Tonkin+Taylor

Job No: 1003449
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Boffa Miskell
Level 3
82 Wyndham Street
Auckland 1010
PO Box 91250
Auckland 1142

Attention: Peter Hall

Dear Peter

Whanganui Prison Stormwater Mitigation Recommendations. Rev1

1 Introduction

Following the lodgement of the Whanganui Prison stormwater resource consent renewal application in 2013, the Department of Corrections has investigated alternative methods to improve the quality of stormwater and achieve a greater level of treatment.

In 2015 MWH was engaged by Department of Corrections to review available stormwater treatment options and recommend an appropriate solution. A combination of a constructed wetland with a gross pollutant trap (GPT) as pre-treatment was proposed, with the wetland proposed to be built on a piece of reserve land managed by the Whanganui District Council. The District Council rejected the wetland option because of operation and maintenance implications. The adoption of the GPT device was retained as an option to reduce the litter contamination risk.

In July 2016, Tonkin & Taylor Ltd (T+T) was commissioned to review the MWH[1] option to improve the Whanganui prison stormwater outfall quality (see Table 1.1 for monitoring results) by painting unpainted metal roofs and install GPT devices. A review of the hydrological performance (including flooding risk) of the GPT system was also undertaken as part of this work.

T+T concluded that a GPT device was adequate to remove part of the relevant contaminants, but did not achieve the desired level of treatment to remove nutrients, heavy metals and *E. Coli* from the stormwater discharge.

[1] Whanganui Prison Stormwater Quality Mitigation Option, MWH, November 2015

Tonkin & Taylor Ltd | 105 Carlton Gore Rd, Newmarket, Auckland 1023, New Zealand
PO Box 5271, Wellesley St, Auckland 1141 P +64-9-355 6000 F +64-9-307 0265 E akl@tonkintaylor.co.nz

Table 1.1: Stormwater Quality Monitoring Results (in the stormwater system)

Contaminant	Sampling location	Units	Median 2012-2013	Median 2014-2015	Median March-August 2017
Total Copper	SWMH1	g/m^3	0.0022	0.002	0.005
	SWMH2	g/m^3	0.0022	0.0025	0.0049
Total Zinc	SWMH1	g/m^3	0.0168	0.03	0.027
	SWMH2	g/m^3	0.017	0.052	0.13
Dissolved Phosphorous	SWMH1	g/m^3	0.019	0.032	
	SWMH2	g/m^3	0.019	0.049	
Dissolved Nitrogen	SWMH1	g/m^3	0.178	0.162	
	SWMH2	g/m^3	0.178	0.29	
Total Phosphorous	SWMH1	g/m^3			0.08
	SWMH2	g/m^3			0.16
Total Nitrogen	SWMH1	g/m^3			1.1
	SWMH2	g/m^3			1.5

Water quality monitoring completed by Horizons Regional Council also show level of phosphorous and nitrogen[2] in the Pauri and Wiritoa lakes exceeding the HRC One Plan target, as displayed in Table 1.2.

Table 1.2: Lakes Water Quality Results[3]

Variable	Unit	Lake Pauri			Lake Wiritoa			One Plan Table E.4 Lake Water Quality Targets
		n samples	median	95%ile	n samples	median	95%ile	
Turbidity	NTU	102	9.99	404	103	2.5	32	-
E. coli	cfu/100ml	76	9	75	77	10	163	<260/100ml in summer
DRP	mg/L	26	0.025	0.07	26	0.003	0.008	-
TP	mg/L	26	0.168	1.272	26	0.028	0.056	Annual average <0.02
Ammonia -N	mg/L	26	0.008	0.150	26	0.005	0.010	<0.4
Nitrate + nitrite	mg/L	26	0.006	0.193	26	0.006	0.024	-
TN	mg/L	26	1.870	11.34	26	0.805	1.164	Annual average <0.337

DRP = dissolved reactive phosphorus, TP = total phosphorus, TN = total nitrogen

Aquatic macroinvertebrate survey results in the receiving channel indicate "poor" in-stream conditions (MCi-sb scores ranges from 46 to 57; QMCI-sb scores from 1.2 to 3.3) in all sampling locations[4].

