REVOLUTION IN WASTEWATER RETICULATION AND ASSET MANAGEMENT

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ABSTRACT

Smart pressure sewer systems are now available on a commercial basis in New Zealand following technical development and field testing by Melbourne's South East Water and Iota Pty Ltd. Smart pressure sewer utilises advances in information technology combined with SE Water's experience as an asset owner and operator of pressure sewer networks to provide a robust solution to address a number of issues confronting wastewater asset owners.

Utilisation of smart pressure sewer technology offers a paradigm shift in all aspects of wastewater reticulation and asset management, including customer interface, fault and maintenance management and complete hydraulic flow control. This includes peak flow shifting, system flushing and storage management.

This paper will document what smart pressure sewer is and how it works. The paper will investigate the implications for asset owners in the New Zealand context, including the hydraulic benefits of the system with a particular focus on peak flow shifting and the ability to reduce peak flowrates. The benefits of reduced peak flowrates on downstream trunk transfer systems will be investigated.

This paper will be of interest to a wide audience involved with the provision of wastewater services, accommodation of future population growth, asset management, system operations and maintenance, and design engineers.

KEYWORDS

Wastewater, Smart Pressure Sewer, Onebox, Asset Management, Infrastructure and Growth.

1 INTRODUCTION

Pressure sewer systems are now established as a viable method of providing wastewater reticulation. The first schemes were installed in New Zealand circa 2007 in both Rodney and Rotorua Districts. Since 2007 pressure sewer systems have become widespread across New Zealand. To date, pressure sewer systems rely on 'simple' pump controls, with pump operating dictated by water level in the pump tank. This introduces some inherent constraints to system hydraulics that must be considered by the asset owner and addressed during the system design.

As part of plans to service 16,000 properties on the Morning Peninsular, located South East of Melbourne, SE Water and Iota sought to address the existing constraints of conventional pressure sewer systems.

The application of information technology by Iota to existing pressure sewer equipment has enabled a paradigm shift in wastewater reticulation. Advances in information technology in capability, reliability and cost have enabled the effective application of this new technology to the wastewater environment. The combined technology and pressure sewer equipment are now commercially available in New Zealand as 'Onebox'.

2 INFORMATION TECHNOLOGY

A number of viable options now exist for two way communications between large numbers of assets (pumps) and a central controller and data repository. The primary requirements for the successful application of information handling systems to the wastewater environment is as follows:

1. Reliability / robustness
2. Simplicity / avoidance of complexity
3. Cost effectiveness
4. Scalability

The Onebox system has adopted a cellular network based 3G SMS two way data communications system combined with server based data repository. System control, system monitoring and data access is achieved by internet access to the server. This enables full real time system monitoring and control from any device capable of accessing the internet. This means that network operators can manage and control the system from the field without the need for specialist hardware, i.e. any smart phone or tablet can be used to manage the network or respond to faults. In addition, more in-depth system analytics can be carried out from desktop PC's with internet access, while IT system back-up and redundancy is easily achieved via the application of remote server hosting, giving advantages in alignment with normal IT business practices.

The Onebox system brings together 3G phone technology and 'conventional' internet connected servers to provide a data platform for the management of pressure sewer systems that is well established and proven within modern business applications.

2.1 LEVEL MONITORING

Conventional pressure sewer equipment use either float switches or pressure switches which measure water level at fixed points within the tank. This is suitable for conventional pump stop start and high level alarms. The Onebox system utilises a pressure transducer to monitor water level, i.e. a conventional 4-20 mA level transducer. This enables monitoring of water level at all levels in the tank instead of at fixed levels as dictated by the position of float switches. This provides a cost effective method of utilising tank storage as operational storage and has other operational advantages that forms the platform for Onebox operation.

In summary, Onebox applies existing and proven technologies, being 3G mobile network data communication, and existing wastewater hardware, being 4-20 mA level transducers, and applies them to the pressure sewer application in order to gain significant benefits from the combined system.

3 PARADIGM SHIFT

The application of the available technology in the pressure sewer application to produce 'Smart' pressure sewer introduces a paradigm shift in all aspects of wastewater reticulation. All conventional thinking and approaches to wastewater servicing ranging from asset planning to operational management is set aside.

