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6 July 2016

Te Runanga o Ngāi Tahu
P.O. Box 13 046
Christchurch 8141
Attention: Matthew Ross **Delivered by email**

Tēnā koe, Matthew.

Review of Documents Related to Akaroa Wastewater Effluent Land Disposal

In response to your request [Email 28 June 2016] to provide a brief review by 12 July 2016 of three documents supplied I have prepared this letter report. I am responding earlier than requested as there are problems with the Beca report which could be significant to land area requirements. I am wondering if a few questions to CCC/Beca/PDP, would be appropriate. [See Appendix]

Documents Reviewed

Akaroa Wastewater Upgrade Irrigation – Preliminary Geotechnical Assessment, CH2M Beca, 13 June 2016 ['Beca Report']
Infiltration Testing Results for Akaroa Wastewater Disposal via Irrigation [v2], PDP, 16 June 2016 ['PDP Report']
Akaroa Wastewater Irrigation to Land Investigations, covering Letter CH2M Beca [Rae Stewart] to CCC [Bridget O'Brien], 15 June 2016 ['Beca Letter']

Notes on the Beca Report

1. Pre-existing land instability at higher elevations is noted. But there is no information about land instability under trees. Canopy interception of heavy rain, litter on the soil surface and tree root systems all contribute to greater stability under trees than for pasture. Extra downslope weight with trees can contribute to less stability, but only on steep slopes.
2. Effluent loading rates [mm/day] suggested by PDP are accepted:

	Summer	Winter	Other
Pasture	7.1	?	?
Trees	5	1.5	3

As a result of an email exchange with PDP [Brough/Offer 15.6.2016], it is stated that: "The average net infiltration rates, accounting for evapotranspiration are expected to be 1.12 mm/day to pasture and 0.85 mm/day beneath trees …."
And further: "the measured infiltration rates have been reduced by a factor of twenty five to allow for variability in ground conditions and the limited number of test results."
This factor is said to be adopted from "EPA (1984)", but I think this is a typographical error, 'EPA (1981)' intended. A note in their Table 5.2 states: "A factor of 25 has been applied in accordance with EPA (1984) that estimates that the loading rate measured by ring infiltration testing is 2 - 4 % of the "effective rate."

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On this basis, test infiltration rates in the topsoil at four sites of 20, 12, 8 and 30 mm/hr are reduced to "factored infiltration rates" of 0.8, 0.48, 0.32 and 1.2 mm/hr. **These are extremely low rates.**

I consider Beca have misunderstood and misinterpreted the EPA Guideline provisions. [They should not be referring to the 1981 edition as there is a 2006 revised edition. Also, they would be better off using the NZ Land Treatment Collective guidelines (2000).]

- It is stated in S10.3.3 of USEPA (2006) that: "Cylinder infiltrometers greatly overestimate operating infiltration rates. When cylinder infiltrometer measurements are used, annual hydraulic loading rates should be no greater than 2 to 4 percent of the minimum measured infiltration rates." This statement is in Chapter 10 on "Soil Aquifer Treatment". Chapter 10 assumes basin infiltration. It is also in the context of expected effluent suspended solids as in its Table 2-3 [for Soil Aquifer Treatment] of 20-274 g/m^3, BOD concentrations as in its Table 10-1: 15-228 g/m^3. It is also stated in S3.5.1: "To account for required intermittent applications (reaeration), the variability of the actual soil permeability within a site, and the potential reduction with time, a small percentage of the vertical permeability is used as the design percolation rate. This small percentage ranges from 4 to 10 percent of the saturated vertical permeability as shown in Figure 3-5. The value used for clear water permeability should be for the most restrictive layer in the soil profile. **Design rates based on field measurement (Section 3.8) may be calculated using different percentages."**
- The comparable statements in USEPA (1981) are in: (a) S4.5.1 of Chapter 4 on "Slow Rate Systems": "4. Establish a maximum daily design percolation rate that does not exceed 4 to 10% of minimum soil permeability. Percentages on the lower end of the scale are recommended for variable or poorly defined soil conditions. **The percentage to use is a judgement decision to be made by the designer**." (b) In S5.4.1 is stated: "… infiltration rates decrease as wastewater solids clog the soil surface. Thus vertical conductivity measurements over-estimate the wastewater infiltration rates that can be maintained over long periods of time. For this reason, and to allow adequate time for drying periods and for proper basin management, annual hydraulic loading rates should be limited to between 4 and 10% of the measured clear water permeability of the most restrictive soil layer." This chapter assumes basin infiltration and gives examples of effluent BOD concentrations as in its Table 4-1 of 24-92 g/m^3.
- The lowest percentage in the USEPA (1981) range [4%] seems to be what the Beca report uses to choose their "factor of 25".
- The proposed Akaroa land disposal system is either sprinkler irrigation for pasture or subsoil perforated pipe for trees. The expected total suspended solids and $CBOD_5$ of the effluent are 2-4 g/m^3 and 5-10 g/m^3. These are one or two orders of magnitude less than those in the USEPA context and examples.
- **The effluent quality and application methods proposed for Akaroa land application are very different from the contexts discussed in USEPA (1981) and USEPA (2006). The Akaroa effluent is essentially clear liquid. Soil surface clogging will not occur in either case of irrigation to pasture or under trees. The "factor of 25" should not be applied.**

