Effective human wastewater management in rapidly growing towns in sensitive receiving environment- A perspective on Queenstown-Lakes District Area

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ABSTRACT
Queenstown-Lakes District is one of the fastest growing districts in New Zealand. It has some of the most pristine alpine lakes and rivers. With its ever increasing resident and tourist population coupled with its sensitive receiving environment, human wastewater discharge has to be managed carefully. While the district has three major human wastewater treatment facilities which cover much of the district, in excess of 28% of the dwellings' discharges are via septic tanks and developer catered treatment systems. Townships such as Kingston, Glenorchy and Cardrona are in need of wastewater reticulation to avoid any short and long-term water contamination issues and any new septic tank discharge restrictions arising from the Otago Regional Council (ORC) plan changes. The paper discusses in detail population dynamics, human wastewater issues and approaches to manage wastewater effectively.

Keywords: Human wastewater, sensitive receiving environment, QLDC, rapidly growing towns, septic tanks, reticulation, land treatment systems

INTRODUCTION
Towns and cities grow for a range of reasons. Lifestyle, employment opportunities, infrastructure, and education are some of the key drivers. Apart from resident population growth and people relocating from other regions, there may be also immigrant influx. When population growth outpaces the infrastructure development, there is increased pressure on the territorial authorities and government agencies to provide for necessary infrastructure. The problem is further accentuated when there is also increasing temporary visitors or tourists to the already growing towns or cities. Queenstown-Lakes District population dynamics is a mixture of increasing resident and visitor population at a very rapid pace.

One of the main reasons for increasing tourists visit to the Queenstown-Lakes district is its spectacular scenic settings with pristine waterbodies and the tranquil resort environment. Ironically, increasing visitor or resident population means increasing human wastewater discharges, both point and non-point sources. In the absence of a clear national or regional human wastewater discharge requirements, the very pristine water quality may be at risk which in turn could affect Queenstown-Lakes district's image as a tourist destination.

Unlike many other international tourist destinations, Queenstown-Lakes District does have a range of tourist towns such as Wanaka, Glenorchy, Arrowtown and Cardrona, rather than the main destination being Queenstown. Equally, there is a range of choice of towns or places (e.g. Wanaka, Arrowtown, Glenorchy, Kingston, Cardrona, Luggate, Hawea) to settle for lifestyle purposes either as permanent or temporary (second homes) residents. Therefore the population and the consequent human wastewater pressure is not just unique to the main centre such as Queenstown, rendering it a wider district issue for the Queenstown-Lakes District Council (QLDC).

This paper intends to assess the nature of population dynamics and the status of the pristine waterbodies within the Queenstown-Lakes District, its growing wastewater management issues and offers some solutions to effectively manage human wastewater discharges in one of the most sensitive and pristine environments.

POPULATION DYNAMICS OF QUEENSTOWN-LAKES DISTRICT

Resident population

Queenstown-Lakes District is one of the fastest growing districts in New Zealand. Between 2001 and 2006 it was the fastest growing area in New Zealand with 34% increase in population (Statistics NZ, 2013). The 2013 census indicated Auckland has been the fastest growing *region* in New Zealand with a population increase by 8.5% to 1.4 million since the 2006 census, adding the size of Tauranga City population to its already fast growing population. Of the territorial authorities, Selwyn has been the fastest growing with a population growth in excess of 32% to 44,595 between 2006 and 2013. Despite a reduction in population growth since the 2006 census, Queenstown-Lakes District is the second fastest growing district in New Zealand with the population increase by 23% to the 2013 population of 28,224 with total dwellings increasing by 20% to 16, 215. While the population increase trend follows roughly that of dwellings, the percentage of households owning their own dwellings is only 59% compared to the national average of 64%.

The population trend between 2001 and 2013 census reveals a different observation to the above. Queenstown-Lakes District had a population increase of 65% followed by Selwyn at 63%. Auckland growth was only 22% well below Waimakariri (35%) and Tauranga (26%). With all territorial authorities collectively achieving an average population growth of 13%, Queenstown-Lakes District population growth is considered as very substantial. As expected population growth within the Queenstown-Lakes District has not been uniform. Some areas have had much faster growth rates than the others (Table 1).

