PATTLE DELAMORE PARTNERS LTD
Level 2, 134 Oxford Terrace
Christchurch Central, Christchurch 8011
PO Box 389, Christchurch 8140, New Zealand

Office +64 3 345 7100
Web www.pdp.co.nz
Auckland Tauranga Hamilton Wellington
Christchurch Invercargill

solutions for your environment

memorandum

TO	Paul Barrett	FROM	Neil Thomas
	Hawke's Bay Regional Council	DATE	21 July 2021
RE	Tranche 2 Groundwater Consents – Ruataniwha Basin		

1.0 Introduction

Pattle Delamore Partners Limited (PDP) has been engaged by Hawke's Bay Regional Council (HBRC) to assist with the technical review of a group of applications to take Tranche 2 groundwater from the Ruataniwha Basin. These applications propose to take deep groundwater (Tranche 2 Groundwater defined in the decision on Plan Change 6 for the HBRC Regional Plan) from bores in the Ruataniwha Basin. The decision defining Tranche 2 groundwater also specifies that the water can only be allocated if the consent holder also augments surface water flows with the intention to ensure that stream depletion effects that could arise as a result of groundwater abstraction are mitigated.

In 2013, as part of the Plan Change 6 hearing process, Aqualinc Research Limited (Aqualinc) developed a numerical groundwater model of the Ruataniwha Basin. The model has been updated and is now being used to investigate the effects of the proposed Tranche 2 abstractions, including abstraction for augmentation, and the modelled impacts of the abstraction on flows in the rivers that flow across and exit the basin are documented in a report prepared by Aqualinc (Weir, 2020).

PDP completed an initial high level review of the report in December 2020 (PDP, 2020) and raised several questions regarding the estimated impacts shown by the model. Aqualinc have completed further work to address these questions, which are documented in a memo from Aqualinc (Weir, March 2021). The purpose of this memo is to review that further work, and HBRC have requested that this memo specifically focusses on the following questions:

- Does the Aqualinc (Weir, 2021) memo address concerns/questions?
- Are there still areas of significant uncertainty?
- Is the model fit for purpose and accurate enough to rely on for making decisions on this proposal?

In addition, HBRC's groundwater modeller has completed a brief review of the Weir (2020) report and made the following comments:

- Simulated heads fail to represent long term trends at a number of wells.
- Simulated heads also fail to represent seasonal variation at a number of wells.
- Lack of information about pumping volumes over the simulation period and volumes for different stresses (recharge, pumping) and no transient water budget.
- Model files should be requested from Aqualinc.

HBRC have also asked that this memo comments on the significance of the concerns raised by the HBRC groundwater modeller. Some of these concerns may stem from incomplete information regarding the model and a brief summary of the model (as we understand it) is provided below.

The purpose of the modelling exercise is to assess the potential effect of the proposed Tranche 2 takes on surface water flows at specific sites and to estimate the effectiveness of the proposed surface water augmentation discharges. The modelling exercise has focussed on simulating flow records and estimating the effect on flows at the Waipawa at SH2 and Tukituki at Tapairu Road sites, although impacts on two low flow sites on the Tukipo River Stream one low flow site on the Mangaonuku Rivers have also been considered and effects on the Tukutuki River at Red Bridge low flow site have also now been assessed. We also note that the Weir (2020) report considers that the most appropriate application of the results of the modelling are to consider the likely changes in river flows and groundwater levels, rather than the absolute/exact values.

The model was originally developed for the Plan Change 6 hearings carried out in 2013, but has since been updated to reflect additional information regarding aquifer parameters described in PDP (2018). These updates included recalibration to allow for the new data regarding horizontal and vertical hydraulic conductivity. However, the model run period did not change and covers the period 1972 to 2012. The model streambed/riverbed conductances were also varied during this update, but while the updated maps of hydraulic conductivity and storage are provided in the Weir (2020) report, updated maps of streambed/riverbed conductance are not provided. This information would be helpful to understand how the update has affected the model parameterisation.

