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IPWEA PUBLIC WORKS TRAINING WEEK 2016

STORMWATER & DRAINAGE
GROUNDWATER MODELLING OF MOUNDING BETWEEN SUBSOIL DRAINS

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1. INTRODUCTION

Subsoil drainage is used throughout the world to control shallow groundwater levels to facilitate land use in both agricultural and urban development areas. The term subsoil implies that a buried pipe is used as opposed to an open drain, usually where land values are high.

The primary mechanism by which subsoil drainage functions is the provision of an outlet from a slotted pipe system such that groundwater can flow by gravity, according to Darcy's law, towards the pipe thus controlling groundwater levels. Subsoil drainage is usually constructed in parallel or sub-parallel lines, so that the water table mounds between the parallel drainage lines.

Critical parameters determining whether a subsoil drainage system operates as intended are: the soil permeability, the volume of water to be drained in unit time, drain spacing and outlet condition.

On the Swan Coastal Plain subsoil drainage has been used for decades in urban developments where the water table has been shallow, generally with success, owing to the permeable sandy soils and the relatively low rainfall in the South West of Western Australia.

This paper describes the application of the IPWEA (2016) Specification Separation Distances for Groundwater Controlled Urban Development Methodology to Subsoil Drains. As such the paper will be of benefit to IPWEA members in particular.

In particular the paper describes the groundwater modelling as unsteady in a 1D vertical slice model using the rainfall predictions based on DoW (2015) future median climate scenarios.

The paper uses a theoretical mounding probability distribution as an example. JDA will publish actual median climate scenario mounding in the near future.

JDA has previously reported on modelling on subsoil drains in sand fill for urban development (*Serafini et.al* (2014)).

2. REGIONAL AND PERCHED WATER TABLES

Figure 1 shows a schematic of a regional and perched water table either of which may exist at a particular location.

A perched water table tends to develop where there is an impeding layer in the soil profile preventing vertical percolation of rainfall. This commonly occurs where imported sand fill is placed above Guildford Formation clays which host the regional water table as depicted in Figure 1.

