IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	applications by Central Plains Water Trust to: Canterbury Regional Council for resource consents to take and use water from the Waimakariri and Rakaia Rivers and for all associated consents required for the construction and operation of the Central Plains Water Enhancement Scheme Selwyn District Council for resource consents to construct and operate the Central Plains Water Enhancement Scheme
AND	
IN THE MATTER OF	a notice of requirement by Central Plains Water Limited to: Selwyn District Council for the designation of land for works associated with the construction and operation of the Central Plains Water Enhancement Scheme

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RESPONSE TO OFFICERS' SUPPLEMENTARY REPORTS AND SUBMITTERS' REPORTS
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INTRODUCTION

1. My full name is Julian James Weir. I have described my qualifications and experience in my main brief of evidence prepared for this hearing.

2. This response contains an initial discussion on model accuracy followed by my specific responses to the following Officers and Submitters' reports:

   - Vince Bidwell – Section 42A report;
   - David Scott – Supplementary Section 42A report;
   - Paul White (for Ngai Tahu) – main evidence;
   - Paul White (for Ngai Tahu) – supplementary evidence;
   - Peter Callander (on behalf of Christchurch City Council);
   - Peter Callander (on behalf of WIL, Kaiapoi Community Board and WDC);
   - Peter Callander (on behalf of quarry operators);
   - Peter Callander (on behalf of CIAL);
   - Richard English – main evidence;
   - Richard English – supplementary evidence;
   - Paul and David Birkett – joint statement; and
   - The Lowland Farming Group – joint statement of evidence.

3. My response is limited to the sections of the Submitters' reports that relate to groundwater flow modelling.

4. The paragraph numbers at the start of the following paragraphs refer to the paragraph numbering in the respective Officers and Submitters' reports, as do the section headings.

OVERALL COMMENTS ON MODEL ACCURACY

5. Several Officers and Submitters have questioned the accuracy of the model predictions, particularly with reference to local knowledge and measured groundwater levels at specific locations in the lower plains. In general, I agree with these remarks, and I do acknowledge that there are differences between measured and modelled groundwater levels; this is discussed in Aqualinc (2007), my main

evidence and in my Response to Sect. 42A Officers' Reports. The following is further information to bring balance to the various opinions on model accuracy that have been presented at this hearing.

6. The Canterbury groundwater model is a regional scale model designed to predict the regional scale effects. There will almost always be differences between the measured and modelled groundwater levels at a particular location because the model cannot (in a practical sense) completely or exactly represent the system (paragraph 26 of my main evidence). Added to this are the inherent uncertainties associated with measured data such as land surface elevations, river and stream flows, invert levels, aquifer tests and groundwater level measurements.

7. It is therefore important to consider the model calibration in a regional context. The overall transient model errors are described in Table 2 of my main evidence and are commonly accepted ways of mathematically describing the regional fit. In my experience, the overall model errors suggest that the transient model is suitably calibrated (paragraph 77 of my main evidence).

8. This is the same conclusion reached by Dr. Noel Merrick, who independently reviewed the calibrated model. Dr. Merrick concluded that the model is well calibrated, has been developed competently, and is suitable for guiding regional water management decisions. It is a faithful simulator of the groundwater system (paragraphs 41-42 of my main evidence).

9. As a further example of this, I present additional examples of the comparison between measured and simulated groundwater levels for three calibration wells located in the lower plains area. The locations of these wells are shown in Figure 1 and the plots are reproduced from Aqualinc (2007) in Figure 2. There is good correlation between measured and simulated groundwater levels.

10. Although the model is suitably calibrated at a regional scale, there are differences between some measured and modelled data (particularly groundwater levels) at specific sites. Mr. Callander has noted some of these in his evidence on behalf of Christchurch City Council and on behalf of Gravel Extractors, as have the Lowland Farming Group in their evidence.

11. The model should not take the place of reliable field measurements. However, it can be used to interpret groundwater levels and stream flows where measurements don't exist, in both time and space.

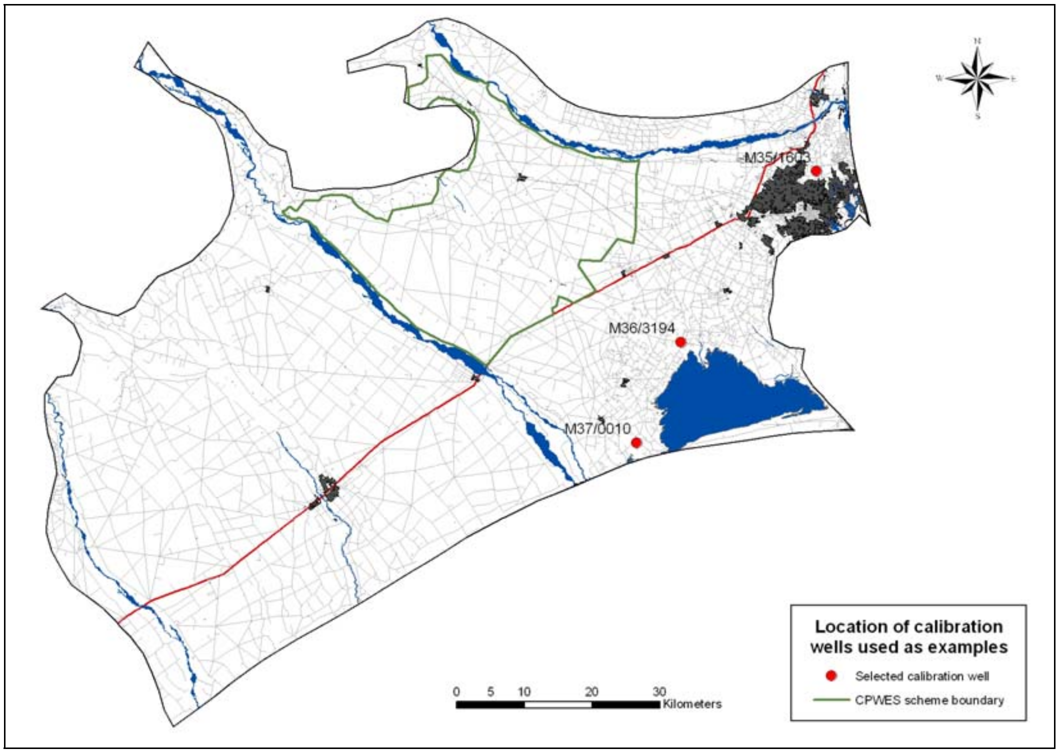


Figure 1: Locations of selected calibration wells

12. There is uncertainty in the modelled prediction of depths to shallow groundwater. This uncertainty stems from uncertainties in both the modelled groundwater level and in the measured land surface elevations. Particularly, the land surface elevations have been taken from 1:50,000 scale topographical maps, which is the best data set that is currently available for much of the plains, yet is still approximate (for example, the maps do not describe the local undulations between contours). Therefore, the depths to shallow groundwater will also be approximate and vary between actual and modelled.

13. In addition, due to scale, the groundwater model does not provide for all the smaller drains and streams that exist. Therefore, the actual drainage network will work more effectively than modelled and the potential groundwater mound is likely to be over stated, particularly in the lower plains area.

