Development of a groundwater model for the Ti Tree Basin

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Using The Finite Element Modeling Package FEFLOW®

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USING THE FINITE ELEMENT MODELING PACKAGE FEFLOW®

INTRODUCTION

The Land and Water Division of the Department of Natural Resources, Environment and the Arts are responsible for monitoring and assessing the water resources of the Ti Tree Basin. The Water Resources Strategy allocates 80% of the good quality water to horticultural enterprises (NTDIPE, 2002).

The model described in this report will address the issues raised in the annual assessment of the performance of the Ti Tree Basin where it was identified that the output from the 2001 Water Studies model (Water Studies, 2001) underestimates the effects of pumping on groundwater levels compared to the observed groundwater level response in the Ti Tree Farms area (TTF). The underestimate in groundwater level response was evident even though actual extraction figures were lower than that used in the predictive modelling scenarios (~1400 ML/yr actual compared with 2000 ML/yr).

Currently groundwater extraction entitlements total just over 5 GL/yr, it is expected that future development in the Ti Tree region could increase this to 10 GL/yr. Groundwater modeling will be utilised to provide an assessment of the impacts on groundwater levels due to current and future development in the Ti Tree Basin.

CONCEPTUAL HYDROGEOLOGY

The main aquifer units of the Ti Tree Basin are in undifferentiated Tertiary and Quaternary sandstones. Drilling and test pumping data shows a 40 metre thick aquifer contributes 95% of the conductivity over the saturated depth. The sandstones are generally underlain by low permeability siltstones and overlain by a layer of lower hydraulic conductivity.

Groundwater flows from east to west and from south to north. Groundwater recharge mounds are present under the Woodforde River and the Allungra Creek floodout. Examination of basin wide water levels also indicate mounding in the south east of the groundwater basin.

The water table gets shallower to the north and the Stirling Swamp is a natural discharge zone for the basin. There is also evidence to suggest that vegetation can also access water in areas where the water table comes within 10 metres of the ground surface.

Water was discharged from the model by evapotranspiration and throughflow to the north. During transient simulations water as also extracted via production bores at the Ti Tree Farms area (TTF), Table Grape Growers of Australia (TGGA), Pmara Jutunta and at Oolloo.

