SMART CONTROL OF PRESSURE SEWER SYSTEMS IN CHRISTCHURCH

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INTRODUCTION

Christchurch City Council is rolling out the use of iota's OneBox control panel to remotely monitor and control individual pressure sewer system pumps, in greenfield areas and in areas where there are wastewater capacity constraints. This accommodates growth without further compromising a wastewater network which is already at capacity. The control panel smoothes out the diurnal flow profile from the catchment. Stormwater inflow can be identified by automatic analysis of monitoring data after every storm, and prompt follow up with property owners means that inflow from the catchment can be eliminated. Pumps can be prevented from pumping during a storm when the network is already at capacity. In combination, this means that the peak flows expected from the catchment are typically around twice the average dry weather flow, compared to five times average dry weather flow for a gravity system. This significantly reduces the cost of downstream wastewater infrastructure.

YEAR CASE STUDY WAS IMPLEMENTED

2015 – ongoing

CASE STUDY SUMMARY

Christchurch City Council was faced with needing to accommodate growth in areas with wastewater capacity constraints, but with limited financial resources. Many of the greenfield areas being developed were better suited to pressure sewer systems, due to poor ground conditions and high groundwater levels. The iota OneBox control panel for pressure sewer pumps offered the Council the ability to carefully manage flows into its wastewater network, and make significant capital cost savings. The Council made the decision that most greenfield areas would be developed as smart pressure sewer systems, and ultimately over 10,000 houses will be on this type of system.

The Council has already saved $8.5 million (NZ dollars) in capital expenditure through the implementation of smart pressure sewer systems to service greenfield areas, by avoiding or reducing the size of wastewater infrastructure due to much better control of wastewater flows. In addition, growth has been accommodated without exacerbating the risk of overflows to waterways. Monitoring and automated reporting of individual pumps means that inflow and infiltration can be addressed promptly with the property owner, avoiding the usual increase in inflow and infiltration over time, thus avoiding the need to oversize wastewater infrastructure.

CASE STUDY DETAIL

There is significant growth in Christchurch, with new greenfield areas of development in the north and southeast of the city. Christchurch's wastewater network has capacity constraints in some areas, with overflows from manholes and to streams and rivers during storm events, due to stormwater inflow and groundwater infiltration. The wastewater network was badly damaged by earthquakes in 2010 and 2011, resulting in a much leakier network, and average daily flows to the Christchurch wastewater treatment plant increased by around 40% depending on groundwater levels.

Peak flows during a storm have also increased, although this is more difficult to quantify as there are many overflows from the network. The wastewater network model for Christchurch shows that for a large storm (24 hour duration, 3 year Average Recurrence Interval), 36,370 m^3 of untreated wastewater discharges via constructed overflows to the stormwater system and discharging to the Avon and Heathcote Rivers. In addition, 41,800 m^3 of untreated wastewater discharges from 125 manholes across the city. This creates risks to both public health and the environment.

Christchurch City Council has a consent to discharge untreated wastewater from 22 constructed overflow points to the Avon and Heathcote Rivers, and the Avon/Heathcote Estuary. Due to the substantial increase in flows following the earthquakes, an interim discharge consent compliance strategy agreement is in place until September 2017, after which the Council either has to comply with its overflow consent or apply for a new consent.

Due to financial constraints, not all earthquake damage to the wastewater network was repaired by the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), which was an alliance between central government, Christchurch City Council, New Zealand Transport Agency and five contractors. There is also a significant amount of damage to private wastewater laterals which is expected to remain unrepaired. This means that the wastewater network is expected to be much leakier than it was pre-earthquake, with high levels of stormwater inflow and groundwater infiltration.

The Canterbury Regional Policy Statement and the Land Use Recovery Plan have both directed Council to accommodate growth in greenfield areas, as well as intensification within urban areas. An extra 23,700 houses are to be built in the Christchurch urban area by 2028.

If not well managed, increasing wastewater flows from this extensive development will make it even more difficult for the Council to achieve compliance with the overflow consent.

