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: 25 February 2008

Report of HOWARD RAYMOND WILLIAMS

INTRODUCTION

1. My name is Howard Raymond Williams. I am currently employed by Canterbury Regional Council as a groundwater resources scientist. Prior to my present employment, I worked for fifteen years as a groundwater scientist, including three years with Pattle Delamore Partners Limited in Christchurch, and the remaining period as an independent consultant in New Zealand, Canada and the United Kingdom. Prior to 1991 I worked as a research and mining exploration geologist, and taught graduate and undergraduate structural geology, tectonics, and engineering geology over a period of thirty years in Sierra Leone, the United Kingdom, Canada, and New Zealand. I hold a Ph.D. in Geology from the University of Exeter (U.K.), and a Masters of Applied Science in Civil Engineering from what is now Dalhousie University in Nova Scotia, Canada. I am registered as a Chartered Geologist in the United Kingdom and a member of the New Zealand Hydrological Society.

2. This evidence is prepared under the provisions of Section 42A of the Resource Management Act 1991 (RMA). This section allows a Council officer to provide a report to the decision-maker on a resource consent application made to the Council, and allows the decision-maker to consider the report at the hearing. Section 41(4) of the RMA allows the decision-maker to request and receive from any person who makes a report under Section 42A "*any information or advice that is relevant and reasonably necessary to determine the application*". This evidence will provide information and advice related to:

- A brief description of the hydrogeology of the Central Plains as context for the following topics;
- A review of the CPW assessment of the effects of the proposed discharge of water on the natural surface water discharge from the irrigated zone and down-gradient of the irrigated zone; and
- A review of the CPW assessment of potential cumulative effects on groundwater levels due to the proposed discharge of water to the ground;
- A review of groundwater and geological issues associated with the construction and operation of the long tunnel, the dam and the reservoir.

3. I also provide a brief 'executive summary' of the key conclusions reached by the Central Plains Water Enhancement Scheme (CPW, the 'Applicant'). I will comment on the Applicant's method of assessment of effects, that is, the type of modelling/assessment used, and whether it is appropriate to quantify the effect using that type of modelling. I will comment on whether the inputs and assumptions used appear to be appropriate, and if not, the reasons for and significance of my conclusions.

4. I will discuss whether I agree with their overall conclusions, and, if not, my reasons.

5. I will state whether I agree with the conclusions of CPW that the effects will be minor, and, if not, what mitigations might be appropriate.

6. I will discuss the reasoning behind the proposed conditions and why they are required.

My key conclusions regarding the Applicant's evidence

7. I generally agree with the Applicant's evidence on the following issues:

- that there will be mounding;
- on the general degree and disposition of mounding;
- on the general relationship between mounding, antecedent groundwater levels and the consequent depth to groundwater;
- on the general increase in low flows in spring-fed streams and drains;
- the effects on groundwater resulting from the building and operation of the long tunnel and the dam;
- the effects on slope stability around the reservoir.

8. I disagree in part with the Applicant's conclusions about the effects of mounding on groundwater levels. I do not accept that the degree of mounding and its distribution is the worst case scenario.

9. I have strong reservations concerning the modelling of flows into the spring-fed streams. Model data to allow me to assess the timing and magnitude of high flows in spring-fed streams and drains has not been made available by Mr Weir or Aqualinc prior to preparing this evidence.

10. I shall itemise my concerns on these matters after I briefly describe the hydrogeology of the Central Plains as contextual backdrop.

Review of the hydrogeology of the Central Plains area

11. Much of the area to be irrigated by the proposed CPW scheme is underlain by deposits of gravel-dominated strata laid down during the Pleistocene glaciation. The gravels were laid down by rapidly migrating braided rivers in the form of broad alluvial fans. On a very limited scale close to major rivers, during interglacial periods, down-cutting and reworking of portions of these matrix-rich strata winnowed the fine grained matrix from the gravel. Apart from this localised effect, the gravel-dominated strata exhibit remarkable uniformity in composition on a regional scale. Observations in natural exposures and from drill logs indicates that layering within individual fans is not laterally continuous.

12. Whilst some workers have subdivided the aquifer system into aquifers and aquitards, in my opinion based on analysis of cable tool drillers logs, the three-dimensional form of the strata is composed of lenses, elongate down-gradient, of differing compositions that on the tens of kilometre scale of the system collectively react as a hydrogeological entity over time periods of months and years.

13. The so-called aquifers are, in a practical sense, zones of preferred screening where drillers and well owners take advantage of good yields at certain depths. Poorer-yielding strata are typical of much of the gravel fan system and differ from the 'aquifers' only by virtue of the connectivity of channels consisting of open gravel. This conclusion is in sympathy with an addendum to the two commonly cited Davey 2006 reports (Davey 2006a, 2006b, 2007). A copy of the pertinent portion of this addendum is appended (Appendix A).

14. The water table in the gravel strata varies in depth from over 100 m in the northwest, to little more than a metre in the southeast. Below the water table, the gravel-dominated strata are saturated with groundwater, derived from both rainfall recharge and seepage from rivers. Groundwater pressures vary spatially and with depth. Within the irrigated area groundwater pressures decrease downwards and towards the sea, indicating that groundwater flows into the deeper strata as well as towards the coast.

15. Contrasts in horizontal and vertical hydraulic conductivity within the strata mean that groundwater levels and pressures and downward flow rates are variable. Overall, the groundwater system appears to respond dominantly to climatic influences but in some areas abstraction distorts the natural recharge and discharge behaviour. Such behaviour has been predicted using both analytical and numerical models.

16. Groundwater abstraction and periods of lower than mean recharge to the system combine to create periods and areas of low groundwater level. Additional recharge resulting from importation of water into the area for irrigation use, such as proposed by CPW, would locally increase groundwater pressures. In addition, irrigation itself can increase rainfall recharge to groundwater by presenting already moist ground to rainfall.

17. There are two key points listed on page 4 of the January 2008 Aqualinc model evidence of Mr Weir: *"(a) The Canterbury aquifer system is complex and is comprised of layers of good water bearing aquifers and poor water bearing aquitards varying in thickness and extent and (b) The groundwater management zones described in the Proposed Natural Resources Regional Plan (PNRRP) do not* *individually and wholly represent independent portions of the aquifer. Groundwater is able to pass between adjacent zones; there are no impermeable boundaries between groundwater zones or between aquifers."*

18. I don't agree with this first key point (a) made by Mr Weir for the area covered by the scheme, neither does Mr Davey. Regardless of the Applicant's assertion as to the geological structure, what is important is that all the surplus drainage finds its way to groundwater over the irrigation season. The partition of groundwater into the various strata is critical to the determination of the magnitude of mounding, its distribution, and the discharge effects of groundwater on the surface waterways.

19. In broad terms I agree with the review of the groundwater system presented by the Applicant in Section 6 of their AEE dated 23/6/2006 and in the quote from the 2008 evidence of Mr Weir. Whilst I disagree with a number of details of their understanding, especially the geological and hydrogeological structure, these probably do not affect the main conclusions reached in their modelling predictions although they might well affect the detail, such as flows and levels in individual streams and bores respectively.

