PRESSURE SEWER VS. GRAVITY SEWER: A CASE STUDY

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ABSTRACT

This paper sets out the design journey incorporating significant innovations in the development of a backlog sewerage scheme for 16,200 properties in the Mornington Peninsula in Melbourne. From the initial considerations for a gravity sewerage scheme the project evolved into the largest low pressure sewer network in Australia. The design utilised monitoring and control technology to optimise the network and overcome potential issues with power outage recovery and odour and corrosion management.

INTRODUCTION

The Peninsula Backlog Sewer Scheme in the Mornington Peninsula to the south east of Melbourne involves the connection of 16,200 properties to a reticulated sewerage scheme discharging to the existing Boneo Sewerage Treatment Plant (STP). The catchment is long and narrow with the most remote connection up to 17km from the Boneo STP. The catchment is also characterised by undulating sand dune formations with associated difficulty in pipe installation. The initial high level feasibility assessment concluded that the environment prohibited a cost effective gravity sewer option and identified a low pressure sewer option being the optimal solution. This was on the basis that the gravity sewer option would require 27 transfer pumping stations and long lengths of gravity sewer with depths exceeding 4.5m on narrow residential streets triggering micro-tunnelling methodology. The high level cost estimate for the gravity sewer option exceeded $500M. The catchment is shown in Figure 1 with the individual reticulation catchment identified by colour and the transfer main alignment shown in blue.

Figure 1 Mornington Peninsula Catchment Area Plan
METHODOLOGY/PROCESS

PERCIEVED BARRIERS TO LOW PRESSURE SEWER

The initial feasibility design took into consideration a number of barriers to low pressure sewer which dictated the scope of works for the overall system as follows:

1. Self-cleansing initial low flows
2. Pipe Sizing - Peak Flow Analysis vs. Self-cleansing
3. Power Outage Response
4. Odour & Corrosion
5. Power Consumption & Maintenance Costs

The feasibility design for the low pressure sewer system addressed the above barriers and represented at a significant cost saving of $150M compared to the high level cost estimate for a gravity option. Achieving this capital cost saving with a pressure sewer servicing strategy required an innovative design which optimised pipe sizes, the number & sizes of transfer pumps stations and the odour & corrosion control provisions.

DESIGN EVOLUTION

Two key innovations led to the evolution of the design to the current scope under construction. The first was the utilisation of dynamic hydraulic model which provides greater detail of system performance and critically an understanding of power outage response. The second innovation was the development of property pump monitoring and control through the ONEbox controller. This allowed peak shifting, flushing cycles and reduced holding times to optimise asset sizing, assist odour control and management of power outage response.

The low pressure domestic pumps are provided with a high pressure cut out facility based on high current monitoring. This has been set at 8 amps which is equivalent to pumping head of 45m to optimise the life of the low pressure pumps. Since the low pressure domestic pumps compete against each other for discharge to the pressure reticulation network the pressure head that each low pressure pump sees is dependent on the number of low pressure pumps in the local reticulation network that are operating. If a low pressure pump cuts out on high current then the pump controller retries the pump after a set time period. The hydraulic model based on a maximum low pressure pump head of 45m and an integrated reticulation and transfer main identified the range of the low pressure pumps in the overall integrated network. This low pressure pump range identified by model became a key design factor in the optimum transfer pump station location. This design approach resulted in the number of transfer pump station being reduced to just 2.