Christchurch was therefore faced with a significant challenge in providing economic and robust wastewater services to new developments, both greenfield and intensification. The challenges included the following issues:

- The need to accomodate growth without exacerbating overflows downstream.
- Poor ground conditions and high groundwater levels driving a preference for shallower infrastructure.
- Capacity constraints in local networks risking high cost and disruption to connect further downstream where greater spare capacity is available.
- Increasing stormwater inflow and groundwater infiltration as the infrastructure in wastewater catchments ages.
- Risk of slow development in greenfield areas, and the associated low flows below self cleansing velocity which results in increased sewage age, odour and corrosion risks.
- Tight financial budgets.

The approach taken by the Council to overcome these challenges was to adopt a telemetry based smart pressure sewer system to service new developments in greenfield areas and for infill in areas with wastewater capacity constraints (O'Brien & Lenihan, 2015). This approach has been well proven by South East Water in Melbourne, where a smart pressure sewer system services over 4,500 properties on the Mornington Peninsula as well as other areas of the city.

A pressure sewer network consists of an individual grinder pump and storage tank for each house. The storage tank is sized to contain 24 hours of average wastewater production from a house (597 L for Christchurch), to avoid overflows on private property in the event of a power outage. Normally pressure sewer pumps have a control panel which turns the pump on and off based on high and low level set points, and an audible and flashing light alarm. The property owner is required to call the Council in the event of an alarm and maintenance staff visit the property to resolve the problem.

In the case of a smart pressure sewer control system, the standard control panel is replaced with an iota OneBox control panel and the float switches in the tank are replaced with a level transducer. A SIM card in the control panel transmits level and pump data to a centralised SCADA system. Alarms are raised through the SCADA system are sent directly to the maintenance contractor, who can view the pump and recent data via a web portal. This allows the urgency of the job to be prioritised (e.g. if the level in the tank is low there is no need to rush to site) and sometimes avoids the need for a call out (e.g. if the alarm is for a power outage and the power recovers). It also avoids the need for the customer to contact the Council directly in the event of an alarm, and by proactively responding to alarms, provides a better customer experience overall.

The iota OneBox control system also allows much better management of wastewater flows. The four main automated modes for controlling pressure pumps which provide benefits to downstream infrastructure are:

- Peak shifting mode – This smoothes the diurnal flow profile by adjusting the pump cut in level at different times of the day to reduce the likelihood of pumping at peak times. This limits the diurnal peak flow to approximately 1.6 times average flow for a given catchment, which means that flow variation is minimised, and pipe sizes can be reduced. This also provides an opportunity to optimise downstream spare capacity knowing peak controlled flows.

- Power outage recovery mode – This provides a controlled recovery from a prolonged power outage with the tanks with the highest wastewater liquid level are given pumping priority, and the maximum number of pumps pumping is limited to a predetermined value based on the capacity downstream. This minimises the risk of overflows on property as well as reducing the overflow risk downstream.

- Storm mode – This allows flow from a pressure sewer catchment to be held back during a storm to free up capacity in the downstream reaches of the gravity network, reducing the risk of overflows. Pumps are inhibited (unless a high level is reached) until the storm passes or until a set period has passed (e.g. 12 hours). After a prolonged storm mode activation it is likely that there will be numerous installations with levels above the pump start level. The OneBox automatically reverts to Power Outage Recovery mode following prolonged storm mode to control flows.

- Flushing mode – This allows the scouring velocity to be achieved each day, by instructing pumps to pump in unison. This reduces the need for flushing the lines with tankers in developing catchments and in pipelines with only a few connections. This also avoids the need for twin pressure mains in developing catchments, such as those originally proposed in the master plan for the South East Halswell greenfield area (Jacobs, 2014), to allow for a staged increase in flow as the catchment develops. Once an operator activates flushing mode for a number of pumps they remain in flushing mode until de-activated through the portal by the operator.

