The Impact of Water Quality on Florida's Home Values

FloridaRealtors®

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Executive Summary

Overview

There has long been a belief that there is a connection between home values and the quality and clarity of Florida waterways. The objective of this study was to determine whether that "belief" is in fact true.

We examined the impact of water quality and clarity on the sale prices of homes in Martin and Lee counties over a four-year period, from 2010 through 2013. What was clearly found was that the ongoing problem of polluted water in the Caloosahatchee and St. Lucie rivers and estuaries has indeed resulted in a negative impact on home values.

In addition, the study found a significant economic impact resulting from improved water quality and clarity - Lee County's aggregate property values increase by an estimated $541 million, while Martin County's aggregate property values increase by an estimated $428 million. These increased property values also provide additional revenue for city and county governments.

How the Study Was Done

We used hedonic pricing models to control for the effects of other factors which are known to affect home prices, thereby allowing for the true impact of water quality to be estimated. The controls we used in the models included structural characteristics for each home that were recorded either in the county property tax rolls or local multiple listing service (MLS) listings. Examples of these structural characteristics include the effective age of the home, lot acreage, heated square footage, and whether the home has a swimming pool.

We also factored in characteristics of the neighborhoods surrounding each home, utilizing school attendance zone maps and corresponding school quality scores, as well as U.S. Census block group-level estimates of median household income and the percentages of residents who are age 65 or older (to identify areas popular for retirees) or less than age 18 (to identify areas popular for families with children). Other controls were put in place to account for whether homes were on a waterfront, as well as their distance to the ocean and other major water bodies, including the estuaries of concern. We also accounted for macroeconomic and seasonal economic effects using standard techniques for these types of models.

For the Lee County models, we chose four different types of ambient water quality measurements from the STORET database maintained by the Florida Department of Environmental Protection (FDEP), each collected roughly once per month at up to 16 separate monitoring sites in the Caloosahatchee River between the W. P. Franklin Lock and the mouth of the river at San Carlos Bay. These measures were not chosen based on whether they are harmful to the ecosystem so much as how well they might represent visible characteristics of the water—something which might impact the opinion of a potential homebuyer viewing the home. In particular, an emphasis was placed on measurements of water clarity.

The first type of measure we used was micrograms per liter (µg/L) of chlorophyll *a* in the water, which captures the extent to which the water is populated by microscopic photosynthetic organisms that can cause discoloration and murkiness in the water. Some of these organisms are harmful to both aquatic life and humans, such as cyanobacteria (i.e. blue-green algae).

The second type of measure we used was milligrams per liter (mg/L) of dissolved oxygen. A lack of oxygen in the water is associated with the presence of algae-friendly nutrients. Moreover, if dissolved oxygen levels remain too low for too long, most aquatic life will begin to die off, which of course can result in unpleasant sights and odors that may impact the perceptions of potential homebuyers.

The third measure, turbidity, is a measure of the cloudiness of water due to any sort of tiny suspended materials, living or non-living. Turbidity is measured by an instrument called a *nephelometer*, which captures its readings with a deflector that measures the way in which a light beam is deflected by particles suspended in the water. Nephelometer measurements are reported in Nephelometric Turbidity Units (NTUs). Higher NTUs mean the water is more turbid.

The final metric is an older and less sophisticated—yet tried-and-true—method of measuring water clarity. For this measurement, an 8-inch wide disk, called a *Secchi disk*, is slowly lowered into the water until it is no longer visible to the naked eye, at which point the depth of the disk is recorded. Secchi disk depth is most often measured in meters; we chose to convert to feet for explanatory purposes.

Using GIS software, each Lee County home sale record in our data set was assigned to the nearest monitoring point for each of the four metrics. Using these assignments, we produced for each home sale record the average value of each metric's measurements over both the full month and full year leading up to the sale's contract date. For example, a home sale with a contract date of July 15, 2013 would first have been assigned the average of all chlorophyll *a* readings occurring between June 16, 2013 and July 15, 2013, and then the average of all chlorophyll *a* readings occurring between July 16, 2012 and July 15, 2013. The process would then be repeated for dissolved oxygen, turbidity, and Secchi disk depth. It should be noted that because each metric in our Lee County data was measured only about once per month anyway, the one-month averages were often simply just the most recently recorded value of a metric. In the few cases where there were no measurements in the month prior to a home sale's contract date, the most recent measurement was substituted, which was never any more than 37 days prior to the contract date.

As for our Martin County models, the St. Lucie River data in FDEP's STORET database was inadequate for our purposes, so we instead used weekly dissolved oxygen and Secchi disk measurements compiled by the Florida Oceanographic Society (FOS). While this prevented us from being able to estimate the Martin County models for chlorophyll *a* and NTUs of turbidity, the FOS data was an upgrade in terms of how frequently it was collected (i.e. weekly instead of monthly). FOS data was also collected over the full four-year time period for the wide portion of the Indian River Lagoon in Martin County extending north from the mouth of the St. Lucie River. FDEP data did turn out to be available for the Loxahatchee River, located in the southern part of the county, so the full coverage area for our models included all estuarine waters of any significant width located in and around Martin County.

Model Results and Estimated Effects

The results of the one-month models and one-year models were statistically significant for all water quality metrics except for dissolved oxygen, which was not significant in either the Lee or Martin County models. These results are discussed at length in Section 4 of this report.

Key findings of note from the one-month models:

- *Three types of water quality measures for Lee County were found to have positive (negative) impacts on home values when water quality increases (decreases). The robust statistical significance of these results strongly supports the notion that water quality plays a role in the determination of nearby home prices.*

- *Statistically significant results were found for two completely separate counties, another strong indicator that the water quality does indeed affect home prices in the hypothesized manner.*

- *Because of the lack of readings occurring more often than about once per month for the Lee County water data, there is the possibility of attenuation bias. What this means is that it is likely that the true effects are even stronger than what the model predicted.*

Selected estimates from the one-month models are displayed in Table ES.1.

Table ES.1
Marginal price effects of changes in 1-month average Secchi disk depth at select distances

Location of Property	Water Quality Measure	Change in Water Quality	Resulting change in Property Value	Standard Error
Lee County				
Caloosahatchee Estuary waterfront	Secchi disk depth	+1 foot	+2.47%	0.41%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+1.93%	0.32%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+1.50%	0.25%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+0.91%	0.15%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+0.34%	0.055%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.045%	0.0075%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.00083%	0.00014%
Martin County				
Waterfront on the St. Lucie Estuary, Loxahatchee Estuary, or Indian River Lagoon north of St. Lucie Inlet	Secchi disk depth	+1 foot	+5.41%	0.86%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+4.21%	0.67%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+3.28%	0.52%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+1.99%	0.32%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+0.73%	0.12%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.10%	0.016%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.0018%	0.00029%

Key findings of note from the one-year models:

- *The effects are much larger when we use the one-year averages rather than the one-month averages. This result indicates while the algal blooms and water discharge events have caused distress to home prices, for the most part, individual events have not affected homebuyers' opinions of homes. The stronger results for the one-year averages means that rather, homebuyers take into account the quality of water over the long term when making their offers. What is happening is that, while one algal bloom is not alarming in isolation, the recurrence of the algal* *blooms on a regular basis is showing up in the one-year models. This regular recurrence is what is concerning homebuyers and sellers. That is, a one-time event may not have a detrimental effect, but multiple times is a big problem.*

- *Secchi disk depth proves to be superior to chlorophyll a, turbidity, and dissolved oxygen in terms of capturing homebuyers' and sellers' perceptions of water quality.*

Selected estimates from the one-year models are displayed in Table ES.2.

