

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

***In the*            The Resource Management Act 1991.  
*matter of***

***And in the*    78 Applications to Take and Use Water in  
*matter of*      the Valetta (55) and Ashburton River (23)  
Groundwater Allocation Zones.**

**Section 42A Officer's Report**

**Date of Hearing: 21 July 2008**

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**RESPONSE BY JON WILLIAMSON TO AQUALINC'S RESPONSE TO THE  
COMMISSIONERS REQUESTS FOR INFORMATION  
DATED 12 FEBRUARY and 14 APRIL 2009.**

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*Dated:* 18 August 2009

**SKM**

## TABLE OF CONTENTS

1. Introduction .....	1
2. Findings .....	1
3. Conclusions .....	8
4. References .....	10

### 1. INTRODUCTION

1.1 This statement provides a commentary on:

- (a) Aqualinc's letter dated 11 June 2009, which was prepared in response to the Commissioner's request for further information (RFI); and
- (b) Aqualinc's letter dated 28 July 2009, which responded to the Commissioners' Memorandum dated 29 July 2009.

1.2 The summary of my findings below is premised on the understanding that the objective of this exercise was to compare the impact on fluxes (particularly vertical leakage) from changed hydraulic properties ( $K_z$  and  $S_y$ ) and hence get a feeling for the sensitivity of the key aquifer hydraulic parameters under contention. The objective, as I understood it was not aimed at assessing whether the simulation maintained an appropriate level of calibration (i.e. comparing calibrations – refer **Section 6.1** Aqualinc letter). If you take a calibrated model and change one set of parameters without compensating by changing other parameters, it goes without saying that the calibration will deteriorate.

### 2. FINDINGS

2.1 Overall, the Commissioner's RFI process has been very helpful in understanding how the model behaves and in my view confirming that the model used for predictive assessment of groundwater effects is highly likely to represent just one version of a range of possible calibrated models<sup>1</sup>.

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<sup>1</sup> A calibrated groundwater model is considered a model that adequately replicates observed fluxes and heads, but does not necessarily infer that it is a faithful predictor of impacts under significantly different stresses to that imposed during the calibration procedure.

- 2.2 An enhanced “feel” for the model’s responsiveness to parameterisation (cause and response relationships within the model) has now been obtained, which provides us with the ability to understand the sensitivity to parameterisation. However, the likely range in effects from the proposed abstraction can not be confirmed at the current time. As alluded to below, to achieve this we would need to calibrate the model with changed parameter sets.
- 2.3 The key aspects to note from the work undertaken by Aqualinc in response to the RFI are described in the following paragraphs.

**Steady State Simulations**

- 2.4 While aquitard  $K_z$  values have been varied significantly (increased by  $10^2$  and  $10^4$ ), a good overall hydraulic gradient is actually maintained within the model. This suggests that the main factor governing groundwater movement and hydraulic gradient in the model is horizontal hydraulic conductivity ( $K_h$ ).
- 2.5 What was initially surprising with the steady state results was that groundwater levels went up with increasing  $K_z$ . In a simple system, you would expect groundwater levels to reduce and hydraulic gradients to flatten with increasing  $K$ . But this is not a simple system, and as Aqualinc rightly point out, groundwater levels have generally increased in the deeper aquifers and aquitards. This is because of the enhanced ability of aquifer medium to transmit water to these locations (i.e. increased leakage). **Paragraphs 2.13 to 2.16** discuss the difference in leakage rates for the Valetta zone from the old to the new models.
- 2.6 Only approximately twelve out of one hundred observation bores are appreciably affected, as listed in **Table 1**. These bores are all in excess of 80 m deep and are located within the mid to upper plains, which is the broad topographical area typically associated with river losses or seepage to groundwater (as opposed to lowland areas where rivers typically gain from groundwater seepages).

