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+64-21-2800750

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Review of Resource Consent Application submitted by Castlerock Farming Company

Abigail Lovett

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Contents

1.0 Introduction

Environment Southland engaged Earth & Environmental Science Ltd (E&E Science) to undertake a technical assessment of the application (APP-20181676) lodged by Landpro on behalf of Castlerock Farming Company Limited (CFCL). The purpose of this report is to provide a review of information provided in the application regarding the assessment of effects of the proposed activities on the receiving environment, including a detailed assessment well interference and stream depletion effects. This review is based on the entirety of the consent application, and includes amendments and changes made by the applicant. All information lodged for the consent application and presented on the Environment Southland website as of July 2020, and further documents and emails provided by the applicant have been considered, including:

- Application dated 11 January, 2019 (Landpro, 2019a);
- RFI issued by Environment Southland (Environment Southland, 2019);
- Response to the RFI 12 March, 2019 (Landpro, 2019b);
- Updated hydrogeological calculations for Castlerock Farming Company Ltd groundwater take application: 18 July, 2020 (Landpro, 2020);
    - Castlerock Dairies Hydraulic Testing Report (31 pages; Liquid Earth, 2020)
- Liquid Earth, 2020. Castlerock Dairies - Request for further information. Prepared by Liquid Earth for Landpro. 13p.

2.0 Consent Application summary relevant to assessment

The following information has been obtained from the consent application documents and is relevant to the technical review:

- CFCL and Okaiterua Ltd. own and operate six properties covering approximately 730 ha; the consent application is for the dairy farm at 72 Castlerock Rd, Lumsden (Figure 2.1).
- CFCL have a number of existing consents that allow for operation of the Dairy Platform, including to take surface water from the Oreti River for irrigation, and groundwater abstraction for stock supply;
    - Continuation of a surface water take from Oreti River (Permit 301933) with maximum allocations of 14,000 m^3/day and 1,260,000 m^3/year, at a rate up to 50 L/s, over a maximum of 28 days continuous (Landpro, 2019);
- CFCL are seeking a consent drill and install up to twelve bores;
    - six bores are intended to be used for groundwater abstraction from the Lumsden Aquifer for the purposes of irrigation, dairy shed washdown, and stock drinking water; proposed maximum allocations of 4,320 m^3/day, 133,745 m^3/yr (updated 2020) at a rate up to 50 L/s;
    - (up to) six additional bores are intended to be used for aquifer testing and/or groundwater monitoring (Landpro, 2019b)
- Additional groundwater is required to supplement the consent allocation of surface water, largely since a low flow cutoff restricts irrigation in (typically) the driest months; and the applicant proposes simultaneous surrender of existing consent AUTH-20171428-02 (43,600 m^3/year) (upon exercising of the new water permit).

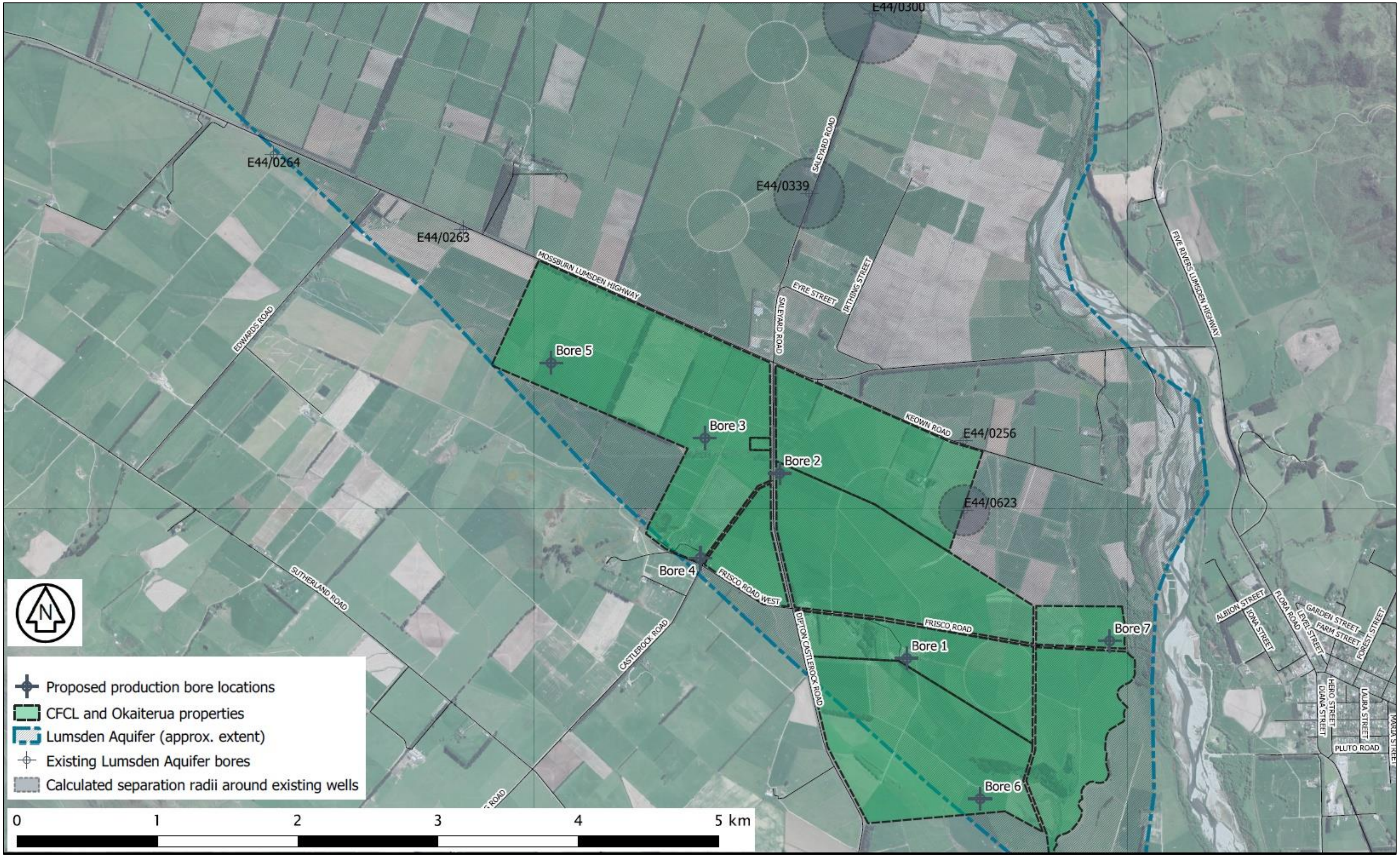


Figure 2.1: CFCL and Okaiterua property boundaries including location of existing and proposed bores (Landpro, 2019a).

3.0 Description of existing environment (Section 2 & Attachment C) relevant to the review

Basic information regarding the geographic setting (e.g., location, topography, heritage, climate, hydrology & soils) in the vicinity of the applicant's property was provided (Pg., 18 – 25; Pg., 59 – 66; Landpro, 2019a). Overall, the hydrogeological setting is characterized by a shallow, unconfined aquifer (Castlerock GMZ) with flow generally following topography, and a deeper semi-confined aquifer (Lumsden GMZ).

- Recharge to the Castlerock aquifer occurs predominantly from rainfall recharge,
- Recharge to the confined / semi-confined zone of the Lumsden aquifer is through vertical leakage from the overlying Castlerock aquifer (Pg., 64; Landpro, 2019a).
- Current centre pivot irrigation coverage (234 ha) with to expand irrigation up to 400 ha total (under an existing permit) were provided.

Table 3.1: Summary of the existing environment for Castlerock (Landpro, 2019a and 2019b).

Surface water	Groundwater Management Zone	Physiographic Zone	Soil types
Murray Creek, Oreti River, New River Estuary	Castlerock (unconfined) Lumsden (confined, semi-confined)	[Not provided]	Morven, Eureka

The following points associated with the 'geographic setting' and 'site description' are important to consider regarding the hydrogeologic setting (Hydrogeology (Pg., 62 – 66; Landpro, 2019a):

- Qmap is a surficial geological map and has limited use for subsurface geology;
- An improved understanding of the spatial representation of bore locations would be been beneficial to the reader, in particular to reduce time spent interpreting information in the consent application (e.g., mapping of bore location with a label of hydraulic properties (Table 1 (Table 6 of SKM report)) would have depicted clearer representation of spatial distribution of bores and hydraulic properties;
- if a clear spatial difference in hydraulic properties existed (e.g., "… *transmissivity of the aquifer south of the Ōreti appears to decrease slightly*"), it is suggested that a better approach would have been to 'group' bores based on location and similar properties (e.g., K = 24 – 80 and K = 100 – 335), rather than to take an arithmetic mean; this applies for transmissivity (T) also;
- plotting the location of Environment Southland groundwater monitoring bores (e.g., Ellis Road; Castlerock) would have further enhanced interpretation of available data; and
- there is potential (at least visually) for a gradual increase in the extent of seasonal drawdown (e.g., summer drawdown is increasing); recovery over time appears to be relatively consistent towards a seasonal peak of around 208.5 m AMSL in Castlerock, but a very slight declining trend in groundwater level may be occurring at Ellis Road; the trends in groundwater levels could have been quantified.

Addition information was provided by the applicant in response (Landpro, 2019b) to an RFI from Environment Southland (ES, 2019). Key information includes the following (Figure 2.1):

1. Approximate locations of existing (Bore 1) and proposed bores (Bores 2 – 7):
    - Bore 1 1242502 mE 4925081 mN E44/0370
    - Bore 2 1241566 mE 4926393 mN (proposed to remove, November, 2019)
    - Bore 3 1241032 mE 4926645 mN
    - Bore 4 1240999 mE 4925789 mN
    - Bore 5 1239935 mE 4927181 mN
    - Bore 6 1242995 mE 4924073 mN
    - Bore 7 1243920 mE 4925199 mN
2. A map showing location of proposed bores relative to surface waterways (e.g., Murrays Creek, Oreti River), and riparian boundaries / seepage wetlands.
3. Identification of seven wastewater disposal systems (e.g., septic tanks) with Bore 4 being identified as the only bore within close proximity (*c.* 150 m) of these sites (e.g., house at 72 Castlerock Rd.).

