Inundation and Views in Coastal Residential Property Values. Does the Sale Price Reflect the Trade Off?*

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Abstract

This study proposes a modeling approach to disentangle the discount due to flooding in residential properties that are located in coastal areas. The study makes three contributions. The first is to incorporate a continuous measure of flood risk in a study of coastal areas, as earlier studies modeled flood risk using a binary variable. The second is to estimate a discount over a three dimensional amenities' set (degrees of view of the ocean, proximity to the ocean and proximity to other waterways), in order to provide a valuation of the trade off between 'views/proximity' and flooding. And, finally it is the first study of its kind for Australia. Data for two coastal sites in the state of Queensland, Australia are used in the study. The results indicate that the identification of a significant discount due to inundation risk is highly dependent on views and proximity to ocean and waterways, but the study demonstrates the methodology proposed here is able to disentangle statistically significant discounts due to inundation risk.

Keywords: hedonic models, spatial econometric models, inundation risk measures, pricing flooding risk

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1 Introduction

Access to environmental amenity can add value to residential property, but residential property exposed to environmental risks can experience reduced value (Rambaldi et al., 2013). These positive and negative contributions to

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land values can be estimated using a variety of techniques, and the literature on the valuation of both amenities and risks is vast (see Freeman (2003, Ch 11) and Palmquist (2005) for comprehensive reviews of property value models). Many studies have sought to analyze historical data sets to understand the factors that have contributed to property values in the past, and how changing access to environmental amenity with urbanization may change property values (Sander and Polasky, 2009; Jim and Chen, 2006). Recently, however, some studies have begun to focus on the implication of environmental risk pricing, especially in the context of future changes to environmental risk, such as climate change (Butsic et al., 2011).

One key area where land values are likely to be affected by changing risk profiles are coastal urban areas at increased risk of storm surge inundation as sea levels rise (Landry and Hindsley, 2011). Beginning to build an understanding of how increased risk may affect property values is vital because in developed countries the family home is the single largest asset of most individuals (Forrest and Murie, 1995; Schwartz and Seabrooke, 2009), and in urban areas it is increasingly the land that the home sits on in which most of the value resides (Cheshire and Sheppard, 1995). The potential effect of changing environmental risk on individual wealth is likely to drive the engagement of coastal communities in the decisions of how to adapt and protect themselves against inundation, as well as how much to spend doing so.

Even though inundation risk is known to affect property values, it has proven very difficult to calculate in coastal regions (Bin et al., 2008; Morgan, 2007). This problem arises because although the risk of coastal inundation increases for property near the coast, this location also brings with it a range of positive amenity values, such as proximity to beaches, waterways, and coastal views. The correlation between the relatively smaller negative pricing signal of increased inundation risk and the relatively larger positive pricing signal of coastal proximity confounds simple attempts to measure inundation pricing in the coastal zone (Bin et al., 2008; Daniel et al., 2009). In most studies of coastal land values, inundation risk is not explicitly considered or effects are captured through the inclusion of dummy variables to measure perturbations to the positive pricing signals against distance to coast (Daniel et al., 2009). However, although inundation risk and coastal proximity are correlated, they are not absolutely causally related - for instance, even in coastal areas it is possible to find properties with significant inundation risk but with few views and relatively far from the coast. Moreover, even if inundation risk is correlated with distance to coast, it is important to attempt to disentangle the two pricing signals if it is expected that some future change might differently affect inundation risk and distance to ocean. This is the case with rising sea levels and changing storm surge events, which can create very finely structured changes to risk profiles, affecting some coastal properties more than others.

Recent studies have started trying to disentangle these two effects by incorporating measures of inundation risk (Daniel et al. (2009)) and coastal view (Bin et al. (2008)) into their hedonic analysis. In this study we begin to extend these approaches in three directions, using a revealed preference approach to estimate the discount in the sale price due to flooding for properties located in coastal areas. The first is that we measure ”inundation risk” through a continuous measure recently proposed by Rambaldi et al. (2013). Earlier studies modeled flood risk using a binary variable. The second is that we estimate the discount over a three dimensional amenities' set (degrees of view of the ocean, proximity to the ocean and proximity to other waterways), in order to provide a valuation of the trade off between 'views/proximity' and inundation. The third is that ours is the first study of its kind for Australia.

2 Property Value Models, Environmental Amenities and Dummy Variables

There are two broad approaches to the valuation of environmental amenities: a stated preference approach, in which people are directly or indirectly asked what they would pay for something; and a revealed preference approach; in which the valuation of the environmental amenity is found by analysing the purchasing behavior of the consumer. In the case of residential property markets, the three common models used in a revealed preference approach are: the repeat sales model, which compares sales of the same property over time to reveal the change in implicit price; the discrete choice model, in which an econometric model describes two or more discrete alternatives; and the hedonic model, in which the market valuation of the property is explained by a number of environmental and non-environmental characteristics. In this study, we used a hedonic approach, and thus we regress the property value on a number of property characteristics, including inundation security, coastal views and proximity to coasts and waterways.

Inundation security can be considered a localized externality (Palmquist, 2005), in that it represents a spatially localized change to environmental amenity of limited scope. Property buyers have the opportunity to choose alternative nearby properties with a similar mix of characteristics, and pay a price premium for properties secure from inundation (MacDonald et al., 1990; Kousky, 2010). Property owners will experience capital gains or losses in proportion to the amenity gained or lost as inundation risk changes, and this can be interpreted as the amount the owners would be willing to accept for the change. The effect of flooding in urban areas has been studied in this way by a number of researchers (for a review see Rambaldi et al. (2013)) making use of a variety of available data on flooding events. Of particular interest to our study, Daniel et al. (2009) use a hedonic approach to study flooding in residential properties in close proximity to the Meuse River (Netherlands), and Bin et al. (2008) estimate a spatial hedonic model for four beach communities in North Carolina (USA). In the study by Daniel et al. (2009), their data are divided in three periods, before a first flooding event (1993), between the first and second flooding event (1995) and after the second flooding event. Their measure of flooding is a binary variable indicating whether the property was in the flood plain (that is, the 100 year average recurrence interval (ARI) flood level for that parcel of land, which provides an indication of the depth of flooding that will occur on average every 100 years). The study controls for distance to the river and finds that properties in the floodplain carry a discount of 7%, while proximity to water has a premium of 3% on sale prices. Bin et al. (2008) use data from 1995-2002 and their model has a 3D based measure of "ocean view" (similar to the measure we use, as described in Section 3) as well as a number of measures of distance to amenities including distance to ocean. The measure of floodplain used is the same as that in Daniel et al. (2009), i.e., the 100 year ARI Level. The spatial weights used in the model are constructed by defining as a "neighbor" all properties that are within 0.5 km distance to each property in the sample. This study computes a dollar value of willingness to pay (WTP) at the mean of the sample and a 95% confidence interval based on a bootstrap approach. They find the mean WTP to avoid location in the floodplain is $36,082, and the interval estimate is [-66,665.42, -1898.48].

The measure of flood risk used in these two studies, a dummy variable that takes the value of one if the property is in the 100 year ARI level, is the standard for the literature (Rambaldi et al. (2013)), even though inundation risk might be expected to increase gradually with property height above sea level and the expected frequency of extreme events. This is partly because inundation risk policy is often discussed in terms of a discrete ARI 100 year inundation region, but also because it is often difficult to define and measure a continuous variable of inundation risk with the data available in these studies. Designing an appropriate measure that is a continuous variable is difficult for several reasons. In many cases the definition is broad and the estimated effect will tend to be an "average" over what is in reality a step-response phenomenon, thus reducing the apparent size and statistical significance. This problem is exacerbated if only a small proportion of the properties exist on one side of the step, such as the urban coastal "strips".

An alternative is to constrain the fit of a linear variable to the region in which a signal would be expected by combining it with a dummy variable. In a recent paper Rambaldi et al. (2013) proposed the use of such a continuous measure of flood plain effect which is a function of the distance that the lowest point on the parcel is below the 100 year ARI level. Their results, based on a spatial error hedonic model and data for 3944 sales of residential properties (detached housing) from 1970 to 2010 for a suburb in the city of Brisbane (Australia), indicate that properties in the 100 year ARI level floodplain experienced a 1.28% discount with an additional discount of 5.45% per meter below the 100 year ARI level.

