WATER CORPORATION

Gnangara Groundwater Dependent Ecosystems (GDE) Risk Assessment

Estimating the risk state of GDEs on Gnangara Mound using the Froend et al[1] risk methodology

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Draft 1.0	21 July 2007	Initial release for comment
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Draft 1.2	25 October 2007	After discussions with Ray Froend
Final 2.0	18 February 2008	Final release version

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1 SUMMARY OF RESULTS

This document is an analysis of the risks of adverse environmental impact on groundwater dependent ecosystems (GDEs) such as wetlands and phreatophytic vegetation on Gnangara Mound identified by Froend et al[1]. A number of abstraction scenarios for public water supply have been used in the assessment methodology proposed by Froend. This analysis shows that different Water Corporation abstraction scenarios have virtually no impact to the risk categories of the GDEs at 2013.

The results show **no change** to the risk category of individual GDEs using three different public water supply abstraction scenarios, 105GL p/a, 135GL p/a and 165 GL p/a. It shows that reducing groundwater allocation for public water supply will not necessarily provide any additional environmental benefit to GDEs. A comparison with the risk categories reported by Froend et al[1] using a different 135GL p/a scenario shows slight differences but these are attributable to an earlier version of PRAMS being used in their 2004 study.

PRAMS groundwater modelling was used to determine the net change in water level from 2003 to 2013 and the rate of this change. These values are then used in the risk analysis model developed by Froend et al[1] to determine the future risk category of the GDEs.

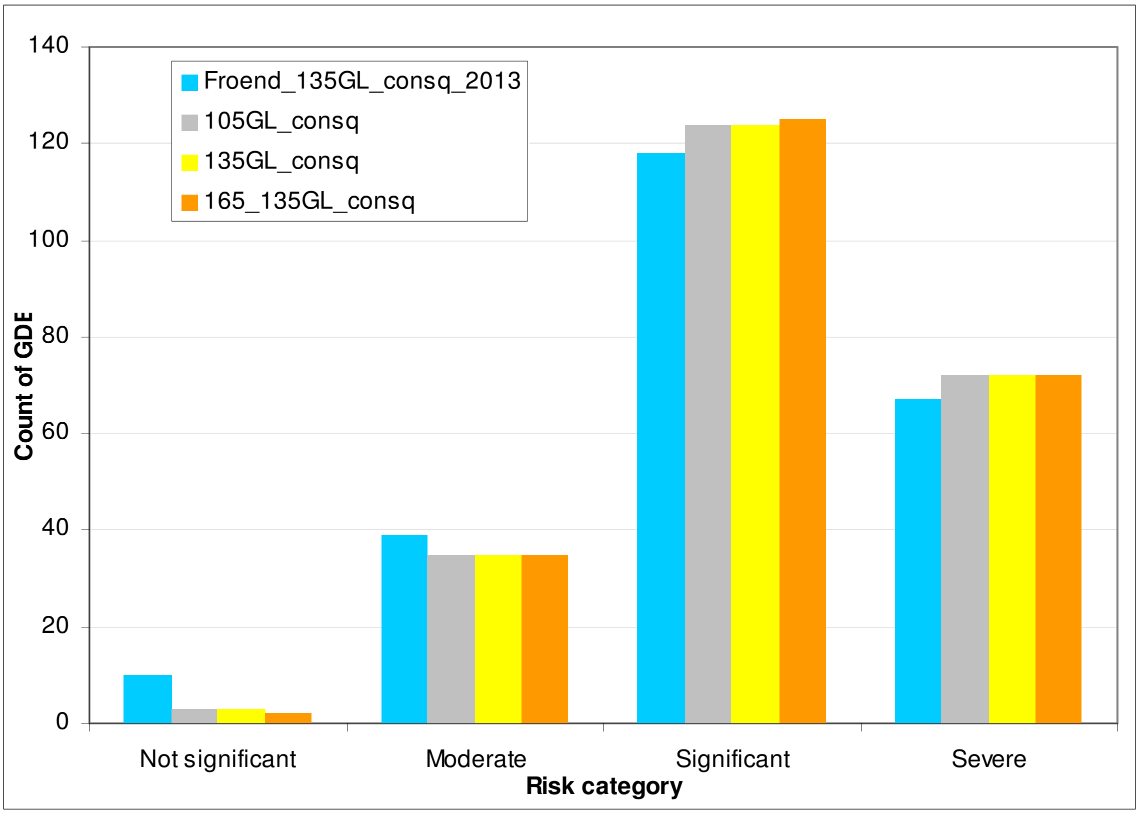

Figure 1: Variation in GDE 2013 risk categories using different Water Corporation abstraction scenarios

This lack of variation in risk categories under these scenarios is a result of the extra volume being taken from the confined aquifers rather than the superficial aquifer. Water level changes between scenarios are minimised even though the scenario abstraction volumes are significantly different.

The following diagram shows abstraction volumes and aquifer breakdown.

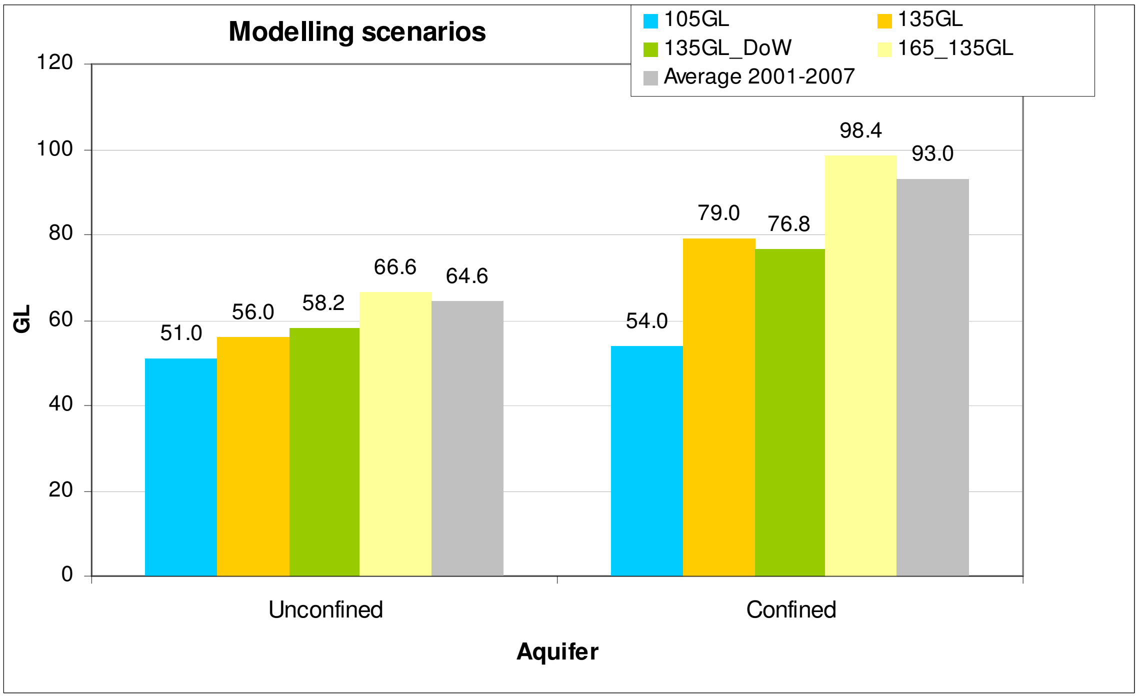

Figure 2: Comparison of historic (2001-2007) abstraction and scenarios by aquifers

1.1 COMMENTS ON PRAMS ACCURACY

This analysis uses the relative changes in water levels provided by the PRAMS modelling. Using the differences minimise any errors inherent in the PRAMS models. The analysis doesn't attempt to use any absolute water level.