4.0 Assessment of Environmental Effects (Section 5; Attachment C – Section 3; email communications)

4.1 Effects on neighboring wells relevant to assessment

The following information from existing documents is relevant to consideration of potential effects on existing groundwater users / neighboring bores/wells:

- a map showing the location of 'proposed take/s' and other users would have been useful;
- Table 2 (Pg., 68; Landpro, 2019a) would have been improved with all bores within a specified 'radius' of the proposed wells, and for all depths to be converted to m AMSL (rather than m BGL) to allow for comparison between sites.
- Table 3 (Pg., 69; Landpro, 2019a): the selection of hydraulic property values (e.g., hydraulic conductivity, transmissivity, storativity) are likely to result in an overly conservative or non-conservative result; this is because it is apparent that two 'groups' of hydraulic properties (representing estimates of actual aquifer conditions) appear in the data (e.g., Table 1; Pg., 65; Landpro, 2019a), and an arithmetic mean is not an appropriate selection.
  - Transmissivity (T) values range from 600 – 3,700, with 'groups' being defined as lower values (e.g., T = 600 – 700) and higher values (e.g., 1,850 – 3,700).
  - Hydraulic conductivity (K) values range from 24 – 335, with 'groups' being defined as lower values (e.g., K = 20 – 80) and higher values (e.g., 100 – 350).
- The issue of whether hydraulic values were conservative or otherwise was addressed through the requirement that the applicant undertook aquifer testing, as per email discussion in November, 2019. It was stated by the applicant that:
  - "*If the Aquifer Testing Reporting … shows that aquifer properties are significantly different (greater than +\- 25%) from those assumed properties in the application, updated calculations or other assessment shall be provided to either:*
    a. *confirm that the interference effects of the water take will be acceptable in accordance with the definitions specified in Appendix L.3 of the WLP, … or*
    b. *propose mitigation measures (such as a reduction in the rate of take) to ensure that interference effects are acceptable … (as defined in Appendix L of the PSWLP).*"
  - The abovementioned statement is the basis for the assessment of the supplementary report, prepared in July, 2020 (assessed in in this review report);
- The application refers to Section 3 (Landpro, 2019a) and indicates (Pg., 34; Landpro, 2019a) "*… effects are expected to be 'acceptable' (according to ES's definition) provided that the water take occurs approx. 180 m or more from the closest relevant bore (E44/0623). The proposed well locations are at least 1.1 km from that bore, and interference effects on neighbouring bores will be insignificant and therefore less than minor.*"
  - The level of uncertainty in the original estimates means that this statement has the potential to be applicable, but that it cannot be guaranteed that this would be the case.

4.2 Effects on stream depletion (relevant to M. Killick emails)

The applicant indicates the likelihood for semi-confined aquifer conditions to be present and potential for stream depletion to occur. Modelling of the stream depletion effects was undertaken and summarised as follows "*… modelled stream depletion for a stream 50 m away from a well taking 50 L/s is approx. 0.5 L/s (~1 %) after 7 days and 1.3 L/s (~3 %) after 28 days, which is the maximum permissible duration of uninterrupted pumping under the proposed conditions. This corresponds to a low degree of surface water depletion (as defined in the WLP), and therefore we consider that the proposed take is highly unlikely to result in any observable effects on surface water near the proposed take*" (Pg., 34; Landpro, 2019a).

The following are considerations regarding stream depletion:

- Initial stream depletion modelling was undertaken using an appropriate method, however, the reliability of parameters used for the modelling had a degree of uncertainty.
- ES queried whether a stream bed conductance value of 1-10 m/day was more representative than the 0.1 m/day that was used (ES, 2019).
    - the applicant provided justification regarding the selection of the parameter value that was supported using information described in the geographic and site setting, valid references, and previous examples.
- Environment Southland stated that the stream bed conductance value was not conservative, and that an agreed value had not been obtained for Murray Creek or the Oreti River.
    - An example using the Ward and Lough (2011) method was provided using a bed conductance of 50 m/day; bore distance of 300 m from the river; aquitard conductance 0.0015/day (aquitard thickness of 15.5 m); and a proposed take of 50L/s is still 'High' (30.5L/s, 61% of pumping, after 28 days. This scenario demonstrated the potential for a higher level of stream depletion that would be appropriate, even with some parameters (e.g., aquitard thickness) being considered conservative.

4.3 Effects on other relevant parameters (aquifer sustainability, water quality, and efficiency of use)

In regard to effects on sustainability and stream depletion:

- Environment Southland indicated in the RFI that the remaining allocable take in the Lumsden Aquifer was approximately 73,900 m^3/yr, rather than the approximately 122,200 m3/yr that the applicant was seeking (ES, 2019), this has been adjusted;
- It has not been suitably demonstrated that there is "*no signs of overallocation*".

The application indicates that indirect effects on water quality, as a result of the take, would be negligible, based on the following (Pg., 34 – 35; Landpro, 2019a):

- it does not result in any intensification of the farming system "… *total amount of water able to be taken by CFCL will not increase (including their existing surface water take).*"; and
- soil moisture would be expected to be low and therefore there is a low (relative) risk of nutrient leaching "…*the risk of nutrient leaching to shallow groundwater or phosphorus runoff is at its lowest*".

The application demonstrated reasonable efficiency of use of the water resource, in particular, the take:

- will only be used if/when low surface water flows restrict the surface water take;
- includes no changes to the total quantity of water allocation sought and used by the applicant for irrigation (e.g., combined surface water and groundwater take); and
- is deemed to be efficient use of irrigation water "… *4,320 m^3/day would represent efficient irrigation for approximately 75 ha of pivot-irrigated pasture (assuming PAW = 60 mm).*"

5.0 Review of updated hydrogeological information (Landpro, 2020; Liquid Earth, 2020a)

The method for assessment of updated hydrogeological information involved a full read of Landpro (2020), including the attachment of Liquid Earth (2020a). Details of the aquifer testing method, analysis, and results were presented in Liquid Earth (2020a). Detailed notes regarding: bore information and a technical assessment of aquifer testing undertaken on Bore 3 and Bore 1 were provided in Appendix 2. The review was paused for further discussion with the applicant and so that basic information, required for a technical analysis of the aquifer test results, could be provided. The majority of this information was provided, however some fundamental information required for the aquifer testing was not provided.

5.1 Bore information provided in Landpro (2020) and Liquid Earth (2020a)

Poor quality control of the aquifer test and lack of consistency between field data and reports has led to a lack of consistency in reporting. This has made it difficult for the reader to cross check information and be confident in the reliability of bore hole and aquifer testing information and to seek verified information from Environment Southland (Figure 5.1). Further, there were inconsistencies between Liquid Earth (2020a) and borelogs in Landpro (2020). The following are overall comments on the quality of bore log information provided in the report, which was deemed to be of poor quality:

- Drillers borelogs:
    - lacked fundamental information (e.g., static water level, screened intervals)
    - did not correspond particularly well with that presented in Liquid Earth (2020a)
    - 'Bore 3' has been referred to using four different names throughout the reporting (e.g., new bore, Castlerock Dairies 3, Bore 3, E45/0762). It is a fundamental requirement of a hydraulic testing report to clearly present and refer to appropriate bores used for testing and observation, which in this case has not been achieved by the authors.
    - Peizo C was interpreted to be "New small piezo across road"; details in Liquid Earth (2020a) and the driller's log do not match, including location, and screened length and screened interval; the drillers log did not include SWL which was identified to be 2.78 m BGL;
    - Details of Creek Piezo did not match the borelog (Landpro, 2020), including total depth, screened length, and screened interval (Table 6.1);
    - For bores that could be matched there were inconsistencies in the location or construction details (e.g., New Site beside new 300 mm and Creek Peizo were deemed to be the same bore, but 3 m screen on the borelog compared to 1.9 m screen in Liquid Earth (2020a).
- Pg., 33, Figure 1: "*Hydrograph from the Lumsden Aquifer at Castlerock monitoring site, 2010 to 2020.*" Does not lead the reader to identify which monitoring site this data is from, as there are multiple monitoring sites in the aquifer, and should have been clear that the monitoring was from the confined, Lumsden Aquifer.
- Uncertainty around details of monitoring bores existed, so Environment Southland database was searched to cross-check information, including:
    - Bore E44/0256: 53 m BGL, confined, seasonal groundwater level monitoring (2004 – present),
    - Bore E44/0255: 30 m BGL, confined, monthly groundwater level monitoring (2004 – present)
- Overall lack of reporting of groundwater levels is poor quality control. It is essential for the reviewer to have clear details of groundwater levels in (m BGL and/or m AMSL) and of drawdown where it occurs; this is particularly important since there has been an offset of the depths of pumping bores and observation bores in a setting where the static water levels should have been quite different (e.g., SKM (2005) identified static water level in Lumsden Aquifer as above ground level in test bore vicinity.
- An attempt was made by the reviewer (Table A2.1, Appendix 2) to detail bores used in Landpro (2020), including identification of bores used for aquifer testing (e.g., Bore 3 (B3); Dairy Shed Bore (DB) and observation bores for aquifer testing (OBS)). The reviewer compiled Figure 5.1 to better understand the spatial context of bore locations and proximities.