An additional key consideration in siting transfer pumping stations was to endeavour to maintain a fully pressurised network upstream of the break pressure at the transfer pump stations in order to minimise air management requirements in the network. This was largely achieved by location of the transfer pump stations at local high points and utilisation of a barometric loop prior to discharge to the wet well to gain addition height. The increased head to pump over the barometric loop was considered a minimal issue when compared to the operational benefit associated with a fully pressurised network. The fully pressurised network provided consistent hydraulic performance and limits the critical management of odours to the transfer pump station sites.
There was an option to design transfer pumping stations as either in-line booster pumps or a more traditional sewer pumping station with discharge to a wet well and consequent break in pressure. The decision was made to provide a wet well mostly on familiarity grounds for ease of operation. The overall network is therefore separated into 3 discrete integrated pressure networks separated by a pressure breaks at the 2 transfer pumping stations. The transfer pumps are designed for cut in/cut out for low flows to achieve self-cleansing velocities and follow the flow for higher flows utilising Variable Speed Drive (VSD). This approach reduces energy consumption and provides a more consistent flow to the treatment plant with consequent operational benefits. It is also noteworthy that the pressure sewer system is not restricted by incoming sewer levels so the transfer pumping station can be located above ground if aesthetic consideration allow. For one of the transfer pumping stations where visual impact can be managed the wet well is an above ground tank and the pumps are dry mounted. This has clear cost implications with reduced excavations but also operational benefits with dry mounting and ease of access to large pumps.

With the scale of the integrated pressure sewer system and long retention times for the sewerage, the resulting anaerobic conditions lead to the reduction of sulphate in the sewage to sulphide. An odour model prepared for the system indicated dissolved sulphide levels of up to 26 mg S/L and low pH of 6.5. The headspace Hydrogen Sulphide (H₂S) levels at the transfer pump stations derived from the model was excessively high with average levels reaching 3500 ppm resulting directly from the high dissolved sulphide levels and low pH. Therefore the strategy for odour & corrosion control adopted was chemical dosing to control dissolved sulphide levels and air evacuation and treatment at the transfer pumping stations. Dosing Ferric Chloride (FeCl₃) upstream in the pressure sewer system effectively controlled dissolved sulphide levels below 1 mg S/L which resulted in reducing headspace H₂S levels in the transfer pumping station to about 50 ppm. Dosing Magnesium Hydroxide (MHL) in addition to maintain pH above 6.5 to ensure the effectiveness of the FeCl₃ dosing was also adopted. Monitoring of pH during operation is intended to minimise the MHL dosing requirement. FeCl₃ dosing was the most cost effective dosing option when compared to alternative liquid phase odour control measures. The air extraction and treatment system selected at the transfer pumping stations consists of a Bio-Trickling Filter in series with an Activated Carbon Bed. The Bio-Trickling Filter Treatment system was selected based on lower operating costs and robust performance based on the controlled range of H₂S to be managed.

The sizing of key assets including the transfer pumping stations and transfer mains was based on the model outputs for design flows and benefited from the complete removal of rainwater from the fully pressurised network and peak shifting using ONEbox based flow control. The complete removal of rainwater can be achieved with pump monitoring and comparison with rainfall data for infiltration on the customer side of the low pressure pump. Figure 2 shows actual data from South East Water’s network identifying rain infiltration indicated by higher frequency of pump runs during a rainfall event which can be subsequently targeted.
In addition the diurnal flow profile associated with sewerage flows generally dictates the minimum capacity for sizing of assets. With a controlled low pressure system the storage available in the domestic pump pods facilitates holding peak flow during peak flow periods. Controlling flows to hold back flow during peak periods and draw down levels in the domestic pump pods during low flow periods or ‘peak shifting’ is utilised to manage flows. Figure 3 below shows actual data from a pressure sewer catchment over 24 hours with and without peak shifting control in operation. The achievable reduction in peak flow is by a factor of 2.

TARGETED SOLUTIONS TO PERCEIVED LOW PRESSURE SEWER BARRIERS

The final design addressed each of the low pressure sewer barrier issues with the benefit of modelling and ONEbox control as follows:

Self-cleansing initial low flows

The ONEbox controller provides a flushing mode whereby all connections within a sub-catchment are controlled through an algorithm to maintain a desired peak flow with multiple property pumps pumping together. This facilitated the design to focus on the optimising the system for ultimate peak demand with larger catchment sizes and providing intermittent flushing cycles for self-cleansing at initial stages with a limited number of connections.