Table 1. **Resident population for 2001, 2006 and 2013 for areas in Queenstown-Lakes District (adopted from Statistics NZ, 2013 by introducing % change for 2001-2013)**

Area	2001	2006	2013	2001-2013 % change
Arrowtown	1,692	2,148	2,445	45
Arthurs Point	282	411	807	186
Frankton	1,641	1,782	1,827	11
Frankton East	153	396	639	318
Glenorchy	267	267	360	35
Hawea	1,062	1,596	2,172	105
Jacks Point	57	192	297	421
Kelvin Heights	792	960	1,011	28
Kingston South	132	201	234	77
Lake Hayes	192	252	318	66
Lake Hayes South	60	615	1,638	2630
Matukituki	282	372	387	37
Outer Wakatipu	414	462	651	57
Queenstown Bay	1,650	1,878	1,962	19
Queenstown Hill	2,337	3,153	3,534	51
Sunshine Bay	1,860	2,256	2,358	27
Wakatipu Basin	837	963	1,104	32
Wanaka	3,330	5,040	6,474	94
Total Queenstown Lakes District	17,043	22,959	28,224	66

For example, between 2001 and 2013 Frankton East and Jacks Point had 318% (153 to 639) and 421% (57 to 297) increase respectively while Lake Hayes South population increased from 60 to 1638 (an increase of 2630%). All areas within the district had an increase but already well established areas such as Frankton (1647 to 1827) and Queenstown Bay (1650

to 1962) only had a relatively small increase of 11% and 19% respectively. Large scale subdivisions have been the catalysts for the rapid population growth in fast growing areas such as Frankton East, Jacks Point, Lakes Hayes South and Wanaka.

Visitor population

Apart from one of the fastest growing resident populations, Queenstown-Lakes District also enjoys a substantial increase in visitor numbers. For example, between 2011 and 2014 the international arrivals to Queenstown Airport increased by 82% from 89,707 to 163,520 (Statistics NZ, 2014). In comparison, larger airports such as Auckland had an increase by less than 10% (from 1,847,213 to 2,029,568) with others with declining numbers (e.g. Christchurch from 422,646 to 420,704 and Dunedin from 16,199 to 13,472).

From Statistics NZ district accommodation December 2014 dataset it is estimated that the current visitor population for Queenstown-Lakes District could be between 10,000 and 11,000 per day, which includes both international and New Zealand travellers. Combined with the resident population of 28,244 the total population on an average day could be around 40,000. With increasing trend in international tourists' influx and domestic tourists combined with increasing resident population, the number of human population at any given time in Queenstown-Lakes District is likely to increase substantially in the next few years.

WATER QUALITY STATUS

Surface water

Queenstown-Lakes District is the origin of the largest New Zealand river, Clutha River. Clutha River originates from Lake Wanaka with combined flow from Cardrona River and Lake Hawea (as Hawea River). Kawarau River orginates from Lake Wakatipu with combined flow from Shotover River it flows into Clutha River at Cromwell. Water quality of the above lakes and rivers is excellent given the alpine catchment. However, Lake Hayes which is considered as picturesque by tourists has poor water quality due to historical nutrient runoff from its farming catchment through Mill Creek and the lake's relatively slow flushing flows and flows.

Table 2. Water quality parameters for Queenstown-Lakes District lakes compared against the NPS value limits

Attribute	NPS Attribute State A Annual median	NPS Attribute State A Annual maximum	NPS National Bottom line Annual median	Lake Hayes	Lake Wakatipu	Lake Wanaka	Lake Hawea
[1]Chlorophyll *a* (mg/m^3) (Ecosystem health value)	≤2	≤10	60 (annual maximum)	42 @9.3 m depth	0.38 @50 m depth	0.96 @17.5 m Depth	NA
[2]Total-N (mg/m^3) (Ecosystem health value)	≤160	-	750	310	50	50	40
[2]Total-P (mg/m^3) (Ecosystem health value)	≤10	-	50	18	3	3	3
[2]Ammonium-N (mg/L) (Ecosystem health value)	≤0.03	≤0.05	1.30	0.032	0.005	0.005	0.005
[2]*E.coli* (cfu/100 mL) (Human health recreation value)	≤260	-	1000	1	2	1	1

[1]Chlorophyll *a* values for the lakes are annual maximum for 2009 (Source: Otago Regional Council, 2009)
[2]Indicator values for lakes are annual medians (Source: Otago Regional Council, 2007)

Table 2 shows annual median water quality parameters and annual maximum chlorophyll *a* levels. Water quality levels are compared against the National Policy Statement (NPS) for Freshwater Quality 2014 values such as ecosystem health and human health recreation for lakes with Attribute State A (highest quality- *lakes ecological communities are healthy and resilient, similar to natural reference conditions*).