It should also be noted that the accuracy of these results is limited by the accuracy of the PRAMS modelling with respect to the superficial aquifer-wetland interface. These results can be checked and refined when a higher resolution groundwater model becomes available which represents this interface more accurately.

2 PURPOSE

This analysis describes the work carried out to estimate the risk state of GDEs on Gnangara using the Froend et al.[1] risk methodology together with PRAMS scenarios from March 2005 for forecast minimum water levels in 2013. It details the likely implications of WC abstraction from 2003 to 2013 on the risk to key GDEs on Gnangara Mound. This is important because the next major source will not be available until 2011 (4 years) and it is likely that abstraction from Gnangara will continue at relatively high levels until at least then. The imperative for this work is that the DoW draft interim water plan due at the end of 2007 is likely to have revised EWR and allocations for public water supply. Any reduction in groundwater allocation to public water supply could have serious implications to the security of the IWSS. This analysis attempts to quantify the additional environmental impacts that can be attributed to increased public water supply abstraction.

The aim of the work is to adopt the risk assessment of Froend et al. [1] in 2004 to assess the changes in risk to GDEs as a result of the March 2005 Corporation abstraction scenarios. For example, for how many and which GDEs would the risk forecast be lower in 2013 for the 105 GL/yr scenario compared with the 135 GL/yr scenario and the 165_135 GL/yr scenario?

3 BACKGROUND

3.1 PREVIOUS FROEND WORK (SEPT 2004)

In September 2004 Froend et al.[1] produced a Task 2 report for DoE (now DoW) which assessed the state or condition of GDEs at 2003 and forecast likely state at 2013 as a result of changes in groundwater levels. The purpose of this assessment was to provide expert guidance to DoW and other regulators in the review of statutory water level criteria on Gnangara and for the revision of licensed groundwater allocations under Section 46 of the EP Act.

Froend et al.[1] describes the overall approach (a summary of this approach is provided in Appendix 1) to determining the risk to GDEs as follows:

> "In Section 3 comment is made on the likely response to water level changes predicted over 2, 5 and 10 year intervals (2003-05, 2003-08 and 2003-13) modelled under PRAMS 3.0. To achieve this, a GDE's susceptibility to groundwater decline is determined using a matrix of conservation values, current ecological condition, historic water level decline and current depth to groundwater. Groundwater dependence and drawdown impacts are largely based on vegetation. Limits of acceptable change are described for each type of GDE (wetland, terrestrial vegetation etc.) and comment made on the current standing of each GDE."

It should be noted that the PRAMS scenario used was based on public water supply abstraction of 135GL p/a and this scenario is *different* to that developed by the Corporation in its March 2005 modelling. A comparison of the abstraction scenarios is shown in Figure 2.

3.2 GDE RISK ASSESSMENT

The risks to the identified GDEs were summarised in Table 9[1] of the report as levels of possible impact categorised as: not significant, moderate, significant or severe for the periods 2003-05, 2003-08 and 2003-13.

The frequency of occurrence of forecast risk at **2005** for 243 of the GDEs listed in Table 9 of the Froend report are classified by the conservation category (see Table 1 in Appendix 1) in Table 1 below.

Cons value	N/A	Not sig.	Moderate	Significant	Severe	Total
1	1	5	25	48	39	118
2		6	17	57	28	108
3		2		10	1	13
4				4		4
Total	1	13	42	119	68	243

Table 1: Frequency of GDE risks by conservation value 2003 to 2013 from Froend et al[1] report

Note: A **lower** conservation value *number* implies a more significant GDE with little evidence of degradation or alteration.

The purpose of this study is to determine the changes to the forecast risk as a consequence of the different Water Corporation abstraction strategies as modelled using PRAMS.

4 WATER CORPORATION ABSTRACTION

This chart shows the changes in WC groundwater abstraction since the mid 1970s, particularly the increases since 1996-1997. Note that since the mid 1990's use of the confined aquifers has increased whilst use of the superficial aquifer in environmentally sensitive areas has generally reduced.

