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Water for a Healthy Country

Valuing Urban Wetlands of the Gnangara Mound

A Hedonic Property Price Approach in Western Australia

Sorada Tapsuwan, Gordon Ingram and Donna Brennan

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CSIRO

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Executive Summary

Up to 60% of potable water supplied to Perth in Western Australia is extracted from the Gnangara Mound groundwater system that lies north of the city centre Many of the wetlands on the Mound are groundwater-dependent and climate change, landuses that reduce recharge and groundwater extraction have resulted in a decline in water levels in many wetlands.

In order to inform decisions about conserving urban wetlands that occur in existing urban areas, creating wetlands in new sub-divisions and urbanising rural wetlands, it is beneficial to be able to estimate the economic value of wetlands.

This study used data on residential property sales price, along with property and neighbourhood attributes to value urban wetlands in the Perth metropolitan area using a hedonic property price approach. It was found that proximity to wetlands increases the sales prices of properties once all other factors are taken into account. The marginal implicit price of being closer to a wetland by 1 metre, evaluated at the mean sales value, is AU$829. If there is more than one wetland within 1.5 kilometres of a property, the second wetland will increase the property price by AU$6,081. For a 20 hectare wetland, the total premium on sales due to wetland proximity for all surrounding residences is estimated to be AU$140 million, based on average property characteristics and median housing densities.

A case study into the value of the Perry Lakes wetlands, located 7 kilometres west of Perth, illustrated the issues encountered in adapting the total sales premium calculation to a particular location. The value of Perry Lakes was estimated at AU$54 million for the existing nearby houses and around AU$25 million for properties proposed in a new residential development adjacent to the Lakes.

It should be noted that the hedonic property price approach captures only the capitalised amenity value for wetland proximity on nearby property prices. It does not reveal the social willingness-to-pay for conservation of the wetland. Hence, the estimated value in this report is merely the lower bound of the wetland value as the value on social services has not been captured in the hedonic approach. In order to capture social values, which are not normally revealed in the market place, other valuation techniques such as stated preference or second stage hedonic analysis would be required to supplement this study.

Additionally, the hedonic values are only a snapshot in time and may change if demand for urban living within proximity of wetlands grows. Nonetheless, the estimates in this study provides a guide to policy makers of the importance of wetlands to Perth property values.

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1. Introduction

1.1. Significance of the Study

The northern Perth metropolitan and peri-urban areas are situated on a vast underground water resource known as the Gnangara Mound. The Mound provides the majority of water used for consumptive purposes in the urban area as well as significant environmental amenity in the form of lakes and wetlands. A chain of wetlands extends north-south along the Swan Coastal Plain, providing many valuable services such as the protection of water quality in rivers and streams, flood control and stormwater detention, and habitat for wildlife as well as recreational and landscape amenities. Most of the urban wetlands are appreciated for their aesthetic qualities and other indirect uses because the ecological functions of urban wetlands have been severely altered to the extent that they now bear little resemblance to their original state (EPA, 2006).

As a consumptive resource for urban water supply, the Gnangara Mound can be divided spatially into the urbanised area, and the protected water catchment zone in the peri-urban area, where the bore fields used to supply the reticulated scheme are located. The urbanised area, which overlays a superficial aquifer which effectively acts as a large stormwater recycling facility from which water is sourced for the purpose of irrigating lawns and gardens (Smith *et al.*, 2005). The use of bore water within the urban area services both public open space and private lawns and gardens which provide a substitute for scheme water. It has been estimated that use of this resource equates to approximately 145 gigalitres per year (Lieb *et al.*, 2007).

In the urban area the groundwater levels have been less severely affected by climate change than in most other areas, as the net extraction for irrigation is slightly offset by higher recharge associated with urban landscapes. However, there is evidence of groundwater decline in some urban areas and this has led to an interest in recharging or supplementing urban wetlands. The drying climate experienced over the past 30 years has led to increased pressure on the aquifer as a source of supplementary water supply for garden irrigation, as a 40 percent reduction in mean run-off into surface water storages has led to outdoor water restrictions for scheme water use, resulting in an increased demand for sinking backyard bores for garden irrigation. If the trend continues, there is an increased likelihood that the presently unlicensed and unmanaged backyard bore use may conflict with the management of urban groundwater levels and associated wetlands, which may cause a loss of urban amenity value.

These management issues highlight the need for a better understanding of the economic value of maintaining wetlands in both the peri-urban and urban areas. Non-use values are likely to dominate in the urban areas, and are amenable to quantification using hedonic price analysis of property sales data. The value of urban wetlands will be useful to policy makers dealing with water use conflicts between maintaining amenity value and consumptive demand for bore water, as well as for the purpose of evaluating supplementary pumping into wetlands and artificial lakes to preserve aesthetic values. It will also inform the broader land use planning issues regarding management of the Gnangara Mound area, where urbanisation of areas currently under exotic plantations may improve wetland amenity as well as provide a source of funds for on-ground rehabilitation of degraded groundwater dependent ecosystems in the peri-urban area. The work presented in this report forms part of a larger study into integrated land and water management on Gnangara Mound.

1.2. Approaches to Wetland Valuation

Previous valuation studies of wetlands have come up with a wide range of estimates, due in part to differences in the wetland attributes that are valued and also to differences in methodology (Boyer and Polasky, 2004). The RAMSAR Convention Bureau (Barbier *et al.*, 1997) reviewed various economic techniques available for valuing wetlands, in order to provide guidance to policy makers and planners on the potential for economic valuation of wetlands and

how such valuation studies should be conducted. One technique that can be used to value environmental amenities that are not sold in the market and do not have direct market value, such as wetlands, is the hedonic pricing method.

The hedonic pricing method is based on the idea that properties are not homogenous: they differ in respect to a variety of characteristics, such as number of bedrooms, bathrooms, lot size, proximity to parks, schools, etc. Property prices can be affected by all these location-specific environmental, structural, and neighbourhood characteristics. The method relies on observable market transactions, for instance, property sales data, to place values upon the various characteristics that make up a heterogeneous product (Boxall *et al.*, 2005). The hedonic approach can also be used to value wetlands as prices of properties near wetlands contain a capitalised amenity value for wetland proximity, so that when the properties are sold, the new buyers have to pay for this amenity value in the form of higher house prices (Loomis and Feldman, 2003). The important assumption is that the individuals have information on all alternatives and must be free to choose a house anywhere in the market (Freeman, 2003). The model also assumes that the housing market is in equilibrium, individuals have made their utility-maximizing choices given the prices of alternative housing locations and these prices just clear the market (Freeman, 2003).

Boyer and Polasky (2004) discussed three studies in the United States that have applied the hedonic method to estimate the value of urban wetlands to nearby properties (Lupi *et al.*, 1991; Doss and Taff, 1996; Mahan *et al.*, 2000). These studies found a significant relationship between sales prices and proximity to wetlands as well as sales prices and size of wetland. Lupi *et al.* (1991) estimated a US$19 increase in property prices if the wetland area increased by one hectare in Ramsey County, Minnesota. Mahan *et al.* (2000) conducted a study in Portland, Oregon, and found that increasing the size of the nearest wetland by one acre increased the residence's value by US$24. They also found that reducing the distance to the nearest wetland by 1,000 feet increased the value by US$436. Doss and Taff (1996) studied the effects of proximity to different types of wetlands to property prices. They found that the implicit price is positive at the mean distance: moving an additional 10 meters towards an emergent-vegetation wetland increases house value by $136, towards open-water wetlands by $99, and towards scrub-shrub wetlands by $145.

Other non-market valuation techniques such as stated preference have also been applied to value urban wetlands, which attempt to capture both the private amenity value and social use and non-use values. Gerrans (1994) conducted a survey to value the Jandakot wetlands in Perth, Western Australia. He used a double-bounded dichotomous choice contingent valuation (CV) method and found the average household willingness-to-pay for conservation of the wetlands was AU$31.15 per annum. Streever *et al.* (1998) estimated the willingness-to-pay value and examined attitudes towards wetland conservation in New South Wales. Respondents to a questionnaire survey indicated a median willingness-to-pay of AU$100 per household per year for 5 years. Morrison *et al.* (1999) used a choice modelling approach to estimate the non-use environmental values provided by the Macquarie Marshes, a major wetland in New South Wales. They found that households were willing-to-pay AU$0.05 for an extra square kilometre of wetland area. More recently, Whitten and Bennett (2004) applied choice modelling to estimate the social values generated by an array of alternative privately owned wetland management options in the Murrumbidgee River Floodplain (MRF) in New South Wales. On average, respondents to the MRF questionnaire were willing to pay a once-off figure of AU$11.39 per household for an extra 1000 hectares of healthy wetlands.

