BORING INJECTION INNOCULATES AGAINST EXPENSIVE UPGRADES

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ABSTRACT

Queenstown Lakes District Council's (QLDC) water supply systems include 17 reservoirs with associated rising and falling mains. Although this technology is well established and robust it is an expensive way to address the needs of an ever-growing community and associated peak water demand.

Water modelling has been used to demonstrate the effectiveness of direct injection as a means to address peak water demand.

Over the last four years QLDC has undertaken thirty to forty exploratory bores and constructed eight production bores. This was in order to either improve existing bore fields, or to provide an entirely new water source.

The overriding principle has been to optimise or re-utilise existing assets rather than expenditure on new and relatively expensive capital upgrades. Wherever possible the opportunity to improve redundancy and resilience has been pursued.

This paper will describe the voyage of discovery - the highs (the excitement of drill rig operators) and the lows (silt, silt and eggy smelling water). It will describe modelling outcomes and present the various solutions now being considered for a number of unique situations in the QLDC area.

KEYWORDS

Direct Injection, Bore Field, DWSNZ, Security, Optimise, Redundancy, Resilience, Water Supply Modelling, Long Term Plan.

1 INTRODUCTION

Queenstown Lakes District Council (QLDC) water supply systems include 17 reservoirs with associated rising and falling mains. Although this technology is well established and robust it is an expensive way to address the needs of an ever-growing community and associated peak water demand.

The QLDC area is a destination for both winter and summer tourism. The area also contains a significant number of holiday homes. Consequently water demand is driven by both winter and summer peak populations. The demand in summer is further exacerbated by the desire for domestic and lifestyle irrigation.

The peak instantaneous demand occurs on a limited number of hours on a number of days. Upgrading existing reservoirs and falling mains to address peak instantaneous demand is relatively expensive with the benefits only being realised for a few hours per annum.

QLDC's Long Term Council Community Plan (LTCCP) contained $20-30M of water supply upgrade projects. A number of these projects had stalled due to financial implications and doubt over their appropriateness. In May 2010 an internal review of these stalled projects was undertaken. The review agreed that there was a need to investigate alternative water sources, reticulation, reservoirs and treatment facilities.

QLDC has been investigating the use of Direct Injection (DI) to address peak demand and general supply of potable water. DI is the pumping of water direct into the reticulation system rather than by gravity from a reservoir. DI can be associated with increased electricity consumption to maintain Level of Service (LOS) pressures. The flip side to this is that additional pumping (and electricity consumption) can be used to address peak demand rather than capital upgrades.

DI relies on the injected water being treated to a sufficient standard as described in the Drinking Water Standards for New Zealand (DWSNZ). QLDC has the distinct and enviable advantage of having a ready supply of surface fresh water from lakes and rivers. QLDC has five raw water intakes that provide the vast majority of potable water. In general the raw water is of a very high standard, however it is easily affected by storm events giving rise to elevated turbidity and issues with compliance with DWSNZ.

Bore water is naturally filtered and offers a more secure supply compared to a raw water intake. Bores located within 100 m of a body of water are normally considered as surface water in terms of water take. It follows that successful bores within 100m of a body of water could offer consistent water quality, increased security and compliance with DWSNZ without necessarily a reduction in the gross consented water take.

Bores are relatively cheap to construct compared to raw water lake intakes. However in some areas the use of bores had been discounted due to an assumed local geology primarily of compacted alluvial till. In addition QLDC's five existing bore fields were of varying suitability. The general assumption was that bores were unlikely to be successful. This assumption had not been challenged previously, therefore QLDC started a district-wide investigation into locating suitable bore fields in conjunction with investigating DI as a means to addressing sustainable and compliant water supplies district-wide.

2 THE BORING TRUTH

Over the last four years, QLDC has undertaken 30-40 exploratory bores and constructed eight production bores either to improve existing bore fields, or to provide an entirely new water source. The bores needed to have good extraction rates and to meet the highest levels of security (in respect to the DWSNZ) wherever possible.