In a similar manner, a dummy variable can also be used to filter the fit to properties in which confounding influences are expected to be minimized. Managing the impact of competing effects is likely to be especially important in the case of coastal inundation where the large positive effect of coastal view and proximity confounds the smaller negative effect of increased inundation risk in a significant proportion of the limited sample of properties facing inundation risk. Importantly, although inundation risk and coastal view and proximity are spatially correlated, in large and diverse datasets there are likely to exist properties facing significant inundation risk despite having few views, and vice versa. If the data sets were sufficiently large, enough of these cases might exist such that separate statistically significant signals could be discerned for both positive amenity related to coastal proximity and negative amenity related to increased inundation risk. Although research datasets of this size and quality are not available in Australia, we can start to disentangle the effect of this correlation by examining how the observed discount due to inundation changes as the filtered with a dummy variable to gradually reduce the impact of the confounding influences of coastal proximity and views.

This is what we do here, by recalculating the discount due to inundation in two case study regions, when the definition for properties facing inundation risk is conditional on it being at a certain distance from the coast, distance from a waterway, or with only a limited coastal view. The current study covers sales of single dwelling residential properties in two coastal urban localities. In each case there is a subset of properties that are close to the ocean (and/or other waterways) and in the floodplain. When the inundation price regression is unfiltered and all properties in the ARI 100 year basin contribute equally to the estimate, we might expect to discern a positive price effect with increased inundation risk because of its correlation with coastal proximity. As the filter modifies the definition of the inundation plane effect to separate properties close to the water or with extensive views, we would expect the number of properties with significant positive valuations to decrease, revealing a more appropriate representation of the negative effect of inundation risk pricing. Eventually, we would expect the filter to remove so many properties close to the water or with extensive views that the result on the remaining sample would lose statistical significance. A key question is: in what sorts of datasets, and which coastal communities, are we likely to be able to disentangle the positive premiums of coastal views and proximity from the negative premiums of increased inundation risk in a statistically significant manner?

3 Methodology and Data

The method adopted in this study is an extension of the works of Bin et al. (2008) and Rambaldi et al. (2013). The econometric model used is a spatial error hedonic model. Bin et al. (2008) use a spatial autoregressive model (SAR), while Rambaldi et al. (2013) estimated both a spatial error model (SEM) and a Spatial Durbin model (SDM)[1] (the reader is referred to LeSage and Pace (2009) for a comprehensive treatment of spatial econometric models). This paper models inundation, views and proximity to ocean/water by using a three dimensional amenities' set to extend the modeling of Bin et al. (2008). It also uses the continuous measure of inundation risk proposed by Rambaldi et al. (2013). The next two subsections present the spatial hedonic model used in the study, define the measure of inundation risk and show how the trade off between views, proximity and inundation are modeled, followed by a description of the data.

3.1 Modeling

The model is a log-linear hedonic model with spatial errors where the 'floodplain effect' is defined using a continuous measure which is a function of the vertical distance below the 100 ARI level of each property. We capture the

[1]We estimated an Spatial Durbin Model for both sites and found the marginal effects to be almost identical to those obtained with the spatial error model. The results are not presented here.

view/distance effect by introducing a filtering indicator as an extension to Rambaldi et al. (2013)'s definition of when a property is in the floodplain. The measure used in this study provides a combined indicator that includes the degree of view of the ocean as well as distance to the coast and waterways (details shortly) of properties in the floodplain. The model is specified in equations (1),

$$\begin{aligned} y_i &= \beta_0 + \sum_{t=1}^{T} \delta_t D_{it} + [\theta_1 F_i^{FD} + \theta_2 F_i^{FD} F_i^L] + \sum_{k=1}^{K} \beta_k X_{ki} + \epsilon_i \\ \epsilon_i &= \lambda \sum_{j=1}^{N} w_{ij} \epsilon_j + u_i \end{aligned} \tag{1}$$

where,

$y_i = \ln(Sale\,Price_i)$, $i = 1, ..., N$ and $t = 1, ..., T$

D_{it} time dummy =1 if property i was sold in year t

$[\theta_1 F_i^{FD} + \theta_2 F_i^{FD} F_i^L]$ filtered floodplain effect explained in Section 3.1.1

X_{ki} value of the kth hedonic characteristic for property i. The full list of hedonic characteristics is discussed in Section 3.2.

ϵ_i is a spatially correlated error

$0 \leq w_{ij} \leq 1$ ($\sum_{j=1}^{N} w_{ij} = 1$) is the weight of property j on property i based on their distance computed using a Delauney triangulation.

$0 \leq \lambda < 1$ is a spatial correlation parameter

$u_i \sim N(0, \sigma^2)$ is random noise.

The Rambaldi et al. (2013)'s floodplain effect is based on the term $[\theta_1 F_i^{FD} + \theta_2 F_i^{FD} F_i^L]$. However, the definition of F^{FD} used here is modified from that in the original study to allow for the study of the sensitivity of the floodplain effect estimates to proximity to ocean/water and views through a number of scenarios discussed in the next sub-section.

3.1.1 Construction of Variables to Capture Flooding, Views and Proximity to Ocean/Water

As indicated above we define the floodplain effect (see equation (1)) as follows

$$Flood\ Plain\ \ Effect = \begin{cases} (\theta_1 + \theta_2 F_i^L) \times 100 & \text{if } F_i^{FD} = 1 \\ 0 & \text{if } F_i^{FD} = 0 \end{cases} \tag{2}$$

The effect is a function of two unknown parameters, θ_1 and θ_2, and two variables, F^{FD} and F^L.

The variable F^L measures flood depth in meters and it is defined as

$$F^L = (100 \text{ year ARI}) - (\text{minimum parcel height}) \quad (3)$$

The variable F^{FD} is the "filtered floodplain dummy" which is defined as follows,

$$F^{FD} = Flood\_Dummy \times View\_Dummy \times Coast\_Dummy \times Water\_Dummy \quad (4)$$

where,

$Flood\_Dummy$ is $= 1$ if property is identified to be in the 100 Year ARI floodplain. This is the definition of F^{FD} used Rambaldi et al. (2013)

$View\_Dummy$ is $= 1$ if property has a $View$ Factor $< v_1$, where $0 < v_1 \leq 1$

$Coast\_Dummy$ is $= 1$ if property distance to coast $> v_2$, where $0 < v_2 \leq 400$ meters

$Water\_Dummy$ is $= 1$ if property distance to waterway $> v_3$, where $0 < v_3 \leq 100$ meters

Our extension in the definition of F^{FD} allows the floodplain effect to be estimated by imposing a filter on the properties that define the effect. The filtering is based on views of the ocean and both the *distance to waterway* and the *distance to coast* as separate measures. Separating the ocean and other waterways (lakes, creeks, rivers, etc.) is of practical importance in this study as the areas under study include estuaries opening to bays. As found by studies such as that of Bin et al. (2008) some of these type of features of the terrain might carry a market premium as well as be a source of flooding.

3.1.2 Computing the Discount Due to Flooding

By varying the values of v_1, v_2, v_3, the number of properties in the sample that define the *floodplain effect* varies in three dimensions, by the degrees of view, the distance to ocean and the distance to waterway. As a result, the estimates of the parameters θ_1 and θ_2 vary leading to different estimates of the floodplain effect. The estimate of interest is the percent discount (per meter below the 100 year ARI Level) in the sale price due to inundation of properties within the "floodplain" as defined by v_1, v_2, and v_3. As the model (1) is log-linear, the value of interest is given by the semi-elasticity (percent change in the dependent variable per unit of the independent variable). The semi-elasticity computed here provides the percent price discount per meter below the 100 year ARI level defined by the floodplain effect in (3), and it is of the form (see Hill et al. (2008), pp. 184-186)

$$\%\Delta Price\ per\ metre = 100 \times (e^{\hat{\theta}_2} - 1 + e^{\hat{\theta}_1} - 1) \quad (5)$$

The computed semi-elasticities are tabulated and plotted as functions of distance to ocean and waterways and by degree of views to study how the valuation of flooding changes at different values of these amenities. The range of values of v_1, v_2, and v_3 that can be used depends on the available information for each site.