In addition to that, groundwater quality monitoring undertaken in 2013 and 2014 indicated that, in some instances, levels of Zinc, Copper, and *E.Coli* measured in groundwater are exceeding target values[5].

[2] Whanganui Prison Stormwater Quality Mitigation Options, MWH, 2015
[3] Whanganui Prison Stormwater Consent - Further Effects Assessment, MWH, 2014
[4] Whanganui Prison Stormwater Consent - Further Effects Assessment, MWH, 2014
[5] Assessment of Effects of Waste Water Disposal on Groundwater Levels and Groundwater Quality, MWH, 2014.

HRC asked Department of Corrections to look at the feasibility of moving the stormwater discharge point from the prison to avoid discharging to the lakes. T+T prepared a feasibility assessment of the drainage channel option to an alternative point of discharge downstream of the lake system in August 2017[6]. This assessment found that a connection between the prison and the channel downstream of the lakes is possible and would be 1.06 km long, when aligned along a paper road corridor. However, the proposed drainage channel would be technically challenging, would have suboptimal hydraulic performance (due to the poor gradient) and has high construction risks. The estimated cost of this option is also high. Overall, for these reasons, the proposed drainage channel has been defined as having a low level of engineering feasibility.

It was therefore decided to progress to this report, which evaluates treatment devices to achieve a practicable option for the management of stormwater runoff discharges from the Prison.

2 Scope

The scope for this stage of the project is to suggest possible alternatives or additional stormwater treatment infrastructure that could provide a satisfactory level of treatment and assess them with the HRC One Plan. Litter, Zinc and Nutrients (Nitrogen and Phosphorous) are the contaminants of concern and their removal should be maximised to comply with stormwater quality standards before being discharged.

3 Stormwater treatment options

Possible stormwater treatment options have been thoroughly assessed in previous work including site controls, gross pollutant traps, wetlands and discharge diversion channels. MWH reviewed and reported on the available treatment train approaches[7] for the Whanganui Prison, they mentioned stormwater filters as adequate devices but did not review their applicability further.

Proprietary stormwater treatment devices have the same benefits as GPTs in terms of retrofitting the existing primary stormwater drainage system of the prison, but would provide a higher level of treatment for nutrients and heavy metals. Two devices have been reviewed; they are the Stormwater360 Jellyfish filter and the Hynds Environmental Up-Flo filters. They have been assessed to identify the best practicable option to treat stormwater to levels that satisfy Horizon Regional Council One Plan standards.

Both systems are widely used in New Zealand (Auckland Council approved) and globally (Australia, United States). These treatment device have low hydraulic head requirement that allow them to operate in flat terrain. Though both devices have an internal bypass system for larger storm events, each option will be installed in an offline configuration to provide additional resilience against high flows inundating the device.

3.1 Jellyfish filter

The Stormwater360 Jellyfish filter (as seen in Figure 3.1) is a stand-alone system that provides high flow pre-treatment and membrane filtration. As contaminated water enters the Jellyfish chamber through an inlet pipe, gross pollutants and sediments settle to the bottom. The untreated water is then forced through tentacle like membrane cartridges trapping TSS, silt sized particles (as small as 2 microns), and a high percentage of particulate-bound pollutants; including phosphorus, nitrogen, metals and hydrocarbons[8]. Treated water is released to the environment through an outlet pipe.