**Table 1.** Summary of 12 observation bores showing significant divergence.

Bore	Approx. Depth (m)	Model Aquifer Layer
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K36/0436	111	3
K36/0439	230	5
K36/0493	132	3
K36/0494	173	3
K36/0495	195	4
K37/1457	158	2
L35/0163	83	2
L35/0207	131	3
L36/0023	109	2
L36/0064	89	3
L36/1157	100	2
L36/1226	109	3

- 2.7 A key impact of increasing  $K_z$  is that groundwater gradients from the river steepen and enhance transfers in and out of the rivers. As discussed below, this is a function of maintaining streambed conductance values that were appropriate under the previously calibrated model, but not necessarily appropriate under the current parameter set<sup>2</sup>.
- 2.8 The response with higher  $K_z$  values indicates that under this new “un-calibrated” model, too much water is getting into the deeper aquifers resulting in higher simulated heads than observed. However, it is apparent from the flux data provided for these new models, that significant increases in losses from the rivers and increases in groundwater returning to the rivers are now occurring. Hence, if the river transfer function was dampened (while maintaining the new hydraulic conductivity parameter sets within the model), it could be expected that the model could be readjusted to correct for both the simulated pressure heads in the twelve deep bores and the river flux issue.
- 2.9 The above point reiterates the messages in my response evidence, with respect to parameter uncertainty (refer **Section 5**, particularly paragraphs 5.2 to 5.5), where I said “if different sets of parameters are used in the model to make predictions (all sets being considered to calibrate the model), will different model outcomes occur?”

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<sup>2</sup> To check on appropriateness of streambed conductance, concurrent gaugings during low flow times would be required right along the main rivers (i.e. not an easy check) so that losses and gain on a reach-by-reach basis could be compared. Alternatively, streambed conductance can be estimated during the calibration process by manipulating until net groundwater seepage to the river matches recorded river baseflows.

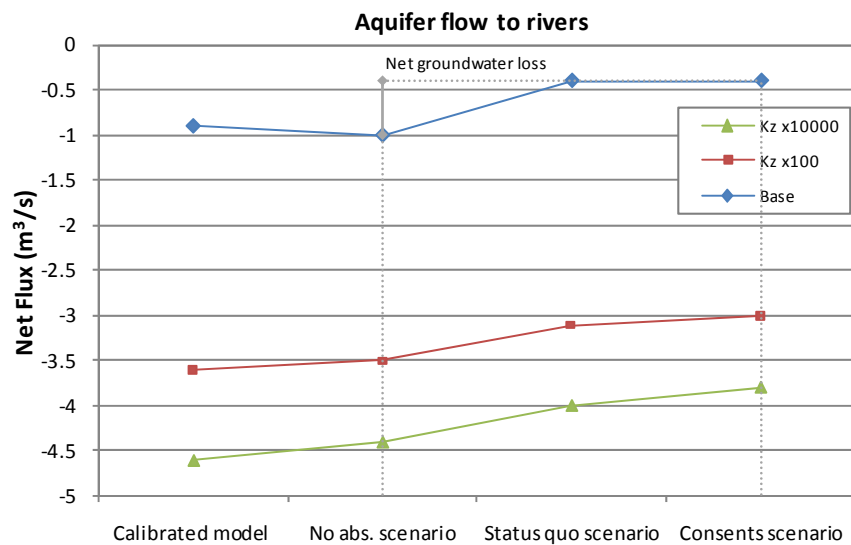
- 2.10 If we were to compare a number of equally well calibrated models, in this case we would need to accept the new imposed  $K_z$  values and manipulate other parameters such as recharge rates or streambed conductance to obtain new calibrations. Given that the model maintains a reasonable head gradient throughout the system, I consider this to be realistic and achievable for this model.