3.2 Data

The data used in this study are from two sites. The sites are coastal localities in the state of Queensland (Australia) in the Moreton Bay and Cairns local government areas. The two localities are 1700 kms apart. Cairns is in the north of the state, while Moreton Bay is an area at the north of the city of Brisbane (approximately 40 kms from the Brisbane Central Business District). It is part of the greater Brisbane as a substantial proportion of its population commutes into Brisbane for work in weekdays (Figure 1 shows a map of the state of Queensland where Cairns and Brisbane can be identified). The data are transaction records on residential vacant land or residential property (land and structure). The data do not include units, terraces or townhouses. To the extent possible a set of similar hedonic, environmental and location characteristics has been collected for each site. Table 1 provides a list with a description of each measure. Tables 2 and 3 provide descriptive statistics corresponding to each site.

The data are collected from a number of sources (Table 1) and extensive cleaning and checking is required to insure consistency. Transaction records with inconsistent data are checked against other sources when possible (e.g. Google Satellite View might be used to check the proximity to a waterway). The process of cleaning data is somewhat incremental, and the extent to which it is necessary depends on the original source data, the size of the data set, and the strength of pricing signal necessary to yield a statistically significant relationship between property price and the variable of interest, in this case inundation security.

The descriptive statistics for the two sites (Tables 2-3) show that the data available for Cairns are considerably smaller and spread over a much longer time period than those available for Moreton Bay Regional Council. The data for Moreton are 13,090 transactions of sales between 1991 and 2010 while there are 2704 transactions for the Cairns and Clifton Beach area covering the period 1961-2011. The Moreton data has the largest number of transactions spread over a range of distances and views (details will be presented in the next section) and it is the most suitable for the objective of disentangling the discount due to flooding from the premium due to views and proximity to ocean and waterways.

Inundation depth for each site is estimated as the difference between the basin-fill ARI 100 year inundation level and the lowest height of each property. This yields two pieces of information: a binary variable for the properties which receive some inundation during an ARI 100 year event; and the depth of inundation on the property during an ARI 100 year event. The first of these is the binary variable traditionally used in these analyses (e.g. Bin

Figure 1: Map of the State of Queensland. Source:www.atn.com.au

Table 1: Description of Variables

Variable	Type/Units	Source
Sale Price	dollars	RP Data Ltd
LAND		
large plot	Dummy = 1 if Lot Size > 2500 mm^2	Authors' construction
Vacant land	Dummy	Authors' construction
Lot Size	sq. meters	RP Data Ltd
Min Parcel Height	meters	LiDAR Ground Point DEM (with reference to Australian Height Datum)
Flood Depth	meters	100 year ARI Level are: 2.4 meters for Moreton Bay ; Varies by property and it is based on hydrological modelling by Local Council for Cairns/Clifton Beach
Distance to Coast	meters	ArcMap, Council, PSMA
Distance to Waterway	meters	ArcMap, Council, PSMA
Distance to Offensive Industry	meters	ArcMap, Council, PSMA
Distance to (Urban) Park	meters	ArcMap, Council, PSMA
Distance to Bus Stop	meters	ArcMap, Council, PSMA
Distance to Schools	meters	ArcMap, Council, PSMA
Distance to Shops	meters	ArcMap, Council, PSMA
Distance to Rail Station	meters	ArcMap, Council, PSMA
Distance to Boat Ramp	meters	ArcMap, Council, PSMA
Distance to Pubs and Clubs	meters	ArcMap, Council, PSMA
Distance to Hospital	meters	ArcMap, Council, PSMA
Views	Proportion of nearby ocean visible (range [0,1])	ArcMap, raw LiDAR, Council aerial photography
STRUCTURE		
House footprint	sq. meters	Local Council
Age	years	Authors' construction from council data on sewerage line connection (Moreton Bay) and survey dates (Cairns)
Bathrooms	number	RP Data Ltd
Bedrooms	number	RP Data Ltd
Car spaces	number	RP Data Ltd

Table 2: Descriptive Statistics - Moreton Bay

Variable	**Minimum**	**Maximum**	**Median**	**Mean**	**Std Dev**
Sale Price	15500	1250000	161250	191833	129756
LAND					
large plot	0	1	0	0.089	
Vacant land	0	1	0	0.252	0.434
Lot Size	261	10610	635	960	1074
Min Parcel Height	0.000	26.661	7.551	8.215	4.667
Flood Depth	-24.361	2.400	-5.151	-5.815	4.667
Distance to Coast	16	5777	1379	1394	931
Distance to Waterway	5	864	251	271	163
Distance to Offensive Industry	175	8378	2275	2868	1827
Distance to Park	7	984	110	133	110
Distance to Bus Stop	15	4349	224	472	803
Distance to Schools	10	6547	321	649	1093
Distance to Shops	10	4797	399	530	487
Distance to Rail Station	2454	13584	6610	6970	1764
Distance to Boat Ramp	56	6294	1602	1974	1464
Distance to Pubs and Clubs	14	5336	1237	1436	925
Distance to Hospital	10	13255	2263	3200	2709
Views	0.000	0.982	0.002	0.126	0.234
STRUCTURE					
House footprint	0	921	173	162	119
Age	0	86	10	12	11
Bathrooms	0	4	1	1	1
Bedrooms	0	8	3	3	2
Car spaces	0	5	1	1	1
Number of transactions	13,090				
Period	1991-2010				

Table 3: Descriptive Statistics - Cairns

Variable	Minimum	Maximum	Median	Mean	Std Dev
Sale Price	6184	5000000	195000	249937	196955
LAND					
large plot	0	1	0	0.064	0.245
Vacant land	0	1	0	0.109	0.312
Lot Size	263	699300	610	1357	14665
Min Parcel Height	0.000	48.455	2.901	5.738	6.04
Flood Depth	-45.555	1.608	0.009	0.158	1.63
Distance to Coast	59.658	1973.804	687.252	787.221	410.82
Distance to Waterway	12.054	2432.510	473.125	741.597	611.35
Distance to Industry	755.464	23266.45	3705.68	11350.15	9902.96
Distance to Park	10.254	585.661	133.920	171.962	120.35
Distance to Bus Stop	27.455	1321.907	244.347	269.453	154.68
Distance to Schools	208.992	7100.065	1640.727	3284.787	2529.025
Distance to Shops	16.992	21340.33	18048.577	10830.447	9378.326
Distance to Rail Station	14.297	6861.716	593.452	2786.800	2739.82
Distance to Boat Ramp					
Distance to Pubs and Clubs	116.686	21268.234	2499.384	9905.076	9421.82
Distance to Hospital	37.964	20476.087	1811.567	9465.882	9070.02
Views	0.000	0.995	0.000	0.086	0.192
STRUCTURE					
House footprint	0.000	660.680	172.080	186.587	106.48
Age	0	126	47	49.362	40.95
Bathrooms	0	6	1	1.4	0.78
Bedrooms	0	9	3	3	1.54
Car spaces	0	6	2	1.5	0.95
Number of transactions	2704				
Period	1961-2011				

et al. (2008)), and the second provides a continuous measure of inundation risk as used in the more advanced model of Rambaldi et al. (2013). In the current analysis, detailed hydrodynamic inundation levels were available for the Cairns case study, but only broad scale ARI 100 year inundation levels were available for the Moreton Bay study. The outcome of the model should not be overly sensitive to the specific threshold level of inundation chosen (because the inundation depth provides a continuous measure of inundation risk), although it will affect the statistical significance of the results generated.

The measure of view used in this study is similar to that used in Bin et al. (2008). A physical model of the environment was derived combining a Geosciences Australia smartline to define the coastal boundary to the ocean, a DEM (digital elevation model) overlaid with building footprints and heights (derived from high resolution LiDAR) and multiple view points from each property. The ArcGIS Skyline/Skyline Barrier tool was used to determine visible objects in the physical model and a Manifold GIS system was used to extract visible ocean areas. The ocean view score is the amount of ocean area visible as a proportion of the total area of ocean in the case study area. The Moreton Bay data have the widest spread of properties across the view factor. The Cairns dataset has the majority of properties (80%) in a location with a view factor of ten percent or less. For sites with a small distribution of view factors it is not possible to disentangle the affect of ocean view on property values, but, conversely, ocean view is only likely to affect the value of a very small proportion of properties in the sample.

