SMART PRESSURE SEWER COLLECTION AND TRANSFER: THE FLINDERS SEWERAGE PROJECT

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ABSTRACT

The Flinders Sewerage Project is an innovative backlog sewerage scheme located on the Mornington Peninsula, south-east of Melbourne, Australia. The scheme is made up of two pressure sewer collection networks within the towns of Flinders and Shoreham, and an 18 kilometre long transfer system from Flinders to Balnarring. From Balnarring sewerage flows through an existing transfer system to the Somers sewage treatment plant.

This paper outlines the Flinders Sewerage Project and the smart pressure sewer technology and networks developed as part of this project. The application of this technology combined with other innovations resulted in: capital savings, reduced operational risk, reduced environmental impact, improved service outcomes, and reduced loading of the downstream transfer systems. Focus is given to the major project innovations, and their benefits, including:

- The introduction of SCADA to pressure sewer systems;
- Pressure based pump and network control;
- Sealed pressure vessel wet wells;
- Dispersed emergency storage within the pressure sewer network and household pumping units;
- Low flow high head progressive cavity sewage pumping;
- Sewage pressure sustaining valves;
- Rapid hydraulic model building and network optimisation; and
- A fast track approvals strategy based on early adoption of trenchless technology and nominated construction impact zones.

KEYWORDS

Pressure sewer, smart network, transfer, high head pumping.

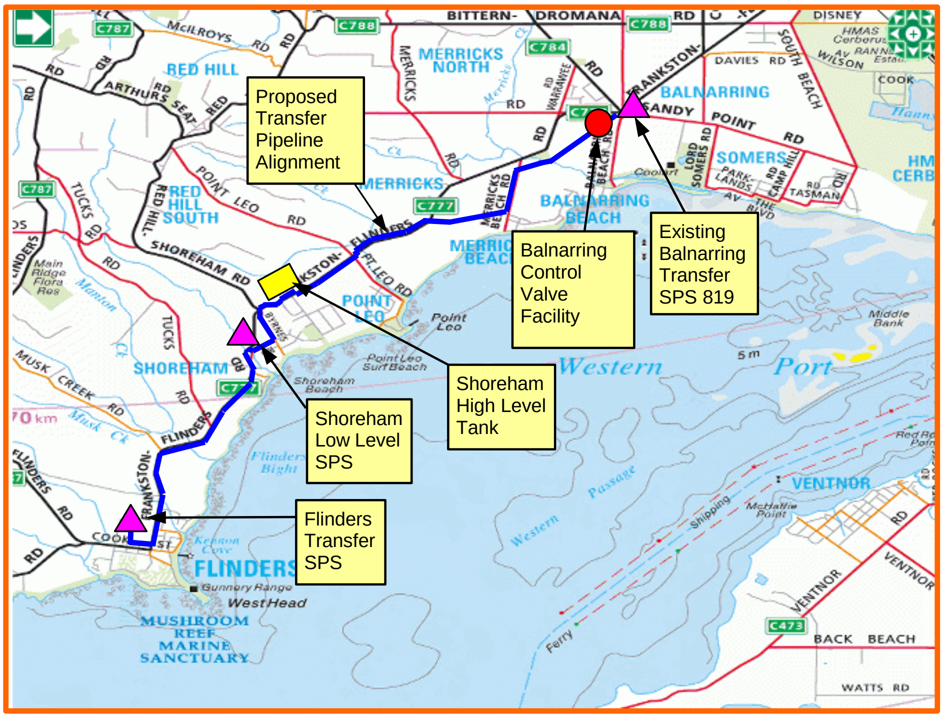
1 INTRODUCTION

1.1 BACKGROUND

In 2003, Mornington Peninsula Shire Council, Fisheries Victoria, the Environment Protection Authority (EPA) and the Department of Human Services (DHS), along with South East Water (SEWL), identified concerns with sewage contamination on the coastal foreshore in the Flinders and Shoreham area, located on Victoria’s Mornington Peninsula.

The pollution was attributed to a failure of some of the septic tank systems (1250 No.) servicing properties in Flinders and Shoreham. This pollution was a risk to the health and safety of residents and could affect the viability of local tourism and mussel farming. Therefore, addressing major pollution and environmental concerns was the primary driver to sewering Flinders and Shoreham.

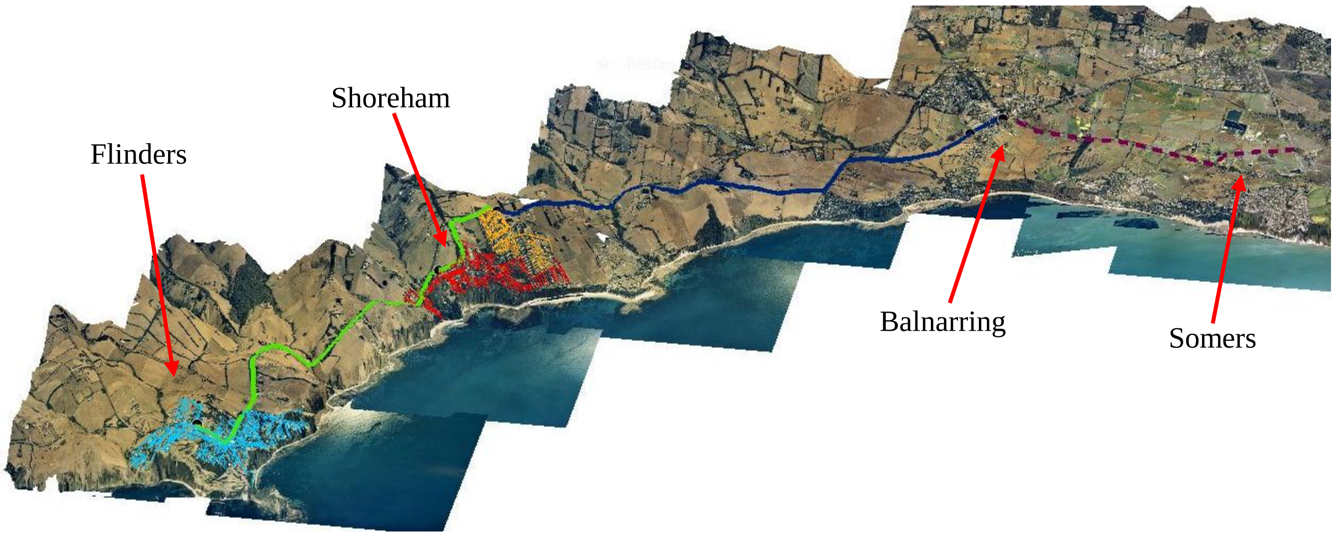
Figure 1: The Flinders Transfer System – Plan



1.2 THE FLINDERS SEWERAGE PROJECT

In 2004, SEWL selected MWH to undertake design for the Flinders Sewerage Project which involved a that sewer system, six associated pumping stations and a 24 km long transfer system to Somers WWTP. In 2006, after 18 months of planning, design and consultation, SEWL decided to scrap its proposed gravity sewerage scheme due to its cost and concerns raised by residents regarding disruption during construction. Based on previous successful experience with pressure sewer technology at Tooradin, Australia's first pressure sewer scheme, SEWL decided to pursue a pressure sewerage system (PSS) with a number of innovative components to serve the Flinders and Shoreham. The scheme is comprised of two pressure sewer collection networks within the towns of Flinders and Shoreham townships (800 and 450 properties respectively), and an 18 km long transfer system from Flinders to Balnarring. From Balnarring sewage flows through an existing transfer system on to the Somers sewage treatment plant. Figures 1 and 2 show the location and scale of the project.

Figure 2: Aerial View of the Flinders Sewerage Project

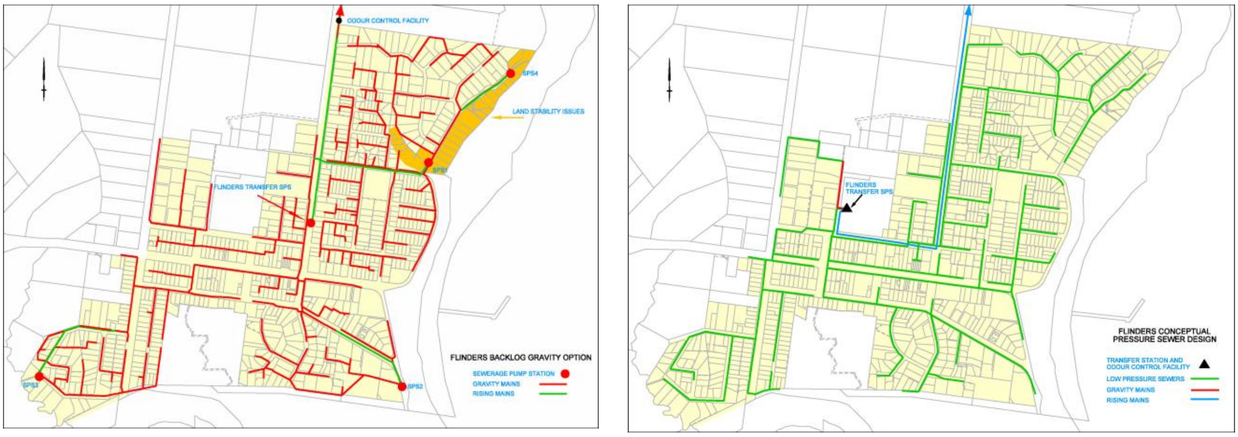


1.2.1 CHANGE FROM GRAVITY TO PRESSURE SEWER COLLECTION

Flinders was originally designed as a gravity sewerage system running predominantly through private property. However, this was found to be unpopular and financially unviable primarily due to the need for open cut construction of gravity sewers and the ensuing amenity disturbance that would occur. A large volume of expensive on-grade trenchless construction would have been required to minimise this disturbance to the environment and private property.