### Flux Budgets

- 2.11 Given that the models are no longer calibrated, we cannot place too much faith on the accuracy of the absolute magnitude of fluxes reported by the “un-calibrated” models. However, we can compare the:
- (a) relative response between scenarios within individual models (i.e. models with the same parameter sets),
  - (b) relative response between models, and
  - (c) scale of difference in flux magnitude between models.
- 2.12 **Figure 1** and **Figure 2** assist with this by providing water balance components of the Valetta Zone (only) of the model for: i) net aquifer-river transfers, and ii) net inter-aquifer transfers, respectively. The data in these graphs has been calculated from zone budget information presented in **Appendix C to F** of Aqualinc’s reply. Positive values represent a net groundwater gain in the aquifer, while negative values represent a net groundwater loss from the aquifer.
- 2.13 To assist in evaluating these charts, the following worked example is provided. In **Figure 1**, an example of a relative response would be the differences in net aquifer flow to the rivers between say the “No abstraction scenario” and the “Consent scenario”. For the “base model” this is approximately a  $0.6 \text{ m}^3/\text{s}$ , which represents a reduction in losses from the aquifer (i.e. groundwater flow to the river of  $1.0 \text{ m}^3/\text{s}$  reduces to  $0.4 \text{ m}^3/\text{s}$ ). If we look at the same relative response for the “ $K_z \times 100$  model”, the relative response is approximately  $0.5 \text{ m}^3/\text{s}$  also, while for the “ $K_z \times 10000$  model”, it is approximately  $0.6 \text{ m}^3/\text{s}$ .
- 2.14 When comparing the relative responses overall, the above analysis indicates that the impact on the river does not vary significantly between

models. The implication of this is that varying  $K_z$  in the aquitards does not appreciably impact on the overall budget of transfers to the river under steady state conditions, even though the absolute magnitude in transfers has increased.

2.15 A key consideration for the Commissioners on the later point regarding will be whether the change in absolute magnitude has implications that are a) location specific; and/or b) seasonal. However, it is not possible to evaluate this with the data currently presented.