4 Results

The first set of results showed the estimates of model (equation 1) for each site when the data was not filtered for views or proximity (Table 4). When no filtering for views or proximity were applied, equation (4)'s definition became $F^{FD} = F^{D} = Flood\_Dummy$ and the definition of $Flood\ Plain\ \ Effect$ was the same as that used in Rambaldi et al. (2013). The results were as expected for the coastal case studies analyzed, in that the aggregate flood plain effect for Moreton was positive and significant, indicating the proximity and views of the ocean and waterways offset any discount due to flooding (computing the percent change in price using equation (5) gave a 16.56% premium). Similarly, the aggregate effect for Cairns was also positive, 5.41%. However, although the coefficient of F^D was positive, the coefficient attached to the flood level was negative, which showed there was a significant discount if the parcel was below the 100 Year ARI level.

The filtered specification (equation 4) in equation (1) was estimated by varying v_1, v_2 and v_3, which resulted in a change in the definition of which properties were used in the model to *define the floodplain effect* (equation (2)) through equation (4). In the Moreton dataset, filters were implemented in combination across v_1, v_2 and v_3, whereas in Cairns the threshold level of viewfactor was held constant at $v_1 = 0.20$, given the small variance in ocean view factor across the data set and the fact that 80% of properties had a view factor less than or equal to 0.10.

Table 4: Parameter Estimates of Model (1) for the Two Sites Without Filtering for Views or Proximity to Waterways or Ocean ($F^{FD} = Flood\_Dummy$)

	Moreton			Cairns	
VARIABLE	COEFFICIENT	SERR		COEFFICIENT	SERR
intercept	9.586*	0.110		6.591*	0.367
F^L	0.045*	0.013		-0.063*	0.027
F^{FD}	0.113*	0.010		0.109*	0.027
view	0.084*	0.009		0.378*	0.032
Large Lot	-0.136*	0.017		-0.078*	0.051
Vacant	-0.271*	0.016		-0.307*	0.034
Lot Size	0.221*	0.009		0.260*	0.019
Age	-0.005*	2.88E-04		-4.23E-04	2.61E-04
HouseFootprint	0.001*	4.05E-05		4.88E-04*	8.49E-05
Bath	0.067*	0.005		0.087*	0.011
Beds	0.042*	0.004		0.028*	0.006
Cars	0.011*	0.003		0.018*	0.007
dist_coast	-5.68E-05*	5.65E-06		-3.72E-04*	2.78E-05
dist_waterway	-4.91E-06	1.46E-05		1.21E-04*	2.18E-05
dist_OffenIndus	3.31E-05*	3.22E-06			
dis_industries				-5.28E-05*	1.59E-05
dist_parks	-1.43E-04*	2.01E-05		-2.02E-04*	5.90E-05
dist_busStop	1.36E-05	8.66E-06		3.51E-04	4.37E-05
dist_Schools	1.83E-05*	7.29E-06		-1.07E-04	2.06E-05
dist_Shops	-1.02E-05	6.36E-06		3.28E-05	1.10E-05
dist_BoatRamp	1.19E-05*	4.75E-06			
dist_PubsClubs	8.65E-06*	3.25E-06			
dist_Hospitals	-1.04E-05*	1.26E-06		1.01E-04	1.64E-05
$\hat{\lambda}$	0.689*	0.013		0.396*	5.32E-03
lnL	6178.653			829.18	
$H_o: \theta_1 = 0, \theta_2 = 0$ p-value	F-stat 72.617 0.000			F-stat 8.384 0.001	

* Significant at the 5% level. Estimates of year dummies not shown

In Moreton, a total of 259 combinations were tested: v_1= 0.9, 0.85, 0.8, 0.7, 0.6, 0.5, 0.4, 0.2, v_2 = 50, 100, 200, 250, 300, 350, 400 meters, v_3 = 25, 50, 75, 100 meters. The detailed results are presented in the Appendix, and were summarized in meshed 3D plots (Figure 2), in four panels corresponding to one of four values of *View* (v_1 = 0.2, 0.4, 0.6, 0.9). Each 3D plot showed the variations in the distance to the coast and waterways over the X and Y axis, respectively. The vertical (Z) axis showed the percent discount in price per meter below the 100 year ARI level, which was defined as the *negative* of the computed semi-elasticity in (5). A row in each of the appendix tables provided the estimates of one model. The estimates of θ_1, θ_2, the number of properties that met the $F^{FD} = 1$ and corresponding average value of F^L, as well as the computed semi-elasticity were presented.

The first clear pattern that could be observed from Figure 2 is that across the range of values of the view factor the lowest discount was found at distances close to the coast and waterways, as expected. The second is that as the view of the ocean increased the discount was uniformly smaller at all distances. In all cases the percent discount per meter below the 100 year ARI level was highest at distances greater than 450m from the coast and 60 m from other waterways with a discount of 22% for properties with reduced views and around 17% for properties with views of 0.8 or higher. The percent discount when properties were in close proximity to the ocean and other waterways (distances from 50 Mts from the coast and 25 Mts from other waterways) was 6% when the view factor was less than 0.20, 1.3% at views of 0.6 and there was no significant discount for properties with views 0.8 or higher.

The results for Cairns (Table 5) were obtained using $v_1 = 0.20$ and variations of $v_2 = 50, 150, 250, 300, 400$ and $v_3 = 10, 15, 20$. These combinations resulted in approximately 45% of the transactions in the sample to be associated with properties that fell within the floodplain. The average flood depth (F^L) was around half a meter in all cases. While the estimate of θ_1 was positive, the estimate of θ_2 was negative and around -0.09 for all models. The pattern of discount seemed to be related to the distance to waterways. There was no significant discount at 50 or less meters from the ocean, but the discount was similar once the property was at a distance of more than 50 meters to the ocean. A discount of 3% per meter below 100 year ARI level was found when the property was at 10 or less meters from a waterway and the discount decreased to 1/2% once the distance to waterway was more than 20 meters.

5 Discussion

The results obtained from the conventional approach to modeling the risk associated with coastal inundation are as expected, positive. That is, when the risk is estimated via a binary variable and the distance to the coast/waterways are views are added to the model as stand along control variables. This is because the effect calculated is confounded