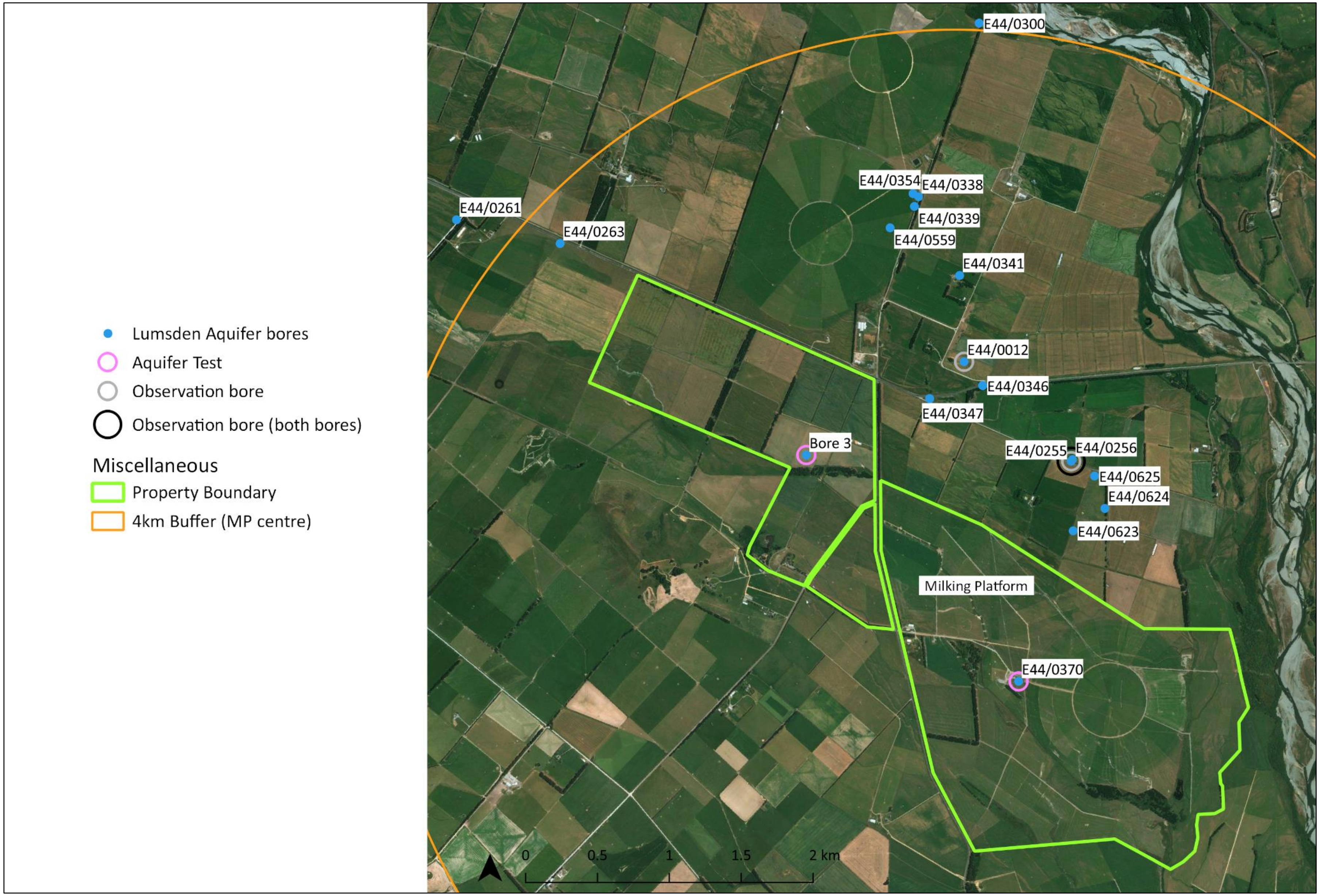


Figure 5.1: Location of bores in the Lumsden Aquifer within an approximately 4 km radius of Castlerock Farm (Environment Southland, 2020). Aquifer test bores (e.g., Bore 3 and Bore 1 (E44/0370)) are shown, as are bores that were used as observation bores in the Lumsden Aquifer during aquifer testing (e.g., E44/0012 and E44/0255) .

5.2 Review of Liquid Earth (2020a) content

There was a high number of typing and formatting errors in the report. This made reviewing and understanding the content of the report difficult for the reader, and multiple assumptions or 'best guesses' were required.

- Table 1 (Pg., 33): inconsistencies in labelling, with no consistent name between the borelogs presented in Landpro (2020) or previous submitted documents (as described in Section 6.1); Bore 3: bore depth is incorrectly listed as total drilled depth (including over drilling), rather than installed depth;
- there was insufficient references provided to support data presented in the report, including very few (if any) references to data and information provided in Tables and Figures throughout the report.
  - A lack of referencing made it difficult for the reader to have confidence in the quality of information and/or to cross check information with the source.
  - Table and Figure titles generally lacked a sufficient description to fully understand the data that was being presented. Tables and Figures should be able to be read and interpreted without the need to refer to the text in the body of the report, however, this was not possible.
    - Example: Figure 1 *"Hydrograph from the Lumsden Aquifer at Castlerock monitoring site, 2010 to 2020."* lacked fundamental information of information source, measurement units, and location;
    - Example: Table 1 (and Table 6) "*Bore construction details*", this description does not provide any context for the report, or identify source for quality control).
- Information was sourced from driller's logs provided in Landpro (2020)
  - Identification of source information is important when typing errors (e.g., a bore diameter of 3.51 mm) occur (e.g., Table 6). This information was checked against the bore details for E44/0370 on the Environment Southland bores database for accuracy, and diameter was changed to 150 mm.
  - Written text regularly refers to the incorrect Table (e.g., text indicates "*Drillers logs from the production bore and piezometer are summarised in Table 2.*"). The reader then has to determine that reference was meant to be to Table 7, rather than Table 2.
- These compounding effects constantly lead the reader to check the validity of information and detracts from the readability of the report. Aside from providing technical inaccuracies, it makes it very difficult to absorb information provided in the report and be confident in the level of quality control of the aquifer testing and report writing.
- Datasets were requested from Environment Southland (2020) to clarify inconsistencies (Figure 6.1).
- The hydrogeology of the site was characterised as:
  - unconfined aquifer (< 9 m BGL);
  - clay-bound gravels (aquitard) (11 – 29 m BGL); and
  - confined / semi-confined aquifer (30 – 56 m BGL).

5.3 Review of aquifer test method (Liquid Earth, 2020a)

Overall, an insufficient description of aquifer test method for Bore 1 and Bore 3 were provided in the report as detailed in Appendix 2. In particular, there was lack of appropriate:

- Description of antecedent conditions in the pumping bores, including lack of initial water level data;
- Description of equipment used (e.g., loggers, manual water level measurement indicators, manual flow measurement; pump type; pump capacity; pump power supply);
- Description of methods used (e.g., manual flow measurement; depths loggers installed; programming of dataloggers including intervals)
- Disposal of pumped water (e.g., for Dairy Shed bore, is interpreted to have infiltrated into unconfined aquifer and influence monitoring piezometer B)

- Quality control of aquifer test measurements (e.g., no manual measurements for > 12.5 hours during testing)
- Location of observation bores has left observation bores that are quite a distance away for the pumping rate; either didn't carry out the corrections to get an accurate cure match on drawdown data at distance, really difficult to get a good curve match when it is some distance (e.g., > 1 km); can have an enormous amount of slop in T and S coefficients and leakage that are derived from the data
- The curve matching to distant monitoring bores (e.g., 1.5 – 2 km) with a very low drawdown compared to the pumped bore (e.g., 22 m to 0.17 m) puts the observation on a thin edge of the drawdown cone, and reduces the reliability, particularly compared to a monitoring bore in closer proximity (e.g., < 500 m) of the pumping site.
- In addition, the two bores were tested independently however the proposal seeks a 'borefield' type of abstraction setting with up to six bores pumping at the same time. Therefore, the cumulative effects of abstraction from multiple locations would need to be determined. This cannot be obtained from the information presented so far.

5.4 Aquifer test interpretation

Additional aquifer test result data was available that had not been analysed for Bore 3 and Bore 1. This included recovery data for the step drawdown testing in Bore 3 and drawdown data from both tests that were digitized from figures presented in the report. As part of this review, transmissivity values were estimated through aquifer test analyses (e.g., averaging the pumping rate throughout the test (Q/t) and solving through the Eden Hazel method) (Appendix 1). Results indicated significantly lower transmissivity values (e.g., 29 – 90 m^2/day) compared to those presented in Liquid Earth (2020a).

- Bore 3 Step Drawdown T = 29.1 m^2/d
- Bore 3 Theis Recovery T = 95.2 m^2/d
- E44/0370 Step Drawdown T = 89.7 m^2/d

Based on this information, it would be reasonable to suggest that the pumped aquifer has a Transmissivity that is closer to 100 m^2/d than 1,500 m^2/d on the basis of step drawdown pumped bore data. The decision was made to terminate the review process and to engage with the processing officer and applicant.

5.5 Reliability of (initial) aquifer testing information

Based on the entirety of information presented in the updated hydrogeological report (Landpro, 2020; Liquid Earth, 2020a) and as summarised in Sections 5.1 – 5.4, it was concluded the reliability of aquifer test results were low to very low. This conclusion does not take into account the considerable typing and reference errors that were evident in the reporting, which add confusion but do not materially change the aquifer testing results.

In response to the issues identified in Section 5.1, 5.2, 5.3, and 5.4, a meeting between the processing officer, applicant, an reviewer was held on Tuesday 18th August, 2020.

6.0 Meeting between applicant, processing officer, and technical reviewer

The following information is copied from an email sent by Ms. Robertson (19 August, 2020) to those parties that attended the meeting. It is provided to provide a record of the discussion and of further information requested (and agreed to be provided by) the applicant.