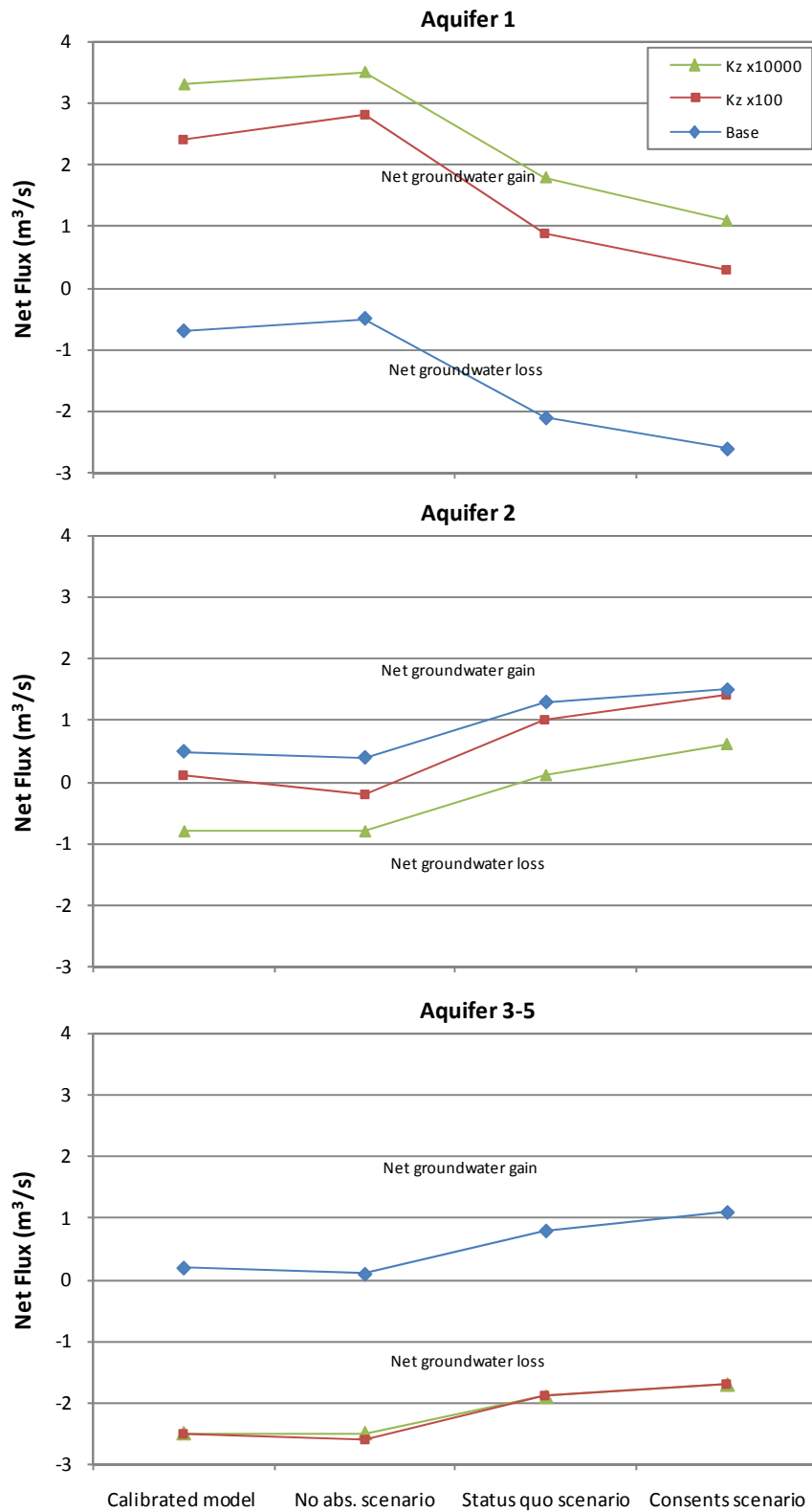


**Figure 1.** Net aquifer-river interaction (negative values indicate net groundwater loss = net groundwater flow to the river).

2.16 **Figure 2** provides an analysis of the net groundwater flux or leakage between vertically adjacent aquifer zones. The computed data assesses only groundwater transfers between layers (i.e. no external or lateral transfers). Again, positive values represent a net groundwater gain within that aquifer, while negative values represent net groundwater loss from that aquifer. **Appendix A** provides the datasheets for these calculations.

2.17 With increased abstraction the net overall groundwater loss from Aquifer 1 increases under each scenario. What is interesting is that the relative response is similar for each model (i.e. it makes no difference whether we assess the results from the calibrated model or the new models).

- 2.18 However, what is different between models is the absolute magnitude in net fluxes. With increasing  $K_z$  in the models, the net gain in groundwater in the shallow aquifer from the underlying aquifers increases significantly. This is because the impedance to vertical flow has been removed and the vertical pressure gradients now permit flow to transfer from the deeper aquifers to the shallow. Given the observed head increases in the deeper bores of the mid to upper plains area and the steepened hydraulic gradient between the river and shallow aquifer, this upward migration of groundwater is likely to be occurring predominantly in the mid to lower areas of the plains.
- 2.19 The response observed in the steady state simulations is more realistic in my view than the previous model, but the new models need re-calibrating (as discussed above) to enable reliance on actual values suggested by the model.
- 2.20 The overall implication of the steady state simulation tests undertaken with higher  $K_z$  values, is that the model is extremely sensitive to vertical hydraulic conductivity and this has had:
- (a) a marked impact on simulated leakage rates;
  - (b) no appreciable effect on the overall flux balance to the rivers when comparing relative responses within model scenarios (e.g. the four scenarios of the base case or the four scenarios of the  $K_z \times 100$  case);
- 2.21 However, localised (river reach) and seasonal impacts were not able to be assessed given the information available. As highlighted to above, this is an important consideration.



**Figure 2. Net inter-aquifer transfers** (only flow between aquifers, excludes external transfers).

### Transient Simulations

- 2.22 Under the transient simulations,  $S_y$  is increased from 0.01 to 0.1, which is still at the lower end of the range for clean gravel, but nevertheless more realistic than 0.01 for the majority of gravel deposits within the Canterbury plains, which typically display a sandy or silty matrix.
- 2.23 The impact of increasing  $S_y$  is a dampening in the oscillatory response of the model, which is as expected, and in fact serves to partially compensate for the impact on oscillatory response of increased  $K_z$ .
- 2.24 The key observations identified with increasing  $K_z$  in the transient model include:
- (a) The oscillatory response increases significantly as the system is regularly pulsed throughout the upper profiles with recharge waters from the land and rivers. This effect makes the calibration appear poor, but if streambed conductance were lowered, the model could be re-calibrated.
  - (b) The starting condition used for the run do not match the observed data, hence storage in the system is not consistent with the field. This can also easily be improved.
- 2.25 What is important when assessing the transient simulations is the simulated trend. If you ignore the vertical offset, the model response is actually quite good and could be improved with reduction in streambed conductance, as noted previously.

