PATTLE DELAMORE PARTNERS LTD
295 Blenheim Road
Upper Riccarton, Christchurch 8041
PO Box 389, Christchurch 8140, New Zealand

Tel +64 3 345 7100
Web www.pdp.co.nz
Auckland Tauranga Wellington Christchurch

solutions for your environment

25 June 2018

Raelene Stewart
Associate - Project Management
Beca
PO Box 13960
CHRISTCHURCH 8141

Dear Raelene

IRRIGATION MODEL RESULTS FOR LAND DISPOSAL OF TREATED WASTEWATER AT GOUGHS BAY, ROBINSONS BAY AND POMPEYS PILLAR

1.0 Introduction

Christchurch City Council (CCC) is investigating treated wastewater irrigation options for the proposed Akaroa Wastewater Treatment Plant (WWTP). As part of the peer review work by the Technical Experts Group, Pattle Delamore Partners Ltd (PDP) prepared a soil moisture balance assessment for irrigation of wastewater to land. This assessment was summarised in the letter to Beca "Irrigation Model Results for Akaroa Treated Wastewater Land Disposal at Robinsons Bay" dated 9 May 2017. Since this letter was prepared, Beca has carried out additional work and revised the predicted wastewater flow for the new scheme.

PDP has now updated the soil moisture balance assessment to incorporate the revised wastewater flow provided by Beca. The purpose of this letter is to present a preliminary estimate of the required irrigable area and wastewater storage volume using the revised flow.

Three potential irrigation areas have been modelled in this assessment, including: Goughs Bay, Robinsons Bay and Pompeys Pillar.

2.0 Model Method and Inputs

2.1 Wastewater Flow Estimate

Beca has provided PDP with a revised short term current and future (2052) wastewater flow estimate for Akaroa. The flow was developed in two parts described in the following sections.

Part 1: Population Based Flow Estimate

Beca has provided PDP with a population derived flow estimate, developed based on measured Biological Oxygen Demand (BOD) data from the wastewater treatment plant. Three distinct periods of population trends were identified over the year, including: winter (1st Mar – 23rd Dec), summer (24th Dec – 28th Feb) and peak (31st Dec – 6th Jan). Table 1 shows the current estimated population for Akaroa based on the BOD analysis.

The future (2052) population of Akaroa was estimated by assuming a 0.25% increase per year for the resident population and a 0.40% increase per year for the summer population. These percentage increases were provided by CCC.

Table 1: Current and Future Population Estimate based on BOD

Period	Current	Future (2052)
Winter (1st Mar – 23rd Dec)	765	840
Summer (24th Dec – 28th Feb)	2077	2348
Peak (31st Dec – 6th Jan)	3273	3723

The population estimates were converted into a daily wastewater flow by assuming a daily flow generation of 220 L/s/person.

Figure 1 shows the resulting current and future (2052) population derived flow over the year.