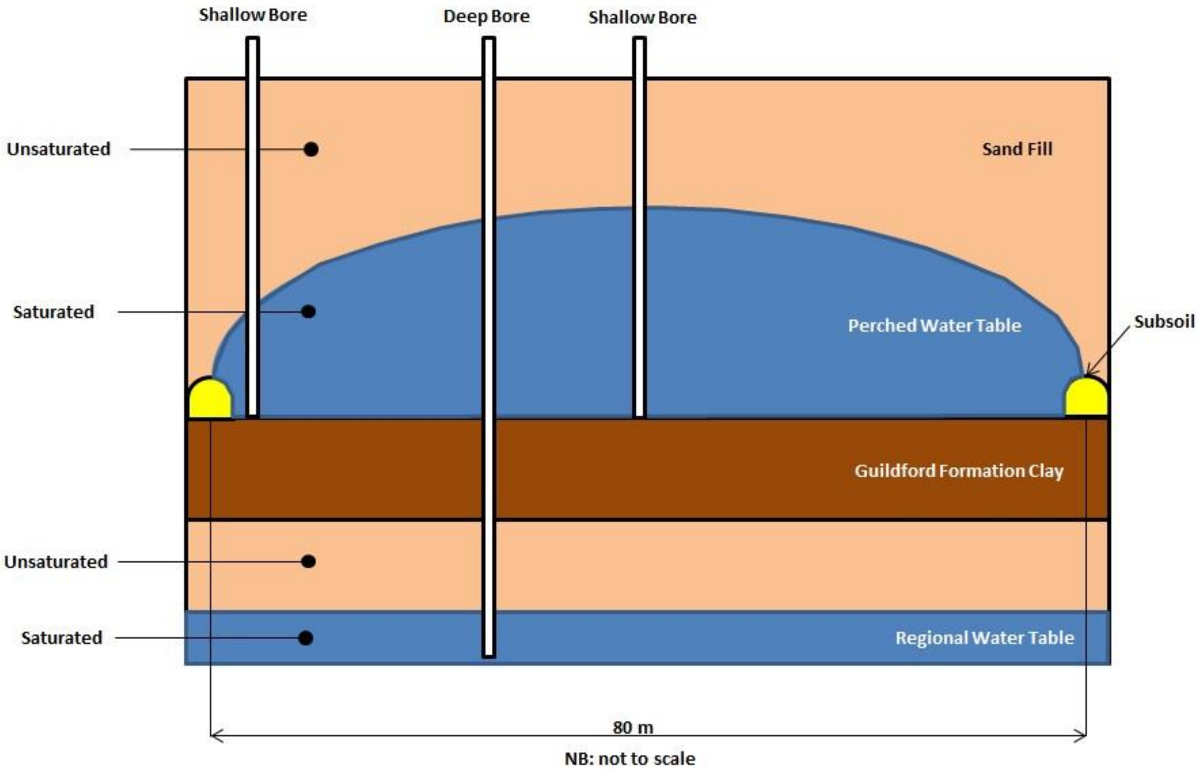

Figure 1: Schematics of Regional and Perched Water Table (Serafini et.al (2014))

The mounding of the water table associated with rainfall recharge is illustrated in Figure 1 and the height of this mound at mid drain spacing is crucial for determining fill requirements for urban development.

The height of this mounding depends on the soil parameters as well as the climate scenario.

The focus of this paper is the choice of climate scenario.

Figure 2 shows a flow chart for application of the method presented in this paper.

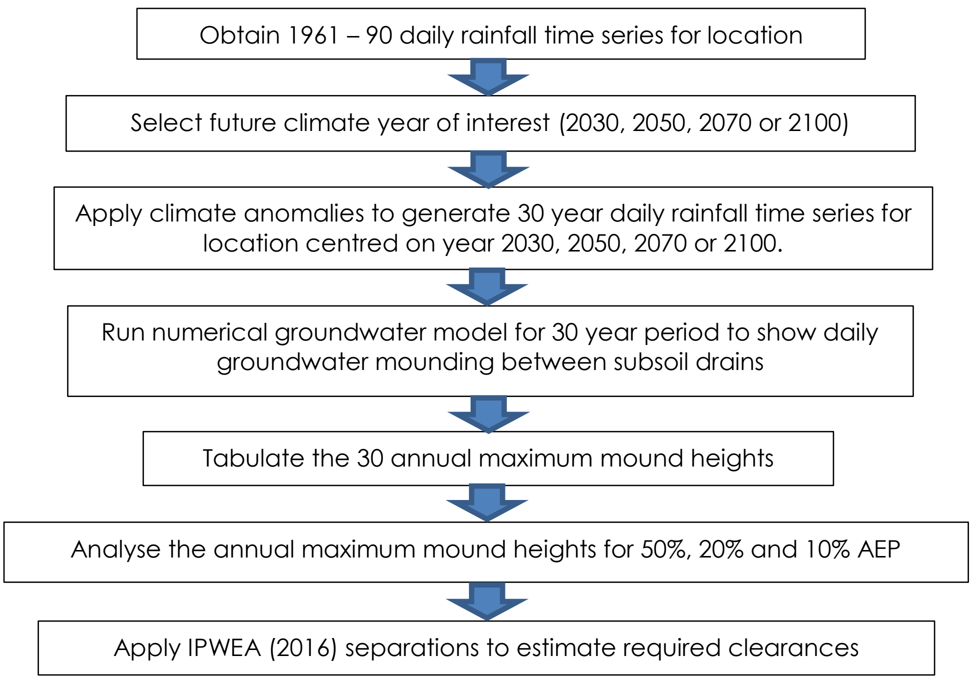

Figure 2: Flow Chart of IPWEA (2016) Climate Scenario Modelling

3. FUTURE CLIMATE PROJECTIONS FOR WESTERN AUSTRALIA

DoW (2015) describes the importance of standardising future climate scenarios used for modelling water resources in WA noting that since 1970's south west Western Australia has experienced declining rainfalls and general circulation models (GCMS) suggest that this trend will continue into the 21st Century.

In 2013 the Department of Water developed standard climate scenarios for 5 broad climatic regions across WA to enable consistent application of climate projections.

The climate scenarios are reported using anomalies – the average change in climatic variable for a future period compared to the baseline period. The period 1961 to 1990 has been adopted as the baseline period for WA.

DoW (2015) analysed 12 GCMS with 4 emissions scenarios resulting in 48 scenarios.

These were ranked in terms of percentage change to rainfall from the baseline period (1961 to 90) through to 2100. All 48 scenarios indicated a reduction in rainfall to 2100 from the baseline period for South West WA.