3.1 CUSTOMER INTERFACE

The 3G data interface for each separate grinder pump introduces the ability for network operators to be alerted to alarms without the involvement of the property owner. Conventional pressure sewer equipment produces an audible and visual alarm when a fault occurs, i.e. a siren and red flashing light. This requires the property owner to respond to the alarm and then contact the network operator or service agent.

The removal of the property owner from alarm notification has significant advantages for a number of reasons:

1. Property owner does not need to be at home, nor be able to hear the alarm;
2. Property owner, or neighbours, are not disturbed or disrupted;
3. Avoids interaction of property owner with network operator or local authority – i.e. follows the 'flush and forget' principle of provision of wastewater services ;
4. Continuous level monitoring allows network operators to schedule and prioritise maintenance visits – directly reduces after hours and weekend callouts.

A primary shortcoming of conventional pressure sewer systems is the requirement for wastewater alarms on private property and the need for local authorities to interact with property owners in the event of an alarm. Property owner concerns around disruption from alarms can detract from the benefits of pressure sewer systems. Additionally, alarms due to network operation (closed valves, planned maintenance etc) can cause disruption to property owners. The ability to monitor alarms remotely and not have alarms disrupt property owners is a significant advantage to network operators, particularly in the context of planned network shutdowns.

3.2 HYDRAULIC FLOW CONTROL

The advent of smart pressure sewer introduces the ability to control each individual grinder pump operation. This in turn introduces the ability to control all aspects of hydraulic flows emanating from a smart pressure sewer network.

Onebox uses algorithms to control flow according to requirements. Operating regimes can be identified as primary or standard regimes such as peak shifting or system flushing, and specific regimes, such as operational events. Any operating regime can be called up by any duly authorised operator, and from any PC or internet connected mobile device, i.e. from within the field or from the office.

3.3 PEAK SHIFTING

All wastewater networks have some form of diurnal flow, with the peak flow greater than the average flow for that network. All assets, downstream trunk transfer capacity (pump stations, rising mains and storage) and wastewater treatment plants (inlet works and peak hydraulic capacity) must be sized to accommodate the peak flows from catchments. This can add significant cost to the provision of assets, especially trunk transfer assets such as rising mains, transfer mains and pump stations.

The Onebox system attenuates diurnal peak flows by controlling individual pump operation. Individual tank volume is utilised as operational storage. In theory, with the available technology and pump management algorithms, it is possible to reduce the peak flow to equal the average flow, i.e. a peaking factor = 1. However, with any application involving engineers and engineering, a safety factor is required. In practice, the Onebox system can reduce peak flow so that the peak flow is 1.5 times the average flow, i.e. Onebox achieves a peaking factor of 1.5.

Typical gravity networks have a peak flow of 6 or 7 times the average flow. This is without consideration of adverse inflow and infiltration which can lead to significantly greater peak flow out of gravity catchments. The ability of pressure sewer systems to exclude inflow and infiltration has previously been demonstrated[1]. Peak flows from conventional pressure sewer systems in sufficiently large catchments have been demonstrated to be 2.5 time the average flows[2], during normal operations.

Peak design flowrates for downstream infrastructure can then be based on 1.5 times the average flow with smart pressure sewer system. This allows for the construction of smaller downstream infrastructure, offering considerable cost savings, or alternatively allows a greater population to be serviced by the same sized infrastructure.

3.4 SYSTEM FLUSHING

Under certain sets of conditions, conventional pressure sewer systems can become susceptible to low wastewater velocities. This can lead to the retention of solids which contributes to potentially significant odour and corrosion issues. The circumstances that can lead to this are as follows:

1. Poor hydraulic design;
2. Networks designed for large final populations in relation to the initial or existing population, giving a lack of self-cleaning in the early stages of catchment build out; and
3. Variable population areas such as holiday / resort type / seaside communities.

It is noted that holiday type communities are often well suited to pressure sewer systems due to the low environmental impact of these systems, and that these types of communities often close to coastal or lake areas, or areas of outstanding natural beauty.