The disadvantage of using stated preference technique is that the estimated value of environmental amenities are based on a hypothetical market scenario, therefore, the findings are generally open to a lot of criticism, particularly when it comes to comparing the hypothetical value to actual willingness-to-pay. The hedonic property price approach on the other hand, is based on real market transactions which have occurred in a market setting and therefore could overcome hypothetical bias. Nonetheless, urban wetlands have both public and private use and the hedonic method may not fully capture the public service component of wetlands as this value is presumably not fully reflected in property market prices. One of the key considerations in choosing which non market valuation method to use is therefore the extent to which amenity

values are likely to be the main driver of social values. In this case study we focus on wetlands in the Perth metropolitan area which are significantly modified compared to the more natural wetlands of the peri urban area. Whilst they may conceivably still have non-use values associated with them (for example, they support various flora and fauna including migratory birds, and there may be heritage and bequest values as well), the main value is thought to be their recreational and visual amenity. For this reason, and to avoid the problems of hypothetical bias associated with stated preference techniques, we use the hedonic property price approach.

2. Development of the Hedonic Price Function

2.1. Study Area

Figure 1 shows the study area, including the locations of the wetlands and the properties sold during the study period, which was selected as July 2005 to June 2006. The study area extends approximately 13 kilometres north-south and 9 kilometres east-west, covering an area of around 86 square kilometres north of the Swan River. Most of the area is relatively flat, but there is a line of low hills paralleling the coast about 2-3 kilometres inland. There are 32 wetlands inside or within a 2 km buffer around the study area. They range in size from 0.3 to 329 hectares. Some of the wetlands are natural and retain some of their original character, while others are man-made or extensively modified.

The study area includes 26 suburbs in three local government authorities in the Perth metropolitan area, namely the Towns of Cambridge and Vincent and the City of Stirling. It includes beachside suburbs popular with both locals and tourists, inner urban suburbs with café living in the southeast corner and some less affluent areas in the northeast. There is a light industrial and commercial area directly north of Herdsman Lake, the largest wetland in the study area. A large parkland / nature reserve, named Bold Park lies to the west of the Perry Lakes, which are used in the case study of Section 4. A major freeway passes through the study area, running approximately from the city centre (near the Perth GPO) to just east of the chain of wetlands on the northern boundary of the study area. In and around the study area there are several golf courses, large shopping centres, places of tertiary education and numerous small parks and reserves.

2.2. Data Sources

This study used data from multiple sources, but there are essentially two types of data, namely geospatial data and property sales data. The geospatial data consist of point data (centroids) for the properties sold and points of interest, such as schools, shopping centres and parks; line data for the coastline; polygon data for the wetland and suburb boundaries; and digital elevation data. The wetland data were obtained from the WA Department of Water, and the other spatial data from Landgate, the WA government agency responsible for property and land information. The property sales data consists of the property sales price and characteristics of the property, such as land area, and the number of bedrooms and bathrooms. These data were also acquired from Landgate. Summary statistics for the variables used in the study are presented in Table 1. Note that this study considered only the sale of free-standing houses with land; data on units, villas, apartments, retirement villages and vacant land were excluded from the analysis. The study focussed on free-standing houses because the data for other dwelling types was not detailed enough to permit a reliable hedonic analysis.
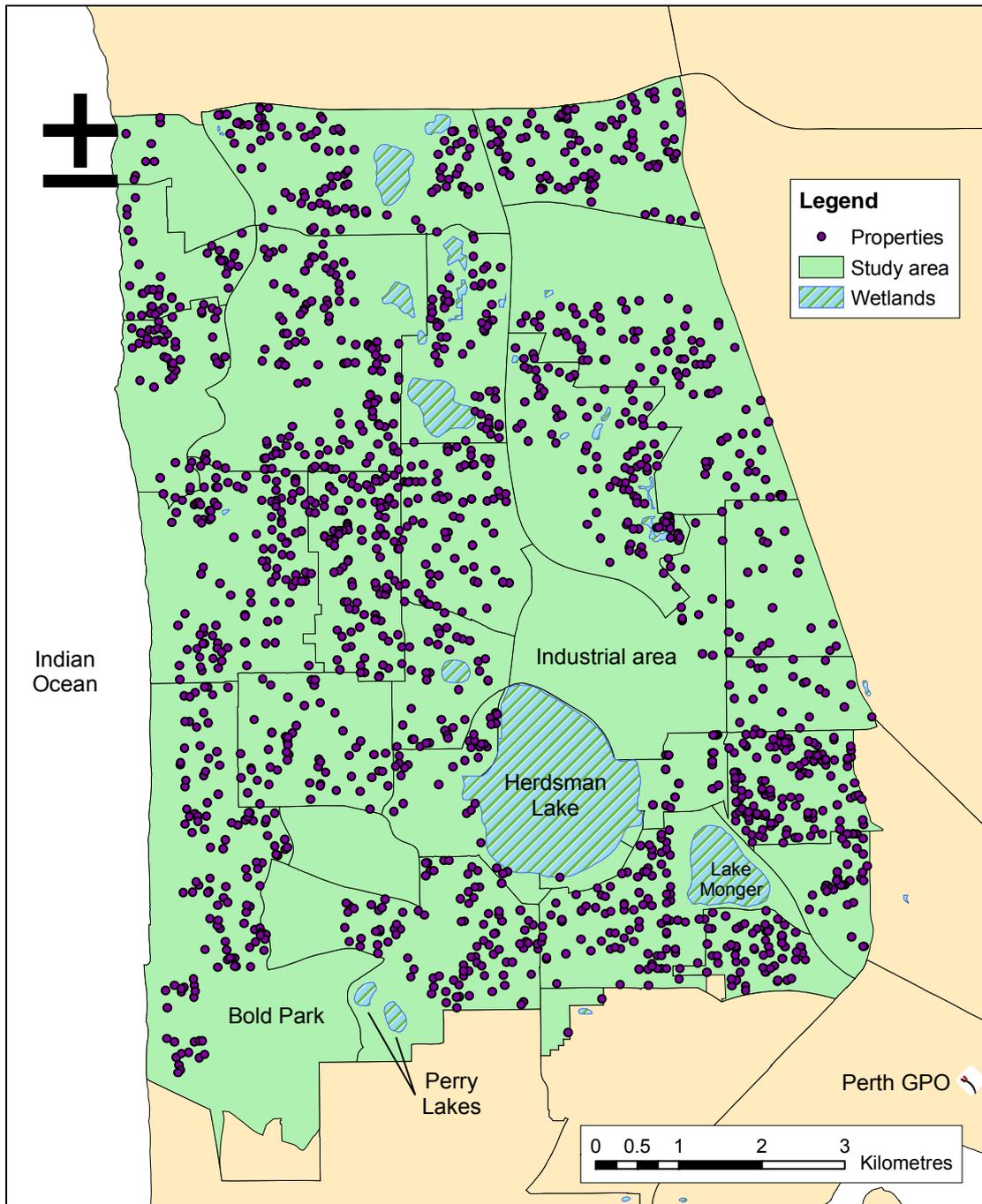
Figure 1. The study area, showing the location of properties sold during the study period, wetlands and suburb boundaries.

Table 1. Model variables with their descriptions and statistics.

Variable	Description	Mean	S.D.	Min	Max
Dependent variable					
ADJSALE	House sales price in AU$ adjusted to June 2006 value	794,922	418,156	95,130	4,960,857
Structural attributes					
AREA	Total land area or lot size in square metres	704	279	91	8,498
BED	Number of bedrooms	3.16	0.85	1	6
BATH	Number of bathrooms	1.45	0.65	1	5
STUDY	Number of studies	0.21	0.42	0	2
CARPARK	Number of parking spaces in garage or carport	0.65	0.78	0	4
DINING	Number of dining rooms	0.64	0.49	0	2
GAME	Number of games rooms	0.15	0.36	0	2
AGE	Age of the house in years	39.42	22.26	1	106
ROOF	Dummy variable for tiled roofing (1 if tiled, 0 otherwise)	0.84	0.37	0	1
Neighbourhood attributes					
DBEACH	Distance in metres to beach	4,074.76	2,402.60	93.80	8,667.50
DSCHOOL	Distance in metres to nearest primary or secondary school	572.64	281.19	41	1,803.80
DCITY	Distance in metres to city GPO	8,828.44	3,131.24	2,064.90	15,309.70
DFWY	Distance in metres to nearest freeway entrance	2,197.48	1,431.26	117	7,164.60
ELEV	Elevation of property above sea level in metres AHD	26.14	12.18	4.30	71.40
MEDINC	Median weekly household income of suburb in AU$	829.76	170.36	650	1,125.86
Wetland attributes					
DWETLAND	Distance in metres to the edge of the wetland nearest the property	943.35	637.27	2.30	3,244.90
NUMWET	Number of wetlands within 1.5 km of property	2.37	2.36	0	12

The dependent variable of the hedonic price function is the actual sales price of houses recorded. Due to recent rapid increase in demand for houses in the Perth metropolitan area from the mining boom in Western Australia, Perth property prices have experienced significant growth over a short period of time. To adjust for market growth over time, sale prices in this study were adjusted by the market growth index from Landgate to a June 2006 value[1]. The average adjusted sales price was AU$794,922. Actual sales prices are preferred over other forms of prices such as assessed, appraised, or census tract estimates because actual sales more closely reflect the equilibrium market price (Mahan *et al.*, 2000).