6.1 Meeting Notes (direct copy)

- *Tim provided a summary of the application to date*
- *Brydon provided a brief overview of the hydrogeological setting and knowledge of the Lumsden Aquifer.*
    - *Including hydrological setting (e.g., North Range Aquifer (confined), boundary with Lumsden Aquifer (confined), and Castlerock Aquifer (unconfined), previous consent applications (SDC, English's), pSWLP*
    - *There was general agreement on the hydrological setting and that overall, although conceptually formed, it is a complex system (e.g., hydraulic properties vary spatially, transition from confined to leaky-confined).*
- *The Aquifer Testing Method and Report were discussed, the following matters were covered in relation to concerns raised in Ms Lovett's technical review:*
    - *Intention of aquifer testing was to understand if parameters used for modelling were acceptable to understand stream depletion and interference effects (in particular on those wells of concern).*
    - *Aquifer testing was carried out by Washingtons. The applicant agreed that the data had limitations.*
    - *Data was collated before the test and following.*
    - *Washingtons had one pump set up with a generator.*
    - *A logger had also been installed on Mr Menlove's bore from December 2019 through to June, unfortunately there was a failure at the time of the test (insufficient capacity).*
    - *It was confirmed to the best of the Mr Mullers knowledge neighbouring bores were not pumping at the time the test was undertaken.*
    - *There was discussion around the test data, Mr Muller and Mr Hughes agreed to supplying data for each of the aquifer tests (step draw down and constant rate tests).*
    - *There was discussion around the rapid recovery of the bore tests and corrections made to the data. Manual data and logger data had some inconsistencies.*
    - *There was agreement that reasons for the corrections and or lack of corrections would be supplied.*
    - *Mr Muller explained the observation bores were chosen as those are the ones which significant concerns have been raised regarding potential for interference effects. In his opinion better to monitor interference effects directly in the bores of concern.*
    - *It was discussed whether there was consideration given to aquifer testing both bores at once. Mr Muller outlined it would have been complex to complete aquifer testing simultaneously, given the set up used. Mr Muller and Mr Hughes consider little would be gained by testing at the same time as the individual results can be added together.*
    - *There was discussion about the cumulative interference effects of the activity, including the effects already being experienced in the aquifer, the effects added as a result of this activity, and the timing of effects being during summer (as opposed to winter when water level has recovered). No agreement was reached on this issue.*
    - *There was discussion on the scale and significance of the activity, in particular the need for the aquifer test requirements to be commensurate with the scale and significance of the activity. No agreement was reached on the scale and significance of the activity.*
    - *There was brief discussion on the modelling of the proposal, however, this was not discussed at length given the differing opinions on the reliability of the data. It was concluded further information to be provided and then this could be revisited.*

- *Stream depletion effects were discussed broadly - it was agreed that based on the bore locations in the aquifer testing results, stream depletion effects are unlikely to be significant. However, this may differ if other bore locations are used in the final proposal so still required consideration (e.g., due to heterogeneity of system; transition to leaky-confined system).*
- *Appendix L.1 of the pSWLP was discussed including the aquifer tests alignment with it. It was agreed further information provided by the applicant, may satisfy some of those matters detailed in the Appendix assessment (Table 6.1; Lovett).*

6.2 Additional information / data requested, and agreed to be provided by the applicant (copy)

- *Antecedent condition datasets (e.g., > 24hrs data for aquifer test bores; barometric pressure);*
- *Relationship between data in the pumped bores and the ES monitoring bore (relevant to the correction applied)*
- *Step test data and constant rate data (manual and data logger; interval for manual measurements);*
- *Explanation of the aquifer test setup/method, including pumping setup (backflow prevention); how flow rate was monitored manually; interval of manual monitoring;*
- *Explanation as to the corrections made (or not made) to the aquifer test raw data (e.g., field data); was there any correction for barometric pressure?*
- *Explanation as to analysis of some data over others, for example the constant rate test has been used over the step test data.*

6.3 Provision of addition data and information

The majority of this data was provided by Mr. Mueller on Thursday 27th August, 2020 via an email communication and Liquid Earth (2020b). Outstanding data (as of 10 September, 2020) for Bore 1 and Bore 3 aquifer test included:

- Dataset for pumping flow rate during the constant rate aquifer testing (manual and/or automatic); and
- Dataset for barometric pressure during the aquifer testing (logger and/or local climate station) and any corrections made from barometric pressure.

7.0 Appendix L of SLWP (2018)

Appendix L.1 of the SWLP (2018) stipulates minimum aquifer test requirements to support resource consent applications to take groundwater (other than replacement consent applications for abstraction volumes that have been occurring with no adverse effects of a more than minor scale). The proposed abstraction was deemed to be a new (rather than replacement) consent application, to abstract groundwater from a Confined Aquifer (Lumsden), at a take of > 750 m^3/day (4,320 m^3/day) (Table L.1). The requirements for the proposed take were therefore (pSWLP, 2018):

> "*A step-drawdown aquifer test comprising a minimum of 3, 1-hour pumping steps followed by measurement of water level recovery. The maximum pumping rate utilised should be equal to or greater than the maximum proposed abstraction rate. A 24-hour constant-rate aquifer test undertaken at the maximum proposed abstraction rate. Water level monitoring should include drawdown and recovery (to within 10% of the initial static water level) in the pumped bore and in at least two observation bores in the source aquifer and one observation bore in the overlying aquifer within the area of localised drawdown. The pump rate should be kept constant within +/- 5%.*"

Overall, the aquifer testing undertaken on Bore 1 and Bore 3 does not meet the requirements of Appendix L.1 for the reasons identified in Table 6.1. The applicant cites an interpretation of wording of the terminology (e.g., should versus shall) in Appendix L.1. Any consideration of this interpretation is best made by Environment Southland (or other suitably qualified) policy staff and is not addressed further in this report.

Table 6.1: Summary of the SLWP (2018) criteria for aquifer testing related to the suitability of aquifer testing and results provided for CFCL presented in Landpro (2020). Revised following 18 August meeting and information subsequently provided. Italicised text in commas in the Description Column is a direct response from the applicant (e.g., Comment A1).

Criteria (Table L.1)	Bore 3	Bore 1	Description
Step-drawdown aquifer testing			
A step-drawdown aquifer test comprising a minimum of 3, 1-hour pumping steps…	Yes	Yes	Step drawdown aquifer tests were undertaken satisfactorily. [applicant indicated test results unreliable]
… followed by measurement of water level recovery.	Yes	Yes	Manual recovery was reported for Bore 1 (data of lower reliability).
The maximum pumping rate utilised should be equal to or greater than the maximum proposed abstraction rate.	Yes*	Yes*	Bore 3: pumping rate 6 – 17 L/s Bore 1: pumping rate 4 – 16 L/s Comment A1:"*The pumping rate used for both bores was consistent with the maximum rate of abstraction proposed for each bore, but less than the total proposed abstraction rate. If the intent of the wording in Appendix L.1 is as interpreted in the EES Report, this reccommendation would be impossible to meet for any application to take groundwater where not all bores have been drilled. Further pump testing on any new bores will be carried out, generally in accordance with the proposed consent conditions.*"
24-hour constant rate aquifer testing (+ recovery)			
A 24-hour constant-rate aquifer test undertaken…	Yes	Yes	Bore 3: 72-hour constant rate test; and Bore 1: 30-hour constant rate test
… at the maximum proposed abstraction rate	Yes*	Yes*	Bore 3: pumping rate 12 L/s Bore 1: pumping rate 13 L/s See Comment A1: above

Water level monitoring should include drawdown and recovery (to within 10% of the initial static water level) in the pumped bore …	Not agreed	Not agreed	Initial water levels were not reported. See Section 1.3 and 2.2 of supplementary aquifer testing report.
(to within 10% of the initial static water level) … and in at least two observation bores in the source aquifer …	No^	No^	Drawdown cone appeared to intersect the monitoring bores: - Bore 3: during recovery, groundwater level decreased to less than the initial (static) groundwater level (Figure 9); - Bore 1: recovery was < 60% recovery (Menlove) and < 30% recovery (Bore 3). Uncertainties remain regarding the observation bore dataset. Comment A2: "*Bore 3 test: Complete recovery was observed in the uncorrected data from bore E44/0012, although based on the correction applied later recovery may have been closer to 75%. Limited recovery data is available for E44/0255 due to logger failure."* Comment A3: *"Bore 1 test: recovery of 60-70% for two monitoring bores."* Comment A4: "*Minor non-compliance for both tests, but as per note below monitoring to 90% recovery is a recommendation, not a requirements (i.e. the wording in the Appendix is "should", not "shall")*"
(to within 10% of the initial static water level) … and one observation bore in the overlying aquifer within the area of localised drawdown.	Yes	Yes	Bore 3: monitoring occurred (Figure 8); Bore 1: monitoring occurred with minor issues from discharge (Figure 15).
The pump rate should be kept constant within +/- 5%	Not agreed	Not agreed	Insufficient information on the pumping rate and quality control of the pumping rate were provided. Dataset was requested and not provided (qualitative only). Comment A5: "*Bore 3 test: Pump rate initially set too high, adjusted back to constant rate (12.2 L/s) by 8 hours into 72 hour test. Again, Appendix L.1 states pump rate "should" (not "shall") be constant – standard analytical packages can account for issues with pump rates.* *Bore 1 test: Pump rate constant (to within 0.1 L/s) in all measurements during test.*"

* For that bore only, addition aquifer testing required for additional bores.

^Minor non-compliance for both tests, but as per note below monitoring to 90% recovery is a recommendation, not a requirements (i.e. the wording in the Appendix is "should", not "shall").