The adopted pressure sewer system consists of smaller diameter pressure mains in road reserves, constructed cost-effectively by horizontal directional drilling (HDD), without the constraints of tight level and grade tolerances. The proposed gravity sewer collection system for the Flinders township included four neighborhood pump stations and was estimated to cost between \$15 million and \$18 million. The alternative PSS reduced the capital cost to \$12 million, including the cost of redesign. The change from gravity to pressure sewer also greatly reduced the disturbance to the local environment and community during construction. Figure 2 shows the gravity collection work originally proposed (left) and the PSS network adopted (right).

Figure 3: Flinders gravity collection work originally proposed (Left) and the PSS network adopted (Right)



The financial benefit of PSS collection relative to gravity sewer collection extends beyond the raw capital cost. Project cash flow and financial risk management were also improved. By its nature, a gravity system has a front loaded spend profile. The majority of the scheme cost in the collection network, the full capital cost of a gravity system must be spent even if no-one connects to it. Whereas with a PSS, the upfront capital spend and associated risk is much less because the cost of a PSS is comprised of network and pump components. The majority of the scheme cost is in the pump component. The network component must be spent upfront, but not the pump component. The pump component only needs to be spent once a customer chooses to connect. Hence, the financial exposure of a PSS proponent is less than that of a gravity sewer scheme proponent with regard to low connection rates.

1.2.2 PRESSURE SEWER SYSTEMS

A PSS uses the pressure from individual pump units to collect and transport wastewater. Each property within the PSS is provided with a small tank with a pump unit installed to which all household wastewater is diverted. The tank fills until a predetermined level is reached, then the pump unit is activated to discharge wastewater into the PSS network. The tanks can also have a relatively large emergency storage (24 hours for an average house), to cater for inactive pumps. PSSs have a long history of use in the USA, where they are predominantly employed to sewer low lying, flat and/or sandy areas with high water tables where conventional gravity sewerage systems would not be feasible. In 2001, SEWL implemented the first Australian PSS to sewer the Tooradin township backlog sewerage scheme. For further explanation of pressure sewer systems refer to the WSAA Pressure Sewer Code referenced.

1.2.3 THE PROJECT TEAM

The project was delivered by the ***'us'*** – Utility Services Alliance between South East Water Limited, Thiess Services and Siemens. MWH carried out hydraulic modeling and design. Development and supply of the

Pressure Sewer Pump equipment was undertaken by NOV Mono, formerly Mono Pumps Australia. MWH provided hydraulic modelling, design, environmental impact assessment and statutory planning services.

2 PRESSURE SEWER TECHNOLOGY AND SMART NETWORKS

The goal of this paper is to make a constructive contribution to the water industry pressure sewer body of knowledge by outlining the key innovations developed in the course of delivering this project. It is not intended to promote any particular brand of pressure sewer technology. Specifically the paper aims to:

- Introduce the concept and objectives of a smart network;
- Explain principles and associated benefits of the key innovations: pressure based pump and network control, and the integration of Supervisory Control and Data Acquisition (SCADA) functionality into pressure sewer equipment; and
- Outline how smart network functionality is beginning to be incorporated into PSS technology and to explain the benefits this is creating for PSS networks and downstream transfer systems.

The pressure sewer market and technology are evolving rapidly. At the time of writing, pressure-based pump and network control and SCADA functionality were available from multiple pressure sewer pump manufacturers. These features, combined with a network design verified by hydraulic modelling, are current best practice and enable smart network functionality in pressure sewer networks.

2.1 WHAT ARE SMART OR INTELLIGENT NETWORKS?

A definition for a smart (or intelligent) network from the IT industry is *"A network that is not passive. It contains built-in diagnostics, management, fault tolerance and other capabilities that keep it running smoothly."* - Computer Desktop Encyclopedia copyright ©1981-2012 by The Computer Language Company Inc.

2.2 SMART PRESSURE SEWER NETWORKS

If typical smart network objectives are applied to PSS the objectives of a smart pressure sewer system might be a network that:

- Is 'self healing' under fault or emergency conditions by detecting and responding to problems automatically;
- Has greatly enhanced data gathering capabilities which enable real-time monitoring and control of network performance at the global and local level;
- Allows rapid fault diagnosis and response;
- Optimises and reduces energy use; and
- Is efficient.

These objectives are starting to be attained in PSS networks by using pressure based pump control and incorporating full SCADA functionality.

3 PRESSURE SEWER COLLECTION NETWORKS

3.1 LESSONS LEARNED FROM FIRST GENERATION AUSTRALIAN PRESSURE SEWER SCHEMES

Based on SEWL's experience of installing and operating Australia's first pressure sewerage system in Tooradin, and subsequent backlog schemes in Warneet and Cannons Creek, a number of issues that could potentially impede the viability of implementing pressure sewer at Flinders were identified. These issues included:

- Customer involvement in operations;
- Inadequate emergency storage at pump units;

- Inadequate protection against high system pressures; and
- Management of peak power outage recovery flows.

3.1.1 CUSTOMER INVOLVEMENT IN SYSTEM OPERATION

In these first generation pressure sewer systems, all control and monitoring is local to the individual pump. If there is a problem at a pump, a red light flashes and a siren sounds. The system operator is reliant on the customer to call the fault in for action; that is, the customers must be involved in system operation. The customers know about problems before the operator does. Operations can only be reactive. Furthermore, to shut down the network, operators must visit each property to isolate each pump. Then, once the work has been carried out, they must go back to each property to switch the pumps back on again.

3.1.2 INADEQUATE EMERGENCY STORAGE AT PUMP UNITS

In the Tooradin pressure sewer system, the individual pumping units were found to have insufficient storage above alarm level. The small amount of storage did not provide adequate time for operations to respond to faults.

3.1.3 MANAGEMENT OF SYSTEM PEAK PRESSURES

Pressure sewer pumps are typically progressive cavity pumps. These pumps can produce extremely high shut-off heads. These high shut-off heads can be hazardous for the pump and the downstream network. (These damaging high heads can also occur during a power outage recovery event.) Pumps need to be protected from high heads because the manufacturers only warrant their pumps up to a certain head, usually significantly lower than the shut-off head. Pipe networks need to be protected from high pressures for obvious reasons!

Each pump requires a high pressure cut out. Conventionally, this was done using a thermal switch in the pump stator to cut out the pump motor. This provides some protection to the pump, but not the network. This is due to the time lag between generating high pressure in the system and creating sufficient heat in the pump stator to trigger the thermal cut out switch. Also, once heat builds up in the pump, it will take some time to cool down, creating subsequent nuisance trips. Operational experience in the Australian market has found this form of over-pressure protection to be inadequate for both pump and network protection.

3.1.4 EFFECT OF HIGH POWER OUTAGE RECOVERY FLOWS ON DOWNSTREAM INFRASTRUCTURE

When a town and PSS loses power, sewage accumulates in the house tanks. Once power is restored, all the house pumps attempt to start and this results in huge peak flows at the network outlet. In the case of the Flinders pressure sewer system, flows as high as 120 L/s [20 x Average Dry Weather Flow (ADWF)] were predicted at the network outlet. These high power outage recovery (POR) can be problematic to handle. They are typically managed using attenuation storage at the outlet of the collection network.

3.2 SECOND GENERATION PRESSURE SEWER SYSTEMS

Since completion of Australia's first generation pressure sewer schemes, SEWL gained valuable experience and knowledge of pressure sewer scheme implementation and operation. The requirements for the next generation of PSS pumps to be installed for SEWL were developed from this heightened awareness and knowledge. The revised PSS pump requirements included:

- Knowing when there is a problem, before the customer via remote monitoring;
- 24 hours storage (above alarm level) within the individual pump units;
- Improved over pressure protection; and
- Operation as an integrated system with the transfer system.

SEWL went to market and found that no manufacturer met all of their requirements. The selected supplier offered a more technically advanced control system including telemetry and self-diagnostic capabilities. This manufacturer also committed to custom design their current pressure sewer pump to better meet SEWL's specific requirements. The suppliers research and development department developed the pump unit in collaboration with SEWL operations and maintenance personnel, who provided test sites, feedback and design enhancement suggestions.

3.2.1 IMPLEMENTATION OF TELEMETRY INTO PRESSURE SEWER SYSTEMS

The Flinders PSS has full SCADA functionality. This was the first fully integrated SCADA system incorporated into a pressure sewer system. The SCADA system includes:

- A two-way radio link to each pump in the system, removing the customer interface for pump operation;
- A remote "global shutdown system" to be used during failure or leak events, to shut off all pumps within a system remotely (significantly reducing system shut-off times which reduces the risk of any potential sewerage spills to the environment); and
- The ability for operations staff to obtain pump unit information remotely for fault diagnosis, prior to attending pump "call outs" or for system performance monitoring.

3.2.2 ENHANCED OVER PRESSURE PROTECTION

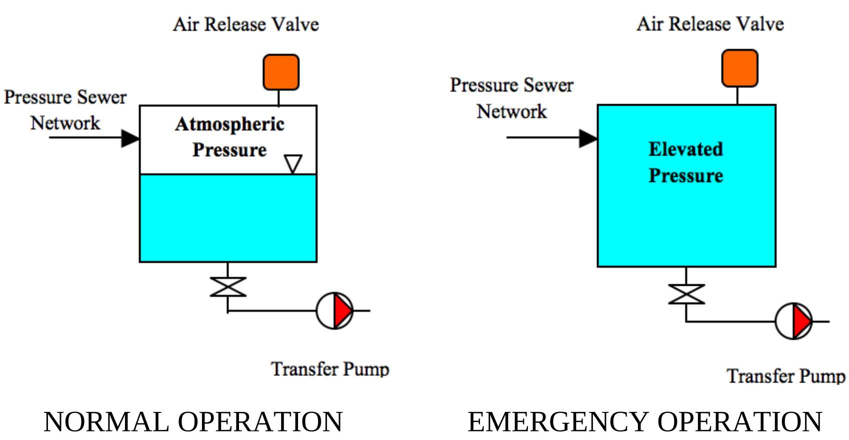
To ensure that the pump doesn't operate when it senses pressures above the pump's rated design pressure, it has an electronic current sensing over-pressure protection rather than just the stator over temperature device conventionally used. It is instantaneous and it protects both the pump and the network.