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[1] Except for the suburbs of Jolimont and Leederville, for which Landgate growth index data were unavailable. For these suburbs, the market growth index from the Real Estate Institute of Western Australia (REIWA, 2006) was used to make the adjustment.

For each property sale there is a set of attributes associated with the property which help to explain the sales price. We have classified the attributes into structural, neighbourhood and wetland categories as seen in Table 1. Note that we have included in this table only those variables that were found to have a significant effect on sales price.

A geographic information system (GIS) and a mathematical software package were employed to process the spatial data for the hedonic model. The distance to the nearest wetland was defined as the distance measured from the centroid of the property lot to the edge of the nearest wetland. Distance to points of interest, such as neighbourhood parks, train stations, shops and golf courses, were calculated using the distance measured from the centroid of the property lot to the centroid of the point of interest, instead of the edge. Suburb median income levels were included as a proxy for neighbourhood wealth. Distance and other spatial data forming the neighbourhood and wetland attributes for each property were attached to the property sales record.

The explanatory variables were checked for missing observations or unrealistic values, such as, houses with 0 bedrooms or bathrooms, and sales values that were unusually high or low. A total of 1,741 observations of house sales was used for the analysis.

2.3. Estimation Method

The statistical/economic software package was used to perform a least squares regression to estimate the hedonic price function. The Box-Cox regression procedure indicated that a log-linear functional form would best fit the data. Consequently, the general specification of the regression equation was:

$$\ln ADJSALE_i = \beta_0 + \sum \beta_j S_{ji} + \sum \beta_k N_{ki} + \sum \beta_l W_{li} + \varepsilon_i \qquad (1)$$

for $i = 1, 2, \ldots n$ and where

$\ln ADJSALE_i$	is the natural logarithm of the sales price of house i
β	are the various regression coefficients
S_{ji}	is the jth structural variable for house i
N_{ki}	is the kth neighbourhood variable for house i
W_{li}	is the lth wetland variable for house i
ε_i	is the error term for house i, with $E(\varepsilon) = 0$ and $V(\varepsilon) = \sigma^2 > 0$.

A step-wise regression approach was used to select variables with statistical significance and a variance inflation factor (VIF) of less than 10. The approach is iterative and starts with an initial list of candidate explanatory variables in linear form on the right hand side of equation (1). The right hand side is then modified in several ways: excluding variables found not to have a significant effect on the sales price; including additional candidate variables and testing them for significance; and modifying the functional form of the explanatory variables. Different functional forms are suggested by inspecting scatter plots of the variables and reviewing equation forms used in previous hedonic studies.

During the regression development, a larger set of structural, neighbourhood and wetland attributes than those listed in Table 1 was included in the intermediate models. Structural attributes such as the type of wall material and numbers of family rooms, meal areas and tennis courts, were not significant. Neighbourhood variables capturing the closest distance to different classes of points of interests, namely preschools, TAFEs and universities, parks (that do not have wetlands), golf courses, train stations and commercial areas, were likewise dropped from the model as they were found to be insignificant or collinear with other variables. Several additional wetland attributes were also considered for inclusion in equation (1). For instance, the

distances to two iconic local lakes, Herdsman Lake and Lake Monger (Figure 1), were included in the model to determine whether there is any preference to live near these two particular lakes. It was found that these variables were not significant, and hence they were dropped. Similarly, the size of the nearest wetland in hectares was also in an earlier version of the model, but this variable was also dropped due to insignificance.

In the final form of the hedonic pricing function, most right hand side variables appear in a linear form, but there are some exceptions. Land area (*AREA*) appears as both linear and squared terms. The number of bedrooms (*BED*) and elevation (*ELEV*) appear only as squared terms. It is helpful to define additional variables that reflect these dependencies: $AREA2 = AREA^2$, *BED2* $= BED^2$ and $ELEV2 = ELEV^2$. The distance to the beach and the nearest wetland were found to have more complicated forms as discussed below.

Various inverse relationships between sales and the distance to the beach (*DBEACH*) were explored. The best form found for *DBEACH* used both linear and inverse power law terms:

$$\ln ADJSALE_i = \ldots + \beta_{DBEACH}.DBEACH_i + \beta_{INVBCH} \cdot \frac{1}{DBEACH_i^{\gamma}} + \ldots \qquad (2)$$

This form of *DBEACH* dependence allows *ADJSALE* to diminish with distance quite rapidly when close to the beach and to decrease at a slower rate when further away. The form is motivated by the expectation that a property very close to the beach, and possibly with beach views, will have a much higher sales price than a property slightly further away lacking a beach view. The exponent γ was found by running a series of regressions in STATA using do loops for different values of γ ranging from 0.01 to 1.00. The value of γ that gave the smallest root mean square error (RMSE) was chosen. The best fit occurred for $\gamma = 0.48$. For convenience, a new variable $INVBCH = 1/(BEACH^{\gamma})$ was defined, so that equation (2) becomes linear in *DBEACH* and *INVBCH*.

A number of forms for the distance to the nearest wetland (*DWETLAND*) were also tested. The best fit occurred with:

$$\ln ADJSALE_i = \ldots + \beta_{DWETLAND}.DWETLAND_i + \beta_{INVWET} \cdot \frac{1}{\alpha + DWETLAND_i} + \ldots$$

$$(3)$$

The shifted inverse relationship provides a gradual downward sloping curve suited to our *a priori* expectation that as distance to wetland increases, property price decreases but at a slowing rate. A non-zero value of α in equation (3) allows the curve to intersect the y-axis instead of increasing to infinity, that is, *ADJSALE* remains bounded as *DWETLAND* approaches zero. Values of α in the range 5 to 500 were tested using a do loop, with the best fit occurring for $\alpha = 275$. The values of α and γ were determined concurrently using nested do loops. As above, it is convenient to define a new variable $INVWET = 1/(\alpha+DWETLAND)$, and then equation (3) becomes linear in *DWETLAND* and *INVWET*.

By combining the existing explanatory variables in Table 1 with the newly defined variables, *AREA2*, *BED2*, *ELEV2*, *INVBCH* and *INVWET*, the hedonic pricing function can be written in the strictly log-linear form of equation (1).

3. Results and Discussion of the Analysis

3.1. Hedonic Price Function

The Breusch-Pagan test was applied to the regression equation and found significant evidence of heteroskedasticity at the 5% level. A robust regression estimate was therefore performed to deal with this property. The final regression coefficients β in equation (1) and regression statistics are presented in Table 2. All the variables included in the model were significant at the

1% or 5% levels except for *DFWY* (distance to the nearest freeway entrance) which was significant at the 10% level.

Table 2. Regression results

Variable	Coefficient	Std. Err.	T - ratio	95% C.I. on Coefficient	
AREA	4.83E-04[††]	3.70E-05	13.06	4.10E-04	5.55E-04
AREA2	-1.97E-08[††]	4.05E-09	-4.86	-2.76E-08	-1.17E-08
BED2	8.79E-03[††]	1.23E-03	7.15	6.38E-03	1.12E-02
BATH	9.20E-02[††]	1.13E-02	8.16	6.99E-02	1.14E-01
STUDY	7.87E-02[††]	1.44E-02	5.46	5.04E-02	1.07E-01
CARPARK	-2.11E-02[††]	6.82E-03	-3.1	-3.45E-02	-7.74E-03
DINING	-0.039671[††]	0.0125338	-3.17	-0.064254	-0.0150878
GAME	0.0381667[†]	0.0150296	2.54	8.69E-03	0.0676448
AGE	-1.35E-03[††]	3.83E-04	-3.52	-2.10E-03	-5.96E-04
ROOF	-6.19E-02[††]	1.60E-02	-3.88	-9.32E-02	-3.06E-02
DBEACH	-4.21E-05[††]	5.32E-06	-7.91	-0.0000525	-0.0000317
INVBCH	17.73623[††]	7.88E-01	22.51	16.19096	19.28149
DSCHOOL	0.0000717[††]	2.20E-05	3.26	2.85E-05	0.0001149
DCITY	-8.23E-05[††]	2.94E-06	-28.02	-0.0000881	-0.0000765
DFWY	1.63E-05	9.43E-06	1.73	-2.17E-06	3.48E-05
ELEV2	0.000104[††]	7.79E-06	13.34	0.0000887	0.0001193
MEDINC	2.80E-04[††]	4.68E-05	5.97	1.88E-04	3.71E-04
DWETLAND	0.0000584[††]	0.0000191	3.05	0.0000209	0.0000959
INVWET	1.73E+02[††]	1.82E+01	9.48	1.37E+02	2.09E+02
NUMWET	7.65E-03[†]	3.22E-03	2.38	1.34E-03	1.40E-02
CONSTANT	12.88491	0.0780702	165.04	12.73179	13.03804

Adj. R-squared	0.7264		Additional parameter values:	
Root MSE	0.2194		α = 275	
n = 1741			γ = 0.48	

[†] significant at the 5% level
[††] significant at the 1% level

The area of the land, the number of bedrooms, bathrooms, studies, car parking spaces (garage and carport combined), dining rooms and game rooms, the age of house and type of roofing material were all found to have a significant influence on sales prices. Tiled roofs were not preferred over other types of roofing, such as metal, iron and aluminium, as indicated by the negative sign of the *ROOF* coefficient. Extra bedrooms, bathrooms, studies and game rooms all increased sales prices. Counter-intuitively, extra car parking spaces and dining rooms were found to negatively influence sales. Older houses sold for less than newer houses as the coefficient of *AGE* was negative.