Clearly, with the exception of Lake Hayes all the other lakes meet the NPS's highest limits for Attribute State A for lakes falling well within the required thresholds. It is noteworthy that there is little or no faecal bacteria in all lakes, including Lake Hayes, indicating the relatively faecal contamination free catchment. While annual maximum chlorophyll *a* level in Lake Hayes is high, it is below the national bottom line value of 60 mg/m^3. All the other parameters for Lake Hayes fall within Attribute State B limits for lakes (State B- *lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated from natural reference conditions*) .

When compared water quality status with the Otago Regional Council (ORC) Plan Change 6A Schedule 15 limits for Lakes Wakatipu, Wanaka, Hawea and Hayes the regional council Schedule indicates that with the exception of total phosphorus (TP) for Lake Hayes all other limits are met for all lakes. The 2009 annual maximum for TP for Lake Hayes observed in Table 2, however, meets the ORC limit. The ORC limit for Lakes Wakatipu, Wanaka and Hawea are as follows: TN = 100 mg/m^3, TP = 5 mg/m^3, ammoniacal-N = 0.01 mg/L and *E.coli* = 10 cfu/100 mL and Lake Hayes are TN = 550 mg/m^3, TP = 33 mg/m^3, ammoniacal-N = 0.1 mg/L and *E.coli* = 126 cfu/100 mL (note ORC TN and TP units are converted from mg/L to mg/m^3 to make comparison with NPS limits).

Groundwater

Despite the presence of large lakes and rivers in Queenstown-Lakes District and with a high threshold ORC permitted activity for surface water take (1000 m^3/day), there is a high use of groundwater aquifers by the rural and town communities. Some main aquifers under use are Wanaka Basin- Cardrona Gravel, Cardrona Ribbon, Wakatipu Basin, Gibbston Valley, Hawea Basin, Kingston and Glenorchy. Groundwater quality is generally excellent, well below 1 mg/L of nitrate-N.

HUMAN WASTEWATER MANAGEMENT

While larger towns such as Queenstown and Wanaka have reticulated sewage discharges, other small towns continue to rely on individual septic tanks or consented discharges provided by the developers (Table 3) except for larger part of Hawea. About 28% of the dwellings in Queenstown-Lakes District are serviced by septic tanks and private effluent treatment schemes (Crowther, 2011).

Judging by a recent ORC technical report (Leslie, 2014), it is clear that in addition to towns such as Kingston and Glenorchy there are numerous individual septic tanks spread throughout the Queenstown-Lakes District. Given the outdated and lenient septic tank discharge permitted activity rules in Regional Plan – Water for Otago, many septic tanks may not need a resource consent to install and operate. The septic tank permitted activity rules allow most septic tank discharges, provided the volume does not exceed 2000 L/day and the discharge is located >50 m from a stream, wetland or a groundwater bore. According to the newly operative Water Plan Change 6A, the Wakatipu, Wanaka and part of Hawea Basins fall within the *nitrogen sensitive zone*. Rule 12.C.1.3 requires nitrogen (N) discharged to land by farming activities which may result in N entering water is a permitted activity provided the discharge does not exceed a set annual loading rate.

Table 3. Status of human wastewater discharges in Queenstown-Lakes District

Area	Resident Population	Status of human wastewater discharge
Arrowtown	2,445	Connected to Shotover Treatment Plant
Arthurs point	411	Connected to Shotover Treatment Plant
Frankton	1,782	Connected to Shotover Treatment Plant
Frankton East	639	Connected to Shotover Treatment Plant
Glenorchy	360	Septic tanks, long drops and developer reticulation consented land discharge
Hawea	2,172	Connected to Hawea Treatment Plant
Jacks Point	297	Developer reticulation-decentralised consented land discharge
Kelvin Heights	1,011	Connected to Shotover Treatment Plant
Kingston South	234	Septic tanks
Lake Hayes	318	Connected to Shotover Treatment Plant
Lake Hayes South	1,638	Connected to Shotover Treatment Plant
Matukituki	387	Septic tanks
Outer Wakatipu	651	Septic tanks
Queenstown Bay	1,962	Connected to Shotover Treatment Plant
Queenstown Hill	3,534	Connected to Shotover Treatment Plant
Sunshine Bay	2,358	Connected to Shotover Treatment Plant
Wakatipu Basin	1,104	Connected to Shotover Treatment Plant
Wanaka	6,474	Connected to Wanaka Project Pure Plant
Cardrona	NA. May be part of Wanaka population	Septic tanks and developer reticulation consented land discharge