20. A fundamental aspect to the groundwater model is the allotment of a value of hydraulic conductivity to each element for each layer. I have examined the maps in Appendix A of the evidence of Mr Weir that have been based on a number of aquifer tests of variable quality and duration. In my opinion, there is little justification for the spatial distribution of conductivities and, specifically, for the sudden variations in magnitude of the conductivity. In a July 2007 consent hearing for the Selwyn-Waimakariri applicants, Professor Jamie Shulmeister of the University of Canterbury had the following to say (my bolding): "*At gross scale there will be a general sheet-like characteristic to the deposits…. At finer scale, however, these gravel packages are highly heterogeneous (mixed up). They comprise a mix of gravel sheets and alternating channel bar and channel fill deposits. The sheets and gravel channel fills will be fairly continuous in a **down-channel** direction but will pinch out **laterally** and have limited vertical dimensions. Unit thicknesses for the gravel sheets will be typically in the order of 0.2 to 1.0 m, while the channels can and will be much deeper.It should be noted, however, that the deepest, most continuous channels are likely to have been formed during interglacial incision events. In my opinion, and consistent with the views of Wilson (1973), these interglacial channels are likely to act as foci for groundwater flow within the gravel mass. They will not, however, act as individual, mappable aquifers because they lack lateral extent and are hydraulically linked to the material outside the channel.The sediments will fine downstream with very coarse gravels and boulders present near the former glacier limits. Sorting will also improve downstream and it is to be expected that hydraulic conductivity will increase coastward.*"

21. It is generally accepted by those in the hydrogeological community with the benefit of geological training, that horizontal hydraulic conductivities in alluvial sedimentary strata are commonly anisotropic, reflecting the generally linear transport of detritus. Normally, the conductivity in the transport direction of the original sediment is the greatest, that at right angles is lesser in magnitude, and the least is the direction normal to stratification[1]. No allowance has been made of this effect in the calculation of conductivities in aquifer tests, nor in the model, yet it remains a significant issue that will have a bearing on the following sections of my evidence.

Detailed comments on the CPW evidence

22. In the sections that follow I have sub-divided my comments into a series of topics, including: mounding and groundwater levels; other effects associated with groundwater mounding, including malfunctioning of wastewater and stormwater systems, changes in stream flow, and the state of Te Waihora / Lake Ellesmere; the need for mitigation and conditions to deal with adverse effects; mitigations suggested by the Applicant; monitoring suggested by the Applicant; requirement for and reasoning behind proposed conditions, and; tunnelling and ground stability issues around the reservoir. Within these comments I

[1] See: p67-71 in Physical and chemical hydrogeology; Domenico and Schwartz (1990), John Wiley.

also quote or précis the Applicant's conclusions and show the extent to which, and why I differ from these conclusions.

Mounding and groundwater levels

23. I start this section with a number of key conclusions that have been reached on behalf of CPW by Mr Weir, and others[2], regarding aspects of groundwater quantity:

(a) There will be mounding of the groundwater system, especially within the uppermost strata, within and down-gradient of the irrigation scheme;
(b) As a consequence of the mounding (a), groundwater levels may rise to near land surface in areas down-gradient of the proposed irrigation scheme;
(c) As a result of (b), flows in spring-fed streams and drainage waterways will increase;
(d) As a result of (c), surface and sub-surface discharge to Lake Ellesmere / Te Waihora will increase, leading to a likely need for an increase in the number of lake openings
(e) As a consequence of the mounding (a), groundwater levels in strata lying below the uppermost strata will also receive additional recharge within and down-gradient of the scheme, this has ramifications for water quality. In addition, CPW is of the "*view that the scheme will approximately restore the balance and patterns of groundwater flow, levels and fluctuations that existed around 1990. This is based on a comparison of the net amount of groundwater withdrawn for irrigation in the central plains since 1990, and the modelled amount of recharge that the scheme will provide to the groundwater system, leading to an expectation that these two figures will be roughly equal. We expect the major movements in groundwater levels with the scheme will continue to be dominated by natural variations in rainfall from year to year and flows in the alpine rivers, as they have been in the past*[3]*.*"

24. The Applicant's key conclusions have been determined from the results of several years of three-dimensional numerical groundwater modelling undertaken by Aqualinc culminating and communicated in Mr Julian Weir's evidence circulated to ECan on 11th January 2008. Whilst the details of precision and accuracy of earlier versions of this model have been questioned by Environment Canterbury, the current results stem from a revised model that purports to address these concerns. My evidence is partly reliant on that of my ECan colleague David Scott, whose evidence is concerned with the plausibility and uncertainty inherent in the Aqualinc groundwater model in its various versions.

25. I have read the revised evidence by Julian Weir in association with the Aqualinc groundwater model 2 report (L07079/1) describing the revised model. Whilst I accept the main thrust of the conclusions, I cannot accept that the revised results are a realistic prediction of mounding and related surface water discharge effects.

26. In my opinion, there is little disagreement that mounding will occur as a result of irrigation with imported water. However, the details of its spatial and temporal development and magnitude are still unclear, even after examining the revised modelling report and Mr Weir's evidence. The model particle track evidence of Mr Weir (map on page 130) indicates that recharge to deeper strata must result in subdued changes in pressure and flow direction in deep strata. The corollary is that nitrogenous groundwater will move to greater depths and at greater rates than currently, with ramifications for water quality, as will be discussed by my colleague Carl Hanson. In the event that adverse effects of mounding are ever found to be greater than expected from the model, I have made recommendations relating to a series of conditions to remediate these potential effects.

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[2] Aqualinc groundwater model 2 report (L07079/1)
[3] CPW memorandum regarding mounding: Lewthwaite to Fietje 14/12/2007.

27. Mounding effects where groundwater levels are deep below the ground surface are not generally considered an adverse effect, quite the opposite. However, where groundwater levels are already close to surface, mounding might have adverse effects such as:

(a) groundwater appearing at surface;
(b) soils becoming waterlogged and 'sour';
(c) wastewater and stormwater discharges to ground not functioning properly;
(d) man-made and natural waterways not coping with increased discharges.
(e) in addition, an increased number of artificial lake openings may be required for Lake Ellesmere / Te Waihora.

28. Previous Aqualinc modelling evidence used steady-state scenarios that were difficult to relate to the naturally variable climatic and irrigation stresses incident on the area.

29. In an effort to assist the Commissioners, ECan urged the Applicant to consider undertaking transient modelling of the groundwater mounding effects. Although the new groundwater model, described in Mr Weir's most recent evidence, does not specifically show the variable effects of transient mounding on maps, this can be assessed from the transient modelling plots of groundwater levels for individual wells in his Appendix E.

30. Mr Weir's evidence contains plots of dry, average and wet year mounding scenarios. It is important to grasp that dry years cause the greatest mounding because of the greater amounts of irrigation water used. Conversely, wet years produce less mounding. I have no difficulty with this approach as an assessment method but consider that it is not necessarily the most realistic and certainly does not lead to identifying the 'worst case'. I shall show that background, antecedent groundwater levels have also to be kept in mind when assessing the effects of mounding of groundwater levels.

31. I present the following as an indicative example of mounding associated with a dry irrigation year on the back of a wet winter, as actually happened during the 2006-7 irrigation season. I have taken Mr Weir's transient modelling plot of well L36/0142 (Weir evidence: page 80, location map on page 78) and measured the simulated mounding during the early part of the 2006-7 irrigation season (Figures 1 and 2).