[6] Whanganui Prison Stormwater Outfall Relocation, Tonkin and Taylor, August 2017.
[7] MWH, Whanganui Prison Stormwater Quality Mitigation Options Report section 7.3.2.3, Nov 2015.
[8] Contech Engineered Solutions LLC, http://www.conteches.com/products/stormwater-management/treatment/jellyfish-filter

Figure 3.1: Typical Vault Jellyfish filter

The number of cartridges vary based on the treatment design flows. Cartridges can be easily removed and maintained using a low pressure water system. As previously mentioned, the device will be installed in an offline configuration as seen in Figure 3.2. This is to allow for the bypassing of peak flows that are in excess of the filter capacity.

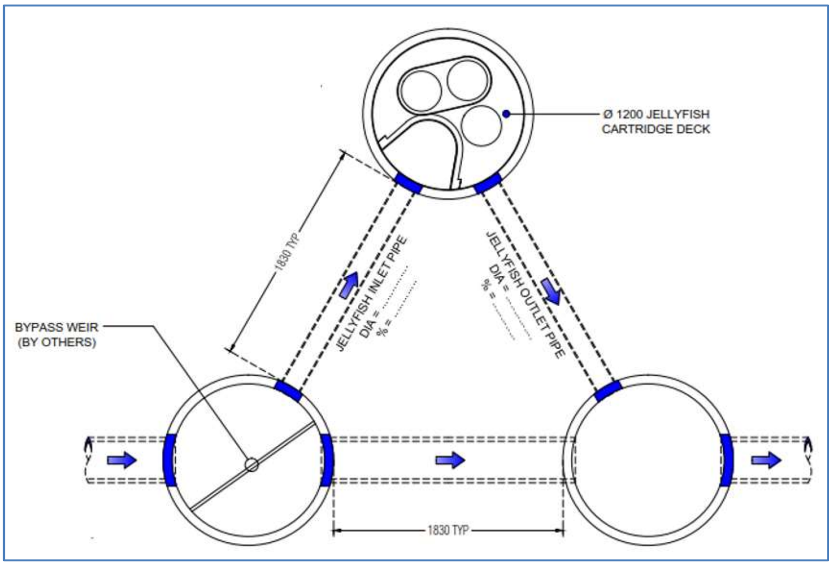

Figure 3.2: Typical Jellyfish filter offline configuration

Depending on the number of required filters, the host structure can be a standard pre cast concrete manhole (as illustrated on Figure 3.2) or a larger underground chamber (as illustrated on Figure 3.1).

3.2 Up-Flo filter

Similar to the Jellyfish filter, the Hynds Environmental Up-Flo filter provides a stand-alone system that produces high flow pre-treatment and modular filtration. Untreated water enters the system through an inlet pipe. As gross pollutants and sediments settle to the bottom, the untreated water flows upwards through filtration modules that trap fine sediments, nutrients, metals, oils and grease[9]. Treated water is discharged into the environment through an outlet pipe.

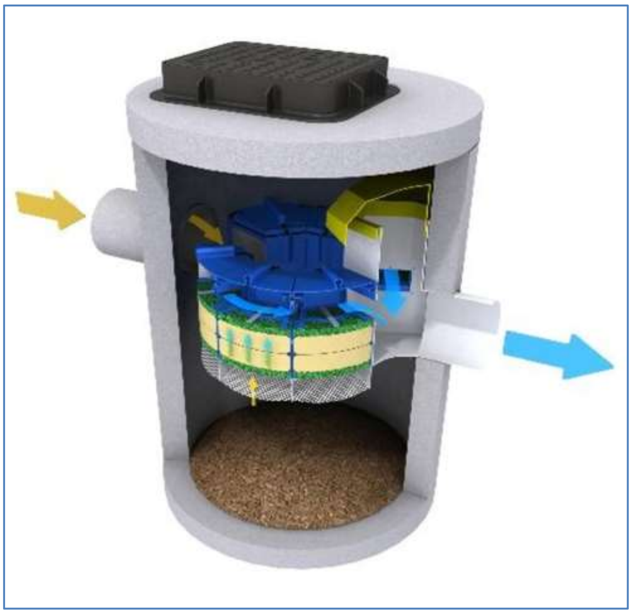

Figure 3.3: Typical Up-Flo Filter

Depending on the design flow, the number of filter modules can change. Modules can easily be removed for maintenance purposes. As with the Jellyfish filter, an offline configuration will be adopted to provide a bypass for peak flows in larger storm events.