3. As the infiltration rates as in 2 above are used in the mounding calculations, these are probably also incorrect. Simplifying assumptions in the mounding calculations could be unrealistic and have significant effects on the conclusions.
4. It seems that hydraulic conductivity, K, in Table 5.2 is taken from the PDP infiltration rate, without taking piezometric gradient in to account. Although this would be an error, the numerical values are probably similar. [PDP report p. 7: "Infiltration rates of the sub-surface

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soil ranged from 0 mm/hr to around 30 mm/hr. The bulk hydraulic conductivity of the loess in the area is of similar magnitude."]

Notes on the PDP Report

1. The double-ring infiltrometer method used for the infiltration field tests is accepted as good practice by CCC and other agencies. Of two procedures, PDP have used the 'Falling Head' procedure; the alternative 'Constant Head' procedure is preferable and research papers I have seen show that it gives more accurate results. ["Care must be taken to maintain the water levels in the inner and outer cylinders at the same level during the measurements." (USEPA 2006)] This is a minor comment and I accept the infiltration values obtained are fit for purpose.
2. A road reserve [Site 3] is probably not a good place to measure infiltration. The soil profile will have been disturbed and might also be compacted.
3. As for the Beca report, reference is made to USEPA (1981) to note that the double-ring infiltrometer method over-estimates vertical infiltration. USEPA (2006) states in S10.3.3: Cylinder infiltrometers greatly overestimate operating infiltration rates. When cylinder infiltrometer measurements are used, annual hydraulic loading rates should be no greater than 2 to 4 percent of the minimum measured infiltration rates." But see the comments on this in Beca Report 2 above.
4. USEPA (1981) is also quoted as stating: "the double ring infiltration test can over-estimate the true infiltration rate by as much as 40%." So their Table 3 measured infiltration rates of 0 to 30 mm/hr are reduced to "likely saturated rates" "in the order of 0 to 18 mm/hr" [as if 30 was a 67% over-estimate!]. Even correcting the arithmetic, I consider 0 to 21.4 mm/hr as pessimistic.
5. No infiltration rates were measured under trees – an important omission. During assessment of the site of the Wainui effluent disposal site, similar rates are said to have been measured as now measured at Takamatua sites. As far as I know, no wastewater runoff has occurred at Wainui.
6. As an overall comment, the loading rates adopted previously by Beca for trees of 5 mm/d summer; 1.5 mm/d winter, 3 mm/d other,and 7.1 mm/d for pasture, said to have been based on parameters used to size and consent the Wainui scheme, seem likely to be conservative.
7. The comment that it "may be possible to deep rip these soils to help improve the sub-soil drainage allowing higher application rates" is a positive suggestion which should be a requirement at the design stage. This would also be likely to increase the Profile Available Water.

Notes on the Covering Letter

1. The letter accurately summarises the two reports.
2. Acceptance of report contents such as effluent loading rates, Profile Available Water, land stability Factors of Safety and other aspects is appropriate in a covering letter but needs to be reconsidered to the extent that report contents are needing to be reconsidered.

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Summary

Information in these two reports additional to that in the Beca "Concept Design Report for Alternatives to Harbour Outfall" is appropriate and useful. I consider that there is a significant misunderstanding of cited material evident in the Beca report which needs to be re-examined. It seems likely that this misunderstanding has affected the land stability estimations, which would in turn affect land areas required.

The omission from field measurements of infiltration under trees at suitable sites, and some apparently very conservative reductions of measured infiltration rates to loading rates, also contributes to possible over-estimation of land area requirements.