Due to smart pressure sewer's ability to control pump starts, an operating regime can be programmed to maximise the number of simultaneous pump starts to induce minimum flushing velocities. This serves to ensure solids self-cleansing velocities are achieved on a regular basis, and correspondingly reduce the risk and severity of odour and corrosion issues that may occur with conventional pressure sewer systems.

3.5 STORAGE MANAGEMENT

Using the integrated pump controls of smart pressure sewer, the on-property pressure sewer tanks can be used as operational storage. Because the system is smart, in that every tank level can be monitored independently, the risk of uncontrolled spilling is mitigated. This is achieved by pumps being allowed to pump out a portion of tank volume when they reach a critical level (i.e. 95% of storage). In the case of planned maintenance with closed network valves, operators can monitor individual tank levels and respond accordingly, i.e. with a vacuum loader to individual properties, or with by-pass pumping of reduced flows of only high level tanks pumping down.

Smart pressure sewer introduces the use of decentralised storage. Storage is installed when properties are constructed on each section in a development, meaning that total storage volume is increased within a catchment integral with increasing population in that catchment. This has advantages of future asset planning, being that separate storage tanks do not need to be constructed ahead of population growth, and the associated long term planning and capital planning processes are somewhat simplified. Additionally, the implications for capital expenditure and cash flow are significant. In the context of private land development, the developer does not face significant upfront capital cost, but can enjoy positive cash flow where expense for the wastewater equipment is primarily incurred at the time the sections are sold.

3.6 FAULT & MAINTENANCE MANAGEMENT

Smart pressure sewer offers benefits for both fault management and maintenance as described below.

3.6.1 FAULT MANAGEMENT

Operational benefits for fault management significant. As stated in 3.1 above, the customer interface is improved by removing the requirement for the customer to be involved in the fault process, and removing the requirement for the customer to interact with the network operator.

Significant cost savings and an improved level of service are achievable via the use of smart pressure sewer. Operators can monitor the level of wastewater in any unit with a fault and prioritise the urgency of attending that fault. This has been demonstrated to result in the majority of faults being programmed for attendance during the normal working week, avoiding after hours and weekend attendance where it is not required.

The data communications system allows the type of fault to be communicated. This means that service technicians or network operators can, in the majority of cases, diagnose the fault without attending site. This reduces costs incurred from double attendance of site, and also provides an increased level of service to customers who have operators enter their property once only to rectify a fault.

3.6.2 MAINTENANCE MANAGEMENT

The ability to control the pump operation of all pumps means that operators can shut down flow from particular streets of areas of networks without operating valves. At the same time, operators can observe storage levels and respond accordingly where required. This ability simplifies the implementation of any planned works either within the pressure sewer network, or in the downstream trunk network. A simple example is that for a confined space entry to any pump station, chamber or manhole in the downstream network can be facilitated with reduced flow into that asset by the network operator in the field, via any internet connected mobile device, without physically needing to drive around the network and manually close valves, including returning to open valves, or forgetting to open previously closed valves until a spill occurs, etc.

The identification of network faults can also be readily identified in the network. It is not uncommon for pressure sewer valves to inadvertently be left in the closed position. With conventional systems, individual pumps would alarm, requiring the home owner to phone in a fault. The calls are generally received by a call centre, who must then route notifications into a maintenance job management system, of which then network operator then needs to assess various faults to determine the wider picture within the network. This may take some time, especially if property owners are not home when the alarms first occur (i.e. during the day, when a valve was closed).

With the smart pressure sewer, a network operator can quickly assess the location and any pattern in multiple faults, via any mobile device or office based PC. This results in the much quicker identification and resolution of a network fault, and does not disturb customers.

4 IMPLICATIONS FOR ASSET MANAGEMENT

The implications of smart pressure sewer for asset management is described as follows.

4.1 HYDRAULIC CAPACITY

The 'peak shifting' function of the Onebox system has significant benefits for hydraulic capacity. Smart pressure sewer can achieve a peak flow of 1.5 times the average flow. This is compared with a peak flow (PF) of 2.5 times average flow for conventional pressure sewer in sufficiently large catchments. It should be noted that the smaller the catchment (lesser properties) the greater the peaking factor for conventional pressure sewer. Conventional pressure sewer catchments below approximately 500 properties will experience greater peaking factors than a PF of 2.5. This increases the benefits of peak shifting from smart pressure sewer is greater than the benefits described below.