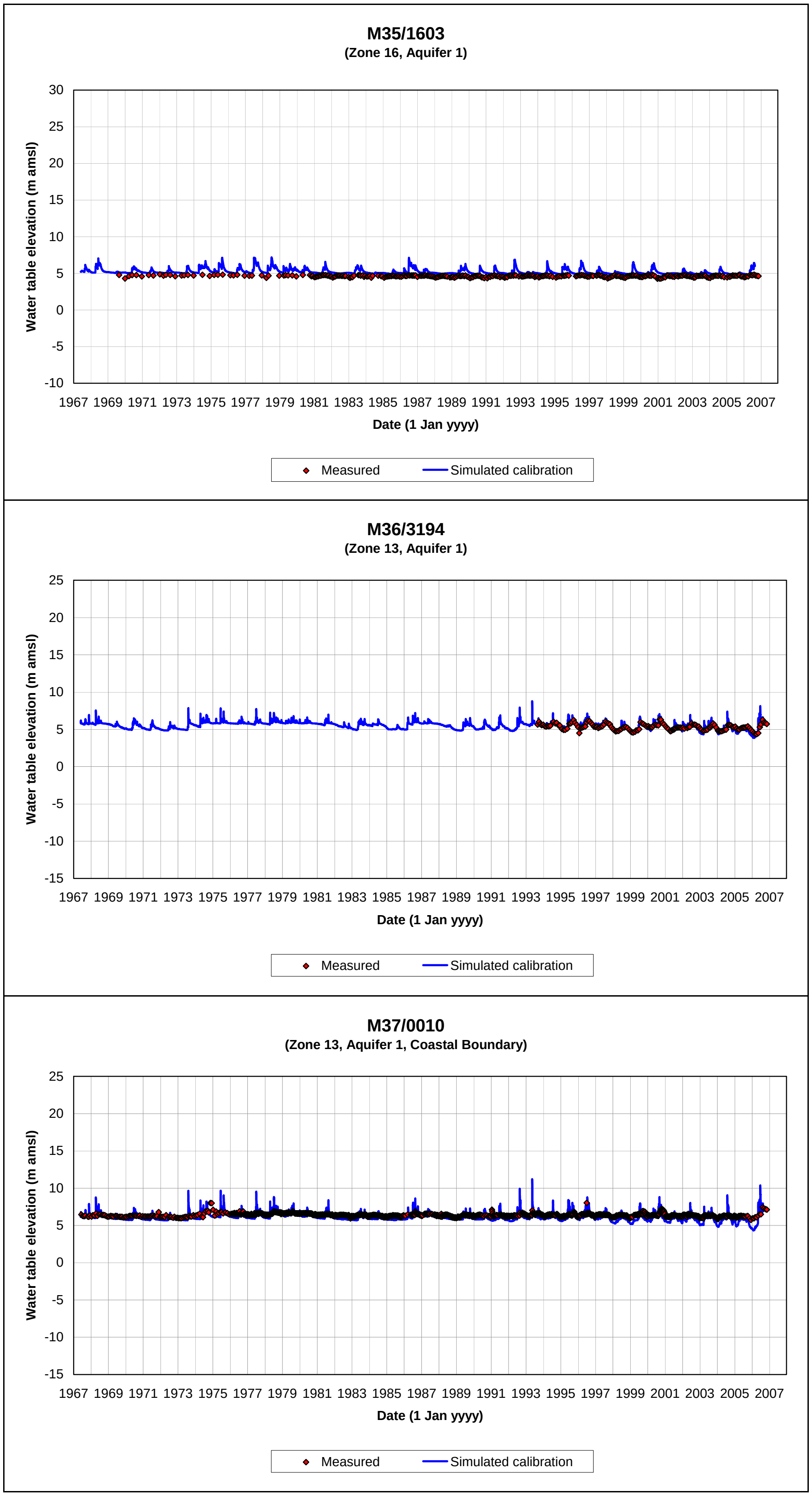


Figure 2: Example calibration plots

14. The key value from the modelling predictions is the trends and patterns of changes, and the magnitude of these trends and patterns over space and time. For this reason, the changes in groundwater levels and stream flows can be accepted as indicative of the likely (or slightly conservative) changes expected at a regional scale, even though predictions may vary at a local scale. For a more accurate prediction of the effects at a local scale, the changes predicted from the groundwater model should be superimposed onto local measured data (where this exists), with a maximum height of the shallow aquifer water level limited by the ground surface. I understand this concept has been employed by Mr. Lewthwaite (on behalf the Applicant) and by Mr. Callander, the Lowland Farming Group and (possibly) other submitters in their consideration of effects at specific locations. This is an appropriate application of the model results.

15. As a summarising remark, I reiterate my comments from paragraph 5 of my response to Section 42A Officers' reports that the Canterbury groundwater model is the most advanced method available to predict the complex interactions of the groundwater system it represents. There is currently no better method of predicting the cumulative effects from the Central Plains Water Enhancement Scheme (CPWES).

OFFICER'S REPORT BY VINCE BIDWELL

16. Dr. Bidwell has considered an eigenmodel method for representing the response of groundwater to land surface drainage. The eigenmodel method is suitable for simulating the land surface response of groundwater at a specific location. It also can be used to determine the relative proportions of land surface recharge and river recharge. However, it has limited use for *predicting effects* in complex three-dimensional aquifer systems. The following are some comments on this method in relation to the CPWES application:

- The eigenmodel theory makes various assumptions to simplify the complex groundwater system. This is necessary to enable representation by the simple eigenmodel.

- The eigenmodel assumes the aquifer system acts as a single unit (i.e. the 'bathtub' theory). Consequently, it cannot simultaneously represent multiple layers with horizontal and vertical anisotropy (as is the case in the Central Plains aquifers). A separate model (each with different coefficients) is required to describe the groundwater response at different locations.

- The eigenmodel assumes that river recharge is steady and therefore does not allow for temporal variations in this recharge. It also does not provide for significant spatial variations in land surface recharge and groundwater abstraction.

- It does not allow for the correlation between system inputs. For example, groundwater levels are predicted to rise due to the extra land surface recharge under the CPWES. In doing so, the difference in elevation between the river surface and adjacent groundwater reduces which results in a reduction of recharge from the river. This rebalancing is not accounted for in the eigenmodel.

- The eigenmodel does not differentiate between offshore discharge and lowland stream flow discharge. It is therefore not possible to quantify the effects of a proposed activity on each of these two discharge mechanisms separately, though I understand that separate models can be constructed to simulate each component independently. In doing so, the relationship between the two outflows is removed.

- It does not report a water budget and therefore there is no independent check to determine if the model is accurately accounting for the water.

Achievable Groundwater Level Prediction

17. Para. 14-15: Based on the calibration of well L36/0092, Dr. Bidwell has concluded that the groundwater model is insufficiently calibrated. I have two comments to make in response to this conclusion:

- It is important to maintain a regional context of the model. I refer back to paragraphs 6 and 7 above for further comment. The overall model correlation coefficient (R^2) of the Canterbury groundwater model is 0.997 (Table 2 of my main evidence) which is greater than the fit for the eigenmodels considered by Dr. Bidwell (0.82-0.91) as reported in Table 5 of MAF (2003).

- The key issues relating to the effects on groundwater flow from the CPWES are rises in shallow groundwater levels and associated increases in lowland stream flows. Bore L36/0092 (referred to by Dr. Bidwell) is 60.6 m deep, is considered to be in aquifer 2, and is located mid-plains. The predicted groundwater levels in this bore, and the predicted rise due to the CPWES, are irrelevant to the key issues. Groundwater levels have been measured in L36/0092 since 1952 and vary between approximately 27 to 57 m bgl (based on data presented on ECan's website). The predicted rise in groundwater levels in this bore as a result of the scheme is approximately 4-11 m (depending on the season). As this bore is in aquifer 2, the rise in groundwater levels would be considered a positive effect (the higher groundwater levels remain well below the ground surface). If the predicted groundwater level rise in this bore is less than what might actually happen, then the positive effects are understated. This is further discussed in paragraphs 23-24 of my Response to Sect 42A Officers' Reports.

Occurrence of Under-Prediction of Groundwater Levels

18. Para. 20: The locations of residuals in the steady state model are provided in Figure 7-4 of Aqualinc (2007).

Consequences of Under-Prediction of Groundwater Levels

19. Para. 21: It is suitable to compare model predictions with observation records for the calibrated model scenario, as this model is attempting to reproduce the observed records. However, it is not suitable to compare model predictions for future scenarios with observed, as the model results will be different to observed records; the model is predicting a response that has not yet occurred. I again refer to paragraphs 23-24 of my Response to Sect 42A Officers' Reports in response to the last sentence of this paragraph.

SUPPLEMENTARY OFFICER'S REPORT BY DAVID SCOTT

Model Conceptualisation

20. Para. 3, 1st bullet point: In the Valetta-Ashburton River hearing, I responded to Mr. Williamson's opinion that the vertical hydraulic conductivities 'are equivalent to that expected for concrete and sedimentary hardrock'. This response is reproduced below (in italics) with edits made to bring into the context of this hearing.