2.1 CONSENT ISSUES - WHY WITHIN 100 M OF SURFACE WATER?

The QLDC area has not only the advantage of a ready supply of surface fresh water from lakes and rivers, but also a number of semi confined aquifers suitable for potable water. The problem is that water extraction from these aquifers is managed and restricted for good reason. The aquifers need to service all users at a sustainable level to avoid depletion. This presents a significant long term risk for maintaining and/or increasing the overall yield and extraction rates for bores servicing an increasing population.

Bore water extracted within 100 m of a body of water is normally considered as surface water in terms of water take. The water extraction is still managed and consents are required however the base permitted yield is usually reasonably generous. To support increased yield and higher extraction rates, the aquifer can be assessed to demonstrate hydraulic connection with the adjacent surface water and correspondingly a lesser influence on adjacent aquifers.

However, this does conflict with the principles of a secure water source as defined in the DWSNZ and is discussed further below.

2.2 BORE SPECIFICATIONS – A PRAGMATIC APPROACH

The existing QLDC bores were relatively small in diameter and ranged between 10 m to 20 m in depth. Most of these bores had capacity or quality issues relating to depth and/or diameter.

The new bores needed to deliver instantaneous peak demand and firefighting rather than a sustained lower yield. Typically, extraction rates need to be in the order of 15 l/s to 80 l/s per bore depending on the size of community being serviced and the bore configuration. Early experience determined that 300 mm diameter casings and 6 m high screens were the minimum requirement. All recent bores have been constructed to this specification which also allows a considerable amount of common componentry.

A variety of pump sizes can fit into a 300 mm casing and still provide sufficient pump cooling. In contrast 150 mm casings limit the size of pumps to about 15 l/s. Screens come in 3 m lengths and there is little or no cost saving to having a part length, hence 6 m being set as the minimum requirement.

The DWSNZ considers the depth of bores in assessment of water security. Bores are considered less secure when less than 30 m deep. Ultimately, the depth of the bore is determined by the depth of suitable aquifers that can supply the desired yield. However, the drawback with having excessively deep bores is the extra cost of construction. For these reasons, the aim was to find suitable aquifers that could supply the desired yield at depths between 30 m to 50 m.

2.3 SEEK AND YOU SHALL FIND – COST EFFECTIVELY

Early experience determined that 75 mm Aircore bores offer a cost effective alternative to conventional steel casing constructed bores. The 75 mm Aircore bore is capable of providing a detailed bore log and a basic water sample although turbidity is compromised. The hole self-collapses once the rig is removed but a piezo tube can be left in the hole for future monitoring. Depending on the depth and material found, it is practical to expect that up to five Aircore bores can be completed per day.

3 DWSNZ ASSESSMENT – CONNECTION TO SURFACE WATER?

There is a conflict between having a bore field conveniently beside surface water and how the water security could be assessed. Demonstrating that the aquifer is connected to the surface water may avoid constraining restrictions on water take but could mean the bore water is assessed as surface water from a security perspective. A process ensuring the bores are in excess of 30 m deep has been adopted to mitigate any detrimental assessment.

Trying to demonstrate the bore water is secure could be a 3-5 year process of testing revolving round chapter 4.5 of the DWSNZ, specifically *Criterion 1 – Demonstration 2 (composition)* and *Criterion 3 – E-coli monitoring* with no particular guarantee of success regarding chemical composition.

In terms of protozoal compliance, with reference to Table 5.1 of the DWSNZ, QLDC understands that the bore water will be defined as drawing from an unconfined aquifer and will require between 2 to 5 treatment log credits. If treatment in excess of 3 log credits is required (i.e. UV alone is insufficient), additional treatment mechanisms are required and options include: coagulation and membrane filtration, coagulation and rapid granular filtration, filtration without coagulation and disinfection only (such as ozone). This outcome is considered unlikely for Hawea, and is also considered too expensive for practical consideration. Given that the bore water is of high quality with turbidity well below 1.0 NTU and never above 2.0 NTU, it is considered that with Ultra Violet (UV) disinfection the treatment log credits will be met.

If the treated bore water is protozoal compliant then it is also deemed bacterial compliant. Depending on the community's requirements, chlorine can be dosed post UV treatment to meet distribution requirements of the DWSNZ. There is no requirement for chlorine contact time within a reservoir as the water is already sufficiently sterilised post UV treatment. This allows the treated bore water to be direct injected into the distribution system.