The following example can be considered:

1,000 properties with an average daily loading rate of 660 l/property/day:

- Average flowrate Q_{ave} = 7.64 l/s
- Conventional pressure sewer, PF of 2.5, peak flowrate $Q_{max\ 2.5}$ = 19.1 l/s
- Smart pressure sewer, PF of 1.5, peak flowrate $Q_{max\ 1.5}$ = 12.7 l/s

To achieve the $Q_{max\ 2.5}$ = 19.1 l/s for conventional pressure sewer, smart pressure sewer can accommodate 1,666 properties, i.e. for $Q_{max\ 1.5}$ to equal $Q_{max\ 2.5}$, being 19.1 l/s, then smart pressure sewer requires 1,666 properties, or 66% more than conventional pressure sewer.

It is concluded that for existing trunk infrastructure, smart pressure sewer enables two thirds more properties to be serviced in relation to conventional pressure sewer. Correspondingly, new downstream infrastructure can be sized with a peak flow capacity 40% smaller than that required for conventional pressure sewer.

4.2 IMPACT OF GROWTH ON EXISTING INFRASTRUCTURE

Population growth provides economic benefits for the communities that growth occurs in, and is generally encouraged by local authorities. It is a common occurrence in New Zealand that provision of infrastructure inhibits population growth. This is currently a well canvased political topic in the Auckland region, however it is acknowledged that provision of infrastructure to enable growth is a fundamental issue facing asset planners and communities across New Zealand.

Unless capacity exists, growth cannot occur. The specific local body mechanisms for controlling this is generally to require new developments to demonstrate capacity exists, or apply the engineering test that the development "will not have an adverse impact on the performance of existing infrastructure". The investigation of this may be carried out by local authorities via the district planning and land zoning process. It is not uncommon for private land owners to investigate this in order to rezone land and enable developments to proceed on a commercial and planning consent basis.

Smart pressure sewer introduces the ability to control individual pump operation, and to utilise on property storage as decentralised storage within wastewater catchments. By utilising the two way data communications afforded by the 3G mobile network, it is now possible to control individual pump discharge, and development wide discharge based on pre-set conditions. This means that if the downstream network is under stress, then all flows can be held back within the on property tanks, until such time that the downstream network can accommodate additional flows.

The most common scenario in New Zealand is existing gravity networks that suffer rain derived inflow and infiltration and generally being at or under capacity in rain events. This may limit opportunities for residential development around the periphery or within the catchment itself. Flow from new developments can be managed

and reduced or withheld completely to ensure the new development does not adversely impact on the performance of the existing network.

Appropriate measurement points can be determined within the downstream network, such as pump station wetwell levels, pump operation (i.e. standby or assist pumps kicking in) or directly from flowmeters or WWTP inlet works. These control points can then be incorporated into a control algorithm to automatically reduce flows as required. As each tank level is independently monitored, the risk of spilling from individual tanks is mitigated. Control logic within the algorithms enables pumps to operate when tank levels reach 95% of storage.

By utilising the smart pressure sewer systems in this way developments can be allowed to proceed by local authorities without adversely impacting on the performance of existing networks. This ability applies to discrete greenfield developments, and to infill housing within existing catchments. The technology is now available in New Zealand and the cost and complexity to implement pump controls has been reduced to levels that enable adoption of smart pressure sewer in the wastewater servicing environment.

5 CONCLUSIONS

- Smart pressure sewer systems are now commercially available in New Zealand;
- The technological advances behind smart pressure sewer enable a paradigm shift in wastewater servicing;
- Remote alarm monitoring offers costs savings and increased levels of service, including removing customers from involvement in pump faults;
- Direct control of individual pump operation enables control of hydraulic flows including peak shifting, system flushing and the operational use of decentralised storage;
- The peak shifting ability reduces peak flowrates and enables 66% more properties to be serviced for a given downstream peak flow capacity;
- Features of smart pressure sewer can be applied to allow greenfield or infill development to discharge to existing wastewater networks without adversely affecting the performance of the existing network.

ACKNOWLEDGEMENTS

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