> *The vertical hydraulic conductivity values used in the model were derived via calibration. As described in Section 7.2 of Aqualinc (2007), the vertical hydraulic conductivities were initially set the same as the horizontal conductivities (i.e. when the model was first set up). As part of the calibration process, the vertical conductivities were varied until a suitable calibration fit was achieved. These values represent the vertical resistance to flow through the aquifer system and may vary from actual values due to the regional, large scale representation. Even so, the values are within the range of the few values derived from aquifer tests in Canterbury (Appendix C, Aqualinc, 2007).*

The aquitards are not modelled as impermeable. Flow through these aquitards is the only modelled mechanism that is available for water to enter the deeper layers.

The modelled values of vertical hydraulic conductivities range from 10^{-10} *to* 10^{-7} *m/s (*10^{-5} *to* 10^{-2} *m/day, Appendix V, Aqualinc, 2007). Table 2.2 of Freeze & Cherry (1979) summarises typical ranges of hydraulic conductivity values for various soil and rock types; this table is reproduced in Appendix A.*

Freeze & Cherry (1979) describe how fine-grained glacial till and deposits of silt and clay are the most common aquitard material in most of the northern parts of the United States and in the southern parts of Canada. Silts and claybound gravels are commonly described in bore logs from Canterbury, which, based on Table 2.2 of Freeze & Cherry, is consistent with the description of 'glacial till' and 'silt, loess'. These materials have hydraulic conductivity values ranging from 10^{-12} *to* 10^{-5} *m/s. The calibrated values in the Canterbury groundwater model are within this range.*

As part of my Master of Engineering thesis research (Weir, 1999), I conducted a single direct measurement of the hydraulic conductivity of a shallow confining layer using the Hvorslev's Slug Test method. This test resulted in a hydraulic conductivity of the aquitard of approximately 10^{-4} *m/day (or* 10^{-9} *m/s). Although this is a single localised measurement of hydraulic conductivity, it falls within the range of values incorporated in the calibrated groundwater model.*

Based on Table 2.2 in Freeze & Cherry (1979), sedimentary rocks (limestone and sandstone are two sedimentary rocks listed in Freeze & Cherry) have a wide range of hydraulic conductivities which are similar to glacial tills, silt loess, silty sand and clean sand. This range is 10^{-10} *to* 10^{-6} *m/s, which again is consistent with the modelled vertical conductivities.*

In addition, Marseguerra et. al. (2002) describe the hydraulic conductivity of concrete based on experimental data fitting as $2x10^{-11}$ *cm/s, which equates to* $2x10^{-13}$ *m/s. This is three orders of magnitude (i.e. 1,000 times) less conductive than the lowest values of conductivity used in the groundwater model.*

21. I therefore cannot agree that the modelled aquitard vertical conductivities are equivalent to that expected for concrete and sedimentary hardrock. I am confident that the modelled parameters are suitable and that the modelled predictions are reliable.

22. Para. 3, 2nd bullet point.: Mr. Scott's suggestion that the aquifer/aquitard layered sequences may be a convenient mathematical device to represent the effects of **horizontal** anisotropy seems unusual. Horizontal anisotropy is represented by varying the aquifer material properties (particularly hydraulic conductivity) within any layer, and the regional scale anisotropy has been applied as per the hydraulic conductivity zones presented in Appendix A of my main evidence. These are consistent with values derived from aquifer tests. Vertical anisotropy has been represented by the vertical hydraulic conductivities of the different layers, which were arrived at through the calibration process (paragraph 15 of my main evidence and paragraph 20 above). It is standard practice to include 'notional' layers in a sedimentary sequence to control vertical groundwater flow. This allows the replication of the vertical head differences measured between aquifers. I therefore cannot agree with Mr. Scott that the model's hydrological representation may be physically unrealistic.

23. The original annotation of figure 1(b) is missing from Mr. Scott's report. This conceptual model has been reproduced from Davey (2006). Here, Davey annotates this model by describing the blue finger-like pattern as aquifers and the red lines as aquitards. On this same figure, Davey also describes the 'aquifers' as 'intimately connected…permeable lenses…' and the 'aquitards' as '…no direct vertical connection between permeable lenses'. The groundwater model represents the 'intimately connected…permeable lenses' as aquifers and the layers where there are 'no direct vertical connections between permeable lenses' as aquitards.

24. Para. 4: As clarification, I do not reject Dr. Merrick's recommendation that model run times should be reduced. To the contrary, I agree. However, a scientifically valid model was achieved despite extended run times. The extended run times meant that it took longer to reach calibration, and does not alter the validity of the results.

Calibration to Observed Groundwater Levels

25. Paras. 6 and 7: I disagree with Mr. Scott's suggestion that modelled horizontal flow could be over estimated. The aquifer horizontal conductivities are consistent with values derived from aquifer testing. I also do not agree that flows to surface water features could be over estimated. There is no consistent demonstration of this in the comparison of measured and simulated stream flows (paragraph 78-81 of my main evidence). I refer to paragraph 28 of my Response to Sect 42A Officers' Reports for further discussion on the Selwyn River example raised by Mr. Scott. I also refer to paragraph 24 of the same response in regard to the conservativeness of the predicted rise on aquifer 1 water levels.

26. Para. 8 and 9: The changes in groundwater levels using the eigenmodel for well L36/0092 considered by Mr. Scott is conceptually consistent with the predictions from the Canterbury groundwater model, though the Canterbury groundwater model provides for the seasonal variations in land surface recharge (less additional recharge in wet years and more in drier years). For the reasons discussed in paragraph 17 (2nd bullet point) above, a slightly lower 'base case' level is conservative at the location of well L36/0092. Again, I refer to paragraph 24 of my Response to Sect 42A Officers' Reports in regard to the conservativeness of the predicted rise on aquifer 1 water levels.

27. Para. 9 cont.: Based on his eigenmodel predictions, Mr. Scott has concluded that the new dynamic equilibrium could be reached in 6 to 8 years. Based on my assessment of Mr. Scott's Figure 2, the equilibrium is reached in about 4-6 years. Nevertheless, these predicted times are consistent with the predictions from the Canterbury groundwater model of 3 to 5 years (paragraphs 190-196 of my main evidence), that is a few years, rather than tens of years.

28. Further to this, most of the effects from the scheme are predicted to be realised within the first two years of operation (assuming full uptake and use of the water occurs when the scheme commences). In Figure 17 of my main evidence I presented plots showing two time series of transient groundwater levels under the CPWES scenario. One time series commences with the Status Quo groundwater levels and the other with CPWES groundwater levels. The convergence of these two lines describes how rapidly the effects from the CPWES are realised. To clarify this demonstration, I have plotted the difference between the two time series for one of the wells in Figure 17 of my main evidence, L36/0142, and this plot is presented in Figure 3.

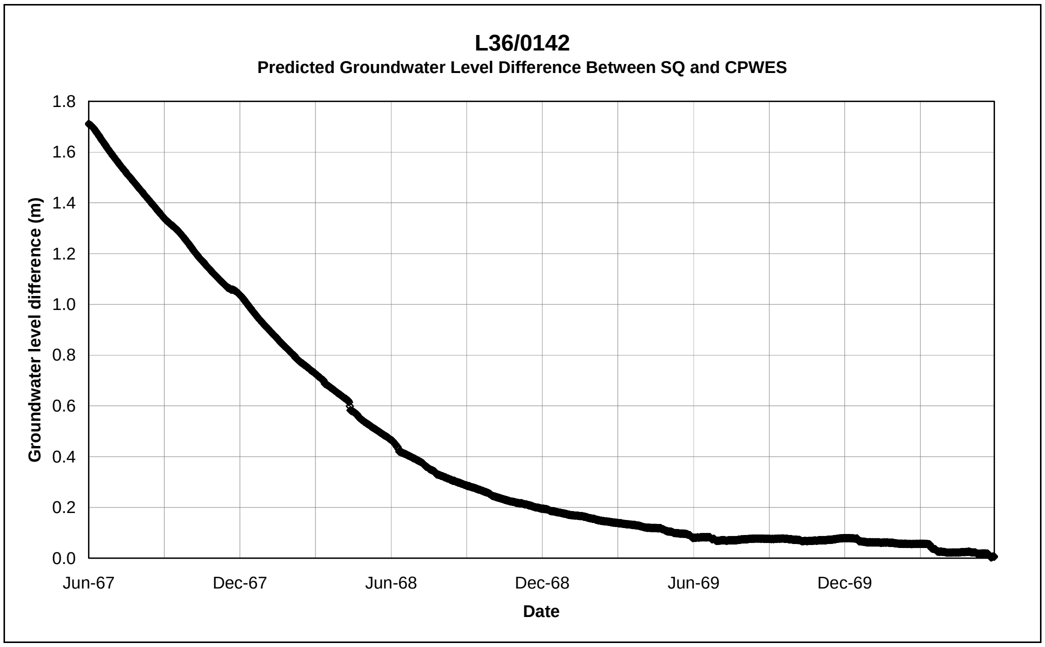


Figure 3: Groundwater level difference example

29. Figure 3 shows how 90% of the effects from the scheme are realised within two years of commencement of the scheme, and the remainder shortly there after.