As expected, sales price was negatively related to the distance to the beach, as captured in *DBEACH* and *INVBCH*, and both variables were significant at the 1% level. The coefficients of the distances to the nearest primary or secondary school and freeway entrance were both positive. The positive relationship implies that the further the property is from these places, the higher the sale price. This may appear counter-intuitive as one would expect being near schools and freeways would allow easy access and convenience therefore should be increasing property prices. A similar effect has been found in Mahan *et al.* (2000) regarding the negative

effect of living near commercial zones due to congestion and noise. Schools and freeway entrances pose similar problems particularly to properties with very close proximity, i.e. those that are next door to schools or freeway entrances. However, the relationship may not be linear, as houses that are relatively close to schools and freeway entrances but are far enough to be removed from congestion and noise may have higher values than properties that are much further away. It was found that both proximity to the city and elevation increased sales price as expected. This concurs with the findings of Mahan *et al.* (2000). The positive coefficient for *MEDINC*, a proxy for socio-economic status of the suburb, indicates that houses gain value simply by being located in suburbs where people with higher socio-economic background prefer to live, or the so called "rich suburbs".

The effect of wetland proximity on sales price appears through three variables: *DWETLAND*, *INVWET* and *NUMWET*. The coefficients of *DWETLAND* and the inverse distance variable *INVWET* = 1/(α+*DWETLAND*) are both positive. Figure 2 shows the net effect of distance to the nearest wetland, combining the effects of *DWETLAND* and *INVWET*, on sales price. The significant negative relationship between distance to urban wetlands and sales price was also found by Lupi *et al.* (1991); Doss and Taff (1996); and Mahan *et al.* (2000). There was a rapid decline in value in the first few hundred metres from the wetland edge, which is possibly related to views, the amenity value of wetland frontage and/or convenience of easy walking access to the wetland. The value continued to fall, but at a slowing rate, with increasing distance until a minimum sales price was reached at around 1.5 km from the wetland. Beyond about 1.5 km, the slope levelled off, which means that distance to wetland no longer had an impact on sales price[2]. Notice at the tail of the curve, around 2.5 – 3.3 km, the slope showed a very slight positive increase. Whilst this price effect seems counter-intuitive, it is only a very small effect (only 2% of the sample was located in this distance range) and should not affect the analysis. The variable *NUMWET* accounts not for the distance to the *nearest* wetland, but the *number* of wetlands near a property. It had a positive coefficient, meaning that being close (within 1.5 km) to multiple wetlands further increased property values.
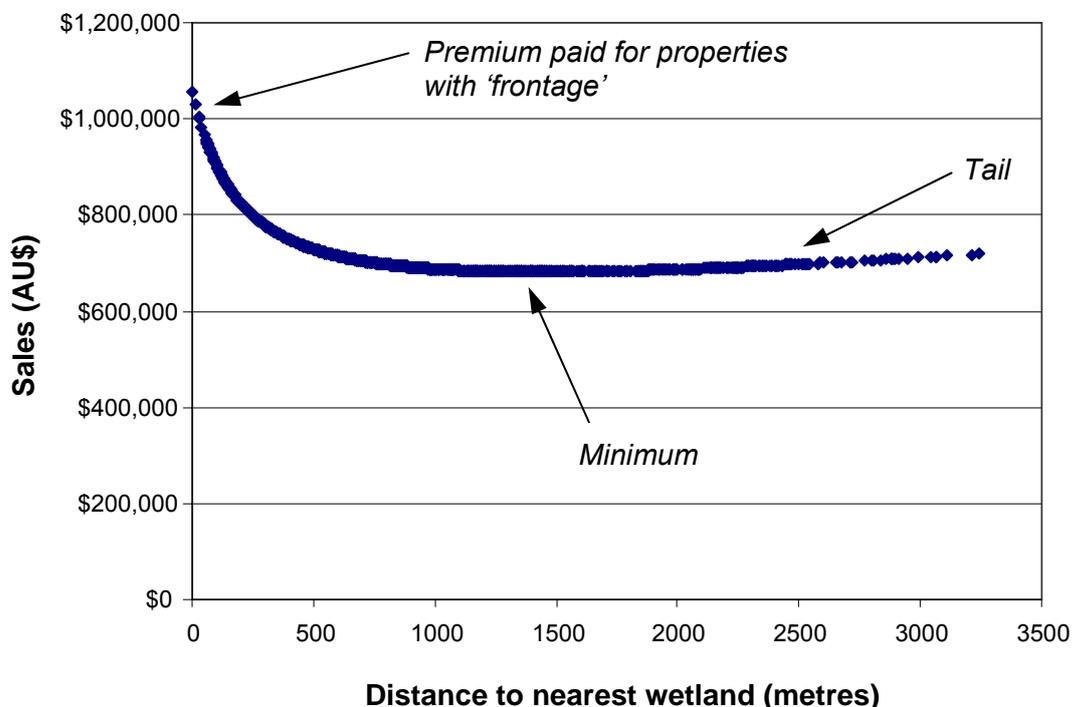

Figure 2. The effect of distance to the nearest wetland on the estimated sales price, holding all other variables constant at their average values for the study area.

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[2] Within the range 1.5 – 2.5 km, the slope was not significantly different from zero at the 95% confidence level.

The combined effect of the proximity to the beach and the nearest wetland on the expected sales price is shown in Figure 3. Being located a certain distance, say 500 metres, from the beach had a much greater effect on price than being the same distance from the nearest wetland. However, for properties close to the beach, also having a nearby wetlands increased the price dramatically.
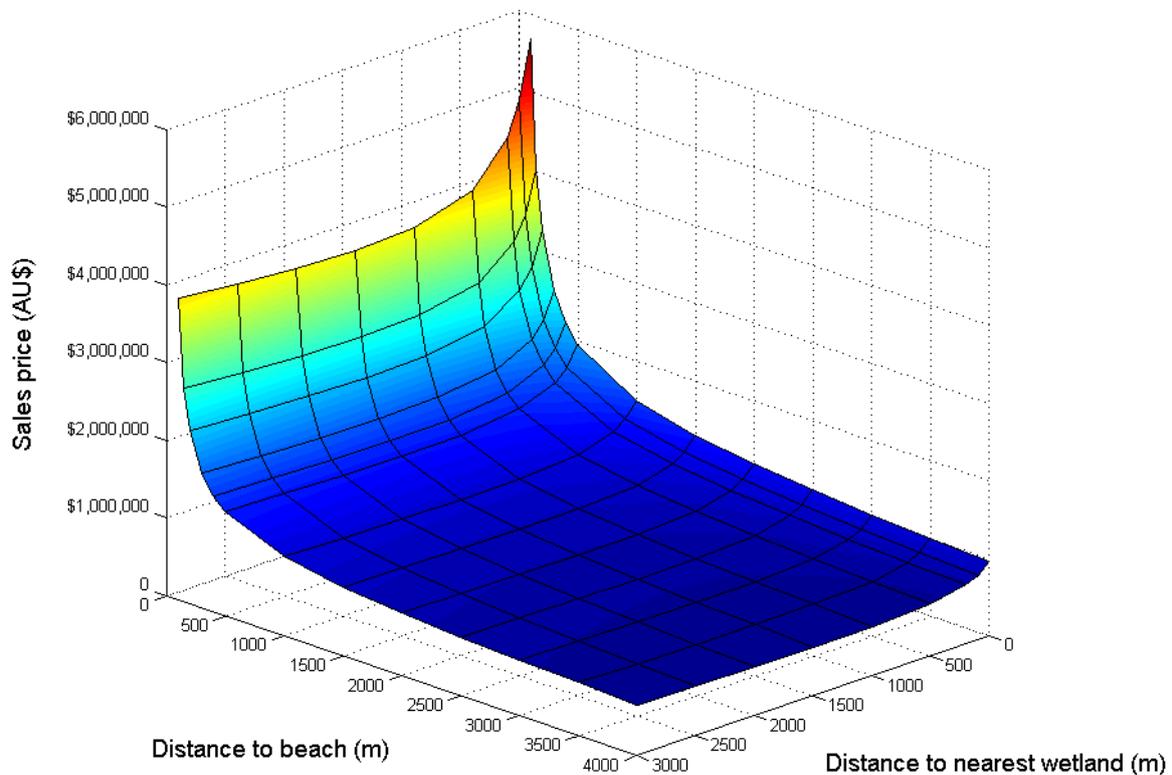

Figure 3. The effect of proximity to the beach and wetlands on the estimated sales price, holding all other variables constant at their average values for the study area.