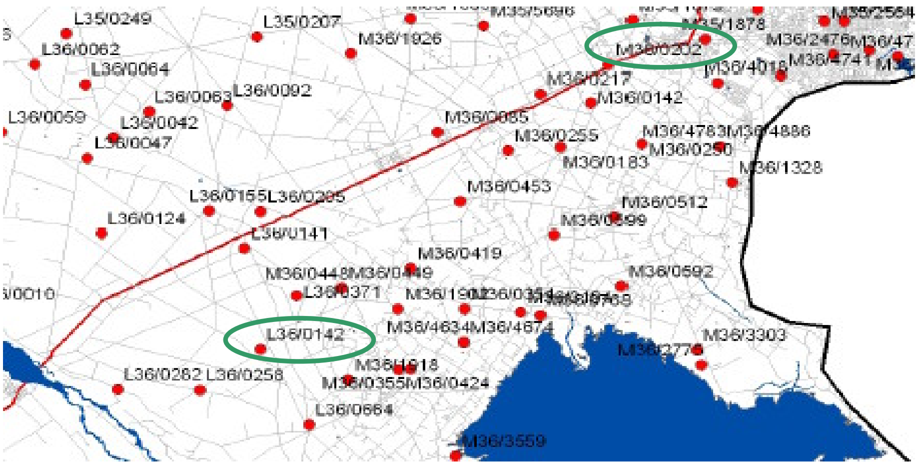

Figure 1: Map showing location of ECan monitoring wells L36/0142 and M36/0202 (Source: Weir evidence, page 78)

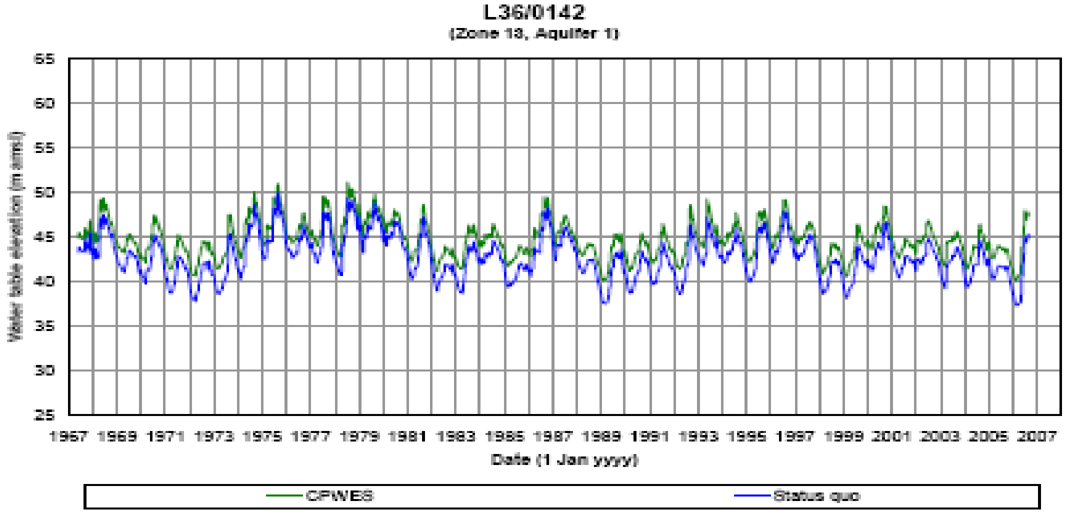

Figure 2: Time series plot of ECan monitoring well L36/0142 with status quo and CPWES simulations to show the time-varying nature of mounding (Source: Weir evidence, page 80)

32. The modelled mounding for the 2006-7 irrigation season amounts to just less than 3 metres. This value can be compared with that predicted for a dry year using the map of mounding contours (Figure 3, copied from Weir evidence page 107).

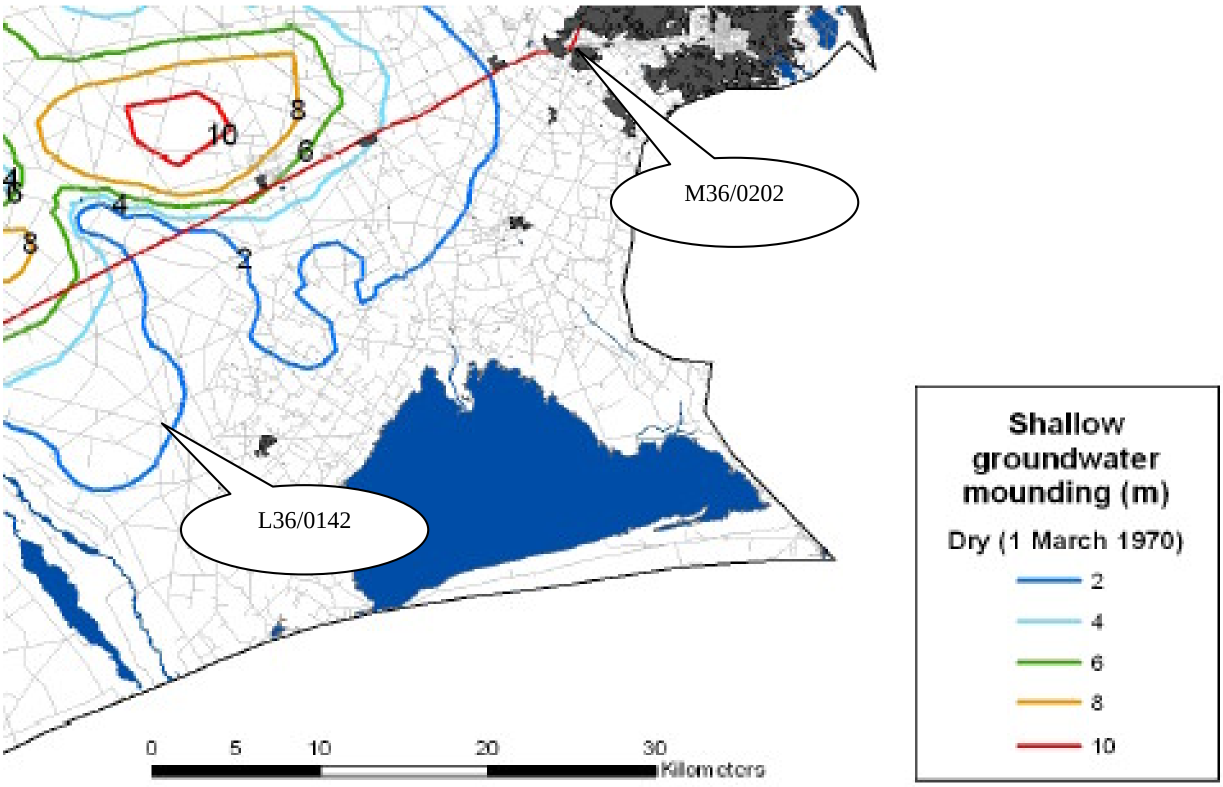

Figure 3: Map showing modelled dry year mounding distribution. Location of L36/0142 and M36/0202 indicated (Source: Weir evidence, page 107)

33. The comparison indicates that the 2006-7 'wet year' predicted mounding of ~3 m is nearly 50% greater than that predicted by the model even for a dry year such as at 1st March 1970 (~2 m) as shown in Figure 3. This level of mounding brings the resultant groundwater level to ~48 m amsl[4], to within about 5 m of the land surface (52.75 m amsl), a value similar to that predicted for that area in the wet year depth to groundwater map on Weir evidence page 116 (Figure 4).