8.0 Summary based on all information presented to date

8.1 Hydrogeologic setting

It was established by the applicant in the original application and further emphasised during the meeting that the site setting of the Lumsden Aquifer is characterised by a highly variable (e.g., heterogeneous) hydrogeologic setting. As a result, it is likely that areas of the Lumsden Aquifer have an increased level of confinement compared to other areas of the aquifer. Results of the aquifer testing support the idea that in the area that aquifer testing was undertaken, the aquifer is confined. However, use of what are considered relatively 'distant' (e.g., 1.5 – 2 km) monitoring bores as observation bores in the aquifer test; use of groundwater levels from a long term (further distant *c.* 3.5 – 5 km) monitoring bore as a correction factors; and uncertainty around correction for barometric pressure, considerably reduce the reliability of results obtained from those aquifer tests. Additional factors as a result of the management of aquifer testing also reduce the reliability of the results, as discussed in more detail in Appendix 2.

8.2 Updated aquifer test data and analyses

Provision of additional information on the aquifer testing resulted in some improvement of the reliability of the aquifer test information. However, the reliability of the aquifer test data and subsequent aquifer test analyses was likely to remain moderate – low. This conclusion was primarily based on the following facts:

- Poor quality control of aquifer test management led to loss of datasets reducing the datasets available for analysis and in turn decreased the overall output of the aquifer test and reliability of results;
- The drawdown induced in the observations bores (*c.* 0.2 m) was less than what is ideally obtained during an aquifer test (e.g., as recommended In Environment Canterbury guidelines);
    - As a result, the measured groundwater levels in the observation bores were 'noisy' due to external interference, which reduced the reliability that water level changes were directly induced by the pumping bore; and
    - The use of quite distant drawdown data means that the granularity of the drawdown is low when it comes to curve matching; which is demonstrated by poor curve matching of observation bore datasets in the applicants analysis;
- It was obvious that the output dataset of the aquifer testing groundwater level in the observation bores was being influenced by external factors.
    - To address this, a correction was made to the groundwater level datasets from Bore 3 test, based on groundwater level in a distant bore (c. 2 km) rather than on original datasets (e.g., barometric pressure); however, no correction was made to groundwater level datasets from Bore 1 test.
    - Although a discussion as to why a correction was / was not made has been provided by the applicant, it is important to note that the observed drawdown is already low (e.g., *c.* < 0.2 m); therefore, the lack of comprehensive correction further reduces the reliability of this observation (e.g., the direct relationship between pumping the pumped bore and groundwater levels in the observation bore is reduced);
- These compounding factors results in overall, relatively poor curve matching of groundwater levels in the observation bores which aquifer test analyses is undertaken.
- In the event of low reliability and reliance from distant observation bore curve matching, the next area with good quality aquifer test data is the aquifer test bore, for which the following considerations need to be made:
    - drawdown in the pumped bore is influenced by a number of factors (e.g., well storage);
    - although there is much improved granularity in the data-points (e.g., less noisy), near-field influences may assume disproportionate scale meaning that the wider aquifer is poorly represented in the results.

8.3 Stream depletion

A primary requirement of the technical review was to address the following:

- "*the aquifer testing report to confirm or otherwise, what the hydraulic connection is, between the take and nearby waterways and therefore what associated management approach should be used, in accordance with Appendix L.2 stream depletion*".

Although there were considerable quality control issues with the aquifer testing (as described in Section 5 and Appendix 2), datasets from the aquifer testing were sufficient enough to identify that stream depletion as a result of pumping 'Bore 1' and 'Bore 3' was unlikely. Therefore, the following statement by the applicant … "*Groundwater levels in the shallow piezometers monitored were essentially static during both CRTs, as discussed in detail in the Hydraulic Testing Report. On this basis, stream depletion effects would be expected to be negligible.*" is supported. There was a consensus on this conclusion between the applicant and technical reviewer during the August 18th meeting. Therefore, information presented in the application supports the proposed water take from Bore 1 and Bore 3 being fully attributed to groundwater take from the Lumsden Aquifer (with no adjustment made for a surface water take); and that stream depletion effects (if any) from pumping Bore 1 and Bore 3 are likely to be negligible.

8.4 Interference effects

A primary requirement of the technical review was to address the following:

- "*the aquifer testing report to confirm or otherwise, the interference effects on any neighboring wells are considered acceptable in accordance with Appendix L.3 of the SWLP. This assessment should take into consideration cumulative effects present within the aquifer such as those being experienced in bore E44/0256, E44/0012, E44/0300 (ES ground water monitoring bore) which M. Killicks advice (28 January, 2019) highlights that acceptable limits may have already been exceeded.*"

Overall, it was concluded that the aquifer testing results were of low reliability and therefore results of the bore interference effects modelling were not deemed to be reliable. Key factors that have contributed to this outcome include:

- considerable quality control issues with the aquifer testing (as described in Section 5 and Appendix 2);
- additional information was requested form the applicant and a component (but not all) of this information was provided, with outstanding datasets including:
    - reasonable temporal measurement pumping flow rate during the constant rate aquifer testing (manual and/or automatic);
    - barometric pressure during the aquifer testing (logger and/or local climate station) and any corrections made from barometric pressure;
- distance of monitoring bores (e.g., 1.6 – 2 km from the pumping bore (Bore 1 and Bore 3), combined with a low pumping rate and slender effect (< 0.2m drawdown) being induced;
- corrections to data being based on a further distant long-term monitoring bore; and
- failure to comply with all of the requirements of Appendix L.1 (pSWLP, 2018), described in Table 6.1.

The method selected for modelling bore interference effects (Section 4, Landpro, 2020) appears to be appropriate based on the hydrogeologic setting and known wells in the area (e.g., Table 4; Pg., 11). The data presented in Table 5 demonstrates that maximum modelled drawdown is likely to be a small proportion of drawdown (e.g., < 0.4 m for all four wells) is likely to be induced in nearby bores, equivalent to *c.* 10% of seasonal variation. It is important to note that the modelling and these conclusions are reliant on the information obtained from the aquifer testing.

The applicant notes the following (Pg., 12), Landpro, 2020 are relevant regarding: reliability of aquifer testing results; and the difference in abstraction volume undertaken during testing compared to proposed abstraction rate of 50 L/s:

- "*While estimates of remaining available drawdown are inherently approximate and somewhat subjective, the data presented in Section 2 indicates that these values are likely to be generally accurate.*"
    - Comment: there is a reasonably high level of subjectivity and estimation as to effects on neighbouring bores;
- "*However, as noted above in the discussion regarding stream depletion, the above modelled drawdown results from only approximately half of the pumping rate which the applicant is seeking. The following section discusses various scenarios for achieving the remaining half of the target pumping rate, and potential effects of those scenarios.*"
    - Comment: while the two aquifer tests monitored the effect on neighbouring bores of pumping a single bore over 30 to 72 hours, the requirement for high reliability aquifer parameters is to project combined, multi-bore pumping effects. This is to recognise the longer pumping durations sought within consent conditions in the water take application.

The applicant made the following statement… :

- "*As shown on the attached Well Location Plan (18180_2), there were originally 7 proposed production bore locations which the applicant was considering as sources for their proposed water take.*" …
- "*As such, the remaining options for the applicant to source additional water are drilling a new bore at one of locations 4-6, or re-drilling bore 1 at a larger diameter.*"
- *"The applicant's intention is to carry out additional pump testing when the additional well(s) are drilled and update the hydrogeological calculations included here to confirm that the effects are acceptable (generally in line with the process outlined in the consent conditions already volunteered)."*
- *"However, in our opinion the applicant's existing pump testing data, along with that available for neighbouring sites, is sufficient to demonstrate that effects are highly likely to be acceptable*".

It is important to consider the following, with regard to the conclusions by the applicant, listed above:

- The application is for a proposed pumping rate of 50 L/s, whereas aquifer testing was undertaken at rates of 12 – 13 L/s. It is important to note that any limitations associated with aquifer testing at a lower rate (and lacking the cumulative effects) will not necessarily be accounted for in the bore interference modelling for a greater volume of abstraction.
- Certain aspects of Appendix L.1 are not agreed by the applicant and technical reviewer. It is recommended that any additional aquifer testing be undertaken to comply with Appendix L.1, or a factually supported discussion on why the appendix was not adhered to. A suitably experienced policy specialist (e.g., Environment Southland policy staff) would be best placed to comment on the requirements of Appendix L.1 with regards to the terms 'should' and 'shall'.

8.5 Conclusions

Conclusions of Landpro (2020), Pg., 18:

- "*The results of pump testing carried out at the site broadly confirmed the hydrogeological conceptual model of the site on which the HA included with the application was based.*"
    - Comment: agreed, aquifer likely to be spatially heterogeneous, but demonstrated to be reasonably well confined in the area of aquifer testing (e.g., "*Analysis of aquifer test results suggests that while the Lumsden Aquifer is well confined in the vicinity of Bore 3 it becomes increasingly semi-confined to the east reflecting the reduction in thickness of the aquitard sediments.*").

- "*Calculations of interference and stream depletion effects of the proposed water take indicate that these will remain within acceptable limits for a range of scenarios involving the existing wells which have recently been tested and one or more additional well.*"
    - Comment: agreed with regard to stream depletion; the situation with interference effects is more complicated, although the modelling was undertaken using appropriate methods, it is the reliability of the input data that is not agreed between the applicant and reviewer;
- "*Because the two existing wells do not provide the full quantity of water sought by the applicant, at least one additional well will be required, and pump testing of the new well(s) will also be required. An updated assessment of the hydrogeological effects of the proposed take can be provided as a condition of consent once this additional pump test is completed.* "
    - Comment: In lieu of Environment Southland having such a document, it is recommended that all further aquifer testing by the applicant should comply with minimum aquifer test requirements (e.g., Guidelines for analysing and reviewing aquifer tests that support consent applications and/or comply with consent conditions, (Environment Canterbury, 2015)). These guidelines (or similar) would be considered as the minimum quality control requirements to produce reliable data from the aquifer testing. Had similar guidelines been followed for the aquifer testing completed to date, then it is likely that the input data to the modelling would have been regarded with considerably increased reliability.
- "*However, the HA stated that "the proposed water take is not expected to have significant adverse effects in terms of interference with other bores, stream depletion, or aquifer sustainability", and the data discussed in this report and the attached HTR provides a high level of confidence that this statement remains correct.*"
    - Comment: it was reasonably well demonstrated that stream depletion was unlikely to have significant adverse effects (with reasonable confidence); however, as detailed in this review, modelled bore interference effects have considerably less reliability (e.g., low confidence, and certainly not '*a high level of confidence*' as stated); as a result, the actual interference effects on neighboring bores form pumping 50 L/s of groundwater from the Lumsden Aquifer at the study site may, have not been determine with a high level of reliability.