It is noteworthy that the distance to the nearest park was not a significant explanatory variable for the house sales price (Section 2.3). This was surprising as it might be expected that proximity to a park would attract a premium. There are a number of possible explanations. We did not distinguish between types of parks, which range between local neighbourhood parks that are small and numerous, and larger tracts of greenspace that include active and passive recreational amenity. Moreover, the distance to park data were calculated using the park's centroid rather than the more correct polygon data for the park boundaries, and this contributes to inaccuracies in the calculated distance, particularly for large parks. This preliminary result, that there is no amenity value for parks, implies that if a neighbourhood wetland were to dry up and leave a passive greenspace in its place, then the total premium of the amenity of the wetland would be lost, because there is no value associated with the greenspace left behind. However, more detailed analysis of the value of parks and public greenspace may be required in order to properly compare the values of public open space attributes, including wetlands and alternative landscapes.

3.2. Marginal Implicit Prices and Elasticities

From the hedonic property price function estimated in (1), the partial derivative with respect to any of the variables (i.e. property characteristic) gives the marginal implicit price (MIP) of that characteristic. In other words a MIP is the additional amount that must be paid by any purchaser to move to a property with a better level of a particular characteristic while other things are held equal. For example, if two houses have similar characteristics, except for one is closer to the beach than the other, the one closer to the beach will be more expensive as there is a MIP associated with being closer to the beach. Table 3 reports marginal implicit prices for the model variables. This allows one to estimate, for example, that an extra bedroom will increase the average house price by AU$86,195, holding every other characteristic equal. Also shown in Table 3 are the elasticities of the sales price with respect to the model variables. Elasticity is defined as the percentage change in the sales price for a unit change in the model variable under consideration. Note that Table 3 includes only the original variables from Table 1; however, the effect of the new variables defined in Section 2.3 has been properly accounted for. For instance, the MIP reported for *DBEACH* in Table 3 includes contributions due to both *DBEACH* and *INVBCH*.

Table 3. Marginal implicit prices and elasticities of structural, neighbourhood and wetland variables.

Variable[3]	MIP at the mean of ADJSALE (AU$)	Elasticity at the mean of ADJSALE (%)
AREA	344.43	0.043
BED	86195.57	10.8
BATH	73163.95	9.20
STUDY	62538.95	7.87
CARPARK	-16786.84	-2.11
DINING	-31535.26	-3.97
GAME	30339.54	3.82
AGE	-1071.40	-0.13
ROOF	-49210.42	-6.19
DBEACH	-133.13	-0.017
DSCHOOL	57.00	0.0072
DCITY	-65.42	-0.0082
DFWY	12.96	0.0016
ELEV	9137.41	1.15
MEDINC	222.18	0.028
DWETLAND	-829.39	-0.10
NUMWET	6081.71	0.77

In graphical terms, the marginal implicit price for the distance to the nearest wetland is the slope of the curve in Figure 2. Very close to the wetland, the MIP is highly negative, meaning that the impact on property price from moving away from the wetland is quite high. The MIP then

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[3] For variables with a non-linear effect in the hedonic equation (*AREA*, *BED*, *DBEACH*, *ELEV* and *DWETLAND*), MIP and elasticity depend not only on *ADJSALE*, but on the value of the variable of interest. In calculating MIP and elasticity, the variable of interest was set to the value that predicts the mean *ADJSALE* when all the other original variables are set to their means (Table 1).

approaches zero at around 1.5 km. The MIP reported in Table 3 for *DWETLAND* was evaluated at a distance of 120 metres, which is the distance that corresponds to the mean sales price when all other original variables take on their mean values given in Table 1. At this distance from the wetland, a property will experience a reduction in sales price of approximately AU$829 if the property were to be one metre further away from the wetland. Since the average property price in the study area is around $790,000, moving 1 metre away from the wetland will reduce the property price by 0.1%, which is the elasticity. Assuming that adjacent properties are separated by about 25 metres on average, this means that an average property located 120 metres from a wetland is worth around AU$20,000 more than its neighbour positioned 25 metres further away. From the results for *NUMWET*, it can be stated that if there is more than one wetland within 1.5 km of a property, the presence of a second wetland will increase the property price by AU$6,081, or 0.77%, as households have more options as to which wetland they can easily visit. Contrary to Lupi *et al.* (1991); Doss and Taff (1996); and Mahan *et al.* (2000), we did not find any significant relationship between sales price and size of wetland.

3.3. Total Wetland Premium

Another way the hedonic price function, equation (1), can be used is to estimate the total premium in sales price due to wetland proximity, P_T. Essentially, P_T is the integral with respect to land area of the product of the sales price premium and the housing density. The integral is evaluated within an annular *premium zone* surrounding the wetland of interest, which we assume to extend from the edge of the wetland out to a distance corresponding to the minimum in the price – wetland distance curve in Figure 2, which is about 1.5 km. To gain an appreciation for the premium calculation, it is helpful to consider a simplified case, namely an isolated circular wetland surrounded by housing of uniform density as shown in Figure 4. With these assumptions, the total premium due to a wetland can be estimated by:

$$P_T(R) = \int_R^{R^*} P(r).n.2\pi r.dr \qquad (4)$$

where

R $= (A/\pi)^{1/2}$ is the effective radius of a wetland of area A

R^* is the radius at the outer edge of the premium zone

$P(r)$ $= (ADJSALE|_r - ADJSALE|_{r=R^*})$ is the sales price premium at radius r, that is, the difference between the sales price of a property at radius r and the sales price of a property having identical attributes except that it is with located at the edge of the premium zone, that is, at $r = R^*$; other distance attributes being assumed to remain unchanged

n $\neq n(r)$ is the housing density, defined as the number of houses per unit land area

The edge of the premium zone, located at the minimum in the price–wetland distance curve (Figure 2), may be found from equation (1) by setting $\partial ADJSALE / \partial r = 0$, which yields:

$$R^* = R - \alpha + \sqrt{\beta_{INVWET} / \beta_{DWETLAND}} \qquad (5)$$

By substituting values in equation (5), it may be seen that the edge of the premium zone occurs at a distance $D^* = (R^* - R) = 1446$ metres, or about 1.5 km from the edge of a wetland as observed from Figure 2. Note that the edge of the premium zone was always located at this distance, irrespective of the size of the wetland or the values of any of the explanatory variables in the hedonic price function. However, the size of the premium zone, measured in terms of area, increased as the size of the wetland increased.

The housing density values, *n*, can be determined from GIS analysis of the study region, by counting the number of all residential properties, not only those sold during the study period, located within the premium zone of each wetland then dividing by the area of the premium zone,

excluding the area of the wetland itself. The median, lower and upper quartile values of n were found to be 5.3, 4.5 and 6.6 properties per hectare, respectively. Note that n is less than the reciprocal of the land area for each property (1/$AREA$) because, while n includes the property land area, it also includes the area of nearby roads and verges, any parkland surrounding the wetland, and the area of any other features, such as schools and shopping centres, within the premium zone.
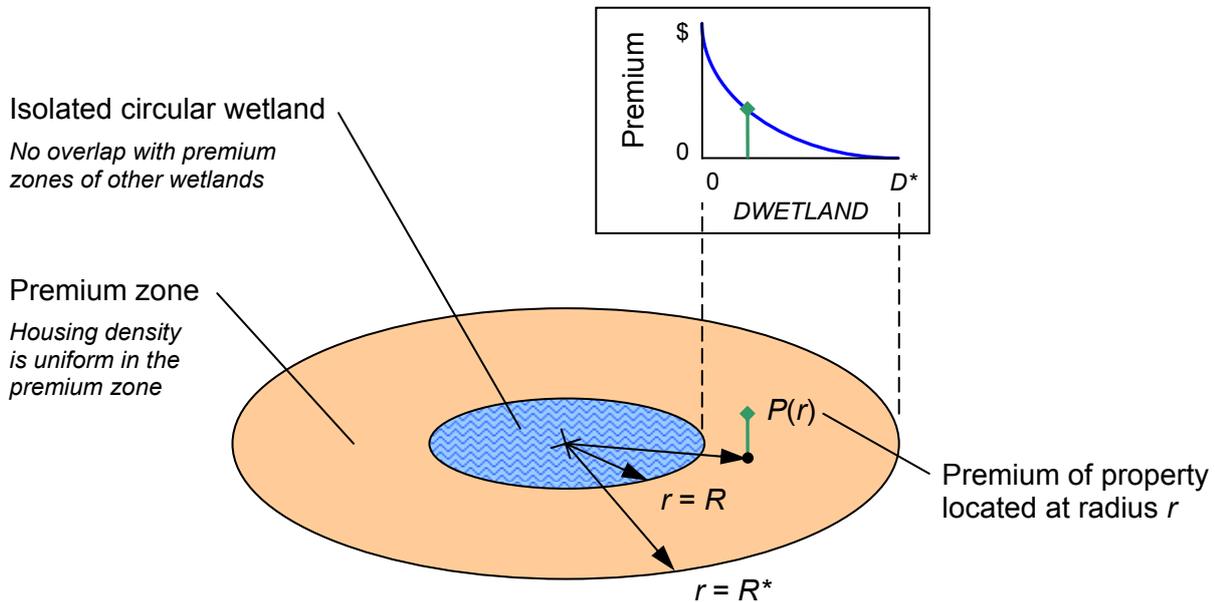

Figure 4. Spatial arrangement used to calculate the total wetland premium for an isolated circular wetland surrounded by houses with a uniform density.