30. Para. 10: Mr. Scott comments that demand for irrigation water is not particularly dependent on prior winter recharge. Except for the start of an irrigation season, I would agree with this. A wet winter delays the start of an irrigation season due to the storage of moisture in the soil profile. The subsequent demand for irrigation is then dependent on the rainfall and crop water requirements in summer and autumn, which will vary from season to season.

31. Related to this, and to Mr. Scott's suggestion in his paragraph 11 regarding a worst-case prediction, is that when groundwater levels are high (say due to extended periods of above average recharge), groundwater outflow is also high (head versus flow relationship). Consequently, high groundwater levels fall rapidly after the cessation of high recharge. As an example, the measured groundwater levels in bore L36/0092 (Figure 4) show rapid decline after relatively short periods of high levels.

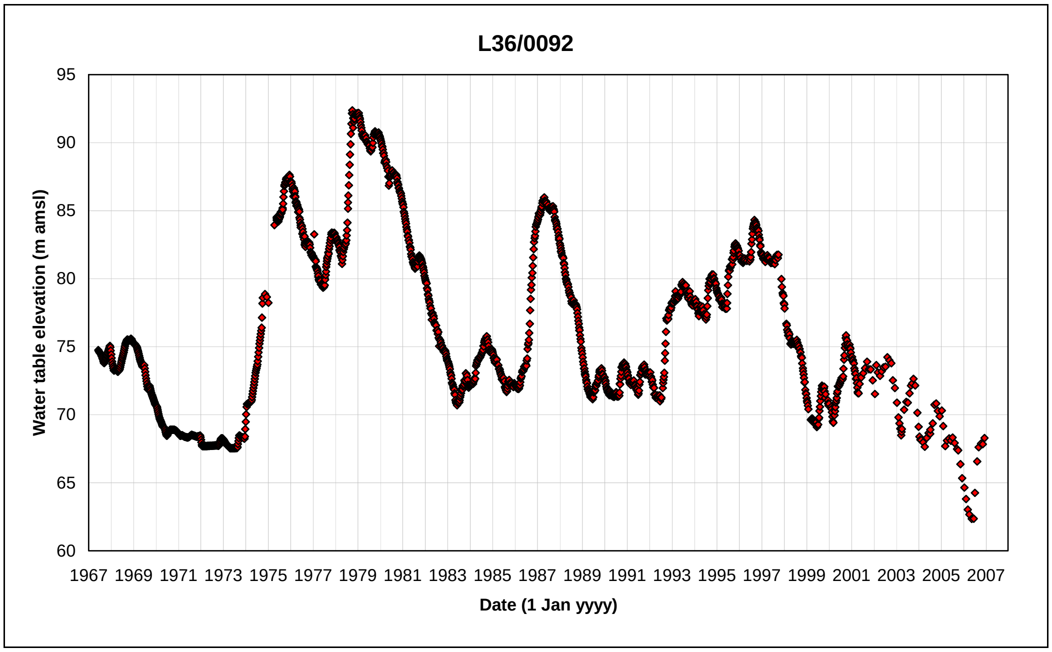


Figure 4: Measured groundwater levels in bore L36/0092

32. The conclusion from this is that extended periods of high groundwater levels coinciding with extended periods of high irrigation demand do not exist. Periods of high irrigation demand occur when there is little rainfall, which corresponds to periods of low natural land surface recharge and naturally declining groundwater levels.

33. Para. 11: I am not an expert on climate change, but I understand that most climate change scenarios project slightly less rainfall on the Canterbury Plains and a small increase in PET (Woods *et. al.*, 2008). This will result in less land surface recharge to groundwater and therefore lower groundwater levels. The result of this is that any potential groundwater mounding from the CPWES will occur on top of lower groundwater levels and therefore the potential adverse effects of shallow groundwater level rise will be reduced.

34. Para. 12: I wish to reiterate that I still consider that the variability in groundwater levels introduced by the CPWES will be less than the natural variability due to climate (in most areas of the plains). Using the same example referred to by Mr. Scott (M35/1000), status quo water levels vary by 12 m (between the highest and lowest measured water level) over the period simulated. The additional rise in groundwater levels due to the CPWES is approximately 3 m, which is one-quarter of the natural variability. My conclusion from this is that the CPWES is predicted to cause a rise in groundwater levels, but the overall variation in groundwater levels will still be dominated by climatic variations.

RESPONSE TO SUBMITTER'S REPORT BY PAUL WHITE (BRIEF OF EVIDENCE) FOR NGAI TAHU

35. Mr. White makes many references to Krom & Weir (2006). I have stated in paragraph 4 of my Response to Sect. 42A Reports that all components of Krom & Weir relating to groundwater flow have been superseded by the assessment presented in my main brief of evidence. Therefore, any comments by Mr. White relating to this document are not material to this hearing.

Summary of Submission

36. Para. 3.10: Mr White considers that 'groundwater users will probably hold, or increase, their allocation to guarantee security of supply'. I disagree that groundwater users will probably increase their allocation as ECan's current 'red-zone' consenting process makes this very difficult. Farmers may hold onto their existing allocation and only use this when CPW water becomes restricted. However, in doing so, others would be prevented from 'using' this water, which would result in overall less groundwater abstraction than is currently the case.

37. Para. 3.11: The effective allocation as listed on ECan's web site on 2nd September 2008 is 157.25 MCM/yr for the Selwyn-Waimakariri zone and 247.99 MCM/yr for the Rakaia-Selwyn zone. These sum to 405.24 MCM/yr, which equates to an annual average take of 12.8 m^3/s. The current allocation limit (as at 2nd September 2008) for Rakaia-Selwyn and Selwyn Waimakariri allocation zones are 336.3 MCM/yr, which equates to an average annual take of 10.7 m^3/s.

38. The additional land surface drainage predicted as a result of the CPWES is approximately 4.1 m^3/s (refer to Appendix P of my main evidence). ECan's 2nd order allocation method arbitrarily assumes that half of the land surface drainage is available for allocation. Hence, by this method, an additional 2.05 m^3/s of land surface drainage is created in the allocation zones as a result of the CPWES. Adding this to the existing 10.7 m^3/s equates to a total of about 12.75 m^3/s, almost equivalent to the existing effective allocation of 12.8 m^3/s (see paragraph 37 above). Given that existing irrigation abstraction is predicted to reduce with the operation of the CPWES, I cannot agree with Mr. White that ' a substantial risk of unsustainable use of the groundwater resource…will remain after CPWES development'.

39. Para. 3.12: I discuss the water budget components later in my response.

40. Para. 3.14 and Para. 16.25: Except for one, the particle tracking estimates presented in my evidence indicate that groundwater reaching Christchurch City

originates from outside the CPWES boundary. One particle is predicted to originate from just within the north-eastern corner of the boundary (i.e. within the Groundwater Protection Zone identified in the NRRP). However, it is no longer planned to supply this area from the scheme and therefore particles of water from this area that reach Christchurch city will not be source from within the CPWES boundary.

41. Paras. 3.19, 3.29 and 12.12: Here (referring to his paragraph 12.12), Mr. White has made the assumption that changes in groundwater recharge to Lake Ellesmere catchment, Christchurch City catchment and to the Little Rakaia River catchment are linearly proportional to the existing balances. This may not be the case, as changes to the relative components of the water balance are a function of various parameters including aquifer hydraulic conductivity, groundwater levels, pumping, relative location to streams and drains etc. Based on the modelling work I have undertaken, the aquifer system is non-linear, and therefore the changes in the water budget components predicted by Mr. White may not be correct.