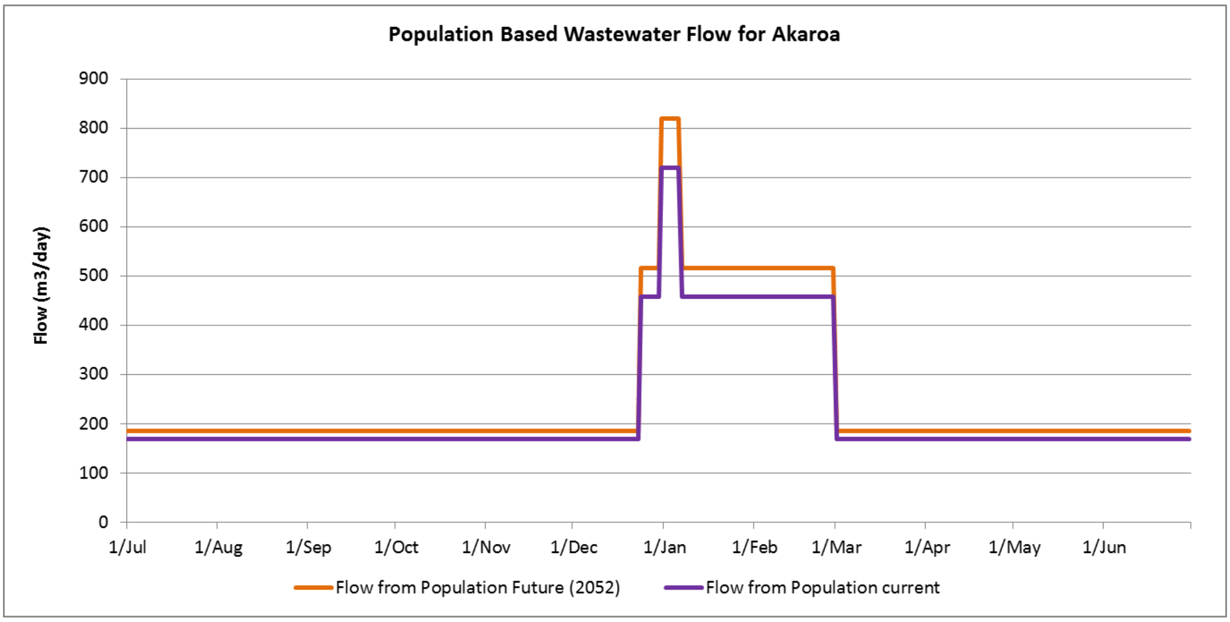

Figure 1: Daily Population Based Wastewater Flow for Current and Future (2052) Scenarios

Part 2: Inflow and infiltration (I&I)

Beca has provided PDP with a daily I&I estimate from 2009 to 2017 which has been generated from a rainfall based I&I software package utilising the Stanley Park Rainfall Gauge hourly rainfall from 2009 to 2017 (full period of available hourly records). The estimate assumes a constant year round infiltration of around 325 m^3/day to account for groundwater leakage into the system.

Figure 2 shows measured flow at flowmeter PS616 (located immediately upstream of the treatment plant) versus the Beca I&I estimate. The population derived flow has been added to the I&I estimate to enable a direct comparison to the measured flow.

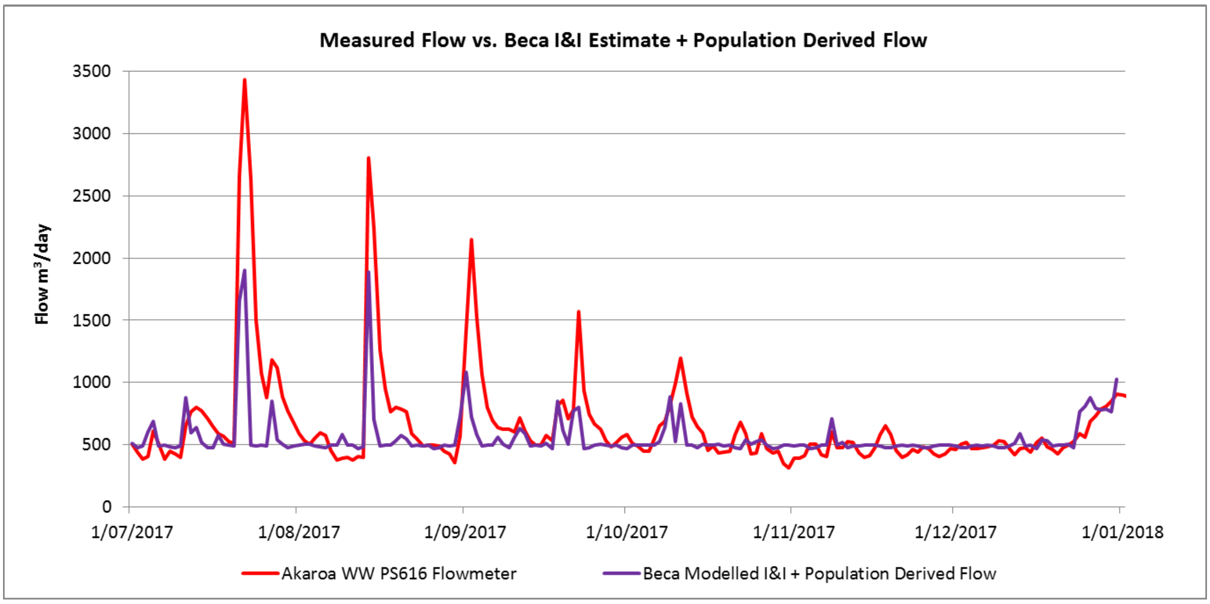

Figure 2: Measured flow at PS616 vs. Beca I&I Estimate

Figure 2 shows that the Beca I&I estimate underestimates I&I during and immediately after large storm events. PDP has modified the Beca I&I estimate to create a short term I&I estimate that better fits the measured flow. This modification included increasing the peak I&I and adding a tailing off factor to gradually decrease I&I over a number of days once the storm event has passed.