The total premium was estimated by substituting equations (1) and (5) into equation (4) and performing the integration. While this integral does not have an analytical solution, it is readily evaluated by numerical methods.

Figure 5 shows how the total premium due to the presence of a wetland changed with wetland size and housing density, assuming all other explanatory variables remained at their mean values. As wetland size increased, the total premium increased due to two effects: an increase in the area of the premium zone and an increase in the number of properties very close to the wetland (frontage), which is related to the wetland perimeter. Even small wetlands contribute a large premium to their neighbourhood. The total premium in sales price for a 20 hectare wetland, which is approximately the mean size of wetlands in the study area, was approximately AU$140 million. For a wetland the size of Lake Monger (Figure 1), about 70 hectares, the premium was about AU$200 million. As seen in equation (4), the total premium is directly proportional to the housing density n, so increasing the density by 10% increased the total premium by 10%. However, the calculations behind Figure 4 do not take into account any change in the $AREA$ variable for each property, so the change in total premium with n shown in the figure will likely be smaller in reality. The values in Figure 5 should be treated as indicative only, because they apply for a hypothetical case of an isolated circular wetland surrounded by houses at the median housing density that have all other attributes at the mean values found in the study (Table 1). However, in Section 4 the total premium calculation is applied to a particular set of wetlands in the study area and these simplifying assumptions were not used.
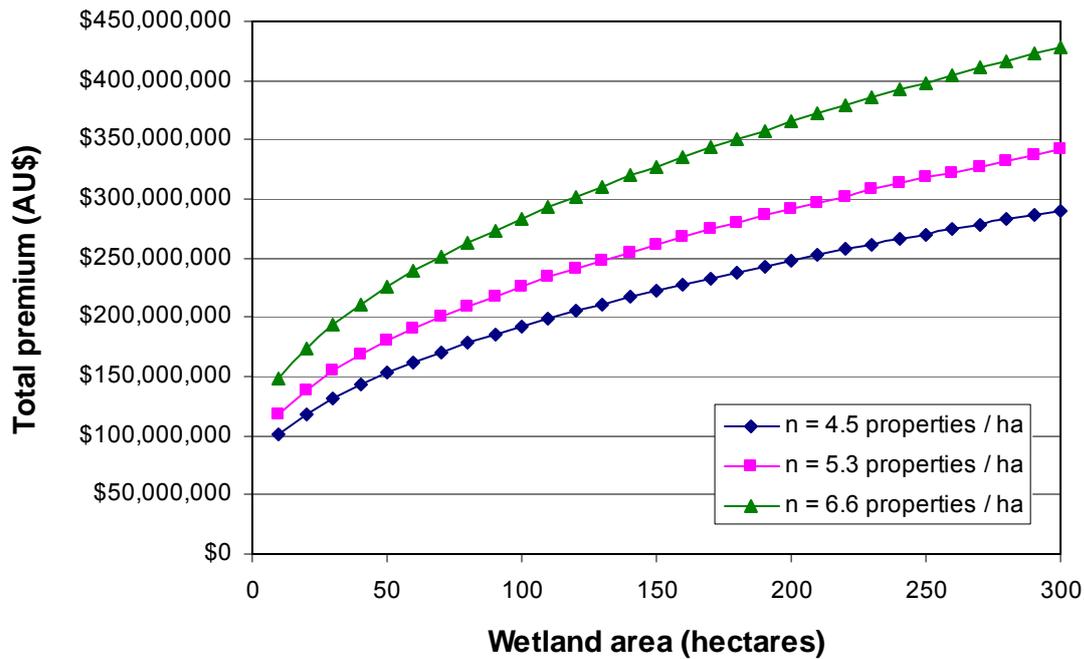
Figure 5. Total premium in sales price due to wetland proximity as a function of wetland size for lower quartile, median and upper quartile housing densities.

It should also be noted that this total premium is likely to underestimate the social willingness-to-pay for the wetland for a number of reasons. Firstly, it only includes the values associated with direct use values, and does not consider other values associated with the wetland that might be held in society more generally, such as the provision of habitat for migratory birds. Secondly, while it is an indication of amenity value it may not include the consumer surplus enjoyed by residents. However, the premium that we have estimated does provide an indicator of the possible loss to the capitalized amenity value of properties near the wetlands, if the wetland were to disappear, due to a fall in the groundwater table for instance. It should also be noted that the estimated value of wetland premium is only a snapshot in time. If in the future preferences for living near wetlands remained favourable then, as property prices increase, the estimated capitalized value of wetlands will increase as well. The prediction of future wetland values or the loss of consumer surplus due to the disappearance of wetlands can be estimated using a second stage hedonic analysis.

4. Case Study: Perry Lakes Development

4.1. Background and Motivation

East and West Perry Lakes are located in southern edge of the study area in the suburb of Floreat (Figure 1). The lakes are the main feature of the Perry Lakes Reserve which is just east of Bold Park, the largest patch of remnant bushland in the Perth metropolitan area. Immediately to the west of the reserve lies the Perry Lakes Stadium complex. In an attempt to slow declining lake water levels, groundwater has been pumped into the lakes since 1993. Increasing amounts of groundwater are needed to maintain even the current small areas of open water during summer. Perry Lakes provide a habitat for various bird species and other fauna, as well as providing aboriginal heritage, European heritage, recreational and educational social values (Beckwith Environmental Planning, 2006).

There are plans to redevelop the 16 hectare Perry Lakes Stadium site for housing (LandCorp, 2006). CSIRO has been involved in the investigations into the possibility of using treated

wastewater, from the nearby Subiaco Waste Water Treatment Plant, to recharge the aquifer down-gradient of the lakes to thereby maintain water levels in the Perry Lakes (McFarlane *et al.*, 2007). In this section we apply the hedonic pricing model to estimate the economic value of having water in Perry Lakes.

The new development is envisaged to be a 'high quality residential development' comprising some 350 to 400 dwellings (LandCorp, 2006). It is planned to incorporate 'a diverse range of housing types… ranging in height from 2 storeys on the north and eastern perimeter through to 5 storeys in the south west quadrant' with 'a mix of unit sizes'.

4.2. Modified Total Premium Calculation

This case study demonstrates some of the factors that need to be considered to adapt the total premium calculation to particular wetlands of interest. In particular, the differences between the Perry Lakes case study and the hypothetical case considered in Section 3.3 are given below. The Perry Lakes region is illustrated in Figure 6.

1. The Perry Lakes are not a single circular wetland, but a pair of adjacent, roughly oval-shaped wetlands.

2. They are not distant (isolated) from other wetlands: the premium zones of the Perry Lakes overlap the premium zones of several nearby wetlands as shown in Figure 6: Herdsman Lake, the Mabel Talbot Park wetland, Lake Jualbup and Lake Claremont. All of these wetlands are increasingly drying out due to lower than average winter rainfall and the extraction of groundwater for irrigating private and public greenspace.

3. The premium zone surrounding Perry Lakes is not completely filled with houses of uniform density—it contains non-residential areas, including: parklands (notably Bold Park and Perry Lakes Reserve), part of a golf complex, other sporting facilities (Floreat Oval, UWA Sports Park, Challenge Stadium, etc.), schools, a medium size shopping centre (Floreat Forum), and other facilities (UWA Field Station, CSIRO Laboratories, Subiaco Waste Water Treatment Plant, etc.).

4. The attributes of properties within the Perry Lakes premium zone do not have the same values—there is a distribution of attribute values, for example, properties in the western part of the premium zone have a higher elevation and a lower distance to the beach than those in the eastern part; properties in the suburb of Floreat (north and east of Perry Lakes) are on average older than those in other suburbs within the premium zone.