In addition, any group of pumps can be prevented from pumping for a set period via the web portal, so that maintenance or new pipe connections can be made. While the system relies on SIM cards communicating with a central clearSCADA server, the local control panel also holds the most recent instructions sent to it. This means that if there is a communications failure, the pump continues to operate as previously instructed. For example if the pump is in flushing mode, it continues to pump at the same time each day, and if it is in storm mode the pump will continue to be inhibited until the set period of inhibition has passed. However, new instructions (e.g. to enter storm mode) would not be received by the pump and this may result in less than optimal operation of the network. However, it was felt that on balance the risks of communications failures were outweighed by the benefits provided by the smart pressure sewer system.

The monitoring of every pump in the network, and automatic monthly analysis and reporting of every storm identifies those pumps that pumped more frequently than usual during storms, and allows inflow and infiltration to be identified at an individual property level. Local rainfall data is captured within the telemetry system for automatic comparison with monitored pump run data.

A graph from the OneBox portal showing recent infiltration from a new house in the Upper Styx greenfield area is shown in Figure 1. Rainfall is shown in blue and pump run is shown in black from 2pm on 7/9/16 to midnight on 8/9/16. The graph shows the pump run frequency increased 10 fold following a large storm (from 500 L/day to 5,000 L/day), with pump runs persisting after the rainfall ceased. This indicates infiltration rather than inflow, which may be due to poor drainage workmanship. The property owner was visited by Council staff and asked to fix the fault.

Using this information to request property owners to fix faults means that inflow and infiltration are kept to very low levels in the long term, rather than the typical increase in leakiness that is seen as a network ages. This reduces the need for oversized wastewater network infrastructure.