9.0 References

Environment Canterbury, 2015. Guidelines for analysing and reviewing aquifer tests that support consent applications and/or comply with consent conditions. Environment Canterbury Regional Council. 200 Tuam Street. Christchurch. 13p.

Environment Southland, 2019. Request for Further Information under Section 92(1) of the Resource Management Act 1991 - Application for the construction of up to 12 bores to access the Lumsden Aquifer and to take and use water from the Lumsden Aquifer for hydraulic testing and irrigation. Environment Southland Regional Council. Corner North Rd &, Price St, Waikiwi, Invercargill, 9810. 3p.

Environment Southland, 2020. Environment Southland Regional Council. Corner North Rd &, Price St, Waikiwi, Invercargill, 9810. Data requests submitted to datarequest@es.govt.nz and information obtained from the www.eis.es.govt.nz.

Landpro, 2019a. Castlerock Farming Company Ltd., Resource Consent Application to Environment Southland For consent to install bores and take and use groundwater. Dated 2 August, 2019. Landpro, 13 Pinot Noir Drive, Cromwell, 413 p.

Landpro, 2019b. Request for Further Information under Section 92(1) of the Resource Management Act 1991 – Application Insert details from s92 request. Dated 3 March, 2019. Landpro, 13 Pinot Noir Drive, Cromwell, 12p.

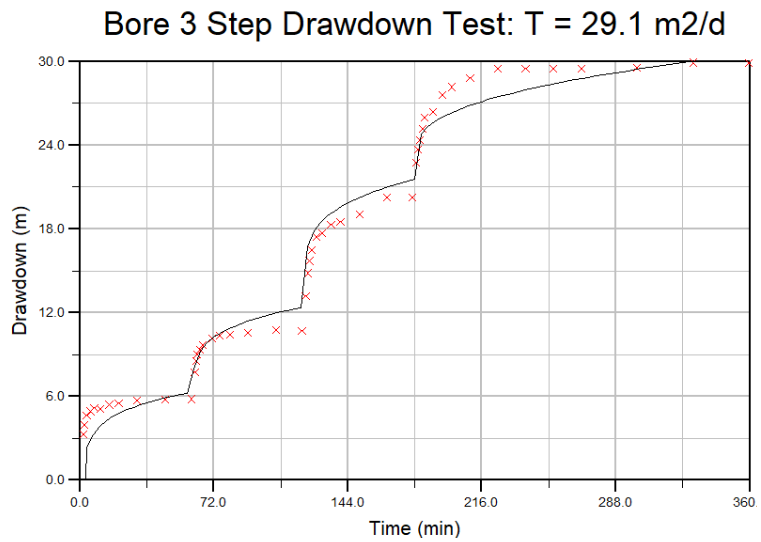
Liquid Earth, 2020: Castlerock Dairies Hydraulic Testing Report. Liquid Earth. No author. No Date. Appended to Landpro (2020).

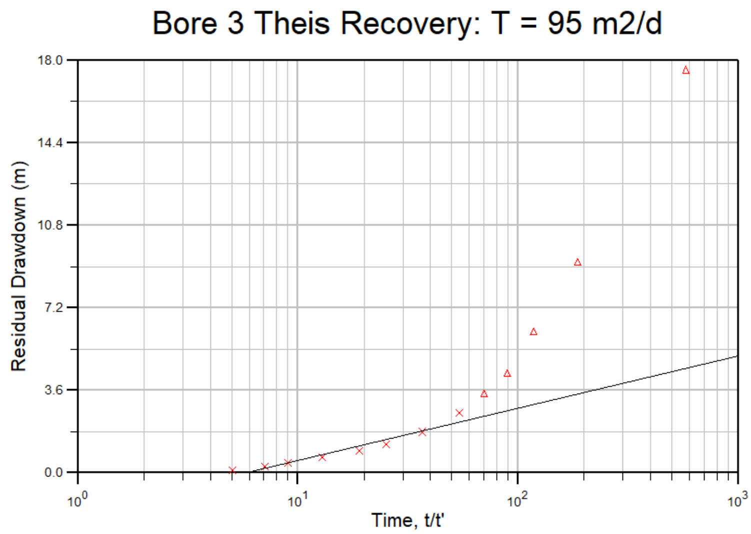
Liquid Earth, 2020. Castlerock Dairies - Request for further information. Prepared by Liquid Earth for Landpro. 13p.

Landpro, 2020. Updated hydrogeological calculations for Castlerock Farming Company Ltd groundwater take application. Landpro Reference: 18180 Council Reference: APP-20191827. 18 July, 2020. 59 p.

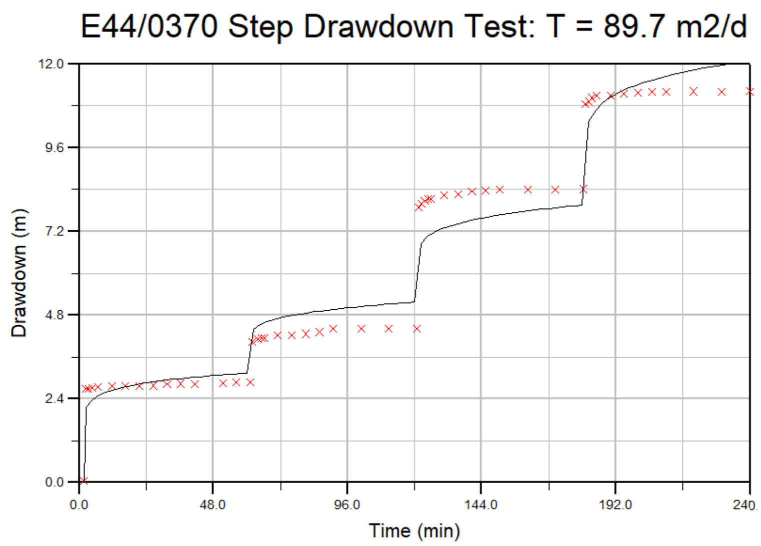
pSWLP 2018. Proposed Southland Water and Land Plan, Decisions Version, 4 April 2018. Environment Southland Regional Council Corner North Rd &, Price St, Waikiwi, Invercargill, 9810. www.es.govt.nz/Document%20Library/Plans,_%20policies%20and%20strategies/Regional%20plans/Southland%20Water%20and%20Land%20Plan/Proposed%20Southland%20Water%20and%20Land%20Plan%20-%20Part%20A%20-%20Decisions%20Version%20(4%20April%202018)%20PDF.pdf

Appendix 1





*note: due to such rapid recovery of data in the pumped bore, the first five data points were discounted from analysis.



Appendix 2

The following section was drafted in an earlier version of this report and is included her for completeness.

Appendix 2.1 Preliminary review of Aquifer testing approach

The approach used for the aquifer testing is not described adequately and therefore the purpose for the installation of monitoring piezometers in the unconfined aquifer is unclear. The report is lacking a suitable description of the design and execution of the aquifer test and in many instances standard procedures are not described or followed. Particular issues with aquifer testing methods for pumped Bore 3 and Bore 1 include:

- limited information is provided for monitoring bores, including:
    - E44/0255: no static water level or screened interval were provided; total bore depth was 30 m BGL (which is on the boundary of the aquitard / semi confining layer); an initial water level of 3.78 m BGL was provided by Environment Southland (2020);
    - E44/0012: no information of bore construction was provided in the report, a check of Environment Southland database indicated a total bore depth of 30 m BGL, and no information on the screened interval; therefore:
        - the aquifer testing is based on the assumption that bore E44/0255 and bore E44/0012 are screened in the Lumsden Aquifer, yet there is no hydrogeological information presented in the report to demonstrate this and this knowledge gap is not addressed suitably;
- It is unclear why the piezometers were only in the unconfined aquifer (e.g., < 10 m BGL) at Bore 3 and Bore 1 aquifer testing sites, other than the requirement for one piezometer under the SLWP, Appendix L (Table L.1);
    - since none of the piezometers were installed into the confined / semi-confined aquifer, the measurements of drawdown obtained from the aquifer testing were much less accurate (due to the considerable distance of the monitoring bores from the pumped bore; e.g., 1.5 – 2 km)
    - as a result, the analysis has been based on distant observations, for which knowledge of bore construction was poor, and resulting drawdown was of poor quality, which has reduced the reliability of results,
    - better use of resources and improved test results would have been obtained if a minimum of one piezometer at each site had been installed into the confined / leaky confined layer, rather than two or three shallow piezometers into the unconfined layer;
- the timing of the aquifer testing during winter coincides with highest groundwater levels (e.g., water table is closest to the land surface); therefore, it must be considered and factored into the assessment that groundwater levels will be lower in summer (as demonstrated by the groundwater level monitoring)
- interference effects on the groundwater level monitoring bores should be less evident in winter, compared to if the test was conducted in summer, which means that results should (theoretically) be more representative of the effects of the pumping bore, rather than periphery drawdown effects;
- however, there was no indication that nearby bores were requested to be turned off during the aquifer testing (as is standard practice), or if not practical, whether bores were pumped at a constant rate;
- furthermore, it is good practice to monitor antecedent conditions in the borehole that the pumping is undertaken on, however this does not appear to have been undertaken or was not reported for either Bore 3 or Bore 1; rather, groundwater level from an Environment Southland monitoring bore (no distance provided) have been used to try and determine the aquifer 'stability' during the test; this data was used for correction of Bore 3 testing but was not used for Bore 1 testing which may indicate the lack of reliability of this data for correction;
- Overall, a very poor description of test method and instrumentation were provided for each of the four aquifer tests, specifically there were no details regarding:
    - the interval logger set to record (e.g., 15 second? 1 min? intervals, or logarithmic?)
    - who programmed the loggers and how they were programmed to record data; related to why 'logger time' was presented in the report; (e.g., was this because actual time and logger time were two different times, which has made correlation of the data difficult?)
    - quality control during the test (e.g., lengthy intervals between manual measurements)

