NEW ZEALAND'S LARGEST PRESSURE SEWER NETWORK – RETICULATING KUMEU, HUAPAI & RIVERHEAD

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ABSTRACT

The Kumeu, Huapai & Riverhead pressure sewer scheme is the largest pressure sewer network in New Zealand. The communities of Kumeu, Huapai and Riverhead had a need for a reticulated wastewater service to remove the public health risk of failing septic tanks and to meet the demands of significant population growth.

Technical requirements of the project included servicing an initial population of 1,447 properties, whilst also providing capacity to service a final population of 5,906 properties. The network was also required to comply with strict hydraulic and wastewater quality requirements, including a maximum discharge flowrate of 85 l/s, in addition to being simple to operate and maintain.

This paper outlines the technical challenges and solutions the team developed to meet those challenges and how Watercare Services Limited has met the needs of the communities of Kumeu, Huapai and Riverhead.

KEYWORDS

Pressure Sewer, Watercare, Dual Mains, Dynamic Hydraulic Modelling

1 INTRODUCTION

The Kumeu-Huapai and Riverhead (KHR) pressure sewer scheme involved the provision of wastewater services via the detailed design and construction of a wastewater reticulation system. The project included the parallel design and construction of a potable water network.
This technical paper focuses on the project's wastewater reticulation complexities and innovations that were carried out by the Watercare Services Limited (WSL) and GHD Limited project team.
The capital cost for the wastewater reticulation was $6.4 million and 32.4 kilometres of reticulation was laid. The ultimate population to be serviced by the wastewater reticulation is 5,906 equivalent tenements, or approximately 15,000 people.
The communities are experiencing significant population growth, with Kumeu-Huapai identified as a growth node in the Auckland Regional Growth Strategy, and substantial residential growth planned for Riverhead. This was a significant factor contributing to the complexity of the project. Eight points of complexity were identified and resolved including complying with a peak discharge flowrate of 85 l/s.

Six points of innovation were developed to overcome the complexities, including:

1. Peak flow restriction of 85 l/s
2. Scale of reticulation
3. Dual mains, residence times and self cleansing velocities
4. Dual main operating philosophy
5. Differentiation of wastewater valves – the triangle valve spindle
6. Efficient management of fittings and materials during construction

The project demonstrated industry leading technical ability in the application of dynamic hydraulic modelling to develop the final solution. Simple and effective management skills were applied to allow the project to overcome complexities, and to be completed on time and within the prescribed budget. The environmental impact of the project cannot be overstated by the provision of a reticulated wastewater network and removing the public health risk of failing septic tanks in the communities.

The project team developed a solution elegant in its simplicity. WSL were satisfied with the project outcomes. This was independently verified by a peer review, which confirmed the project effectively identified and addressed the complexities inherent in providing a reticulated wastewater service to the communities of Kumeu-Huapai and Riverhead.

2 PROVISION OF WASTEWATER TO KUMEU, HUAPAI & RIVERHEAD

2.1 BACKGROUND

Residential growth is occurring to meet the needs of Auckland's expanding population, including significant growth along the SH16 corridor north west of Auckland. The township of Kumeu-Huapai is a growth node in the Auckland Regional Growth Strategy, Northern and Western Sectors Agreement, and Rodney District Council (RDC) District Plan 2000. The District Plan also allows for significant residential development in Riverhead.

The existing population in these townships is approximately 3,000, while the fully developed population is expected to be around 15,000 (RDC Growth Model Ver.14, Rob Bates; August 2008).

Over the past 20-30 years existing residents and developers have applied considerable pressure through council lobbying to have the townships serviced with wastewater.