Although electronic current sensing based over-pressure protection was initially installed simply as a pump protection device, it was realised during system design that it could also be used as a system control device due to the high degree of accuracy achieved in testing. Using this new form of over-pressure protection, the pressure sewerage system can be easily controlled at one point (e.g. at isolation valves), and this allows simple engagement of the individual storages in each property, rather than having to manually turn off individual pumps. This feature is also used to throttle flows at the network outlet at the transfer pumping station which assists greatly with handling peak flows in particular the predicted power outage recovery flow of 120 L/s in the case of Flinders.

3.2.3 EMERGENCY STORAGE USING SEALABLE (PRESSURE VESSEL) WET WELLS

Rather than draining the collection network into a conventional open wet well, with large emergency storages to buffer the potential peak flows, the Flinders pump station uses a Glass Reinforced Plastic (GRP) pressure vessel as a sealable wet well. The wet well is a pressure vessel with a double acting air release valve. Figure 4 shows the principal of operation. During normal operation, the pressure vessel works at atmospheric pressure as an open wet well would. When inflow exceeds outflow, the wet well vessel and upstream network then fill and pressurise. Eventually, the network pressure exceeds the PSS pump cut out pressure and this cuts out the house pumps and engages the remote storage available in each house tank. Each tank holds the equivalent of 24 hours of ADWF. In an emergency situation the dispersed storage available at the customer pots is automatically engaged.

Figure 4: Sealable GRP pressure vessel wet well – Principle of Operation

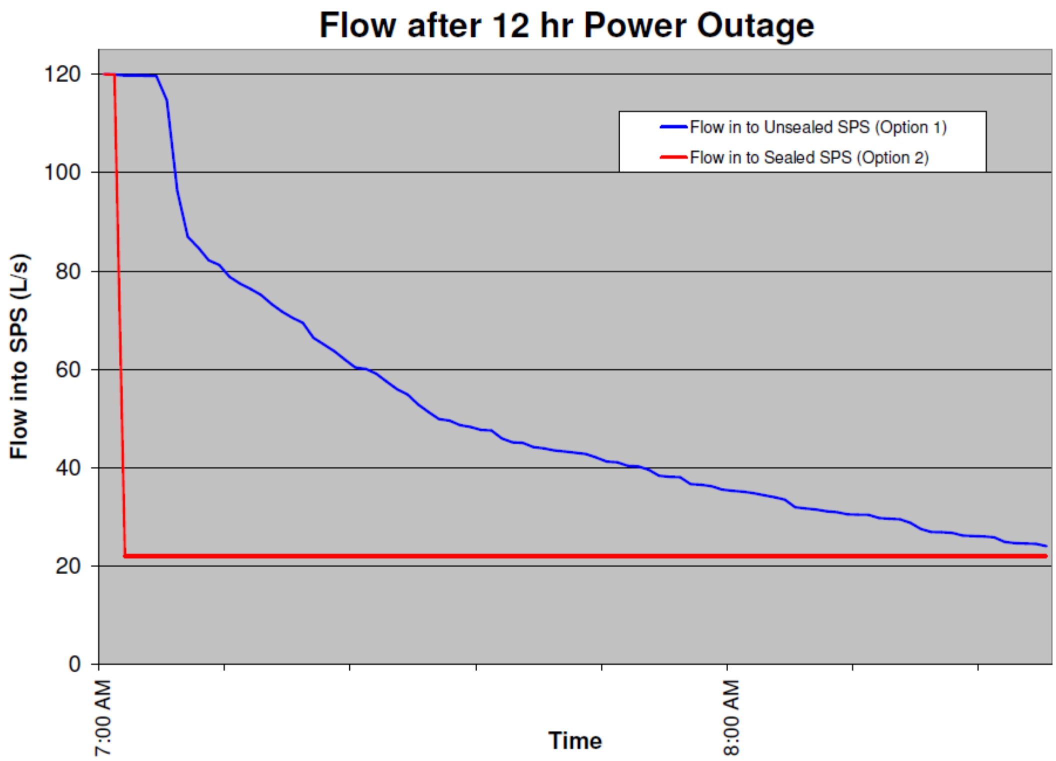


Constraining the PSS network outlet in this fashion eliminated the requirement to build a 150 KL emergency storage at the Flinders transfer SPS. The use of pressure vessel wet wells in conjunction with the current sensing over-pressure pump protection feature to engage the dispersed emergency storage available within the pressure sewer network and pump unit tanks rather than building large emergency storage(s) at the transfer pump stations, saved approximately $1 million.

3.2.4 FLOW THROTTLING AT THE NETWORK OUTLET

The use of enhanced over pressure protection and sealable pressure vessel wet wells has another important benefit of throttling flows at the outlet of the pressure collection network and the start of the 18 km long transfer system. Peak flow events, such as power outage recovery flows, are handled automatically. This feature was used to minimise the transfer pumping flow rate and diameter of the transfer mains, creating substantial project savings in the order of $3 Million. Figure 5 shows a simulated trace of flow at the PSS network outlet during a POR event for a free network outlet and a constrained network outlet.

Figure 5: Hydraulic model simulation of Power Outage Recovery flow at PSS network outlet



4 PRESSURE SEWER NETWORK DESIGN USING HYDRAULIC MODELLING

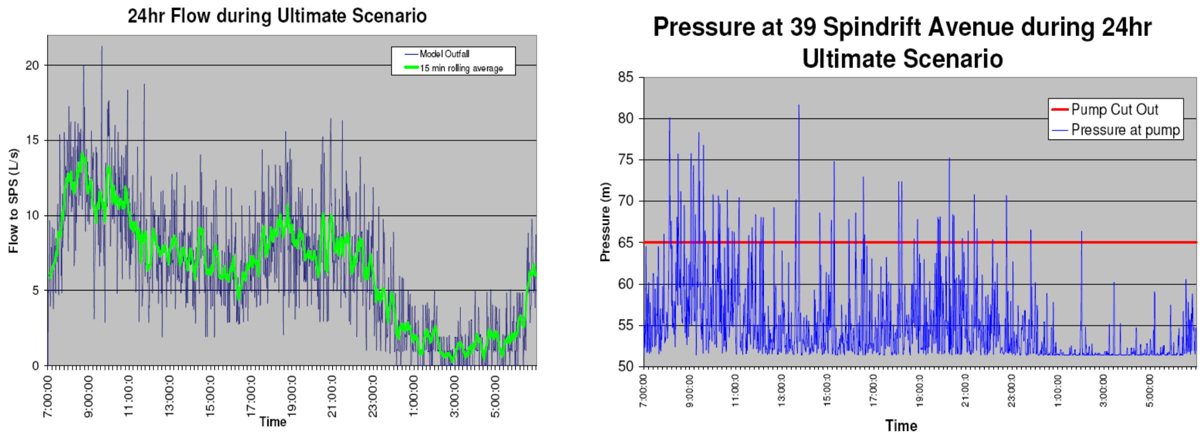
Traditionally, PSS networks have been installed in flat areas and simplified analysis has been used. Historically, simple spreadsheet tools have been used for hydraulic analysis and design of pressure sewer networks. On the Flinders Sewerage Project, dynamic hydraulic modelling was used to carry out PSS network design and optimisation. The preliminary network layout was prepared using GIS software, this information was then imported into Innovyze's (formerly MWH Soft) hydraulic modelling software, H2OMap. Figures 5 and 6 show typical hydraulic modelling outputs.

The advantages of using hydraulic models include:

- Rapid network reconfiguration to assess competing design options, such as growth staging and consideration of time variant design options (e.g. volumetric computations);
- The ability to quickly analyse different operating scenarios such as system start up with low connection rates
- The optimisation of pipe sizes across the reticulation networks;
- Improved quality assurance and data auditing capabilities, thereby minimising risk, particularly when geospatially accurate models are employed; and

- Simple identification of the most hydraulically disadvantaged pumps within the system during all peak operating scenarios.