42. Para. 3.31: I do not agree with Mr. White's prediction that stream flows will increase significantly more than what has been predicted by the Canterbury groundwater model. However, if this was the case, then groundwater mounding would be less than predicted.

The Central Plains Area

43. Para. 6.14: I disagree with the estimate of groundwater discharge into Lake Ellesmere via seepage through the bed of the lake. I refer to paragraph 36 of my Response to Sect. 42A Officers' Reports for discussion on this topic.

General Issue: Water Budget in the Central Plains Area

44. Para. 10.5, 1st and 2nd bullet points: The estimate of river recharge from the groundwater model as presented in Appendix P of my main evidence is a direct output from the model and is the *gross* amount of water moving from streams into the groundwater system. The totals include water that may have entered groundwater from the stream, travelled through groundwater and back into the stream somewhere else, then recounted as it re-enters the groundwater system again further down stream. This is particularly the case for the Selwyn River. In addition, the river recharge component of the mass balances includes recharge from the Waimakariri River to the north. Therefore, the total river recharge and overall model inputs reported will be larger than the other estimates presented by Mr. White, as these other estimates are likely to be *net* inputs.

45. Para. 10.5, 3rd bullet point: For the same reasons as discussed in the paragraph above, the outputs reported are *gross* outputs and will also be larger than the *net* estimates presented by Mr. White.

46. Para. 10.5, 4th bullet point and Para. 15.19: It appears Mr. White has derived the modelled stream flow contribution to Lake Ellesmere from the table in my Appendix L, rather than Appendix P. I agree that the total flows in streams flowing into Lake Ellesmere are less than measured, based on the values reported in Horrel (1992). There are two reasons for this. Firstly, the model includes all the main streams and drains, but due to the large (regional) scale of the model, does not include all of the smaller streams and drains. Secondly, the model does not provide for the quick-flow component of the stream flows (refer to my main evidence, paragraph 84) and so the modelled higher flows will be less than measured. However, the model does appropriately reproduce the base flow time series in the drains and streams that are included in the model (refer to my main evidence, paragraphs 78-84).

47. The consequences of under predicting total stream flows into Lake Ellesmere are that the groundwater mounding as a result of the CPWES will be less than predicted (because more water is able to exit the groundwater system through the lowland drains) and consequently the flow increases in any of the individual streams and drains modelled will be less than predicted (due to the lesser mound and more dispersed drainage mechanisms). In addition, subsurface flows under Lake Ellesmere are likely to be less than predicted, which would result in less bed seepage into the lake. The combined greater flow increase from lowland streams and lesser bed seepage into the lake is likely to result in a similar amount of total flow increase into Lake Ellesmere to what has been predicted under the CPWES.

48. Para. 10.5, 5th bullet point: Estimates of Lake Ellesmere bed leakage referred to by Mr. White have been derived principally by a misbalance of inflows and outflows. I refer to paragraph 36 of my Response to Sect. 42A Officers' Reports for further discussion on measured seepage into Lake Ellesmere. However, if the modelled seepage into Lake Ellesmere was significantly greater than actual, then so too would be the predicted increase in seepage due to the CPWES. This is a conservative prediction of effects.

49. Para. 10.5, 6th bullet point: It appears that Mr. White has misunderstood the water balance reported in my evidence. I refer to paragraph 33 of my Response to Sect. 42A Officers' Reports for discussion on the mass balance reporting and reiterate that the total water balance is accurate (typically much less than 1% difference between input and outputs) but the individual components for sub-zones of the model are not

reported by the software. Hence, the water balances reported in my evidence are approximate only and have been provided to show how the overall water balance changes with the inclusion of the CPWES.

50. Para. 10.6: The Canterbury groundwater model is a *groundwater* model and therefore does not consider rainfall and evaporation in and out of Lake Ellesmere, and surface flows from Banks Peninsula into the Lake. These components do not form a part of the groundwater balance considered by the regional model.

51. Para. 12.2, 1st and 2nd bullet points: Appendix I of my main evidence does not present particle tracking. Appendix I presents the *horizontal* flow divide for each modelled aquifer independently. For the reasons discussed in paragraphs 153-156 of my main evidence, little weight should be given to the modelled flow divide near the inland boundary and for aquifer 5. As discussed in paragraph 157 of my evidence, the horizontal flow directions presented in Appendix I do not provide complete information on the three-dimensional path a particle of water may take as it travels through the multi-layer aquifer system. To consider this, the particle tracking techniques discussed in paragraphs 158-168 of my main evidence have been considered. I refer to paragraph 40 above for additional comment on the particle tracking.

52. Para. 12.7 and 12.8: The message in these paragraphs is unclear, but Mr. White may be trying to demonstrate that groundwater travels predominantly to streams rather than off shore. If this is the case, then it is contrary to his statement in paragraph 12.6 where he agrees with me that a large portion of the water draining into the groundwater system under the scheme will either discharge into Lake Ellesmere or offshore via subsurface flow. It is therefore worth commenting that stream bed leakage parameters and off-shore hydraulic conductivities (resistance to flow) were not assumed; they were determined throughout the calibration process.

53. Para. 12.7, 4th bullet point: The areas of low groundwater nitrate concentration in Mr. White's Figure 12 appear to be in areas that are recharged from water sources low in concentration, primarily rivers (such as the Waimakariri and Rakaia rivers). The low concentration of nitrates around Lake Ellesmere may be due to the diluting effect of the Selwyn and Irwell rivers, streams flowing off Banks Peninsula and groundwater sourced from deeper, cleaner aquifers (i.e. upward movement).

54. Para. 12.8, 1st bullet point: The two references reported here are contradictory. I refer to paragraph 16 of my main evidence for discussion on how the off shore mechanism is represented in the model.

55. Para. 12.8, 2nd bullet point: In his assessment, Krom (2007) has used many simplifying and approximating assumptions, and various 'what if' scenarios. Nevertheless, the water balance presented in Appendix P of my main evidence is consistent with Krom's findings that the off shore groundwater discharge is at most 20% of the discharge from the groundwater system. The off-shore portion of the water balance in my Appendix P is approximately 14% of the total model outflows in the Rakaia-Waimakariri area.

56. I disagree with Mr. White's assumption that the term 'discharge from the groundwater system' referred to by Krom (2007) includes groundwater use and groundwater discharge in spring fed streams. My understanding of reading Krom (2007) is that the term relates only to subsurface flow of groundwater off shore; he separates the 'off-shore flow' and the 'spring fraction' in some of his discussion and presentation of results. If the term was to include groundwater use and discharge to spring-fed streams, then the ratio would be closer to 100%, as apart from seepage into Lake Ellesmere, there is no other mechanism of discharge.

57. Para. 12.8, 3rd bullet point: The range of off-shore discharge presented by Mr. White is very large (0-67% of the total aquifer outflow) and is practically meaningless. His calculations of the off-shore flows in Table 5.10 of White (2008) result from the misbalance between inflows and outflows; they are not verified by an independent method. Because of this, the water budgets in this table will always balance, regardless of error in the individual components.

Central Plains Water Enhancement Scheme and the Catchment of Te Waihora

58. Para. 15.17: Here, Mr. White refers to Table 9.7 of White (2008) which summarises his assessment of some water budget components under pre-historic, current and CPWES conditions. In this table, Mr. White has assumed that there will be no change in groundwater seepage into Lake Ellesmere due to the CPWES, which I consider to be erroneous. In the same table, Mr. White predicts increases in stream flows and off-shore discharge (which would include discharge beyond the lake). For an increase in stream flows and off shore discharge to occur, there has to be an increase in hydraulic gradient. Consequently, the hydraulic gradient between the lake and adjacent (or underlying) groundwater would also increase, therefore increasing the seepage into the lake.

59. In addition, Mr. White has provided for a reduction in groundwater takes in Table 9.7 of White (2008). This is inconsistent with his comment in his paragraph 3.10 where he considers that 'groundwater users will probably hold, or increase, their allocation to guarantee security of supply'.