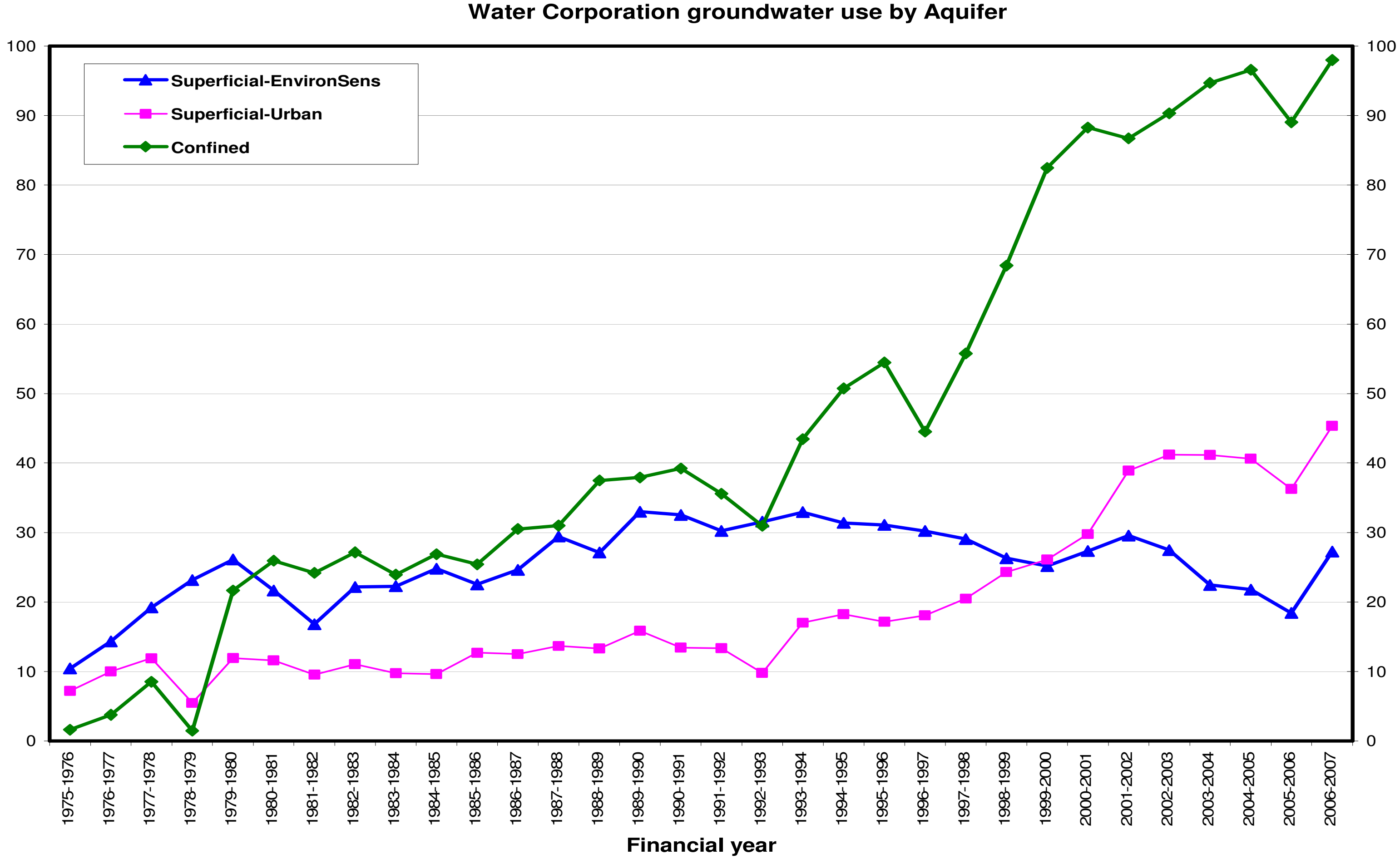

Figure 3: Water Corporation abstraction history

4.1 PRAMS ABSTRACTION SCENARIOS

The PRAMS modelling was carried out in March 2005 with the following abstraction scenarios:

Year	Scenario 1: 105GL	Scenario 2: 135GL	Scenario 3: 165/135GL
2003-2004	actual WC production	actual WC production	actual WC production
2004-2005 to 2008-2009	105GL	135GL	165GL
2009-2010 to 2012-2013	105GL	135GL	135GL

Table 2: Abstraction scenarios used in PRAMS modelling

The increase in abstraction between scenarios was mainly in the extra use of the confined aquifers. *At the time of modelling* groundwater use was expected to remain high until a major new water source began production in 2009. Note that the 165GL scenario reverts back to 135GL p/a after 5 years in 2009-10. The charts below also compare these scenarios against the average actual groundwater use for the period 2001-2007.

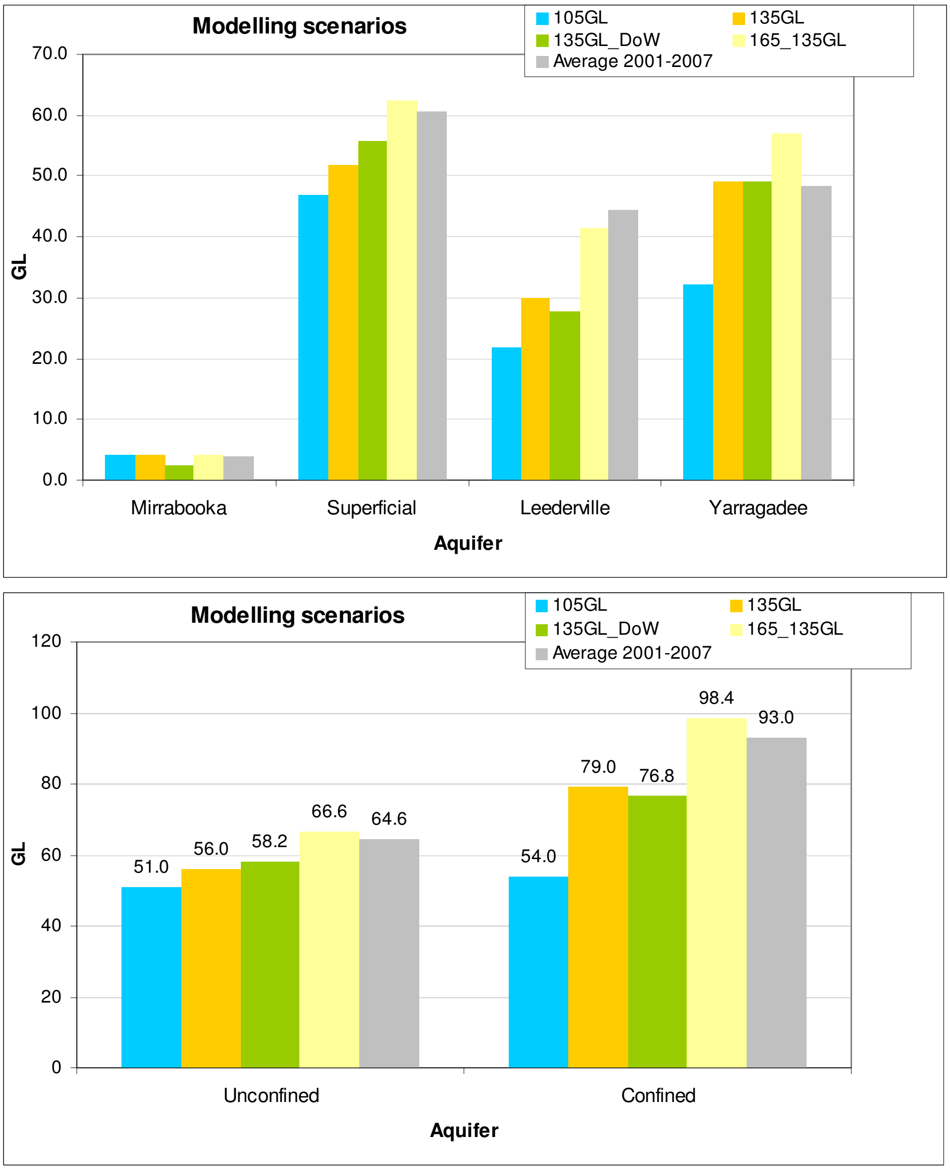

Figure 4: Comparison of historic (2001-2007) abstraction and scenarios by aquifers

5 GDE RISK ASSESSMENT

The risks to the identified GDEs were summarised in Table 9[1] of the report as levels of possible impact categorised as: not significant, moderate, significant or severe for the periods 2003-05, 2003-08 and 2003-13.

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Table 3: Frequency of GDE risks by conservation value 2003 to 2013 from Froend et al[1] report

Note: A **lower** conservation value *number* implies a more significant GDE with little evidence of degradation or alteration.

The purpose of this study is to determine what the changes are to the forecast risk as a consequence of the PRAMS modelled Water Corporation abstraction strategies.

6 WATER CORPORATION APPROACH TO ESTIMATING RISK

The Water Corporation investigated several climate and abstraction scenarios in March 2005 which produce water levels to the end of 2014.

The aim of this work is to adopt the risk assessment of Froend et al in 2004 to assess the changes in risk to GDEs as a result of the March 2005 Corporation abstraction scenarios. For example, for how many and which GDEs would the risk forecast be lower in 2013 for the 105 GL/yr scenario compared with the 135 GL/yr scenario and the 165_135 GL/yr scenario?

Table 9 of Froend et al[1] contains a large number of GDEs, grouped by “Sub-group/GDE”. Not all of the listed GDEs have risk assessments and these can be ignored. A priority is all of the current statutory criteria sites for Gnangara (i.e. ignore Jandakot). The Gnangara wetlands and phreatophytic vegetation categories are the focus, not the caves and other types.