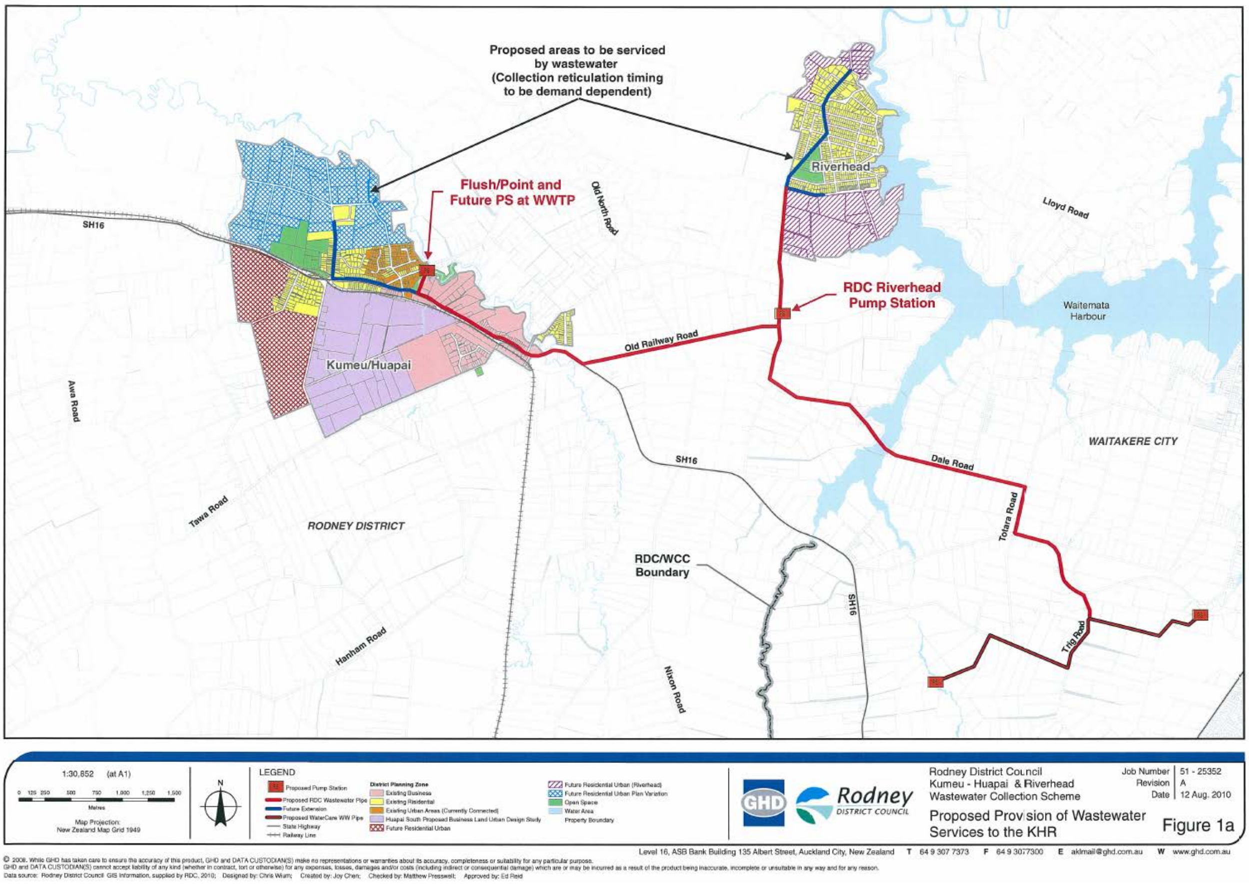
The former Rodney District Council carried out a number of investigations and reports into the servicing of the townships over a number of years, and concluded that a pressure sewer system was the most appropriate form of reticulation. They also recommended that disposal for treatment to the existing Watercare Services Limited (WSL) infrastructure was the preferred treatment and disposal method.

2.2 TECHNICAL DESCRIPTION

GHD was commissioned by WSL to provide water and wastewater reticulation to the communities of Kumeu-Huapai and Riverhead. The capital cost for the wastewater reticulation was $6.4 million and 32.4 kilometres of reticulation was laid. This award submission focuses specifically on the aspects of providing the wastewater reticulation.