5. Although the exact breakdown is not known, a mixture of dwelling types is planned for the new development in the Perry Lakes Stadium site; however the hedonic analysis used data on houses only.
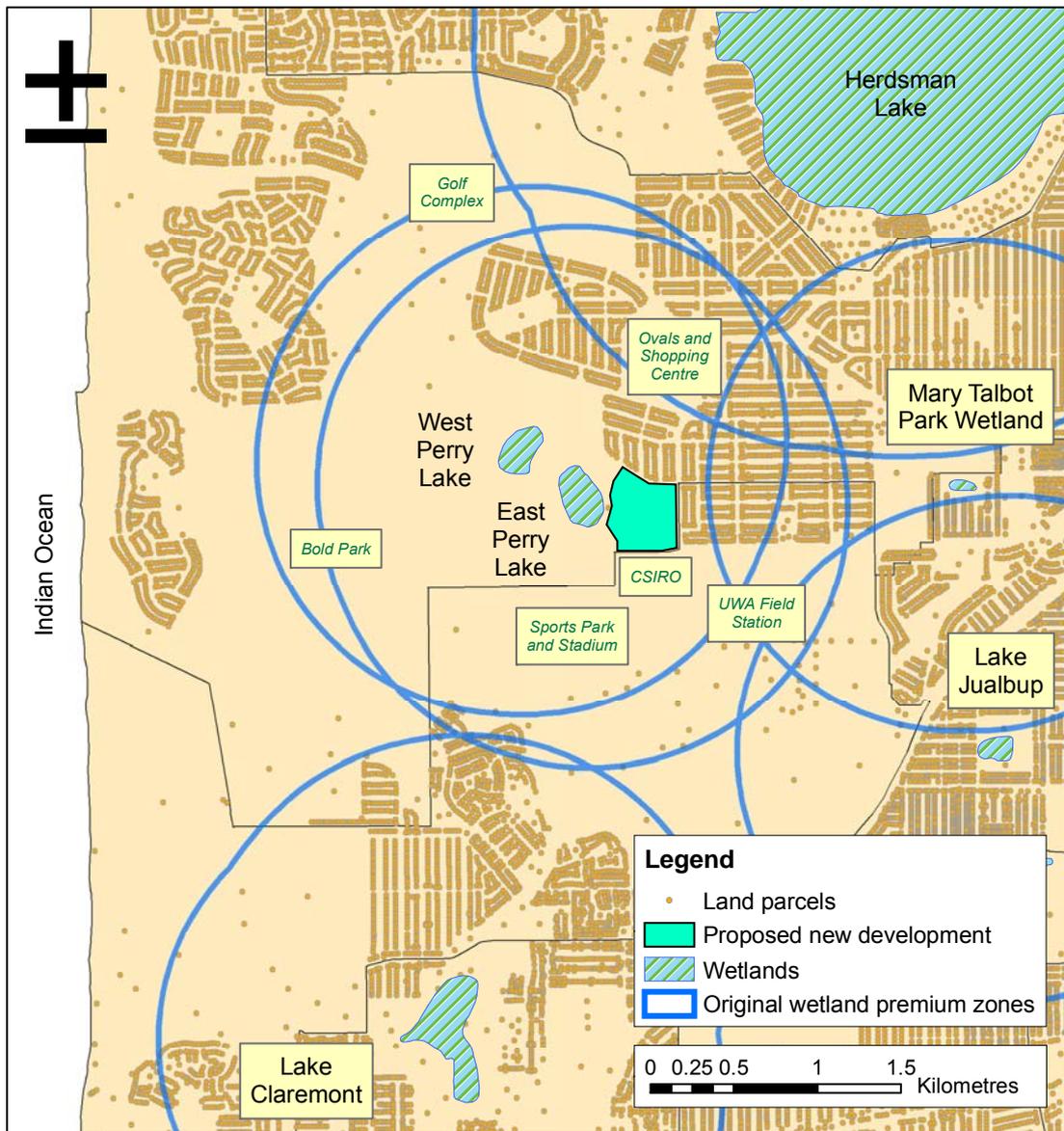
Figure 6. Perry Lakes region, showing existing land parcels (both residential and non-residential), the proposed new development site, wetlands and the original (unmodified) wetland premium zones.

Although the total premium calculated for Perry Lakes followed the spirit of equation (4), the details of the method were different:

a. Actual boundary coordinates (GIS polygon data) obtained from the WA Department of Water of the East and West Perry Lakes were used to address point 1 above. Currently there is less water in the Lakes than corresponding to these boundaries.

b. To deal with point 2, the definition of premium zone for Perry Lakes was modified. Properties are within the *modified premium zone* if they lay within 1446 metres of the edge of East or West Perry Lake *and* the closest wetland was either of the Perry Lakes. This means, for example, that a property that lay 1300 metres from the edge of one of the Perry Lakes and 1000 metres from the edge of Herdsman Lake was *not* considered to be in the Perry Lakes premium zone, rather it would be in the Herdsman Lake premium zone.

c. The third point is addressed by using Landgate data (GIS point data) was to distinguish land parcels in the modified premium zone that were residential from those that were

non-residential. Only the residential land parcels counted towards the wetland premium calculation.

d. Point 4 above was handled by using suburb average data for the structural attributes and calculating individual neighbourhood attribute (*DBEACH*, *DCITY*, *ELEV*, etc.) and wetland attribute (*DWETLAND*, *NUMWET*, etc.) values for each residential property within the modified premium zone.

e. It was not possible to address point 5 adequately, because the data used in the analysis was restricted to houses only. This matter is discussed in Section 4.3.

In contrast with equation (4), the total premium for the Perry Lakes was estimated by:

$$P_{T\ Perry\ Lakes} = \sum_{i \in Z} P_i \qquad (6)$$

where

P_i = ($ADJSALE_i - ADJSALE_i^{No\ Perry\ Lakes}$) is the sales price premium of property *i*, that is, the difference between the sales price of property *i* evaluated as if both Perry Lakes contained water and the sales price of the same property for the situation where neither Perry Lake contained water

Z is the set of properties in the modified premium zone, that is, residential properties for which the closest wetland is either Perry Lake and for which the distance to either Lake is 1446 metres or less

Note that $ADJSALE_i^{No\ Perry\ Lakes}$ was calculated by removing the two Perry Lakes from the wetlands data file. This influences the values of the variables *DWETLAND*, *INVWET* and *NUMWET* in the hedonic price function, equation (1). Essentially, this is equivalent to replacing the open water bodies with plain parkland that, according to the analysis presented in Section 2.3, does not significantly influence the house sales price.

Items a–e above are typical of the considerations needed for using the hedonic pricing function to value particular wetlands.

4.3. Results and Discussion

Wetland premiums due to the presence of the Perry Lakes were estimated for two cases: existing residential properties and properties proposed for the new Perry Lakes development site. Over 90% of the existing residences in the premium zone are houses, rather than another dwelling type such as units or flats, hence it is expected that using our hedonic price function, which is based on house data, will provide a good estimate for the wetland premium for existing properties. However, the new development will incorporate a diversity of dwelling types and sizes (LandCorp, 2006). Clearly, the dwelling mix proposed for the new development is more varied than the house data on which the hedonic analysis was based. Consequently, the true value that Perry Lakes will contribute to the new development cannot be estimated from the current analysis. It is possible, however, to estimate a value *on the basis that houses occupied the new development area*. To this end, it was assumed that houses were located on a regular grid within the new development area at the same density as they appear in the existing blocks immediately to the east of the development site (9.3 properties / hectare). Figure 7 shows the existing residential properties and the properties assumed to be located in the new development in the modified premium zone around the Perry Lakes.
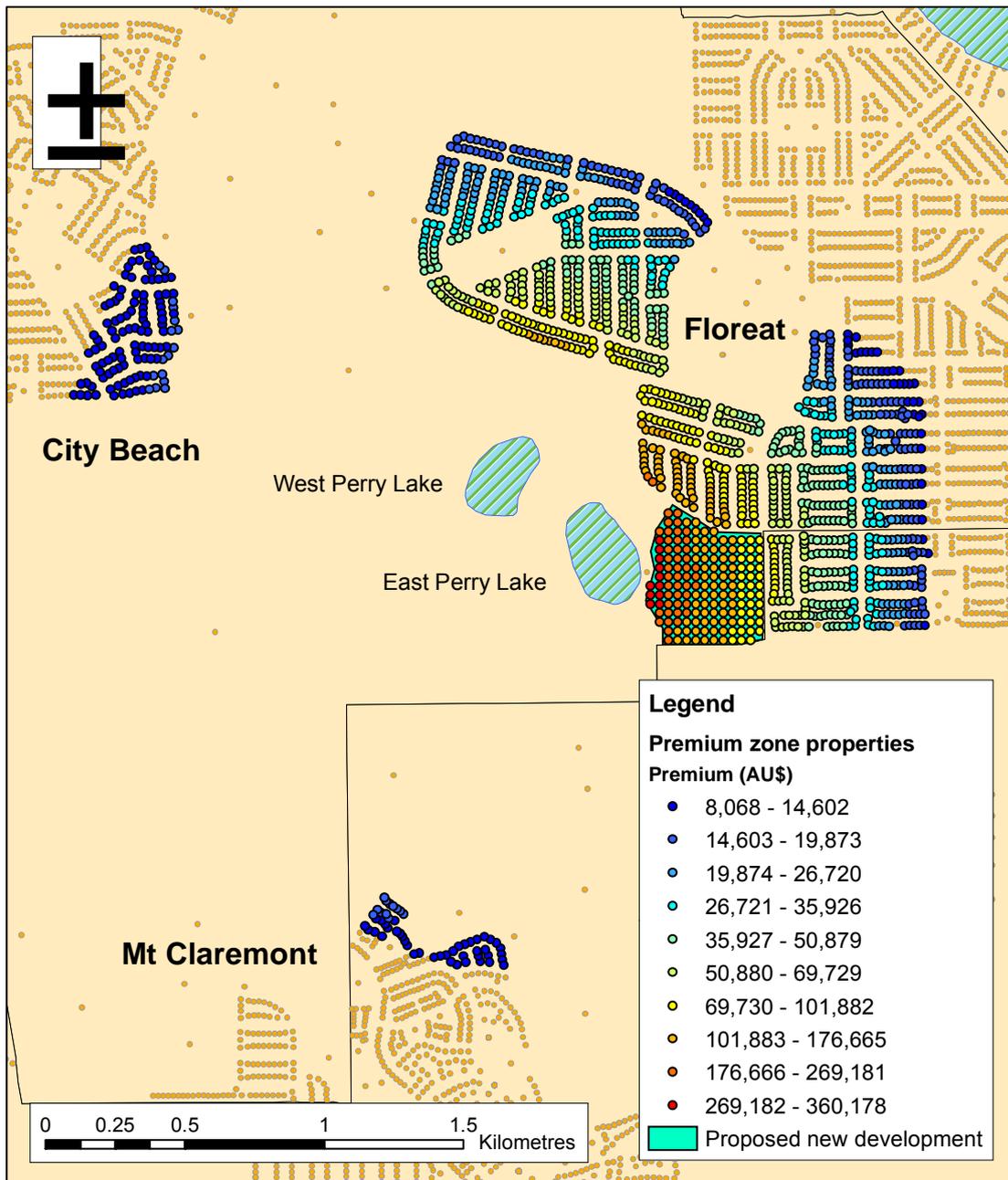
Figure 7. Premiums of properties in the modified Perry Lakes premium zone, including existing properties and properties proposed in the new development, under the assumption that all residences are houses.