Table ES.2
Marginal price effects of changes in 1-year average Secchi disk depth at select distances

Location of Property	Water Quality Measure	Change in Water Quality	Resulting change in Property Value	Standard Error
Lee County				
Caloosahatchee Estuary waterfront	Secchi disk depth	+1 foot	+14.66%	1.02%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+11.42%	0.80%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+8.89%	0.62%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+5.39%	0.38%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+1.98%	0.14%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.27%	0.019%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.0049%	0.00034%
Martin County				
Waterfront on the St. Lucie Estuary, Loxahatchee Estuary, or Indian River Lagoon north of St. Lucie Inlet	Secchi disk depth	+1 foot	+10.32%	1.14%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+8.03%	0.89%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+6.26%	0.69%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+3.80%	0.42%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+1.40%	0.15%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.19%	0.021%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.0035%	0.00038%

In Section 5 of this report, we apply the above results to countywide property data, yielding the following estimates:

- *Other things equal, we find that a one-foot increase in average Secchi disk depth throughout the Caloosahatchee Estuary **raises Lee County's aggregate property value by an estimated <u>$541 million</u>**.*

- *Other things equal, we find that a one-foot increase in average Secchi disk depth throughout the St. Lucie Estuary, Loxahatchee Estuary, and the portion of the Indian River Lagoon north of the St. Lucie Inlet* ***raises Martin County's aggregate property value by an estimated <u>$428 million</u>****.*

- *We find that changes in the water quality of the St. Lucie Estuary, Loxahatchee Estuary, and the portion of the Indian River Lagoon north of the St. Lucie Inlet—as measured by changes to one-year average Secchi disk depth at each monitoring point—resulted in an estimated* ***<u>$488 million reduction</u> in Martin County's aggregate property value between May 1, 2013 and September 1, 2013****.*

Section 1. Introduction

Much was made of the water releases from Lake Okeechobee into the Caloosahatchee and St. Lucie rivers in the summer of 2013. These discharges contributed to extremely unpleasant conditions for anyone on or near either of the two rivers. In Lee County, the Caloosahatchee River turned into a sort of reddish-brown hue, variously described by locals as a "tea" or "cola" sort of color.[1] This murky water flowed out from the mouth of the river into San Carlos Bay, around Sanibel Island, and into the Gulf of Mexico, wildly contrasting with the clear, vibrant greens and blues of the nearby beach waters.[2] At about the same time, parts of the St. Lucie River in Martin County were green as well—not a clear, vibrant green, but rather a thick, slimy green—due to toxic algal blooms.

While these were significant events that garnered a great deal of attention, it was not as though these were first-time incidents in either river. Episodes such as these have occurred many times over the last several years. Naturally, there is concern among residents of both counties not only for the health of their rivers, but also for the local economies that depend on them.

The waters and beaches of Lee and Martin counties have long supported the local marine industries and have attracted recreation and tourism dollars. These are clearly the most vulnerable sectors of each county's economy when it comes to deteriorating ambient water quality.[3] But it is not difficult to imagine other sectors of these local economies suffering ill effects from unsightly and unclean waters, as well.

Many have speculated that real estate is one such sector, and there is some evidence to support this notion. Many Realtors, for instance, have reported lost sales due to poor water quality related to discharges from Lake Okeechobee.[4] Stories have also circulated of outraged tourists vowing never to return after witnessing how bad the water can get, or after being prevented from even entering the water for the duration of their vacations due to health

[1] Spiewak (2013)
[2] Linette (2013)
[3] The term *water quality* can be used in reference to the quality of local drinking water, the quality of water used for industrial purposes, or simply the environmental quality of water bodies present in the area. The term *ambient water quality* refers to the latter.
[4] See, for example, Gordon (2012).

warnings.[5] Yet, while such evidence is compelling, it is also overwhelmingly anecdotal in nature. Little is truly known about the actual extent to which these discharge-related events have impacted—and will continue to impact—the real estate markets in Lee and Martin counties.

It is well established, however, that bodies of water such as lakes, streams, rivers, bays, and oceans generally have a positive effect on the demand for nearby residential properties, thereby increasing their value. Economists typically refer to this type of effect as an *amenity effect*. In theory, poor water quality will dampen the amenity effect generated by a water body, resulting in less demand for nearby properties. This reduced demand will hypothetically manifest in the form of some combination of lower home prices, fewer home sales, and lengthier times on market for nearby properties.

The purpose of this study is to test the above theory by analyzing the impact of short-term and long-term ambient estuarine water quality on the sale prices of single family homes in Martin and Lee counties over a four-year period, from 2010 through 2013. We use hedonic pricing models to control for the effects of other factors which are known to affect home prices, thereby allowing for the true impact of water quality to be estimated.

In Section 2, we offer a brief synopsis of the interdependent relationship between Lake Okeechobee, the Everglades, and the Caloosahatchee and St. Lucie estuaries. In Section 3, we describe the data and methodology we use in our analysis. We report our results in Section 4, and in Section 5, we present simple examples of how our results might be applied in the measurement of countywide impacts. Concluding remarks are offered in Section 6.

[5] See, for example, Hecker (2013). Tourists are, of course, a significant source of vacation home sales and sales to retirees in both counties, as well as elsewhere in Florida.

Section 2. Background: Lake Okeechobee, the Everglades, and the Estuaries

Lake Okeechobee is one of the largest freshwater lakes in the United States, covering over 660 square miles of south central Florida. Twelve times the size of Florida's next largest lake, it appears on even the most basic maps of Florida, and is easily visible from orbit. It is not, however, easily visible from the ground. To get a glimpse of "Lake O," one must first ascend to the top of the 30-foot Herbert Hoover Dike which almost completely encloses it. The dike was originally built by the U.S. Army Corps of Engineers in the 1930s to replace smaller earthen dikes that had failed to contain the lake during devastating hurricanes in 1926 and 1928—catastrophes that resulted in over 2,500 deaths. Following another particularly powerful hurricane in 1947, it was decided that the dike system should be expanded further. Construction was completed in the 1960s, and the dike has not been expanded since.[6]

For several thousand years leading up to this containment, Lake Okeechobee regularly spilled over its banks during rainy seasons, sending sheet after sheet of fresh water rolling south into the Everglades. Today, as Figure 2.1 illustrates, this water is largely rerouted by canals through the surrounding agricultural lands toward the South Florida metroplex. Some of these canals were put in place by the Corps of Engineers in order to regulate flows from the lake, but others had been in place for several decades already, built during early efforts to drain the northern Everglades to make it suitable for agriculture. Especially of note was a canal built in the 1890s which linked Lake Okeechobee to the Gulf of Mexico via the previously isolated Caloosahatchee River.[7] This man-made connection was further solidified by the Corps of Engineers' construction of the Okeechobee Waterway in 1937, which also connected the lake to the St. Lucie River and Atlantic Ocean to the east.

Since the construction of the Okeechobee Waterway, the Army Corps of Engineers has used discharges into the Caloosahatchee and St. Lucie rivers to lower the water level in Lake Okeechobee when its height poses a threat to the structural integrity of the aging dike. Historically, a major problem associated with these releases has been their effect on the Caloosahatchee and St. Lucie estuaries. Estuaries are, by definition, meeting places between

[6] U.S. Army Corps of Engineers (n.d.)
[7] Florida Department of Environmental Protection (2011)