1. While the existing communities of Kumeu-Huapai and Riverhead required reticulated wastewater services immediately, provision for servicing the wider area (as defined by the area of benefit, refer Figure 1 below) was also required. This included accounting for the maximum future population in the detailed design and construction of reticulation assets to facilitate the development of large tracts of greenfield sites. The uncertainty of the rate, timing and specific location of greenfield developments provided a significant uncertainty to the design team. This is addressed in section 2.4.

Figure 1: Scheme Overview & Pressure Sewer Area of Benefit



2.2.1 PRESSURE SEWER SYSTEM FUNDAMENTALS

Pressure sewer systems are entirely different from any other wastewater reticulation. They can be described as having greater similarity to a potable water network than a conventional gravity sewer network. This requires a quantum shift in the thinking, design processes, standards, operational management, and overall asset management for the project team, including the client as asset owner, designers, and associated stakeholders such as Watercare Operations.

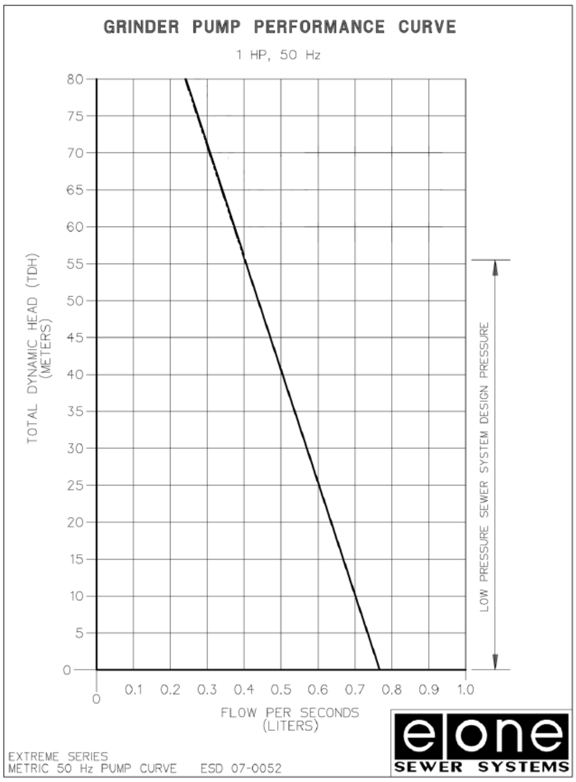
The reticulation itself consists of small bore polyethylene pipe. Sizes range from a minimum of 50 mm OD and include all available sizes such as 63 OD, 75 OD, 90 OD, 110 OD, 125 OD and upwards. Generally sizes of 90 OD or 110 OD are considered large for reticulation that directly serves properties, with the majority of reticulation in the smaller sizes. Larger pipe sizes are used in the project, up to a maximum of 225 OD in Kumeu-Huapai. The network is fully welded using electro fusion and butt fusion welding techniques. Pipe specification is PE 100 PN 16.

Wastewater is conveyed by grinder pumps installed on every property or connection in the network. The grinder pump is located in a collection tank, which is positioned on the private property as close as practical to the gully trap. It then collects wastewater flows from the property via conventional wastewater laterals. The collection tanks are usually polyethylene, except where a trafficable tank and lid is required and concrete tanks are used.

Electricity is taken from the private property circuit board to run the pump. A small pump control cabinet is positioned near the pump and tank on an outside wall of the building.

Attributes of the grinder pump are key to a pressure sewer network. The pumps have a single phase motor as small as 0.75 kW and use a progressive cavity pump mechanism to convey flow, combined with a grinder / macerator fitting to grind solids down to a fine slurry. The head/flow relationship of the progressive cavity pump is important, with a near vertical head curve, as flow is largely independent of head. Refer to the example head curve below of the E-one Extreme series pump. Maximum continuous operating heads for these pumps are in the order of 58 m to 60 m head. This high head ability allows the small domestic pumps to convey wastewater significant distances.