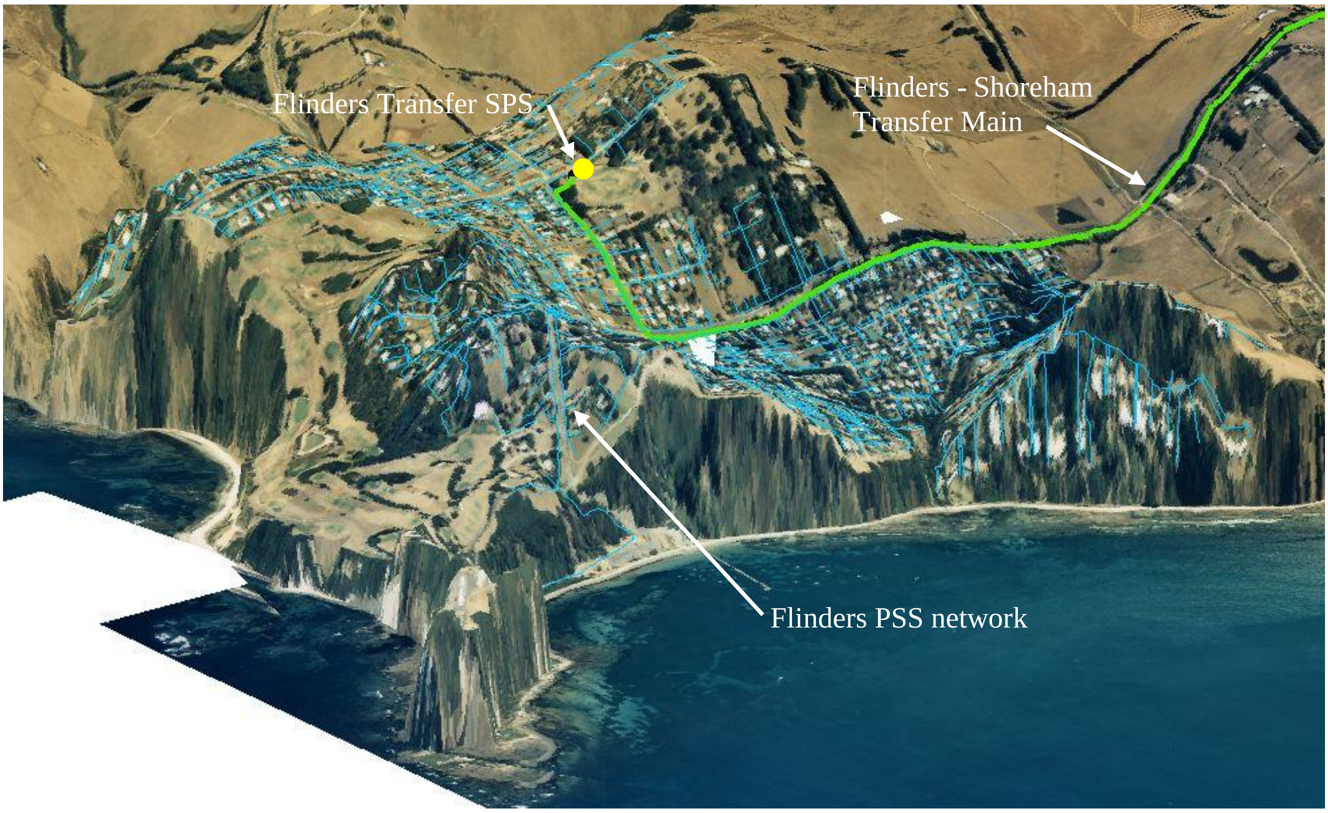
Figure 6: Typical Hydraulic Modeling outputs



4.1 FLINDERS PSS NETWORK

The site of the Flinders PSS network outlet and transfer SPS was selected for its high elevation to ensure most of the Flinders township would pump up to this site, thereby minimising the propensity for air entrainment within the PSS network. The Flinders PSS network was divided into three separate zones, with individual properties allocated between them based on the requirement that the pipes remain full while minimising the operating head on the pumps. Figure 7 shows an aerial photo of the Flinders PSS network. A schematic of the Flinders PSS network is appended to this paper.

Figure 7: Flinders Pressure Sewerage network – Aerial Photo

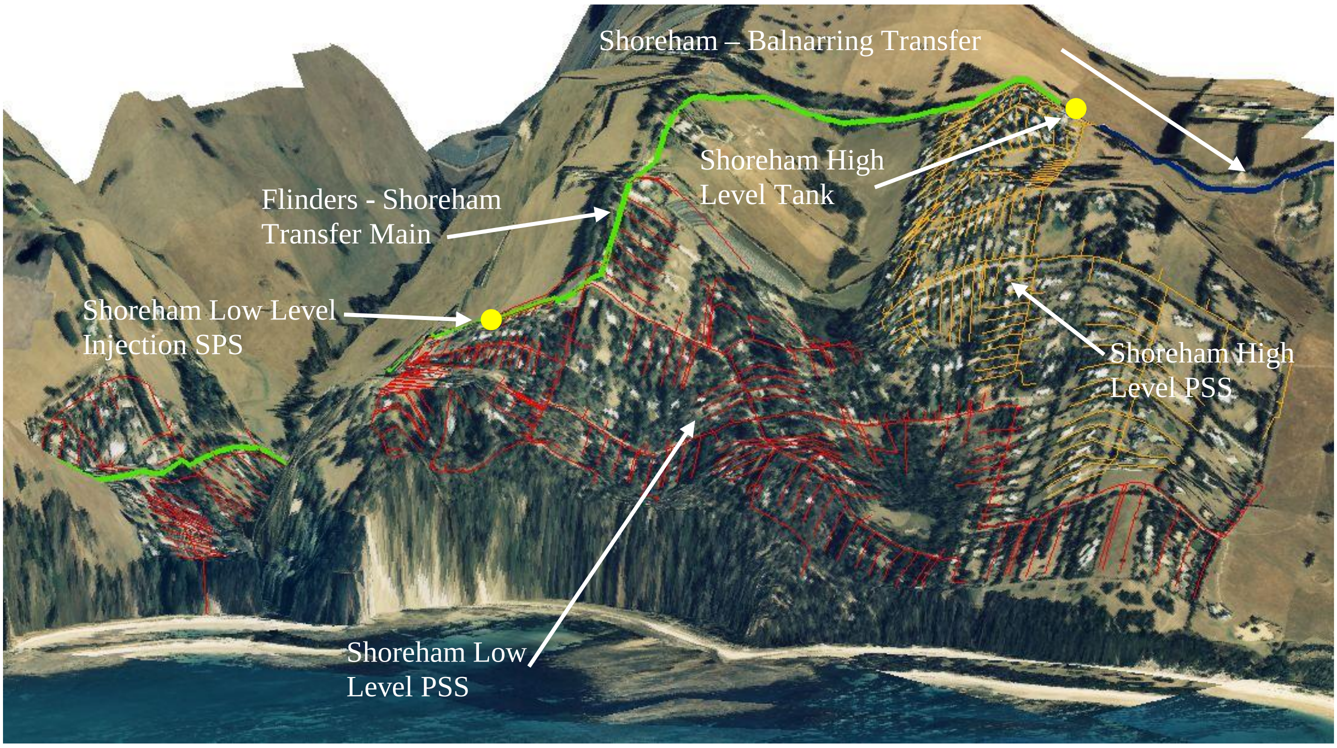


4.2 SHOREHAM PSS NETWORK

The elevation of the Shoreham township ranges from 5 m RL to 80 m RL. Providing sewerage services to Shoreham using PSS technology required two separate networks. The Shoreham low level PSS network discharges to the Shoreham low level SPS, whilst the Shoreham high level PSS network discharges to the Shoreham high level tank.

The Shoreham PSS network was divided into four separate zones, with individual properties allocated between them based on the requirement that the pipes remain full, while minimising the operating head on the pumps. To keep the pipes full, it is necessary to pump to an elevation higher then the household properties. Figure 8 shows the connectivity of the low level PSS network (in red), the high level PSS network (in yellow) and the locations of the Shoreham low level injection SPS and Shoreham high level tank. A schematic of the Shorehan PSS networks is appended to this paper.

Figure 8: Shoreham Pressure Sewerage networks – Aerial Photo

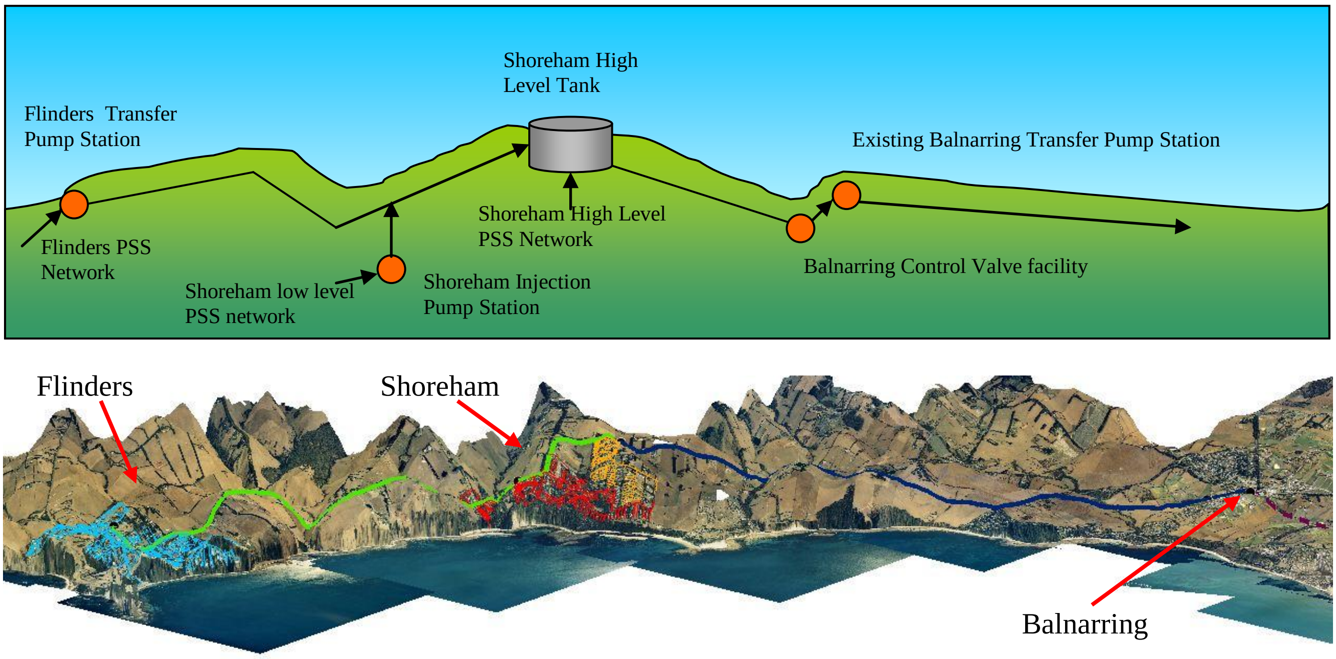


5 TRANSFER SYSTEM

5.1 TRANSFER SYSTEM OVERVIEW

The Flinders SPS and Shoreham low level SPS pump to the Shoreham High Level Tank (SHLT). Flows from the SHLT then gravitate via the Balnarring Control Valve to the existing Balnarring sewerage system and on to the Somers WWTP. Figure 9 shows the connectivity between the three PSS networks and major transfer assets in schematic and aerial photo form.

