

**Before the Commissioners appointed by
Canterbury Regional Council**

IN THE MATTER OF The Resource Management
Act 1991

AND

IN THE MATTER OF Applications by the Central
Plains Water Trust and
Central Plains Water Ltd. to
Take and Use Water for
Irrigation in the Central
Plains area.

Section 42A Officer's Report

Date of Hearing: August 2008

Supplementary Report of Howard Raymond Williams

INTRODUCTION

1. My name is Howard Raymond Williams. Details of my qualifications and experience have been documented in my evidence in chief.
2. This supplementary evidence will provide information and advice related to:
 - Responses to evidence provided on behalf of the applicant by Messrs Julian Weir, Cliff Tipler and Walter Lewthwaite;
 - Response to evidence provided on behalf of TRONT by Mr Paul White; and
 - Response to evidence provided by Mr Richard English.
3. I will indicate whether I agree with the conclusions reached by these witnesses, and, if not, my reasons.
4. I will re-state whether I agree with the conclusions of the applicant that the effects will be minor, and, if not, what mitigations might be appropriate.
5. There are two major points I wish to impress upon the Commissioners:
 - That the numerical groundwater model used by the Applicants is insufficiently precise and accurate to be used to monitor the effects of the Scheme;
 - That adaptive management of the Scheme in the short-term, by reducing use, will not induce short-term remediation of adverse effects.

A) My supplementary conclusions regarding the evidence provided by Mr Julian Weir

6. My evidence in chief includes remarks about the reports submitted by Mr Weir. I do have some additional comments to make about the evidence in response that he submitted to the Hearing, and answers to questions from the Commissioners and from the floor.
7. In his paragraph 17 evidence in chief, Mr Weir, concerning seepage of groundwater out onto the continental shelf, he states that: *“In reality, a combination of these two mechanisms is likely to occur (Aqualinc, 2007). The distinction between these mechanisms is not significant to the Canterbury groundwater resource.”* I disagree with this statement for the following reasons: if the discharge from the aquifer system is dominated by direct groundwater flow to the ocean and upward leakage through sediment into the ocean, then the discharge through the surface water system is minimised, and *vice versa*. Geological evidence from ship-borne surveys indicates that offshore seepage of groundwater to the ocean is unlikely to be large for reason that the hydraulic gradients between the groundwater and the ocean are small and the sedimentary prism through which groundwater is flowing is relatively impermeable (Krom 2007; Herzer 1981). As a result, the natural discharge from the aquifer system, surface flow, is highly susceptible to changes in the groundwater head and flow towards the coast.
8. Given the uncertainties in the aquifer parameters used as input into the groundwater model, and the uncertainties in the recharge and discharge from the model, I am surprised at the confidence Mr Weir has in the outputs from the model. On being questioned about this uncertainty, I took from his answer that he considered that the error in his modelled groundwater levels and surface flows was less than 10%. In my opinion, this is generous and does not take into account acknowledged uncertainties in recharge (say:10%), discharge (say:10%) and aquifer parameters (say:20%). Error theory demonstrates that errors are propagated during mathematical calculations such as numerical modelling, so the uncertainties quoted above would amount to at least 25% using the standard error theory equation for combinations of divisions, multiplications and exponentiation:

$$TE = \sqrt{\sum_1^n (error_1)^2 \dots (error_n)^2}$$

where TE is total error, and in the equation, individual values of error (1 to n) are equal to the uncertainties in the variable divided by the mean of the variable. Standard error theory shows how uncertainties in inputs quickly lead to uncertainties in outputs.

9. In his paragraph 74 evidence in chief, Mr Weir refers to three calibration wells where he depicts modelled and monitored results in his Figure 4. In Figure 4, the simulated record for L36/0142, near Leeston, is not a good fit, it is ‘peaky’, suggesting that groundwater levels are going too high and groundwater is not modelled as discharging into spring fed streams such as Harts Creek. The error in these values is in the order of 30% of the total range in groundwater levels.

Similarly, for well M35/1080, situated to the west of Christchurch, the low

groundwater levels are simulated about 30% below the monitored levels in terms of the normal range.

Again, for well L36/0092, at Courtenay Road, both high and low groundwater levels are poorly simulated in relation to the monitoring record, being as much as 40% different in terms of the normal range. I understand that Dr Bidwell will address the Commissioners separately on this issue.