Figure 2: Example grinder pump head curve



2.2.2 OVERVIEW OF KHR SYSTEM

The overall Kumeu-Huapai and Riverhead system will serve an ultimate population of 5,906 equivalent tenements (ET's), or a population of about 15,000 people. The network was commissioned to discharge to a single central pump station (Riverhead Pump Station) located at the Huapai Golf Course on the Coatesville Riverhead Highway. A second booster station is planned for the site of the decommissioned Huapai Wastewater Treatment Plant (WWTP). The Huapai Pump Station will be constructed in the future, depending on the rate of development growth in the area of benefit. Please refer to Figure 1 for the Area of Benefit and locations of the pump stations.

The single phase 0.75 kW grinder pumps convey flow directly from Kumeu-Huapai and Riverhead to the Riverhead Pump Station. This is a distance of 1,300 m from Riverhead and 4,000 m from Kumeu-Huapai, including pumping through a static head of 20 m.

2.3 COMPLEXITY

The project was required to address a number of fundamental constraints, being:

1. The entire wastewater reticulation has a maximum discharge limit of 85 l/s into the WSL trunk network.
2. The initial population was 1,447 ET's, while the maximum final population required to be serviced is 5,906 ET's (four-fold increase).
3. All branches of the commissioned network must achieve a minimum velocity of 0.6 m/s to allow for self-cleansing and prevent the build-up of solids in the network.
4. No grinder pump could be subjected to greater than 58 m operating head, a requirement that competes directly against the minimum velocity requirement.
5. Wastewater has to be of an acceptable quality, specifically regarding residence time and septicity.
6. Restoration of service must occur within an acceptable timeframe and without intervention (i.e. automatically) following network shut down periods, specifically, following extended power outages.
7. The reticulation must be simple to operate and maintain.

8. The network must be able to be safely and efficiently constructed. The complexity of this was increased by the network running along sections of SH 16, beside the Southern Cross fibre optic cable, a high pressure gas pipeline, high tension power, normal power, telecoms, standard fibre optics, water networks, stormwater and drainage assets, two crossings of the railway corridor, and five crossings of streams or rivers.

The project successfully overcame all of the above, as demonstrated in the following sections.

2.4 INNOVATION

The project demonstrated innovation through processes and outcomes at both macro and micro levels. These are discussed below.

2.4.1 INNOVATION 1: PEAK FLOW RESTRICTION OF 85 L/S

Pressure sewer was selected to provide wastewater reticulation because of its inherently low peak flow rates and ability to exclude inflow and infiltration. Pressure sewer is the only reticulation technology that could meet this requirement. The peaking factors for the communities at full development are:

- Riverhead: 2.40 times average dry weather flow
- Kumeu-Huapai: 2.49 times average dry weather flow

The peak flow from the network is more than half that from a gravity reticulation, based on a standard design peaking factor of 5 times average dry weather flow.

Table 1: Forecast peak flow rates and peaking factors

	15 min Ave Peak l/s	**1 hr Ave Peak l/s**	**Instantaneous (20 sec) Peak l/s**	**Average daily Flow l/s**	**Peaking Factor Observed**
Riverhead at maximum Population (1,584 ET’s)	31.4	31.2	31.4	13.0	2.40
Kumeu – Huapai at Maximum Population (4,320ET’s)	80.2	71.4	87.0	32.2	2.49
Total Scheme at Maximum Population (5,904ET’s)	84.1	77.0	90.9	34.6	2.43

2.4.2 INNOVATION 2: SCALE OF RETICULATION

The KHR pressure sewer scheme is the largest pressure sewer scheme carried out in New Zealand when considering the existing population only. It is believed that the scheme, particularly based on the maximum population of 5,906 ET’s, is the largest of its kind in Australasia and possibly the Southern Hemisphere.

The scale of the reticulation, and the associated design, demonstrate fresh thinking in the provision of wastewater services by WSL.