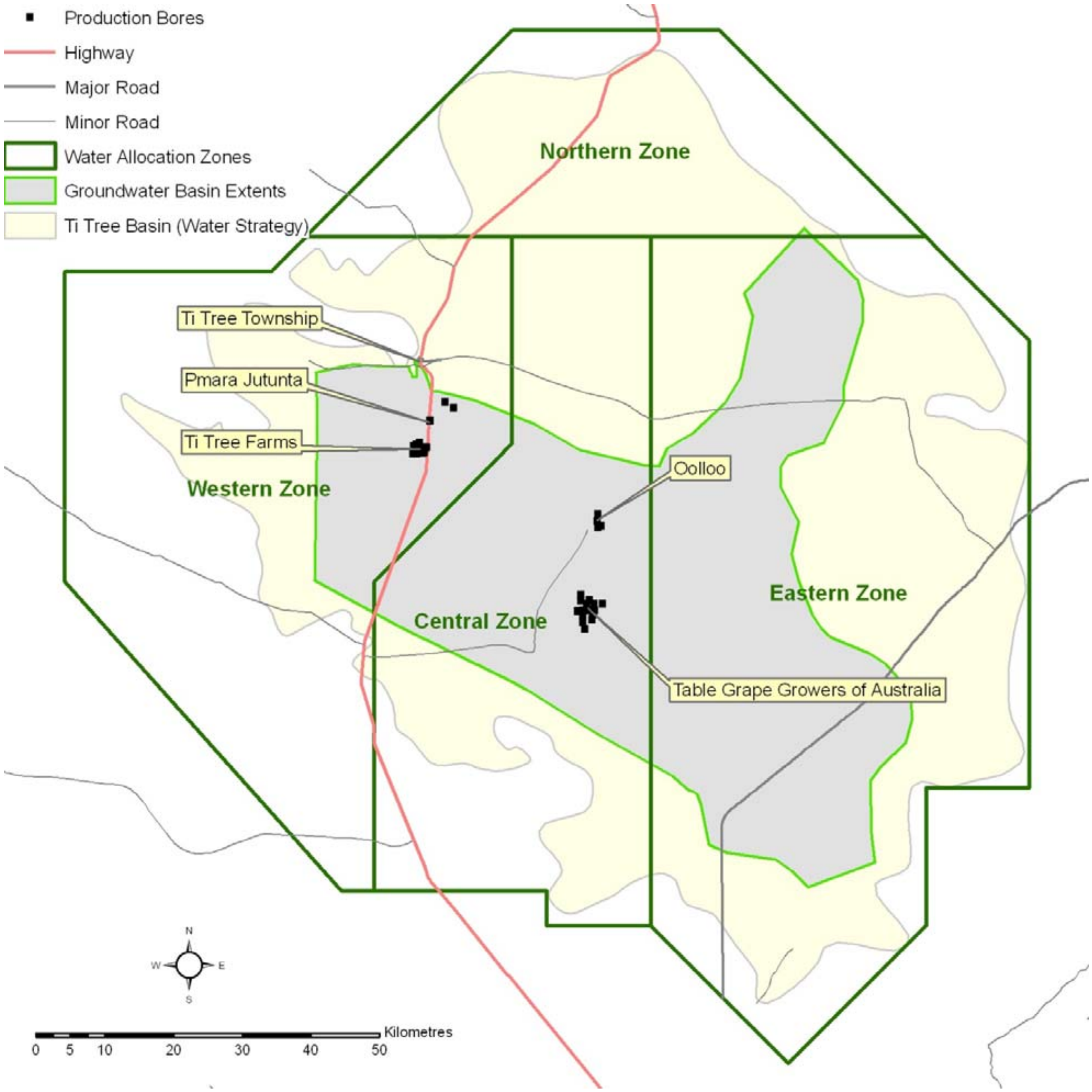

Figure 1 **The extent of the Ti Tree basin (NTDIPE, 2002) and the extent of the groundwater flow model which is based on hydrogeological mapping (Read, et al., 2007).**

GROUNDWATER FLOW MODEL

Development of the finite element groundwater flow model followed the following steps:

- Recreation of the Water Studies finite difference model using finite element method to demonstrate that the results from the finite element method were comparable to the Modflow results;
- Validation of hydraulic parameters against observed pumping and groundwater level data;
- Revision of the extent of the Ti Tree groundwater basin, which provided inclusion of the Eastern Allocation Zone based on recent hydrogeological mapping (Read & Tickell, 2007);
- Calibration of steady state and transient models based on available monitoring data;
- Predictive simulation based on current allocations;
- Predictive simulations based on anticipated future allocations.

MODEL CALIBRATION

Steady State Calibration

The initial values of hydraulic conductivity, specific yield and specific storage were adopted from the Water Studies model (Water Studies, 2001). During the steady state calibration process the validity of incorporating pumping data in the steady state calibration was assessed. It was found that it was inappropriate to include pumping in the steady state calibration as the basin had not reached a state of equilibrium. This resulted in a reduction of the estimate in basin recharge by 60% from approximately 10,000 ML/yr to approximately 4,400 ML/yr. During the transient calibration process (see below) it was found that the hydraulic conductivity of the main aquifer required a similar reduction from 7 m/d to 5 m/d. This resulted in a further reduction of the steady state recharge.

Figure 2 a) presents the steady state calibrated heads and b) a comparison between observed heads and predicted heads for the steady state model. The envelope centred on the 1:1 fit indicates the expected errors due to estimated bore elevations derived from satellite data.