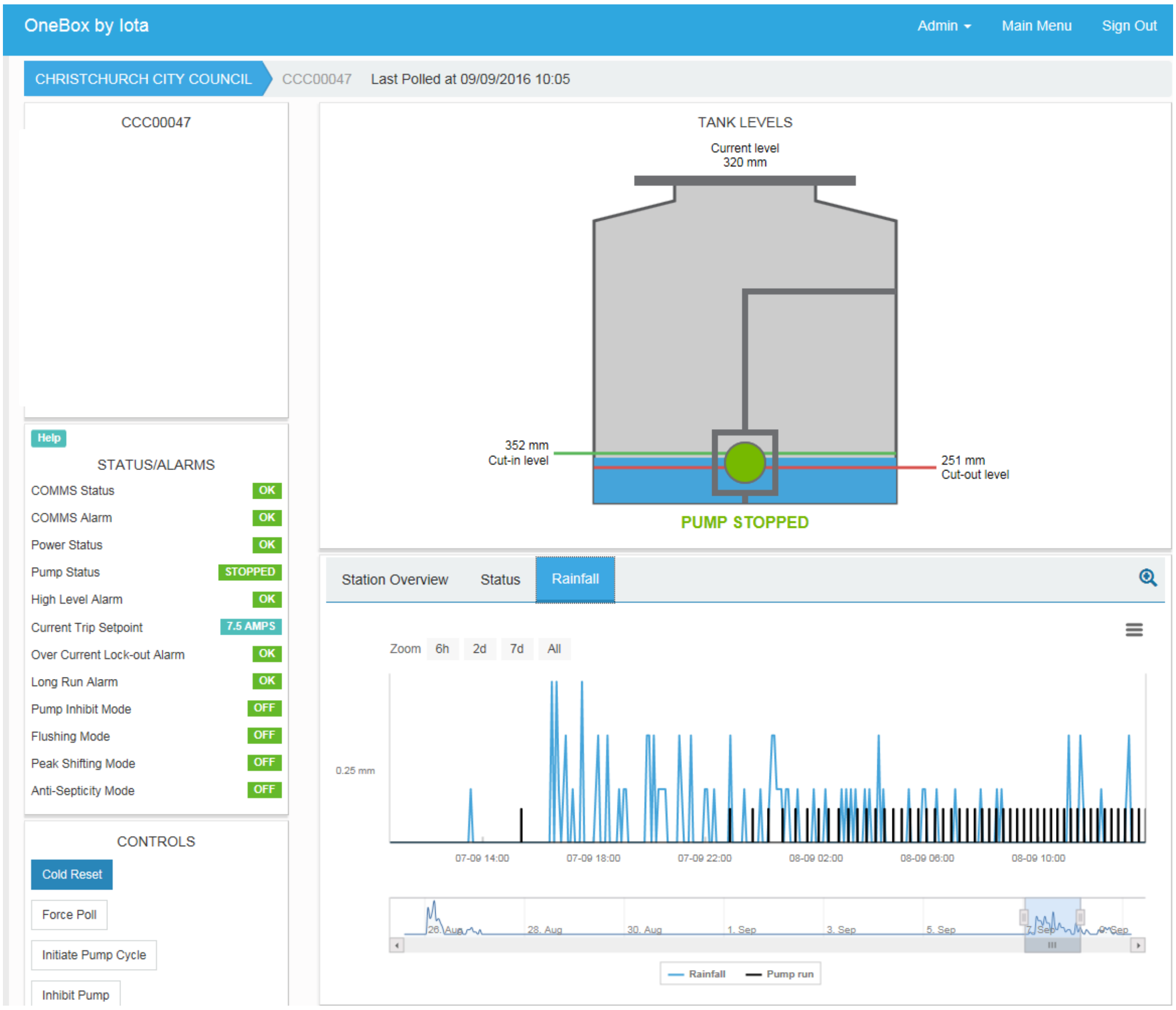

Figure 1 Screenshot from the iota web portal of a pump in a greenfield development area during a rain event

The design based on hydraulic modelling of the smart pressure sewer system has been completed for two major catchments (South East Halswell and Upper Styx) including over 6,000 installations when fully developed. The design adopts OneBox flow management capability based on field test data out of South East Water's network with up to 4,500 installations in place. At present there are 73 domestic and 19 commercial and industrial installations on the OneBox portal which cover a combination of infill and initial greenfield developments.

For the telemetry based smart network following a prolonged power outage the sites with the highest tank level are given priority to pump and the maximum number of pumps that can pump concurrently in a single catchment is controlled. This control mode operates with the OneBox automatically going into a Power Outage Recovery mode (POR) following a power outage greater than 1 hour. In Power Outage Recovery mode when power returns the OneBox selects a randomised start time depending on the tank level. At the OneBox generated start time the OneBox controller requests permission to pump from the clearSCADA server. The clearSCADA server keeps a count of all pumps pumping within a catchment and limits the number of pumps that can pump concurrently.

The peak flow from each catchment within the Christchurch City Council low pressure sewer network will occur following a prolonged power outage. The hydraulic model for the network was assessed for a power outage of 24 hours and determined the peak flow generated for the theoretical inflow of 597 L/property/day. The modelled network is optimised to be the minimum size network which has no overflow during the recovery from a 24 hour power outage. The peak flow is therefore limited by the capacity of the network and pumps which are remote from the network cannot get in due to high head and wait to try again after set delay period of 10 minutes.

Table 1 includes the modelled peak flows following 24 hour power outage with and without the control provided by a smart telemetry network, as well as peak storm flows if the catchment had been developed as a gravity network. The pressure sewer network peak flow is based on and the maximum number of pumps that can pump concurrently. The flow generated by concurrent pumping is estimated based on model output for an approved pump curve. The flow from each pump generally average between 0.5L/s and 0.6L/s depending on catchment characteristics. It can be seen that the flow from a smart pressure sewer network is significantly lower than a non-controlled pressure sewer system and a gravity system.