6.1 FREQUENCY OF GDE RISKS (FOR 234 GDES)

The following tables summarise the GDE risks under various analyses. Note that they are only for the **234** GDEs that could be located (see 6.2 below).

6.1.1 Frequency of GDA risks due to abstraction scenarios

These analyses rely on Froend et al[1] depth to water values for establishing the 2003 depth to water datum.

Conservation value	Not significant	Moderate	Significant	Severe	Total
1	5	23	44	38	110
2	3	16	60	28	107
3	2		10	1	13
4			4		4
Total	10	39	118	67	234

Table 4: Frequency of GDE risks by conservation value **2003** to **2013** from **Froend et al[1]** report

Conservation value	Not significant	Moderate	Significant	Severe	Total
1		20	47	43	110
2	1	15	63	28	107
3	2		10	1	13
4			4		4
Total	3	35	124	72	234

Table 5: Frequency of GDE risks by conservation value **2003** to **2013** using **105GL** abstraction

Conservation value	Not significant	Moderate	Significant	Severe	Total
1		20	47	43	110
2	1	15	63	28	107
3	2		10	1	13
4			4		4
Total	3	35	124	72	234

Table 6: Frequency of GDE risks by conservation value **2003** to **2013** using **135GL** abstraction

Conservation value	Not significant	Moderate	Significant	Severe	Total
1		19	48	43	110
2		16	63	28	107
3	2		10	1	13
4			4		4
Total	2	35	125	72	234

Table 7: Frequency of GDE risks by conservation value **2003** to **2013** using **165_135GL** abstraction

6.1.2 Changes in GDE risk frequencies due to abstraction

The analysis shows little variation in risk between different abstraction strategies and only minor changes to the original GDE risk categories as a result of these scenarios.

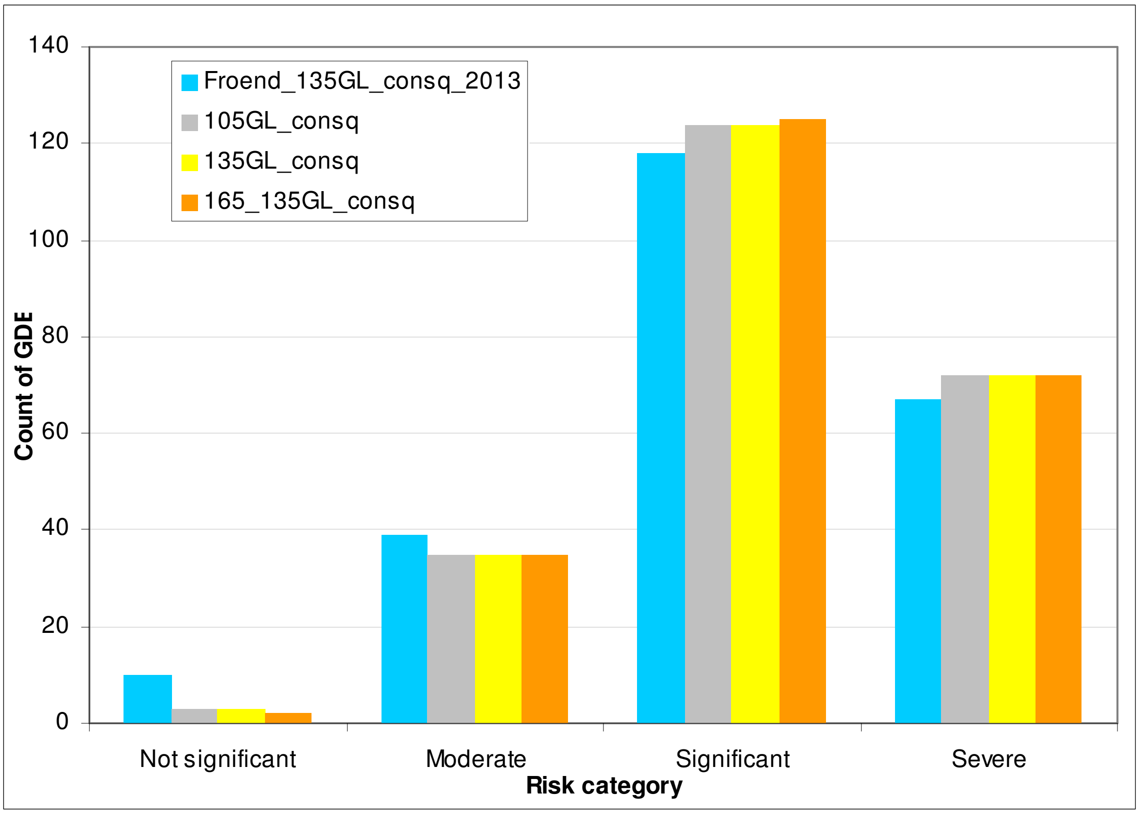

Figure 5: Variation in GDE 2013 risk categories using different Water Corporation abstraction scenario

The most noticeable feature of the figure above is that the risk categories are not sensitive to changes in Water Corporation abstraction. The small differences between the Froend et al[1] risk categories and those derived from Water Corp abstraction result from the location of the GDEs used in this analysis (see 6.2 below).

6.1.3 Effect of different depth to water values for 2003 to 2005 risk

The prediction of future risk is dependant on the depth to water value used as the datum. The following two tables show the changes in risk categories resulting from using different depth to water values.

Conservation value	Not significant	Moderate	Significant	Severe	Total
1	5	23	44	38	110
2	6	16	58	27	107
3	2		10	1	13
4			4		4
Total	13	39	116	66	234

Table 8: Frequency of GDE risks by conservation value **2003** to **2005** using Froend et al[1] depth to water values

Conservation value	Not significant	Moderate	Significant	Severe	Total
1	1	32	36	41	110
2	2	40	40	25	107
3	2	3	7	1	13
4			2	2	4
Total	5	75	85	69	234

Table 9: Frequency of GDE risks by conservation value **2003** to **2005** using **interpolated** depth to water surfaces