Figure 9: The Flinders Transfer System – Schematic and Aerial Photo



5.1.1 HYDRAULIC LOADING

Table 1 below shows the results of the PSS network hydraulic modelling. Flows at the outlet of each PSS network are provided for various operative scenarios.

Table 1: Pressure Sewer Network Design Flows

LPSS Network	Estimated Flow (L/s)					
	Peak Flow Power Outage Scenario	Peak Daily Flow Normal Operation (A) (Ultimate Development)	Average Flow	Low Season Peak Flow	Low Season Mean Flow (Permanent Residents only)	SPS Design Flow Rate
Flinders	120	14.5(A)	6.4	5.5	1.8	16 Minimum (C)
Low Shoreham	47	6.6(A)	2.5	2.2	0.6	7
High Shoreham	36	3.8(A)	1.43	1.7	0.55	4 (B)

Notes:

(A) Corresponds to a 15 minute rolling average peak.

(B) Variable flowrate corresponding to a 15 minute rolling average peak.

(C) The design flow for the Flinders SPS was optimised in conjunction with the diameter and pressure rating of the transfer pipeline.

5.1.2 SOLIDS LOADING

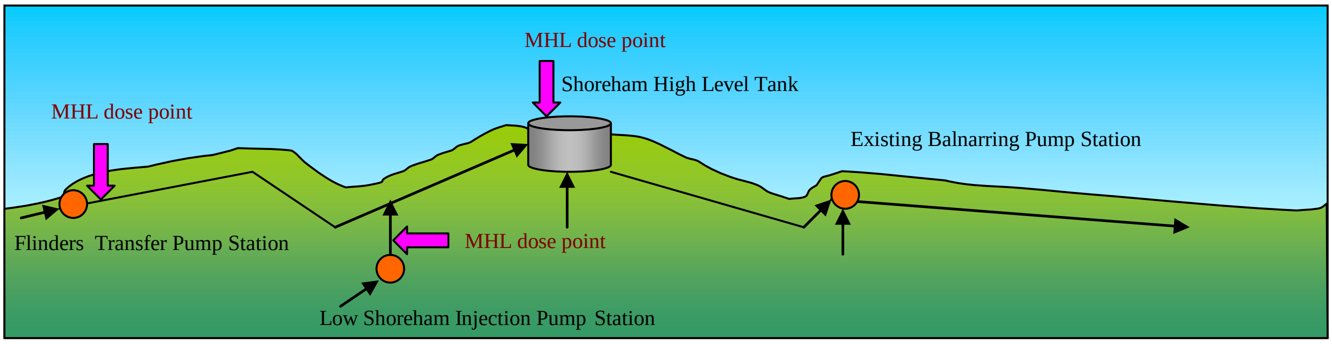
Sewage is macerated by the PSS grinder pump at each property prior to discharge into the PSS network. Accordingly, the transfer system influent has a relatively low solids content. The only solids entering the transfer system must come through the individual household PSS pumps. As such, the largest particle size expected to enter the system through the household pumps was a 4 mm diameter solid. This is much smaller than the solids typically allowed for in raw sewage. This proved to be a big advantage for the transfer system as centrifugal pumps with large solid passing capacities were not required and low flow high head progressive cavity pumps could be used.

5.2 ODOUR CONTROL

Odour generation from the sewage in the transfer system was considered likely because of the detention times in the upstream PSS networks and the long detention time of the transfer system itself. For example, when the sewage enters the Flinders Transfer Pump Station it was predicted to be 9 hours old at ADWF, and 15 hours at low flow. Sewage was expected to be septic when it entered the transfer system. Left untreated high levels of sulphide generation and associated odour and corrosion problems were predicted to occur. To mitigate odour formation and release an odour control strategy was developed. This involved:

- Scouring or cleansing the transfer system each time it operated to remove pipe wall slimes which are a significant source of sulphide generation;
- Keeping the transfer system closed by utilising seal able pressure vessel wet wells;
- Minimising air exchange in and out of the transfer system by keeping the self-draining pipeline in a full condition at all times;
- Dosing all inputs into the transfer system with magnesium hydroxide ($Mg(OH)_2$)) as a liquid (MHL) to raise pH and prevent the release of Hydrogen Sulphide (H_2S). Figure 10 shows the location of the MHL dosing points; and
- Provision of mechanical ventilation at both transfer pumping stations and the Shoreham high level tank.

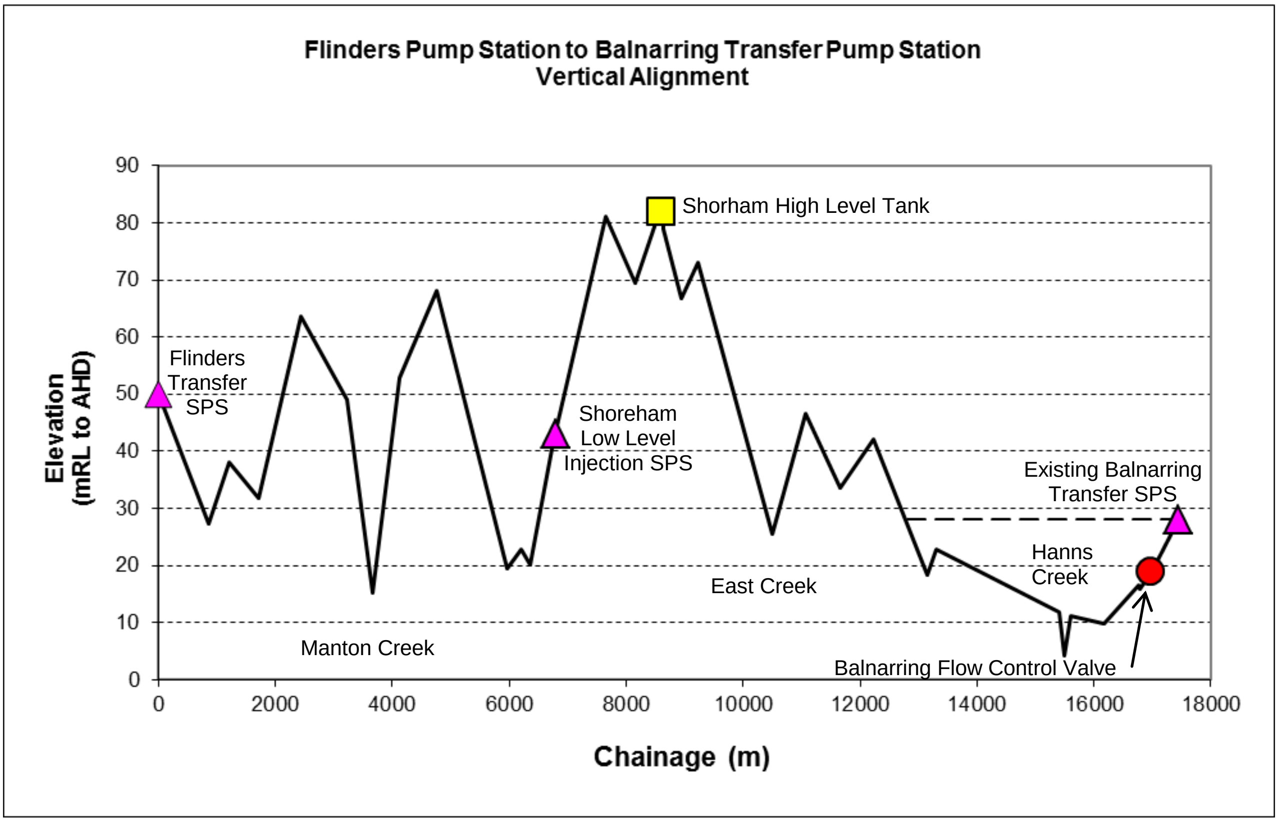
Figure 10: Transfer System Schematic Showing Magnesium Hydroxide Liquid (MHL) dosing points



5.3 TRANSFER PIPELINES

The Flinders township is located approximately 9 km from Shoreham, which is some 9 km from the existing Balnarring sewerage system which transfers another 6 km on to the Somers STP. The transfer system from Flinders to Balnarring crosses undulating terrain, with elevations along the route varying between 5 m and 80 m. The horizontal and vertical alignment of the transfer main is shown in Figures 1 and 11 respectively.

Figure 11: The Flinders Transfer Main – Long Section



As shown in Figure 11, from the Flinders Transfer SPS at approximately 55 m AHD the transfer main passes through undulating terrain to the Shoreham low level SPS at 43 m AHD. Low Shoreham PSS flows enter the transfer system at this point. From the Shoreham low level SPS the transfer main rises to the Shoreham high level tank at approx. 80 m, the highest point in the system. High Shoreham PSS flows enter the Transfer System at the high level tank.

From the Shoreham high level tank, the transfer main descends steeply to East Creek. Once over the next high point, the terrain flattens and continues descending to Hanns Creek. After Hanns Creek, the transfer main gradually rises until it discharges into the existing Balnarring Transfer SPS (SPS819). It is important to note that the last 4.5 km of the transfer main is always filled, as it is lower than the discharge point.

5.3.1 MATERIAL

High density polyethylene (PE100) was selected as the preferred transfer main material due to its high degree of chemical resistance, its resistance to degradation under cyclic loading and its suitability for trenchless installation using horizontal directional drilling (HDD).