Table 1: Catchment Peak Flow Summary

Location	**Catchment Reference**	**Number of Lots**	**Peak Flow Gravity System (L/s)**	**Normal Power Outage Recovery Peak Flow (L/s)**	**Smart Network Power Outage Recovery Peak Flow (L/s)**	**Smart Network Maximum Number of Concurrent Pumps**
South East Halswell	SEH1	4,208	247	143	54	96
South East Halswell	SEH2	600		20	8.4	15
South West Halswell	SWH1	649	22	21	9.0	16
South West Halswell	SWH2	510	18	26	7.7	14
South West Halswell	SWH3	386	13	36	6.0	13
Upper Styx West	SXW1	1,189	41	34	16	27
Upper Styx East	SXE1	311	11	24	5.4	10
Highfield	HIG1	1,912	66	77	25	50

The model enables a sewage age assessment and odour prediction. Minimising pipe size (and hence retention time) in combination with a limited number of strategic air valves means that odour management is minimised. Appropriate odour management at these limited points avoids odour nuisance and reduces corrosion.

The Council's maintenance contractor uses the OneBox portal to review alarms in determining whether a site visit is necessary. Council staff review the monthly infiltration reports after rainfall events to identify sites with inflow and infiltration problems, and request property owners to fix faults accordingly. This has already been used to good effect to identify properties with earthquake damaged laterals and new house builds with poor drainage workmanship.

The reduced flows from a smart pressure sewer system result in significant cost savings by delaying or avoiding downstream infrastructure upgrades. Once it is fully rolled out, over 10,000 houses are expected to be on a smart pressure sewer network in Christchurch (see Figures 2 and 3 for a map).

The measurable impacts from the Christchurch roll out of the smart pressure sewer system are significant capital cost savings in servicing greenfield areas, due to the much lower design flows compared with a gravity or a regular pressure sewer system. For the Upper Styx greenfield area, this meant that the flow from the entire greenfield area could be accommodated within the surrounding gravity network, avoiding the need for a new pump station and pressure main, and saving over $1.5M (NZ dollars). For South East Halswell, the ability to flush the pipelines on a daily basis meant that twin pressure mains to allow for slow development of the area were not required, saving over $2M. For Highfield, the smart pressure sewer system is $1M less expensive than a standard pressure sewer system and nearly $5M less expensive than a gravity system (Jacobs, 2016).