4 MODELLING DIRECT INJECTION

Water modelling has been used to demonstrate the effectiveness of direct injection to address peak demand. Direct injection is sometimes a simple, yet controlled, controlled bypass between rising and falling mains, but in other circumstances relies on an entirely new water source.

The overriding principle has been to optimise or re-utilise existing assets. Wherever possible, the opportunity to improve redundancy and resilience has been pursued. Some modelling briefs relied on a thorough knowledge of existing assets and how their use could be improved, while other briefs only became clear once a suitable bore field had been located and operational scenarios identified.

Where new bore fields have been included in an existing model, this allows a number of new scenarios to be considered in terms of redundancy and resilience. This may then lead to an exponential number of sub-scenarios, therefore direction to the modellers needs to be quite specific.

5 CASE STUDIES

The following case studies present unique situations and a variety of solutions, but all have the common thread of involving a bore field coupled with direct injection.

5.1 HAWEA WATER SUPPLY AND TREATMENT UPGRADES

In 2009 concept design reports for Hawea water supply upgrades had identified costs in the order of $5.5M for a new raw water intake, rising and falling mains, an additional reservoir and reticulation upgrades. The drivers for the upgrades were water quality, capacity and firefighting/LOS pressures. Hawea has approximately 700 residential sections, with potentially another 4-800 sections yet to be developed. The scale and financial implications of the proposed upgrades were inappropriate for a community of this size and the project had effectively stalled.

As an alternative approach, three potential bore field sites were identified due to their proximity to existing reticulation and the lake, QLDC land owner ship and likelihood of finding a suitable aquifer. The first Hawea exploratory bore was constructed at Scott's Beach as it was the preferred site being situated adjacent to the middle of the township and central to the water reticulation network. On achieving a depth of around 30 m, the mood of the drill rig operators became uncharacteristically buoyant; the reason became apparent on closer inspection of the bore log. Although relatively unexpected, the bore log was considered very good. The initial water samples were also good and investigations progressed directly to construction of the first 300 mm bore at Scott's Beach. The other sites were not investigated further.

Table 1: Hawea Typical Bore log and Water Quality Results

BORE LOG:		WATER QUALITY:	
0.00 – 0.20	Top Soil	Turbidity (NTU)	0.16 to 0.17
0.20 – 3.00	Gravels	UV % Transmittance	96.9 to 99.0
3.00 – 15.00	Clay bound gravels	E.coli	< 1
15.00 – 26.00	Damp clay bound gravels	Total Arsenic	< 0.0011
26.00 – 42.00	Wet gravel	Total Nitrate	0.15
42.00 – 48.00	Sandy wet gravels	Phosphate	< 0.2
48.00 – 51.00	Very sandy gravels	Sulphate	3.7

Bore logs indicated the presence of open gravels that had the potential to supply sufficient quantities of water. Step testing of the bores confirmed the high conductance of these layers and high yields. A longer term pumping test was undertaken and data modelled. The model indicated that a large proportion of flow to the wells was sourced from the adjacent lake.

Based on the water quality results, it is considered that Ultra Violet (UV) disinfection will provide sufficient treatment log credits for bacterial and protozoal compliance.