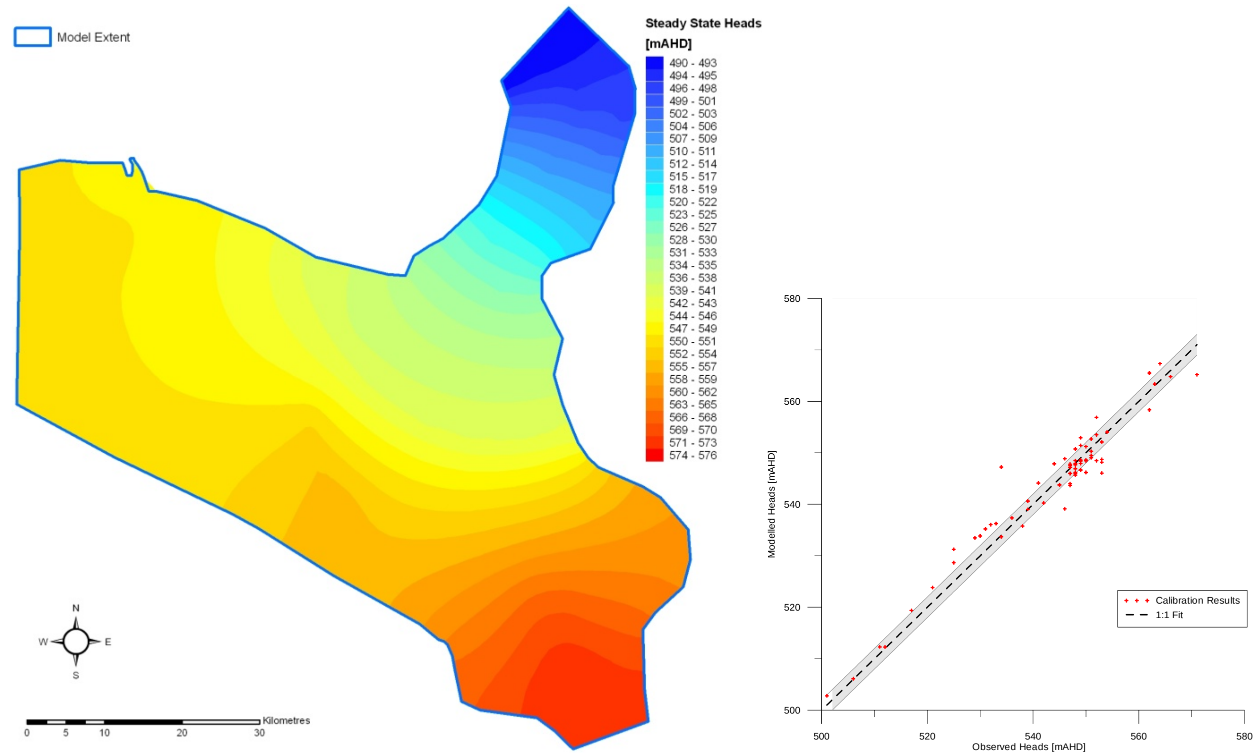

Figure 2 Steady state calibrated heads. The envelope along the 1:1 fit identifies the expected error in measured observations.

Steady State Water Balance

The resulting steady state water budget is presented below in **Table 1**.

Table 1 Steady state water budget for the calibrated finite element model

Component	Recharge	Discharge		Error
		Throughflow	Evapotranspiration	
	[ML/yr]	[ML/yr]	[ML/yr]	
Allungra Creek	1850			
Woodforde River	450			
Other	2130			
Total	**4430**	**1810**	**2620**	**0**

The volume of groundwater stored within the Ti Tree Basin is approximately 1000 times greater than the estimated annual recharge / discharge volumes. Surfer® calculations, using the saturated thickness of the aquifer and assuming a specific yield of 0.04, estimate the stored groundwater volume at 4850 GL (Read, pers comm.) this includes all water quality. This value is likely to be an underestimate as drilling data suggest that the specific yield will increase with depth owing to the increasing coarseness of the sediments in the main aquifer with depth.

Transient Calibration

Transient or time varying calibration of the model was undertaken for the period 1954 to 2007. Recharge estimates to the basin were based on the Water Studies modeling, however, some modifications were required to provide closer agreement with groundwater levels in the TGGA area adjacent to the Alungra Creek floodout. Historic pumping records based on monthly readings of each production bore within the water control district as provided by the licensee were used in the calibration process. Typically data were available from 1995 to present, however, as identified by Water Studies extraction started prior to 1995 (Water Studies, 2001) and an assessment of likely pumping rates pre-1995 was undertaken by matching modeled results with available hydrographs in the vicinity of the respective borefields. Examples of the pumping schedule used in TTF and TGGA are presented in **Figure 3**.

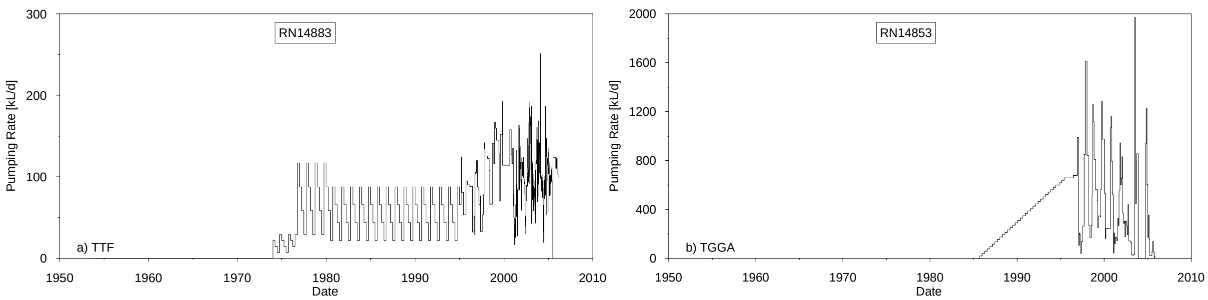

Figure 3 Examples of historic pumping schedules for a) Ti Tree Farms and b) Table Grape Growers of Australia