The model was calibrated to groundwater levels at various sites across the basin. Observed groundwater level time series across the basin reflect the effects of increasing rates of abstraction through time and several sites show a declining trend. Simulating this trend accurately would require reliable information on abstraction rates through time within the basin throughout the model period (1972 to 2012) which is not available, although water use data is available since 2012.

Given the difficultly in simulating the long term trends in groundwater levels, the modelling approach has been to use the model to generate a set of groundwater levels that represent the effects of no irrigation, which are calibrated to winter groundwater levels. Subsequently, the model was run with the current level of abstraction included and compared to recent observed groundwater levels (which include the effects of abstraction). The two simulations therefore present a range of groundwater levels and observed groundwater levels should generally fit within the simulated range. In general, this appears to be the case and the calibration to groundwater levels appears to be reasonable. However, the approach to calibration will inevitably result in uncertainties that would be reduced if the model were set up in such a way that trends could be successfully represented. If this were undertaken, which could be possible if the model was extended to cover more recent years, there would be increased certainty in the model predictions on groundwater levels.

The model was also calibrated to river flows at the Tukituki Tapairu Road site and the Waipawa at RDS SH2 site based on a time series of data between 1987 and 1990, which appears to indicate that the model adequately represents flows at these locations, although it is acknowledged that the modelled flow changes across the basin are small compared to the flow records, so the calibration would still appear reasonable for a range of parameter values. The Weir (2020) reports also presents a comparison between modelled and observed flows for the whole model run from 1972 to 2012, which, based on a visual assessment, again appear to show good agreement. The model was not calibrated to flows in other locations across the basin, nor were observed patterns of gains and losses included as part of the model calibration dataset.

In our opinion, the model is expected to be generally suitable for simulating the likely effects of abstraction on rivers flow at the Tukituki Tapairu Road site and at the Waipawa at RDS SH2 site, although as shown by recent parameter uncertainty simulations described further below, there is some uncertainty in the magnitude (and timing) of effects. Some further work is recommended to reduce model uncertainty, including comparison with measured losses and gains in flow in these rivers, and presentation of a transient water balance to illustrate the timing of effects. However, because the model was not calibrated to flows at other locations across the basin, predictions of effects at those locations are expected to carry a much wider degree of uncertainty. This is discussed further in the next section of the report.

The Weir (2021) memo covers the following areas raised in the PDP (2020) memo:

- Model uncertainty and new monitoring data
- Riverbed conductivities
- Model run period
- River flow calibration data
- River flows under model scenarios
- Climate change
- Cumulative depletion effects from year to year
- Effects on other river sites

The memo also includes some other general topics where little discussion or comment is required, or where agreement was generally reached between PDP and Aqualinc at the meeting held in January 2021.

2.0 Comments on Aqualinc 2021 memo

2.1 Model uncertainty and new monitoring data

2.1.1 Model uncertainty

In the initial PDP review (PDP, 2020) a question was raised regarding the potential for uncertainty in the predictions of changes in groundwater level and river flows made by the model where the Tranche 2 groundwater abstractions were included in the model. Although the model is calibrated, this uncertainty can arise where some parameter values are poorly constrained because their values do not affect simulated groundwater levels or river flows where measured data is available. As noted above, this can occur in areas where no calibration data is available.

To provide an indication of the extent to which the model suffers from this issue, the model was run with all the parameter values multiplied by a factor of 2 and again with values multiplied by a factor of 0.1. The difference in predicted changes in river flows are presented in the Weir (2021) memo.

Overall, the results of the modelling allowing for different values of parameters indicates the same pattern as the results using the calibrated model, that is that average flows at the Tukituki at Tapairu Rd and in the Waipawa at SH2 are expected to decrease as a result of increased abstraction but low flows are expected to increase as a result of augmentation discharges at times of low flows.