Peak Flow Analysis & Asset Sizing
The peak flows in the final design are taken from the dynamic model which are based on monitored dry weather data from elsewhere within SE Water’s network and therefore represent a robust design. The contingency is provided by the peak shifting capability of the ONEbox controller and therefore no additional contingency is deemed necessary. The final design identified a peak flow of 341L/s and a downstream transfer main size of DN450. This represents a significant reduce scope from a traditional design based on Peak Wet Weather Flows with greater system capacity thanks to the peak shifting capability of the ONEbox controller. It would be feasible to further reduce the asset sizing by fully incorporating the peak shifting capability into the design where confidence in the ultimate density of development and customer usage is high.

**Power Outage Response**

The dynamic hydraulic model analysed the system for a power outage of up to 24 hours. As each of the property pump pods contains up to 24 hours storage it is probable that all property pumps will cut in following a prolonged power outage. The property pumps that are most remote from the discharge will be compromised by property pumps downstream. The property pumps include a high current cut out to limit head to 45m to prolong pump life. When the pump can’t operate due to high current trip associated with high head the controller retries after a short time. It this way all property pumps try to discharge until they get a window of opportunity to pump. The dynamic model allowed the reticulation networks to be sized such that no property pump pod would overflow/spill following a 24 hour power outage. The ONEbox controller facilitates added security by identifying potential compromised pumps following power outage and giving them priority to minimise spill risk. The hydraulic design coupled with control capability to manage potentially compromised pumping pods facilitates larger pressure sewer catchments with operational confidence on recovery following a prolonged power outage. With this design approach the reticulation and transfer main are hydraulically connected and operate as a single network upstream of the transfer pump stations.

**Odour & Corrosion**

With transfer pump stations reduced to 2 in number and reticulation connections directly to the transfer main with a fully pressurised network, the potential odour hotspots are limited. The final design has concentrated on these 2 transfer pump station and a local high point upstream of the discharge to the Sewerage Treatment Plant for gas phase odour treatment including Bio-Trickling Filter (BTF) and Activated Carbon Filter (ACF). As the reticulation and transfer system are contiguous and sealed the corrosion issues are removed other than the 2 transfer pump stations where they can be adequately managed. Ferric Chloride (FeCl₃) dosing at the head of the scheme provides maximum system coverage to limit H₂S generation.

**Power Consumption**

The provision of contiguous reticulation and transfer maximises the property pump pressure head with associated reduced power consumption. The ONEbox control facilitates engaging property pumps in off peak periods for peak shifting but this also has the added benefit of
utilising power at non-peak periods. If there is a requirement or financial incentive in the future to only pump outside peak energy demand periods then this can be easily achieved through programming at minimal cost. Whilst the energy consumption of a pressure sewer network is generally greater than that of an equivalent gravity sewer, the significant reduction in flows and the reduced Class A treatment volume is likely to swing the power consumption comparison in favour of the pressure sewer option for the Peninsula Scheme due to the significant pumping requirement for a gravity system and the relatively high peak wet weather flows associated with backlog sewer scheme.

FINANCIAL IMPLICATIONS

The capital cost of a pressure sewer system in comparison to a traditional gravity system was estimated at up to $150M based on a high level feasibility design for both systems. The scope reduction through innovative design for the low pressure system utilising ONEbox capability includes reducing 12 transfer / injection pump stations to 2 and downsizing 6,450m of DN525 transfer main to DN450 with an estimated capital cost saving of up to $12M. Additional capital cost savings for downstream treatment have been identified but not quantified to date.

CUSTOMER IMPACT

The reticulation network and transfer main are being installed using HDD trenchless technology with minimal impact on the ground. The major construction disruption is limited to the 2 transfer pumping station sites. This has had a number of significant customer benefits in addition to the reduced community cost. The reduced scope of works and in particular the reduction in major civil works associated with removing 10 pumping stations will significantly reduce disruption during construction and also public perception with the associated above ground odour management facilities. The duration of the construction contract is also reduced to 18 months which opens up early connection options for all customers. This compares with a 13 year roll out initially envisaged for the scheme based on a staggered construction approach to match SE Water sewer backlog commitments.