Therefore, in response to Mr Weir’s comment in his paragraph 77, and in response to questions from the Commissioners about the accuracy of the simulations: “..the transient model is suitably calibrated based on the ME and the normalised RMS”, I am of the opinion that though these may be coarse measures of accuracy, they do not indicate the accuracy of individual wells or streams, which at times are of several tens of percent inaccurate. I consider this issue of error or uncertainty to be of paramount importance when considering the mounding effects (as addressed in my evidence in chief). I do not believe that the Commissioners have been furnished with sufficient information regarding the uncertainty of any prediction developed from the Aqualinc model.

10. In relation to Mr Weir’s evidence in chief, paragraph 82 et seq. on Cumulative Stream Flows, I make the following observation: Figure 7-10 in the Canterbury Model 2 report (Figure 1) shows that Selwyn River flows at Coes Ford are simulated very differently from monitored flows, especially at low flows.

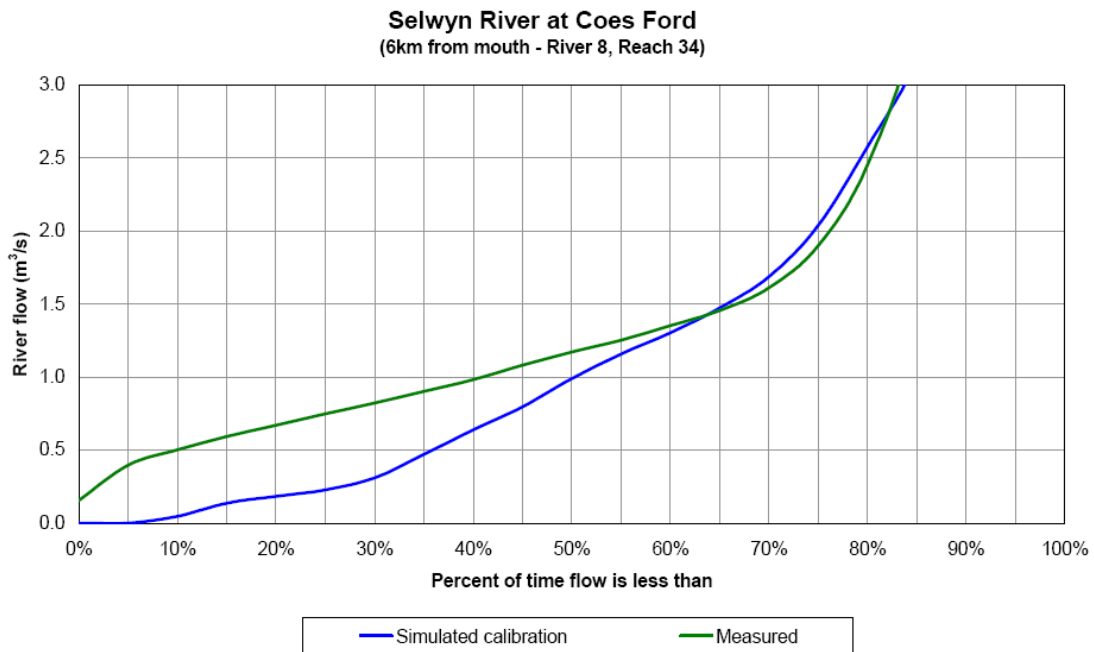


Figure 1: Modelled and monitored flows for the Selwyn River at Coes Ford (figure 7-10 copied from Canterbury Model 2 report).

11. I am concerned that these plots have not been included in Mr Weir’s evidence in chief for they could provide a useful means to illustrate the accuracy of the model in predicting surface flows. In the plot shown above (Figure 1), the median flow is underestimated by 20%, and the low flows by as much as several hundred percent. I understand that Mr Weir modified the model for his January 2008 evidence in chief, but these plots do not appear in that revised document.