The new ORC Plan Change rule restricts N leaching rate at or below 15 kg N/ha/year within the N sensitive zone. The recent technical report by ORC (Leslie, 2014) indicated that a large number of properties within Kingston and Glenorchy will collectively exceed the N sensitive zone N leaching restriction substantially with a majority of the septic tank clusters exceeding 30 kg N/ha/year. While the N leaching rules are not currently applicable to septic tank discharges, when new septic tank rules are set by ORC, it is inevitable that same N leaching restrictions will apply to septic tanks to achieve the same desired environmental outcomes set within the current Plan Change 6A.

A new septic tank N leaching restriction rule will have significant consequences on septic tank discharges in Queenstown-Lakes District, which has the largest N sensitive zone, and on those that are located within the N sensitive areas elsewhere in the Otago Region. The available options are very few. Septic tank owners may have to upgrade their discharge systems significantly to modern N treating devices to collectively achieve 15 kg N/ha/year, which may cost $15,000 to $20,000 per septic tank upgrade. Alternatively, QLDC needs to reticulate the affected septic tanks. What is the current state of the septic tank townships?

KINGSTON

Kingston (Figure 1) is a septic tank township which has many permanent residents and holiday visitors. There are not many commercial or retail outlets except for a camping park facility and a café/store. There are estimated 270 dwellings in Kingston with simple individual septic tank systems. Some properties located near the lakeshore are floodable when lake level is high hence septic tanks may not be usable and may contaminate water at the time of flooding.

Since there is no reticulated water supply, properties rely on shallow groundwater for drinking purposes. Shallow groundwater is likely to be contaminated with faecal bacteria given the shallowness (2-4 m) of the groundwater combined with the old septic tank systems. The local groundwater has not been investigated regularly or extensively by ORC, hence it is difficult to ascertain of any N plume into Lake Wakatipu. Given septic tank clusters caused nuisance algal growth along part of Lake Taupo shores until the mid-1970s

by which time septic tank discharges were reticulated by the Taupo District Council, there is a high potential for similar events around the current pristine Lake Wakatipu shore close to the residential blocks.

A specific groundwater quality study conducted by ORC in Kingston within 2002-2003 indicated 4 bores out of 19 sampled had faecal bacteria contamination (ORC, 2006). These bores were centrally located within the township. Compared to many Queenstown-Lakes District aquifers Kingston groundwater had slightly elevated nitrate-N levels (highest being 2.4 mg/L). This is despite the reducing conditions characterised by high iron levels prevailing in many of the bore sites which are conducive to reduce nitrate in groundwater (Selvarajah *et al*., 1994). The ORC technical report attributed the elevated levels of ammoniacal-N (average of 0.213 mg/L) found in one bore to septic tank effluent contamination and the generally elevated nitrate-N level to garden fertiliser or septic tanks.