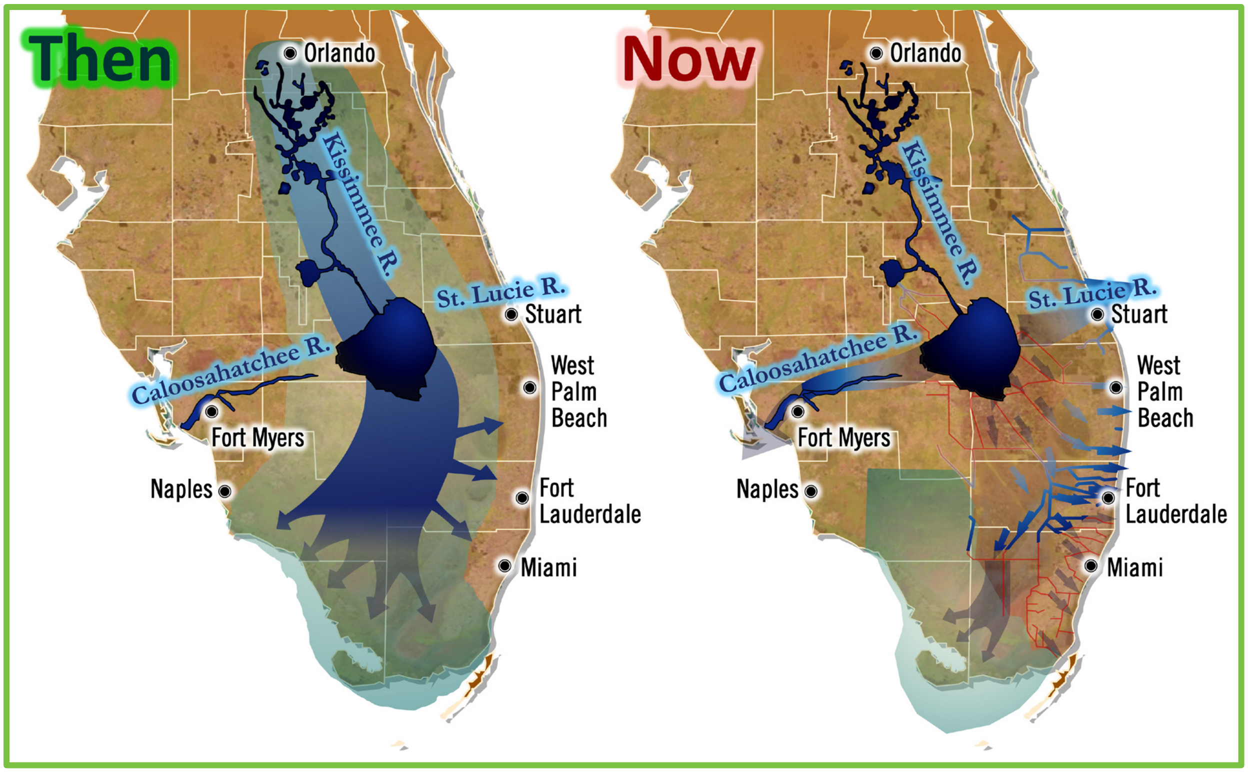

Image source: evergladesplan.org; modified from original (labels added)

Figure 2.1

Side-by-side maps of water flow through the Everglades ecosystem before human intervention (left) and currently (right)

inland freshwater sources and saltwater from the oceans, and the aquatic life that are suited to living in these conditions are sensitive to abrupt changes in salinity. Normally, the salinity of the water in an estuary ebbs and flows along with the tides and any fluctuations in the amount of freshwater flowing into them (due to, say, heavy rainfall events). When enough water from Lake Okeechobee is released over a short period of time, it can effectively push out all of the saline water, causing distress to the aquatic life living within.

More recently, this damage to the estuaries has been amplified by the increasingly high levels of pollutants that have been collecting in Lake Okeechobee for a number of years. Most of the water in Lake Okeechobee comes from the Kissimmee River and its watershed, which begins in the southern suburbs of the Orlando metropolitan area and moves south through a system of canals surrounded by agricultural lands, collecting residential and agricultural runoff as it goes. In 2007, the South Florida Water Management District (SFWMD) extracted several layers of muck from the bottom of Lake Okeechobee in order to expose the natural lakebed. Samples of the extracted muck tested high for a number of pesticides and other contaminants; levels of arsenic were four times higher than what is allowable for residential land.[8]

The high levels of phosphorus and nitrogen found in Lake Okeechobee's water have fueled harmful algal blooms throughout the Everglades ecosystem, including the Caloosahatchee and St. Lucie rivers. Both rivers are already impacted by the phosphorus and nitrogen from local fertilizer runoff, and the Lake Okeechobee discharges only serve to intensify the problem.[9]

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[8] Reid (2007)

[9] Interestingly enough, many have also argued that the Caloosahatchee does not get *enough* water from Lake Okeechobee during dry seasons, which also damages the local ecosystem. See Lollar (2010, Nov.)

Section 3. Methodology and Data Collection

In this section, we outline the design of our hedonic pricing models and describe the data set we analyze with them. In Subsection 3.1, we introduce the concept of hedonic pricing models, and demonstrate why they are useful in the analysis of housing markets. In Subsection 3.2, we lay out the methodology and structure of our hedonic pricing models, and provide a detailed overview of the data set we constructed to test the models.

3.1 Isolating Price Effects in Real Estate Market Analyses

Markets for commodities such as cattle, sugar, copper, or oil are in many ways easier for economists to analyze than housing markets. What can make housing market analysis tricky is the fact that no two homes are exactly alike. With commodities, the lowest price usually determines what sells because price is the only major differentiating factor. By contrast, potential homebuyers may be willing to pay much more for one home versus another based on differences in the characteristics of each home. Even identical models of homes cannot be exactly the same because they cannot occupy the exact same space—any Realtor can tell you just how important location is when it comes to pricing a home.

To illustrate how this aspect of housing markets is problematic for an analyst, let us imagine that we wanted to know how much value that homebuyers and sellers place on waterfront homes in a particular seaside community. A fairly simple approach would be to calculate the average sale price of recently-sold waterfront homes and compare it to the average sale price of recently-sold non-waterfront homes. Now, let us suppose we find these averages to be $300,000 and $200,000, respectively. This result tells us that waterfront homes are selling for a 50 percent premium over non-waterfront homes.

Yet, while that may be true, we cannot necessarily conclude that the waterfront location itself is entirely responsible for the 50 percent sale price premium. What if the schools serving the waterfront areas are more highly rated? What if the waterfront homes are, on average, much larger than the non-waterfront homes? If so, then part of that 50 percent premium may be attributable to higher school quality or greater square footage. Based on what we know so far, we cannot yet discern the true value of the *waterfront* characteristic of these homes.

An economist's go-to tool for solving this sort of problem is called a *hedonic pricing model*.[10] This type of econometric regression model allows us to control for other influential factors in order to isolate the effects that we want to analyze. To generate a hedonic pricing model for the simple example above, we would need to collect data on each home sale in the seaside town over a given period of time. This data would need to include, at a minimum, the sale price for each home and a "yes/no" indicator of whether each home is on the water.[11]

Data must also, however, be collected for the factors for which we would like to control. In this case, we would therefore need the measured square footage of each home and some sort of measure that quantifies nearby school quality for each home. Assuming we have this data, we could then run a hedonic pricing model and obtain an estimate of the value of waterfront vs. non-waterfront property, holding the other factors constant.

There are, of course, a lot more factors that go into the determination of housing prices than we are controlling for above. As a consequence, accurate hedonic pricing models typically require the collection of large data sets containing information about numerous characteristics of each home and its surroundings.

3.2 Hedonic Pricing Models for Lee and Martin Counties

For the present study, our focus is on identifying the effect of ambient water quality on the sale prices of nearby single family homes in Lee and Martin counties. In this subsection of the report, we describe the data set that we constructed for this purpose, beginning with the sale data and control variables we include in the models. Much of the data we collected or constructed was geographic in nature, and we relied heavily on geographic information systems (GIS) software. Because Lee County and Martin County are separate housing markets, and because there are some differences in the type of data we were able to collect for each county, we built our data sets (and estimated our models) for the two counties separately.

[10] Hedonic pricing models were first conceptualized by Sherwin Rosen (1974).

[11] In econometric models, these "yes/no" indicators are typically quantified as "yes"=1 and "no"=0. There are many names for these types of indicators, e.g. binary variables, dummy variables, indicator variables, etc. All refer to the same thing: a numerical representation of a "yes/no" type of characteristic.