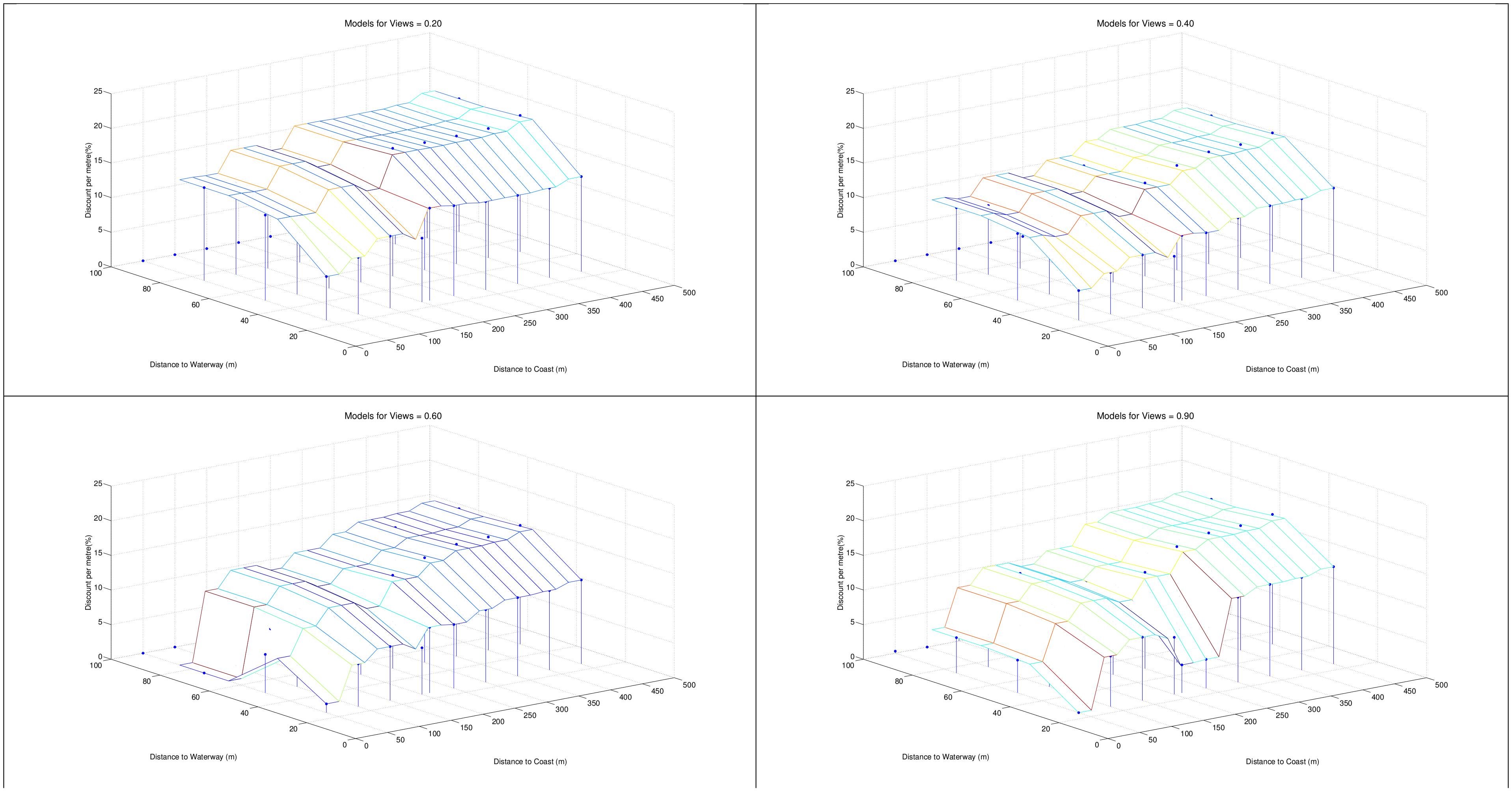

Figure 2: Discount per meter below 100 Year ARI Flood Level. Changes with Ocean Views, Distance to Coast and Waterways for Moreton Bay

Table 5: Cairns -Estimated Percent Discount per meter - Sensitivity Analysis from Estimates of Model 1-v_1 =0.20

Coast (distance from in m), v_2	water (distance from in m), v_3	mean (flood depth) in meters	# of Properties with $F^{FD} = 1$	$\hat{\theta}_2$	StdErr	$\hat{\theta}_1$	StdErr	percent change in price per m below 100 Year ARI
50	10	0.498	1321	-0.092	0.027	0.064	0.025	-2.23
50	15	0.496	1317	-0.085	0.028	0.067	0.026	-1.18
50	20	0.496	1310	-0.087	0.028	0.077	0.025	-0.28
150	10	0.498	1306	-0.092	0.027	0.059	0.026	-2.68
150	15	0.495	1302	-0.084	0.028	0.062	0.026	-1.66
150	20	0.496	1295	-0.086	0.028	0.072	0.026	-0.79
250	10	0.492	1275	-0.096	0.028	0.047	0.025	-4.26
250	15	0.490	1271	-0.088	0.028	0.05	0.025	-3.29
250	20	0.491	1264	-0.090	0.028	0.06	0.024	-2.45
300	10	0.493	1267	-0.094	0.027	0.049	0.025	-3.88
300	15	0.489	1263	-0.086	0.028	0.052	0.025	-2.91
300	20	0.490	1256	-0.088	0.028	0.062	0.024	-2.08
400	10	0.490	1223	-0.087	0.028	0.065	0.025	-1.65
400	15	0.488	1219	-0.076	0.029	0.067	0.025	-0.64
400	20	0.488	1212	-0.081	0.029	0.077	0.025	0.21

with coastal proximity and views . However, when the floodplain effect is defined through a composite variable which is the sum of a continuous measure and series of interacted binary variables to better identify the properties with closest proximity to the ocean and/or waterways, and/or with the highest coastal view, the valuation of the risk is negative, as expected for a significant environmental risk. This insight is vitally important, because even though inundation risk and coastal views are correlated, future changes to climate and sea levels may differentially affect properties along the coastal strip, changing the correlation for groups of properties and affecting the distribution of risks in the community. Understanding these changes will be vital to properly engaging coastal communities in sensible discussions about how adaptation can best protect communities' and individuals' major assets against future coastal inundation events under changing inundation regimes (Yohe et al., 1996; Bin et al., 2011).

The measure developed here (equation 4) shows clearly that property value modelling needs techniques that can disentangle the positive and negative effects that interact in this contested coastal zone. Despite the fact that the interaction between the positive amenity of coastal proximity and negative amenity of increased inundation risk is well known in this relatively new area of research, very few studies have attempted to begin to disentangle this effect (Daniel et al., 2009)). This may be because it is difficult to compile a sufficiently large, high quality data set capable of distinguishing the effect in a statistically significant manner, or until recently it has been computationally difficult to estimate certain important quantities, such as coastal view factors (Bin et al., 2008).

When sufficiently detailed or diverse data are not available, the composite measure implemented here (equation 4) provides a first step towards estimating inundation risk pricing for coastal properties. It allowed us to explore how inundation risk pricing varied across specific parts of the data set, such as properties at risk of inundation but with little or no coastal view, with fewer data requirements than a full hedonic analysis. To our knowledge, no other study has implemented such a technique. The findings were very clear. When the model is a standard hedonic specification (that is, it contains a floodplain dummy variable and regressors that measure the distance to amenities), to estimate the premium associated with inundation risk, statistically significant positive values were measured (16.56% in the Moreton study, and 5.41% in the Cairns study). However, when the discount was calculated by incorporating into the model our composite measure which allows for variation over three dimensions, as well as controlling for the standard hedonic characteristics, it was found to be negative. It became progressively more negative as the threshold for distance to the ocean or waterways was increased, or maximum view factor was decreased, up to as much as ˜22% per meter of inundation for properties that were located more than 0.5km from the ocean and 60m from a waterway in the Moreton case study. As the definition of the measure converges towards a standard binary definition of flood risk, the inundation risk pricing becomes statistically not significant.

In addition to providing estimates of inundation pricing, this approach highlights the type of community structure in which it likely to be possible to disentangle inundation risk pricing from coastal premiums. The Moreton case study allowed good delineation of inundation pricing effects, primarily because it contained a range of properties that spanned all characteristics of interest: inundation risk, distance to ocean, distance to waterways, and, most importantly, coastal view factor. In contrast, the Cairns case study has a relatively smaller sample size which makes the quantifying of the effects weaker as the there is a more limited range of properties with enough variation over all characteristics of interest. This sample contained many properties with very similar inundation risks and coastal viewfactors, making delineation of pricing effects relative to this quantity difficult to estimate. At one level, these characteristics reflected the nature of the community itself – prices in Cairns did not react strongly to coastal views because the topography in the case study area was very flat and almost all properties, except those with absolute coastal frontage, had little to no coastal view. Similarly, inundation risk was very even across the community. However, even though these characteristics did reflect the reality of the case study community that they described, this limitation was important because the case studies that we used were only subsets of the broader urban communities in the area. This means that within the broader case study region, homeowners could choose to live in similar areas with different levels of inundation risk by choosing a location nearby but outside the study area. This highlighted the fact that if the goal of a study were to measure inundation risk pricing, a good representative sample of the area in question must be realized in the datasets used to successfully resolve the structure in inundation pricing. In the current study, it was clear that this was more successfully achieved for the Moreton case than the Cairns case.

These insights are likely to provide important pointers to the development of the relatively new field of inundation risk pricing, especially under sea level rise and climate change scenarios. As digitized housing data improves and becomes more accessible, the size of data sets available for hedonic analysis are likely to increase dramatically. Eventually, these improved datasets will likely provide, at least in some locations, sufficient resolving power to perform full hedonic analysis of inundation risk pricing, by simply covering a large enough sample with diverse enough characteristics that the positive effects of coastal proximity can be separated from the negative effects of increased inundation risk in the coastal zone. In addition, as the risks are described more completely and discussed more broadly in the community, the housing market may well incorporate stronger responses to inundation risk into property values. However, in the meantime, the ability to discern some effect due to inundation risk in the coastal zone, as we do here, is likely to be very important to the discussions currently underway in coastal communities around the world about how best to adapt our coastal communities to protect against inundation as sea levels rise and climates change .