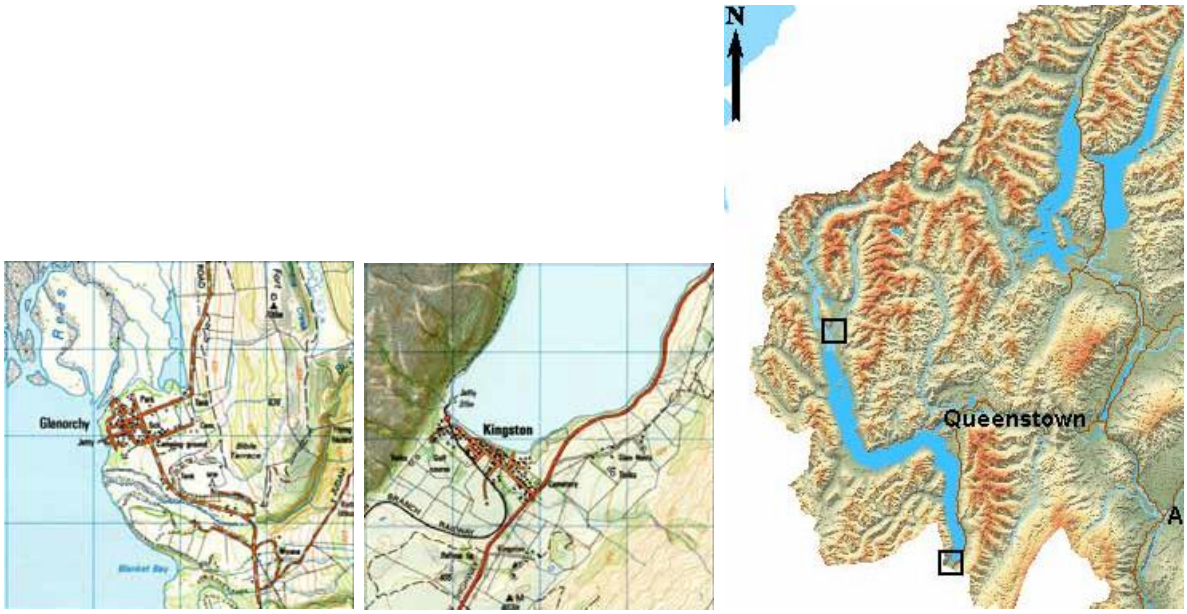

Figure 1. Glenorchy (North Wakatipu) and Kingston (South Wakatipu)

GLENORCHY

There are estimated 125 dwellings in the Glenorchy Township. Unlike Kingston, Glenorchy (Figure 1) has many operational commercial sites (12) such as cafés and tourist retail outlets. Several of these sites have outdated septic tanks for which discharge consents are held at ORC. There is also QLDC operated community facilities including public toilets which are also discharged without up-to-date treatment systems. Part of the township is in the floodplain hence septic tanks could be unusable during floods and may contaminate water. The township water supply is reticulated which is sourced from groundwater. ORC has been promoting reticulation of human wastewater in consultation with QLDC in Glenorchy since 2006. In light of QLDC's move to recognise Glenorchy human wastewater reticulation, in its Long Term Plan, short-term human wastewater discharge consents had been granted by ORC to avoid costly and premature discharge upgrades before the QLDC reticulation.

Fortunately, there had been a major subdivision referred to as Humboldt Park which has estimated 40 properties commissioned a simple land disposal system in the early 2000. This discharge was consented by ORC at that time with the understanding of future upgrade. The discharge into soak holes still continues with short-term consent granted by ORC with the

hope of proper reticulation of the entire Glenorchy Township. Similar to Kingston, any new ORC rule on septic tank N restriction will have significant impacts on local business and residents.

CARDRONA

Although the recent ORC technical report (Leslie, 2014) did not highlight Cardrona as a 'septic tank' hotspot, it has several issues. It has the famous Cardrona Hotel which is very heavily patronised during skiing season, with estimated 300-400 patrons per day. The hotel has a resource consent to discharge its effluent (land disposal) but the system requires a major upgrade. Cardrona also has a number of individual houses and tourist accommodation facilities. The accommodation facilities hold discharge consents with ORC. One of the accommodation discharges uses packed-bed reactor system with drip irrigation. In the absence of a reticulated water supply the hotel, households and accommodation facilities rely on bore water. Since Cardrona River had been over-allocated because of a large historical mining privilege water permit, ORC restricts further groundwater and surface water abstraction from the catchment. Therefore Cardrona Ribbon aquifer is also considered as over allocated.

In the same catchment Cardrona Ski field holds a resource consent to discharge its effluent. The existing discharge is to land over summer from the effluent storage pond. The discharge does require a major upgrade and the new consent granted allowed timeframe to achieve the upgrade, providing sufficient opportunity to involve in a Cardrona wide human wastewater reticulation with QLDC.

In addition to the above discharges consent is also held by a large scale subdivision (Mt Cardrona Ltd) to discharge highly treated low-N human wastewater at 2164 m^3/day to land by drip. The subdivision has not yet commenced. The above actual and potential human wastewater discharge activities clearly indicate a need for a leadership to co-ordinate property development, commercial and water and wastewater activities within the Cardrona area. ORC has been promoting reticulation as a solution since Cardrona River is sensitive to any further N inputs. The newly built Project Pure plant in Wanaka is located within connectable distance and down gradient and has sufficient capacity to deal with Cardrona reticulation. In the absence of any community or councils driven leadership there will be 'piecemeal' approach to human wastewater management in the Cardrona Valley which could collectively cost commercial operators and domestic residents substantial amount of money with poor environmental outcomes.

In the absence of both reticulated water and wastewater networks, combined with heavy tourist influx there are other issues faced by the township in the recent years. *Norovirus* contamination of water supplies have featured at least twice (one at Cardrona Ski Resort and the other at Cardrona Hotel) with significant number of staff and patrons becoming ill. Given the high profile of the New Zealand ski resorts around the globe, NZ's 'clean & green image' and the heavy social media use, any further similar incidents could have significant impact on its image and consequently financial and social implications to the Queenstown-Lakes District and New Zealand.