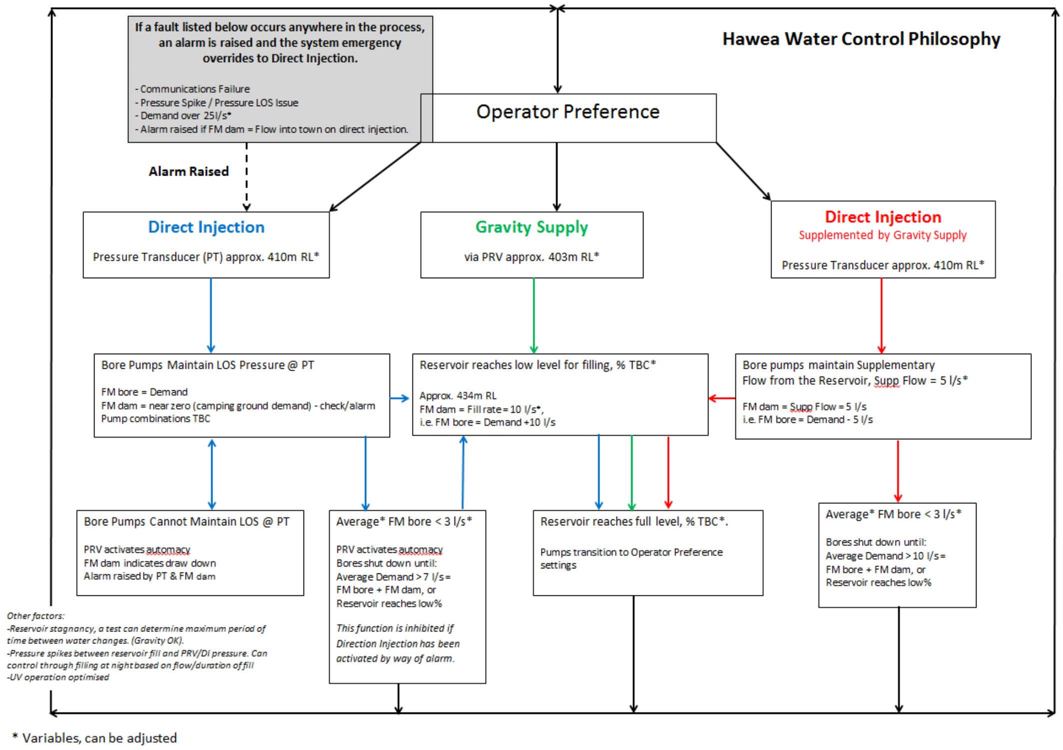
The introduction of a centralised bore field presented a number benefits: a short rising main to the centre of the existing reticulation would be very efficient and reticulation upgrades would be minimised. In addition, the pressure could be dropped to 5-600k Pa rather than 8-900k Pa from the existing reservoir. However, a decision had to be made on whether to retain or decommission the existing reservoir. Although too small to support further development, the existing reservoir could provide a level of redundancy and continue to service a small number of properties on the far side of the Hawea dam. Problems with retaining the reservoir included preventing stagnation without chlorination, increasing reticulation pressure to fill the reservoir, and the long and small diameter reticulation between the bore field and the reservoir. The detailed design retains the reservoir but includes a pressure reducing valve (PRV) in the original rising/falling main. The bore field can operate in three distinct modes:

1. DI above the PRV pressure setting so that the reservoir is effectively isolated. If the reservoir or connecting pipework fails, is not renewed or becomes redundant, then the water supply could be run permanently in this mode.

2. Conventional filling and draining of the reservoir. Although fill rates are limited to about 15 l/s this mode can currently service the township in excess of 50 per cent of the time and is particularly useful for low flow situations, e.g. winter night flows.

3. Combination where the reservoir supplements the bore field and is either filling or draining at about 5l/s. This mode will currently operate for approximately 30 per cent of the time but this will increase with population and consequential water demand. Like option1, this mode allows longer or continuous run times for both the UV reactors and pumps.

Figure 1: Hawea Bore Field Control Philosophy



These modes are automatically selected by the Process Logic Controller (PLC) based on demand and/or servicing requirements, or can be selected manually by the operator.