Table 3.1
Summary statistics for control characteristics and sale prices

		Lee County Stats: ***N*** = 48,572			Martin County Stats: ***N*** = 7,875		
	Units	***Mean***	***Std. Dev.***	***Source***	***Mean***	***Std. Dev.***	***Source***
Structural Characteristics							
Effective age of home	years	15.6	(11.9)	LCPA	19.0	(11.5)	MCPA
Lot acreage	acres	0.297	(0.744)	LCPA	0.382	(0.851)	MCPA
Heated area	sq. ft.	1,827	(676)	LCPA	—	—	—
Total finished area	sq. ft.	—	—	—	2,131	(1,018)	MCPA
Bedrooms	—	3.07	(0.641)	LCPA	3.06	(0.837)	MCPA
Bathrooms	—	2.18	(0.570)	LCPA	—	—	—
Number of stories	—	1.12	(0.318)	LCPA	—	—	—
Garage	—	0.900	(binary)	LCPA	—	—	—
Carport	—	0.0588	(binary)	LCPA	—	—	—
Sea wall	—	0.122	(binary)	LCPA	—	—	—
Boat dock	—	0.0874	(binary)	LCPA	0.0801	(binary)	MCPA
Swimming pool	—	0.390	(binary)	LCPA	0.405	(binary)	MCPA
Located on golf course	—	0.0443	(binary)	LCPA	0.106	(binary)	MCPA
Sale Characteristics							
Short sale	—	0.173	(binary)	MLS	0.136	(binary)	MLS
Foreclosure/REO	—	0.270	(binary)	MLS	0.0903	(binary)	MLS
Neighborhood Characteristics							
Pct. of residents under age 18	%	20.9	(10.6)	ACS	16.5	(7.33)	ACS
Pct. of residents age 65+	%	20.6	(15.7)	ACS	30.7	(16.4)	ACS
Median household income	$10,000s	5.66	(2.00)	ACS	6.67	(2.45)	ACS
Jurisdictional Characteristics							
Millage rate	mills	18.9	(2.45)	LCPA; LCTC	16.4	(0.472)	MCPA; MCTC
Primary School Score	score	279	(33.6)	MAPX; FDOE	293	(41.7)	MAPX; FDOE
Middle School Score	score	260	(31.5)	MAPX; FDOE	293	(34.9)	MAPX; FDOE
High School Score	score	246	(24.5)	MAPX; FDOE	292	(16.3)	MAPX; FDOE
Regional Characteristics							
Statewide home price index	—	139	(8.88)	FDOR	140	(9.39)	FDOR
Flood risk characteristics							
Risk type X02	—	0.121	(binary)	LC; FEMA	—	—	—
Risk type X500	—	—	—	—	0.627	(binary)	MC; FEMA
Risk type A	—	0.00237	(binary)	LC; FEMA	0.00577	(binary)	MC; FEMA
Risk type AH	—	—	—	—	0.0162	(binary)	MC; FEMA
Risk type AE	—	0.330	(binary)	LC; FEMA	0.141	(binary)	MC; FEMA
AE elevation	feet	3.18	(5.16)	LC; FEMA	1.20	(3.20)	MC; FEMA
Risk type VE	—	0.00523	(binary)	LC; FEMA	0.00715	(binary)	MC; FEMA
VE elevation	feet	0.0730	(1.02)	LC; FEMA	0.0750	(0.886)	MC; FEMA
Water Proximity							
Bay waterfront	—	0.00294	(binary)	LCPA	—	—	—
Distance to bay	miles	4.39	(2.50)	LCPA; SFWMD	—	—	—
Gulf waterfront	—	0.00214	(binary)	LCPA	—	—	—
Distance to Gulf	miles	6.48	(2.47)	LCPA; SFWMD	—	—	—
Canal waterfront	—	0.116	(binary)	LCPA	—	—	—
River (non-estuary) waterfront	—	0.00212	(binary)	LCPA; SFWMD	—	—	—
Lake waterfront	—	0.106	(binary)	LCPA	—	—	—
Intracoastal waterway waterfront	—	—	—	—	0.0124	(binary)	MCPA; SFWMD
Distance to I.C.W.	miles	—	—	—	4.54	(3.24)	MCPA; SFWMD
Ocean waterfront	—	—	—	—	0.00426	(binary)	MCPA; SFWMD
Distance to ocean	miles	—	—	—	4.71	(3.12)	MCPA; SFWMD
Estuary waterfront	—	0.00334	(binary)	LCPA	0.0557	(binary)	MCPA; SFWMD
Distance to estuary	miles	4.31	(2.88)	LCPA	1.46	(1.88)	MCPA; SFWMD
Sale price	$	187,226	(245,839)	MLS	320,120	(576,771)	MLS

Source abbreviations: **ACS** – 2012 American Community Survey 5-year estimates (U.S. Bureau of the Census); **FDOE** – Florida Department of Education; **FDOR** – Florida Department of Revenue; **FEMA** – Federal Emergency Management Agency; **LC** – Lee County Government; **LCPA** – Lee County Property Appraiser; **LCTC** – Lee County Tax Collector; **MAPX** – School zone boundary GIS shapefiles from Maponics, LLC; **MC** – Martin County Government; **MCPA** – Martin County Property Appraiser; **MCTC** – Martin County Tax Collector; **MLS** – Local Multiple Listing Services (see full text); **SFWMD** – South Florida Water Management District

3.2.1 Sale data

For the Lee County models, we began with a data set comprised of all single family home listings found in the three multiple listing services (MLSs) serving the area. We did the same for the three MLSs with listings in Martin County.[12] From there, we narrowed our focus to the set of all listings which both (a) successfully resulted in a closed sale, and (b) went under contract for this sale on any date from 2010 through 2013. We then removed any duplicate listings to ensure that each sale is represented only once in the databases.[13]

We primarily chose 2010 as the first year of our four-year analysis period because it was the earliest year for which we had complete MLS data for either county. Similarly, we made 2013 the final year of the analysis period because some of the supplemental database sources we are using were not updated past the end of 2013 at the time we constructed our core data sets in mid-2014. Our focus on the contract (i.e. "pending") date rather than the final closing date for each home is notable because it is the date at which the decision was made to purchase the home, which is much more relevant to the model than the date upon which the sale was closed.

3.2.2 Control characteristics

Summary statistics for the control characteristics (and for sale prices) are provided in Table 3.1. Our list of control variables for the models is rather extensive. We therefore found it helpful to categorize them as follows:

- ***Structural characteristics*** – representing physical features of the property itself
- ***Sale characteristics*** – representing circumstances of the home's sale
- ***Neighborhood characteristics*** – representing demographics of residents of the area immediately surrounding the home
- ***Jurisdictional characteristics*** – representing impact of local government services and public schools

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[12] The MLSs in Florida are each run by one or more of the state's 58 local REALTOR® boards and associations. In partnership with these local boards and associations, Florida REALTORS® receives data feeds from the state's MLSs for use in the production of research and statistics.

[13] In areas served by multiple MLSs, it is not uncommon for homes to be listed in more than one of them.

- ***Regional characteristics*** – representing “macro” housing market conditions at a regional/state level

- ***Flood risk characteristics*** – representing risk posed by flooding

- ***Water proximity*** – representing the location of the home with respect to various water bodies

- ***Time fixed effects*** – sets of indicator variables—one group for months, another for years—that respectively control for seasonal and annual effects not accounted for by the other control variables included in the models

All of the structural characteristic data that we use comes from the offices of the Lee County Property Appraiser (LCPA) and the Martin County Property Appraiser (MCPA). The golf course location indicator was only found in the Lee County data we obtained, but we were able to construct the same indicator for Martin County using a GIS parcel map and property use code data from MCPA. The Lee County data set contains several additional structural characteristics that were not available from the Martin County data. We would note that this is more of a luxury for our Lee County model than it is a detriment to the Martin County model. The most important structural characteristics—those that typically have the greatest impact on housing prices in hedonic pricing models—are all present in the Martin County data, including effective age, lot size, square footage, and presence of a swimming pool.