The regional average change in annual rainfall for the south west to 2030 relative to baseline period is -14%, -5% and -2% for the dry, median and wet scenarios respectively. For the south west to 2100 relative to the baseline period the average change in annual rainfall is -47%, -17% and -7% for the dry, median and wet scenarios respectively.

The dry, median and wet scenarios are approximately the 10th, 50th and 90th percentiles of the 48 scenarios modelled to 2100.

For the period to 2030 the reductions in mean annual rainfall relative to the baseline period of 14, 5 and 2% (dry, median and wet respectively) are spatial averages over the south west, which typically increase from near 0% inland to a maximum (>than the average) in the south west corner of the state.

Figure 3 shows box and whisker plots from DoW (2015) for the wet, median and dry scenarios through to 2100 for Perth Airport.

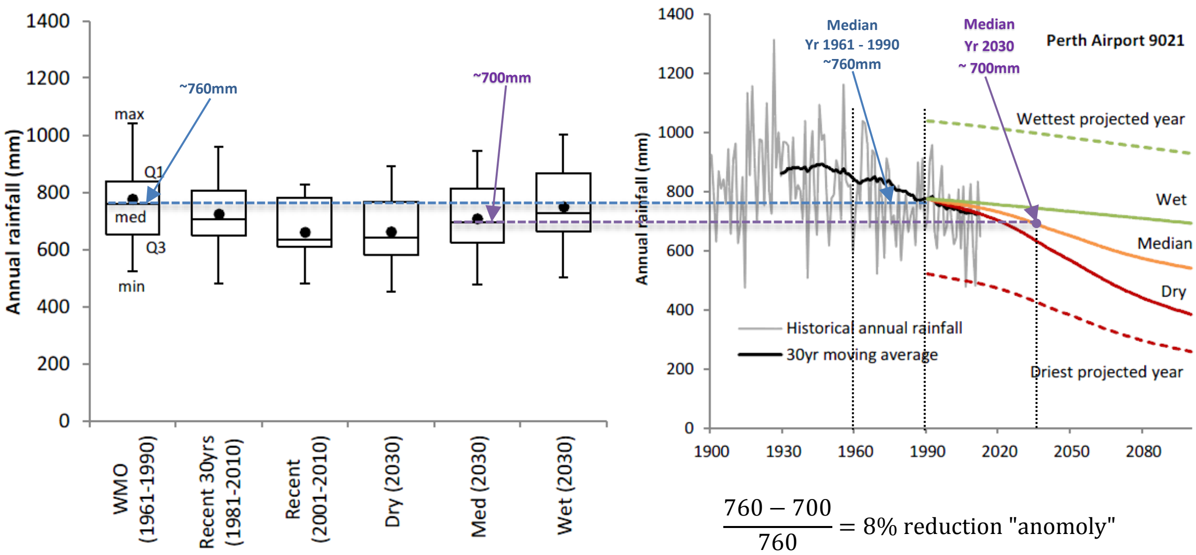

Figure 3: Box and whisker plots of annual rainfall for historical periods and climate scenarios for 2030 (mean showed by dot); and scenarios at Perth Airport, projected mean annual rainfall to 2100 for the wet, median and dry scenarios (DoW, 2015)

Figure 3 shows median rainfall 1961 to 1990 of approximately 760 mm/yr declining to 700 mm/yr by 2030 (8% reduction) relative to baseline, and declining to 550 mm by 2100 (28% reduction).

Time series of 30 year projections of rainfall can be obtained from DoW based on baseline data 1961 to 90 by incorporating monthly anomalies (DoW, 2015).

DoW (2015) recommends which climate scenario to use for water resource applications based on uncertainty and risk management.

Figure 4 shows that for south west WA if the range in climate projections is unlikely to be significant to the outcome of the planning, then use of the median climate projections should underpin the modelling.