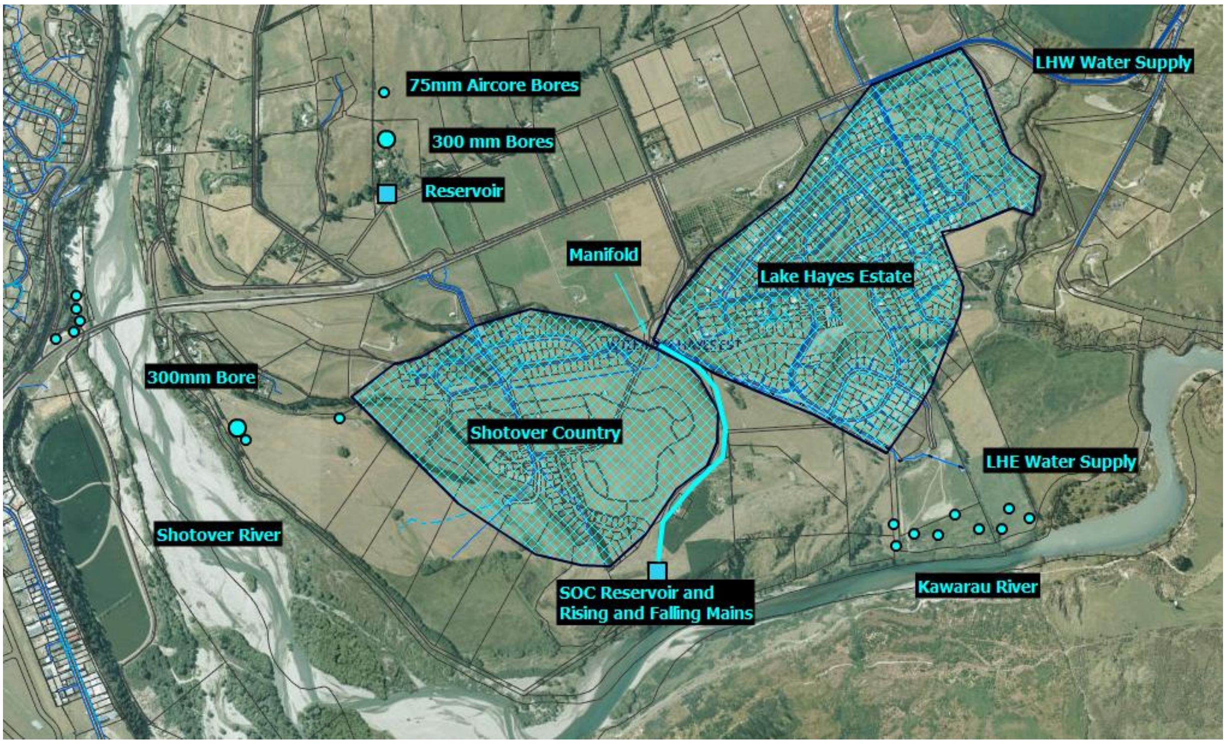
Through water modelling, it was confirmed that four bores with a selection of pump sizes would give the bore field the flexibility to supply between 2 l/s and 85 l/s. Redundancy is provided through duplication of the two mid-range pumps and secondarily by the reservoir. The 300mm bores allow the pumps to be easily upgraded in the future, which based on projected growth should be around 2033.

The Hawea water supply upgrades are currently under construction and are due for commissioning in October 2015. The expected total cost of delivery, inclusive of investigation, modelling, design, MSQA and physical works, will be $1.4M. This represents a $4.1M (or 75%) saving over the conventional reservoir-based concept design estimated at $5.5M.

5.2 LAKE HAYES ESTATE WATER SUPPLY AND TREATMENT UPGRADES

Lake Hayes Estate (LHE) contains 600 to 650 residential lots with demand to further sub-divide adjacent land. LHE had two water supplies that were struggling to address peak demand. The main supply is from the neighbouring Lake Hayes Water (LHW) scheme which is connected to LHE via a single PRV. The LHW scheme is heavily constrained due to the demand from LHE and unfortunately requires ph correction with lime, which attracts some community concern. The second and much smaller supply is the LHE scheme that was originally designed for 50 lots. Irrigation restrictions have been in place for a number of years, however demand has continued to increase due to ongoing building and population growth. The main drivers for upgrades are capacity, firefighting/LOS pressures and community quality concerns.

Figure 2: Lake Hayes Estate (LHE) and Shotover Country (SOC) General Arrangement



The largest adjacent sub-division is Shotover Country (SOC) with a similar number of lots, 600 to 650. The existing supplies for LHE are not capable of supplying SOC as well, therefore a new water supply was required to hopefully provide for both SOC and LHE. Approximately nine Aircore bores were used in paddocks beside the Kawarau River. The majority found unsuitable silts but a potential aquifer was identified eventually. Initial water quality results suggested levels of arsenic above that permitted for potable water. At this stage no other alternative had been identified so a 150 mm bore was constructed for prolonged pumping and water quality testing. The drillers reported eggy smelling waters and testing confirmed that arsenic levels increased with prolonged pumping. This bore and aquifer were consequently abandoned. Fortunately another series of nine Aircore bores identified a very promising aquifer beside the Shotover River; the drill rig operators were very excited and the SOC developer constructed a 300 mm bore without any further delay.