The sale characteristics we include as controls in the model are drawn from the MLS listings. They are indicators of whether a home was advertised as a short sale and whether it was marketed as an REO. These sales were arms-length to the extent that they were openly marketed in a multiple listing service.

For the neighborhood characteristics, we used GIS software to identify the census block group in which each home is located by overlapping the latest census block group GIS maps from the U.S. Bureau of the Census with GIS parcel maps from the county property appraisers' offices. The block group-level demographic data are from the 2012 American Community Survey's 5-year estimates data set. We used the percentage of block group residents under the age of 18 and age 65 and older to account for the idea that families with young children tend to prefer to live near other families with young children, and likewise that retirees generally prefer to live among other retirees. Similarly, block group median household income is included to capture the notion that higher income households are attracted to higher income neighborhoods.[14]

We included each home's effective ad valorem millage rate (as of the last full year before its sale) as the lone local government characteristic in our jurisdictional characteristic category. The school quality scores in this category were constructed using school performance metrics published each year by the Florida Department of Education. These metrics include performance scores, by school, for the reading, math, writing, and science components of the Florida Comprehensive Assessment Test (FCAT). The score for each FCAT component represents the percentage of students who scored "satisfactory" or higher on the exams the prior school year. We summed these four scores to arrive at a total score for each school and assigned these values to each home sale according to school attendance zone boundary GIS maps compiled a third-party provider, Maponics, LLC.[15] The scores assigned to each home sale were those of the academic year prior to the sale.

The lone regional characteristic we used is a monthly statewide repeat-sales single family home price index, which we constructed from home sales reported in the Florida Department of Revenue's annual certified county property tax rolls from 1995 through 2014. A time series graph of the index is displayed in Figure 3.1. We followed the same methodology that S&P Dow Jones Indices uses to produce its popular S&P/Case-Shiller Home Price Indices.[16] As a control variable, the index captures the ebb and flow of the general Florida housing market over the four years covered in the study. One example of why we include this variable is that in 2013, the Florida housing market really took off in terms of both sale prices and the overall volume of sales, to such an extent that the positive effect could likely completely wash out the detrimental impact that the poor water quality of 2013 had on the home sales included in our study. Hence, this is a very important control variable in the model.

Flood insurance costs certainly play a role in the determination of Florida home prices, but unfortunately there is little available data that accurately represents these costs. As an approximation, we obtained FEMA flood insurance risk GIS maps from both counties, and

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[14] We included median household income in terms of tens of thousands of dollars in order to make the model results easier to read; whether dollars are used or tens of thousands of dollars are used in the model has no bearing on the actual results.

[15] The Lee County School District uses a school choice system that allows residents of each attendance zone to choose from a set list of schools, depending upon availability, rather than requiring attendance at a single school. To deal with this minor complication, we simply averaged the scores for each eligible school for each home.

[16] S&P Dow Jones Indices (2015, Feb.) provides a very detailed description of the methodology.

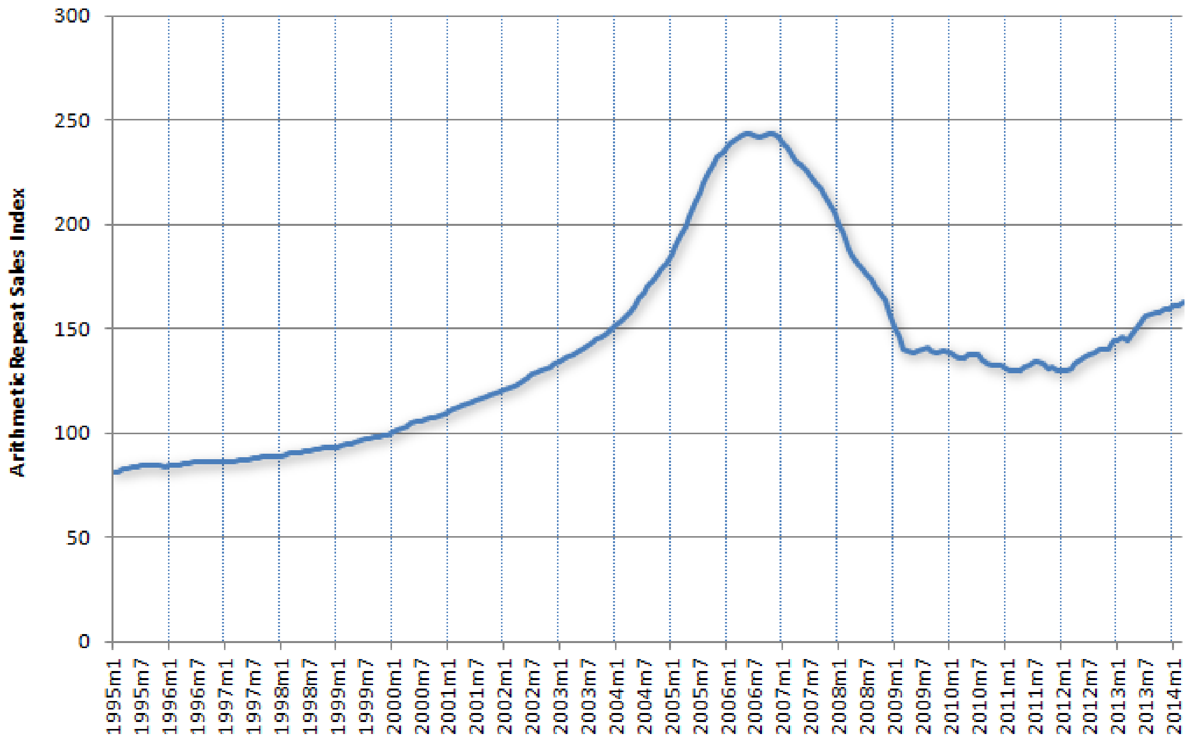


Figure 3.1

A monthly repeat-sales price index for single family homes in Florida. The base month is January of 2000.

attached the risk data to each home under the assumption that these maps play a significant role in determining flood insurance rates. Each risk category was given its own "yes/no" indicator variable, and for homes located in zones with higher risk types AE or VE, the associated estimated flood elevations were included as well. Definitions for the risk type categories are presented in Appendix A.

Proximity to water plays a major role in the determination of home values. In our models, we expect there to be an inverse relationship between property values and the distance from various water bodies. That is, the shorter the distance to a body of water, the greater the property value, other things constant. For the Lee County model, we examined the GIS map of water bodies from the South Florida Water Management District (SFWMD) found within its Arc Hydro Enhanced Database (AHED), and we identified six distinct groupings of water bodies for which to produce proximity measurements:

- ***Bay*** – includes Estero Bay, San Carlos Bay, Matlacha Pass, Pine Island Sound, and other saltwater bodies separated from the Gulf of Mexico by Lee County's barrier islands

- ***Gulf*** – the Gulf of Mexico

- ***Canal*** – predominantly comprised of the canals of Cape Coral

- ***River*** – all rivers and large streams except for the portion of the Caloosahatchee River located downstream from the W.P. Franklin Lock

- ***Lake*** – a number of small to mid-size lakes mapped by SFWMD in the AHED water body map

- ***Estuary*** – the portion of the Caloosahatchee River located downstream from the W.P. Franklin Lock