6 Conclusions

This study proposes a modeling approach to disentangle the discount due to inundation in residential property that are located in coastal areas. In order to estimate the discount the modeling uses a combined measure of inundation risk and a three dimensional measure for *ocean views*, *distance to ocean* and *distance to waterways*. The study makes three contributions, it is the first to incorporate a continuous measure of flood risk, recently proposed by Rambaldi et al. (2013), compared to earlier studies which have modeled flood risk using only an inundated/not-inundated binary variable. It is the first study to estimate a discount over a three dimensional amenities' set (degrees of view of the ocean, proximity to the ocean and proximity to other waterways), in order to provide a valuation of the trade off between 'views/proximity' and inundation. And, finally it is the first study of its kind for Australia.

Data for two coastal sites are used in the study: Moreton Bay and Cairns local government areas in the state of Queensland (Australia). The Moreton Bay site provides the largest diversity of information with properties located in and outside the floodplain area and at a range of distances from the ocean and other waterways. The sample also contains observations spread over a range of ocean view factors (from no view to full view of the ocean). These characteristics make this dataset the richest in terms of information that allow statistical identification of the inundation risk discount taking into account ocean views.

The results indicate that the identification of a significant discount due to inundation risk can be isolated although even in markets when it is highly correlated with views and proximity to ocean and waterways. This is a vital new insight for the growing field of future-focused coastal inundation research under sea level rise scenarios, as opposed to the more common historical assessment of riverine floods. For Moreton Bay, proximity to ocean and waterways seems to fetch a premium, while the results from Cairns indicate only the ocean has a positive effect. Although the size of the discount due to flooding varies across sites, distances and views, the study demonstrates that by applying the methodology proposed here it is possible to disentangle statistically significant discounts due to inundation risk. Improving our understanding of these issues will be vital to beginning to adapt our coastal communities effectively to changing inundation regimes as sea levels rise and climates change.

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A Appendix. Data used to Construct Figure 2. Moreton Bay Estimates of Flood Effect by View and Distances.

Table 6: Estimated Percent Discount per meter - Sensitivity Analysis from Estimates of Model 1-$v_1 = 0.2$

Coast (distance from in m), v_2	water (distance from in m), v_3	mean (flood depth) in meters	# of Properties with $F^{FD} = 1$	$\hat{\theta}_2$	StdErr	$\hat{\theta}_1$	StdErr	%Change	F-Value	p-value
50	25	0.395	382	-0.147	0.046	0.071	0.022	-6.310	5.365	0.005
50	50	0.375	327	-0.194	0.051	0.052	0.024	-12.324	9.787	0.000
50	75	0.381	310	-0.191	0.052	0.039	0.024	-13.426	12.073	0.000
50	100	0.344	275	NS		NS				
100	25	0.377	338	-0.159	0.049	0.063	0.023	-8.202	5.808	0.003
100	50	0.371	307	-0.186	0.051	0.047	0.024	-12.213	10.330	0.000
100	75	0.376	292	-0.183	0.052	0.034	0.024	-13.298	11.458	0.000
100	100	0.336	257	NS		NS				
150	25	0.362	282	-0.159	0.050	0.042	0.023	-10.385	8.154	0.000
150	50	0.354	262	-0.203	0.052	0.031	0.024	-15.160	13.454	0.000
150	75	0.359	248	-0.209	0.053	0.026	0.025	-16.261	13.889	0.000
150	100	0.308	213	NS		NS				
200	25	0.375	250	-0.136	0.052	0.035	0.025	-9.221	5.261	0.005
200	50	0.361	238	-0.194	0.053	0.036	0.025	-13.934	10.538	0.000
200	75	0.363	227	-0.204	0.054	0.032	0.025	-15.120	15.145	0.000
200	100	0.306	192	NS		NS				
250	25	0.369	215	-0.162	0.054	0.019	0.026	-13.033	5.821	0.003
250	50	0.352	203	-0.231	0.056	0.021	0.026	-18.449	16.816	0.000
250	75	0.354	196	-0.226	0.057	0.022	0.027	-18.026	16.408	0.000
250	100	0.313	182	NS		NS				
300	25	0.393	183	-0.167	0.057	0.026	0.029	-12.739	8.259	0.000
300	50	0.374	171	-0.236	0.059	0.026	0.029	-18.403	15.421	0.000
300	75	0.378	164	-0.231	0.059	0.027	0.029	-17.962	15.017	0.000
300	100	0.330	150	NS		NS				
350	25	0.398	178	-0.166	0.057	0.025	0.029	-12.764	10.117	0.000
350	50	0.379	166	-0.235	0.059	0.024	0.029	-18.474	16.098	0.000
350	75	0.384	159	-0.230	0.060	0.025	0.030	-18.007	15.690	0.000
350	100	0.335	145	NS		NS				
400	25	0.398	176	-0.166	0.057	0.023	0.029	-12.928	9.040	0.000
400	50	0.379	164	-0.234	0.059	0.022	0.029	-18.681	16.378	0.000
400	75	0.384	157	-0.230	0.060	0.023	0.030	-18.217	14.733	0.000
400	100	0.334	143	NS		NS				
450	25	0.397	171	-0.176	0.058	0.024	0.030	-13.718	9.741	0.000
450	50	0.378	159	-0.247	0.060	0.022	0.030	-19.690	18.254	0.000
450	75	0.382	152	-0.242	0.061	0.023	0.031	-19.227	16.561	0.000
450	100	0.331	138	NS		NS				
NS	not significant									
%Change	percent change in price per m below 100 Year ARI									
F-value	$H_0 : \theta_1 = 0$ and $\theta_2 = 0$									

Table 7: Estimated Percent Discount per meter - Sensitivity Analysis from Estimates of Model 1-v_1 =0.4

Coast (distance from in m), v_2	water (distance from in m), v_3	mean (flood depth) in meters	# of Properties with $F^{FD} = 1$	$\hat{\theta}_2$	StdErr	$\hat{\theta}_1$	StdErr	%Change	F-Value	p-value
50	25	0.409	422	-0.122	0.042	0.070	0.021	-4.282	8.304	0.000
50	50	0.393	361	-0.149	0.047	0.041	0.023	-9.658	7.071	0.001
50	75	0.399	343	-0.143	0.047	0.028	0.023	-10.526	8.464	0.000
50	100	0.369	308	NS		NS				
100	25	0.393	364	-0.137	0.045	0.066	0.022	-6.034	7.370	0.001
100	50	0.393	329	-0.136	0.047	0.035	0.023	-9.098	4.727	0.009
100	75	0.399	313	-0.129	0.048	0.022	0.024	-9.964	8.572	0.000
100	100	0.365	278	NS		NS				
150	25	0.380	305	-0.132	0.046	0.045	0.022	-7.677	6.872	0.001
150	50	0.380	281	-0.143	0.048	0.019	0.023	-11.400	9.394	0.000
150	75	0.386	266	-0.145	0.048	0.012	0.024	-12.289	9.443	0.000
150	100	0.342	231	NS		NS				
200	25	0.395	273	-0.114	0.047	0.041	0.024	-6.604	4.895	0.008
200	50	0.388	257	-0.136	0.049	0.025	0.024	-10.235	6.999	0.001
200	75	0.391	245	-0.141	0.049	0.020	0.025	-11.199	6.884	0.001
200	100	0.345	210	NS		NS				
250	25	0.398	234	-0.106	0.049	0.009	0.025	-9.116	6.534	0.002
250	50	0.384	222	-0.153	0.051	0.007	0.025	-13.453	10.767	0.000
250	75	0.388	214	-0.149	0.051	0.007	0.026	-13.067	10.658	0.000
250	100	0.353	200	NS		NS				
300	25	0.416	199	-0.136	0.053	0.023	0.028	-10.386	6.785	0.001
300	50	0.401	187	-0.189	0.055	0.021	0.028	-15.099	12.870	0.000
300	75	0.407	179	-0.184	0.055	0.021	0.029	-14.694	8.000	0.000
300	100	0.366	165	NS		NS				
350	25	0.417	189	-0.148	0.054	0.024	0.029	-11.263	8.740	0.000
350	50	0.401	177	-0.202	0.056	0.021	0.029	-16.179	12.325	0.000
350	75	0.407	169	-0.197	0.056	0.021	0.030	-15.781	12.092	0.000
350	100	0.363	155	NS		NS				
400	25	0.418	187	-0.147	0.054	0.023	0.029	-11.401	8.245	0.000
400	50	0.401	175	-0.202	0.056	0.019	0.029	-16.358	13.776	0.000
400	75	0.407	167	-0.197	0.056	0.019	0.030	-15.955	12.313	0.000
400	100	0.363	153	NS		NS				
450	25	0.417	182	-0.155	0.054	0.023	0.029	-12.064	9.434	0.000
450	50	0.401	170	-0.211	0.056	0.019	0.029	-17.163	14.179	0.000
450	75	0.407	162	-0.206	0.057	0.018	0.030	-16.768	13.899	0.000
450	100	0.361	148	NS		NS				
NS	not significant									
%Change	percent change in price per m below 100 Year ARI									
F-value	$H_0 : \theta_1 = 0$ and $\theta_2 = 0$									