The short term I&I estimate was then used to develop a long term I&I estimate from 1972 to 2017. Figure 3 shows an event total plot of measured rainfall verses the short term I&I estimate.

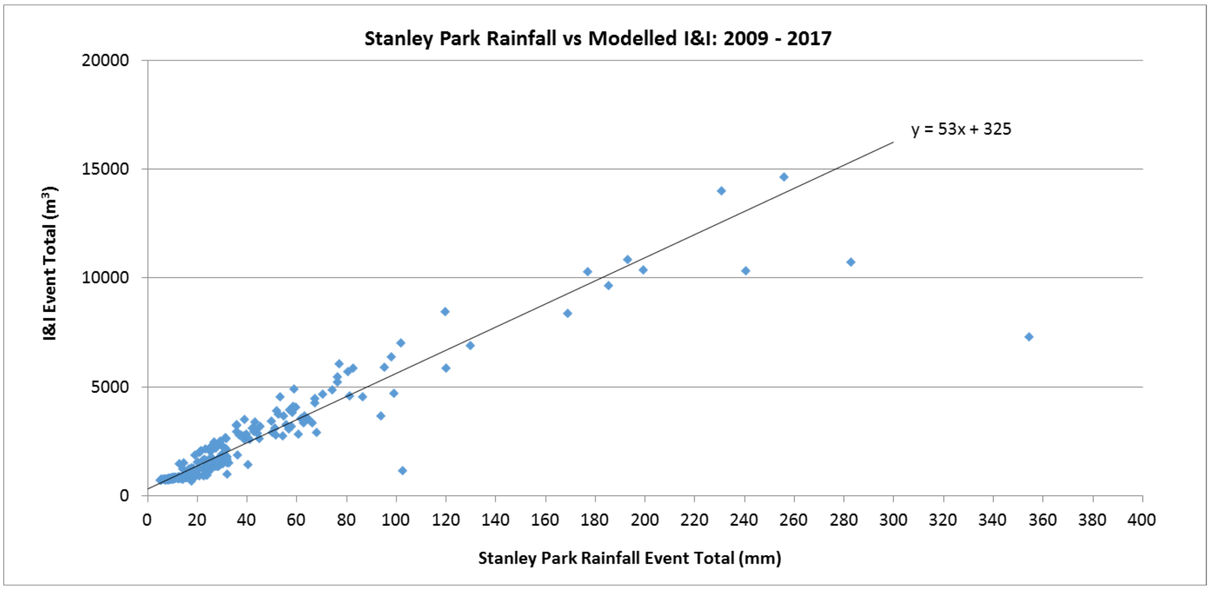

Figure 3: Stanley Park Rainfall vs. Short Term I&I Event Totals from 2009 to 2017

Figure 3 shows that there is a correlation between the measured rainfall and I&I. A linear trendline was fitted to the plot to obtain a relationship between rainfall and I&I. The resulting trendline relationship was then applied to a long term NIWA VCSN (Station 20249) record to obtain I&I for each rainfall event from 1972 to 2017. The VCSN record has been developed by NIWA using interpolation of surrounding weather stations to develop a consistent long term record. The VCSN data includes adjustments for altitude. PDP has reviewed some of the rainfall records available and the VCSN data is consistent with those rainfall records with adjustments for altitude.

Combined Flow

A combined flow was obtained by combining the population derived flow and the short and long term I&I records. Table 2 shows the key statistics for the combined flow compared to the measured flow at PS616 over the period July 2017 to December 2017.