Table 2: Shotover Country Typical Bore log and Water Quality Results

BORE LOG:		WATER QUALITY:	
0.00 – 0.50	Top Soil	Turbidity (NTU)	0.10
0.50 – 34.00	Sandy silty gravel	UV % Transmittance	TBA
34.00 – 35.50	Very silty gravel	E.coli	< 1
35.50 – 40.40	Sandy silty gravel	Total Arsenic	0.0014

Based on the water quality results, it is considered that Ultra Violet (UV) disinfection will provide sufficient treatment log credits for bacterial and protozoal compliance.

The SOC water supply consists of conventional rising and falling mains and a reservoir. The concept was that QLDC would construct a second reservoir in the future to accommodate a fully developed SOC and LHE.

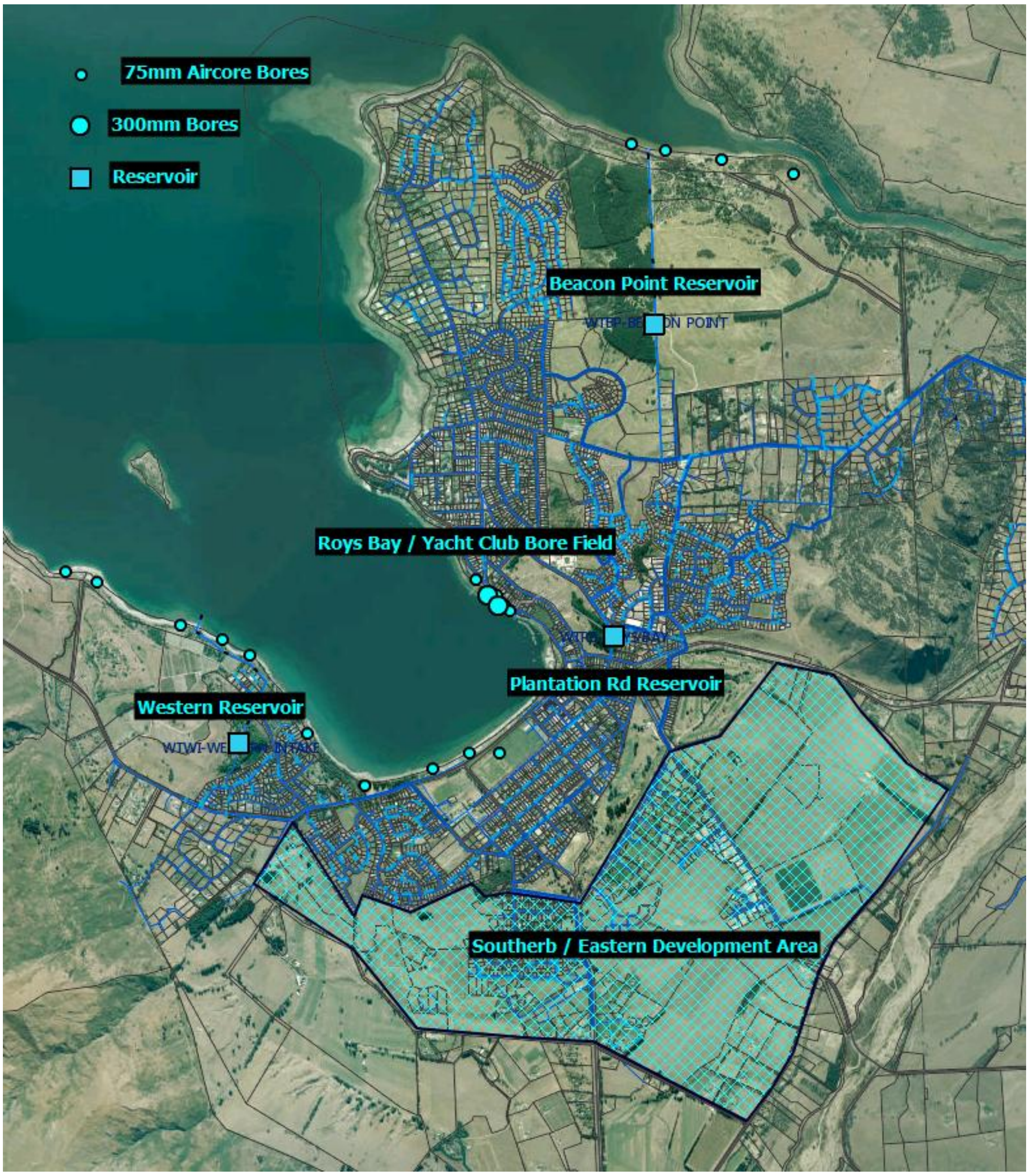
However, on closer inspection, modelling indicated that the SOC falling main would not be able to service both SOC and LHE. An additional falling main would be required as well as a second reservoir at an estimated combined cost of $1.2M. Alternatively, modelling was used to confirm that a PRV bypass between the rising and falling mains could address peak instantaneous flows for both SOC and LHE when fully developed. The constraining factor is friction losses in the single falling main. When demand is high, the losses increase and the PRV will activate. Activation of the PRV overrides the reservoir level control and the bore pumps can DI into the central manifold between SOC and LHE. The bypass has an estimated construction cost of $65K. This represents a saving in excess of $1M (or 95%) compared to constructing a conventional reservoir and falling main.