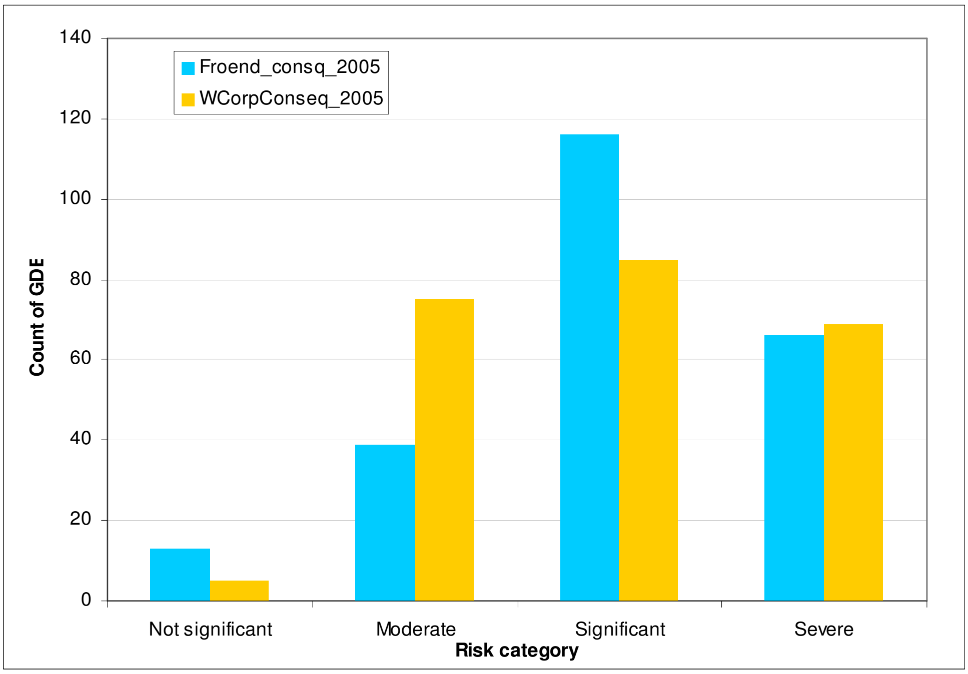

Figure 6: Variation in GDE 2005 risk categories resulting from different depth to water values

6.2 LOCATION OF GDES

The names of the GDEs listed in Table 9 are either a criteria bore site or a wetland name containing a *coordinate* value. An example of this is shown here:

GDE name	Easting*	Northing*
Beenyup Swamp38625648247	38625**0**	648247**0**

* Note that these *coordinates* need to be multiplied by a factor of 10 to convert them to metres and that they are relative to the AMG map grid, rather than the current MGA map grid. Consequently they have been converted to MGA for use in this analysis.

This study applies only to those GDEs from the Froend et al report that could be located geographically. The report totalled 243 GDEs of which only **234** could be located. There is no guarantee that the GDE locations used for this analysis match the locations used in the Froend et al[1] analysis.

6.3 GDE REPRESENTATIVE WATER LEVEL

Clearly the GDEs differ considerably in shape and size and therefore the estimation of the "average" or representative water levels from the PRAMS scenarios was a challenge. The simplest approach was to use the easting/northing for the GDE and use this coordinate to interrogate the PRAMS results and extract the water level at that location.

6.4 PRAMS WETLAND AND GROUNDWATER INTERACTIONS

There are inaccuracies inherent in this process a result of the quality of the superficial aquifer-wetland interface as modelled by PRAMS. The hydraulic characteristics of the wetlands and their connection with the groundwater system are not clearly defined. The relatively large model grid size of 500m doesn't provide very good estimates of the flow in groundwater across this interface when wetlands and lakes are of the same scale as this grid size. As more detailed and accurate models become available this analysis can be verified and refined.

PRAMS uses a simplified drainage package that was developed in Modflow (McDonald and Harbaugh, 1988) to represent wetland and groundwater interactions. This approach is applicable only to drains that gain water from groundwater discharge (gaining streams). However, streamflow data indicate that the relationship between the drainage and groundwater changes with location and time[2].

7 APPENDIX 1 - SUSCEPTIBILITY AND RISK OF IMPACT OF GDES TO GROUNDWATER DECLINE, FROEND ET AL[1]

BACKGROUND

This is a summary of the ecological risk assessment process for groundwater dependent ecosystems (GDEs) such as wetlands and phreatophytic vegetation on Gnangara Mound as developed by Froend et al. (2004) for the Department of Environment.

The risk to GDEs is a summation of scores which reflect the risk susceptibility as a result of the value of the GDE and the past declines in groundwater level plus the risk for predicted magnitudes and rates of declines of groundwater level.

Predicted water regime changes are most often the product of groundwater modelling. This ideally quantifies the spatial and temporal distribution of water level changes across a study area. This project used predicted changes at 2, 5 and 10 year intervals (2003-2005, 2003-2008 and 2003-2013) based on PRAMS 3.0. The scenario used the following components to generate results for April/May minimums (R. Vogwill, DoE, pers. comm., March 2004);

- Climate – rainfall at short-term average.
- Private Abstraction – at 100% of allocation.
- Public Abstraction – Water Corporation pumping at 135GL/yr.
- Landuse – areas from the Future Perth Plan designated for urbanisation, urbanised in 15 years.
- Pines – thinned as per LVL.

The total scores and consequent risk are shown in the following table:

Rating	Risk
13 to 15	Not significant
10 to 12	Moderate
7 to 9	Significant
4 to 6	Severe

SUSCEPTIBILITY BECAUSE OF PAST CHANGES

The susceptibility score for GDEs is composed of:
Conservation value + Current depth to groundwater + Historic water level change
Conservation value scores

Table 1. Wetland conservation value	Score
Ecosystem with international, national or regional conservation values (legislated) that has little evidence of alteration from surrounding land-use practices.	1
Ecosystem with international, national or regional conservation values (legislated) that has evidence of low to moderate impacts from surrounding land-use practices.	2
Ecosystem that has not been assessed for conservation values or is poorly understood, and that has evidence of low to moderate impacts from surrounding land-use.	3
Ecosystem with no recognised conservation values that has been moderately to severely degraded by surrounding land-use patterns	4

Table 2. Terrestrial vegetation conservation value	Score
Ecosystem with international, national or regional conservational values (legislated) that has little evidence of alteration from surrounding land-use practices e.g. Bush Forever sites, sites with Threatened Ecological Communities, JAMBA or CAMBA, in good condition.	1
Ecosystem with international, national or regional conservational values (legislated) that has evidence of low to moderate impacts from surrounding land-use practices e.g. Bush Forever sites, sites with Threatened Ecological Communities, JAMBA or CAMBA, with low to moderate impacts.	2
Ecosystem that has not been assessed for conservation values or is poorly understood, and that has evidence of low to moderate impacts from surrounding land-use e.g. sites that have low to moderate impacts but are not Bush Forever.	3
Ecosystem with no recognised conservation values that has been moderately to severely degraded by surrounding land-use patterns.	4

Current depth to groundwater scores

Depth to groundwater	Score
0-3m	1
3-6m	2
6-10m	3
>10m	4

Historic groundwater level change

Wetlands	No change or increase	<0.25m	0.25 to 0.5m	>0.5m	<0.75m	0.75 to 1m	>1m	<1.25m	1.25 to 1.5m	>1.5m
0-3m	4	3	2	1	-	-	-	-	-	-
3-6m	4	-	-	-	3	2	1	-	-	-
6-10m	4	-	-	-	-	-	-	3	2	1
>10m	5	5	5	5	5	5	5	5	5	5

Terrestrial vegetation	0 to 0.75m	0.75 to 1.5m	>1.5m	0 to 1.25m	1.25 to 2.5m	>2.5m	0 to 1.5m	1.5 to 3m	>3m
0-3m	2	1	1						
3-6m				3	3	2			
6-10m							5	4	4
>10m	5	5	5	5	5	5	5		5

RISK OF FUTURE GROUNDWATER LEVEL CHANGES

The scores and the risk for GDEs as a result of predicted magnitudes and rates of decline (m/yr) of groundwater level changes are shown in the following table.