12. In his paragraph 68 evidence in chief, Mr Weir refers to a Figure 2 showing residual errors. Whilst the mean error may be small, the actual errors for each individual well record may be significant to the interpretation of mounding. A determination of the spatial and depth location of these residual errors would be very informative in showing whether the small or large residuals are located in shallow or deep strata, whether close to the coast, or inland, and whether the errors are time-dependent in that no plots of actual and simulated groundwater levels have been illustrated. It is self-evident that a residual error of one metre in a monitoring record where the range is only two metres, would be highly significant. Such information has not been reported and as a result, the model cannot be adequately assessed.
13. In paragraph 123 of Mr Weir's evidence in chief, he states that: "*However, the low groundwater levels in 2006 were due to a combination of both low land surface recharge and river flows (over the previous years) and localised interference from nearby abstraction wells.*". I wish to make it clear that I disagree with the last part of this statement. In my opinion, the low levels of groundwater in 2006 were a combination of lower than average rainfall recharge compounded over the last few seasons, and overall groundwater abstraction. Modelling of drawdowns in monitoring wells by David Scott and I has indicated that over 50% of the drawdown at a monitoring well is due to abstraction from further than 3 km distance. Therefore, I do not agree with Mr Weir's statement that the low groundwater levels were due to local interference, it was due to cumulative effects whose magnitude are only now being fully appreciated.
14. In paragraph 55 of Mr Weir's response to my evidence in chief paragraph 21, I reiterate that the horizontal anisotropy of the gravel strata has **not** been taken account of in the Aqualinc model (i.e. in the model: $K_x = K_y$). Until horizontal anisotropy is included in the model, then the model cannot be construed as a reliable indicator of groundwater levels, mounding, and surface flows.
15. Paragraph 56 of Mr Weir's response to my evidence paragraphs 30-38, states: "*A date of 1 October 1978 was selected to represent a wet year because this period had higher measured and modelled groundwater levels than any other period from the 40 year simulation. The date was considered representative of a worst case high-groundwater level scenario, not necessarily the wet period predicted to have the largest groundwater mound*". Whilst I appreciate this, it seems to me that the Commissioners might have found it useful to know what the highest mounding event might be (dry year), given high antecedent groundwater levels – that is the true worst-case scenario.
16. In his paragraph 58 Mr Weir responded to my remarks (paragraphs 30-38 in my evidence in chief) about high mounding superimposed on high groundwater levels. Whilst I understand and partially accept his comments about the non-linearity of the system, I would have been better persuaded by seeing an actual simulation of such a situation.
17. In his paragraph 60 Mr Weir talks about temporal decoupling of the aquifer system. I am uncertain about this term but take a stab at responding to it. I consider that there might be periods of high demand following high recharge simply because the duration of storage of water in the characteristically light soils typical of much of the irrigation command area in the upper plains is not likely to

exceed days or weeks. In heavy soils, that readily store water for weeks or months duration, I accept that irrigation demand and, as a consequence, mounding, will be temporally decoupled.

As an example of this de-coupling one could envisage an alternative method of storage (not behind a dam) but in the groundwater system itself with winter recharging of that system by means of a series of injection wells or recharge ponds. Whilst this may be an effective means of getting water into storage, it is well recognised that the aquifer system storage decays at a rate proportional to the volume in storage (cf. radioactivity). Work undertaken (Bidwell 2003, 2005; Williams et al. 2006) indicates that this storage ‘mean residence time’ is about 20 months which means that the “half-life” of the storage is 13.8 months. This means that in the six months between augmenting the groundwater storage and using it the following summer season, a significant proportion¹, approximately one-quarter, of the stored water would be ‘lost’ down-gradient. A similar calculation may be used to assess the decay rate of mounding caused by irrigation though Bidwell (pers. comm. July 2008) considers that the shorter groundwater residence times associated with shallow strata would speed up the decay of groundwater mounds.

18. In his paragraph 36 Mr Weir talks about seepage of groundwater into Lake Ellesmere and how he considers ECan monitoring could be used to justify the high rate of seepage presented in the model. I wish to draw the Commissioners’ attention to the number of uncertain statements that he uses to build this justification. Note also that Horrell (2006) considers such a high rate of inflow from groundwater to be inconsistent with his calibrated and verified hydrological model.

B) My comments regarding the evidence provided by Mr Richard English

19. I broadly disagree with the conclusions provided by Mr English. For example, the large uncertainties in the seepage from the Waimakariri River mean that his use of the flow – seepage plot is not reliable, a point also made by Mr Callander in his submission on behalf of the City of Christchurch.
20. My analysis of groundwater levels adjacent to the river indicates that the fall in head between the river and well M35/0948 is about four metres. The much smaller head changes in the river (~0.3 m) quoted by Mr English are unlikely to induce the large changes in seepage he proposes.
21. I understand that most numerical groundwater flow models, including the Aqualinc model, do include an assessment of, and allowance for, the changing elevation of groundwater and surface water;
22. Comments by Mr English lead me to understand that he considers that there has not been sufficient research to illuminate the processes and constraints on the seepage from the Waimakariri River. The Commissioners were recently updated on just that research topic by Mr White, who tabled a technical report that included details of research carried out by him for IGNS (now GNS Science) and in part paid for by Environment Canterbury.