### 3. CONCLUSIONS

- 3.1 Both the steady state and transient simulations of the various models provide very clear and important insights into how the model performs with differing vertical permeability.
- 3.2 Key findings from the sensitivity testing include:
- (a) vertical leakage between layers increases significantly with increased  $K_z$ .

- (b) a high degree of non-uniqueness in the parameterisation of the Canterbury groundwater model is apparent. This simply means that if we are to have confidence in the model predictions (i.e. understand the envelope of the likely impacts), a range of equally calibrated models implementing plausible parameterisation sets needs to be tested. Within this, we need to understand if the parameters sets and hence resultant model predictions are located centrally in a probability distribution (i.e. the most likely combination).
  - (c) While encouraged by the transient model results, we cannot rely on the actual values generate by these models because of the fact that the model is not calibrated. We can rely on the relative responses between scenarios determined from the same models, but can not compare between models.
  - (d) While the modelling indicates that the system is likely to be leaky throughout the profile (with the  $K_z$  values employed), it is not possible to understand whether the likely impacts are significant. Additional information would be required to evaluate seasonal or localised impacts, and also to accept the absolute magnitude of fluxes and hence impacts predicted.
- 3.3 With respect to the understanding the impacts of increased  $K_z$ , my recommendation is that Aqualinc calibrate the  $K_z \times 10,000$  model by reducing streambed conductance, and if necessary to achieve an acceptable calibration, consider additional layer configurations within the shallow aquifer profile. Following this, the same scenarios should be re-evaluated with just the original calibrated model and the  $K_z \ 10,000$  re-calibrated model.

**JON WILLIAMSON**

**18 July 2009**

#### 4. REFERENCES

Aqualinc, 2009. Valetta and Ashburton River Groundwater Zone Hearing – response to Commissioners' RFI. Letter dated 11 June 2009.

## APPENDIX A – INTER AQUIFER NET FLUX DATA

<i>Calibrated model</i>				<i>No abs. scenario</i>				<i>Status quo scenario</i>				<i>Consents scenario</i>			
Net Inflows				Net Inflows				Net Inflows				Net Inflows			
	Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000
1	7.6	15.6	18.5	1	7.7	15.8	18.5	1	6.9	14.6	17.5	1	6.7	14.3	17.1
2	12.9	23.2	27.9	2	12.9	23	27.9	2	13.4	23.3	27.9	2	13.6	23.5	28.1
3-5	4.8	7.5	10.2	3-5	4.8	7.4	10.2	3-5	5.2	7.7	10.3	3-5	5.4	7.8	10.4
Net Outflows				Net Outflows				Net Outflows				Net Outflows			
	Cal	Kz x100	Kz x10000		Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000
1	8.3	13.2	15.2	1	8.2	13	15	1	9	13.7	15.7	1	9.3	14	16
2	12.4	23.1	28.7	2	12.5	23.2	28.7	2	12.1	22.3	27.8	2	12.1	22.1	27.5
3-5	4.6	10	12.7	3-5	4.7	10	12.7	3-5	4.4	9.6	12.2	3-5	4.3	9.5	12.1
Net Flux				Net Flux				Net Flux				Net Flux			
	Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000		Base	Kz x100	Kz x10000
1	-0.7	2.4	3.3	1	-0.5	2.8	3.5	1	-2.1	0.9	1.8	1	-2.6	0.3	1.1
2	0.5	0.1	-0.8	2	0.4	-0.2	-0.8	2	1.3	1	0.1	2	1.5	1.4	0.6
3-5	0.2	-2.5	-2.5	3-5	0.1	-2.6	-2.5	3-5	0.8	-1.9	-1.9	3-5	1.1	-1.7	-1.7