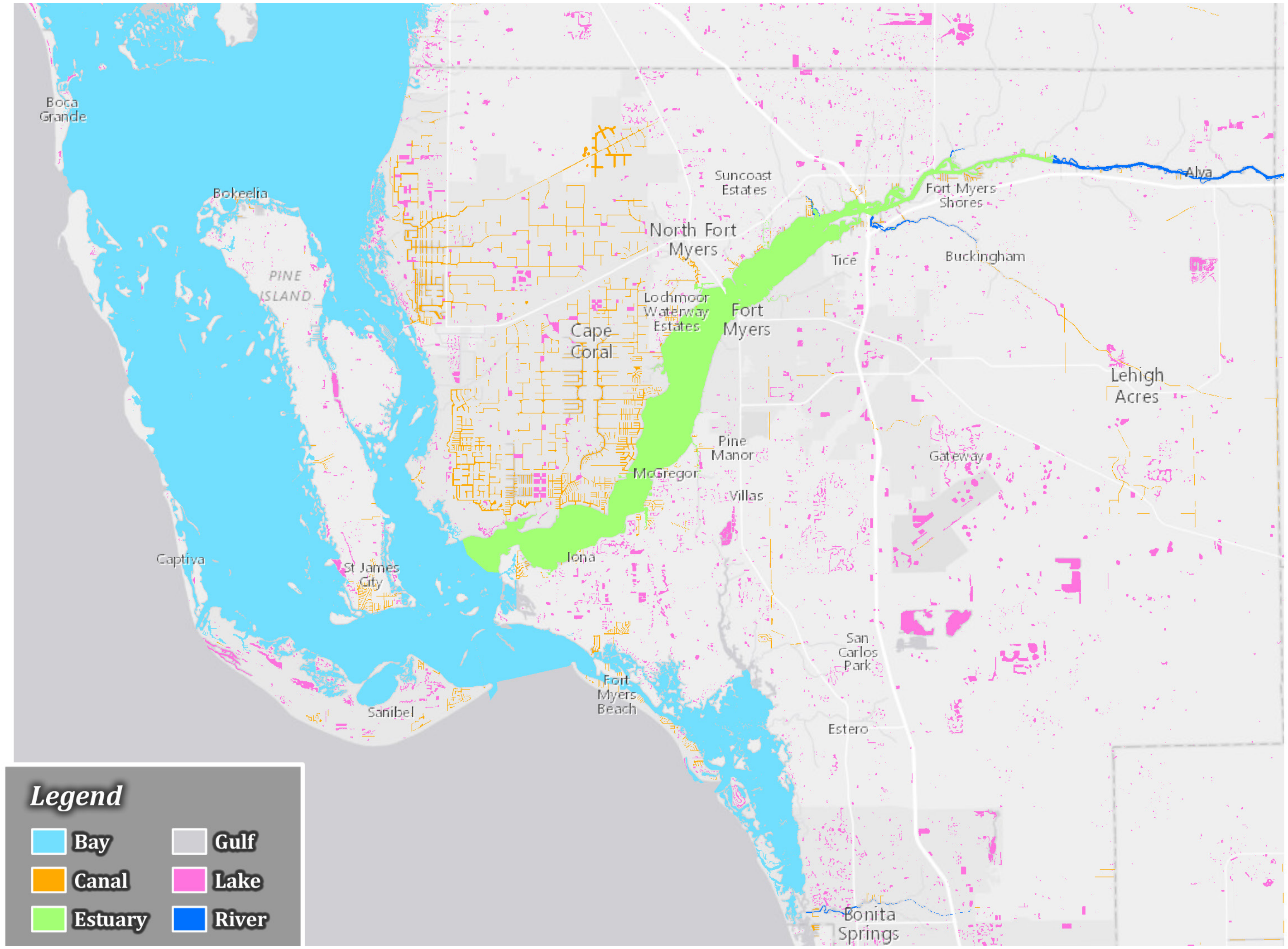
The above water body groups are color-coded and displayed in Figure 3.2. The group names for the water bodies are consistent with their classification in AHED. For each single family home in our Lee County data set, we calculated the direct distance, in miles, to the nearest location of each of these water body types.

If we were to include these raw distances in the hedonic pricing model, we would be making an implicit assumption that the positive impact of a water body on nearby property values declines at a constant rate as we move away from the water body, as depicted in Figure 3.3. This assumption is a bit problematic, because it implies that as we move further away from the water body, there will eventually be a point at which the water body will begin to *negatively* affect the value of the property. In reality, we would just expect the magnitude of the effect to decline toward zero as we move a greater distance away. In light of this issue, we apply a mathematical transformation to all of the raw distance measurements before including them in the model:

$$RelativeImpact = e^{-2 \times Distance}. \tag{3.1}$$

This type of mathematical function is sometimes called an *exponential decay function*.[17] The function appears as the blue curve on the graph shown in Figure 3.4, where the horizontal

[17] Equation 3.1 can alternatively be written as *RelativeImpact* = exp(−2 × *Distance*). The operator function exp() simply means "take *e* to the power of (value in parentheses)." The number *e* is a mathematical constant; it is the base of the natural logarithm and its approximate value is 2.72.



Original water body map file source: SFWMD AHED

Figure 3.2

Map of Lee County water bodies included in the study to control for water amenity effects.

Figure 3.3

A graph illustrating the modeled relationship between home values and distances from a waterfront when raw distance measurements are used in a hedonic pricing model.

axis represents the input value (distance in miles) and the vertical axis shows the corresponding transformed value.[18] The important result from using this function is that we have converted a raw distance measurement into a measure of relative impact that will necessarily be greater than 0, but no greater than 1. This value represents the impact the water body will have on a property value at a given distance *relative* to when the distance is zero. For example, a relative impact value of 0.5 means that the impact is about half of what it would be for a property located on the waterfront. The shape of the curve illustrates that more weight is given to properties in the immediate vicinity of the water body, whereas a few miles out, the water body's influence is negligible.

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[18] We also considered using –1 instead of –2 as the parameter value in the function (shown as the green curve in Figure 3.4), but we ultimately judged the rate of decay over distance was not significant enough to capture the true effect.