- type of logger, accuracy, and depth installed;
- type(s) of manual measurement device were not specified. Did the manual measurements and logger measurements have the same reference point (e.g., was top of casing identified?)
- how manual flow rate was monitored or accuracy of ultrasonic flow meter;
- how pump was powered (e.g., generator or mains electric) as these factors can influence pumping rates obtained during the test
- type of pump and setup of the pump as insufficient details were provided in the report; this is particularly important due to the rapid recovery observed in the aquifer test recovery curves (see below); it is essential to know that a backflow prevention device was installed on the pump and pipe otherwise the recovery results will be significantly impacted. The applicant may need to confirm this detail.
- specific details of any other corrections applied to the raw dataset obtained from field work (i.e. were antecedent trends or barometric interferences corrected for?).
- recovery of groundwater level of 90% of original water level was not adhered to for monitoring bores, so a cross-check for the impact of antecedent trends was not feasible.

- Overall, there is a poor description of quality control methods implemented during the testing:
    - An initial pumping test (e.g., to determine capacity of each bore) was not undertaken and step test results were not interpreted, this resulted on pumping at a rate that exceeded bore capacity for the Bore 3 constant rate test;
    - It was mentioned that flow rate was recorded using an ultrasonic meter and "… *recorded manually at regular intervals during the pumping period*"; however, the actual method of manually checking flow rate should have been provided (e.g., bucket + stopwatch test);
    - No clear details on quality control (e.g., manual measurements), do not appear to be undertaken at expected / standard intervals (e.g., logarithmic) as per 'best practice', no reason is provided for this
        - For example, Bore 1 test, water levels were not monitored during the elapsed period 500 – 1,250 minutes (e.g., 12.5 hours) which is poor quality control of the aquifer test;
- Observation bores (drilled and existing) was of limited value for the entirety of aquifer testing:
    - the closest observation bores in the confined aquifer were some distance from the pumped bore (e.g., Bore 3 aquifer, 1.27 – 1.85 km distant; Bore 1 aquifer test 1.57 – 2.17 km), this resulted in a very low sensitivity of observation bore data used in drawdown curve fitting.
        - the observed maximum drawdown of the monitoring bores in the confined aquifer (e.g., 170 mm) are not particularly reliable results to base the assessment on;
        - the bores installed into the unconfined aquifer provide little additional information to the aquifer testing, other than to demonstrate that the pumping bores were located in a confined / leaky confined aquifer (which was already established prior to testing)
        - further, the recovery of groundwater level of no less than 90% of original groundwater level was not adhered to.

Appendix 2.2 '3. Bore 3 Aquifer testing' (new bore, Castlerock Dairies 3)

Aquifer test general comments

- 'Bore 3' has been referred to in four different ways throughout the reporting including: new bore, Castlerock Dairies 3, Bore 3, and E45/0762). Aside from E45/0762, these names are inferred to be the same bore.
- bore ID (E45/0762) was checked and is located in the Central Plains Aquifer. It was then assumed that this was a typing error: Pg., 45 "*Figure 2 shows a plot of step test results (pumping rate vs drawdown) and well efficiency for E45/0762, calculated using the formula")*
- the location of the aquifer test borehole in relation to each monitoring borehole is not clearly presented in the report, and the construction details of those bores is poorly represented in Table 1;
- it is inferred that "Castlerock bore 3" is screened in the confined aquifer, although this is not implicitly stated in the report;

Variable rate step test comments:

- The aquifer test design, four steps (pumping rates) undertaken at an increased pumping rate over a period of 360 minutes (6 hours) was an appropriate test for the setting;
- basic information regarding the test (e.g., initial water level for pumping bore and monitoring bores) were not provided
- Step drawdown test analysis & results:
  - Visual analysis, results seemed visually suitable, (e.g., began to reach a quasi-equilibrium before next step was initiated); good looking recovery curve.
  - report indicated that Figure 2 showed "*step test results… and well efficiency for E45/0762*", which was the first mention of bore 'E45/0762' (e.g., in the results with no prior reference to location);
  - drawdown of 30 m; assumed long-term sustainable yield 12 – 13 L/s
  - a transmissivity value for the step test was not presented in the report, even though The Eden Hazel Method would have provided one and an appropriate recovery curve appeared to be available for Theis Recovery Method analysis using a volumetric mean pumping rate
  - insufficient recovery data was provided in observation bores

Constant rate step test comments

- A 72-hr constant rate test was undertaken beginning 18 May 2020
  - the report contradictorily states "*A 72-hr constant-rate aquifer test was undertaken on Bore 3…*" then refers to Table 4 (Pg., 36) titled "*Table 4. Location and construction details for bores utilised in the Castlerock Dairies Bore 3 24-hour constant rate aquifer test*"; it is inferred that this was a typing error, and that a 72 hr constant rate test was conducted.
- Aquifer test design
  - It is unclear why the pumping rate for the constant rate test was so high if the step test indicated that 12 – 13 L/s was a more sustainable pumping rate. This may have occurred as the step drawdown test had not been analysed prior to the constant rate test being undertaken.
  - Therefore, analysis of the step-test and/or an initial bore capacity check would have removed the necessity for a reduced pumping rate; it is good practice to pre-pump a bore to ensure that abstraction of the required rate of water it is capable and allow full recovery of water levels before initiating the constant rate test
  - Report states on Figure 4 (Pg., 37) "*Figure 4. Location of bores used for Bore 3 aquifer test*" but bore E45/0112 does not appear to have been monitored during the aquifer test and no explanation is provided
- Aquifer testing
  - Report incorrectly refers to Figure 5 (Pg., 36) "*The location of the production and observation bores is shown in Figure 5 below...*" (assumed it was meant to refer to Figure 4)
  - The report states (Pg., 36) "*the two adjacent piezometers (Piezometer C and Creek Piezometer) located approximately 200 metres respectively from the pumped bore"* but does not reply the actual distance that those bores are from the pumped bore (e.g., in Table 4; Pg. 36).
  - Table 4 was incomplete (e.g., missing distances from Bore 3); no static water levels
  - Figure 4 (Pg., 37) included an additional bore (E44/0012) for which no bore details were provided
  - Report indicates that the unconfined aquifer was subject to interference effects during the aquifer testing; and that the confined aquifer was in receding 'at a stable rate' at a distant site (*c.* 3.5 – 5 km) therefore corrections could be made to address these effects prior to analysis of the aquifer test data (e.g., determine linear relationship for decline in groundwater level of the confined aquifer and remove from the pumped bore dataset)
    - this is based on the assumption that the same relationship is occurring in the pumped bore (c. 2 km distant); it is unlikely that this relationship would be exactly the same at the pumping site, particularly due to factors of heterogeneity previously described;
- Aquifer test results and analysis
  - Water level observations showed a large drawdown in the pumped bore relative to total depth

- Due to the provision of drawdown depths alone and no reference to static water level, it was not possible to determine the depth of final drawdown relative to the pump or top of the semi-confined aquifer;
- Visually, the test appears to have produced reliable data, based on that presented in the report; however, there is a lack of commentary as to any edits to the data and/or corrections;
    - For example, Figure 6 seems very 'clean' compared to what would be expected from pumping, is this a dataset from the flow meter or manual measurements, and if so, how regularly were manual measurements undertaken?
    - The recovery appears to be very rapid, almost too rapid for the test duration (relates to backflow prevention of the pump)
- Pumping at 12.2 L/s, resulted in 26.6 m drawdown,
- It is unclear why the recovery data from the step test not analysed for transmissivity, when a suitable recovery curve was available for analysis
- Figure 8 (Pg., 39):
    - Assumed that 'Castlerock Aquifer' (green line) represents ES monitoring bore (Sutherland Rd?)
    - No change in groundwater levels in shallow piezometers is an expected result and adds little value to the aquifer testing;
    - There is poor correlation between manual and logger measurements, but due to a lack of descriptions, it cannot be determined which measurement is likely to be the more reliable
    - The correction of the logger data for the recession observed in the ES monitoring bore assumes same trend at test site – why was antecedent conditions not monitored in the test bore (e.g., Bore 3…) and/or nearby bore (e.g., E45/0255)?
    - Identify distance between site and make comment on proximity to river? What were river flows doing at this time? If aquifer becomes semi-confined before the east (e.g., different hydraulic conditions), then why was antecedent data from a distant bore (c. 3.5 – 5 km) used to correct aquifer test data? (E45/0255 would have been a better proxy)
    - Has barometric pressure been corrected for?
    - poor quality assurance during the test, why were there no manual measurements taken or reported in E45/0255
    - Hydraulic properties (Liquid Earth, 2020):

Table 5. *Aquifer hydraulic properties calculated from the Bore 3 aquifer test*

Observation Bore	Analysis Method	T (m^2/day)	S	K'/B' (day^{-1})	Sigma	T_o (m^2/day)
E44/0012	Theis	1,320	0.00033			
	Theis recovery	1360				
	Hunt and Scott	1,000	0.00025	0.0001	0.1	100
E44/0255	Theis	1,770	0.00006			
	Hunt and Scott	800	0.00008	0.000065	0.1	100
Bore 3	Theis Recovery	370				

- Summary of aquifer testing in Bore 3:
    - Poor conduction of aquifer test and poor quality control (as described in Section 6.2.1)
    - Inconsistencies in test dates (indicates starting 18th May; then indicates 19th May); one date indicates "logger time" (Pg.,38);
    - Valid interpretation that aquifer is 'confined' in location of bore 3, supported by no response in the shallow piezometers (as would be expected).
    - It is not clearly stated that the drawdown data in observation bores (E44/0012) of 0.15 and (E44/0255) of 0.20 m was corrected for the 'stable recession'; it is interpreted that this was the case as described in the results; issue is that the 'recession' occurred in the aquifer observed at the ES monitoring site (and author based on the assumption same trend was

    - occurring at pumping site; yet have just explained that the aquifer becomes more leaky in that direction).
    - The lack of any mention of data corrections to remove antecedent level trends or barometric pressure effects on a confined or semi-confined aquifer test is a significant oversight in relation to contemporary good aquifer testing practice.
    - The pumped bore recovery transmissivity value of 370 m2/d; none provided for step-drawdown; (data looked appropriate).

