds to buffer daily flows.

- Option (C) Low flow pumping during day, high flow pumping at night using Ashhurst ponds to buffer daily flows.

2.3.3 CONNECTION WITH WHAKARONGO DEVELOPMENT

At least a portion of the wastewater from the Whakarongo development area will need to be pumped into the Palmerston North wastewater reticulation. For the purpose of this analysis it was assumed that a pump station will be constructed near the intersection of SH3 and James Line. Three options were identified to incorporate the Whakarongo system into the proposed Ashhurst rising main. The three options carried forward for options analysis were:

- Option 1 Have Ashhurst and Whakarongo utilise a common rising main.
- Option 2 Re-pump Ashhurst flow at Whakarongo.
- Option 3 Have Ashhurst and Whakarongo utilise separate rising mains.

For Option 2, the topography allows the last 1 km of the Ashhurst only main to be a gravity main. Options 1 and 3 do not enable additional gravity sections.

2.4 OPTION ANALYSIS

In order to select the most cost effective overall solution, the options for the variables discussed above where combined so that the systems could be compared to each other holistically.

As illustrated by the options matrix below this resulted total of 18 options which were assessed.

Table 1: Options Matrix

Discharge Option a	**Pump to Roberts Line**	**1**	**2**	**3**
	Whakarongo Connection	**Common Rising Main**	**Repump**	**Separate Rising Mains**
	Ashhurst Control Philosophy			
A	Normal P/S (ponds not utilised)	aA1	aA2	aA3
B	Night time only pumping	aB1	aB2	aB3
C	Low flow pumping day, high flow at night	aC1	aC2	aC3

Discharge Option b	**Pump to Rosalie - New Gravity to Roberts Line**	**1**	**2**	**3**
	Whakarongo Connection	**Common Rising Main**	**Repump**	**Separate Rising Mains**
	Ashhurst Control Philosophy			
A	Normal P/S (ponds not utilised)	bA1	bA2	bA3
B	Night time only pumping	bB1	bB2	bB3
C	Low flow pumping day, high flow at night	bC1	bC2	bC3

For Option nomenclature, the following should be noted:

- a and b denote the route option between SH3 and the discharge location
- A, B and C denote the pumping philosophy at the Ashhurst pump station
- 1,2 and 3 denote the way Whakarongo is incorporated in the design.

An operational and capital cost estimate was produced for each option. The options analysis was carried out using the Net Present Value (NPV) method. The Net Present Value was calculated for each option over a 25 year design horizon. The assumptions and methodology used to create the NPV cost estimates are given in Appendix A.

The NPV for all 18 options ranged between $5.7 million and 6.3 million. Which is an approximately 11% difference, well within the margin of error of these high-level cost estimates. The cost estimates showed that the capital cost of the rising main formed the greatest component of the NPV. The capital cost for all options were also similar to each other and less than the council's initial budget.

The individual components of option bC1 had other benefits that were not identified in the NPV analysis. These are discussed below:

2.4.1 OPTION b – GRAVITY MAIN ALONG ROSALIE TERRACE

This option would enable growth to occur on the upper terrace of the Whakarongo growth area without the need for additional bulk wastewater infrastructure. This may allow the construction of the proposed Whakarongo Pump Station to be deferred provided development occurs on the upper terrace first.

2.4.2 OPTION C – LOW FLOW PUMP DURING DAY, HIGH FLOW AT NIGHT

This option would help smooth the diurnal flow curve at the Palmerston North WWTP making the treatment plant flows more constant, which will make the treatment plant operation more stable.

It should be noted that for the options assessment cost estimate, it was assumed that this system operated such that its peak day time (12 hrs) flow rate was 25.5 l/s which meant that a peak night time (12 hrs) flow of 57.5 l/s was required to pump the peak design flow of approximately 3600 m^3/d. Therefore the system was sized for a peak flow rate of 57.5 l/s. The ratio between peak day time and peak night time pumping was somewhat arbitrary this stage.