The perception of land stability issues at higher altitudes and on gently sloping land above steeper slopes above populated areas, and possibly the geotechnical information for these issues once re-examined, makes it even more important that appropriate information on application of effluent under trees and positive and negative effects on stability be provided. A strong case is emerging for:

- Land application of effluent under trees
- Pre-treatment of land for permeability enhancement and root growth
- Application by buried perforated pipe
- Mixed indigenous tree and under-storey species appropriate to the area
- Retaining the proposed treatment plant, but with nitrogen removal reconsidered
- Effluent loading rates according to effluent volumes by season, infiltration rates and nitrogen loads
- Multiple purpose disposal sites for amenity values

Ngā mihi,

David Painter
Dr DJ Painter BE(Hons); PhD; F.IPENZ; Principal

Appendix: Questions I would like to have answered by CCC/PDP/Beca

1. What information has been considered on land stability under trees? I understand that canopy interception of heavy rain, litter on the soil surface and tree root systems all contribute to greater stability under trees than for pasture. Extra downslope weight with trees can contribute to less stability, but only on steep slopes.
2. In the light of Q1 and other information such as proximity and size of blocks, is it certain that: "The same land that would be suitable for irrigation to trees would be suitable for irrigation to pasture."? [Concept Design Report Executive Summary]
3. What are suggested effluent loading rates for pasture [7.1 mm/day Summer] in Winter and at other times?
4. Has effluent surface runoff as a result of loading rate exceeding infiltration rate ever been observed at the Wainui Wastewater Scheme?
5. Why was the use of a 'falling head' procedure for the double-ring method preferred to a 'constant head' procedure? [PDP Letter Report]
6. Why were no infiltration tests on loess under trees carried out? What rate would be expected?
7. What would infiltration rates be following deep ripping at sites where an impermeable layer [0 mm/hr] was encountered?

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8. Why is USEPA (1981) cited when there is a 25-year-younger revised and updated edition USEPA (2006)?
9. Why has reference not been made to the NZ Land Treatment Collective Guidelines (2000) for utilisation of sewage effluent on land?
10. Why was a factor of 25 times reduction used "to allow for variability in ground conditions and the limited number of test results" [Table 5.1 in the Preliminary Geotechnical Assessment]. Was the completely different effluent and application [low TSS and BOD; sprinkler or perforated pipe] at Akaroa compared to context in USEPA (1981) [high TSS and BOD, basins] taken in to account?
11. Was hydraulic gradient used in deriving the hydraulic conductivity in Table 5.2 from infiltration test results? [D'Arcy's Law]
12. Why is it considered reasonable to reduce measured infiltration rates [Table 3 of PDP Letter Report] from 0 to 30 mm/hr to "likely saturated rates" of 0 to 18 mm/hr? I note that the USEPA (1981) over-estimate 40% is the extreme of some examples of 1981 practice and that 30 down to 18 implies an over-estimate of 67%.
13. Are the "average net infiltration rates, accounting for evapotranspiration" of 1.12 mm/day to pasture and 0.85 mm/day beneath trees [PDP email Brough/Offer 15.6.2016] intended to be a year-round daily average? Do they differ only because of different application rates assumed or are different AETs due to crop factors assumed?
14. Why is it assumed that "no water is lost through evapotranspiration" in groundwater mounding calculations [Preliminary Geotechnical Assessment S5.2]?
15. Do the mounding calculations allow for lateral flow down the increasing lateral piezometric gradient?
16. Is the monotonously linearly increasing mounding height shown in Figure 5.1 considered to be physically reasonable?
17. Why is the Proposed Loading Rate in Table 5-2 [0.014] "Double the maximum loading rate" previously suggested? [Sites either do or do not have a zero permeability layer.]
18. What would the expected effects be on Summary conclusions [Preliminary Geotechnical Assessment]:

> The proposed loading rate is expected to result in an increased moisture content and groundwater mounding in the loess. The latter will accumulate with time if the application of wastewater is ongoing and is not mitigated by evapotranspiration effects.
>
> the margin of stability of steeper areas downslope of the proposed irrigation blocks may reduce by 10 to 20 % after 1 year of treated wastewater application
>
> the short term stability, as might be experienced during an earthquake, could decrease by 30 % to 40 % ignoring any reduction in soil suction or mechanical bonding.

of more realistic consideration of evapotranspiration, groundwater and loess geometry and undrained shear strength?