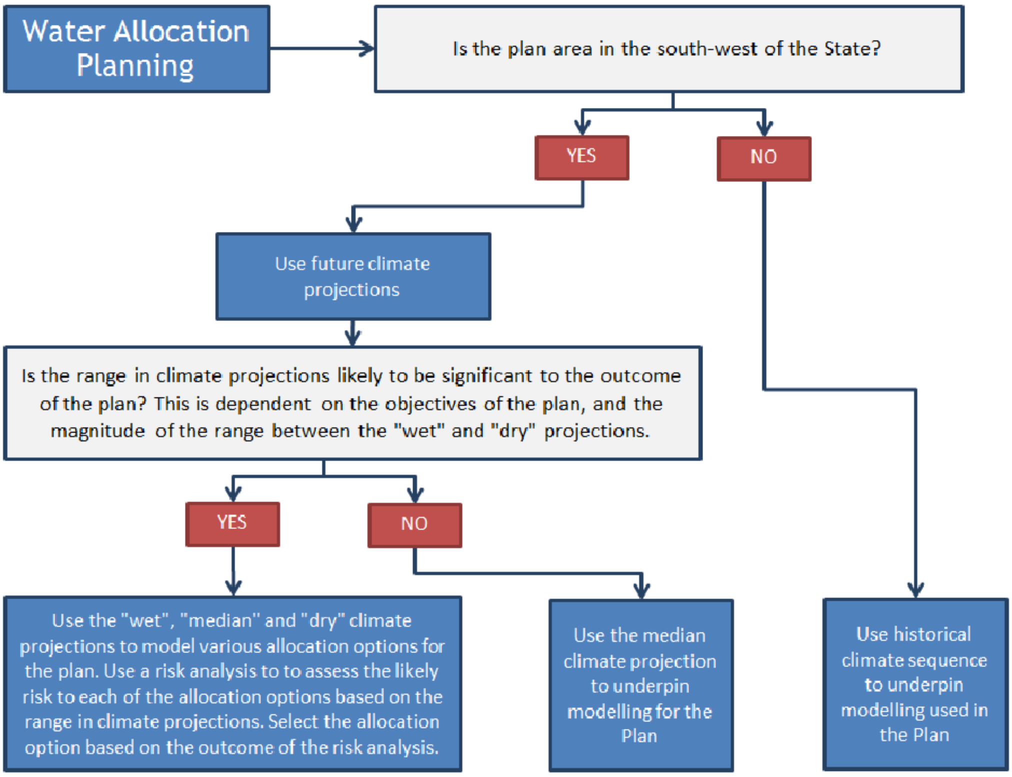

Figure 4: Department framework used to select an approach to incorporate climate in water allocation planning (DoW, 2015)

On this basis IPWEA (2016) adopted the median climate scenario as described below.

4. IPWEA (2016) SPECIFICATION SEPARATIONS DISTANCES FOR GROUNDWATER CONTROLLED URBAN DEVELOPMENT

For unsteady groundwater modelling of water table mounding between subsoil drains, IPWEA (2016) recommends application of a 30 year daily time-step rainfall record should be used as described in DoW (2015), see above.

JDA is currently resourcing this median rainfall projection for several locations in south west WA area for application of the IPWEA (2016) methodology.

The 30 year rainfall simulations of subsoil drain mid space groundwater mounding will result in 30 annual maxima values which can be subjected to annual maxima frequency analysis using a suitable probability distribution such as normal, lognormal, log Pearson III etc.

Table 1 and Figure 5 show an annual maximum analysis of a theoretical series generated by JDA with 30 data points with mean 1.0m and 0.3m standard deviation fitted to the Log Pearson III distribution by method of moments.

The fitted distribution can then be used to assess mound heights associated with various annual exceedance probabilities (AEP's), see Table 2.

From Table 2 it can be seen that AEP's between 10 and 50% are recommended by IPWEA (2016) for estimating water table mounding for different infrastructure requirements.

TABLE 1: 30 Theoretical Groundwater Mounding with Mean 1.0m and 0.3m Standard Deviation

Rank	Mound (m)	Rank	Mound (m)
1	1.84	16	0.92
2	1.54	17	0.92
3	1.46	18	0.90
4	1.41	19	0.87
5	1.28	20	0.86
6	1.22	21	0.80
7	1.19	22	0.68
8	1.14	23	0.67
9	1.04	24	0.67
10	1.03	25	0.62
11	0.99	26	0.61
12	0.98	27	0.60
13	0.96	28	0.48
14	0.93	29	0.36
15	0.92	30	0.17