The type of cartridge filter can also be changed to suit the nature of the contributing sub catchment and associated contaminants (sand or CPZ mix).

4 Concept design

4.1 Location

The available locations for the treatment devices are located outside of the prison grounds either directly downstream of the existing manholes and within the road corridor or within the reserve land, as displayed on Figure 4.1. Liaison with the Whanganui District Council will be required for the approval of any works on their property.

[9] Hynds Environmental LLC, http://www.hyndsenv.co.nz/wp-content/uploads/EVS-1-Up-Flo-Filter.pdf

Figure 4.1: Existing stormwater manholes and available treatment infrastructure location

4.2 Hydraulic design

All normal stormwater flows up to the water quality volume design peak flow (1/3 of 2 year ARI)[10], which is calculated to be 125 l/s, will pass through the treatment device. This will include the first flushes of contaminants. Flows greater than 125 l/s will bypass the treatment device.

The water quality volume design peak flow (125 l/s) was used to model the inlet and outlet pipes connecting the proposed treatment device to the existing network. Flows were diverted towards the proposed treatment device though the use of weir structures (650mm in height) in both manholes (MH1 and MH2 as illustrated in Figure 4.2).

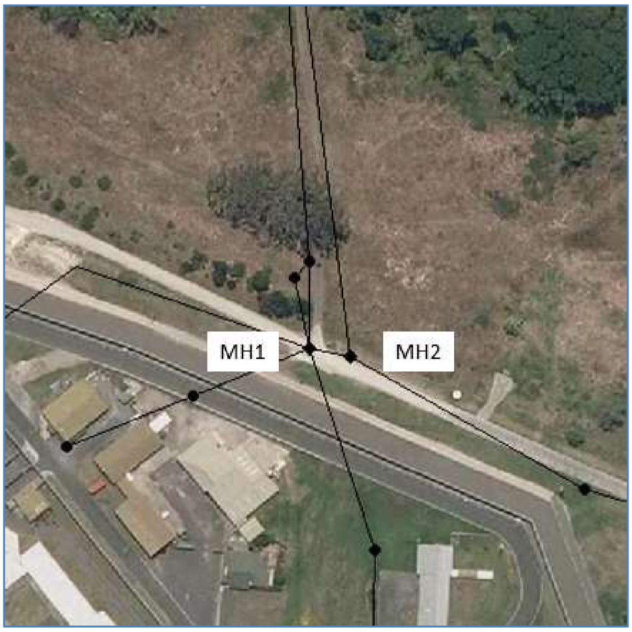

Figure 4.2: SWMM model configuration

[10] As per Auckland Council Technical Publication number 10.

As well as diverting flows, these weir structures aid in providing enough hydraulic head to drive flows through the treatment stage as well as satisfy bypass requirements. However, the hydraulic head is achieved by backing-up stormwater within the upstream pipe network.

Correspondence with Stormwater360 for the Jellyfish filter confirmed that a treatment device containing 32 membrane cartridges with a hydraulic head of 150mm would be required to treat water quality volume (WQV) peak flows[11].

Hynds Environmental confirmed that a treatment device containing 81 module membranes with a hydraulic head of 250 mm would be required to treat WQV flows.

4.3 Flood assessment

Using a SWMM model[12], a hydraulic assessment of both the existing pipe network and the proposed network with the treatment device was undertaken.

The 10 year ARI peak design flow[13] was used to assess the conveyance within pipes for the existing scenario (no stormwater treatment). Modelling showed that the existing pipe network was running at capacity, resulting in some localised flooding.

The addition of treatment devices is expected to cause a limited increase to the existing upstream flooding. The prison's drainage network appears to be under capacity during a 10 year storm event including predicted climate change. Because of the site's flat topography, it is not expected that site flooding would impact on other properties.