Table 8: Estimated Percent Discount per meter - Sensitivity Analysis from Estimates of Model 1-$v_1 = 0.6$

Coast (distance from in m), v_2	water (distance from in m), v_3	mean (flood depth) in meters	# of Properties with $F^{FD} = 1$	$\hat{\theta}_2$	StdErr	$\hat{\theta}_1$	StdErr	%Change	F-Value	p-value
50	25	0.417	433	-0.063	0.037	0.047	0.020	-1.262	3.487	0.031
50	50	0.405	368	-0.070	0.040	0.012	0.021	-5.545	4.687	0.009
50	75	0.412	349	NS		NS				
50	100	0.383	314	NS		NS				
100	25	0.391	372	-0.138	0.045	0.065	0.022	-6.167	6.830	0.001
100	50	0.393	333	-0.136	0.047	0.035	0.023	-9.160	6.022	0.002
100	75	0.400	316	-0.129	0.048	0.021	0.024	-9.975	6.181	0.002
100	100	0.366	281	NS		NS				
150	25	0.379	311	-0.133	0.045	0.046	0.022	-7.790	4.556	0.011
150	50	0.380	285	-0.143	0.048	0.019	0.023	-11.451	8.907	0.000
150	75	0.386	269	-0.145	0.048	0.012	0.024	-12.279	9.484	0.000
150	100	0.343	234	NS		NS				
200	25	0.393	279	-0.115	0.047	0.041	0.024	-6.727	4.403	0.012
200	50	0.389	261	-0.136	0.049	0.024	0.024	-10.297	7.715	0.000
200	75	0.392	248	-0.141	0.049	0.020	0.025	-11.199	6.923	0.001
200	100	0.346	213	NS		NS				
250	25	0.396	240	-0.108	0.049	0.010	0.025	-9.210	5.435	0.004
250	50	0.385	226	-0.153	0.051	0.007	0.025	-13.464	9.691	0.000
250	75	0.388	217	-0.148	0.051	0.008	0.026	-13.039	10.692	0.000
250	100	0.354	203	NS		NS				
300	25	0.413	205	-0.139	0.053	0.024	0.028	-10.481	8.165	0.000
300	50	0.401	191	-0.188	0.055	0.020	0.028	-15.111	12.401	0.000
300	75	0.407	182	-0.184	0.055	0.021	0.029	-14.662	10.891	0.000
300	100	0.366	168	NS		NS				
350	25	0.414	195	-0.150	0.054	0.026	0.028	-11.336	7.681	0.001
350	50	0.401	181	-0.202	0.056	0.021	0.029	-16.181	14.303	0.000
350	75	0.407	172	-0.197	0.056	0.022	0.029	-15.730	15.175	0.000
350	100	0.364	158	NS		NS				
400	25	0.414	193	-0.150	0.054	0.024	0.028	-11.481	6.564	0.001
400	50	0.402	179	-0.202	0.056	0.019	0.029	-16.350	13.309	0.000
400	75	0.407	170	-0.197	0.056	0.020	0.030	-15.904	12.332	0.000
400	100	0.364	156	NS		NS				
450	25	0.414	188	-0.158	0.054	0.024	0.029	-12.131	7.759	0.000
450	50	0.401	174	-0.211	0.056	0.019	0.029	-17.145	14.317	0.000
450	75	0.407	165	-0.206	0.057	0.019	0.030	-16.696	13.914	0.000
450	100	0.362	151	NS		NS				
NS	not significant									
%Change	percent change in price per m below 100 Year ARI									
F-value	$H_0 : \theta_1 = 0$ and $\theta_2 = 0$									

Table 9: Estimated Percent Discount per meter - Sensitivity Analysis from Estimates of Model 1-v_1 =0.7

Coast (distance from in m), v_2	water (distance from in m), v_3	mean (flood depth) in meters	# of Properties with $F^{FD} = 1$	$\hat{\theta}_2$	StdErr	$\hat{\theta}_1$	StdErr	%Change	F-Value	p-value
50	25	0.435	459	NS		NS				
50	50	0.426	394	-0.036	0.033	-0.014	0.019	-4.965	4.907	0.007
50	75	0.437	370	-0.032	0.034	-0.024	0.020	-5.550	6.815	0.001
50	100	0.406	328							
100	25	0.391	393	-0.132	0.044	0.046	0.021	-7.673	6.208	0.002
100	50	0.393	354	-0.128	0.046	0.015	0.023	-10.448	9.301	0.000
100	75	0.402	332	-0.126	0.047	0.007	0.024	-11.121	10.587	0.000
100	100	0.362	290	NS		NS				
150	25	0.380	332	-0.130	0.045	0.026	0.022	-9.520	6.877	0.001
150	50	0.381	306	-0.137	0.047	0.000	0.023	-12.851	13.694	0.000
150	75	0.389	285	-0.142	0.047	-0.003	0.024	-13.527	14.244	0.000
150	100	0.340	243	NS		NS				
200	25	0.393	300	-0.110	0.046	0.018	0.023	-8.589	5.488	0.004
200	50	0.389	282	-0.128	0.048	0.002	0.024	-11.851	8.968	0.000
200	75	0.395	264	-0.138	0.048	0.003	0.024	-12.614	10.581	0.000
200	100	0.342	222	NS		NS				
250	25	0.396	261	-0.102	0.048	-0.012	0.024	-10.929	8.266	0.000
250	50	0.385	247	-0.145	0.049	-0.015	0.025	-14.914	16.292	0.000
250	75	0.392	233	-0.144	0.050	-0.010	0.025	-14.433	13.406	0.000
250	100	0.349	212	0.018	0.059	-0.045	0.027	-2.544		
300	25	0.411	226	-0.127	0.051	-0.004	0.026	-12.289	10.229	0.000
300	50	0.401	212	-0.173	0.053	-0.007	0.027	-16.591	19.576	0.000
300	75	0.410	198	-0.174	0.054	-0.001	0.027	-16.079	15.406	0.000
300	100	0.360	177	0.003	0.067	-0.041	0.030	-3.795	2.687	0.068
350	25	0.412	216	-0.137	0.052	-0.004	0.027	-13.205	9.980	0.000
350	50	0.401	202	-0.185	0.054	-0.008	0.028	-17.682	19.914	0.000
350	75	0.411	188	-0.186	0.055	-0.002	0.028	-17.152	16.873	0.000
350	100	0.358	167	-0.010	0.068	-0.042	0.031	-5.089	3.661	0.026
400	25	0.412	214	-0.137	0.052	-0.006	0.027	-13.328	11.430	0.000
400	50	0.401	200	-0.185	0.054	-0.010	0.028	-17.828	19.646	0.000
400	75	0.411	186	-0.185	0.055	-0.004	0.029	-17.322	17.799	0.000
400	100	0.358	165	NS		NS				
450	25	0.412	209	-0.144	0.053	-0.006	0.027	-13.986	13.425	0.000
450	50	0.400	195	-0.193	0.055	-0.010	0.028	-18.577	21.456	0.000
450	75	0.410	181	-0.194	0.055	-0.005	0.029	-18.082	18.934	0.000
450	100	0.356	160	NS		NS				
NS	not significant									
%Change	percent change in price per m below 100 Year ARI									
F-value	$H_0 : \theta_1 = 0$ and $\theta_2 = 0$									