Whilst the modelling suggests that the direction of effects on flows at the main basin outlets (i.e., the Tukituki and Waipawa Rivers) would be similar regardless of the model parameters, there are some aspects where further information would be helpful:

- The results of the modelling indicate that the total change (i.e., reduction) in average flows is likely to be in the order of 198 L/s in the original model (at flow sites Waipawa at SH2 and Tukutuki Rd at Tapairu which capture the water exiting the basin). Although it is not specified in the memo, subsequent email correspondence with Aqualinc indicates that the irrigation pumping is around 241 L/s on average, which is more than the average reduction in flows, indicating other changes to the water balance occur. This compares to the allocated volumes sought based on 90th percentile demands (i.e., a higher demand than an average year) that are equivalent to 305 L/s (from Table 27 of the model report, where total irrigation pumping is 9,609,600 m^3/year). It is understood from that email correspondence that the average augmentation take is 83 L/s, which compares to the augmentation volumes sought based on 90th percentile demands that are equivalent to 163 L/s (from Table 27 of the model report, where total augmentation pumping is 5,145,700 m^3/year).
- It would helpful if a transient water balance were supplied to help understand how the model water balance adjusts to the impacts of pumping and the timing of this. It would be helpful for this to include the changes in land surface recharge with irrigation as well as the river flow changes. The transient flow balance should be supplied for the original model, as well as the models where the parameters are varied. The flow rate plotted at each site could be focussed on baseflows to help identify the impact on baseflows more clearly.
- The impacts on other streams simulated in the model appear more varied compared to the Waipawa and Tukituki flow sites (although they are related and it is therefore important that the effects on local streams are well understood). As noted above, the model is not calibrated to flows in these streams and therefore the parameters controlling changes in flows are less well constrained. Further information should be supplied regarding the patterns in gains and losses across the basin, and how these change due to variations in the parameter sets. These model patterns should also be compared to observed patterns.

With respect to quantifying the uncertainty in the model predictions, ideally, data would be presented that explicitly shows which parameters have the greatest impact on the predicted flow changes, and how the uncertainty in those parameter values results in a range of predicted flow changes. We disagree with the comment that predictive uncertainty quantification takes a long time to generate and requires large computing power; computing power can be cheaply hired via a wide range of commercial cloud services and linear uncertainty analysis is not particularly time consuming given the model was calibrated using PEST.

Despite this, given the sensitivity assessments that have been considered extensive uncertainty assessments may not be required to enable the model to be used specifically for the purpose of assessing flow changes at the Tukituki at Tapairu Road, Red Bridge and Waipawa at SH2 flows sites and augmentation requirements. This is because the model was calibrated to flows at these sites and the sensitivity analysis did not indicate substantial changes in the direction of effects. The model predictions of changes in flow at the Tukituki and Waipawa flow sites is also relatively small compared to total flows in the rivers (HBRC (2012) reports a MALF of 2,839 L/s for the Waipawa at SH2, 2,534 L/s for the Tukituki River at Tapairu Rd and 5,902 for the Tukituki River at Red Bridge). However, further information on the water balance is required before we can reach a position on making recommendations on further work required.

More detailed uncertainty assessments may be required to understand impacts on flows in other streams modelled within the basin. This is because the model is not calibrated to flows at these locations, or to the pattern of gains and losses in flows along the major rivers in the basin. If this indicates significant uncertainty and impacts on these streams are a significant portion of the changes in the Tukituki and Waipawa flow sites, further work to increase model certainty in those streams would also be required.

As noted above, it would also be helpful if a map or table were provided showing the difference between modelled streambed conductivities and the modelled underlying strata and how this changed as part of the model recalibration. This information would help to illustrate the sensitivity of the model to streambed/riverbed conductivities outside the global changes used in the sensitivity analysis above. As noted later in this memo, concurrent gauging data is available that would be expected to reduce uncertainty on streambed/riverbed conductance.

2.1.2 New monitoring data

Further monitoring data has been considered to help identify if the model represents recent low flows in rivers and lower groundwater levels. This data consists of extended datasets for monitoring bores that were used as part of the model calibration, as well as data from other bores, including ones that were installed and/or monitored since 2012. In addition, river flow data from additional sites (on the Tukipo River and Mangaonuku Stream) was considered that covers part of the model run period and extends beyond the model run.