¹ Where Half-life = $t_{1/2} = -\ln(0.5) * \text{Mean residence time}$; and $\text{Storage}_{(t=1)} = \text{Storage}_{(t=0)} * 0.5^{(t/t_{1/2})}$

C) My comments regarding the evidence provided by Mr White

23. Mr Paul White has presented a great deal of evidence, a small part of which necessitates a response. In addition, he tabled a voluminous technical report that contains much useful information and conclusions which underpin his evidence, some of which I wish to highlight. I have the following comments concerning issues raised in his evidence.
24. In paragraph 3.52 of his evidence, Mr White describes the potential for reduced seepage from the Waimakariri River on the basis of reduced wetted area, unlike Mr English who considered it to be simply a head issue. I concur with Mr White on this issue, that wetted area is likely as important, if not more important than the small head changes associated with change in river stage.
25. In paragraph 6.14, Mr White describes groundwater input into Te Waihora as equivalent to $0.1 \text{ m}^3/\text{s}$. This value is vastly different from that modelled by Mr Weir ($12.6 \text{ m}^3/\text{s}$ as quoted in Figure 11 in his evidence in chief). I concur with Mr White, partly because I accept the reported results of careful measurement of highly variable seepage rates into the lake by ECan staff (Ettema and Moore 1995). Whilst at least three spring discharges are known around the western perimeter of the lake, there has been no observation of spring discharges into the remainder of the lake of a magnitude able to incorporate this modelled input. My examination of infra-red images of the lake derived from Landsat monitoring has not confirmed any thermal expression expected to result from groundwater discharge to the lake. Finally, a groundwater seepage into the lake of the magnitude derived from the modelling by Weir is not consistent with the long monitoring and lake modelling record produced by Graeme Horrell in his evidence for the Rakaia-Selwyn Hearing (Horrell 2006 paragraphs: 69-78).
26. Nowhere in pertinent sections of his evidence (Sections 6 & 10) does Mr White support subdivision of the Central Plains aquifer system into aquifers, to be managed independently. Indeed, in his accompanying technical report, he concludes in section 5.4 that: *“Therefore separate management regimes for shallow and deep aquifers are not appropriate and the aquifers should be managed as one.”* I concur with this statement.
27. I also concur with Mr White’s comments about water budgets in his supporting technical document, paragraph 10.7. There is still considerable uncertainty as to how much and from where water enters and leaves the system.
28. I concur with Mr White’s conclusions in his section 9.5 in his technical document, based on the elegant analysis in his technical report (Section 9.2, page 116), that groundwater use is likely to be maintained at or above current levels unless a decision is made to direct users in the proposed scheme to relinquish all or part of their groundwater consents in favour of surface water ones.

If existing groundwater users became shareholders in the Scheme and relinquished all or part of their consents then there would be an opportunity to transfer all or part of those takes elsewhere in the allocation zone. Groundwater abstractions transferred outside the Scheme area might reduce mounding down-gradient, or could be removed altogether from the allocation block to reduce its fully allocated

status. Quantifying these effects would be problematic given the uncertainties in the modelling.

D) My comments regarding the supplementary brief of evidence provided by Mr Lewthwaite (April 2008)

29. At the request of the Commissioners, Mr Lewthwaite prepared some additional evidence on specific issues. In addition I will address issues raised in his supplementary evidence section 8 (Groundwater levels in lower plains).
30. Both Mr Lewthwaite and I agree that the main control on groundwater levels is recharge derived from rainfall. However, he fails to mention that it is widely held that abstraction and use of groundwater have significantly changed natural levels of groundwater and flows in spring-fed streams (White 2008; NES 2008).
31. In his paragraph 58 in his response to the ECan s41A report, item 4 in his table, Mr Lewthwaite draws attention to adaptive management to address adverse effects of the scheme. In my opinion, during times of localised or short-term flooding, no amount of adaptive management will remediate the situation because of the long time lag between cause (water use and mounding) and effect (raised levels and flows). In my opinion, the only effective adaptive management would be on a time scale of years, not months. Such a time-scale of adaptive management of groundwater resources is being formulated in the Central Plains.

E) Questions derived from the Commissioners

32. **How deep are the Christchurch City Council wells?** Mr Callander in his evidence on behalf of the City of Christchurch stated in his paragraph 2.6 that: *“The urban water supply is provided from 55 pumping stations that source their water from 164 wells ranging in depth from 16-222 m. The location of the pumping stations, which supply seven different pressure zones.”* I concur with this statement.
33. **Is rise in groundwater levels in the Christchurch area an actual/potential effect? Is it a concern in regards to quarrying?** Mr Callander in his evidence on behalf of the City of Christchurch stated in his paragraphs 4.11 to 4.13 that there is concern about the maintenance of gravel quarry activities should groundwater levels be raised as a result of the CPW scheme. This issue is also raised by evidence of Bligh, his section 28.