2.4.3 INNOVATION 3: DUAL MAINS, RESIDENCE TIMES AND SELF-CLEANSING VELOCITIES

Due to the significant differences in initial and final populations, it was not possible to optimise a single pipe to meet final capacity requirements and achieve acceptable initial hydraulics (residence time and self-cleansing velocities). A single pipe could not meet three of the eight requirements outlined in section 2.4. Dynamic modelling demonstrated that, particularly for Kumeu-Huapai, pipes sized for final capacity did not achieve acceptable hydraulic characteristics until a significant number of additional equivalent tenements had been connected. In real terms, a significant amount of property development was required to achieve acceptable hydraulic characteristics. This would take a number of years and would provide unacceptable system performance until that time.

Table 2: Catchment build out populations

Catchment	**Equivalent Tenements**	**Total Flow m^3/day**
Kumeu – Huapai Initial	927 ET's	612 m^3/day
Kumeu – Huapai Final	4,320 ET's	2,851 m^3/day
Initial Population Percentage of Final	**21.5%**	**21.5%**
Riverhead Initial	520 ET's	343 m^3/day
Riverhead Final	1,584 ET's	1,046 m^3/day
Initial Population Percentage of Final	**32.8%**	**32.8%**

To address this issue, John McCann (WSL), suggested a dual main concept, which was developed by GHD. The dual main concept was applied to both catchments and is based on the following principles:

- Dual mains installed only where sufficient future flow exists to categorise the pipes as a 'transfer' main.
- As a 'transfer main' dual mains can only accept bulk connections.
- Dual mains shall be of differing sizes, providing a larger 'parent main' and parallel 'jockey main', giving three capacity stages in the build out:
  1. Jockey main only - initial flow capacity
  2. Parent main only - intermediate flow capacity
  3. Both mains - full capacity
- At low or initial population levels only the smaller jockey main is commissioned, the large parent main shut off with valves reducing the retained volume of the network.

The benefit of dual mains is demonstrated by a significant reduction in network volume when servicing the initial population (refer to Table 3 below for network volume reductions). This directly allowed the network to achieve acceptable residence times and provided the ability to reliably achieve self-cleansing velocities during the early stages of network commissioning and development of the areas of benefit.

Table 3: Reticulation volume with jockey mains and/or parent mains in use

Catchment	Initial Reticulation Volume Jockey Main Only	Final Reticulation Volume – Parent Main and Jockey Main In Use	Initial Volume Percentage of Total
Riverhead	30.8 m^3	59.1 m^3	52.1%
Kumeu - Huapai	30.4 m^3	97.6 m^3	31.1%