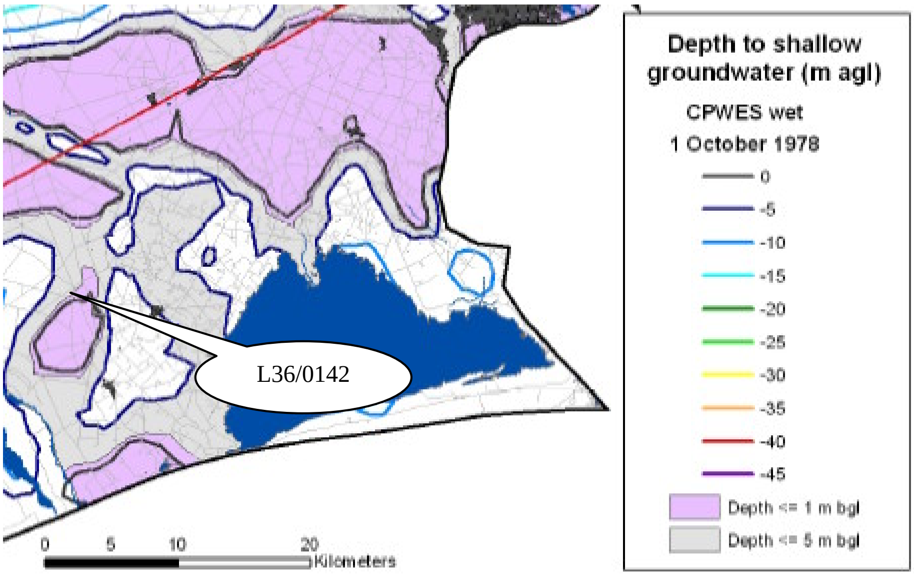

Figure 4: Map showing depths to groundwater in a 'wet' year (Source: Weir evidence page 116)

34. However, during the irrigation year 1978-79, chosen as the wet year for the transient modelling, a corresponding mounding of only 2 m is modelled for the summer of 1978-79, but it occurs on the back of much higher late winter groundwater levels, bringing the mounded level to 51.2 m amsl, representing a depth to water below the land surface of only 1.5 m. Comparison of this two metres of modelled mounding at the location of L36/0142, with the plot of wet year mounding (Figure 5, and Weir page 109), shows that the amount of mounding for this location is more than shown on the map portrayed in Figure 5.

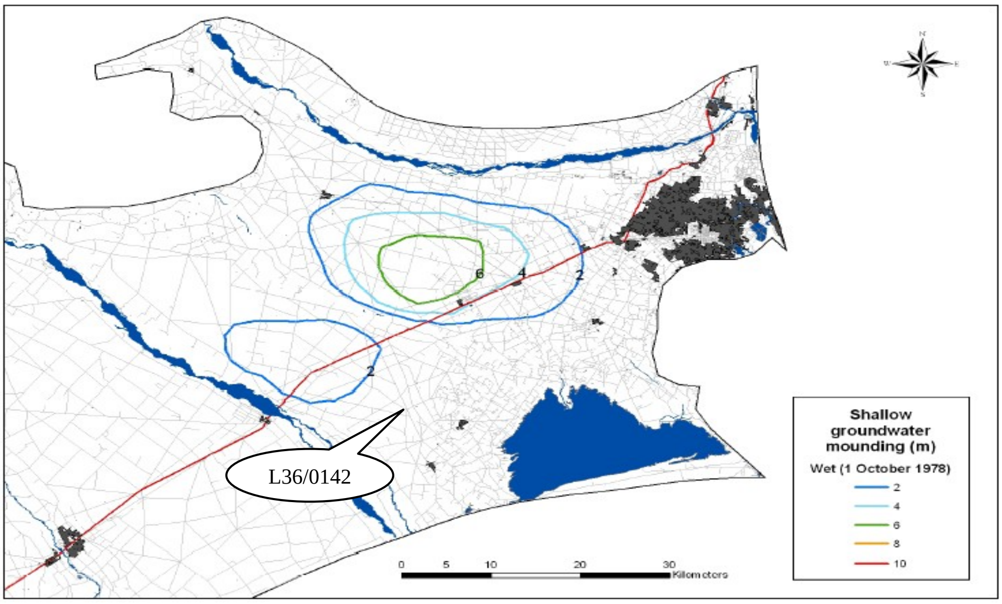

Figure 5: Map showing mounding in a wet year (Source: Weir, page 109)

4 amsl = above mean sea level

35. What the preceding four paragraphs serve to indicate is that whilst I am in agreement with Mr Weir's conclusions that mounding will occur, and with the general disposition of mounding magnitude, I am uncertain whether the mounding scenario for a dry or wet year is a realistic assessment of the worst case scenario.

36. The transient plots seem to indicate which years might be the worst case, being those representing an average summer mounding (only 2 m) on the back of high antecedent groundwater levels. My colleague David Scott addresses similar issues in his evidence. In terms of mounding, perhaps Mr Weir should have used 2006-07 as a worst-case year. However the antecedent water table in 1978-79, had it occurred in 2006-7, would have been a better candidate for a worst case.

37. The foregoing assessment indicates that the historic climate data used in the modelling and the choice of wet and dry years will not necessarily result in a worst case scenario. The irrigation year 2006-7 represented the year with the greatest mounding, and the year 1978-79 represented the year when the effects of mounding, compounded by high groundwater levels, created the least depth to groundwater. I recommend that the Applicant undertakes similar analyses on other wells to determine whether my conclusions are consistent across the area down-gradient of the proposed Scheme.

38. My analysis also indicated that the wet year mounding map and the plot of the corresponding year for L36/0142 produce two different values of mounding, allowing the conclusion that the mounding maps are not necessarily as precise as they could be.

39. Next, I will address the water management ramifications of the predicted mounding. Later in my evidence I will describe what mitigation might be required to minimise any adverse effects.

Other effects associated with groundwater mounding

<u>Groundwater appearing at or near surface</u>

40. Mounding of groundwater levels to near surface, induced by the CPW scheme, would be expected to increase the area and magnitude of this natural effect (See maps in Appendix G in Mr Weir's evidence).

41. My analysis of the transient groundwater plots described in the preceding section broadly concurs with Mr Weir's evidence that the wet year plots for 1 October 1978 (pages 115 and 116) are a reasonable though not necessarily precise prediction of minimum depths to water. These two plots indicate that there is an increase in the area of land underlain by very shallow groundwater and that while the increase in area is least for wet years, the area as a whole is larger in wet years. My assessment of transient mounding has uncovered some uncertainties in the degree and location of mounding.

42. Mr Weir has also reported on his modelling of the timing of mounding and whether this is a variable, dependent upon the state of the groundwater resource.

43. It is a given that mounding, like drawdown, in large aquifer systems is not instantaneous, it develops and recedes slowly. Examination of the transient plots of groundwater level in Appendix E confirm that the highest mounded water levels occur in the late winter period of August to September. Mounding magnitudes, as plotted in Appendix F are highly variable. What has not been modelled are the cumulative effects of a succession of dry or wet years on the groundwater system. I understand that such modelling is not yet feasible because of the excessively long model run times.

44. Whilst mounding would be most critical as an adverse effect at times of high natural groundwater level, it may be argued that mounding at times of low groundwater level, during the irrigation season for example, is a benefit.

45. Mounding occurs both in what may be described as the unconfined aquifer zone and also in the confined zone to the east. When mounding occurs in the unconfined zone, then groundwater will appear at or close to surface. Existing depression springs will develop and new ones form, leading the water away at surface. If mounding occurs in the confined zone, then artesian springs will become more active, and wells previously typically sub-artesian, might become flowing artesian.

46. Therefore, in the unconfined zone, it is critical for the reliable determination of adverse effects to know the magnitude of raised groundwater levels. Analysis of a modelled transient time series plot of groundwater levels for a Hornby area bore (for location, see Figure 1) M36/0202, indicates that the dry year (1/3/1970) is not the most conservative value of mounding; the 2006-7 season exhibits the highest mounding, at 2.5 m (Figure 6).

47. If this modelled 2.5 metres of mounding associated with a wet groundwater year is superimposed on the groundwater record for the wet year of 1978-79, then the groundwater level would be at or above ground level for an extended period.