Table 2: Measured and Modelled Wastewater Flow Estimate (Jul 2017 – Dec 2017)

	Measured at PS616	Short Term Estimate		Long Term Estimate	
		Current	Future	Current	Future
Average (m³/day)	665	672	691	673	690
Median (m³/day)	528	497	514	493	510
Max (m³/day)	3,432	3,458	3,474	3,341	3,357
Min (m³/day)	318	473	490	493	510
Volume (m³)	122,400	123,700	127,100	123,800	127,000

Figure 4 shows the measured flow at PS616 along with the final modelled short term and long term daily flow over the period July 2017 to Dec 2017.

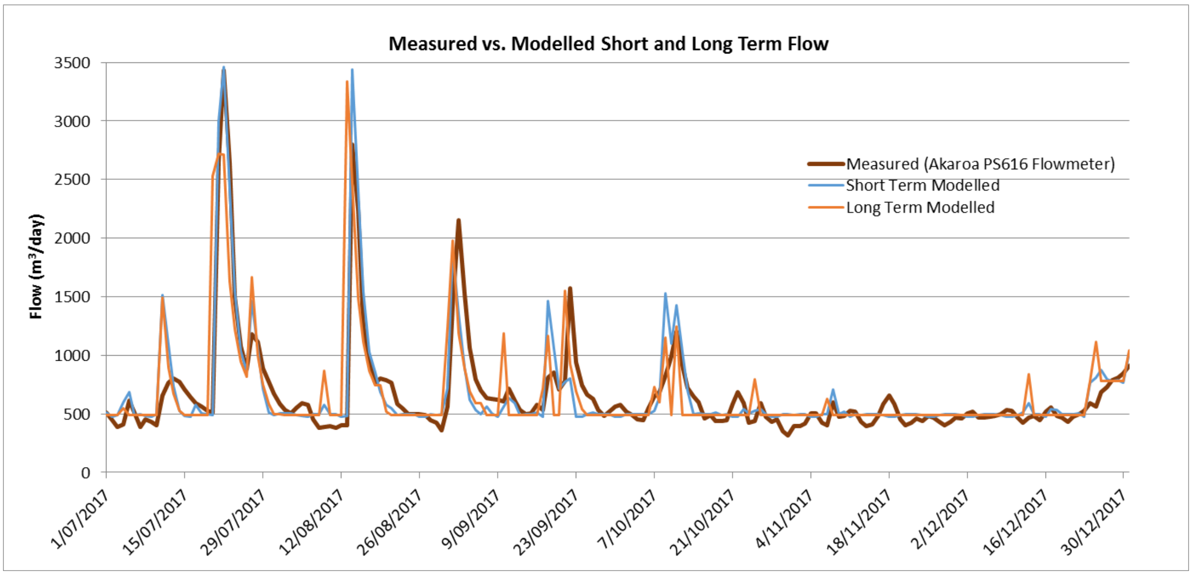

Figure 4: Measured vs. Modelled Short and Long Term Flow

Figure 4 shows a good fit of both the short and long term modelled flow to the measured flow.

Table 3 shows the flow statistics for the final short and long term flow over the full model period.

Table 3: Modelled Wastewater Flow Estimate

	Short Term Estimate (2009 to 2017)		Long Term Estimate (1972 to 2017)	
	Current	Future	Current	Future
Average (m^3/day)	658	683	707	731
Median (m^3/day)	501	518	493	510
Max (m^3/day)	5,318	5,334	9,676	9,692
Min (m^3/day)	441	389	447	463
Average Annual Volume (m^3/year)	240,000	250,000	258,000	267,000

Table 3 shows that the maximum flow in the long term estimate is significantly higher than the short term estimate. This is a result of wetter periods in the 1970's which are not present in the short term estimate.

Wastewater flow data from the flow meters does not take into account overflows from the sewage network. PDP has been provided with information from CCC (via Beca) that indicates that there have been 20 overflows since July 2017. Of these 20 overflow events, 9 have estimated volumes of discharge between 6.5 and 2,225 m^3. To accommodate this overflow volume, additional storage volume will be required. A decision on how CCC will manage these overflows is yet to be confirmed. Once that decision has been made, the impact on the storage required can be considered further.