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22 August 2016

Attention: Bridget O'Brien

Dear Bridget

Response to David Painter Letter "Review of Documents Related to Akaroa Wastewater Effluent Disposal"

On 16th June 2016 CH2M Beca (Beca) issued reports on the geotechnical ground testing and infiltration testing that had been undertaken for Akaroa Wastewater in May 2016 by both Beca ("Akaroa Wastewater Upgrade Irrigation – Preliminary Geotechnical Assessment" dated 13 June 2016) and Pattle Delamore Partners (PDP) ("Infiltration Testing Results for Akaroa Wastewater Disposal via Irrigation"). Christchurch City Council (Council) passed this information to the Ngāi Tahu parties for their review.

On 13th July 2016 we received a copy of a letter from David Painter titled "Review of Documents Related to Akaroa Wastewater Effluent Disposal" dated 6th July 2016 and issued as Draft. We have reviewed the questions raised in Mr Painter's letter and offer our response to these.

As an overarching statement we note that the comments raised by Mr Painter are very detailed. The reports being reviewed were provided as summaries of preliminary physical ground testing undertaken to better inform the concept design assumptions around slope stability and infiltration rates. The reports were not intended to be (and are not) wastewater disposal design reports or feasibility assessments of disposal of wastewater to land.

Responses to the individual questions raised by Mr Painter are included in the attached table. As mentioned at our hui on Tuesday 2nd August, we have considered the matters raised by Mr Painter and don't consider that any of these would affect the overall findings and conclusions of the land testing reports submitted. We would be happy to discuss these responses further if required.

Yours faithfully

Raelene Stewart
Job Manager

on behalf of
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No	Question from Mr Painter	Response from Beca/PDP
1	What information has been considered on land stability under trees? I understand that canopy interception of heavy rain, litter on the soil surface and tree root systems all contribute to greater stability under trees than for pasture. Extra downslope weight with trees can contribute to less stability, but only on steep slopes.	The 13 June 2016 report is a geotechnical report that provides a conceptual assessment of groundwater response to application of wastewater; it is not an assessment of the feasibility of disposal of wastewater to land, nor is it a land disposal design report. Trees may intercept water, induce pore water suction and provide minor shallow mechanical stabilisation through their roots, however they would not noticeably influence the high level slope stability findings of this geotechnical report.
2	In the light of Q1 and other information such as proximity and size of blocks, is it certain that: "The same land that would be suitable for irrigation to trees would be suitable for irrigation to pasture?" [Concept Design Report Executive Summary]	Some of the statements in the concept design report are superseded by the findings of the land testing report. The assessment of suitable land is being updated for these findings.
3	What are suggested effluent loading rates for pasture [7.1mm/day Summer] in Winter and at other times?	The PDP report states that there should be no application in winter subject to a soil moisture balance. Given winter evapotranspiration rates are low (1mm/day or less) if any application is made over winter it will be at rates that typically average less than 1mm/day. Note the application depth may be a few mm subject to the soil moisture balance but this will represent several days of ET losses. Throughout the rest of the year the same approach would be taken.
4	Has effluent surface runoff as a result of loading rate exceeding infiltration rate ever been observed at the Wainui Wastewater Scheme?	There have been no reports of runoff at Wainui. The current loading rate is well below the design loading rate.
5	Why was the use of a 'falling head' procedure for the double-ring method preferred to a 'constant head' procedure? [PDP Letter Report]	The falling head test is used as it is simpler to manage than the constant head.
6	Why were no infiltration tests on loess under trees carried out? What rate would be expected?	Tests were carried out at locations that also allowed geotechnical investigations. This meant open country was preferred. The results are consistent with those under trees at Wainui.
7	What would infiltration rates be following deep ripping at sites where an impermeable layer [0mm/hr] was encountered?	Infiltration rates following deep ripping are uncertain but are likely to be similar to those areas where there was no pan identified (12 – 24 mm/hr) provided the ripping allowed complete penetration of the 0 mm/hr layer and this was able to be maintained.