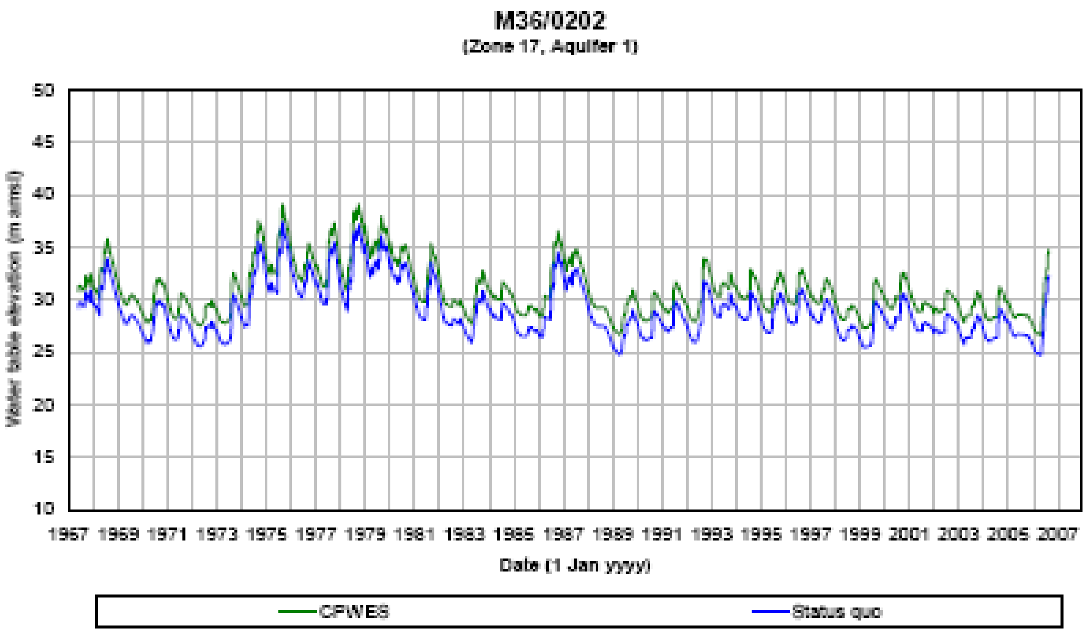

Figure 6: Time series plot of modelled groundwater levels for well M36/0202 (Source: Weir, page 97)

48. Whilst my analysis is only indicative, it highlights the issue of whether the plots and maps of mounding in Mr Weir's evidence are truly representative of dry, wet and average years. I strongly suspect that they are not.

49. Modelled mounding magnitude differs from year to year and does not apparently strictly relate to antecedent groundwater level. A true worst case scenario would include the greatest mounding on the greatest groundwater level.

<u>Soils becoming waterlogged and 'sour'</u>

50. I have been unable to find in the AEE any comments on the physical and agronomical effects on soils of increasing the period during which water is present at or near the ground surface.

51. Generally speaking, I understand that the longer the period when water saturates a soil, the more damage it does to its fertility, its fauna and flora, and its ability to be mechanically worked by farmers. I am not an expert on these matters, and cannot comment further. It seems to me that clarification is required on this issue which could be addressed by the setting of appropriate conditions, or compensation for loss of ability to use or work the land.

Malfunctioning of wastewater and stormwater discharges due to high groundwater levels

52. According to the modelling results described by Mr Weir, much of the area where mounding of groundwater is predicted to occur is already characterised by high groundwater levels in winter periods. Such prediction is borne out by observations of groundwater levels in ECan monitoring wells, and from photographic evidence of flooding. As such, much of the land subdivision and associated discharges to ground of stormwater and wastewater in these areas, should already have had to make provision for short-term high groundwater levels.

53. However, it should be borne in mind that flooding events of the mid 1970s occurred at a time when there was little subdivision in the areas typically flooded. Much of that farmland area flooded in the 1970s is now decorated with large new houses (e.g. west of Tai Tapu) and subdivisions peripheral to small towns (e.g. Lincoln).

54. An issue for this Hearing is whether the modelled elevations in groundwater level are sufficiently precise to predict whether current stormwater and wastewater systems will continue to function as designed once the proposed Scheme is up and running. Maps in Mr Weir's evidence (pages 115 and 116) indicate that there may be areas peripheral to those already existing, where adaptation of wastewater disposal systems may be required to ensure that they are still operating within their consent conditions and do not represent a health hazard.

55. If existing landowners are disadvantaged from a rise in groundwater levels, resulting from the CPW scheme, such that their wastewater and stormwater discharges become ineffective, then it is appropriate for this Hearing to consider compensation of down-gradient landowners for the costs incurred in redesigning and building their systems.

56. This is an issue that may be addressed by the setting of appropriate discharge conditions and is dealt with later in my evidence.

Man-made and natural waterways coping with increased discharges

57. The Applicant considers it "*is also clear that in areas that could potentially be affected by groundwater mounding there are already extensive drainage networks in place, with generally enough capacity in both the main trunk drains and in secondary feeders to handle an expected increase in baseflow produced by the Central Plains scheme*[5]."

58. There are differences between the Groundwater Model report released in July 2007 and a revision described in Mr Weir's evidence. These differences were itemised in Mr Weir's evidence (paragraph 57) but for some model results, the details of this distinction between the two model outputs has not been included in Mr Weir's evidence. For example, there are no flow duration plots for the Selwyn River, only cumulative volume (requested of Applicant on 14th January 2008). This makes comparison of the two versions of the model problematic.

59. Over the last few years preceding the winter of 2006, and more recently, since the winter of 2007, flows in man-made drains and natural waterways have been much lower than average. The modelling

[5] ibid.

presented by Aqualinc in Mr Weir's evidence (Appendix L) does not provide sufficient detail to indicate whether individual drains and streams are still able to cope with the predicted increases in flow[6]. The data in Appendix L suggest that the Selwyn River, as predicted at Coes Ford, will be the greatest beneficiary of the increased flow, with its mean flow doubling, and its low flow going up six-fold.

60. Unfortunately, the flow duration curves for the Selwyn River have not been included in Mr Weir's evidence despite the presence of cumulative flow values in Appendix L of his evidence. Although flow duration plots are presented in Appendix S in the Canterbury Groundwater Model version 2 report[7], there is no equivalent set of plots in his evidence, only cumulative flow plots (Appendix B). Therefore, I am unable to assess the high flows in the Selwyn River. In my opinion, the modelled increased mean flow in the Selwyn River resulting from the Scheme discharge is unexpectedly large.

61. In contrast, flows in the River Irwell and Hanmer Road Drain do not show such large modelled increases in flow when expressed in terms of their 7 day MALF. However, under average conditions, the scheme would increase flows by about 50%.

62. The right-hand two columns in Appendix L for these two waterways indicates a barely significant contribution from the scheme under median conditions, raising flows only slightly. In my opinion, the contents of Appendix L are difficult to interpret and require further explanation, with the inclusion of flow frequency plots that would allow better understanding of the simulated effects on surface water bodies.

63. Given the data in Appendix L, I am unable to judge the quality of the flow predictions, especially high flows. In some cases they indicate considerable increases that are likely to be beneficial, in other cases (e.g. Harts Creek, Halswell, LII), the status quo values of flow are not at all similar to monitored flows, while the increases due to the Scheme are marginal and little improvement over the status quo.

64. It seems to me that predicted flows in the Selwyn River are probably too great, and occur not only at the expense of flows in other streams but may also involve a lowering of groundwater levels. This unlikely partition of flow that is at variance with monitoring. This effect, and others that cast uncertainty on the accuracy and precision of the model are dealt with by my colleague, David Scott.

65. Regardless of the modelling, were drains unable to cope with any increased flows, then a condition requiring the CPW consent holders to clear existing, or create additional drains when necessary, might be appropriate. Some of these old drains have ecological values which may become violated by attempts to deepen them.