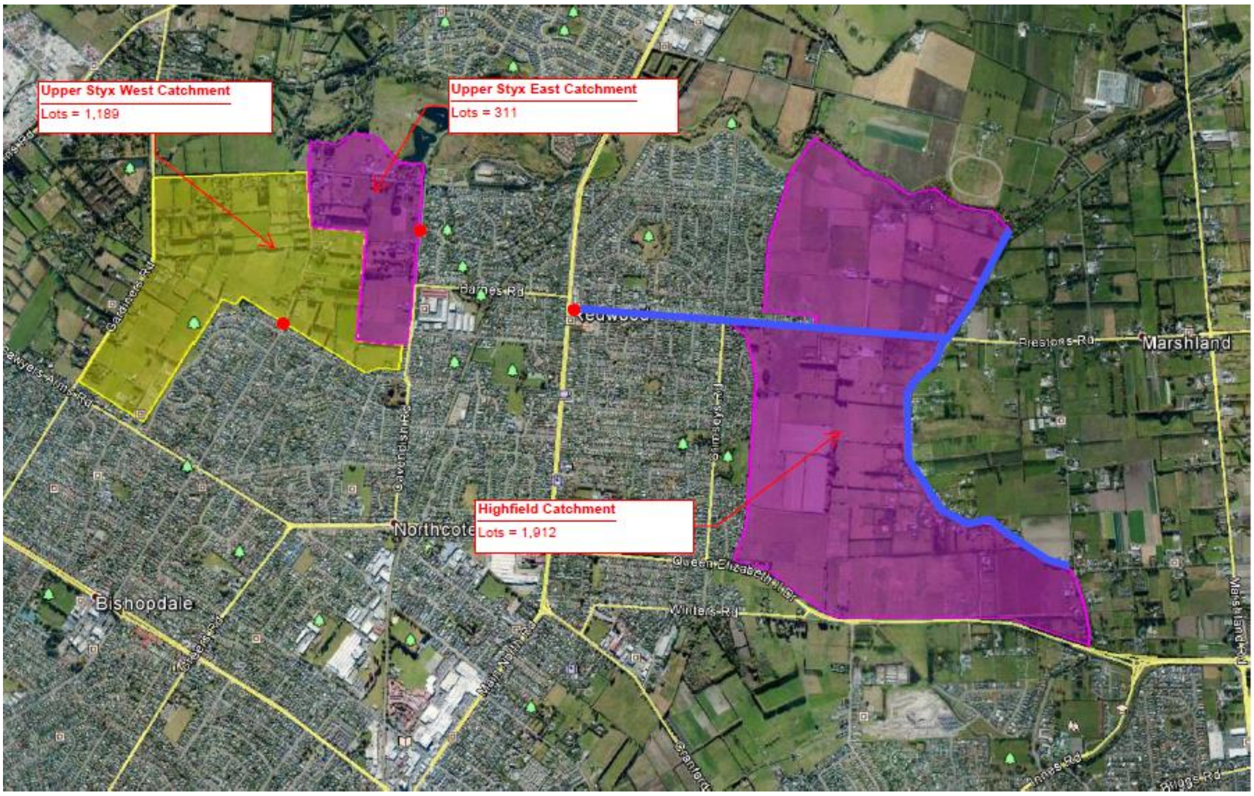

Figure 2 – Smart pressure sewer catchments in the north of Christchurch

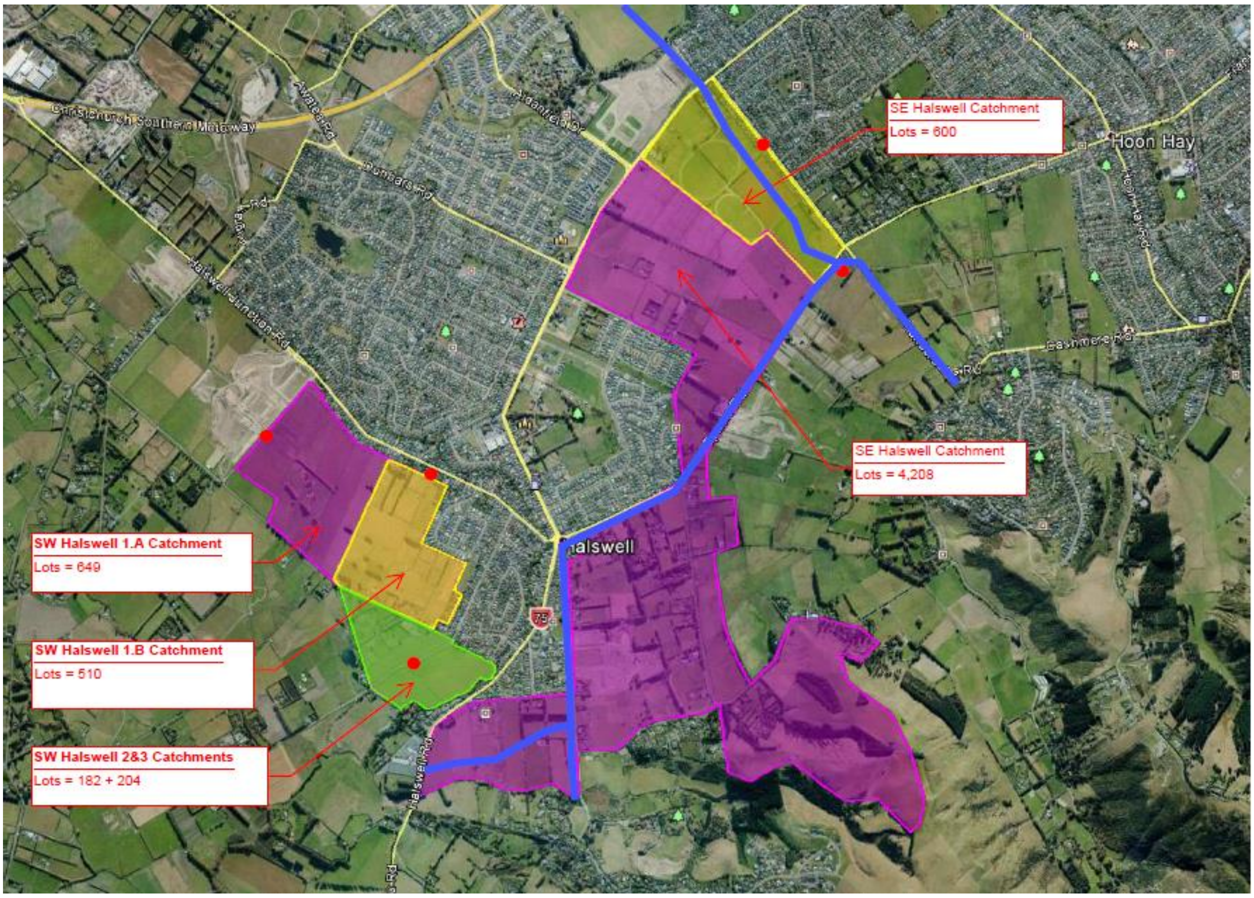

Figure 3 – Smart pressure sewer catchments in the south east of Christchurch

The ability to prevent the pumps from discharging during a storm when the wastewater network is at capacity, means that growth can be accommodated without exacerbating overflows, which is a significant win from a sustainability perspective.

The additional running cost associated with communications for a smart pressure sewer system is offset by the reduced capital cost with flow management, and the reduced operating cost with alarm detail and post alarm monitoring. Alarms are sent directly to maintenance contractor via email or SMS. The contractor has access to the OneBox portal to interrogate and understand the alarms with real time monitoring. This means the maintenance contractor can identify the issue and required response time. In many cases the maintenance contractor can avoid a site visit or delay a site visit thereby reducing costs.

The control of flows and alarms directly to operators with access to real time monitoring reduces overflow risk both on property and in the downstream network. The sustainable outcome of reducing overflow risk and a reduced cost is expected to improve in time with the introduction of lower cost communications through narrow band technology.

A key lesson learnt is the importance of detailed hydraulic modelling to optimise network sizing (i.e. sizing of pipes and downstream pump stations) based the available control modes. This ensures optimal cost savings and ease of operation.