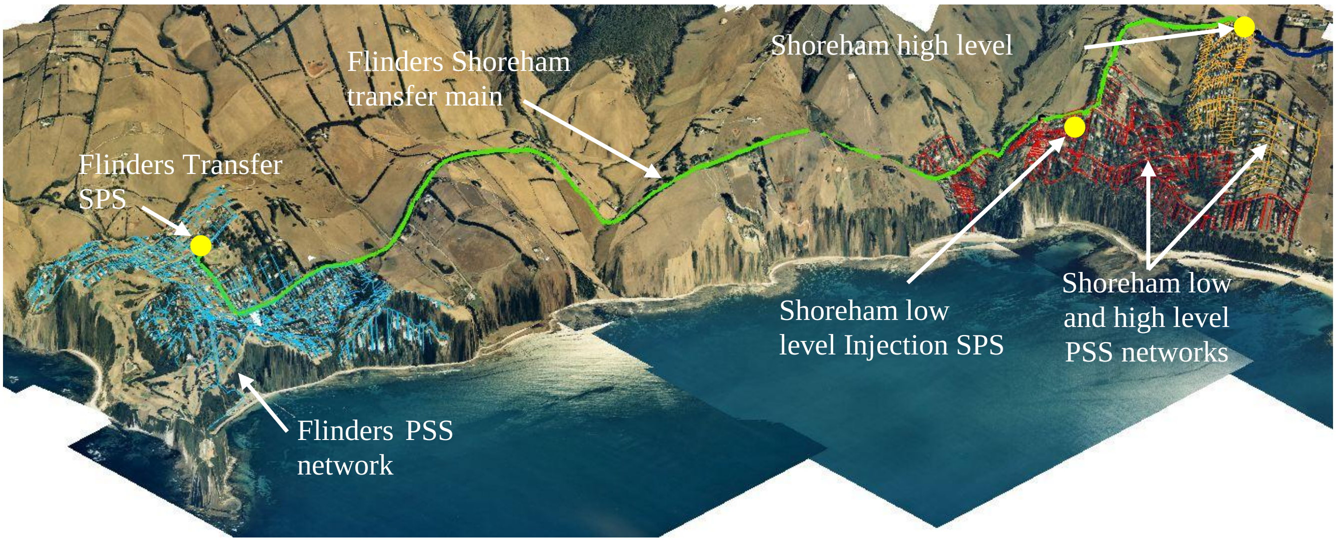
5.3.2 SIZING CRITERIA

The transfer mains were sized to self-cleanse during every operation. A minimum pipe wall shear stress of 2.87 Pa was adopted as self-cleansing (slime-stripping) design criteria. Shear stresses will increase as the pipe ages and becomes rougher internally, whereas pipe hydraulic capacity will reduce. Therefore, to ensure that slime-stripping will occur during the initial period of pipeline operation, a Colebrooke – White ks value of 0.1 mm was adopted for use in shear stress calculations. Conversely, to ensure the pipe has adequate long-term hydraulic capacity, a higher ks value of 0.6 mm was used. The selected pipes had to satisfy both the hydraulic and slime-shearing constraints to be deemed acceptable.

5.4 FLINDERS TO SHOREHAM HIGH LEVEL TANK PUMPED SYSTEM

This leg of the transfer system, shown in Figure 12, receives pumped flows from the Flinders transfer SPS and the Shoreham low level injection SPS.

Figure 12: Aerial View of the Flinders-Shoreham Transfer System and Flinders and Shoreham PSS Networks



The main was sized so that self-cleansing and slime-shearing conditions are created when only Flinders transfer SPS is pumping to the Shoreham High Level Tank. Therefore, each time Flinders Transfer Pump Station operates, the Flinders to Shoreham High Level Tank main is cleansed. A range of pipe diameters and flow rate combinations were evaluated for the Flinders – Shoreham pipeline. Table 2 shows the pipe wall shear stresses generated for a range of pipe and flow rate combinations. Acceptable pipe and flow rate combinations are highlighted.

Table 2: Flinders to Shoreham High Level Tank Pipe Diameter and Flow rate Combinations

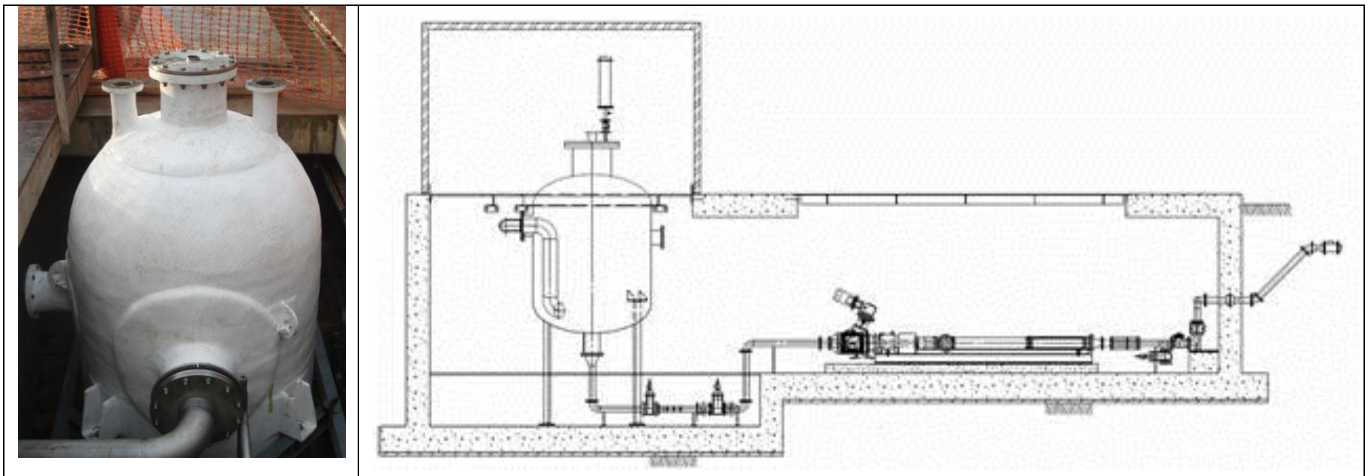
Nominal diameter (DN)	Internal diameter	Flow	Velocity	Pipe roughness $k_s = 0.1$	Shear stress
(mm)	(mm)	(l/s)	(m/s)	(mm)	(Pa)
180	138	16	1.070	0.1	2.95
180	138	17	1.137	0.1	3.31
180	138	18	1.203	0.1	3.69
180	138	19	1.270	0.1	4.09
180	138	20	1.337	0.1	4.51
200	154	16	0.859	0.1	1.89
200	154	17	0.913	0.1	2.12
200	154	18	0.966	0.1	2.37
200	154	19	1.020	0.1	2.62
200	154	20	1.074	0.1	2.89
200	154	21	1.127	0.1	3.17

The minimum design flow for the Flinders transfer SPS and transfer main is 16 L/s as described in Table 1. Slime shearing conditions are achieved at 16 L/s in the DN 180 mm pipe (highlighted in red above), and at 20 L/s in the DN 200 mm pipe (highlighted in green above). However, the head required pump 16 L/s through a 180 mm pipe is greater than 200 m when transient conditions are considered. This is higher than the pressure rating of PN 20 pipe used. Therefore the combination of a DN 200 mm pipeline and a duty flow of 20 L/s was selected as the optimum pipe diameter and flow rate combination.

5.5 TRANSFER PUMP STATIONS

The typical arrangement for the transfer pump stations is shown in Photograph 1 and Figure 13. The functionality of the sealable pressure vessel wet well is explained in section 3.2.3.

Figure 13: Sealable GRP pressure vessel wet well and Flinders Transfer Pump Station - Section



5.5.1 PUMP DUTIES

Table 3 shows the pump duties for the Flinders and Shoreham transfer pump stations when each are operating independently and when they are both operating at the same time. These pump duties are based on normal operation within the upstream PSS networks as this is the most severe design case.

Table 3: Transfer Pump Station – Pump Duties

Pump Station	System Operating State	Static Lift	Fittings Loss	Friction Loss	Duty
Flinders Transfer Pump Station	Flinders pumping alone	31.4 m	2.2 m	97.8 m	20 l/s @ 131.4 m
	Both Stations pumping	31.4 m	2.9 m	114.8 m	20 l/s @ 149.1 m
Shoreham CFA Injection Pump Station	Shoreham CFA pumping alone	41.3 m	0.1 m	2.7 m	7 l/s @ 44.1 m
	Both stations pumping	41.3 m	1.5 m	38.0 m	7 l/s @ 80.8 m

Note: Pump duties based on normal operation.

5.5.2 LOW FLOW HIGH HEAD PUMPING FROM FLINDERS TO SHOREHAM

This leg of the transfer system would have ordinarily been divided into a series of transfer stations because conventional centrifugal sewage pumps employ large clearances and specially designed impellers (so that they are able to handle sewage debris such as fibrous materials, grits and solids) and such centrifugal sewage pumps are typically limited to low heads (typically in the order of 70 m).

Low flow high head progressive cavity pumps with small clearances were able to be used because all the raw sewage solids and debris are macerated by the individual household pumps before they reach the transfer stations. The use of these higher pumping pressures meant that it was possible to pump directly from Flinders to the Shoreham high level tank with a single lift. This would not have been possible using typical centrifugal sewage pumps. Fewer pump stations reduced both the capital and operating expenditure requirement.