A second scenario in which a smaller treatment device per outlet pipe was also considered. It produced similar flooding outputs compared to a single treatment device, so was not pursued due to its lower economic viability.

4.4 Wider flooding issues

Stormwater runoff for events up to the 10 year ARI will enter the pipe network which diverts runoff from the natural overland flow path and ultimately conveys runoff to the Lakes. This will result in a minor increase in runoff volume entering the Lakes. This increase is expected to be negligible, as the Pauri Lake catchment is roughly 900 ha, whereas the contributing prison catchment is 22 ha (approximately 2% of Pauri Lake catchment), and runoff diversion to the lake is capped at flows equal to the 10 year ARI. Runoff in excess of the 10 year ARI runoff will not enter the pipe network, but follow existing overland flow paths. With the exception of the slight increase in runoff entering the Lakes mentioned above, there is not expected to be any increase to flood volume or frequency downstream of the site in large events.

5 Theoretical contaminant removal rates

The level of contaminant and gross pollutant removal for the Up-Flo filter and Jellyfish filter have been researched and published in peer reviewed journals and case studies. Both treatment devices are expected to provide a similar level of contaminants, heavy metal and nutrient removal. These removal rates are strongly dependent on the contributing catchment landuse and especially for nutrients that are bound to sediment particles.

Coarse pollutants (trash and debris) and sand particles are removed via settlement in the internal sump through a built in separation skirt on the Jellyfish Filter and a trash screen on the Up-Flo filter.

[11] As defined in *ARC TP108 Guidelines for stormwater runoff modelling in the Auckland Region*, 1999
[12] US EPA Storm Water Management Model v5.1
[13] WDC Land Development and Subdivision Engineering Document 2012, Part 4

Table 5.1: Indicative level of pollutant removal for Up-Flo Filter[14][15]

Pollutant of Concern	% Removal
Total Trash	99%
Total Suspended Solids (TSS)	82%
Total Phosphorous (TP)	72%
Total Nitrogen (TN)	37%
Total Copper (TCu)	76%
Total Zinc (TZn)	83%
Turbidity (NTU)	61%

Table 5.2: Indicative level of pollutant removal for Jellyfish Filter[16]

Pollutant of Concern	% Removal
Total Trash	99%
Total Suspended Solids (TSS)	89%
Total Phosphorous (TP)	59%
Total Nitrogen (TN)	51%
Total Copper (TCu)	>80%
Total Zinc (TZn)	>50%
Turbidity (NTU)	<15%

The water quality targets of the Horizons One Plan for lakes are presented in Table 5.3.

Table 5.3: Horizons Regional Council One Plan Water Quality targets for lakes[17]

Variable	Target
E. Coli	<260/100ml in summer <550/100ml in winter
Total Phosphorous (TP)	Annual average <0.02g/m^3
Total Nitrogen (TN)	Annual average <0.337g/m^3
Ammonia – N	<0.4g/ m^3
Total Copper (80% level of protection, no hardness correction or dilution allowed)[18]	0.0025g/m^3
Total Zinc (80% level of protection, no hardness correction or dilution allowed)[14]	0.031g/m^3

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[14] Rocla Pty Ltd, http://www.rocla.com.au/Up-Flo-Filter.php
[15] Cai, Y., Pitt, R., Togawa, N., McGee, K., Osei, K., Andoh, R. (2014). Full Scale Up-Flo Filter Field Verification Tests, Journal of Water Management Modelling , JWMM.C365
[16] Contech Engineered Solutions LLC, http://www.conteches.com/products/stormwater-management/treatment/jellyfish-filter
[17] Horizons Regional Council, One Plan Schedule E Table E.4., 2014
[18] Table 3.4.1, ANZECC guidelines

An 80% level of protection was chosen as the current lake system has been qualified as having "poor" associated in-stream conditions based on an aquatic macroinvertebrate survey completed in 2014[19].