Table 4 and Figure 7 show the results of the premium calculations. The effect of wetland proximity on the premium can be seen in Figure 7, with properties within a few hundred metres of the lakes' edges attracting premiums over AU$100,000. Most of the properties in the new development have this size of premium. The average premium due to the Lakes is around AU$41,000 for existing properties and about AU$159,000 for properties in the new development. Properties on the edge of the premium zone, despite being relatively far from Perry Lakes, did not have zero premiums as may be expected, because *NUMWET*, the number of nearby wetlands, still contributes to the sales price.

Table 4. Premium estimates for Perry Lakes, for both existing properties and the new development site, under the assumption that all residential properties are houses.

Quantity	Estimate
Current residential properties	
Number of properties	1300
Average sales price with Perry Lakes	AU$ 920 K
Average sales price without Perry Lakes	AU$ 879 K
Average premium due to Perry Lakes	AU$ 41 K
Total premium due to Perry Lakes	AU$ 54 M
Properties proposed in the new development	
Number of properties	157
Average sales price with Perry Lakes	AU$ 936 K
Average sales price without Perry Lakes	AU$ 777 K
Average premium due to Perry Lakes	AU$ 159 K
Total premium due to Perry Lakes	AU$ 25 M

The total premium due to the presence of water in Perry Lakes, calculated using equation (6), is shown in Table 4 with other summary data. It can be noted that the wetland average amenity value is substantially higher for the new development when expressed on a per property basis at $159,000 per house compared to $41,000 for the established properties. This is because the new site is adjacent to the wetland, whereas the established properties are on average further away. In aggregate there are almost 10 times as many established properties, but the aggregate amenity value for these properties is only about double the value of the new development at AU$ 54 million for existing properties compared to around AU$ 25 million for properties in the new development. Recall that the estimate for the new development is on the basis that the properties are houses, which is known to be inaccurate. In the new development, the assumed number of dwellings ~157 is less than planned 350-400 according to LandCorp (2006), but the price of individual dwellings is expected to be greater (because houses are more expensive than units), so the net effect on the total premium estimate is uncertain.

This case study has shown that the loss of Perry Lakes may have significant economic impact on surrounding property values. However, losing Perry Lakes would also have social and environmental impacts that go beyond the loss in recreational amenity and capital values for the neighbourhood that we estimated here. Resident surveys have demonstrated a strong demand for open water and complaints are made whenever lake levels drop (McFarlane *et al.*, 2007). A certain level of water in the lakes is required for the survival of long-necked tortoises and waterfowl use the lakes when there is sufficient water. Artificially maintaining the water level through pumping groundwater into the lakes is becoming more costly due to the lowering groundwater table.

However, the results of this study imply that there are significant private amenity values associated with the wetland which indicate that it may be worth using artificial means of supplementing water in the lakes, and also that there might be potential for funding such activity through a tax or rating based on property values. That there may also be public benefits from supplementing the wetlands also implies that partial public funding might be part of the policy solution, and given the increasing cost of pumping groundwater into the lakes to maintain water levels due to declining groundwater levels, investigation of other mechanisms for sourcing water are also worth investigating. To this end, the CSIRO and the Water Corporation are conducting a detailed investigation into the possibility of augmenting groundwater levels in the vicinity of

Perry Lakes using highly treated wastewater from nearby Subiaco Wastewater Treatment Plant (WWTP) as reported in McFarlane *et al.* (2007). This may be an option to help maintain the water level in the lakes and increase the use of treated recycled wastewater. It can also be noted that urbanising the area around the wetland as in the proposed development may result in increased run-off and recharge of local groundwater levels, which should also reduce the amount of water needed for supplementation of the wetland. All of these factors together imply that there are potential public and private benefits associated with the proposed development project that may be of technical and policy relevance to broader metropolitan land use planning in the Perth region.

5. Conclusion

The hedonic property price approach can be used to value wetlands in the Perth metropolitan area, by estimating the capitalised amenity premium on property prices associated with wetland proximity. These estimated values represent a lower bound on the social value of wetland services as other public values are excluded from the estimation. Nonetheless, the estimates in this study do provide some insight to policy makers of the impact on amenity values – as capitalised in property values – if wetlands were left to dry.

As anticipated, both the distance to the nearest wetland (*DWETLAND*) and the number of wetlands within 1.5 km of a property (*NUMWET*) significantly influenced house sales price, along with a number of other property-specific and neighbourhood attributes. This is consistent with findings from previous studies by Lupi et al. (1991), Doss and Taff (1996), Morrison et al. (1999) and Mahan et al. (2000). Several functional forms for the effect of *DWETLAND* were evaluated. The best fit was obtained for the model in which the logarithm of the sales price depended linearly on both *DWETLAND* and 1/(275+*DWETLAND*). This functional form suggests that wetland distance influences sales price within a premium zone extending approximately 1.5 km from the edge of a wetland.

For a property that is 245 metres away from the nearest wetland, which is the distance corresponding to the mean sales price in the study, reducing the wetland distance by 1 metre would increase the property price by AU$463. Similarly, the existence of an additional wetland within 1.5 kilometres of the property would increase the sales price by AU$6,081. The hedonic price function, when combined with information on housing density, can be used to estimate a total premium on house sales due to the presence of a nearby wetland. The total premium in sales price for a 20 hectare isolated circular wetland surrounded by uniform density housing was around AU$140 million, all other variables being held at their mean values.

In a case study on the value of Perry Lakes, the total premium calculation needed to be adapted to account for: the non-circular shape of the wetlands, the presence of neighbouring wetlands with overlapping premium zones, non-uniform housing density, a distribution of structural and neighbourhood attribute values, and non-house residences. All but the last of these were successfully treated. Perry Lakes are estimated to contribute a total premium of AU$ 54 million to existing properties and around AU$ 25 million to properties in a proposed new residential development adjacent to the Lakes.

This study has shown that the existence of urban wetlands helps increase sales prices of surrounding properties. It is supported by recent trends in new housing developments in Perth which have created artificial wetlands to add extra environmental appeal to their properties. However, the results also raise the need for greater emphasis on policies to manage the superficial aquifer under the Perth metropolitan area because reduced rainfall over the past 30 years has resulted in a lowering of groundwater tables and a drying of wetlands in some areas. Aside from the amenity value associated with wetland proximity, there are a number of policy issues relating to land and water use planning in the metropolitan area. For example, urbanising around existing wetlands can act to increase recharge into the wetlands, which may help to mitigate some of the impacts of reduced rainfall. Moreover, given the high private amenity values associated with new urban developments around wetlands, there may be scope for raising financial resources for funding other wetland rehabilitation measures via a property tax,

for example. On the other hand, policies they encourage increased installation and extraction of groundwater by backyard bores may exacerbate the problems experienced with drying urban wetlands,..

Some of the limitations of the present study, which could be addressed in future research, include the limited spatial extent of the study, that it reflects current values which may increase in the future as wetlands become more scarce, and that it only covers the private amenity value. The study was conducted on a relatively local scale in a study region measuring about 9 by 13 kilometres, which represents only 4% of the land area on Gnangara Mound. In order to estimate the current and potential future amenity value associated with maintaining the wetlands it would be necessary to broaden the spatial scope of the study, and conduct more detailed investigation of wetland characteristics. For example, a spatial hedonic analysis could also be carried out to study the spatial dependency of house prices, in which prices of nearby properties are used to explain the price of any specific property, in order to improve the accuracy of the parameter estimates. Accuracy could also be improved by obtaining cadastral information and constructing explanatory variables that capture wetland quality, auxiliary wetland amenities (such as park benches and playgrounds) and wetland view or frontage, as well as performing a second stage hedonic analysis to estimate the willingness-to-pay function.

Moreover, hedonic price analysis should be supplemented by other non market valuation techniques which can account for other social values of wetlands including their ecological function and existence and bequest values. These values are likely to be particularly important in the peri-urban areas where the wetlands potentially maintain more of their original ecological function.

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