In the subsequent preliminary design phase this ratio was investigated in more detailed. It showed that by having the same peak flow rate day and night of 41.5 l/s the required rising main diameter could be reduced by one pipe size which offered significant savings. This option still favored night time (off peak) pumping during normal dry weather flows but during wet weather flows (high levels in the maturation pond) it meant that it could pump at the peak rate for 24 hrs a day. A pump control philosophy was proposed that would result in the pump station typically only pumping at night during dry weather.

It is acknowledged that this concept is not as effective at smoothing diurnal peaking of wet weather flows at the WWTP. However, the discharge consent conditions for the Palmerston North WWTP are more stringent during times of low river flow (dry weather). Therefore there is more margin for variation in the effluent quality in wet weather events.

If the flat peak flow rate of 41.5 l/s was used in the NPV analysis for this option, it would have lowered the NPV of this option making it more favoured.

By retaining the ponds a greater level of emergency storage is made available making this option more conservative at no additional cost.

2.4.3 OPTION 1 – COMMON RISING MAIN WITH WHAKARONGO

This reduced the cost to service the Whakarongo Growth area significantly. Subsequent detailed hydraulic analysis showed that the additional flow from Whakarongo did not warrant an increase in pipe diameter from what was already required to service Ashhurst. This essentially means the rising main for Whakarongo could be provided for no additional cost.

2.4.4 OPTION ANALYSIS DISCUSSION

In this instance the NPV methodology proved to be inconclusive as a decision making tool as the separation of all options was within the margin of error of the cost estimates. A Multi Criteria Analysis (MCA) process that assess and scores other attributes as well as costs could have be used to separate these options. However, in this case one option had clear non-cost attribute advantages and also happened to have the lowest NPV (by a very small margin). It was therefore decided that a detailed MCA was not required as the preferred option was easily selectable – option bC1.

While the NPV analysis was not effective in separating the options it was still a useful procedure as it proved that all 18 options would result in a similar cost and therefore the preferred option could be selected based on non-cost attributes.

3 CONCLUSIONS

By selecting an innovative design that involved retaining the existing treatment ponds for pretreatment and flow buffering a solution was provided that was estimated to cost less than PNCC’s initial budget while providing the following benefits:

- A high level of emergency storage, reducing the risk of overflow.
- The ability to only pump at off peak times during dry weather flow, smoothing the diurnal pattern at the receiving WWTP creating a more stable treatment process at times when the discharge consent conditions are more stringent.
- Flow buffering of the diurnal pattern also reduce the peak design flow rate from 83 l/s to 41.5 l/s allowing a reduction in the size of the rising main and pump station resulting in what is likely to be the lowest cost solution.
- Pretreatment reduced the risk of the wastewater going septic in the long rising main reducing the risk of the associated issues of odour and corrosion.

In this instance the NPV options analysis procedure was not effective in separating the options as the separation of all options was within the margin of error of the cost estimates. The NPV analysis was still a useful procedure in it proved that all 18 options would result in a similar cost and therefore the preferred option could be selected based on non-cost attributes.

ACKNOWLEDGEMENTS

Palmerston North City Council

APPENDIX A

Estimations of Annual Operating Costs

The annual operating costs were calculated separately for each of the 25 years of the planning period. It was assumed that the proposed new infrastructure is commissioned all at the same time (1 June 2013).

It has been assumed that the majority of the capital expenditure will take place 6 months prior to the commissioning date.

All capital infrastructure has been sized on the ultimate flow of the growth horizon (2031 flow) based on the projected growth rate.

Pumping Energy Costs

The unit rate for electricity of 22 cent per kWh was sourced from PNCC. It is unlikely that time of use will be beneficial due to the capacity of the power supply required and therefore a flat electricity rate was used for the options assessment.