Appendix 2.3 Review of 'Dairy Shed (E44/0370) Aquifer Test'

Aquifer test general comments

- This bore has been referred to in three different ways throughout the reporting (e.g., Dairy Shed bore, bore 1, E44/0370), these are interpreted to all be the same bore;
- the location of the aquifer test borehole in relation to each monitoring borehole is not clearly presented in the report, and the construction details of those bores are poorly represented (e.g., information in Table 6 (Pg., 43) and does not include distance from pumped bore;
- it is inferred that "Dairy Shed bore" is screened in the confined aquifer, although this is not stated in the report;
- It is unclear why the piezometers were only in the unconfined aquifer (e.g., < 10 m BGL) as discussed in Section 6.1.1

Variable rate step test comments:

- The variable rate test comprised four steps of c. 60-minute duration increasing from 3.9 to 15.5 L/s over a total period of 240 minutes; the test was undertaken on 23 June, 2020;
- This was an appropriate test for the setting, however, basic information regarding the test (e.g., initial water level) was not provided.
- Poor description of test method, instruments, and quality control, lacking details of:
    - the interval logger set to record (e.g., 15 second? 1 min? intervals, or logarithmic)?
    - quality control during the test (e.g., intervals of manual measurements)
    - type of logger, accuracy, depth installed;
    - how flow rate was monitored (automatic, manual)
    - how pump was powered (e.g., generator or electric) as these factors can influence the test
- Step drawdown test analysis & results:
    - Visual analysis, results for steps seemed visually suitable, (e.g., began to reach a quasi-equilibrium before next step was initiated);
    - No recovery curve was presented which is strange, as often recovery provide the best (clean) data and the most accurate estimate of hydraulic properties;
    - Based on an assumed available drawdown of 22 m, the long-term sustainable yield of the bore up to 15 L/s
    - a transmissivity value for the step test was not presented in the report and no recovery data was presented; no explanation was provided

Constant rate step test comments

A 30-hr constant rate test resumed on (24 June, 2020) and the bore was pumped at a rate of 12.7 L/s throughout the test period.

- Aquifer test design
    - The test proposed monitoring of water levels in the pumping bore; three piezometers installed in the unconfined aquifer (c. 200 m distant); and two existing bores in the confined aquifer (e.g., E44/0255 (a.k.a Menlove), 1.6 km away) and (Bore 3, 2.2 km distant).
    - Basic information for these bores is presented in Table 9 (Page 46);
    - Confusion is generated through the introduction of a 'parameter' titled "Distance from CE11/0008"; based on information presented in the report, it was then assumed that this was the name given to a monitoring bore?

    - Further, Table 9 and Figure 12 (Pg., 46) do not replicate information, (e.g., CE11/0008 is not on Figure 12),
    - It is poor test design and execution to discharge water from the aquifer onto land where it can influence water levels in the unconfined aquifer (as described on Pg., 48)
- Aquifer testing
    - There is a poor description of test procedure, quality control, methods used, and instruments used, as described in Section 6.2.1.
    - Table 9 was incomplete (e.g., no static water levels)
    - the closest observation bore in the confined aquifer was some distance from the pumped bore (1,570 m) resulting in a low sensitivity in values used in the drawdown curve (not particularly reliable data to base the assessment on)
    - although information from monitoring bores was provided, no corrections were made to the dataset
- Aquifer test results and analysis
    - Contrary to the description provided, it appears as though the pumping rate was variable over the aquifer testing period and/or the logger was bumped/moved during the testing (e.g., Figure 14)
    - No reason was provided for why the dataloggers in Peizo A and Peizo C did not record any data (e.g., human error), so reliance was on manual data
    - Water level observations: drawdown in pumped bore c. 32 m
    - Visually, (Figure 14) overall the test appears to have produced reliable data; however, there is a lack of commentary as to any edits to the data and/or corrections;
        - The recovery appears to be very rapid – as insufficient details were provided in the report to ensure that a backflow prevention device was installed on the pump and pipe (applicant may need to confirm this);
    - Pumping at 12.2 L/s, resulted in 26.6 m drawdown,
    - Figure 15 (Pg., 49):
        - No change in groundwater levels in shallow piezometers A and C (manual monitoring only) shows 'no connection' at this location; change in water level of Peizo B shows response to pumping and/or discharge
        - poor correlation between manual and logger measurements
    - Figure 16 (Pg., 49)
        - poor correlation between manual and logger measurements (e.g., Bore 3 transducer and Bore 3 manual are often > 20 mm different; E44/0255 manual and transducer are up to 80 mm different); suggest that there was an issue with the logger?
        - Drawdown curves should still be suitable to analyse; based on the limitation of large distance (e.g., 1.6 km).
    - Hydraulic properties: transmissivity ranges from 590 – 1,600 m^2/day

Table 10. *Aquifer hydraulic properties calculated from the E44/0370 aquifer test*

Observation Bore	Analysis Method	T (m^2/day)	S	K'/B' (day^{-1})	Sigma	T_o (m^2/day)
E44/0255	Theis	1,540	0.00009			
	Theis recovery	1,620				
	Hunt and Scott	750	0.00012	0.00009	0.1	100
Bore 3	Theis	820	0.0001			
	Hunt and Scott	750	0.0001	0.00002	0.1	100
Bore 3	Theis Recovery	590				

        - Although the data was of poor quality, the drawdown in the two distant bores (Menlove and Bore 3) were used for analysis; although the recovery curves did not reach required recovery, their data may prove to more reliable data in terms of representation of aquifer hydraulic properties than the drawdown data, yet pumped bore data often was not analysed or not included in further analysis of results;

- It is unclear why transmissivity values from the pumped bore (530 m2/day) were not presented in Table 10; it is also unclear why the drawdown data for the pumped bore was not calculated;

- Summary of aquifer testing in Bore 1 (Dairy Shed Bore):
  - Poor execution of aquifer test and poor quality control (as described in Section 6.2.1)
  - It is unclear why there is a difference in actual time and 'logger time'; no details of who programmed the loggers, or if they were programmed correctly were provided
  - Valid interpretation that aquifer is 'confined' in location of Dairy Shed bore, is supported by no response in the shallow piezometers (as would be expected)
  - The lack of any mention of data corrections to remove antecedent level trends or barometric pressure effects on a confined or semi-confined aquifer test is once again a significant oversight in relation to contemporary good aquifer testing practice.
  - Given the distant location of monitoring bores, the most reliable data is from the pumped bore (e.g., transmissivity 530 m2/day); this would have been strengthened if the step drawdown test data was also analysed and presented.

Table A2 includes additional information which was required to provide an appropriate review of the hydrogeological dataset (in purple text), and was obtained from Environment Southland. Note at the time of writing this table was incomplete

Table A2: Summary of hydrogeological borelog or well information obtained from Landpro (2020); Liquie Earth (2020) and and Environment Southland (2020). Figure 6.1 shows Lumsden Aquifer bores. NOTE: Table incomplete

Alternative name/s	Report name / ID	Diameter (mm)	Depth (m BGL)	Screen (m BGL)	SWL (m BGL)	NZTM (X, Y)	Aquifer Test
Borelogs presented in Landpro (2020)							
Site A	-	150	10	7 - 9	1.3	1242502 4925081	OBS
Site B	-	50	10	7 - 10	1.1	1242375 4924955	
Site C (#4)	-	50	8.5	5.5 - 8.5	0.86	1242432 4925024	
Site D (#1)	-	50	4.7	1.7 - 4.7	1.4	1243885 4925203	
Site E	-	300	28.32	23.5 - 26.5	?	1243966 4925199	
Site F (#2)	-	50	6	3 - 6	1.37	1243967 4925199	
^New Small Peizo Across Rd (#6)	-	50	5	2 - 5	?	1241312 4926583	
New 300 mm	Bore 3	300	53.15	46.9 - 53.15	11.53	1241023 4926658	ST, CRT (B3)
New site, beside New 300 mm	-	50	4.9	1.9 - 4.9	1.73	1241125* 4926493*	
Bores presented in Liquid Earth (2020) that could not be matched with Landpro (2020) drill logs							
Does not match drill log	^Peizo C	50	5.0	3 - 5	2.78	1241232 4926645	OBS (B3)
	Creek Peizo	50	4.9	3 – 4.9	-	1241125 4926495	OBS (B3)
Error	*E45/0762*						*Modelled (B3)*
Additional bores presented with incomplete or incorrect information							
Bore 1 Dairy Shed bore	E44/0370						ST, CRT (1)
(English) E44/0012	Bore D	250	30	-	-	1242122 4927308	OBS (B3)
Menlove	E44/0255	150	30	-	3.78	1242868 4926615	OBS (B3)
ES monitoring (by river)	E44/0300						drawdown
On-farm	E44/0623						
Off-farm	E44/0339						
Irrigation	E44/0256*	300	53	27 – 30	4.12		

^ potentially the same bore