During the transient calibration it was identified that in order to reproduce the observed groundwater levels that the initial hydraulic conductivity of 7 m/d and specific yield of 0.07 were too high. In a trial and error approach these initial values were reduced until closer agreement between modeled and observed groundwater levels were obtained. A hydraulic conductivity of 5 m/d and a specific yield value of 0.04 were used in the final model.

Comparison of the observed and modeled hydrographs in the TTF area and the TGGA area are presented in the following sections.

Ti Tree Farms

The results from the modeling in the vicinity of Ti Tree Farms are presented in the following hydrograph plots. RN005507 is located approximately 3 kilometres from the TTF borefield and RN005724 is located within the TTF borefield.

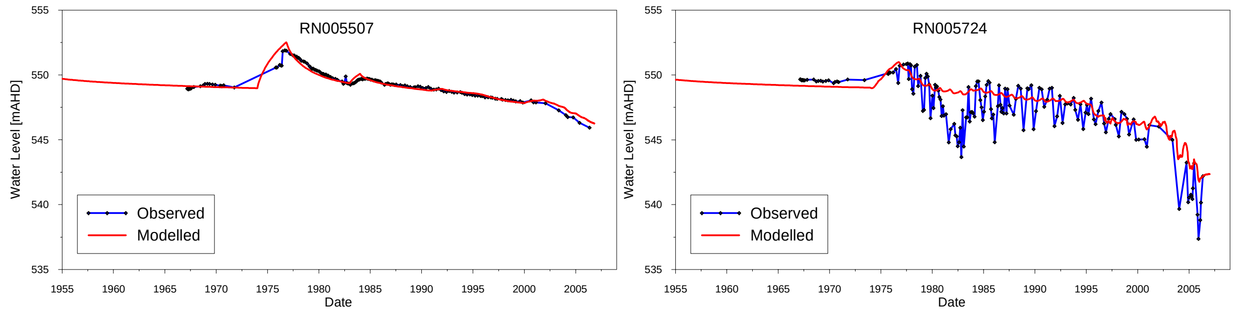

Figure 4 Comparison of the predicted and observed groundwater levels in the vicinity of the Ti Tree Farms borfield.

Territory Grape Growers of Australia

The results from the modeling in the vicinity of Table Grape Growers of Australia are presented in the following hydrograph plots. RN013926 is located approximately 10 kilometres from the TGGA borefield and RN014191 is located within the TGGA borefield.

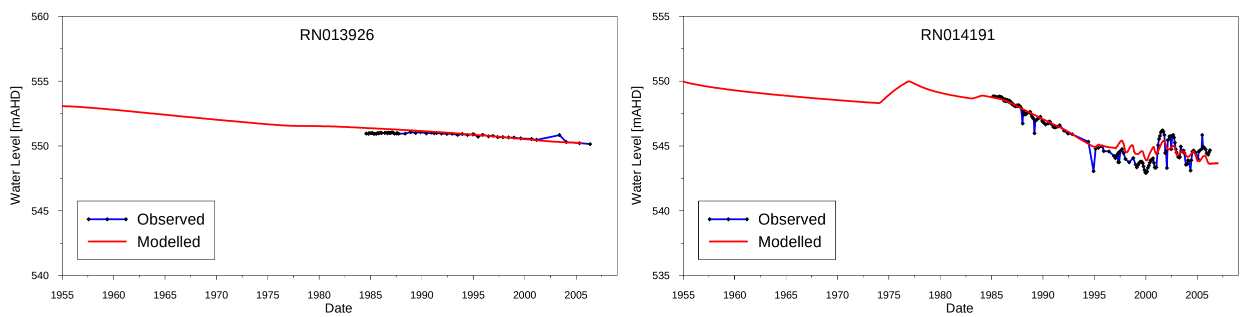

Figure 5 Comparison of the predicted and observed groundwater levels in the vicinity of the Table Grape Growers of Australia borefield.