66. Alternatively, this is an issue that may be addressed by the setting of appropriate discharge conditions and is dealt with later in my evidence.

<u>Potential increase in number of artificial openings of Lake Ellesmere / Te Waihora</u>

67. Increased flows (see Weir's evidence Appendix L) in the order of 50% in the lowland spring-fed streams such as the Selwyn (Waikirikiri), LII, Halswell, and Harts Creek will mean that the lake level will increase over that experienced during natural discharge conditions, especially in summer, but also in winter. If the lake is to continue to be managed at the consented height (opening at 1.13 m amsl), then an increase in the number of openings will likely be required. Currently, the lake is opened with a long-term mean frequency of 3.3 openings a year, mainly in winter and early summer. Changing the timing and frequency of openings is problematic if ecological management of its flora and fauna is to be optimised. My colleague, Shirley Hayward, will present evidence on this topic.

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[6] Note that the first row in Appendix L should be in units of m^3/s, not L/s.
[7] Aqualinc report L07079/1.

68. I consider the modelled inflow to Lake Ellesmere from groundwater of 11 to 12 m^3/s to be a gross over-estimate (Weir evidence, Appendix P, page 139). ECan monitoring of groundwater seeps and springs on the floor of Lake Ellesmere[8] and verified modelling of the lake water budget by Graeme Horrell[9,10] indicate a value at least an order of magnitude lower than modelled. Inconsistencies of this magnitude in the water budget are worrisome when considering the reliability of the groundwater model.

69. The issue of lake opening frequency may be addressed by the setting of appropriate discharge conditions and is dealt with later in my evidence. Uncertainty in the prediction of flows into Lake Ellesmere mean that there is uncertainty in the need for mitigation.

The need for mitigation and conditions to deal with adverse effects

70. Even with the introduction of new modelling evidence from Mr Weir, my assessment of the severity of adverse mounding and discharge effects has been hampered by my inability in the time frame allotted, and with the type of detail provided, to determine, from the Applicant's transient modelling, the precise magnitude and timing of effects resultant from a combination of realistic transient climatic and irrigation scenarios. Neither have I had the benefit of auditing electronic data derived from the transient model predictions to assess the severity and timing of any predicted adverse effects.

71. Given that adverse effects may range in a spectrum from de minimus effects through to fatal flaws, the evidence I have read still leaves me uneasy about the magnitude and significance of some of the modelled effects and whether mitigation of effects is practical.

72. In light of the foregoing, dealing with potential adverse effects may be undertaken by the setting of appropriate conditions; these are dealt with in a subsequent section of my evidence where I also give my views on how conditions might be applied to mitigate adverse effects. Before that section I wish to comment on some mitigations and monitoring proposed by the Applicant.

Mitigations suggested by Applicant

73. The Applicant has suggested the following mitigatory and decision-making regime[11] (my bolding):
"In those locations where it can be demonstrated that there are adverse effects as a direct consequence of CPWES the following solutions should be considered for case-by-case adoption:

- ***Tolerate a limited amount of short term flooding**. The present drainage schemes have not been designed to prevent inundation of land in heavy rainfall events, and a similar scale of ponding, thought to be up to about 12 hours in some places, should be acceptable post- CPWES,*
- ***Widen or deepen trunk drains to increase their capacity**. Over most of the rural land it will be practical to widen or deepen trunk drains, and this will enable them to provide the extra capacity to accommodate the calculated increase in baseflows,*
- ***Install more drains to provide a more intensive secondary feeder system**. Where groundwater levels rise between streams and trunk drains it will be feasible in many locations to install more drains to take water to the trunk systems, using open or subsurface drains as appropriate.*

For urban situations there will be less tolerance of short term flooding, particularly in dwellings, but the principles of monitoring and remedial actions will be similar. Further solutions that might have to be considered will include:

- ***Pumped solutions,***

[8] Ettema, M and CR Moore (1995): Seepage in Lake Ellesmere; Environment Canterbury Technical Report U95/18.
[9] Evidence presented at Rakaia-Selwyn groundwater application hearing 2006.
[10] see also: Taylor, K (1996), page 101, Table 7.8
[11] CPW memorandum regarding mounding: Lewthwaite to Fietje 14/12/2007.

- ***Contributions to the costs of managing increased flows or of infiltration reduction programs in sewerage reticulation systems****.*

A further longer term solution, that could be considered if it becomes necessary, is ***a reduction in the amount of irrigation within the scheme****. This is unlikely to be considered in the short term and it must be seen as a future contingency only if it is crucial, as it could affect the financial viability of the scheme."*

74. I offer the following comments on these mitigation measures:

- The timing and frequency of short-term rural flooding may be significant in determining whether they are socially and economically acceptable. Whilst short-term flooding may be acceptable at a frequency of once a year, or less, it may not be acceptable more frequently. For example, the Applicant has predicted that water levels might occasionally return to peak 1994-6 levels. Whilst there was no long-term flooding during that period, there was certainly short-term flooding in the peripheral areas to Lake Ellesmere. In my opinion, two questions need answers: How will the cut-off frequency be managed; and, how will the proportion of flooding due to natural versus Scheme causes be assessed? I do not know the answers but am willing to work co-operatively towards getting them.
- In theory, the surface water drainage network can cope with 1990s-style and magnitude of flooding events. However, since that period, many drains have not enjoyed such flows and may have silted up or become vegetated to some degree, so not allowing them now to respond in the same way to flood events. Construction of new drains or maintenance of existing ones would need to be done prior to any flooding in order to be effective. Who would pay for and be responsible for such work (e.g. Selwyn District Council)?
- Urban environments are indeed less tolerant of flooding but similar to the rural environment will require contributions to any additional costs for drainage improvement or compensation for damage.
- Whilst the time-lag between cause and effect is large, immediate reduction in irrigation scheme discharge will likely have little or no immediate effect on existing flooding. If repeated flooding occurs, then there may be no option other than to reduce the Scheme discharge which will indeed have an economic impact on the shareholders.

75. The Applicant also made comments on decision-making mechanisms with the following[12]:

"It is clear that the principle of adaptive management will be a necessary feature of future management of groundwater mounding, i.e. situations will have to be considered and solutions implemented case by case as the scheme develops. With variations that occur in geohydrology over short distances, uncertainties in fine points of groundwater modelling and unknown future developments in groundwater usage in the plains, it is impossible to establish in advance the needs of particular locations. This will be especially important for secondary drains and urban situations.
A core issue will be to determine in both broad guidelines and on a case-by-case basis the cause of drainage situations and therefore responsibility for costs of mitigatory actions. CPWES proposes by way of condition that a panel be established with the responsibility to address this matter and recommend solutions to CPWES and affected parties. It is proposed that this panel should include the following people:

- *A representative of CPWES management,*
- *A representative of drainage management from the lower plains,*
- *An engineer with expertise and experience in both large scale and localised solutions to land drainage,*
- *An engineer or scientist with expertise and experience in Canterbury groundwater systems.*

[12] CPW memorandum regarding mounding: Lewthwaite to Fietje 14/12/2007.

- *In addition it is considered that a review panel should be appointed to arbitrate in the event of disagreement with the recommendations of the drainage panel. This arbitration panel should have technical and legal expertise."*

76. I have the following comments on these decision-making proposals:

- The first paragraph from this quote suggests that there is recognition by the Applicant of uncertainty in the predictions from the modelling. Unfortunately, this uncertainty has not been adequately described in Mr Weir's evidence.
- It may sometimes be hard to determine the relative degree of cause accorded to the CPW Scheme and to Mother Nature for flooding or other adverse effects. A drainage panel, as suggested by the Applicant, is a fall back position. In my opinion, though, the Commissioners should be made aware by the Applicant, prior to granting consent, just what the predicted effects are likely to be under worst case conditions and what the solution(s) would be. Should a problem arise, the drainage panel could assess the state of groundwater and surface water and make recommendations based on the prediction and proposed solution.
- In my opinion, a review panel might cause delay in getting to the right decision. What is needed is an ability to make the right decision, quickly, with a planned process that swings into action when required.
- In my opinion, Environment Canterbury should have at least one place on any review panel.