QUEENSTOWN

Table 2 shows that Queenstown Shotover Treatment Plant serves a large number of areas within the Queenstown-Lakes District. QLDC holds a 35 year consent to upgrade and discharge highly treated effluent to land within the Shotover Delta. Given the alpine environment and the town's high profile as a tourist destination, the discharge quality should

be better than that of other global alpine resorts. In addition to the high discharge quality, the entire sewage network has to be managed to the highest standards to avoid any accidental sewage spillages into Lake Wakatipu which have frequented in the recent years. The proposed treatment plant has sufficient capacity to accommodate increasing wastewater volume within the consent period. Many potential large developments including 5-Miles and Remarkable Park could be easily accommodated within the term of the consent.

WANAKA

Following the significant upgrade of the Wanaka wastewater treatment system, referred to as Project Pure, the Wanaka treatment plant also has substantial capacity to accommodate increasing wastewater inputs (consented volume = 26,400 m^3/day). The highly treated low-N and low faecal bacteria Sequencing Batch Reactor system discharge is to land. As a result of the upgrade, the historical and pond treated discharge had been ceased from the Clutha River headwaters. While Project Pure had been a success story, due to high level of treatment more sludge has been produced at the Project Pure treatment plant (about 2-3 m^3/day). Currently the sludge has been dumped at the QLDC Victoria Flats Landfill at a cost of \$180/m^3. Hopefully, when Fulton Hogan's sludge drying plant in Luggate is operational, sludge could be converted to biosolids.

HAWEA

Hawea treatment plant holds a short-term consent (expiry in November 2022) to discharge its 775 m^3/day pond treated effluent to cut & carry (summer) and land disposal (winter) systems. If further large developments are introduced, either the plant will be significantly upgraded or the land discharge area will be increased.

CONCLUSIONS AND RECOMMENDED APPROACHES

It is very clear that Queenstown-Lakes District is one of the fastest growing districts in New Zealand. Judging by the increasing international arrivals at the Queenstown Airport, local and international visitors and residential population there will be increasing demand on local infrastructure including human wastewater management. The district is well poised to deal with any significant increase in residential or visitor population in the Wakatipu and Wanaka areas. However, some townships such as Glenorchy, Kingston and Cardrona require water (with the exception of Glenorchy) and wastewater reticulation before localised water pollution becomes an issue. The district council had an excellent track record in working closely and cost effectively with the regional council to improve its existing treatment plant discharges.

Having worked with QLDC, its engineering staff, consultancies and local communities for the past 10 years I recommend the following approaches to manage human wastewater effectively:

1. QLDC needs to manage all septic tank discharges proactively, tactically and strategically since it grants permits for the installation of septic tanks.
2. In association with ORC, QLDC has to develop and implement a strategy for septic tank management in its district. Such a strategy will have thresholds for triggering reticulation and regulating septic tanks efficiently until reticulation.
3. Prolonging a decision on reticulation could cost the district and the community substantially. The cost to the district is associated with lack of growth due to uncertainty while the cost to residents is associated with 'double' expenditure (i.e. cost of installing septic tank and cost of reticulation). These could be avoided with proper proactive and timely approach.

4. In the absence of a QLDC owned and operated treatment plants, QLDC should collaborate with larger developers and encourage their own reticulation and treatment similar to Jacks Point development.
5. If human wastewater is reticulated the discharge has to be of high quality with systems managed to international standards to avoid any breaches.
6. There should be a strategy for funding any reticulation. Funding mechanism may vary depending on the circumstances. Where high visitor numbers are experienced there may be introduction of a 'bed-tax' which would require government support to introduce.
7. Monitoring and predicting resident and visitor population accurately is very critical to planning and designing new reticulations and treatment facilities.
8. Due to the sensitive receiving environment and ORC's preference for land based systems, all reticulated discharges have to be either land disposal or treatments, similar to the existing Project Pure and Hawea systems and the to-be-built new Queenstown wastewater treatment system.
9. Any sludge produced from the treatment systems should be converted to biosolids to be recycled.
10. To resolve excessive N loadings from septic tanks into N sensitive zones and to improve its outdated septic tank rules ORC should introduce new septic tank rules as soon as possible.
11. As it did in the past ORC should continue to collaborate with QLDC to co-ordinate consenting of human wastewater discharges within areas that require reticulation.

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