Considering the water quality sampling undertaken between March and August 2017 and more specifically the average concentration during this period, the theoretical average contaminant concentrations after treatment with the proprietary filters are presented in Table 5.4. These are the water quality concentration in the stormwater discharge to the drain linking the lakes. These concentrations are compared to the target for lakes in the One Plan without allowance for mixing of the discharge and lake water, as is typically allowed for when measuring pollutant discharges

Table 5.4: Theoretical post treatment water quality results in the stormwater

Variable	Pre treatment (average March-August 2017)	Post treatment with Up Flo filter [g/m^3]	Post treatment with Jellyfish filter [g/m^3]	Target (Horizons One Plan) for Lakes
E. Coli [CFU/100ml]	5-1300	No published data	No published data	<260 in summer <550 in winter
Total Phosphorous (TP) [g/m^3]	0.173	0.048	0.071	Annual average <0.02
Total Nitrogen (TN) [g/m^3]	1.38	0.87	0.68	Annual average <0.337
Ammonia – N [g/m^3]	Unknown	Unknown	Unknown	<0.4

Based on these assessments the stormwater discharges post treatment would still be expected to be above Horizons Regional Council One Plan targets for lakes. Ideally the mixing of the discharge with the receiving water would dilute the discharge to an allowable level, however the level of pollutant in the receiving environment is already above the One Plan targets, and is similar to the pre-treatment levels of pollutants in the discharge. Nevertheless, the proposed stormwater treatment will improve the water quality of the stormwater discharging to the lake and will be an improvement to the water quality of the receiving environment. The overall water quality in the lake will be dominated by inflows from the wider catchment.

The proprietary device suppliers have not published any data/removal rates associated with *E. Coli*. However, some research on Up-Flo filters are showing some removal rate in bacteria[20] concentration.

Reduction rates of Copper and Zinc have not been included in Table 5.4 because the pre-treatment levels of these contaminants are already below the One Plan limits.

At this stage, the adoption of proprietary treatment devices is considered best practicable option. These treatment devices combined with the recommendations adopted during the previous stage of this project (painting the un-painted roofs and upgrade of some of the site activities e.g. addition of saw dust skirt) are expected to improve the stormwater discharge quality.

6 E. Coli

The presence of E.Coli has been detected in some samples of stormwater from the site. The source of this contamination has not been identified. Further sampling would be necessary to conclusively determine this source of contamination. Groundwater quality and levels were assessed in MWH

[19] Whanganui Prison Stormwater Consent - Further Effects Assessment, MWH, 2014
[20] Full Scale Up-Flo Filter Field Verification Tests, Journal of Water Management Modelling, Cai & al, 2014

(2014)[21] which detected high background levels of E. Coli, particularly after large rainfall events. The study proposed that while E. Coli levels may be affected by wastewater discharges, it is likely that elevated E. Coli levels are the result of local stock and soil contamination. Therefore, groundwater seepage into drainage infrastructure is a potential source of contamination.

7 Limitations/assumptions

The following limitations and assumptions apply to the findings of this report:

- The invert and lid levels used for this assessment have been based on the topographical survey results collected by Taylor Patrick Ltd in June 2017.
- The hydrological and hydraulic SWMM model was built on survey data and a simplified drainage network geometry. It was created to obtain an estimated runoff and required treatment peak flows for various storm events. These peak flows were then used in the design and preliminary sizing of the treatment devices.
- For the sake of the hydraulic modelling, it has been assumed that the two discharge pipes are free flowing and their operation not impeded by any downstream high water levels. Anecdotal backflow up the discharge pipes has been observed in the drainage network though.
- The published contaminant removal rates depend on the contributing sub catchment and monitoring would have to confirm their efficiency and removal rate at the site.
- The water quality results post treatment have been calculated using the proprietary devices manufacturer published contaminant removal rates.