PREDICTIVE SIMULATIONS

The future effects of the current pumping regime on the groundwater levels in the Ti Tree Basin were investigated by extending the simulation time of the model for a further 50 years. Two scenarios have been investigated one involving the current borefields and another incorporating bores in areas where development is anticipated to occur in the future. To improve the response in these additional areas the model mesh was modified to provide greater refinement in the vicinity of these borefields. The layout of the model is presented in **Figure 6** the modified mesh, and the locations of the current and anticipated future borefields are identified.

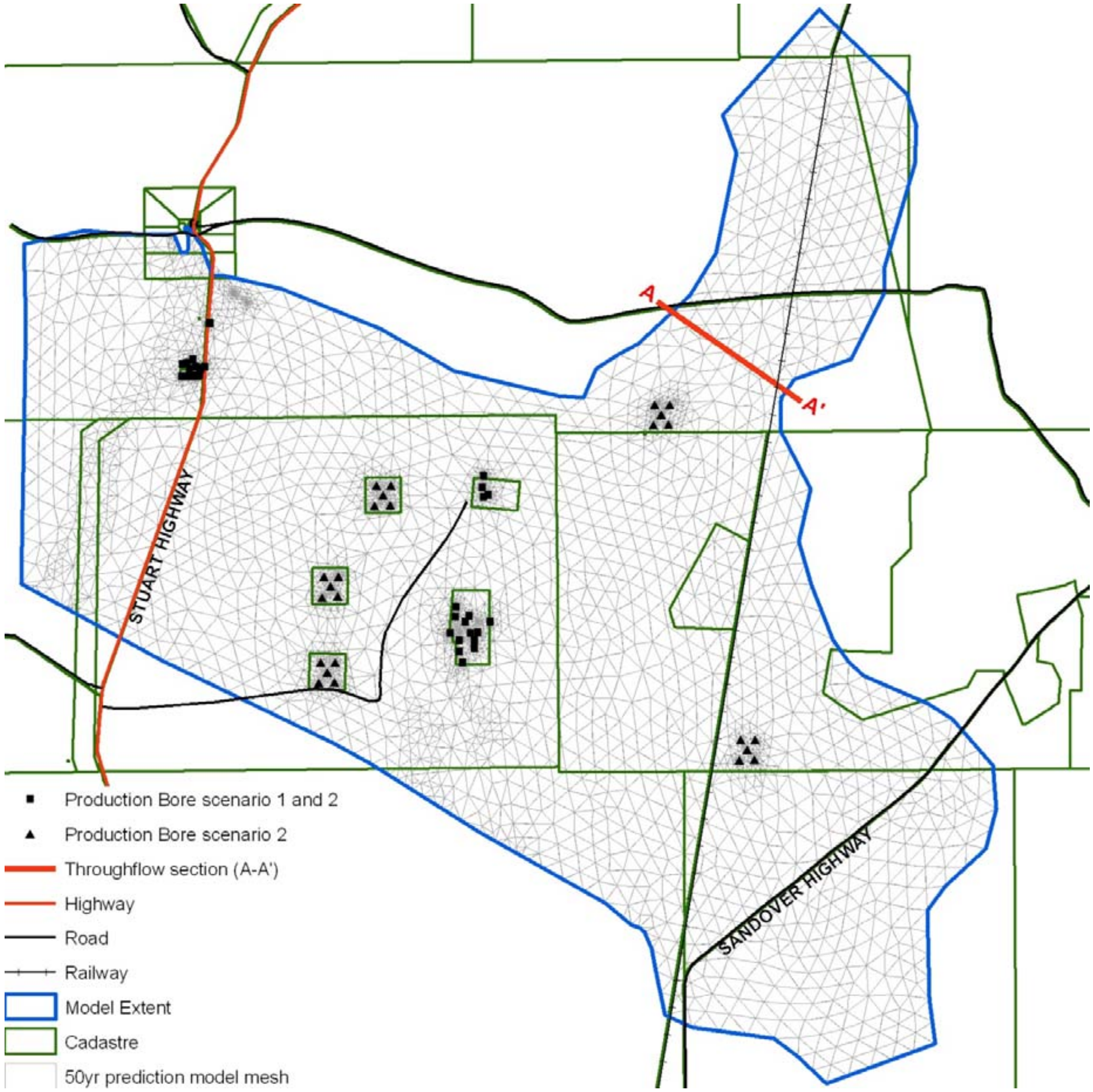

Figure 6 Geometry of finite element mesh with locations of the borefields for future horticultural regions. A-A' indicates the location of the section used to determine variations with throughflow.