The amount of electricity used by pumps was estimated based on the size of the pump motors in kW which was then multiplied by the estimated average daily runtime required to meet the demand. It was assumed that on average the pump stations run at a flow rate of 35% of the peak design flow (this assumes that flow control is achievable due to the installation of either multiple pumps or VSDs)

New Pressure Mains

Annual operational and maintenance costs for new pressure mains were assumed as 0.5 % of the capital cost of the main.

New Gravity Mains

Annual operational and maintenance costs for new pressure mains were assumed as 0.6 % of the capital cost of the main.

New Pump Stations

Annual operational and maintenance costs for new pump stations were assumed as 2 % of the capital cost of the pump station.

Capital Provision for Replacement Costs

Useful asset lives were derived from the figures provided in the latest version of the PNCC Wastewater Asset Management Plan.

Apportionment of capital cost across various asset components was based on GHD’s knowledge of typical assets.

The capital provision for capital cost allows for the perpetual replacement of assets.

Bulk Treated Effluent Pump Stations

Sizing

Effluent transfer pump stations are sized on a kilowatt bases. Motor size estimates for each pump station were calculated based on the estimated peak operating point (head and flow) of the pump station. Motor sizing assumes 50% pump efficiency.

The peak flow was dependant of the pumping regime options as outlined below:

Option A – No Ponds: Peak flow = 2031 peak daily flow (3585 m3/d) x assumed diurnal peaking factor (2.0) = 83.0 l/s

Option B – Night Time Only Pumping = Peak flow = 2031 peak daily flow (3585 m3/d) / assumed night time run time (14 hrs) = 71.1 l/s

Option C – Low Flow Pumping During Day High Flow During Night. Day Flow (12hrs) =3 x ADWF = 25.5 l/s, Night Flow = 2031 peak daily flow (3585 m3/d) / volume pumped during day (1100 m3) / night run time (12 hrs) = 57.5 l/s

Cost Estimates

The cost to design and construct a wastewater pump station was estimated by reference to the GHD Australia Cost Database. This database has been compiled using a number of construction projects in which GHD Australia has been involved. The database costs are based on 2011 construction costs. It has been assumed that minimal change in overall construction cost has occurred since then.

GHD’s experience indicates that one Australian construction dollar approximately equals one New Zealand construction dollar. That is to say that it costs the same amount in Australian dollars to construct a project in Australia as it does in New Zealand dollars to construct the same project in New Zealand and therefore no exchange conversion is required.

The database figures show there is not a linear relationship between motor capacity and cost for stations. A trend line has been applied to the data to obtain the following formula which was used in the cost estimates:

Cost per kilowatt = 95136*Pump station size (kW) -0.596

The above formula has been used to estimate capital cost of pump station construction and allows for professional engineering fees (design etc.).

Pressure Mains

Pipe Sizing

Required sizes of wastewater pressure mains were calculated based on the following assumptions:

— The maximum allowable flow velocity is 1.4 m/s at the maximum design flow. This was to keep the maximum pumping pressure below 100 m.

— Pipe sizes were selected based on nominal diameters only. The assumed nominal size selection is listed below.

– 150 mm

– 200 mm

– 225 mm

– 250 mm

– 300 mm

– 375 mm

– 450 mm

Cost Estimations

The unit rates used are based on GHDs recent New Zealand projects. It is assumed that the mains will be constructed in PE.

Where dual mains are to be laid a $100/m cost benefit has been allowed for laying the least cost main in a common trench at the same time.

Gravity Mains

Pipe Sizing

Required sizes of wastewater gravity mains were calculated based on assumed grades obtained from the preliminary long section. Pipe sized to covey peak flows with no surcharging above the soffit.

Cost Estimations

The unit rates are the same as those used for pressure mains. In GHD experience there is minimal cost difference between laying pressure sewer mains or sewer gravity mains as they are both laid to grade and can both be relatively deep (depending on topography) .

Ashhurst Pond Upgrades

The unit costs for the works required at the Ashhurst Ponds were estimated based on GHDs experience.