The SOC bore field has also been identified as the preferred water supply for the Frankton Flats development area. At the time of writing, modelling has not been completed but it is expected that the bore field combined with DI will have a significant influence over the strategy for water supply to the greater Queenstown area.

5.3 WANAKA WATER SUPPLY WATER SUPPLY AND TREATMENT UPGRADES

Wanaka has two separate raw water intakes and reservoirs known as Western and Beacon Point. There was a third intake known as Roys Bay which has recently been decommissioned. The Roys Bay rising main is intact but redundant, whereas the associated Plantation Road reservoir is now supplied from the higher Beacon Point reservoir.

Figure 3: Wanaka Water Source and Reservoir General Arrangement



Wanaka is subject to ongoing sub-division and increasing demand for water. QLDC's Long Term Plan (LTP) contemplates a new reservoir known as the Hawthenden Reservoir. The main driver for the Hawthenden Reservoir project was to address development-driven water demand in Wanaka's southern and eastern environs. The Beacon Point Reservoir is remote from these areas and is already subject to demand issues. Western Reservoir is too low to service these areas by gravity alone. The recent decommissioning of the Roys Bay intake has added demand on the Beacon Point Reservoir and reduced redundancy throughout the network. The Hawthenden Reservoir site is against the hillside to the south of Wanaka and quite remote from existing infrastructure. Being remote, the cost of delivery is considerable and has been estimated at $15M for the LTP.

Wanaka also has an issue with algae in the lake water. Although harmless, the algae increases maintenance costs (the fowling of screens and filters) and potentially will have an effect on proposed UV upgrades. Locating potential bore fields was identified as a relatively simple and cost effective means to address both increasing demand and water quality.

Following successful exploratory bores at Lake Hawea, four 75 mm Aircore bores were completed around the shores of Lake Wanaka in May 2011. These bores were located adjacent to existing raw water intakes at Western, Roys Bay and Beacon Point. Having arrived in clean overalls, the drill rig operators finished the first day covered in blue silts, which was not a good sign. The bores indicated consistent underlying saturated silts to a depth of at least 50 m that are not suitable for bore water extraction. The following day, the Roys Bay bore, which was located in the Wanaka Yacht Club car park, indicated suitable gravels for bore water extraction.

Another nine Air-core bores were completed in October 2011. Eight of these bores were located between the previous set and confirmed the consistency of the underlying silts. The ninth bore was located in the yacht club peninsula and indicated suitable gravels for bore water extraction. A further five bores were completed in March 2012, two of these bores indicated that Waterfall Creek did not have an associated fan of gravel deposits to any suitable depth and was an unsuitable area for bore water extraction. The other three bores were located at the Wanaka Yacht Club car park and further defined the extent of suitable gravels. The aquifer is localised around the yacht club and is more than 20 m deep, but unfortunately less than 30 m deep.