Scenario 1

Scenario 1 incorporates the *current pumping entitlements* and *no recharge* to the groundwater basin. The annual pumping regime for each of the bores followed that proposed by Water Studies ie 0.1, 0.4, 0.3 and 0.2 of the total extraction for each quarter of the water year (Water Studies, 2001). The results from modeling Scenario 1 are presented below as water levels for TTF and TGGA.

Scenario 2

A second scenario investigated the inclusion of extraction due to the anticipated future pumping in currently undeveloped areas in the Central and Eastern zones of the basin. It was assumed that each property had an allocation of 1000 ML/yr and employed 5 production bores to extract the groundwater using a similar annual pumping regime applied in the previous scenario.

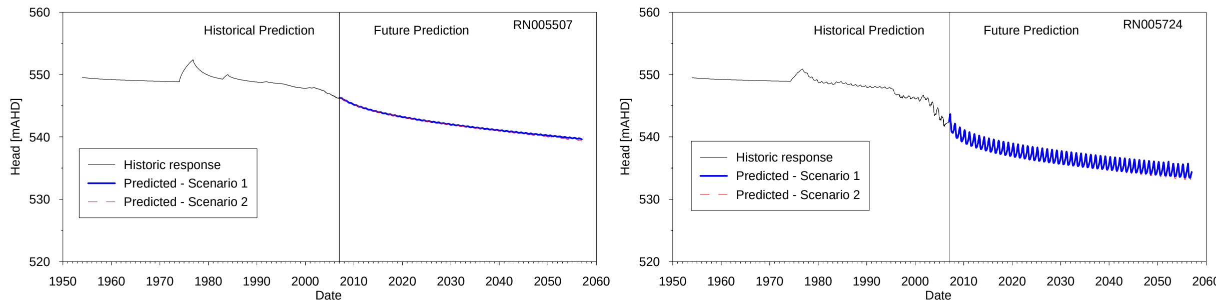

Figure 7 **Predicted water level in response to pumping at TTF a) RN5507 and b) RN5724**

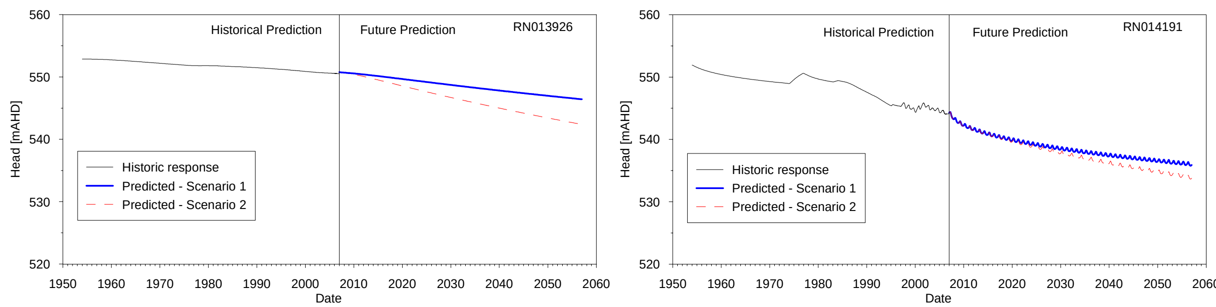

Figure 8 **Predicted water levels in response to pumping at TGGA a) RN13926 and b) RN14191.**

Effects on Groundwater Dependent Ecosystems

A reduction in the supply, quality, volume, timing or location of available groundwater can have adverse effects on the health, growth or maintenance of groundwater dependent ecosystems (GDE's) within the landscape (Eamus, et al., 2006). Based on the results from the two scenarios the impact on water levels and annual throughflow, parameters which could affect groundwater dependent ecosystems, can be assessed. **Figure 9** presents the effects of the current pumping regime on a) throughflow and b) groundwater levels in the area identified as being likely to be groundwater dependent (section A-A′ on **Figure 6**).