An analysis of groundwater levels that I undertook for ECan monitoring and enforcement, in 2007, in the area immediately south of the Waimakariri River, where gravel is traditionally quarried, showed that several quarries were in 2006-7 quarrying at depths below surface that made their pits flood during and after the wet winter of 2006. Resource consent conditions specifically disallow this and I understand that some pits required importation of clean hard fill to remediate the situation. Mounding resulting from the CPW scheme can only raise the groundwater levels in this area, potentially causing further reduction in the depth to which quarry operators may work.

If less water was used by the Scheme, then mounding and its effects on quarries would likely be less.

34. What is the historic pattern of groundwater levels and water levels in the lowland drainage system? I will comment on this query using ECan records for flow in Selwyn River at Coes Ford (Figures 2 and 3), and from both long-term and medium-term monitoring wells L36/0127, L36/0142, L36/0163, L36/0311, and M36/3194, whose time series plots are appended below as Figure 4, 5 and 6.

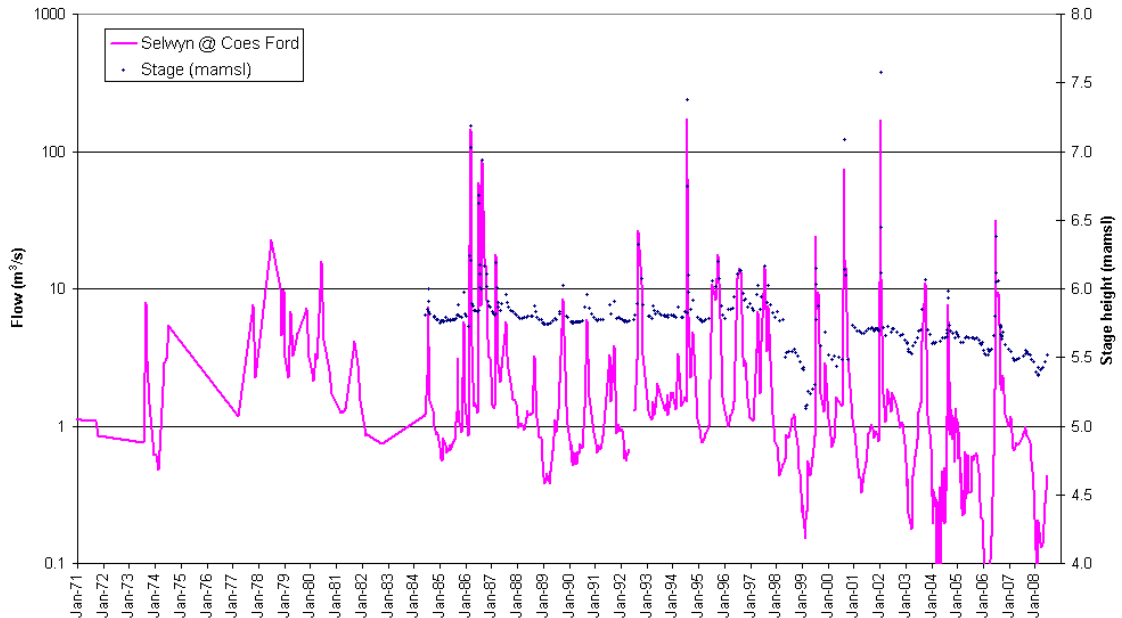


Figure 2: Flow monitoring and stage height record for Selwyn River at Coes Ford

35. Note in Figure 2 that there is a generally declining trend in both stage and flow, especially over the last decade.

36. In Figure 3, the monitored flow in the LII river is shown, as measured at ?? Road. Note also that the flows, and especially the lowest measured flows in each year of the record for this river have also declined over the last decade.