3.0 Irrigation Methods

3.1 Irrigation of Native Trees via Drip

For irrigation to native trees, drip irrigation is assumed and the wastewater is applied to the land irrespective of soil moisture conditions. The following key assumptions have been made:

Irrigation Demand Threshold:	Irrigation occurs regardless of PAW (even if PAW is at field capacity)
Extreme Rainfall Cutoff:	If rainfall > 50mm/day then irrigation ceases
Irrigation Season:	All year round
Irrigation Efficiency:	100% efficiency
Maximum Irrigation Application (mm/day):	Dec–Feb: 2.75, Mar–May, Sep–Nov: 2.15, Jun–Aug: 1.5

The maximum irrigation application per day is less than the Long Term Acceptance Rate of the soils and is selected to avoid surface ponding when the PAW is at field capacity.

3.2 Irrigation of Pasture via Impact Sprinklers

For irrigation to pasture it is assumed that impact sprinklers (such as K-line or fixed pole mounted sprinklers) are used and the wastewater is applied to the land based on a soil moisture balance (i.e. Irrigation is only applied when the soil moisture content is assessed to be less than the maximum Plant Available Water). The following assumptions have been made:

Irrigation Demand Threshold:	Irrigation based on daily soil moisture balance up to a maximum Plant Available Water
Irrigation Season:	All year round, Dec to Mar for south facing land (15.3 ha) at Goughs Bay
Maximum irrigation application rate:	7 mm/day
Irrigation Efficiency:	85% efficiency

3.3 Soils and Rainfall

The following soils and rainfall parameters have been assumed for each irrigation area:

Soil Profile Available Water (PAW)

Goughs Bay	Pasture: 36 mm
Robinsons Bay	Pasture: 48 mm, Trees: 85 mm
Pompeys Pillar	Pasture: 48 mm, Trees: 85 mm

Rainfall

Goughs Bay	NIWA VCSN 20379 and Long Bay Road AWS
Robinsons Bay	NIWA VCSN 20249 and Akaroa EWS
Pompeys Pillar	NIWA VCSN 20380

4.0 Model Results

4.1 Pasture Irrigation at Goughs Bay

Approximately 115 ha of irrigable pastoral land has been identified at Goughs Bay (Townshend Land Study Area). Table 4 shows the peak storage required to spray irrigate this area.

Table 4: Peak Storage Required for 115 ha Spray Irrigation at Goughs Bay

	Short Term Modelled (2009 – 2017)		Long Term Modelled (1972 – 2017)	
	Current	Future	Current	Future
Peak Storage (m^3)	43,000	45,000	63,000	69,000

Table 4 shows that a higher storage volume is required based on the long term model results. The higher storage volume is a result of wet periods in the 1970's which the short term model does not consider.

Table 5 shows the peak storage required for pasture and tree irrigation at Goughs Bay using the future population estimates. The long term (1972 to 2017) model results have been presented as they produce the most conservative storage volumes.

Table 5: Model Results for Irrigation to Pasture at Goughs Bay

Pasture	**Irrigation Land Area (ha)**	**70**	**80**	**90**	**100**	**115**
	Peak Storage (m^3)	98,000	91,000	85,000	78,000	69,000

Figure 5 shows the annual peak storage used for each year under 115 ha of pasture irrigation at Goughs Bay.