Two 300 mm bores were constructed adjacent to the yacht club. The first was constructed and tested in April 2012. Modelling of the aquifer was undertaken by Aqualinc. The conclusion was that the aquifer was not hydraulically connected to the lake by any significant degree, but instead either an isolated aquifer or indirectly connected to the Cardrona aquifer. The apparent hydraulic disconnection to the lake adjacent to the bore was a surprise, but may be explained by the fine 'glacial flour' suspended in the lake settling on the lake floor. This sediment could effectively seal the lakebed. The second bore was constructed in June 2012. A number of tests were conducted including simulation of the second bore providing passive injection into the aquifer from the lake. The conclusion was that passive injection into the aquifer from the lake was feasible albeit with a number of risks that require further assessment.

Table 3: Wanaka Yacht Club Typical Bore log and Water Quality Results

BORE LOG:		WATER QUALITY:	
0.00 – 3.10	Silty Gravels	Turbidity (NTU)	0.29
3.10 – 10.80	Silt	UV % Transmittance	99.8
10.80 – 21.40	Silty Gravels	E.coli	< 1
21.40 – 21.55	Silt	Nitrate	0.92

Although the bores are less than 30 m deep, it is considered that Ultra Violet (UV) disinfection will provide sufficient treatment log credits for bacterial and protozoal compliance based on the water quality results.

The bore field is ideally located to reutilise the redundant Roys Bay Rising main. It is QLDC's intention to initially develop the bore field without creating a connection to the lake, i.e. no passive injection. The initial, Stage 1, development of the bore field will see UV treated bore water direct injected via the existing rising main into central Wanaka's upper pressure zone. Modelling suggests that this will maintain LOS pressures during peak day demand and will assist with deferring the large LTP projects associated with southern Wanaka. Stage 1 will also allow full assessment of the aquifer's recharge rate and sustainable yield.

Water modelling has also shown that the bore field could affect a 90 per cent maximum reduction of raw water intake per annum, and correspondingly reduce algae ingestion by a similar amount. The actual effectiveness of the bore field in this regard will be dependent on the aquifer's recharge rate and sustainable yield. Stage 2 development of the bore field could see connection to the lake by passive injection bore if deemed justifiable.

The Wanaka Yacht Club bore field and treatment plant is due for construction during the 2015/16 financial year. In addition to the two 300 mm bores already constructed, it has been estimated to cost $350K to complete and deliver Stage 1.

6 CONCLUSION

Although the QLDC situation is not unique, there will only be a limited number of communities where the coupling of bores and direct injection is possible or appropriate. Potentially some communities may be able to use other forms of water treatment to allow strategic direct injection into their distribution networks to defer or remove the need for expensive reservoir-based upgrades.

However, for the QLDC area it has been demonstrated via modelling that direct injection, in its various forms, can play a significant role in deferring, or replacing, conventional reservoir-based upgrades at a fraction of the cost. Investigation and construction is ongoing and results from both will undoubtedly influence QLDC's water supply strategy district wide. Correspondingly the extents of operational and financial benefits have yet to be fully understood.

Aircore bores have been used extensively and cost effectively to locate and develop bore field sites. Just as importantly they have been used to rule out areas that would otherwise continue to be considered a possible bore field site. There are still some areas within QLDC that have yet to be explored and undoubtedly Aircore bores will be used at existing bore fields in Luggate and Arrowtown to identify the best location for ideally deeper, more secure and higher yielding replacement bores. Aircore bores have already been used in Arthurs Point with great success to identify the best location for new bores to replace the original and surprisingly shallow bores.

Although the QLDC area has abundant fresh surface water of a very high standard, there are still issues with complying with the DWSNZ. Bore fields can offer a cost effective alternative to raw water intakes and address both capacity and quality issues. Another benefit of adding bore fields to an existing scheme is the de-centralisation of supply and corresponding increase in redundancy and resilience.

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