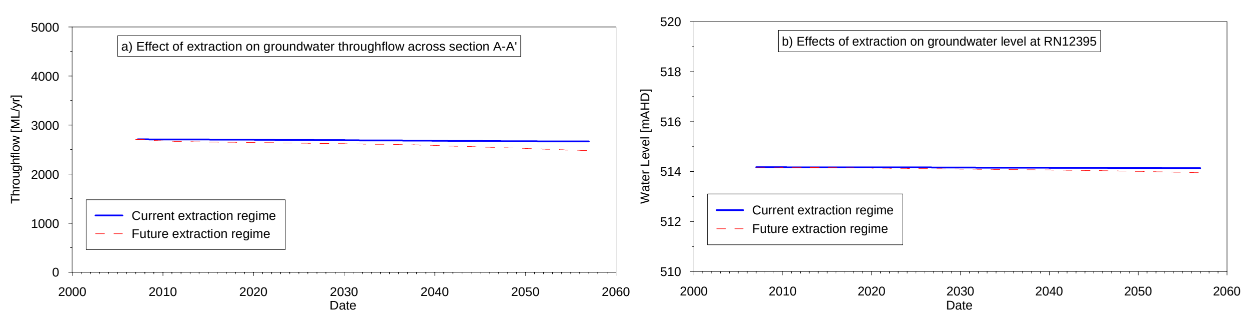

Figure 9 **predicted effects of extraction scenarios on a) throughflow to the north and b) water levels at RN12395.**

It is apparent that the current pumping regime (Scenario 1) will have little impact on the areas where GDE's are thought to exist over the next 50 years. This is primarily related to the distance between the borefields and the location of probable GDE's. The second scenario, however, does show some impacts with slightly less than a 10% decrease in throughflow to the north (**Table 2**), and a reduction in the water level in the area by less than 1 metre. The observed effects are due to the proximity of the northern most borfield used in the second scenario (**Figure 6**). Given the relatively slow changes in both groundwater flux and water levels it is expected that plants reliant on this resource will be able to adapt, however, to reduce these effects it is suggested that development is restricted to the south in the main portion of the Ti Tree basin.

Table 2 Summary of impact on water levels and throughflow

Date	Throughflow [ML/yr]	Change	Throughflow [ML/yr]	Change
2007	2710		2710	
2057	2670		2480	
Difference	**40**	**1%**	**230**	**8%**

DISCUSSION AND CONCLUSIONS

The finite element groundwater model developed by the DNRETA addresses limitations of previous modeling and provides a platform to build upon as future improvements on the understanding of the groundwater resources of the Ti Tree Basin emerge.

Calibration of the finite element groundwater model has resulted in a reassessment of steady state recharge to the groundwater basin. The previous estimate of 10,000 ML/yr has been reduced to 4400 ML/yr approximately 40% of the initial value.

Discrepancies between the recent observed groundwater levels and those predicted from previous modeling has identified that the values used for hydraulic conductivity and specific yield were overestimated. Transient calibration of the recent finite element model has resulted in a revision of the hydraulic conductivity and specific yield to 5 m/d and 0.04 respectively.

The current pumping regime will have little effect on the areas where groundwater dependence of ecosystems is thought to occur. This is due to the very large distances between borefields and the GDE's and also due to the large volumes of groundwater in storage ~4850 GL compared with the current annual extraction rate of 5 GL and the likely future extraction of 10 GL.

It is unlikely that future development in the region will have adverse effects on GDE's provided they are kept within the Western, Central and southern portion of the Eastern Allocation Zone.

The effects of interference between the current borefields are likely to be minimal and it is recommended that future bores be constructed with the top of the screened interval at or deeper than the top of the more productive aquifer zone (approximately 520 mAHD).

The major issue that will be faced by the stakeholders is the long term performance of the borefields. It was identified in previous reporting (Knapton, Ti Tree Health of the Basin 2004/05, 2005; Knapton, Review of the Ti Tree Groundwater Level Monitoring Network, 2006; Knapton, Ti Tree Health of the Basin 2005/06, 2006) that available drawdown will become an issue in bores where the groundwater level in the borefields approaches the screened interval of the production bores.

The time varying nature of historical recharge in the Western portion of the groundwater basin are relatively well quantified, however, limitations exist with respect to the quantification of the transient recharge processes in the Eastern Zone of the groundwater basin. Although not an immediate issue, a more satisfactory characterization of recharge should be determined to provide water balance estimates. A more robust method of determining the location and volume of recharge across the basin is required given that the current method is based on trial and error. Catchment yield / rainfall / runoff analysis may provide a more satisfactory result.

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