Maintenance is critical for the good performance of proprietary devices and suppliers usually provide an initial maintenance schedule that is updated depending on the rate of contaminant accumulation. It is therefore required to regularly monitor the filters in the first few months after installation to understand the devices maintenance frequency. The device supplier will provide an initial maintenance schedule based on the contributing catchment land use, size of the cartridges and the targeted pollutant removal efficiency.

The accurate construction costs for these two options are not known at this stage although Stormwater360 indicated a cost of $260,000 for the supply of their system excluding delivery and associated diversion pipe costs. Hynds Environmental gave an indicative price of $294,000 for the supply of their system excluding delivery and associated diversion pipe costs.

Preliminary construction cost estimates have been developed and these include design, consenting, construction and a variable contingency, they are presented in Table 7.1.

Table 7.1: Preliminary Construction Cost Estimate

ID	Option description	Construction costs	
		Low - 0% contingency	High - 30% contingency
1	Stormwater360 Jellyfish Filters	$ 420,000.00	$ 550,000.00
2	Hynds Environmental Up Flo Filters	$ 480,000.00	$ 620,000.00

[21] Assessment of Effects of Waste Water Disposal on Groundwater Levels and Groundwater Quality. MWH, 2014

8 Recommendations

Both reviewed devices have been compared and their respective benefits and disadvantages are presented below.

Table 8.1: Advantage/disadvantage of treatment devices

ID	Option description	Advantages	Disadvantages	Cost
1	Stormwater360 Jellyfish Filters	• Approved by various national and international regulatory entities • Efficient treatment device (removal rates presented in Table 5.2) • Preliminary estimated footprint is 13m^2 • Short construction timeframe	• Maintenance intensive	$420K-$550K
2	Hynds Environmental Up Flo Filters	• Approved by various national and international regulatory entities • Efficient treatment device (removal rates presented in Table 5.1) • Better anticipated Phosphorous removal rate. Phosphorus is generally the limiting nutrient for freshwater systems. • Preliminary estimated footprint is 28m^2 • Short construction timeframe	• Maintenance intensive	$480K-$620K

At this stage the theoretical assessment of the resulting water quality post filtration devices do not meet Horizons Regional Council targets for lakes, but are likely to meet these with mixing (subject to lake water quality). However the definition of the actual removal rate is based on the supplier's published results and the performance of these devices is expected to vary with the quality of the stormwater inflow.

Both devices offer similar treatment rates and similar costs. The Stormwater360 option is, however, more compact and would occupy a smaller overall footprint (single 4.5m x 2.8m underground concrete chamber, 13m^2) due to the lesser number of required cartridges. Hynds Environmental recommendation is to adopt four 3m diameter manholes installed in series (28m^2).

300mm diameter inlet and outlet diversion pipes with an additional manhole downstream of the treatment device are also to be constructed.

The installation of a 0.65m high weir in both manholes MH1 and MH2 is required to provide the driving head necessary to make the treatment system work efficiently and provide a structural bypass of flows during larger storm events.

The current pipe network appears to be at capacity during larger storm events and the proposed treatment systems is not expected to significantly impact on the drainage network conveyance capacity.

As is usual with treatment devices, maintenance is critical and will need to be completed on a regular basis to maximise the treatment efficiency.

Ongoing targeted stormwater quality sampling could be done to seek to identify the contamination sources. The source of nutrients in the stormwater could be associated with offsite land uses (farming) that is affecting the groundwater, which could be confirmed by the on-site stormwater quality sampling.

Other on-site stormwater management processes remain required, especially non-structural practises, which have been identified in previous reports.

We recommend the adoption of the Up-Flo filtering system because of its higher estimated phosphorous removal rate.

9 Applicability

This report has been prepared for the exclusive use of our client Boffa Miskell, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:

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Katherine Heays

Water Resources Engineer

Authorised for Tonkin & Taylor Ltd by:

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Tim Fisher

Project Director

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