No	Question from Mr Painter	Response from Beca/PDP
8	Why is USEPA (1981) cited when there is a 25 year younger revised and updated edition USEPA (2006)?	USEPA (1981) provides additional detail with respect to interpretation of small scale testing such as double ring infiltrometer testing. It suggests that where such tests, which can overestimate permeability are used the long term rate could be as low as 2 % to 4 % of that measured The PDP report only refers to the 1981 USEPA document as it is the reference for the reduction in infiltration rates. The 2006 USEPA report refers back to the 1981 report on that specific matter.
9	Why has reference not been made to the NZ Land Treatment Collective Guidelines (2000) for utilisation of sewage effluent on land?	USEPA guidance is, in our view, wider ranging and more useful for the assessment carried out
10	Why was a factor of 25 times reduction used “to allow for variability in ground conditions and the limited number of test results” [Table 5.1 in the Preliminary Geotechnical Assessment]. Was the completely different effluent and application [low TSS and BOD; sprinkler or perforated pipe] at Akaroa compared to context in USEPA (1981) [high TSS and BOD, basins] taken into account?	The reductions applied to infiltration rates are considered appropriate. The findings of the geotechnical report will not noticeably alter with consideration of evapotranspiration. Groundwater mounding was considered only below the area of application grading down to assumed present groundwater level.
11	Was hydraulic gradient used in deriving the hydraulic conductivity in Table 5.2 from infiltration test results? [D’Arcy’s Law]	Double ring infiltrometer and falling head tests were carried out and calculation of K followed accepted practice (this includes consideration of change in head with time).
12	Why is it considered reasonable to reduce measured infiltration rates [Table 3 of PDP Letter Report] from 0 to 30mm/hr to “likely saturated rates” of 0 to 18mm/hr? I note that the USEPA (1981) over-estimate 40% is the extreme of some examples of 1981 practice and that 30 down to 18 implies an over-estimate of 67%.	There are insufficient tests for such a wide area of investigation to confidently predict the higher infiltration rates. It is prudent to use a more conservative infiltration rate at this time. It is noted that there is an error in the PDP report as an overestimation of 40% brings the infiltration rate down from 30 mm/hr to 21 mm/hr not 18 mm/hr as reported. This change does not impact on the conclusions reached.
13	Are the “average net infiltration rates, accounting for evapotranspiration” of 1.12mm/day to pasture and 0.85mm/day beneath trees [PDP email Brough/Offer 15.6.2016] intended to be a year-round daily average? Do they differ only because of different application rates assumed or are different AETs due to crop factors assumed?	These are year round daily averages and differ because of both different application rates and loss factors (ET/interception of rainfall).

No	Question from Mr Painter	Response from Beca/PDP
14	Why is it assumed that “no water is lost through evapotranspiration” in groundwater mounding calculations [Preliminary Geotechnical Assessment S5.2]?	The effect of evapotranspiration is not expected to be significant in relation to the net mounding of groundwater in the loess. The order of mounding estimated is used to assess influence on land stability not design of the infiltration system. The PDP drainage calculations take into account evapotranspiration (as well as other losses that would occur before water drains through the soil - notably runoff and interception by tree canopy).
15	Do the mounding calculations allow for lateral flow down the increasing lateral piezometric gradient?	Groundwater mounding was considered below the area of application grading down to assumed present groundwater level.
16	Is the monotonously linearly increasing mounding height shown in Figure 5.1 considered to be physically reasonable?	The calculations demonstrate that groundwater mounding could occur and the graph in Figure 5.1 gives an indication of the rate of mounding and mounding height for use in slope stability assessment. Obviously mounding would not increase linearly ad-infinitum.
17	Why is the Proposed Loading Rate in Table 5-2 [0.014] “Double the maximum loading rate” previously suggested? [Sites either do or do not have zero permeability layer].	Because half of the sites indicated 0 mm/hr application rate, double the loading rate was applied to the remaining area.
18	What would the expected effects be on Summary conclusions [Preliminary Geotechnical Assessment]” ■ The proposed loading rate is expected to result in an increased moisture content and groundwater mounding in the loess. The latter will accumulate with time if the application of wastewater is ongoing and is not mitigated by evapotranspiration effects. ■ The margin of stability of steeper areas downslope of the proposed irrigation blocks may reduce by 10 to 20% after 1 year of treated wastewater application ■ The short term stability, as might be experienced during an earthquake, could decrease by 30% to 40% ignoring any reduction in soil suction or mechanical bonding. Of more realistic consideration of evapotranspiration, groundwater and loess geometry and undrained shear strength?	The purpose of the assessment was to gain an understanding of the potential impact of land application of wastewater on slope stability. Consideration of location-specific slope and piezometric geometries, evapotranspiration and mounding might result in local differences to the findings, however they would not alter the overall findings of the stability assessment presented which is a high level on-average assessment.