Score	Risk
4	Low
3	Moderate
2	High
1	Severe

The scores for the magnitudes and rates of decline of groundwater levels for wetlands and phreatophytic vegetation are shown in Figures 1 to 4.

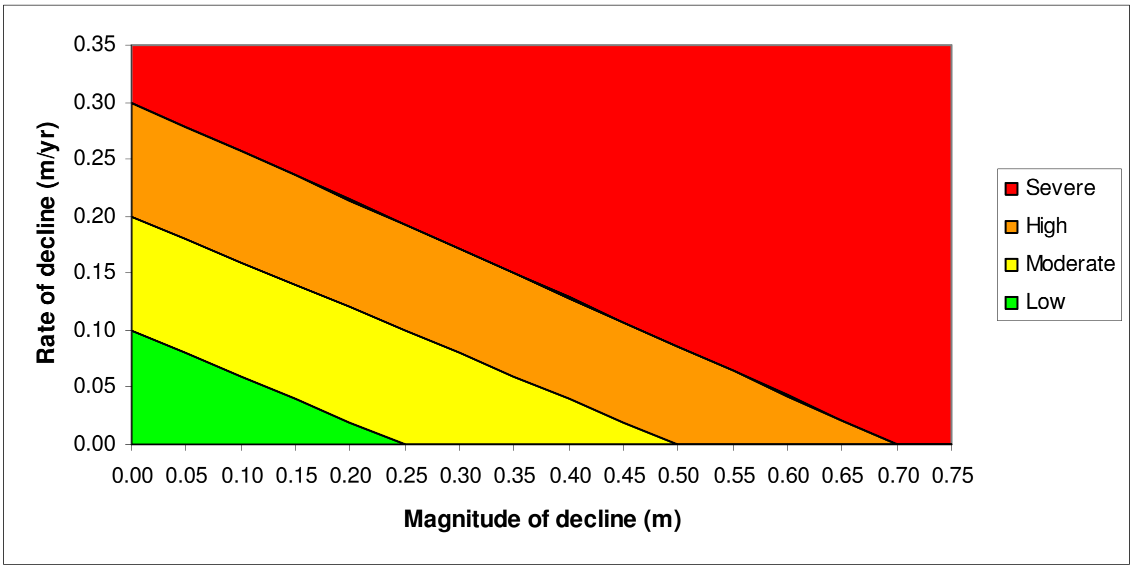

Figure 7: Risk of impact for wetlands.

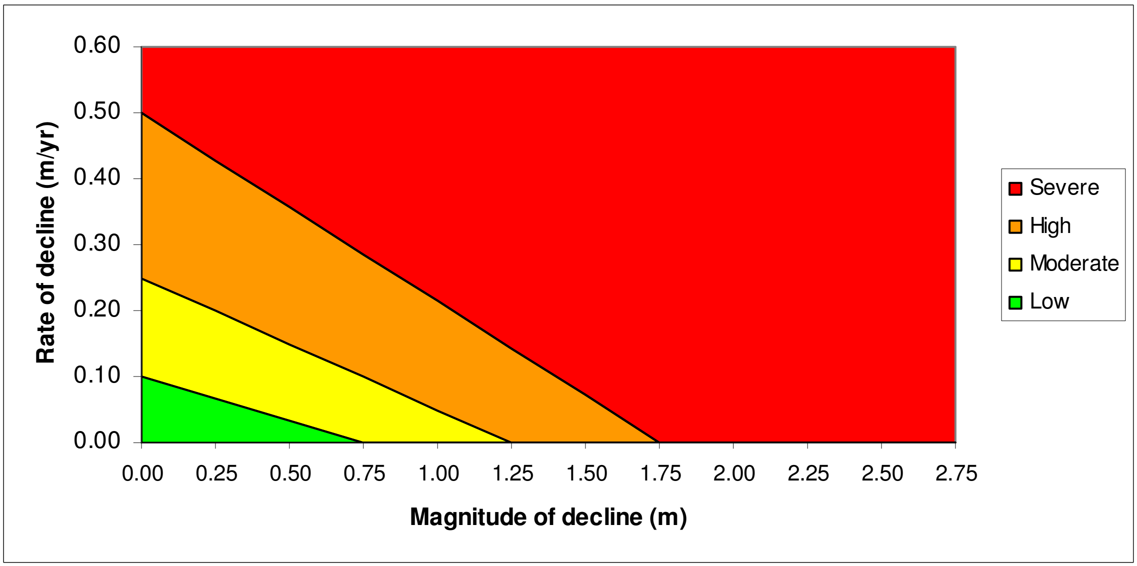

Figure 8: Risk of impact for phreatophytic vegetation in the 0 to 3m depth to groundwater.

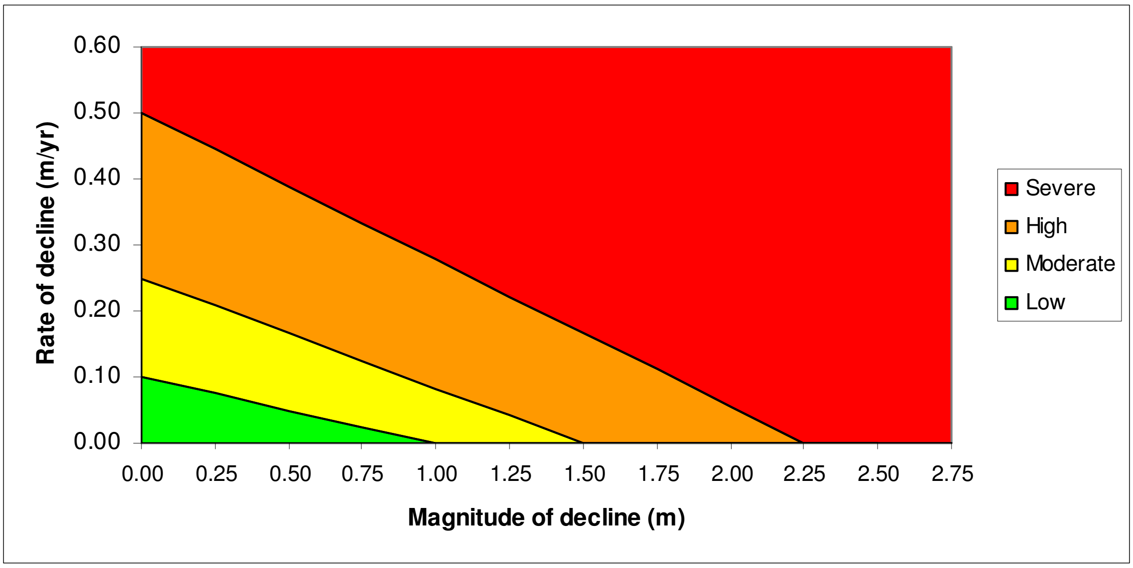

Figure 9: Risk of impact for phreatophytic vegetation in the 3 to 6m depth to groundwater.