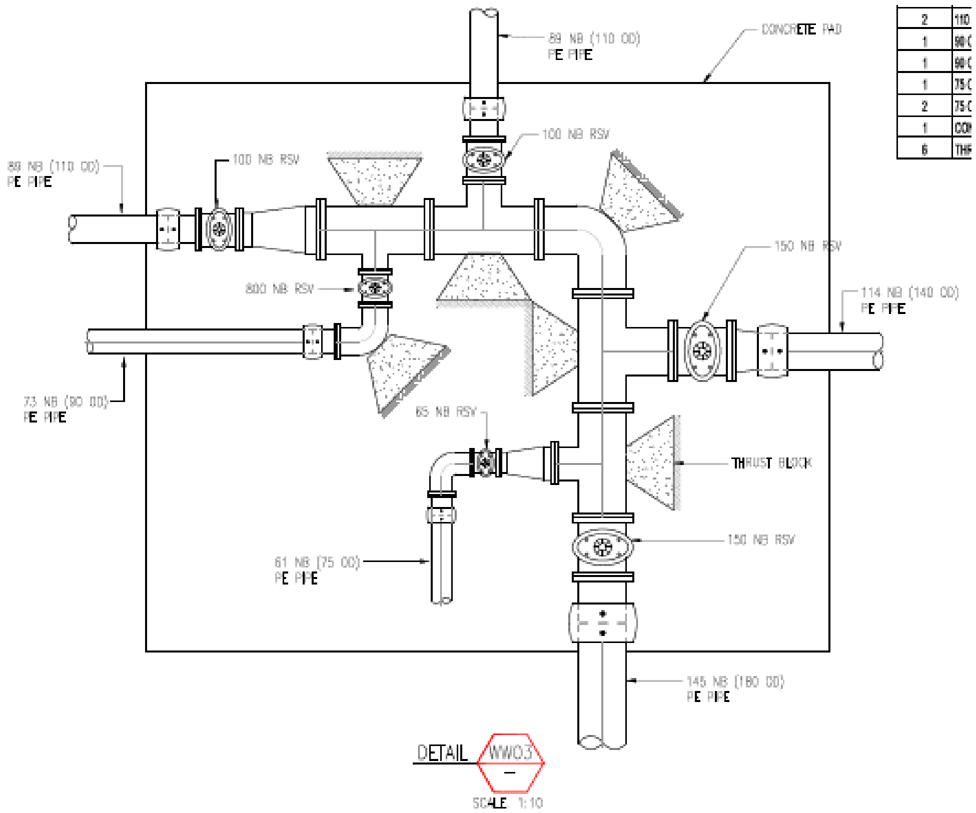
2.4.4 INNOVATION 4: DUAL MAIN OPERATION PHILOSOPHY

The requirement for a simple to operate and maintain network was considered (Section 2.3, point 7). Dual mains had the potential to introduce an unwanted level of complexity to the network. This was addressed by producing a simple and intuitive operating philosophy that included:

- The jockey main always laid 'beside' the parent main, with the jockey main teeing off and back onto the parent main just clear of intersections and connections with other street lines. In this way the dual mains can be considered as one line in regards to connectivity with other streets and associated mains.
- The jockey main valve is always on the tee of the parent main. From an operator's perspective, the valve bonnet facing 90 degrees to the direction of pipe can then be easily confirmed as the jockey main valve, and consequently the valve bonnet facing the direction of pipe will always be the parent main valve. This is intended to remove the risk of operator confusion and simplify the operation of the dual main network. It is intended that once operators are familiar with the philosophy (rules) regarding valve set out, the network will be operated without heavy reliance on as-built plans.

Figure 3 depicts an intersection detail, with a dual main coming in from the left, joining together as one main to pass through the intersection and passes out of the intersection at the bottom, splitting in to a dual main again. Single mains tee into the network coming in from streets at the top of the intersection, and from the right of the intersection.

Figure 3: Intersection detail



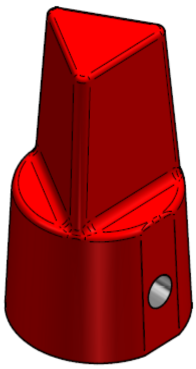
2.4.5 INNOVATION 5: DIFFERENTIATION OF WASTEWATER VALVES – THE TRIANGLE VALVE SPINDLE

The wastewater reticulation was constructed concurrently with the potable water reticulation. It is an unfortunate fact that line valves on pressure sewer networks look exactly the same as those on a water network i.e. blue coated resilient seated valves. The only differentiation is that wastewater valves are specified to close in the opposite direction to water valves. The project team felt that, even when using red valve box lids, there was a risk that valves could get confused, particularly in the future when lids go missing, get buried, or are overgrown.

The team overcame the risk of confusion between the water and wastewater valves by using a triangle valve spindle for all wastewater valves - a simple yet elegant solution. This requires a different valve key to wastewater, and regardless of the colour of the lid, it is obvious to operators what type of valve they are looking at.

The new WSL standard triangle spindle cap for pressurised sewer was designed by John McCann from WSL for this project. It is now used as standard, and is manufactured and sold throughout New Zealand.