Photograph 1: The Flinders Sewage SPS chamber (During Construction) showing progressive cavity pumps

5.5.3 VARIABLE HEAD BOOSTER PUMPING

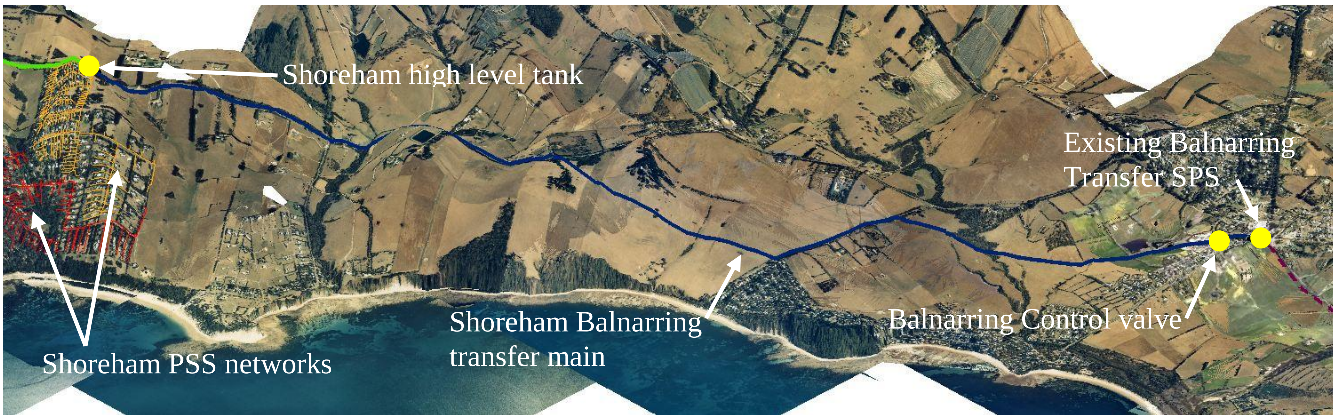
The transfer pump stations face a broad range of duty heads, shown in Table 3. Both the suction head and discharge head experienced by the transfer pumps are variable due to the various operating scenarios possible. On the suction side, pressurisation of the PSS network and wet well pressure vessel can vary suction head by up to 80 m. On the discharge side, the transfer system is an injection system, so the discharge head varies depending on which transfer SPSs are operating at any given time.

Another advantage of using progressive cavity pumps is that they are rotary positive displacement pumps. They are able to provide a stable flow rate as the system head changes. As such, they are particularly well suited to this transfer system where total system head can vary dramatically due to two pump stations injecting into the same transfer main and the method of engaging emergency storage within the PSS networks and household tanks. On the other hand, the performance of centrifugal pumps and the stability of the duty flow produced are highly sensitive to variations in system head making them unsuitable for use in this transfer system.

5.6 SHOREHAM HIGH LEVEL TANK TO BALNARRING FALLING SYSTEM

This leg of the transfer system receives pumped flows from the Flinders Transfer SPS, the Shoreham injection SPS and the High Shoreham LPSS network. These flows are collected in the Shoreham High Level tank. The transfer main includes a downstream control valve, which under normal operating conditions will keep the main full. This control valve forms part of the odour control strategy. This pipeline has been sized so that self-cleansing and slime-shearing conditions are created and the transfer main is scoured each time the downstream control valve is opened. Figure 14 shows an aerial photo view of the Shoreham – Balnarring transfer system.

Figure 14: Aerial View of the Shoreham-Balnarring Transfer System



The Shoreham high level tank receives total flows of 31 L/s from the upstream systems of Flinders and Shoreham. An additional allowance of 4 L/s was provided for a future connection for the town of Point Leo. The flows are listed in Table 4.

Table 4: Shoreham High Level Tank to Balnarring - Induced Head Pipeline required capacity

Contributing System	Flow (L/s)
Flinders Transfer SPS	20
Shoreham Low Level SPS	7
High Shoreham High Level SPS	4
Allowance for future Point Leo connection	4
TOTAL	35

In order to pass forward all received flows, this pipeline would require an ultimate capacity of 35 L/s. Taking all losses into account, the average pipe slope from the Shoreham High Point Tank to the Balnarring transfer SPS is 0.555% (1 in 180). A range of pipe diameters were assessed for this pipeline. Table 5 shows the pipe wall shear stresses generated for each pipe diameter at this slope. The selected pipe is highlighted in green.

Table 5: Shoreham High Level Tank to Balnarring Pipeline Diameter and Flow rate Combinations

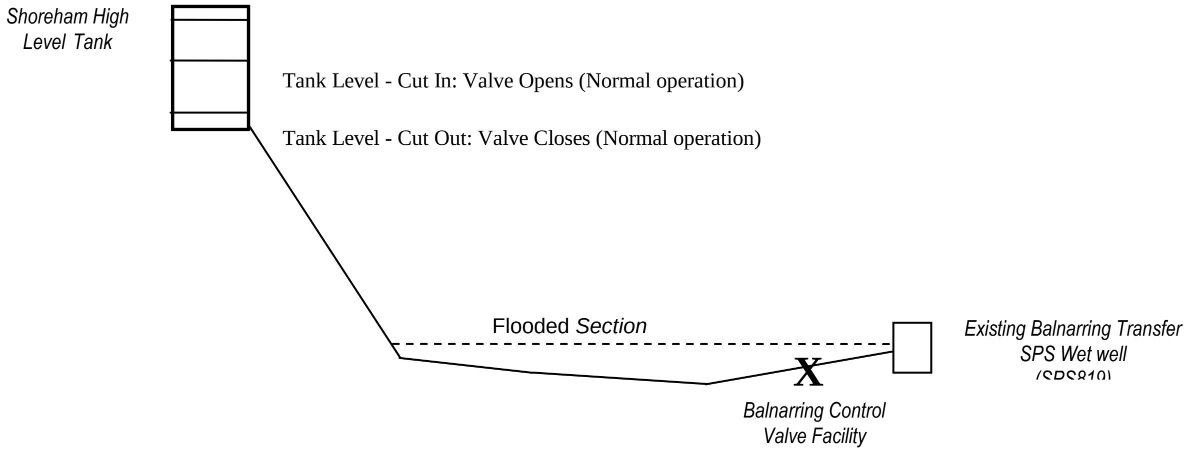
Average Slope of Pipe		Nominal Diameter	Internal Diameter	Capacity	Velocity	Shear Stress
(1 in …)		(mm)	(mm)	(L/s)	(m/s)	(Pa)
1 in	180	250	192	25.3	0.875	2.61
1 in	180	280	215	34.2	0.942	2.92
1 in	180	315	242	46.8	1.017	3.29

A DN 280 mm pipe was the smallest pipe that achieved the minimum required pipe wall shear stress for creating self-cleansing and slime-shearing conditions. The capacity of the pipe at 34.2 L/s was slightly less than the required pipe capacity of 35 L/s given in Table 3. However, this short fall in capacity was deemed acceptable due to the availability of buffer storage at the Shoreham high level tank to attenuate peak flows. The goal of minimising system detention time to aid odour management also added weight to the decision to select a DN 280 mm pipe.

The DN 280 mm gravity pipeline from Shoreham High Level Tank to the Balnarring Outfall SPS falls approximately 50 m over some 9 km of undulating terrain as shown in Figure 11. The SHLT location was selected to maximise driving head, while minimising any impact on vegetation and nearby private residences. As 200 m^3 of odorous foul air would otherwise have been purged every time either the Flinders SPS or Shoreham SPS operated, the Balnarring Control Valve Facility (BCV), employs sewage pressure-sustaining valves to keep the transfer main full of fluid (i.e. without air), by controlling the flow between the SHLT and the discharge point.

This arrangement also enhances system reliability by controlling sewer slime growth and flushing sedimentation, which is especially important in the 4.5 km long flooded section shown in Figures 11 and 15. The high level, flushing volume stored in the SHLT provides a high pressure, long duration flush when the BCV opens, which maximises the pipe flow velocities and pipe wall shear stresses to self-cleanse the pipe, throughout the period that the BCV is open. The SHLT also includes two hours of emergency storage to provide operational flexibility.

Figure 15: Shoreham to Balnarring Transfer System - Schematic



5.7 IMPACT OF SMART PSS NETWORKS ON DOWNSTREAM TRANSFER SYSTEM

Table 6 illustrates the benefits to the transfer system created by the smart PSS networks upstream. The table shows how the transfer flow rates and size and requirement of downstream infrastructure required was reduced as the sewerage collection system was changed from gravity to first generation pressure sewer and finally to second generation smart pressure sewer. Other benefits of utilising smart PSS networks include:

- Engaging the emergency storage available within the pressure sewer network and pump unit tanks rather than building large emergency storage(s) at the transfer pump stations, saving approximately $1 million.
- Reducing the typical transfer pump flow rate peaking factor from the industry standard 6 x ADWF to 3x ADWF;
- Shortened the length of the transfer system by 5 km, resulting in a saving of $2 million. The transfer system was originally intended to extend to the Somers STP. However as the outlet flow rate reduced, the opportunity to shorten the transfer system was identified and adopted;
- Minimised pipeline construction costs;
- Minimised environmental impacts because smaller pipe diameters increased the cost competitiveness of horizontal directional drilling thereby making trenchless construction more feasible; and
- Minimised transfer system detention times thereby reducing odours.

Table 6: Flinders Transfer SPS Transfer design requirements against reticulation type

RETIC TYPE	NORMAL NETWORK OUTFLOW (PDWF)	PEAK NETWORK OUTFLOW	TRANSFER PUMPING FLOW RATE	TRANSFER MAIN DIAMETER	EMERGENCY STORAGE REQUIRED AT SPS
Gravity	N/A[a]	45 L/s (PWWF)	45 L/s PWWF ≈ 6 x ADWF	256	Yes
1^{st} generation pressure sewer	14.5 L/s	120 L/s (POR)	20 L/s PDWF ≈ 3 x ADWF	154	Yes
2^{nd} generation pressure sewer	14.5 L/s	120 L/s (POR)	20 L/s PDWF ≈ 3 x ADWF	154	No