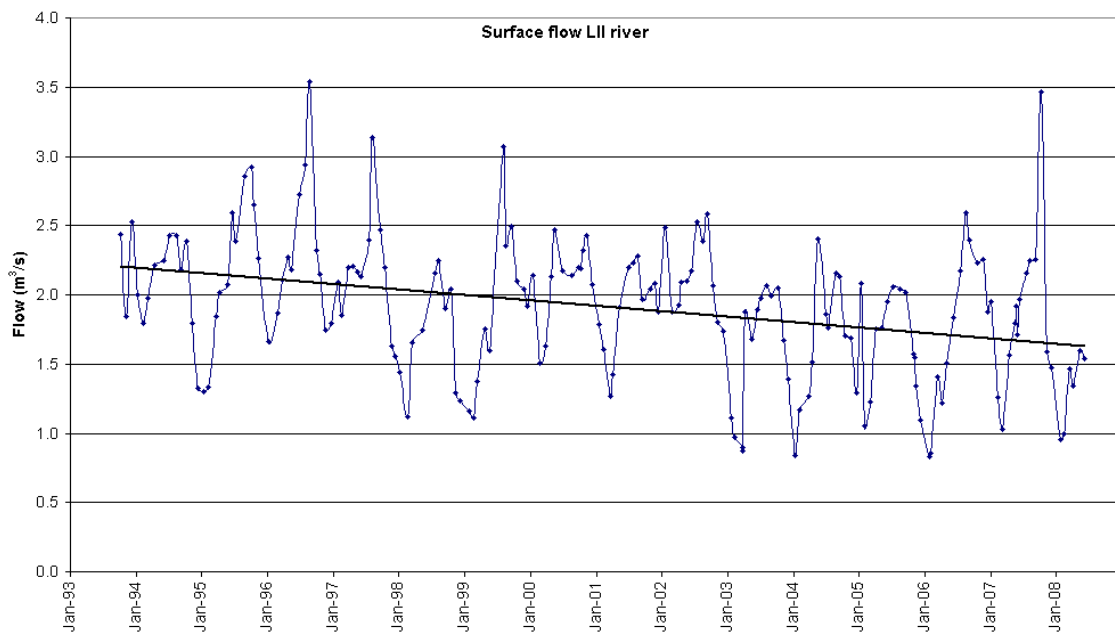


Figure 3: Flow monitoring for the LII River at Pannetts Road

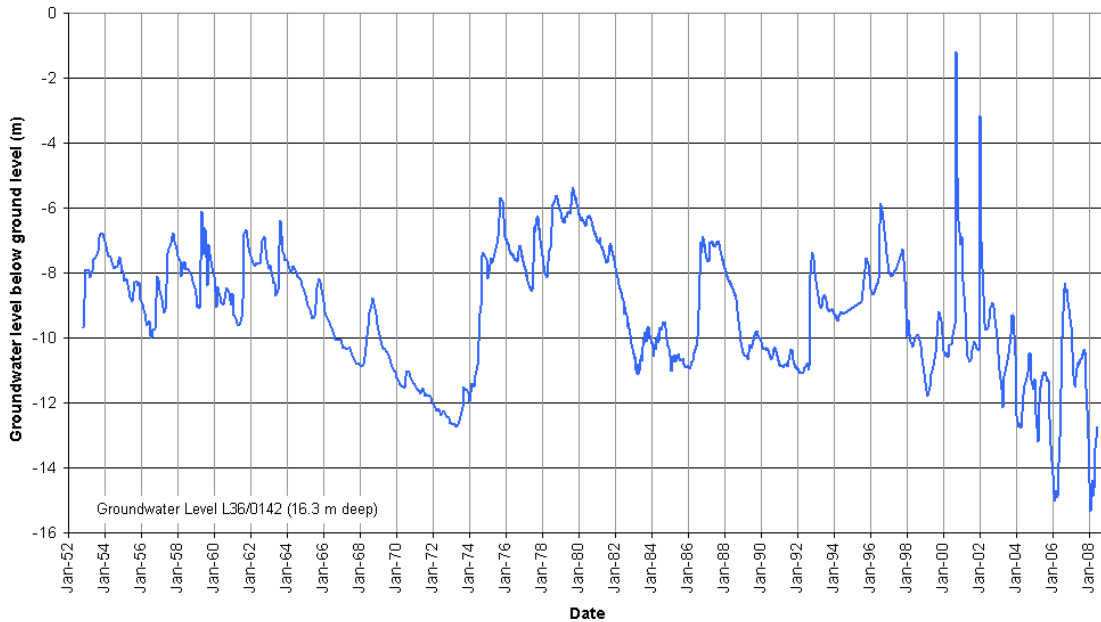


Figure 4: Groundwater level monitoring record for well L36/0142, 5 km up-gradient of Harts Creek in the Rakaia-Selwyn Groundwater Allocation Zone

37. The monitoring record for groundwater levels in L36/0142 (Figure 4), illustrates the declining trend in levels, especially over the last decade and the rapid decline in levels even after the wet winter of 2006. The general maximum groundwater level of six metres below ground level is rarely exceeded because the groundwater level is buffered by the discharge from the aquifer at Harts Creek and other spring-fed streams.