Central Plains Water Enhancement Scheme and the Catchment of Christchurch City

60. Para. 16.14-16.15: Mr. White considers that the groundwater mounding indicates the potential for groundwater to move towards Christchurch city. I disagree. The groundwater mound itself does not necessarily imply a change to the direction of groundwater flow. A lack of change towards the city is demonstrated by the flow divides presented in Appendix I of my main evidence. Also, the particle tracking indicates that water flowing under Christchurch city is unlikely to originate from within the CPWES boundary. I refer to my paragraph 40 above for further comment.

Central Plains Water Enhancement Scheme and Groundwater Recharge from the Waimakariri River

61. Paras. 18.12-18.16: Here Mr. White considers that the reduction in Waimakariri River flows will reduce the amount of recharge flowing towards Christchurch City and therefore will lower groundwater levels, move dry stream beds eastward, reduce stream flows, and reduce off-shore discharge. In forming this opinion, it appears that Mr. White has omitted to consider the interactive nature of the groundwater-river system, and the rebalancing that occurs when changes are introduced to the system.

62. A reduction in river flows alone will reduce river recharge to the groundwater system, but this is mitigated by the increased land surface recharge and subsequent rise in groundwater levels due to the transmission and use of the water for irrigation. I refer to paragraphs 136-148 and 173-178 of my main evidence for further discussion on this. The complex interaction between aquifer inputs and outputs has been represented by the groundwater model. A rise in groundwater levels is predicted, as is an increase in lowland river flows and off-shore discharge due to the CPWES. I therefore cannot agree with Mr. White that groundwater levels, stream flows and off shore discharge will reduce, or that dry stream beds will move east. Mr. White's comments under paragraph 18.16 (1st bullet point) are inconsistent with his statement in his paragraph 3.20.

RESPONSE TO SUBMITTER'S REPORT BY PAUL WHITE (SUPPLEMENTARY EVIDENCE) FOR NGAI TAHU

Waimakariri River Groundwater Discharge and Irrigation

63. Para. 7.2: In this paragraph, Mr. White states that 'discharge through the Waimakariri River bed is estimated…as at least 10.1 m^3/s to Christchurch groundwater and…spring fed streams'. This is inconsistent with paragraph 18.14 in

his main evidence where he states that 'current groundwater recharge from the Waimakariri River to Christchurch City is estimated as 6-7 m^3/s.

64. Para. 9.2: In this paragraph, Mr. White states that 'the reduction in average groundwater discharge from the Waimakariri River to Christchurch groundwater and…spring-fed streams as approximately 0.5 m^3/s due to the CPWES irrigation take'. However, in paragraph 18.15 of his main evidence, he discusses a reduction in the range of 1-1.5 m^3/s, which is different to the values in his supplementary evidence.

65. Paras. 9.3 and 9.4: Given the rebalancing of the groundwater system and the extra water entering the groundwater system from the CPWES (paragraph 62 above), I do not agree that the CPWES will result in a significant water budget issue for Christchurch. Overall, I predict there will be more water flowing in the groundwater system towards Christchurch and West Melton with the CPWES than without, and therefore I expect flows in the Avon and Heathcote rivers to be enhanced.

RESPONSE TO SUBMITTER'S REPORT BY PETER CALLANDER ON BEHALF OF CHRISTCHURCH CITY COUNCIL

66. Para. 3.17: Mr. Callander has quoted paragraph 177 of my main evidence. In the verbal delivery of my evidence, I advised the Commissioners of a typographical error in this paragraph. The values of 5% and 8% for the reduction in groundwater recharge for the Waimakariri and Rakaia rivers respectively are switched. The correct numbers are 8% for the Waimakariri River and 5% for the Rakaia River. I do not consider that this correction will alter Mr. Callander's conclusion.

67. Para. 5.4: Mr. Callander has referred to the flow divides predicted for aquifers 4 and 5. I refer to my paragraph 51 above for discussion on these flow divides and agree with Mr. Callander where he states that 'in reality, there is little data to be certain of the direction of these deep flow paths'. I comment again that these flow divides do not represent the three-dimensional path a particle of water may take as it travels through the multi-layer aquifer system.

RESPONSE TO SUBMITTER'S REPORT BY PETER CALLANDER ON BEHALF OF WIL, KAIAPOI COMMUNITY BOARD AND WDC

68. Paras. 4.4-4.6. Mr. Callander has raised concern regarding the reduction of Waimakariri River recharge to groundwater, both to the south and to the north of the

river. Losses to groundwater to the south of the river (towards Christchurch City) are discussed in my paragraph 62 above.

69. Losses to the north are not specifically addressed in my evidence, though I make comment on the potential effects in paragraph 51 (4th bullet point) in my Response to Sect. 42A Officers' Reports. I add to this that the predicted reduction in Waimakariri River recharge water (8%) is the total reduction that includes losses to the north and to the south. This loss would be shared between each side of the river, so the reduction to groundwater in either direction will be less than the 8%. Shallow aquifer hydraulic conductivities are typically higher on the south side of the river than the north (refer to Aqualinc, 2007, Appendix J), and so I would expect that the south side (which receives the additional land surface recharge from the CPWES) to experience a disproportionately larger amount of the reduction, compared to the north, likely to be in the order of one-third north, to two-thirds south.

70. Para. 4.5: I refer to paragraph 66 above regarding corrections to typographical errors in paragraph 177 of my main evidence.

RESPONSE TO SUBMITTER'S REPORT BY PETER CALLANDER ON BEHALF OF QUARRY OPERATORS

71. Para. 3.8: I disagree that there is considerable uncertainty as to the magnitude of the increase predicted by the model. I consider the predicted mound to be a reasonable prediction given the scenario simulated. I refer to paragraph 14 above regarding the application of regional model predictions at a local scale.

72. Para. 3.9: I consider that the level of model accuracy should not be of concern to the quarry operators. In the four examples of model fit Mr. Callander has presented in his Figure 4b, the variations in groundwater levels are either equal to, or a little greater than, measured (i.e. modelled water level fluctuations are either similar to, or a little greater than, measured). Where variations are greater than measured, the predicted mounding will also be greater than what might actually occur, which is a conservative prediction of effects.

RESPONSE TO SUBMITTER'S REPORT BY PETER CALLANDER ON BEHALF OF CHRISTCHURCH INTERNATIONAL AIRPORT LTD

73. My response in paragraphs 71-72 above are also applicable to the parts of Mr. Callander's submission (on behalf of Christchurch International Airport Ltd) that relate to groundwater flow modelling.

RESPONSE TO SUBMITTER'S REPORT BY RICHARD ENGLISH (BRIEF OF EVIDENCE)

74. I have met with Mr. English on several occasions and have exchanged various telephone calls and emails discussing his evidence, the model and its predictions. Overall there are various aspects of Mr. English's evidence that I agree with, and some of the key concepts that Mr. English discusses are inherent in the groundwater model.

75. However, I do not agree with the final conclusions reached by Mr. English. While individual components of the aquifer system may respond in the ways discussed by Mr. English, the system is complex and non-linear. Many of the individual components of the hydraulic system interact with each other. The result is a system that responds to changes in inputs and outputs in quite a different manner to the theoretical way an isolated portion of the system may respond.

Summary of Evidence

76. Para. 9: I disagree that the crucial aspects of the data under-pinning the model are little better than 'guestimates'. The model has been based on measured data and calibrated to this.

77. Para. 12, 3rd and 4th bullet points, and paras. 106-108: The predictions by Mr. English that the CPWES will result in lowered groundwater levels (pressures) and resulting reduced Avon River flows are contrary to the predictions of the groundwater model and contrary to fundamental physics of groundwater flow. The CPWES will result in a net increase of water into the aquifer system. This can therefore only result in a rise in groundwater levels and subsequent increase in groundwater fed stream flows (and off-shore flows), as predicted by the model.

Inter-Relationship Between Aquifers

78. Para. 22: I agree that the aquifers are inter-connected to some degree, but the scale (in time and space) affects the hydraulic response between aquifers. In most areas, the hydraulic response from one aquifer into another is very slow and damped due to the confining nature of the aquitards that separate the aquifers.

THE AQUALINC MODEL

Background

79. Para. 31: The potential for non-uniqueness has been addressed by the sensitivity analysis conducted on the steady state model using PEST (Dougherty, 2004). The

PEST analysis is described in paragraphs 92-100 of my main evidence. Several hundred runs were conducted during model calibration to confirm optimal parameter selection.