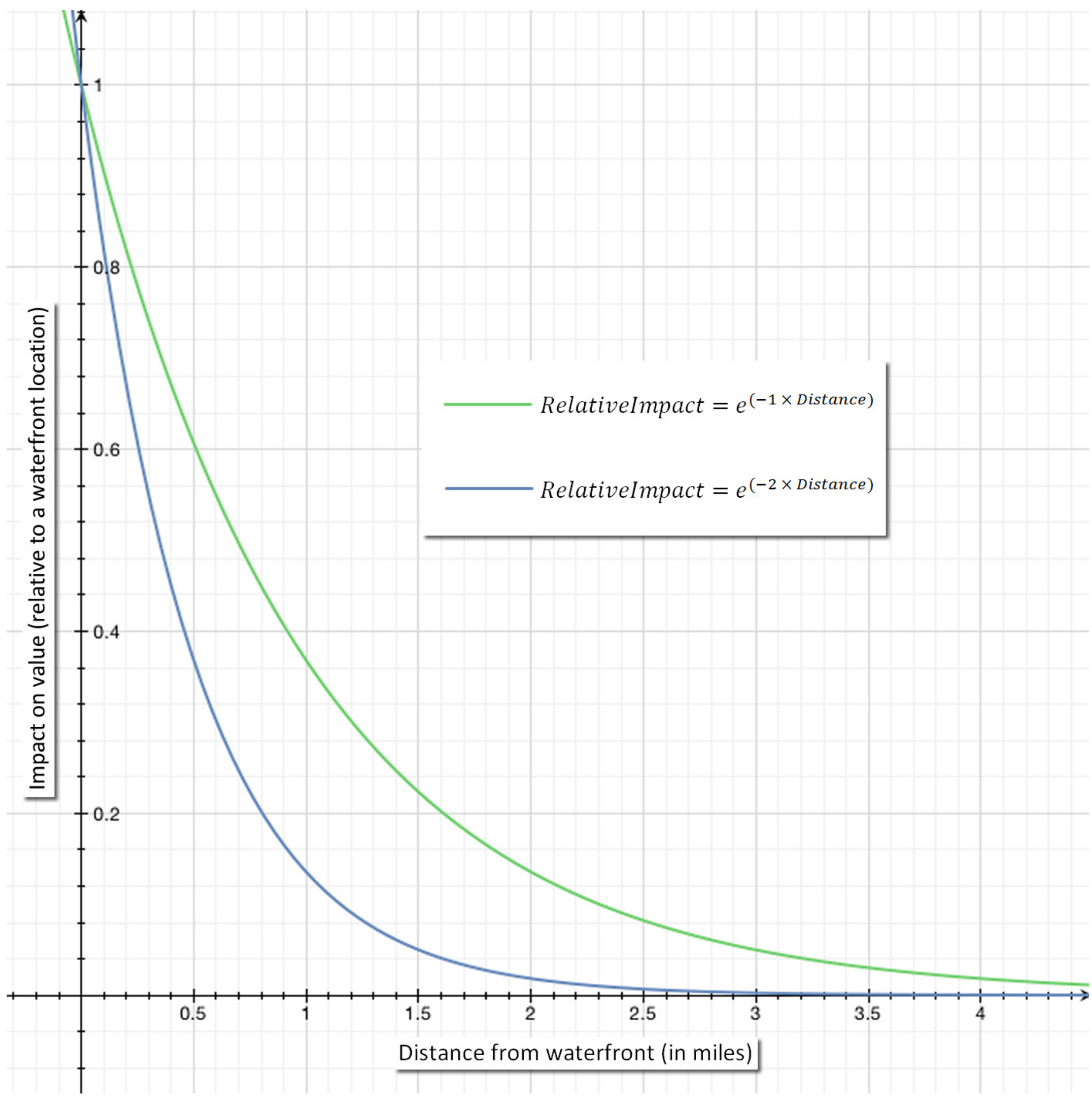


Figure 3.4

Graphs of exponential functions mapping raw distance measurements into relative impact measurements. The blue curve represents the particular function used in this study, *RelativeImpact* = exp(−2 × *Distance*).

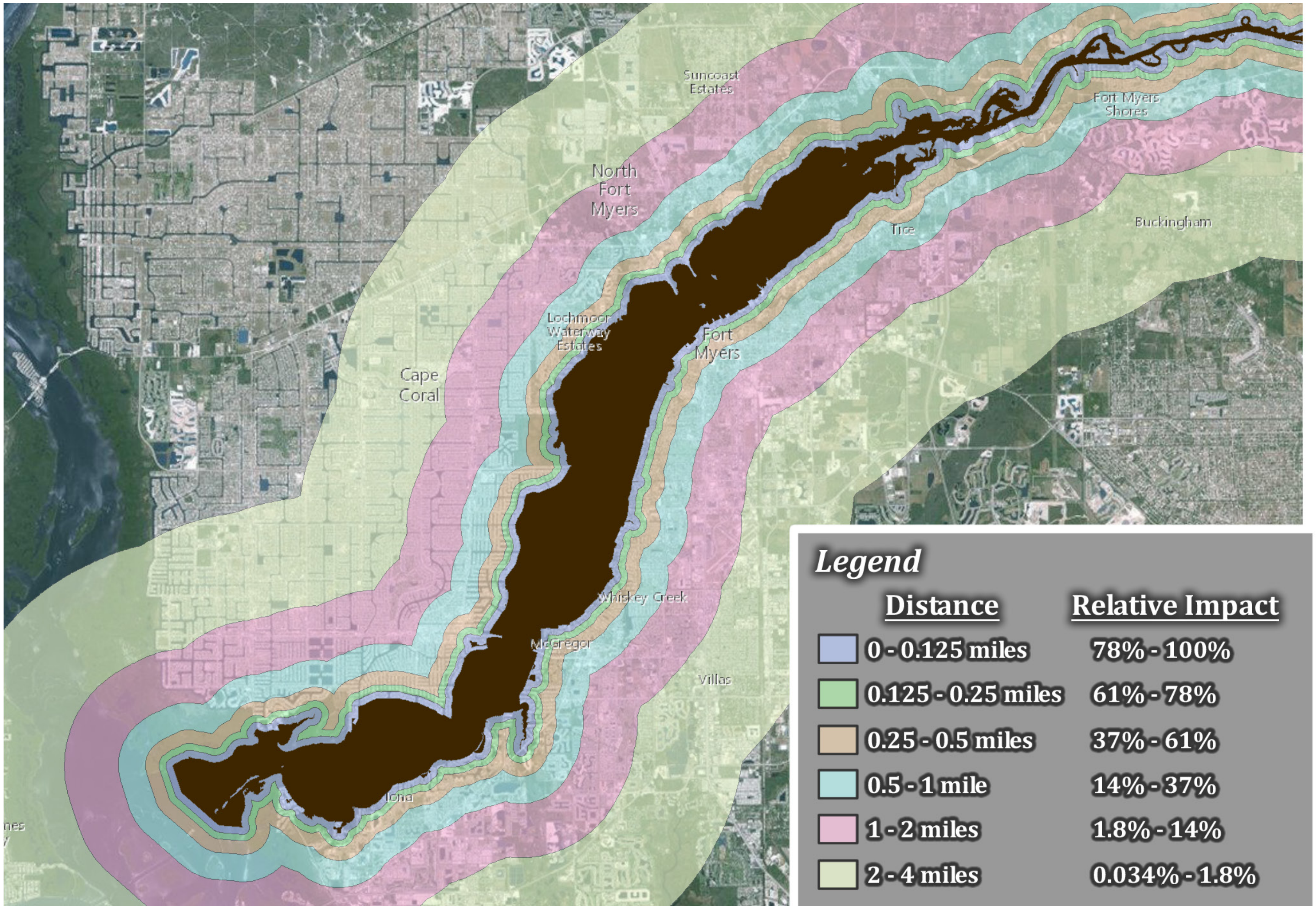
Figure 3.5 shows how the relative value impact of proximity to the Caloosahatchee Estuary changes over various distance intervals in our model. These intervals are represented as different colored bands surrounding the estuary. In the legend, the distances characterizing each interval are displayed alongside their transformed values (which are converted to percentages for easier interpretation).

To better understand how to interpret the map, let us examine the orange band (i.e. the third band out from the estuary) as an example. This band covers properties located between a quarter mile and a half mile from the Caloosahatchee Estuary. The corresponding range of relative impact values, as shown in the legend, goes from about 37 percent to about 61 percent. Essentially what this means is that the water's impact on the value of a property half a mile away is expected to be about 37 percent of what it would be if the property were located at the river's edge. Likewise, the impact on a property located a quarter of a mile away is about 61 percent of what it would be if the property were on the water. Anything located between a quarter mile and a half mile away will have an intermediate percentage value somewhere between 37 percent and 61 percent.

There is one other important takeaway from an examination of Figure 3.5: the relative impact becomes quite negligible as we move beyond a distance of one mile from the river. Only properties that are within easy walking distance of the river enjoy significant relative impacts due to water proximity. Keep in mind, also, that these relative impacts by themselves tell us no more about the actual dollar value associated with proximity to water than the original raw distance measurements do. They are simply another input into our hedonic pricing model.

One downside to using a distance-based measure (regardless of whether transformed or not) to capture the effect of water proximity is that it fails to fully capture the added value of being right on the water. That is, waterfront homes have benefits not shared by non-waterfront homes located even right across the street. It is very reasonable to assume that there should be an additional jump in value associated with having markedly easier access to the water and a great waterfront view. As a result, in addition to our distance-based measure, we include a waterfront indicator variable in the model for each of the six water body groups. These indicators were already present in the data we obtained from the Lee County Property Appraiser's office.[19]

[19] The LCPA data did not distinguish between an Estuary waterfront and a River waterfront as we have defined them, so we used the water body and parcel GIS maps to identify them.