Although the model run has not been extended to the present day, the extended data for the bores used as part of the model calibration appears to be generally consistent with the 'envelope' of groundwater levels. Data available for the new bores, or bores that were not originally considered as part of the calibration dataset is generally consistent with the modelled data and modelled levels are within a few metres of observed level, although there are some differences of up to 20 m. However, given that these data were not included in the original model calibration, these differences are not surprising. Overall, the results are generally consistent with the new data. We understand that the key purpose of the model is to predict general changes in groundwater levels in shallow strata and in river flows and in general, while further calibration would improve the model, we would not expect these differences to have a substantial impact on the prediction of general changes in shallow groundwater levels or river flows at the Tukituki and Waipawa flow sites (although substantial changes could occur in specific locations), although as indicated in this memo, further information is required to improve our confidence in the model predictions, including at the Tukituki and Waipawa flow sites. However, we do have concerns about the use of the model for assessing effects on smaller waterways and local bores within the basin. It is very important that localised assessment of effects on stream flow changes and groundwater levels for the abstractions proposed is also based on local aquifer parameters from pumping tests, groundwater level information and trends, rather than relying on a regional scale model. However, the regional model may be helpful for considering cumulative effects. The local stream depletion assessments should be compared to the regional model results to improve confidence in the model's predictive ability.

The extended datasets of river flows for the Tukituki and Waipawa Rivers appear to fit with the model flows well, as would be expected given the model was calibrated to flows in these two rivers and the modelled changes across the basin as small compared to river flows. The fit between the model flows and observed flows in the Tukipo and Mangaonuku River is less precise and low flows are overestimated in these watercourses, although as these datasets were not included in the original data used for model calibration, this difference is not surprising.

The memo notes that although there are differences between the modelled and observed flows in the Tukipo and Mangaonuku River, 'the use of the model to predict changes in low river flows is sound'. In general, that is likely to reasonable for the predictions of flows at the Tukituki and Waipawa flows sites (acknowledging the further work we have recommended to improve model confidence). However, as noted above, it is not calibrated to flows at other sites within the basin. For example, in the plots for the modelled and observed flows for Mangaonuku Stream upstream of the Waipawa confluence it is evident that the modelled flows never drop below a flow of around 1.5 m^3/s, whereas the observed flows drop to less than 1 m^3/s, albeit this a is synthesised flow record. The model does not appear to match the dynamic response of the river at this location. As a result, it is possible that model will underestimate the impact of abstraction on river flows at this point. However, it is noted that the forecast changes in average flows at this point are in the order of 50 L/s, compared to a MALF of 1,170 L/s (HBRC, 2012). We recommend that some further work should be required to improve confidence in the predictions. This should include comparison with the concurrent gauging information.

2.2 Riverbed conductivities

Further information on riverbed conductivities was requested to help identify whether the model reasonably reflects observed data for riverbed conductivities. Some information has been presented comparing observed river losses and gains along particular reaches of rivers where flow data is available to modelled losses and gains. Data was reportedly only available along the Tukipo between SH50 and Ashcott Road.

The comparison presented is uncertain because it does not account for tributaries between the two sites, however broadly the model appears to represent the observed flow change between the sites, although there appears to be tendency for the model to overestimate the difference in flows. However, we would not expect this to substantially affect modelled predictions due to the Tranche 2 groundwater abstractions.

In the absence of sufficient useful data, there is remaining uncertainty in the riverbed conductivity. This has been explored to a degree in the two sensitivity assessments described above. As outlined above, it would be helpful to further understand the contrast in riverbed hydraulic conductivity and the underlying strata.

HBRC have also confirmed that they do hold data on patterns of river flow losses and gains (from concurrent gauging surveys) along many of the streams and rivers within the basin. This information is available from times that overlap with the model run period and it would be very valuable to compare this with the modelled predictions of patterns of gains and losses, to improve confidence in the model's predictive ability, both for the main rivers as well as the smaller streams.