Figure 4: New WSL standard triangle spindle cap for pressurised sewer

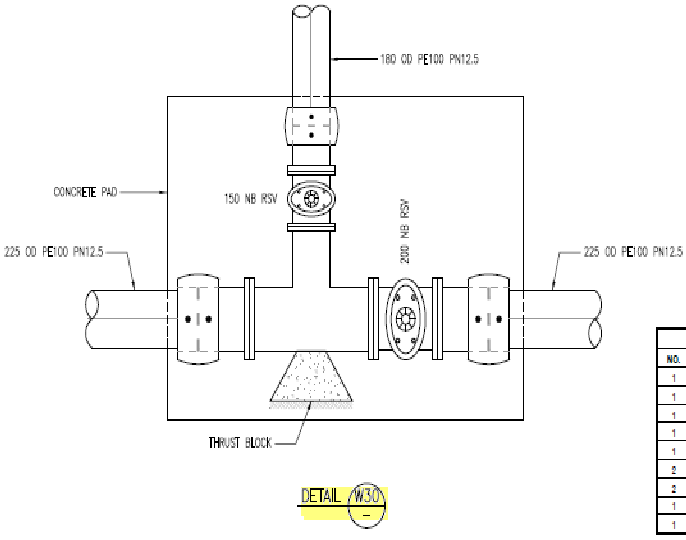


2.4.6 INNOVATION 6: EFFICIENT MANAGEMENT OF FITTINGS AND MATERIAL

To carry out the construction of the project, 465 separate fitting details were required (tees, valves and associated arrangements) across work sites spread over an area of up to 8 km apart. It was quickly determined that for the project to be completed on time and within budget, innovative thinking was required to efficiently manage fittings and materials on site for each detail. Missing one item, no matter how small, would prevent the assembly of a detail. The work-gang would then need to return to the depot for the missing item.

To minimise the risk of missing items, each detail was itemised with all required fittings to complete that detail. All fittings were then assembled and dispatched by the supplier on one pallet, identified by the design detail number. Each pallet was delivered to each specific site with the necessary fittings and materials for assembly. The plan detail and photo below shows a prepared pallet with all fittings required for a tee and valve arrangement ‘W30’.

Figure 5: Design detail 'W30'



DETAIL 30 - COMPONENTS LIST	
NO.	DESCRIPTION
1	150 NB RSV
1	150 / 200 NB FLANGE REDUCING TEE
1	150 NB EF COUPLER
1	150 NB STUB FLANGE
1	200 NB RSV
2	200 NB EF COUPLER
2	200 NB STUB FLANGE
1	THRUST BLOCK
1	CONCRETE SLAB

Photo 1: Design detail 'W30' ready for dispatch with all fittings on one pallet

2.5 DYNAMIC HYDRAULIC MODELLING

It was recognised that particular technical capability was required to successfully overcome the complexities of the project. This was apparent given the scale of the proposed reticulation, and that it was to be pressure sewer, which has no similarities to gravity wastewater and established design methodologies would be of no value.

GHD turned to its international network of technical specialists and introduced notable experience in the area of dynamic hydraulic modelling of complex pressure sewer and hybrid wastewater networks to the project.

One of the fundamental issues with the hydraulic design of pressure sewer is reliably predicting the peak flow rate in the network. Pumps start randomly across the network depending on water levels in each collection tank. However, flow into each collection tank occurs semi-randomly with a higher frequency during the morning, and again to a slightly lesser extent during the evening. This is the well-recognised 'morning flush' and the typical diurnal curve of wastewater network flows. Various empirical methods are available for the prediction of peak flows, however these empirical methods do not have the resolution or accuracy to meet the project requirements as outlined in the section 2.3, particularly around population growth, hydraulic design, and wastewater quality.

The dynamic modelling software Infoworks CS was used to complete the hydraulic design of the networks. GHD achieved significant advances in the capability of the modelling software by writing a software 'plug in script' referred to as the "real time controller" (RTC).

The RTC enabled the accurate prediction of private grinder pump tank filling and pump operation to model flows into the network. The network could then be modelled, literally as a water network running in reverse. Standard hydrographs for domestic residences and various public and commercial properties were loaded into the RTC to model each individual property's input into the network. This included schools, offices, commercial and industrial areas, as well as residential lots.