Adopting hydraulic model design with full OneBox control provides Christchurch City Council with the knowledge to maximise opportunities for the best utilisation of their existing network saving significant capital expenditure, and the ability to provide wastewater services to accommodate growth without exacerbating overflows to the environment.

The key benefits for the Council in using pressure sewer networks with iota OneBox control panels are:

- Reduced risk of overflows in the downstream network as a result of these developments
- Maximising the use of the existing gravity network, in some cases avoiding the need for new pump stations and pressure mains, with significant capital cost savings
- Reduced pipe sizes, resulting in decreased capital costs
- No need for twin pressure mains to allow for gradually increasing flows in developing catchments, saving approximately 25% in capital costs
- Automated reporting to identify properties with inflow and infiltration issues every month, meaning that inflow can be addressed promptly with the property owner, avoiding the usual increase in inflow and infiltration over time
- Specific alarms to the maintenance contractor, and the ability for them to use a web portal to view individual pressure pumps
- Better customer experience, as the maintenance contractor can receive and respond to the alarm before the customer is aware of the problem.

References

Jacobs SKM (2014). South East Halswell Wastewater Strategy Development, report prepared for Christchurch City Council.

Jacobs (2016). Highfield Development Area Wastewater Master Plan Development, report prepared for Christchurch City Council.

O'Brien, B. and Lenihan, V. (2015). Better Management of Wastewater Netwokr by Remotely Controlling Pressure Sewer System Pumps. Proceedings Water NZ Conference, Hamilton, New Zealand, 16-18 September 2015.