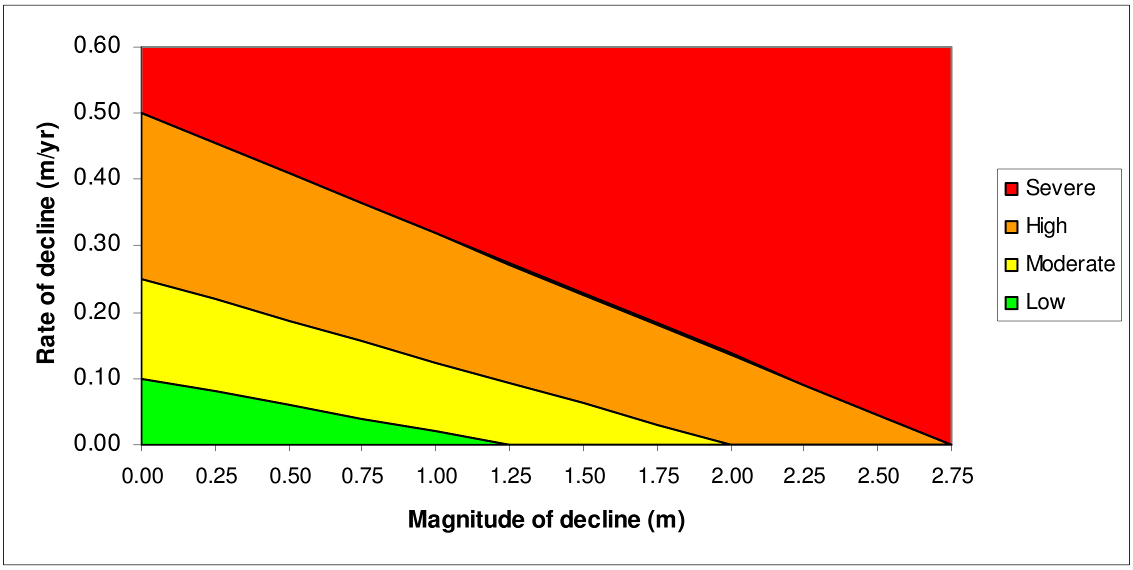

Figure 10: Risk of impact for phreatophytic vegetation in the 6 to 10m depth to groundwater.

Source: Froend et al.[1]

8 APPENDIX 2 - PRAMS MODELLING

The Water Corporation used PRAMS to investigate several climate and abstraction scenarios in March 2005 which produced water levels to the end of 2014. The modelling period was January 2003 to June 2014.

8.1 CLIMATE SCENARIOS

For the March 2005 PRAMS modelling exercise a synthetic climate sequence was developed using climate data from the period 1997-2004. The synthetic sequence was developed to match the median rainfall for the period 1997-2004. As two (2) years have elapsed since the modelling exercise we analysed the most recent climate to see how different it was from the climate used in the modelling. When the extra two years of data was added the actual median rainfall for the period 1997-2006 is the same as that of the earlier period, since 2005 rainfall is greater and 2006 rainfall is less then median respectively. However the averages are all lower as expected.

Two sequences are shown here, the totals using the 1997-2004 period are slightly higher than if the later period were used.

Perth Airport sequence				
	1997-2004		1997-2006	
Month	Year	Rain	Year	Rain
Jan	1998	2.6	1998	2.6
Feb	2001	1.8	2005	2.8
Mar	1998	29.8	1998	29.8
Apr	1997	28.2	1997	28.2
May	2003	84.4	2003	84.4
Jun	1998	128.4	1998	128.4
Jul	2002	134.4	1997	125
Aug	2000	130	1997	128.2
Sep	2003	95.4	1999	91.8
Oct	1998	36.4	1998	36.4
Nov	2001	22.2	2006	19.2
Dec	2004	3.2	2006	4
Total		**696.8**		**680.8**

Perth Regional Office sequence				
	1997-2004		1997-2006	
Month	Year	Rain	Year	Rain
Jan	1998	3.4	1998	3.4
Feb	2002	4	2002	4
Mar	1999	23.9	1999	23.9
Apr	1997	32.3	2000	31.8
May	1998	82	1998	82
Jun	2004	121.3	2004	121.3
Jul	2002	121.9	1997	120.1
Aug	2000	144.6	2003	137.7
Sep	1999	99.6	1998	90.9
Oct	2004	35.4	2004	35.4
Nov	2001	23.3	2003	20.7
Dec	2003	4.6	2005	5.9
Total		**696.3**		**677.1**

Table 10: Climate scenarios used in PRAMS modelling

Although the sequences used in the modelling are higher than if they incorporated the most recent climate this change is not considered enough to significantly affect the modelling results. *Hence we decided that the synthetic sequences derived for the scenario modelling using the 1997-2004 climate data are still valid for the period 1997-2006.*

8.1.1 Climate Stations

Of the five climate stations used in the modelling two cover most of the Gnangara Mound being *Perth Regional Office* and *Perth Airport* as shown in this map.