The RTC led directly to the reliable optimisation of the entire network, including pipe sizing, prediction of peak flow velocities at critical points in development growth, and in output hydrographs to assist in the optimisation of downstream trunk infrastructure.

The use of dynamic hydraulic modelling was also integral to the determination of recovery times of the network following extended power outages. These were demonstrated to be within acceptable timeframes. The use of dynamic hydraulic modelling also identified exactly how the network would behave under stress, such as during recovery from extended power outages, so that weaknesses could be addressed in the design phase and designed out.

This resolved the issue highlighted in Section 2.3, point 6 - restoration of service must occur within an acceptable timeframe and without intervention (i.e. automatically) following network shut down periods, specifically, following extended power outages.

2.6 SUSTAINABLE SOLUTION

Sustainable solutions are simple solutions - the elegance of the solution to address the complexities of this project is in its simplicity.

The best example of this is the triangle valve spindle, which simply removed the risk of operators mixing up water valves with wastewater valves. It had no additional cost over a square spindle but avoids the reliance on as-built plans to operate the network. It also overcame the risk of coloured valve covers getting lost, buried or over grown in the future.

While the use of dual mains had the potential to add complexity to the operation of the network, the dual main philosophy was simplified to an intuitive level. The identification and operation of dual lines is a logical and simple process, based on the position of valves and the facing direction of the valve bonnet.

Additionally, the elegance of the project is demonstrated by what it is not. There are no large storage tanks, no complex SCADA telemetry control, no interlinked booster pump stations and no reliance on operator control or input. No compromises were required in the design. These are all aspects that could have been adopted, and would have been required to achieve the flow limit of 85 l/s if the project, had been designed differently.

2.7 ENVIRONMENTAL CONSIDERATIONS

Providing a benefit to the community is the very essence of being an engineer. As the benefit of building a bridge across a river so that the community can farm the land on the far side is apparent, so is the benefit of providing reticulated wastewater and removing the public health risk of failing septic tanks.

The importance and benefit of providing reticulated wastewater to the KHR communities cannot be overstated. The KHR area is made up of clays, with very poor draining ability, which led to the inability of septic tank effluent to drain away. This often resulted in ponding and on-flow to neighbouring properties and/or public spaces. As such, the public health risk was significant.

Anecdotes from residences are recounted to demonstrate the importance of wastewater reticulation. During winter or over wet periods, the sheen on surface water (i.e. puddles) was particularly notable. One resident, a grandmother in Huapai, recalled taking her young grandchildren for walks. As they delighted in jumping in puddles, she eventually had to stop taking them for walks during winter months to avoid the risk of sickness because she knew the puddles were contaminated with septic tank effluent.

Pressure sewer systems provide an additional fundamental environmental benefit as the network is sealed so they cannot spill. There are also no manholes to surcharge. In the event of a network failure the on-property control panel will alarm warning the resident to reduce water consumption. This combined with 24-hour storage in each on-property tank means the possibility of spilling at the gully trap is nearly non-existent. Wastewater overflows, network discharge consents, and containment standards are a thing of the past, and are not applicable to Kumeu, Huapai or Riverhead.

Disruption to communities during the construction of gravity wastewater schemes can be significant. This is due to the requirement of laying pipe to grade and installing frequent manholes, which leads to significant trenching and excavation. Associated environmental issues include noise, dust, heavy vehicle movements, disruption to trees and difficulty crossing obstructions such as streams and stormwater culverts.

The project was delivered entirely by trenchless directional drilling. This significantly reduced the disturbance to the environment and disruption to the community that usually occurs during the provision of wastewater reticulation by gravity networks.

3 CONCLUSIONS

The provision of a reticulated wastewater system to the communities of Kumeu, Huapai and Riverhead has addressed a significant public health risk.

The provision of the reticulated wastewater system presents 8 points of complexity.

A total of 6 points of innovation were identified and used to address the complexities of the project and to facilitate successful project outcomes.

The Kumeu, Huapai and Riverhead pressure sewer scheme is an example of a successful large scale pressure sewer reticulation.