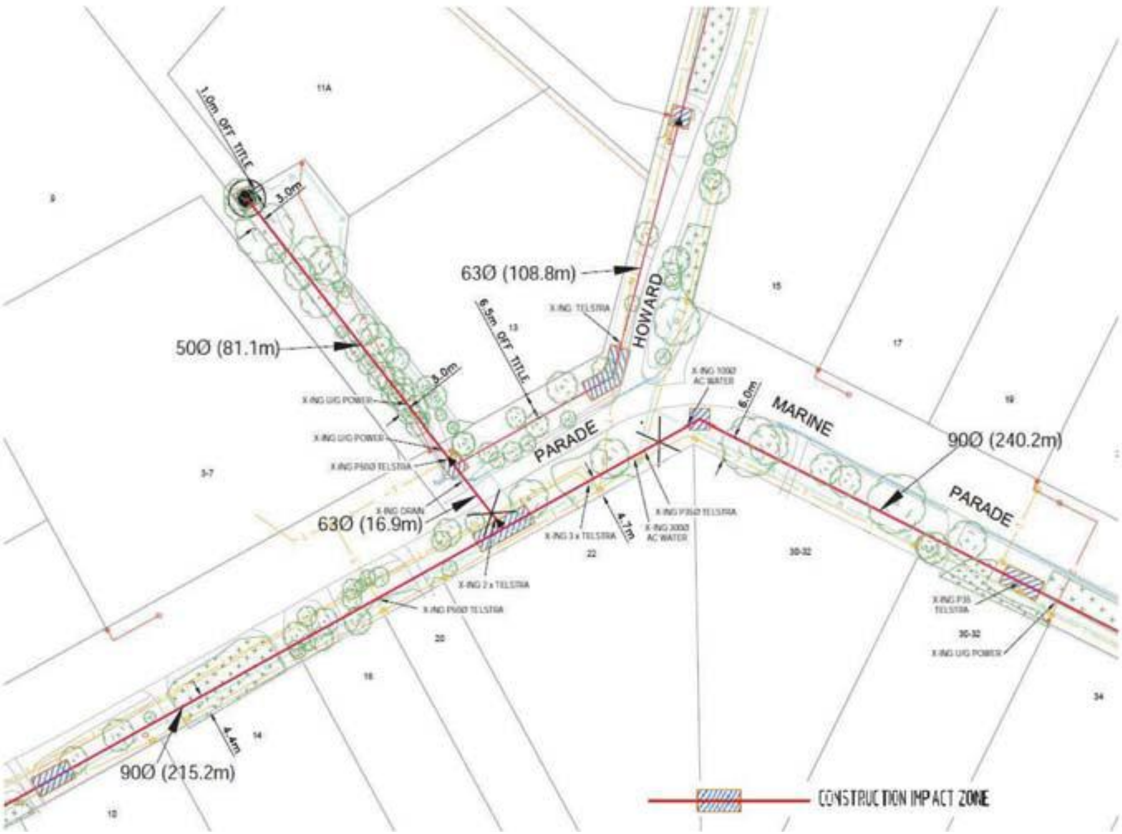
(A) For original gravity option the Flinders Transfer SPS received a mix of gravity and intermittent pumped flows.

6 APPLICATION OF NOMINATED CONSTRUCTION IMPACT ZONES

The project area included significant stands of high value native vegetation. Planning approvals at Local and State levels of government were required for the removal of vegetation. As approvals must be obtained before any works can commence, the planning process poses the risk of significant delays to project construction. For example, the Flinders PSS required a planning permit for vegetation removal which took seven months to be approved from the time it was submitted.

The Flinders Sewerage Project was constructed in two stages; Flinders then Shoreham. Learning from the delays experienced during the first stage of approvals, a new approach was developed for the second stage. Although the works were to be undertaken predominately by directional drilling, excavation works were required at all changes of pipeline direction, at connections, valves and at intervals of approximately 100 m which is the standard length the directional drilling machines can drill per operation. These locations were nominated as Construction Impact Zones (CIZ). All works were to be undertaken only from these CIZs, which would be demonstrated (during the design development) to be clear of vegetation or cultural heritage sites. A typical plan is shown in Figure 16. Edwards, French and Ogier (2009) provide further detailed explanation of the application and use of the CIZ approach.

Figure 16: Plan showing proposed reticulation and CIZ locations



The early adoption of trenchless technology combined with nominated CIZs greatly simplified the Environmental Impact Assessment process by focusing on approximately 100 CIZs. Detailed assessment was only required within the nominated CIZs. Without this methodology, detailed assessment of 11 km of pipeline alignments would have been required, which would not have been practical. Through best practice environmental engineering and stakeholder consultation the project was able to:

- Avoid vegetation removal, disturbance and minimise environmental impacts;
- Improve timeframes for and reduce the risk associated with planning approvals; and
- Improve customer and stakeholder relations.

7 CONCLUSIONS

The Flinders Sewerage Project was an innovative backlog sewerage scheme. This project was successfully delivered. It received the following recognition from Industry:

- Winner of the 2010 IWA Asia Pacific regional Project Innovation Award, Small Project category;
- Highly commended at the 2009 Australian Water Association (Victorian) excellence awards in the Infrastructure Project Innovation category; and
- Highly commended at the 2009 Engineers Australia Victorian Engineering Excellence Awards in the Engineering Technology category.

The project demonstrates the benefits of developing technical partnerships to deliver innovation. The innovations implemented for this project have since been adopted and reused on subsequent projects by the project participants and others. The key lessons learned on this project include:

- Combining pressure sewer technology and trenchless technology early in the project life cycle can, in a backlog context, provide a very cost-effective township sewer system;
- Using pressure based PSS pump control can greatly improve handling of both peak system pressures and peak system flows; and
- Integrating SCADA functionality in PSS enhances network monitoring and control. This enables rapid fault detection, diagnosis and response which effectively removes the customer from system operation.
- Dynamic hydraulic modelling is a valuable optimisation and verification tool for PSS network design;
- Pressure-based control of pressure sewer networks in emergency conditions can be used to facilitate engagement of the emergency storage available within individual properties, and thus attenuate peak power outage recovery flows;
- Adoption of smart pressure sewer technology can create large savings and efficiencies in downsteam transfer systems; and
- Applying a nominated construction impact zone methodology and committing to trenchless construction techniques can be high effective in obtaining stakeholder endorsement and reducing the delays and risk typically associated with approvals;

8 ACKNOWLEDGEMENTS

I would like to acknowledge the following parties for their contribution to this project:

- Our client South East Water Limited and in particular to Steven French for his trust and leadership. Rather than focusing on design cost control, design was initially undertaken through a cost-plus arrangement between MWH and SEWL, which focused on engineering innovation. This created a collaborative environment in which trust and innovation flourished. Without this we would not have achieved the results we did;
- The '***us***' construction and commissioning delivery team in particular Colin Feldtmann and Michael Lowe;
- Our technology partner NOV Mono (Australia);
- Sydney Water and Priority Sewerage Program Alliance, in particular Ivan Lowe and Wayne Kennedy, who hosted a SEWL-MWH delegation for a knowledge sharing workshop and site visits in May 2006 following the decision to adopt pressure sewer in lieu of gravity;
- The MWH environmental, modelling and design teams for their efforts in helping deliver this result, in particular: David Hicks, Peter Allen, David Angus, Ivan Lowe, Alex McKenzie, Dwayne Deprez, Chris Povey, Brett Donaldson, Carly Martin, Richard Smith, and Kerry Brooksmith; and
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APPENDIX – FLINDERS AND SHOREHAM PSS NETWORKS - SCHEMATICS

Figure 17: Flinders Pressure Sewer Network - Schematic

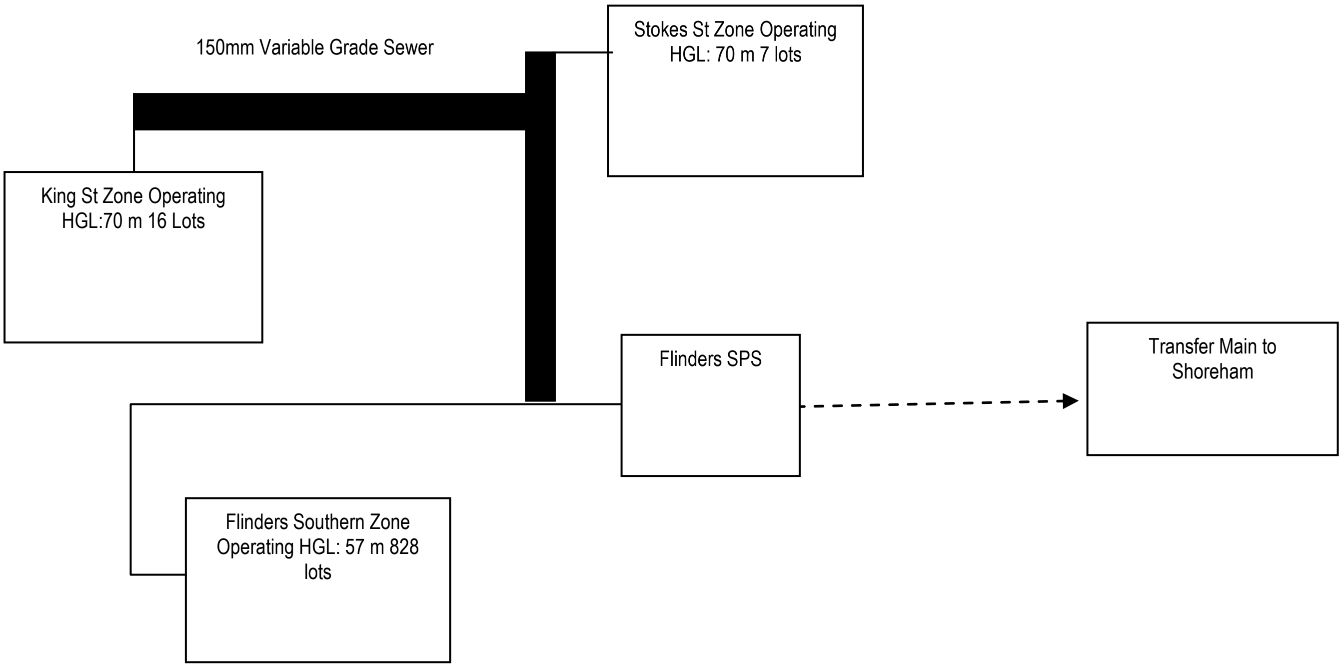

Figure 16: Shoreham High and Low Level Pressure Sewer Networks