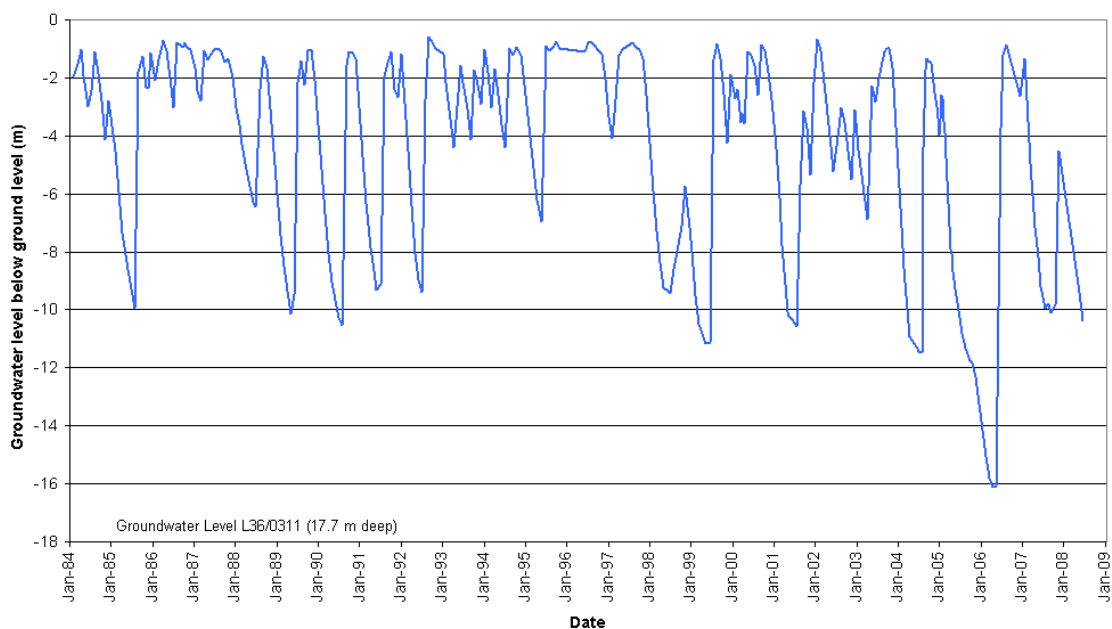


Figure 5: Groundwater level monitoring record for well L36/0311, in the Rakaia-Selwyn Groundwater Allocation Zone

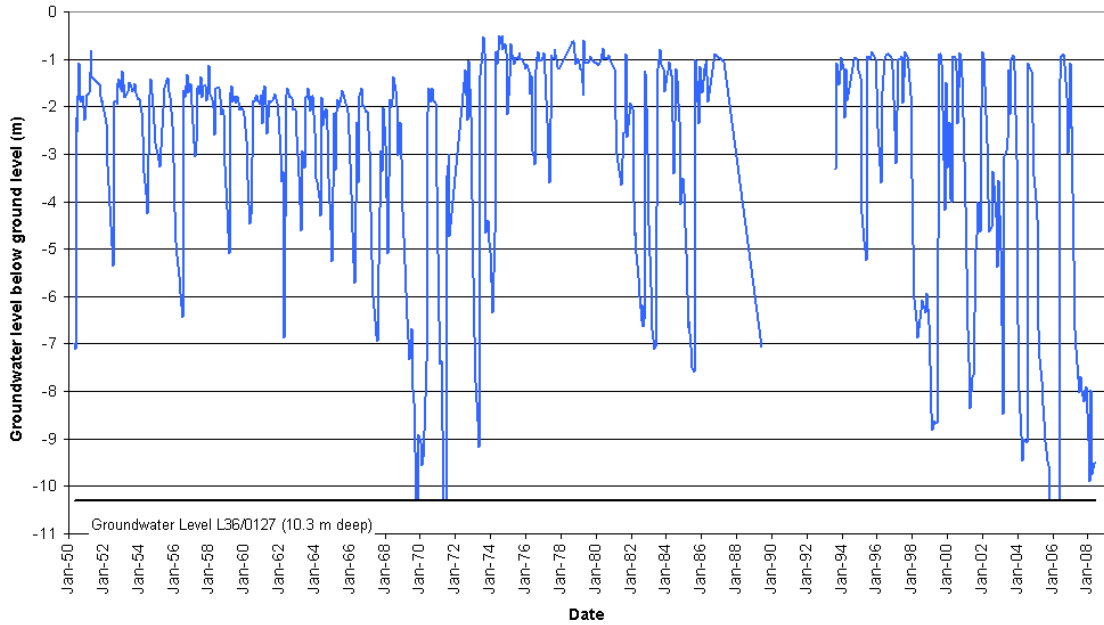


Figure 6: Groundwater level monitoring record for well L36/0127, close to the Selwyn River, in the Rakaia-Selwyn Groundwater Allocation Zone

38. In Figures 5 and 6, the monitoring records for wells L36/0311 and L36/0127 shows how the groundwater level generally fails to ascend to greater than a well-defined level. This is because the groundwater discharges from the aquifer rather than producing higher levels. Note, however, how the minimum levels have been decreasing over time, a cumulative effect of climate and abstraction.
39. In Figure 7, the very shallow well M36/3194 also shows the decline in groundwater levels.