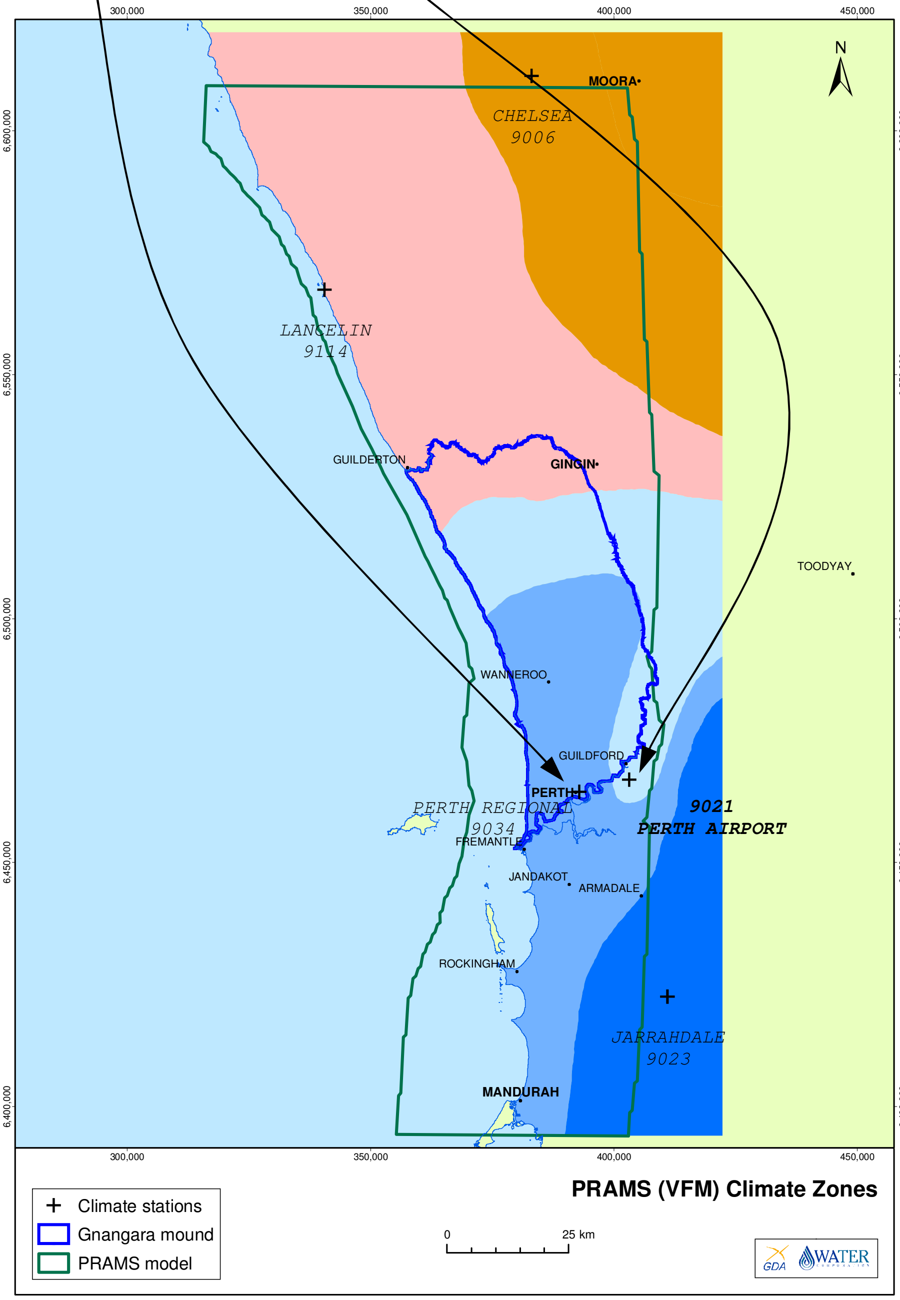

Figure 11: PRAMS (VFM) Climate zones

8.1.2 Synthetic sequences

For the relevant two stations the differences due the recent climate when compared to the 1997-2004 sequence is shown here:

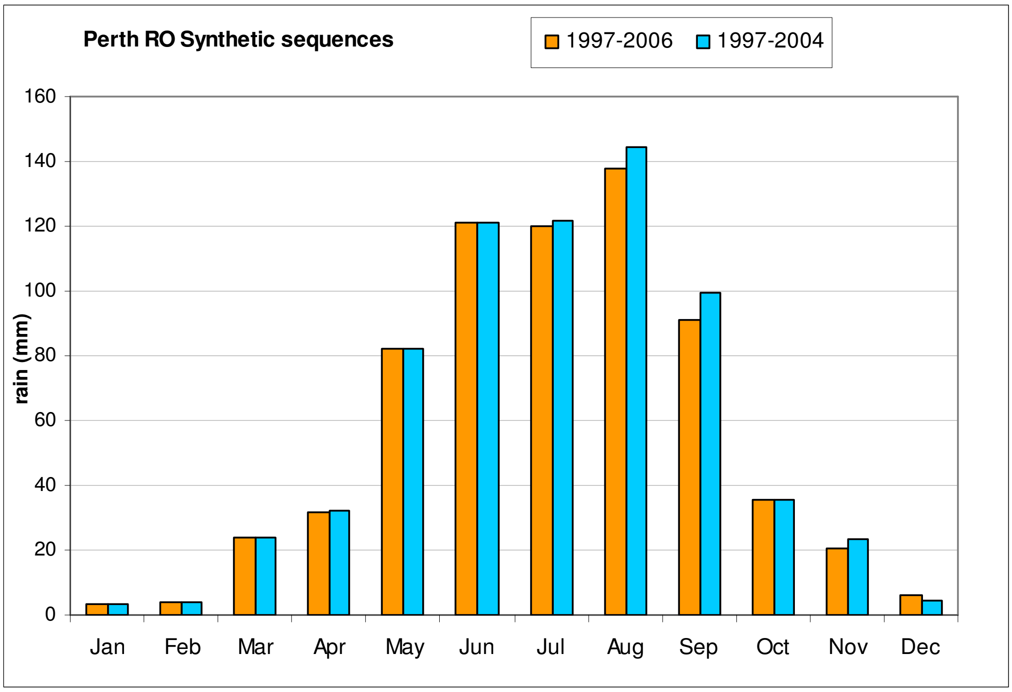

Figure 12: Synthetic climate sequences for Perth Regional Office station

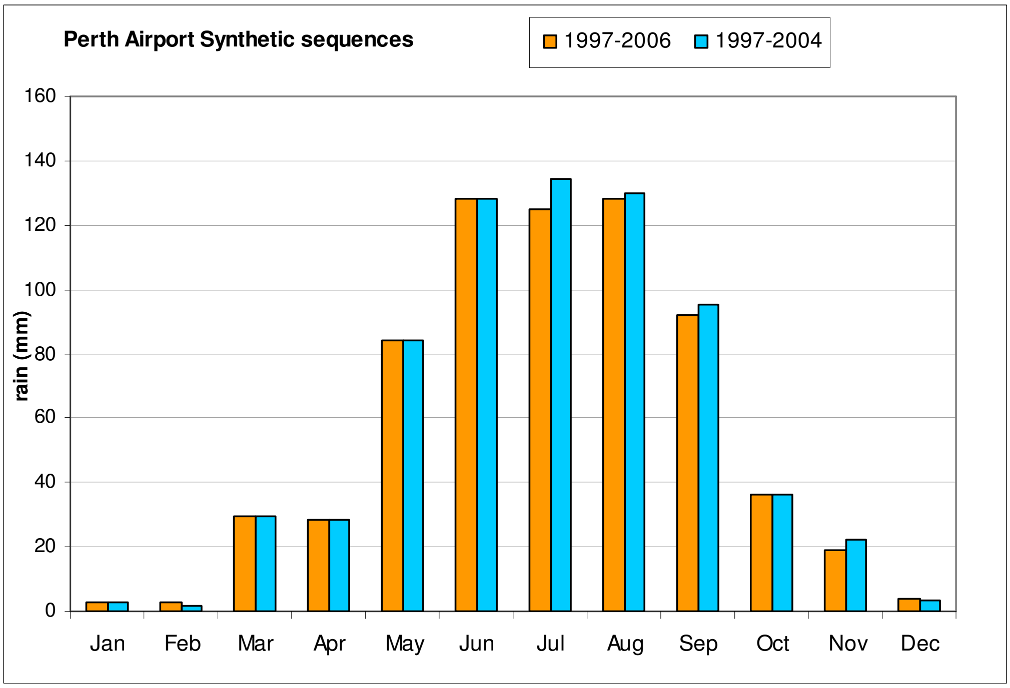

Figure 13: Synthetic climate sequences for Perth Airport station

9 REFERENCES

1. *Study of Ecological Water Requirements on the Gnangara and Jandakot Mounds under Section 46 of the Environmental Protection Act: Task 2: Determination of Ecological Water Requirements.* Prepared for: The Water and Rivers Commission by Dr. R. Froend[1], R. Loomes[1], Dr. P. Horwitz[1], M. Bertuch[1], Dr. A. Storey[2] and M. Bamford[3] (1: Centre for Ecosystem Management, ECU; 2: School of Animal Biology, UWA; 3: MJ and AR Bamford, Consulting Ecologists), September 2004.

2. Davidson, W.A., & Yu, X, 2007, Perth Region Aquifer Modelling System – PRAMS, Hydrogeology and Groundwater Modelling, Western Australia Department of Water, Hydrogeology Record Series HG 20.