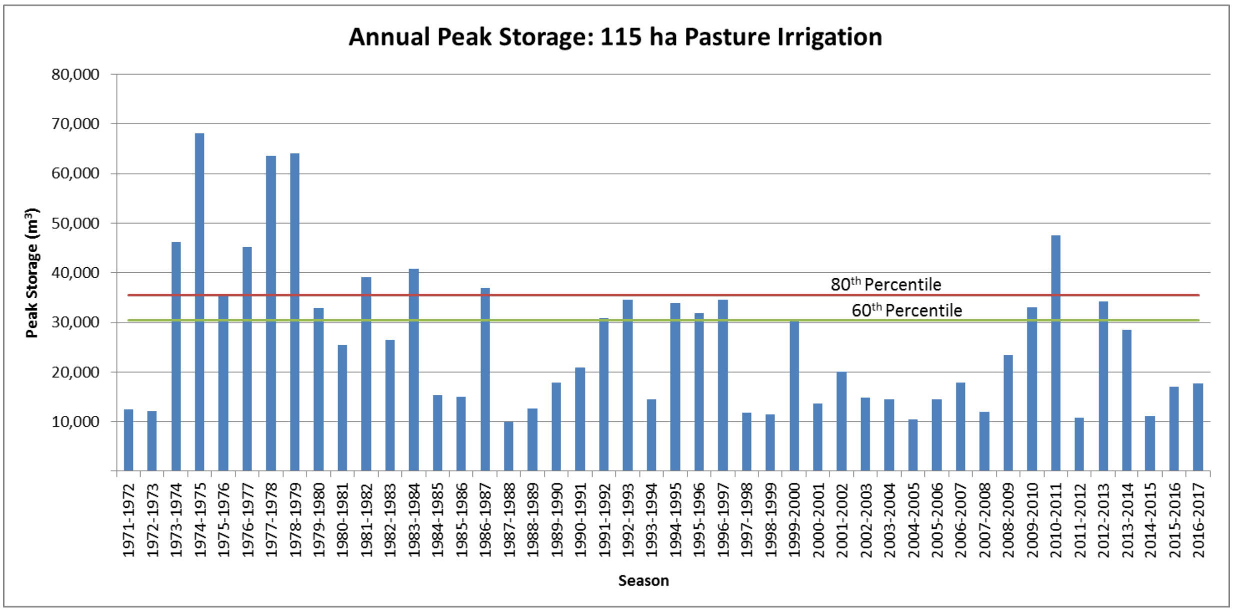

Figure 5: Annual Peak Storage

Figure 5 shows that the 1974 to 1975 season results in the highest peak storage volume (69,000 m^3). The 80th percentile peak storage is 36,000 m^3. This represents a typical irrigation scheme where storage is provided to meet demand approximately 4 out of 5 years. If the storage provided is less than the peak storage (69,000 m^3), excess flow will need to be discharged into the environment via other means.

4.2 Trees or Pasture Irrigation at Robinsons Bay

Table 6 shows the peak storage required for pasture and tree irrigation at Robinsons Bay using the future population estimates. The long term (1972 to 2017) model results have been presented as they produce the most conservative storage volumes.

Table 6: Model Results for Irrigation to Native Trees and Pasture at Robinsons Bay

Native Trees	**Irrigation Land Area (ha)**	**50**	**60**	**70**
	Peak Storage (m^3)	43,000	34,000	28,000
Pasture	**Irrigation Land Area (ha)**	**60**	**80**	**100**
	Peak Storage (m^3)	100,000	85,000	71,000

4.3 Trees or Pasture Irrigation at Pompeys Pillar

Table 7 shows the peak storage required for pasture and tree irrigation within at Pompeys Pillar for the future population estimates. The long term (1972 to 2017) model results have been presented as they produce the most conservative storage volumes.

Table 7: Model Results for Irrigation to Native Trees and Pasture at Pompeys Pillar

Native Trees	**Irrigation Land Area (ha)**	**50**	**60**	**70**
	Peak Storage (m^3)	40,000	31,000	27,000
Pasture	**Irrigation Land Area (ha)**	**60**	**80**	**100**
	Peak Storage (m^3)	105,000	90,000	77,000

5.0 Conclusions

The wastewater flow for Akaroa has been estimated by combining population derived flow with a modelled I&I estimate. The average annual volume of wastewater is approximately 240,000 m^3 to 260,000 m^3 under the current scenario and approximately 250,000 m^3 to 270,000 m^3 under the future (2052) scenario.

Based on the revised wastewater flow estimate for the future population estimates 69,000 m^3 of storage is required to irrigate 115 ha of land at Goughs Bay. The model results show that the required storage volume can be significantly reduced if wastewater is applied using drip irrigation to native trees. There is little difference in the required storage between Goughs Bay, Robinsons Bay and Pompeys Pillar.

6.0 Limitations

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of wastewater flows provided by Beca from Christchurch City Council and the analysis of future flows carried out by Beca. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Beca for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Yours faithfully

PATTLE DELAMORE PARTNERS LIMITED

Prepared by

Richard Brunton
Senior Environmental Engineer

Reviewed and Approved by

Eoghan O'Neill
Technical Director – Water Infrastructure