Table 10: Estimated Percent Discount per meter - Sensitivity Analysis from Estimates of Model 1-v_1 =0.8

Coast (distance from in m), v_2	water (distance from in m), v_3	mean (flood depth) in meters	# of Properties with $F^{FD} = 1$	$\hat{\theta}_2$	StdErr	$\hat{\theta}_1$	StdErr	%Change	F-Value	p-value
50	25	0.430	475	NS		NS				
50	50	0.424	407	-0.032		-0.020	0.019	-5.129	4.352	0.013
50	75	0.436	379	-0.030		-0.028	0.019	-5.668	5.474	0.004
50	100	0.406	337	NS		NS				
100	25	0.388	409	-0.114	0.043	0.030	0.021	-7.693	5.960	0.003
100	50	0.391	367	-0.119	0.046	0.008	0.022	-10.493	10.345	0.000
100	75	0.402	341	-0.122	0.047	0.003	0.024	-11.159	11.577	0.000
100	100	0.363	299	NS		NS				
150	25	0.376	348	-0.112	0.044	0.010	0.021	-9.616	5.846	0.003
150	50	0.379	319	-0.130	0.046	-0.008	0.022	-12.911	11.482	0.000
150	75	0.390	294	-0.138	0.047	-0.007	0.024	-13.567	13.542	0.000
150	100	0.342	252	NS		NS				
200	25	0.388	316	-0.091	0.045	0.000	0.022	-8.651	6.550	0.001
200	50	0.387	295	-0.120	0.047	-0.006	0.023	-11.935	7.879	0.000
200	75	0.395	273	-0.134	0.048	-0.002	0.024	-12.675	11.035	0.000
200	100	0.344	231	NS		NS				
250	25	0.390	277	-0.083	0.047	-0.030	0.024	-10.883	11.891	0.000
250	50	0.383	260	-0.136	0.049	-0.022	0.024	-14.936	16.190	0.000
250	75	0.393	242	-0.140	0.050	-0.014	0.025	-14.464	13.376	0.000
250	100	0.352	221	0.021	0.059	-0.049	0.026	-4.810	4.137	0.016
300	25	0.404	242	-0.103	0.051	-0.025	0.026	-12.240	11.903	0.000
300	50	0.397	225	-0.163	0.053	-0.016	0.026	-16.611	17.585	0.000
300	75	0.410	207	-0.169	0.054	-0.006	0.027	-16.095	15.338	0.000
300	100	0.363	186	NS		NS				
350	25	0.404	232	-0.112	0.051	-0.026	0.026	-13.173	11.128	0.000
350	50	0.397	215	-0.175	0.053	-0.017	0.027	-17.687	19.796	0.000
350	75	0.410	197	-0.180	0.054	-0.007	0.028	-17.157	16.208	0.000
350	100	0.361	176	NS		NS				
400	25	0.404	230	-0.112	0.051	-0.028	0.026	-13.301	13.248	0.000
400	50	0.397	213	-0.174	0.053	-0.019	0.027	-17.840	18.946	0.000
400	75	0.411	195	-0.180	0.054	-0.009	0.028	-17.316	19.589	0.000
400	100	0.360	174	NS		NS				
450	25	0.404	225	-0.118	0.052	-0.029	0.026	-13.968	13.471	0.000
450	50	0.396	208	-0.182	0.054	-0.019	0.027	-18.586	21.387	0.000
450	75	0.410	190	-0.187	0.055	-0.010	0.029	-18.046	19.507	0.000
450	100	0.358	169	NS		NS				
NS	not significant									
%Change	percent change in price per m below 100 Year ARI									
F-value	$H_0 : \theta_1 = 0$ and $\theta_2 = 0$									

Table 11: Estimated Percent Discount per meter - Sensitivity Analysis from Estimates of Model 1-v_1 =0.9

Coast (distance from in m), v_2	water (distance from in m), v_3	mean (flood depth) in meters	# of Properties with $F^{FD}=1$	$\hat{\theta}_2$	StdErr	$\hat{\theta}_1$	StdErr	%Change	F-Value	p-value
50	25	0.435	486	NS		NS				
50	50	0.430	418	-0.021	0.032	-0.027	0.018	-4.723	5.836	0.003
50	75	0.445	385	-0.026	0.033	-0.026	0.019	-5.104	5.981	0.003
50	100	0.416	341	0.034	0.035	-0.038	0.020	-0.292	2.395	0.091
100	25	0.393	418	-0.097	0.041	0.019	0.020	-7.299	6.336	0.002
100	50	0.398	376	-0.098	0.043	-0.005	0.022	-9.872	9.528	0.000
100	75	0.412	345	-0.110	0.044	-0.001	0.023	-10.475	9.446	0.000
100	100	0.375	303	NS		NS				
150	25	0.383	357	-0.094	0.042	-0.001	0.020	-9.138	9.217	0.000
150	50	0.387	328	-0.106	0.044	-0.021	0.022	-12.132	12.824	0.000
150	75	0.402	298	-0.123	0.045	-0.011	0.023	-12.630	14.832	0.000
150	100	0.356	256	-0.016	0.052	-0.037	0.024	-5.211	3.386	0.034
200	25	0.396	325	-0.073	0.043	-0.012	0.022	-8.240	6.542	0.001
200	50	0.395	304	-0.097	0.045	-0.020	0.023	-11.216	10.456	0.000
200	75	0.408	277	-0.119	0.045	-0.006	0.024	-11.785	11.194	0.000
200	100	0.360	235	NS		NS				
250	25	0.398	286	-0.063	0.045	-0.043	0.023	-4.180	14.468	0.000
250	50	0.392	269	-0.108	0.046	-0.037	0.023	-13.890	19.638	0.000
250	75	0.407	246	-0.122	0.047	-0.019	0.025	-13.339	13.967	0.000
250	100	0.368	225	0.018	0.054	-0.049	0.026	-4.734	4.198	0.015
300	25	0.399	247	-0.090	0.050	-0.037	0.025	-12.278	12.823	0.000
300	50	0.392	230	-0.150	0.052	-0.029	0.026	-16.715	20.421	0.000
300	75	0.410	207	-0.169	0.054	-0.006	0.028	-16.095	17.170	0.000
300	100	0.363	186	0.007	0.065	-0.047	0.030	-3.889	3.267	0.038
350	25	0.400	237	-0.099	0.051	-0.039	0.026	-13.249	12.739	0.000
350	50	0.392	220	-0.161	0.053	-0.030	0.026	-17.817	21.496	0.000
350	75	0.410	197	-0.180	0.054	-0.007	0.028	-17.149	15.601	0.000
350	100	0.361	176	-0.005	0.068	-0.047	0.030	-5.158	4.274	0.014
400	25	0.400	235	-0.099	0.051	-0.040	0.026	-13.384	14.291	0.000
400	50	0.392	218	-0.161	0.053	-0.032	0.026	-17.985	19.475	0.000
400	75	0.411	195	-0.180	0.054	-0.009	0.028	-17.316	18.369	0.000
400	100	0.360	174	-0.006	0.067	-0.049	0.030	-5.381	4.474	0.011
450	25	0.399	230	-0.105	0.052	-0.041	0.026	-14.049	15.800	0.000
450	50	0.391	213	-0.169	0.054	-0.033	0.027	-18.734	22.593	0.000
450	75	0.410	190	-0.187	0.055	-0.010	0.029	-18.054	20.118	0.000
450	100	0.358	169	-0.015	0.068	-0.050	0.031	-6.337	4.885	0.008
NS	not significant									
%Change	percent change in price per m below 100 Year ARI									
F-value	$H_0: \theta_1 = 0$ and $\theta_2 = 0$									