Central Canterbury Plains Aquifer Recharge

80. Para. 32, 1st bullet point: I add to this item that recharge due to irrigation and water races is also a component of inputs to the groundwater system.

Waimakariri River Recharge – 'Conventional' Theory

81. Para. 38: The Canterbury groundwater model does not assume a constant loss from the Waimakariri River. The loss is variable and is calculated by the groundwater model as a function of river flows, river stage, bed shape, bed conductivity and adjacent aquifer water levels and conductivity.

82. Para. 42 and 66 (Graph 8): A zero loss at zero flow may not be a true representation of the river system if underflow is present (which is likely). If the visible flow in the Waimakariri was to go dry, there may still be flow of water within the bed of the river which would recharge adjacent groundwater. In this case, a zero flow would not result in zero losses, and Mr. English's relationship in his Graph 2 would not be valid.

83. I add to this that there is no apparent trend in the flow-loss relationship presented in Mr. English's Graph 2, and indeed there is a large amount of scatter (as observed by Mr. English). Mr. Callander reached a similar conclusion (paragraph 3.13 of his evidence on behalf of Christchurch City Council) where he comments that there is 'no evidence of declining recharge at times of lower river flows'.

84. Para. 43: The flow-loss assumptions referred to by Mr. English are not part of the groundwater model.

Waimakariri River Flows and Adjacent Aquifer Levels

85. Para. 48 and 56: In paragraph 48, Mr. English has shown a relatively good correlation between Waimakariri River base flow and nearby shallow groundwater levels. I conclude from this that adjacent shallow groundwater levels are dominated by the river. I disagree with Mr. English's conclusion in his paragraph 56 that 'the quantum of the flow loss is very sensitive to the level of the adjacent aquifer.' As discussed in my paragraph 81 above, the loss is a function of many factors including adjacent groundwater levels, but not just groundwater levels alone. The loss is also sensitive to the other factors (such as cross-sectional shape, bed conductivity etc.).

Loss Mechanism and Aquifer Recharge from the Waimakariri River

86. Para. 72: I agree with Mr. English that the ability of the aquifer to carry away recharge from the river is a limiting factor. This is a function of the aquifer hydraulic conductivity. However, again, this is one of many factors affecting losses. The ability of the aquifer to carry water away is a function of the hydraulic properties and the hydraulic head, which vary over time and space.

87. Para. 76: I agree that river underflow may be present, and is not well understood. The presence of underflow means additional water is flowing in the bed of the river. Therefore, the total flow is greater than what can be seen and the overall effects on the groundwater system from reductions in the visible flow (due to the CPWES take) is lessened. Not providing for this underflow therefore presents a conservative prediction.

The Model With Respect to Flow Loss

88. Para. 77: The method of representing the streams is documented in Appendix A of Aqualinc (2007). As previously discussed, no relationship between loss and flow is assumed; this is calculated. The resulting output of flow losses from the Waimakariri River (and the Rakaia River) are presented in paragraphs 173-178 and Appendices M and N of my main evidence. I am unsure of the other information that Mr. English suggests we ‘are not prepared to divulge’.

89. Para. 77 cont.: A comparison between the average measured and modelled losses from the Waimakariri River is provided in section 7.5.14 of Aqualinc (2007). The average modelled losses (approximately 7 m^3/s) are very similar to the measured (also approximately 7 m^3/s) and therefore the groundwater model suitably replicates this recharge mechanism.

90. Para. 81: I can confirm that the internal angle of the modelled Waimakariri River cross-section is approximately 178-179 degrees, which is consistent with Mr. English’s conclusion based on the NIWA cross-section data.

91. Para. 83: I agree with Mr. English’s general conclusion that the model contains some form of ‘feedback loop’ to calculate river losses. However, as discussed in my paragraph 75 above, Mr. English’s final conclusions seem to omit this aspect of the hydraulic balance.

92. Para. 87 and 88: I agree that the impact of the CPWES on recharge cannot be quantified precisely. That’s the nature of a regional scale representation. However, there is no better method currently available to predict what the likely effects will be on the aquifer system. Additional field information will always assist in improving the robustness of a groundwater model, particularly in areas where there is little existing

data (such as deeper layers). However, due to the regional scale of the model, a finer level of hydrogeological detail at a local scale is unlikely to result in a substantially different prediction of effects on the environment.

An Alternative Scenario

93. Para. 90: This statement is erroneous. The increase in aquifer levels is an output from the model, not an input, as are the river flow losses.

94. Para. 95: This conclusion is based on the assumption that the direct linear relationship between water level and losses is correct. There is large scatter in Mr. English's Graph 7, and he has ignored the rebalancing effects of the hydraulic system. My comments in paragraph 75 above apply to this conclusion.

95. Para. 96: Mr. English's prediction that Waimakariri River recharge will reduce by about 88% seems unusual. The model predictions suggest that the reduction will be more like 8%, much less than Mr. English's predictions. In addition, Mr. English's predictions are inconsistent with Mr. Callander's opinion that the change in aquifer recharge from the Waimakariri River is most likely to be of a minor nature (paragraph 3.19 of his evidence on behalf of Christchurch City Council).

96. Para. 97: The reported 8% reduction is the long-term average loss, as it is the long term values that describe average aquifer through flows. I can confirm that the predicted losses (calculated by the model at daily time intervals) vary from this average, both more and less. A time series of this loss is presented in Appendix N of my main evidence.

97. Para. 98: The relationships that Mr. English has described are isolated and simplistic. Again, I refer to my comments in paragraph 75 above. Further to Mr. English's 3rd bullet point, I can confirm that the model does rebalance as necessary, and does so at each calculation time step.

AQUIFER ISSUES WITH RESPECT TO CPW SCHEME

Aquifer Flow Patterns

98. Para. 104: I disagree that the model is 'seriously underestimating the quantum and impact of the reduction in recharge from the Waimakariri'. As stated in paragraphs 150-151 of my main evidence, on a regional basis, the direction of groundwater flow and the general flow divide are not predicted to noticeably change with the inclusion of the CPWES.

Aquifer Levels and Potential Contamination

99. Para. 117: The particle tracking predictions presented in Appendix J of my main evidence suggest that particles entering groundwater from under the scheme will not travel to the deep aquifers. I therefore cannot agree with Mr. English's suggestion that 'the latter appears to be at odds with the particle tracks…'.

RESPONSE TO SUBMITTER'S REPORT BY RICHARD ENGLISH (SUPPLEMENTARY EXPLANATORY NOTES)

100. Paras. 15-16: One key missing aspect of this conceptual model is that when aquifer water levels increase (say from river recharge), the aquifer through flow will increase as there is greater head pushing the water through the 'pipe'. I have briefly discussed this is my paragraph 86 above.

101. Para. 18-21: I refer to my paragraphs 81-85 above for comments relating to this conclusion.

102. Para. 23: I refer to my paragraph 95 above for comments relating to this conclusion.

103. Para. 25: I refer to my paragraph 79 above for comments relating to this statement.

104. Paras. 27-38: I refer to my paragraph 87 above for comment relating to this issue.

JOINT STATEMENT OF PAUL AND DAVID BIRKETT

Selwyn River Effect on Aquifer

105. Paras. 2.6-2.7: With regard to the model's accuracy in predicting the depth to shallow groundwater level, I refer to paragraphs 12 and 14 above.

106. Para. 2.8 and 5.1: I refer to paragraph 13 above regarding the representation of the drainage system in the model and the conservativeness of this.

Direct Effect On Our Farm

107. Para. 3.2: The nearest shallow ECan monitoring well to the Birkett's property is L36/0664 (18 m deep) which is located approximately 1.5 km west of the property. Water levels in this well have been recorded since late 1993 and vary between approximately 6.5-11.7 m bgl. The rise in groundwater level predicted as a result of the CPWES is approximately 1.5 m (maximum) during a wet (high groundwater level) period. Based on the measured groundwater levels, this would then result in groundwater levels nearing 5 m bgl in the vicinity of the Birkett's property. I do not have expertise in soil or agricultural science, but I would expect this depth to be below the typical rooting depth of most crops farmed in the area. Lucerne is a crop

that has potentially deep roots, often extending down to the nearest water levels a few metres down. In this case, should groundwater levels rise, the lucerne rooting depth would reduce accordingly.