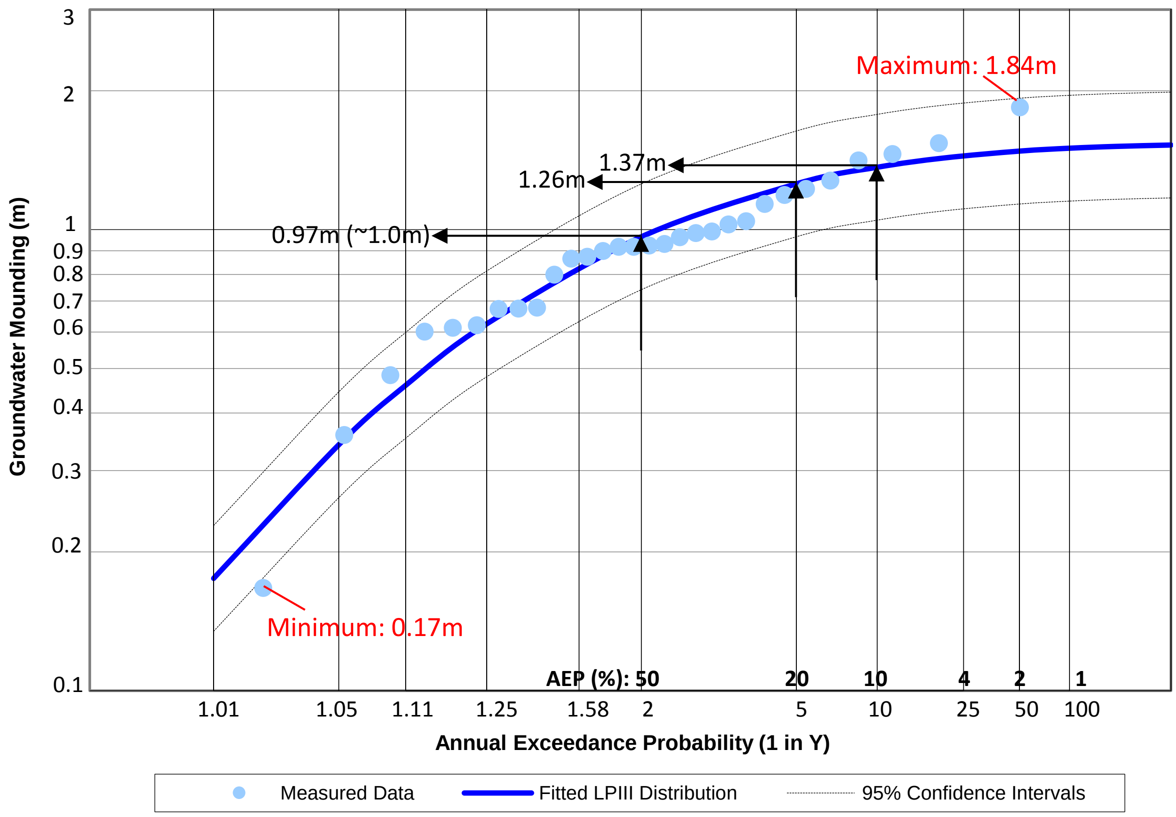

Figure 5: Annual Maxima Analysis of 30 year Mound Peaks

Figure 5 shows that the 10%, 20% and 50% AEP groundwater mounds are 1.37m, 1.26m and 0.97m respectively.

Table 1 shows the 30 theoretical mounds with mean 1.0 and 0.3m standard deviation that generated by JDA from largest to smallest. 10%, 20% and 50% AEP groundwater mounds are directly calculated as 0.92m (50th percentile), 1.19m (80th percentile) and 1.42m (90th percentile). Note that these results are calculated without fitting the Log Pearson III distribution so slight difference is expected. This ranking method is considered an alternative method to frequency analysis of the data.

5. INFRASTUCTURE SEPARATION DISTANCES

Based on the theoretical 30 year annual maxima to 2030 described above. Figure 6 shows the separation distance schematically. Note that separation is defined from ground surface to the groundwater mound (phreatic surface), not from ground surface to subsoil drain inverts.