2.3 Model run period

Since the end of the model period (2012), some dry summers have occurred with long periods of lower flows in the rivers, and an increase in abstraction is also expected to have occurred. Additional information has now been provided regarding the extent to which low flow restrictions would be required based on recent data (i.e., post 2012) compared to the modelled period (1972 to 2012). This information helps to identify whether comments in the Weir (2020) report covering the effect of the Tranche 2 augmentation discharge on flows would apply based on more recent flow data. Tranche 2 augmentation discharges would occur when low flow thresholds are breached in specified rivers.

In general, the results of this assessment suggest that, while in some cases lower flows occurred in the record since 2012, there is no substantial difference in the flow records that would cause a significant difference in predicted effects due to abstraction. Therefore, the record against which the effect of the Tranche 2 abstractions are considered appears to be reasonable in this regard, although as noted in Weir (2021) there will be periods where there will be both insufficient water for irrigation and augmentation. This is an important consideration as in some years, the augmentation water will not be available (once the consented limit is reached) to mitigate stream depletion effects. In addition, it is understood that the full allocated Tranche 1 volume is not expected to have been utilised yet, so additional abstractive pressure is expected to occur even without the Tranche 2 abstractions.

2.4 Climate change

Some further consideration of the potential impacts of predicted climate change on recharge to the model, and therefore to the impact of the Tranche 2 consents is provided at a high level. In general, this shows that the rainfall is expected to reduce slightly, while temperature and evapotranspiration demand is expected to rise slightly. Low flows in streams and rivers are expected to reduce slightly.

Combined these predicted changes are expected to result in increased demand for irrigation water, together with increased times when augmentation water is required if flow rates drop below the trigger levels. However, the impacts of the proposed consents, as noted in the memo (Weir, 2021) may be limited because the consents are limited by annual volumes. However, there will be increased risks borne by the applicants and other irrigators in the area as their annual volumes may be insufficient. We note that there is also a greater risk of insufficient augmentation water being available.

2.5 Other considerations

There are a number of other considerations in the Weir (2021) memo including cumulative depletion from year to year, effects at the Red Bridge flow site and effects on other river sites.

Cumulative depletion effects would occur from year to year but based on the Weir (2021) memo, these are effectively included at the start of the model run where irrigation is included because the starting heads are based on a steady state run with abstraction. The steady state water balance presented indicates that the increase in abstraction of around 0.47 m^3/s is accounted for through:

- a decrease in groundwater discharge to surface water of around 0.2 m^3/s and
- an increase in surface water seepage to groundwater of around 0.2 m^3/s

Although the steady state water balance is helpful here, a transient water balance (as suggested by the HBRC groundwater modeller) would also be useful to show how effects vary through time, and how time lags in the system occur such that the impact of abstraction on river flows is delayed.

The memo briefly discusses the effects on flows at Red Bridge and consideration of the flows at that point indicates that effects would be small, with flow on only two days dropping below the 2023 low flow trigger (5,200 L/s) as a result of the change in flow upstream. We do note that the river frequently drops below that low flow limit so any decrease in flows will have an impact. It would be helpful if further information was supplied to show what the modelled changes are over time (for example if there is generally a positive change at low flows as with the other flow sites). A graph showing the modelled change over time would also be useful. Impacts of this flow site on the augmentation requirements should be considered and specific comments on whether sufficient water will be available to mitigate effects at that site provided.

It is understood that the contour maps of aquifer properties in Appendix C in Weir (2020) are being reproduced so that it is easier to interpret the scales. This would be helpful to illustrate that the properties are in line with PDP (2018) at the pilot points used, which we understand was the case from our discussions in the January 2021 meeting between PDP and Aqualinc and the information presented in Weir (2020).

2.6 Summary and conclusion

This memo intended to answer the following three questions:

- Does the Aqualinc (Weir, 2021) memo address concerns/questions?
- Are there still areas of significant uncertainty?
- Is the model fit for purpose and accurate enough to rely on for making decisions on this proposal?