108. Since regional groundwater levels are no shallower than 6.5 m bgl, the perched water table described by the Birketts is likely to be caused by land surface drainage (from rainfall and irrigation) that is unable to percolate through to the regional water table, likely due to the heavy soils composed of 'the finer silts and clays' (paragraph 5.4 of the Birkett's statement). By definition, a perched water table has a hydraulic breakage between the bottom of the perched water and the underlying regional groundwater table. If there is a perched water table, then the predicted rise of the regional groundwater table due to the CPWES may cause one, or (over time) a combination, of the following:

- If groundwater rises but does not intercept the base of the perched water layer, then there will be no change in the drainage properties of the perched table. The hydraulic breakage between the two will still exist.
- If groundwater rises and intercepts the base of the perched water layer, but does not rise higher than top of the layer, then a hydraulic link between the perched water and the regional water table will be formed and the drainage from this perched layer will be increased. Drainage will be increased because the hydraulic conductivity of saturated materials is greater than that of similar unsaturated material. This is provided for by FEMWATER (the numerical code used for the Canterbury groundwater model) in its representation of saturated and unsaturated soils.
- If groundwater rises above the perched layer and into the root zone of the crops, then adverse effects may occur from reduced drainage and root inundation. As discussed in paragraph 107 above, this is unlikely to occur at this location.

109. Para. 3.7: The prediction of effects from a dry-summer wet-winter combination is inherent in the predicted effects by simulating the historical climate patterns over the last 40 years. The date of October 1978 was selected as the worst-case period of high groundwater levels based on historical data.

Drains

110. Para. 5.2: Much of the historical flooding in the lowland area can be attributed to high-intensity rainfall events rather than elevated groundwater levels. The photograph referred to in this paragraph is an example of this. If the drain was

working as intended (i.e. lowering groundwater levels by drainage), then the water level in the drain would be a measure of the adjacent groundwater levels. Adjacent groundwater cannot rise much higher than the water surface in the drain, because in doing so, it would discharge into the drain and groundwater levels would subsequently lower.

111. In the photograph, it appears that the drain's water surface is significantly lower than the water on the paddock, perhaps by up to a metre. Adjacent groundwater levels would therefore also be at a similar level (i.e. about 1 m lower than the adjacent land surface). It is therefore not likely that groundwater is causing the flooding. I would consider that the low infiltration rate through 'the finer silts and clays' (paragraph 5.4 of the Birkett's statement) would be the likely cause of the land surface ponding during high intensity rainfall events.

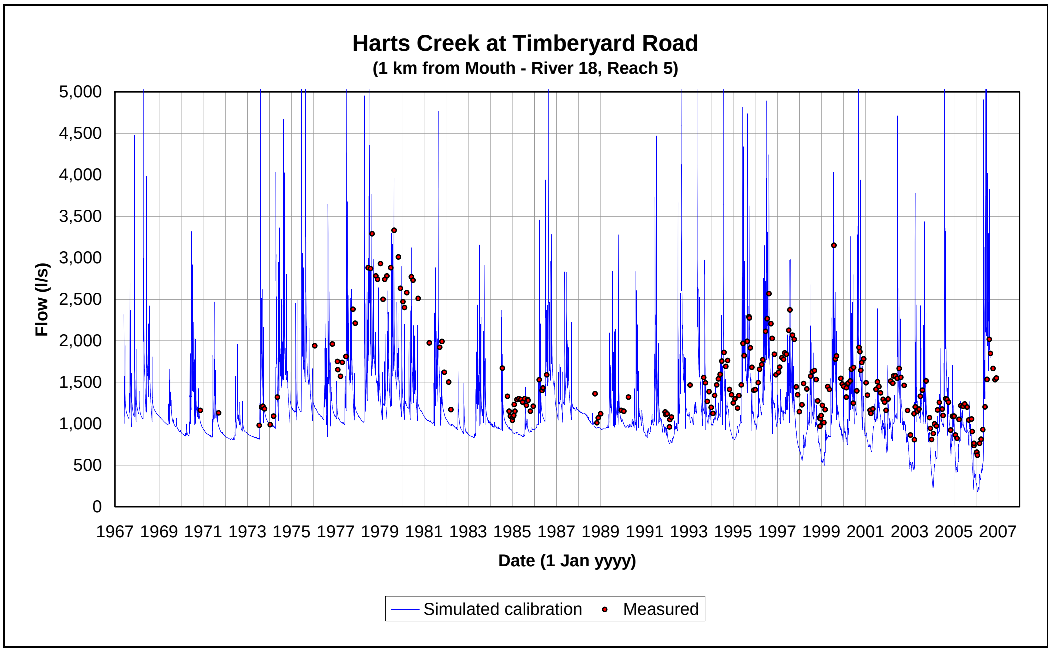
Modelling of Groundwater

112. Para. 6.2: Again, I refer to paragraphs 12 and 14 above regarding the model's accuracy in predicting the depth to shallow groundwater level.

113. Para. 6.4: I can confirm that the area used to consider the percentage increase in shallow groundwater did not include Banks Peninsula and the 'mountains area back to the provincial boundary'. The area of land used is the *model* area between the Rakaia and Waimakariri rivers (paragraph 146 of my main evidence). The model area does not include Banks Peninsula or the mountainous area of the Southern Alps (refer to Figure 1 of my main evidence).

Stream Flow Statistics

114. Para. 7.3: Comparisons between modelled and measured flow in lowland streams and drains (including Harts Creek) are provided in Appendix Q of Aqualinc (2007). The comparison for Harts Creek is reproduced below. In my opinion there is a good correlation between simulated flow and the few measured gaugings that are available for most of the flow sites. I should restate that the status quo scenario (from which stream flow statistics are reported in Appendix L of my main evidence) assumes the irrigated area in 2006 occurred right through from 1967. Therefore, the modelled flows in the lowland drains and streams will be lower than measured over much of the simulation period due to this status quo level of irrigation.



Selwyn Data

115. Paras. 8.2-8.4: The predicted flow increase for the Selwyn River is due to the rise in groundwater levels adjacent to the river and the by-wash discharge from the CPWES. While the CPWES will introduce more water to the groundwater system, as a result more water will exit the groundwater system, and the Selwyn River is a key mechanism for this. The flows in the Selwyn River reported in Appendix L of my main evidence are for Coes Ford, which is at the lower end of the river near Lake Ellesmere, and so represents a discharge from the system. The flow increase at Coes Ford is a combination of extra gains from groundwater (in the lower reaches) and reduced losses to groundwater (in the upper reaches). More of the water flowing down the river will reach Coes Ford, rather than seep into groundwater.

116. The balance between groundwater level rise (due to extra recharge) and reduction in river losses to groundwater is accounted for in the groundwater model. The Birkett's comment in paragraph 8.4 that the effects of groundwater mounding and river flow increases are independent is incorrect. The reported predictions are the net, rebalanced, effect.

Climatic Variations

117. Para. 9.4: Based on data from ECan's long-term monitoring wells, groundwater levels in the lower plains have variations of several meters. For example, well M36/0355 (61 m deep, located just north of Leeston) has measured variations in the order of 8 m (from highest to lowest). Similarly, well L36/0664 (18 m deep, located approximately 1.5 km west of the Birkett's farm) has measured variations in the order of 5 m. Wells located closer to the coast (or to Lake Ellesmere) have lesser variations due to the moderating effect of the sea (or the lake), but the predicted groundwater level mounding is also much less. Hence, I still conclude that climate will have a greater influence on groundwater level variations than the CPWES.

STATEMENT OF JOINT EVIDENCE OF THE LOWLAND FARMING GROUP

Evidence from Farm Well Monitoring

118. Para. 4.20 and 4.21: Based on my experiences, McMillan's finding of differences between theoretical and actual aquifer performance is common. Differences between measured and predicted often occur due to local heterogeneity. McMillan's examples are local-scale models and the predictions will vary at a regional scale.

119. Para. 7.1, 1st bullet point: The groundwater model does recognise the variability and nature of the groundwater levels in the lowland plains area. The transient response of groundwater levels over time and space is replicated sufficiently well to give confidence in the model predictions.

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Appendix A: Range of Hydraulic Conductivity Values from Freeze & Cherry (1979)

Table 2.2 Range of Values of Hydraulic Conductivity and Permeability