Monitoring suggested by Applicant

77. The Applicant has suggested the following monitoring regime (my bolding):

- *"**Existing arrangements for monitoring flows and groundwater levels be continued for all utilities** (There are extensive networks and programs of monitoring currently conducted by ECan regarding stream and drain flows and groundwater levels, and by SDC regarding the sewerage systems that have established a database for an initial baseline report, and these should be continued),*
- ***Changes in groundwater consents and use of groundwater throughout the plains, and water use from a CPWES supply be monitored and assembled into an annual report** (This would be a cooperative exercise between CPWES and ECan),*
- ***Groundwater modelling continue periodically, including upgrading and rerunning a suitable groundwater model**, to aid understanding of contributions to effects from the scheme and natural events[13]."*

78. My reaction to these monitoring proposals are:- There should be an annual comprehensive report on water quantity (and quality) and usage issues representing the results of the operation of the scheme on existing and new consents, and results of groundwater levels and surface flow monitoring in order to assess the operational effects of the scheme. I propose that reasonable extra costs associated with this monitoring and reporting would be borne by the consent holder;- I accept that there is a need to improve our understanding of the behaviour of the aquifer system and its response to the CPW scheme and that modelling is one tool to achieve this. Whether the Aqualinc model is suitable for this task is arguable and is commented upon by my colleague David Scott.

Requirement for and reasoning behind proposed conditions

Condition to manage the severity of groundwater mounding and flooding

[13] CPW memorandum regarding mounding: Lewthwaite to Fietje 14/12/2007.

79. This is required in order to protect land users against unacceptable groundwater levels induced by the Scheme. A difficulty with such a condition is that mounding and consequent flooding takes time to develop and wane. If mounding were to develop to unacceptable levels, then it would take weeks, if not months for a reduction in mounding to occur if irrigation was constrained.

80. As outlined in my evidence, we do not have precise information on the dynamics of mounding for the proposed scheme from which we could develop a management plan. However, we do have experience with other surface water-sourced irrigation schemes such as the Mayfield-Hinds fed from the Rangitata Diversion Race. Down-gradient of that scheme, mounding occurs after a few months of irrigation and continues after irrigation has ceased (Dommisse 2007, Figure 6.4 and Section 6.1), representing the monitored transient effect that is the opposite of that experienced beneath irrigation sourced from groundwater. However, it must be admitted that the RDR scheme, as also the Northbank scheme on the north side of the Rakaia River, are both largely border dyke schemes.

81. A similar study of the groundwater effects resulting from the Ashburton-Lyndhurst border dyke irrigation scheme also indicated the occurrence of mounding (Vincent 2005, Figure 5.2).

82. Waimakariri Irrigation Limited operates a dominantly a spray-irrigated scheme; considerable mounding occurs beneath the irrigated area to the west of Kaiapoi to the extent that summer groundwater levels usually increase over those monitored in winter by as much as three metres.

83. Effective management of mounding would require continuous assessment of groundwater levels with the recognition of trigger levels set up in such a way as to manage unacceptable levels prior to their occurrence. Realistic trigger levels would definitely need more precise modelling of transient mounding effects.

84. I do not consider that a condition limiting the volume of water used for irrigation would be an effective means of limiting adverse effects. Compensation for loss of land/earnings might be a workable solution to the issue.

85. A major difficulty will be provision of reliable data on the degree to which the scheme might, or might not exacerbate an already adverse natural environmental condition. Compensation might allow for irrigation to continue throughout the scheme area instead of constraining some or all of the scheme shareholders to manage groundwater levels that are locally unacceptable.

86. Significant thought needs to be applied to how the Applicant and the Council might come to agreement about distinguishing between effects caused solely by Nature, and those that could reasonably be caused by the Scheme. Perhaps the model will help, but not in its present form.

<u>Condition to manage increase in lake opening</u>

87. This is required in order to protect land users and the sensitive environment surrounding the lake from unacceptable flooding. A difficulty with such a condition is the expectation that mounding, and therefore, discharge to the lake, takes time to develop and wane. If discharge dependent upon mounding were to develop to unacceptable levels, then it would take weeks, if not months for a reduction in mounding and consequent flow to occur if all irrigation ceased.

88. Currently, we do not have precise predicted information on the dynamics of mounding and its effects on the lake from activities associated with the proposed scheme. However, Horrell (Taylor 1996) modelled lake openings as part of his research into Lake Ellesmere dynamics. In theory, given a specific discharge and lake status, the increase in the number of openings ought to be predictable.

89. Effective management of mounding-related lake openings, using the existing lake trigger level, would be for CPW to pay for openings over and above the mean frequency of 3.3 per year.

Ground stability and groundwater water effects associated with the long tunnel option and the reservoir [I'd move this section to the end of the report. In its current position, it interrupts your discussion of the mounding issues]

90. I have reviewed the pertinent sections of the AEE document[14], that deals with the creation and operation of the long tunnel.

91. The geological map and cross-section in that document indicates that groundwater levels will be at or close to the same level as the tunnel invert from the portion close to the intake as far south as Barrs Road. South of Barrs Road, groundwater levels will be distinctly higher than the tunnel invert.

92. I interpret this to mean that great care will be required to balance the use of pressurized tunnelling techniques with the groundwater pressure in that portion of the tunnel located within saturated gravel strata. Too great a pressure will mean that groundwater would become contaminated with any bentonite slurry, too little, and the tunnel floods during construction. I anticipate that the tunnelling contractors will use best practice methods to obtain this balance and that a management plan associated with a number of related construction and operation issues will be formulated. Once lining of the tunnel is in place, this issue should disappear.

93. I do not see the creation of a tunnel in the gravel strata used as an aquifer as being any impediment to groundwater flow nor to groundwater quality, providing the best practice methods are adhered to during its construction.

94. I have undertaken a brief analysis of earthquake records (data downloaded from IGNS website in January 2008) for the area and note that there are no recent low Richter magnitude earthquakes in the area occupied by the dam and reservoir (Figure 7).

[14] Central Plains Water Enhancement Scheme: Assessment of Effects on the Environment for Long Tunnel 42156547, April 2007.