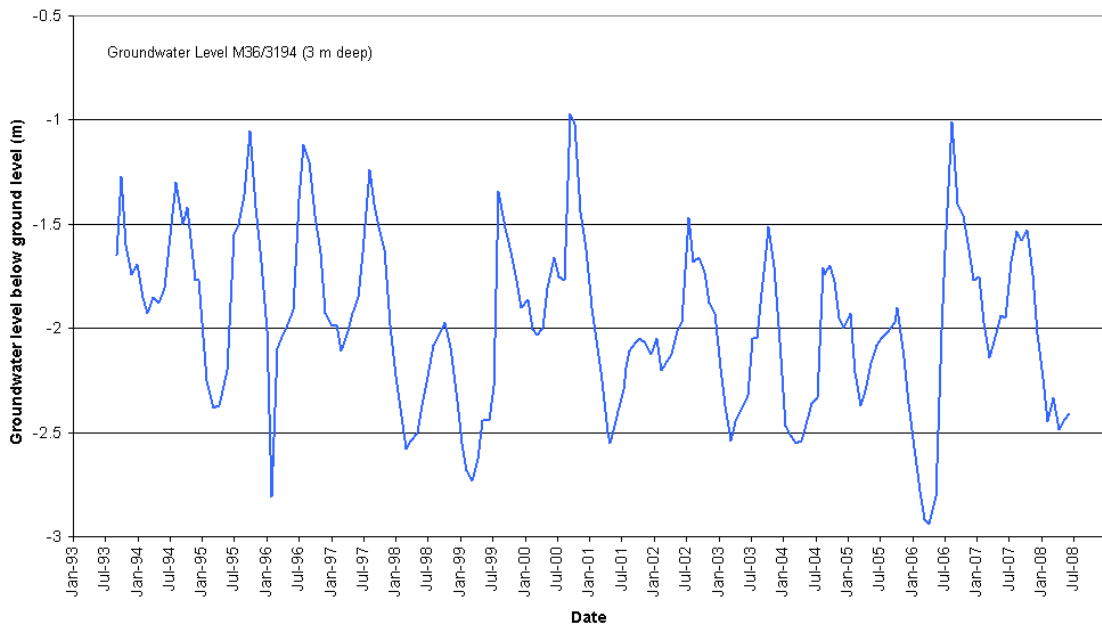


Figure 7: Groundwater level monitoring record for well M36/3194, in the Rakaia-Selwyn Groundwater Allocation Zone

40. To conclude this commentary on groundwater levels and surface flows the following remarks may be made:

- Mean and minimum groundwater levels exhibit a general decline, especially over the last decade;
 - Maximum groundwater levels in this coastal portion of the aquifer system are generally constant, reflecting the ability of seasonally high groundwater levels to discharge into the surface flow system.
 - Surface flows have also declined over the last decade and show a consistent relationship with the groundwater levels.
41. In conclusion, whilst there is evidence that the aquifer system has in the past had to discharge via the spring-fed stream system during periods of high groundwater levels, there is no monitoring data to support an increased flow of groundwater either directly into Lake Ellesmere, or beneath the coast during these times. In my opinion, all extra recharge developed by the scheme will likely discharge through the spring-fed stream system.

F) Concluding comments on effects and their mitigation

42. To conclude this supplementary evidence I wish to re-state and emphasise the following comments.
- I do not accept that the applicant has provided sufficiently precise and accurate information by way of modelling to allow robust assessment of the mounding, depth to groundwater and related surface water discharge effects.
 - I do not accept that the applicant has provided sufficient means to address potential adverse effects in a timely manner. Their suggestion for a committee to be set up to study any potential adverse effect, in my opinion needs to be replaced with a definite action plan.
 - I do not accept that the applicant appreciates the long time-frame necessary to forestall adverse mounding and discharge effects should they develop in this large aquifer system. Once they have developed they are likely to remain adverse for weeks and months.

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