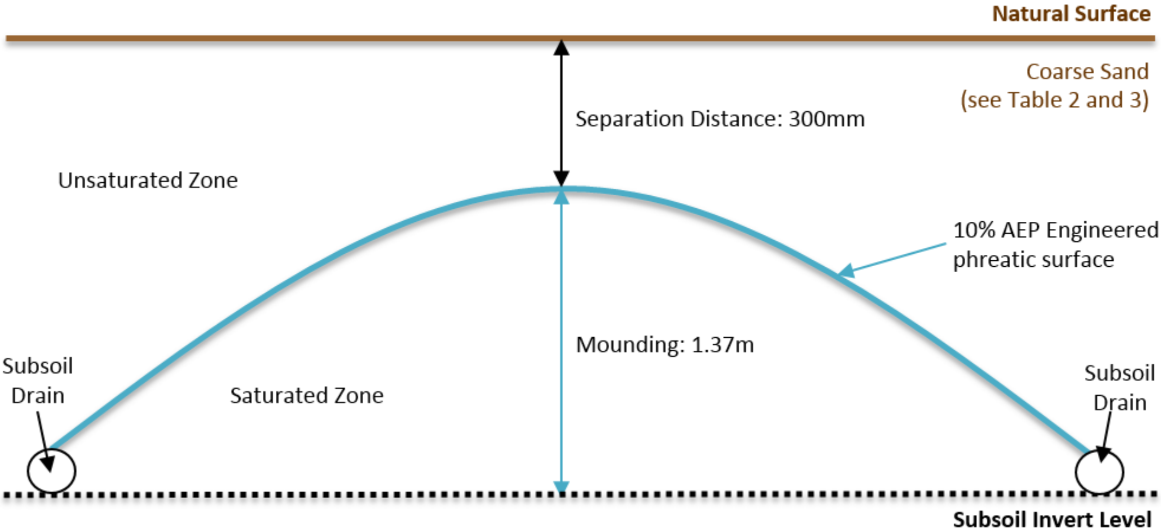

Figure 6: Separation for 2030 Median Climate Scenario of Turfed Open Space: Sport Function and Local Catchment

Table 2 summarises the infrastructure separation requirements based on IPWEA (2016).

TABLE 2: IPWEA (2016) SPECIFICATIONS

INFRASTRUCTURE	AEP MOUNDING (%)	SEPARATION CRITERIA (mm)	AEP MOUNDING (m)	SEPARATION (mm)
Drainage (infiltration systems & devices)				
Underground	50	0	1.0	0
Surface	50	300	1.0	300
Private Gardens				
Residential lots 400 to 800 m^2	50	Note 1	1.0	300
Residential lots <400 m2	50	Note 2	1.0	150
Public Open Spaces (Turfed)				
Sport				
Local	50	Note 3	1.0	300*
Neighbourhood	20	Note 3	1.26	300*
District	20	Note 3	1.26	300*
Regional	10	Note 3	1.37	300*

Notes:
1. 300mm of coarse sand applied to anticipated garden areas in the rear of lots above the 50% AEP mound.
2. 150mm of coarse sand applied to anticipated garden areas in the rear of lots above the 50% AEP mound.
3. Refer Table 3.
4. * assuming Coarse Sand

TABLE 3: SEPARATION DISTANCE FOR TURFED OPEN SPACE BASED ON TYPICAL SOIL TYPES (IPWEA, 2016)

SOIL TYPE	SEPARATION DISTANCE
Gravel	
Coarse	150 mm
Medium	150 mm
Fine	200 mm
Sand	
Coarse	300 mm
Medium	450 mm
Fine	650

6. CONCLUSIONS

This paper presents the first known application of the DoW (2015) Future Climate Scenarios to groundwater modelling estimation of water mounding between parallel subsoil drains as recommended in IPWEA (2016) guidelines.

The paper is based on future climate modelling assuming median scenario for the south west of WA to 2030 using monthly anomalies from the baseline rainfall period 1961 to 1990 for a specific location in the south west of WA.

The results presented assume a normal distribution of annual maxima mounds mid-spaced between subsoil drains with a mean of 1.0m and standard deviation of 0.3m.

Actual annual maxima from the future medium scenarios for several locations in the south west WA are currently being evaluated by JDA.

The future median climate scenario is a hypothetical climate series of 30 year centred on the year 2030.

Future 30 year future climate series can be derived using the monthly anomalies centred on the year 2050, 2070 or 2100.

The year 2030 is used as the near term planning time horizon for urban development, assuming a redevelopment of land use would occur at some time between the present and say 2050 roughly centred on 2030.

7. Acknowledgements

The authors acknowledge the assistance of Joel Hall (DoW) in interpreting the climate change scenarios defined in DoW (2015).

8. REFERENCES

Department of Water (2015), *Selection of Future Climate Projections for Western Australia*, Water Science Technical Series Report, no. WST 72 September 2015.

Institute of Public Works Engineering Australasia (2016), *Specification Separation Distances for Groundwater Controlled Urban Development*, Prepared by the Land Development in Groundwater Constrained Landscapes Steering Group, February 2016.

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