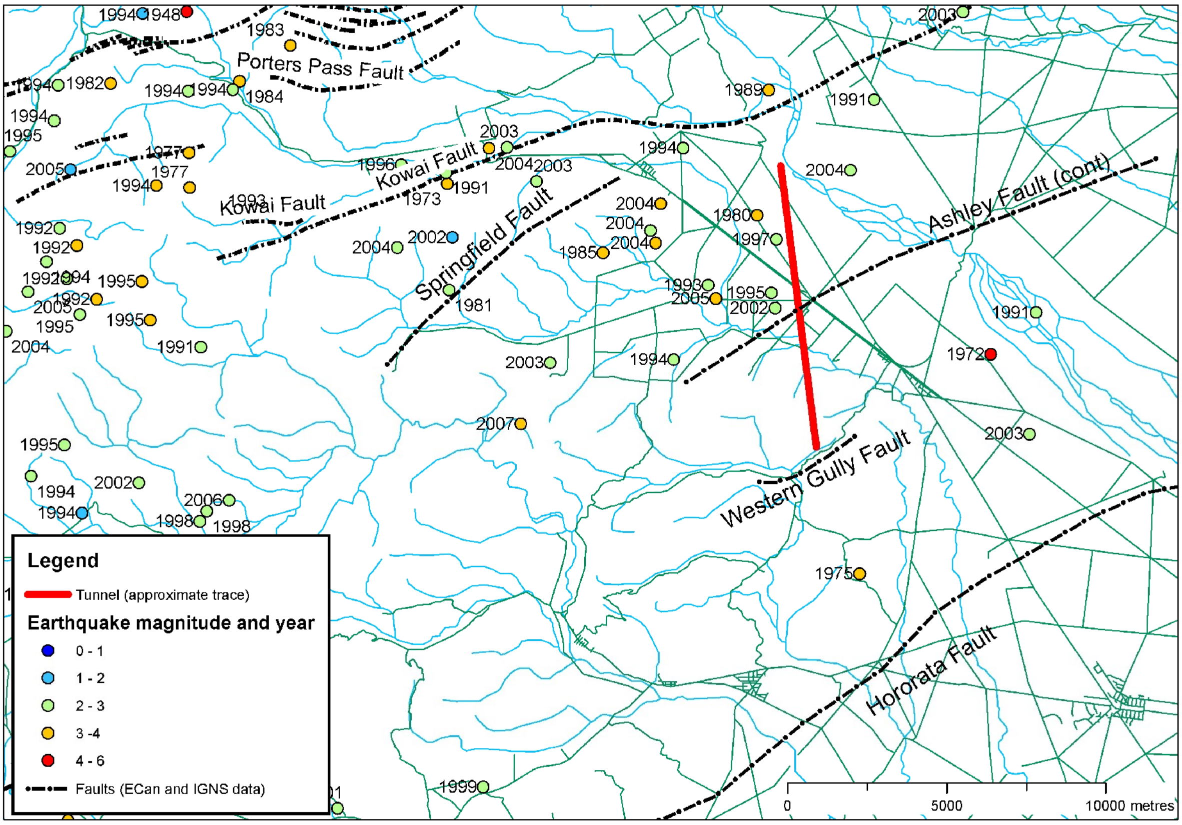

Figure 7: Map showing locations of earthquakes (GNS data) and fault locations (ECan, URS and Campbell data[15])

95. There are earthquakes and a continuation of the Ashley Fault lying along a zone traversed by the tunnel (Figure 7). I do not consider these earthquakes and the fault traversing the tunnel trace as being a major issue in that, at worst, the tunnel might require maintenance should a major slip occur along a fault that crossed the tunnel.

96. I have read the Dam Safety Assurance Report (June 2006) and note the description of fault structures and the risk assessment procedure. I have no comment to make about dam stability and the risk of earthquake hazard other than to agree that motion along the Hororata Fault and, or Porters Pass Fault is the most likely to cause damage to the proposed dam.

97. I have briefly visited the reservoir site and agree with the Applicant's description of the geology (Geotechnical Investigation: September 2002, Section 4.3). I note that the surface slope angles and orientations of bedding and other slip surfaces in the areas peripheral to the intended reservoir are potentially unstable, and should they show signs of any instability during assessment for the design phase of the reservoir, then these slopes can be modified to a more stable form.

98. I anticipate that any potential groundwater seepage beneath the dam structure, in the underlying sedimentary and volcanic strata, will be managed by grouting, as necessary, as determined during the detailed design phase exploration of the dam footprint.

99. The incidence of coal mines and coal-bearing strata in the reservoir footprint is unlikely to cause water chemical quality issues despite the common occurrence of arsenopyrite in coal. I would expect the

[15] Campbell, J 2003: Active faults and folds under the Canterbury Plains; Royal Society of New Zealand Workshop and Field Trip (October 2003).

water seeping into the mines from the reservoir to become chemically reduced and therefore not conducive to the production of acid mine drainage. If acid mine drainage from the mines were to develop it would be highly diluted by the water imported into the reservoir to the extent that it would likely pose no significant risk to aquatic or human health.

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APPENDIX A: ADDENDUM TO ENVIRONMENT CANTERBURY REPORTS U06/08 AND U06/10

Introduction

Since completing Environment Canterbury Reports U06/08 (Davey 2006a) and U06/10 (Davey 2006b) I have been advised that my description of the formation and characteristics of aquifers and aquitards has been misunderstood and/or misinterpreted. This Addendum responds to those concerns and at the same time provides updated versions of two schematic cross-sections which contained printing errors in some print runs of the U06/10 report.

Example of apparent misunderstanding

I understand that my description of aquifers (Davey 2006b) has been described as being very consistent with that in the Canterbury Groundwater Model Report of Aqualinc (2005). I do not agree with this. In a superficial sense the block model produced by Aqualinc is similar to the disposition of aquifers and aquitards as proposed by me, however my understanding of the formation and characteristics of aquifers and aquitards, mainly as outlined in Davey (2006a), is quite different to that of Aqualinc.

Aqualinc explain the aquifers as being sediments that have been reworked during the interglacial periods, and the inland aquitards as being glacial deposits that haven't been reworked. In Davey (2006a) I explained how the sediments of the Canterbury Plains, inland from and distal to the Christchurch confined aquifer system, were deposited almost entirely within glacial times, and that reworking of these in the interglacial periods could not have resulted in the extensive and thick aquifers that exist.

My interpretation of the aquifers is that they are located within gravels deposited during glacial times, and are the result of primary permeability of those sediments, with some modification of the permeability by the passage of groundwater through them. I am unaware of any field evidence for the 'reworking' theory of aquifer formation in the Canterbury Plains. This theory seems to have developed within the Canterbury groundwater literature from mere speculation.

Photographs of a discharging aquifer within mapped glacial period gravels are given in Davey (2006a). In my opinion, this and other evidence presented in this report clearly shows that aquifers consist of interconnected lenses of highly permeable gravel within much less sandy gravel. Reworking of these gravels is not necessary to explain the channel deposits which form the permeable lenses. In addition, and perhaps more importantly, my understanding of the plains aquitards differs from that of Aqualinc. Drill logs throughout the plains (excluding the confined aquifer system) are conspicuously lacking in any strata which would conventionally be described as aquitards. There is no evidence of laterally continuous layers of sand, silt, peat or clay which could constitute highly impermeable aquitards.

My view is that the aquitards consist of relatively thin (relative to the aquifers) sandy gravel layers through which few or no highly permeable lenses penetrate – either vertically or horizontally. Evidence for this is the lack of iron staining within the interpreted aquitards. The coincidence of iron staining and aquifer material has long been known to drillers and gallery diggers in the Canterbury Plains, and photographs illustrating iron staining (associated only with highly permeable lenses) are shown in Davey (2006a).

My view is that the aquitards represent interglacial surfaces that are likely to be more permeable than the current land surface. This is because the current land surface has thin deposits of soil and loess. There is no evidence in drill logs for the preservation of such deposits on interglacial surfaces. In contrast, there is abundant evidence of the current land surface allowing rapid rainfall recharge to underlying aquifers, and even more rapid recharge from border dyke irrigation.

The aquitards beneath the plains are considerably less transmissive than the aquifers. As a result they commonly display quite different water levels in different aquifers. In addition, lack of drawdown in one aquifer during a brief pumping test from a well in another aquifer is commonly observed.

In my view aquitards will allow quite ready vertical movement of water through them. They are leaky aquitards, not aquicludes. I understand that the Aqualinc model shows no real distinction in properties between coastal (confined aquifer system) aquitards and inland aquitards. It is commonly accepted that the coastal aquitards consist of silt, sand, clay and peat and are considerably less permeable than the inland sandy gravel aquitards.

Grant Davey
19 October 2007

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