In general, the memo provided does address many of the concerns and questions after the review of the draft model report, although there are a few areas where further consideration is required. As with any model, there are areas of uncertainty, however the main purpose of the model is to consider the impact of the Tranche 2 abstractions, including the augmentation flows, on river flows at specific flow sites. In effect, the question the model seeks an answer to is whether the proposed Tranche 2 takes will cause adverse effects on river flows at the low flow sites and whether this can be mitigated with augmentation.

In the Weir (2020) report the adverse effects are defined as impacts on the Waipawa at SH2 and Tukituki at Tapairu Road flow sites and the conclusion in the Weir (2020) report and the additional memo (Weir, 2021) is that adverse effects at the sites are not expected to occur as a result of the combined Tranche 2 abstractions and augmentation flows. We note the following:

- The model is calibrated to flows at the Waipawa at SH2 and Tukituki at Tapairu Road flows sites (although the modelled flow changes are not large across the basin);
- Comparison of the model to observed flows at the Waipawa at SH2 and Tukituki at Tapairu Road flows sites outside the calibration period indicates good agreement between simulated and observed flows (although a range in parameters can achieve this);
- The sensitivity analyses carried shows a consistent direction of effect at the Waipawa at SH2 and Tukituki at Tapairu Road flows sites (i.e., reduction in average flows and increases in low flows) despite relatively large changes in parameters.

However, the Tranche 2 takes will impact other streams and rivers across the basin. It is not clear that the model is suitable for forecasting effects on these other streams because:

- the model is not calibrated to flows in smaller streams and rivers, which include low flow sites for example on the Tukipo River.
- the model was not calibrated to observed patterns of gains and losses from the rivers and streams within the basin (including the Waipawa and Tukituki).

For these reasons, further work is required to improve confidence in the model predictions, including at the Waipawa at SH2 and Tukituki at Tapairu Road.

At present, the further information that is required to help understand the potential effects of the Tranche 2 abstractions includes the following:

- A transient water balance to help understand how the model water balance adjusts to the impacts of pumping. The transient flow balance should be supplied for the original model, as well as the models where the parameters are varied.
- The flow rate at each site could be focussed on low flows to better understand the differences between the modelled and observed low flow at each site.
- Further information should be supplied regarding the patterns in gains and losses across the basin, and how these change due to variations in the parameter sets. These model patterns should also be compared to observed patterns.
- Information on how the streambed/riverbed conductances vary across the basin and how these were changed as a result of model updates and recalibration in 2020.
- Information on how streambed/riverbed conductances compare to the hydraulic conductivity of the modelled strata immediately underlying the stream.
- Clear maps to show the parameter values.

- Further information on the Red Bridge flow site regarding impacts and augmentation requirements.

Aside from this model information, additional information will also be required for localised assessments, based on site-specific aquifer parameters.

3.0 References

HBRC. 2012. Hydrology of the Tukituki Catchment. Flow metrics for 17 sub-catchments. September 2012.

PDP. 2018. Ruataniwha Aquifer Properties Analysis and Mapping. Prepared for Hawke's Bay Regional Council. 14 December 2018.

Weir, J. 2020. Ruataniwha Basin: Tranche 2 Groundwater Modelling. 28 October 2020.

Weir, J. 2021. Ruataniwha Tranche 2 Groundwater Modelling – Response to PDP's Preliminary Comments. 29 March 2021.

Weir, J. 2013. Statement of Evidence of Julian James Weir for Ruataniwha Water Users Group (Groundwater Modelling). Expert evidence presented before a Board of Inquiry for the proposed Tukituki Catchment Plan Change 6. 7 October 2013.

4.0 Limitations

This memorandum has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Hawke's Bay Regional Council and others (not directly contracted by PDP for the work), including Aqualinc Research Limited. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the memorandum. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This memorandum has been prepared by PDP on the specific instructions of Hawke's Bay Regional Council for the limited purposes described in the memorandum. PDP accepts no liability if the memorandum is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Prepared by

Neil Thomas
Groundwater Service Leader

Reviewed and approved by

Hilary Lough
Technical Director – Water Resources