Original water body map file source: SFWMD AHED

Figure 3.5

A map depicting various distance-from-waterfront intervals for the Caloosahatchee Estuary. Corresponding transformed values are displayed in the legend.

For our Martin County models, we constructed our distance-based measures in the same fashion as those for the Lee County models. Our data sources did not include waterfront indicators, so we constructed them using GIS parcel maps from MCPA and the water body GIS map from SFWMD's AHED geodatabase. We then formed three groups of water bodies:

- ***Intracoastal Waterway*** – includes all of the Indian River Lagoon in Martin County that is located south of the St. Lucie Inlet[20]
- ***Ocean*** – the Atlantic Ocean[21]
- ***Estuary*** – includes the St. Lucie Estuary, the Loxahatchee Estuary, and all of the Indian River Lagoon located north of the St. Lucie Inlet

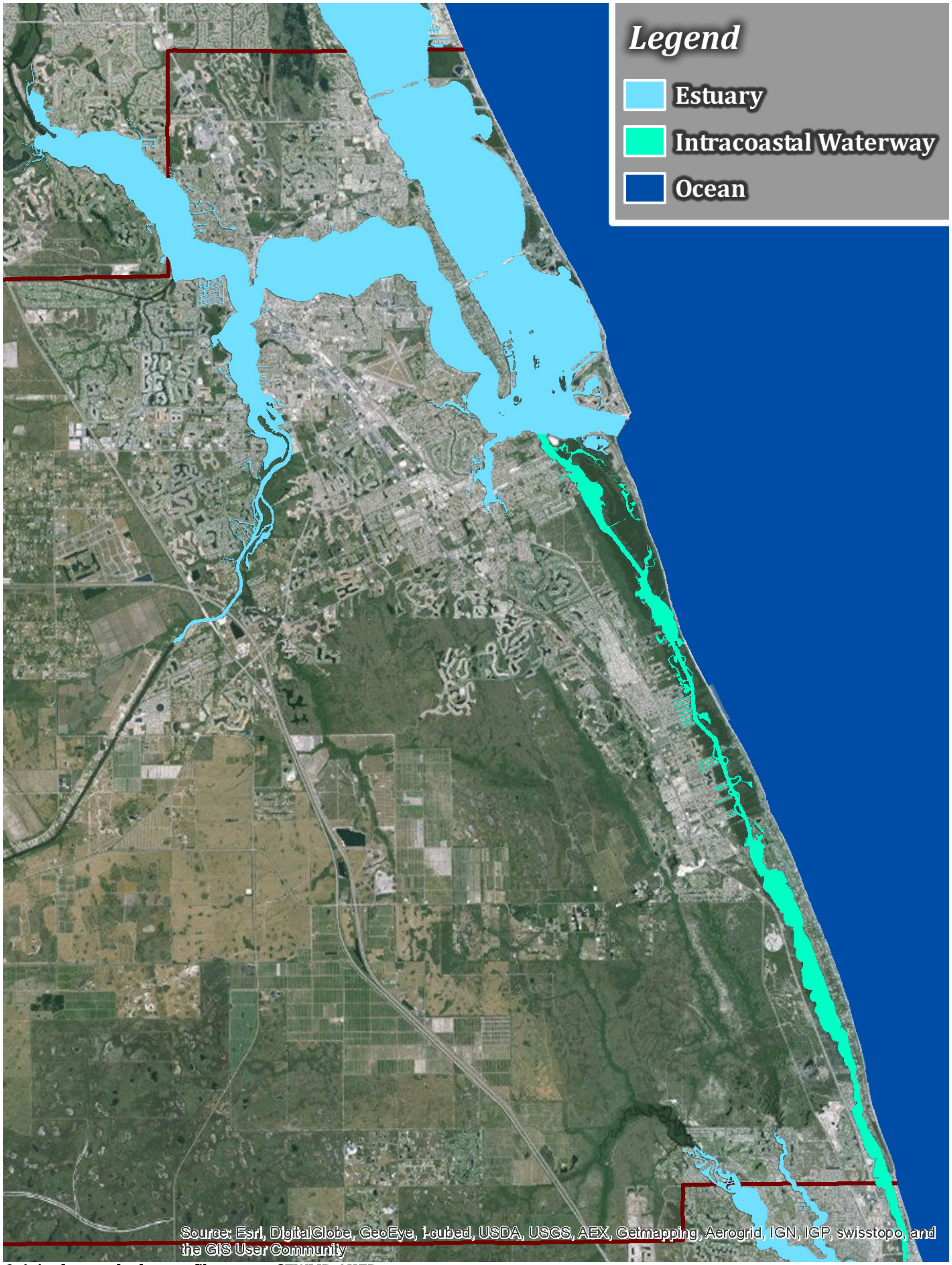
These water body groups are color-coded and displayed in Figure 3.6. There are, of course, noticeably fewer groups here than we used in the Lee County model. A comparison between the AHED water body maps and aerial images of Martin County revealed that numerous lakes and streams were not included in the AHED maps, which prevents us from accurately representing these categories in the model.[22] We did not include a canal group simply because of the insignificant number of residential canals located in the county.

The final group of controls we include with the models are commonly referred to as *time-fixed effects* in econometrics. We include one set of fixed effects for months, and another for years, that serve to account for any seasonal or long-term macroeconomic effects that are not picked up by the other control characteristics.

3.2.3 Measuring Ambient Water Quality

In terms of constructing our models, there are still two key questions that we need to answer. First, how exactly should we measure water quality? And second, how do we account for the influence of proximity to the water on the impact of water quality?

[20] This portion of the Indian River Lagoon was excluded from the Estuary category because of a lack of consistent water quality monitoring over all four years of the study.
[21] We omit the indicator variable (but retained the transformed distance measure) for the *Ocean* category from our model because it is highly collinear with the indicator variable for flood risk type VE. In other words, it provides what was essentially redundant information and its inclusion would cause complications in the model. Because it is not our variable of interest, we are not missing anything by excluding it.
[22] The AHED coverage for these water body types in Lee County was much more complete.



Original water body map file source: SFWMD AHED

Figure 3.6

Map of Martin County water bodies included in the study to control for water amenity effects.

The answer to the first question is more complicated than one might think. There is a wealth of ambient water quality data out there, but at the same time, the water quality data we can use in our model must meet some very specific criteria. We face the difficult task of quantifying the ambient water quality of the estuaries *as perceived by potential homebuyers and sellers*. The first criterion, therefore, is that we need to choose types of water quality measures that represent aspects of the water that are readily apparent to a person inspecting a nearby property. In Section 2, we noted that nitrogen and phosphorus runoff are key contributors to algal blooms in the estuaries, and there happens to be a reasonable amount of nitrogen and phosphorous measurements available in our study areas from various sources. However, nitrogen and phosphorus counts are actually fairly poor candidates for our analysis, because their presence does not *directly* influence the decisions of homebuyers and sellers.

Certainly, nitrogen and phosphorus frequently play a role in *causing* undesirable conditions in the estuaries, but a measurement which shows elevated levels of either element does not guarantee that an algal bloom is present. Whether an algal bloom occurs depends on more than just the presence of nitrogen and phosphorus—the water also needs to meet other criteria related to temperature, salinity, and other factors. So, for our purposes, the more appropriate indicators will directly measure the *visible* characteristics of the water, because we aim to represent, as best we can, factors which might impact the opinion of a potential homebuyer viewing a nearby home. The water quality characteristics in our model are, therefore, not chosen based solely on the potential damage they can cause to the ecosystem.

Once we find some water quality metrics that meet this standard, the next step is to ensure that measurements are taken from multiple locations across each estuary. The Caloosahatchee and St. Lucie estuaries are quite large, so it is unreasonable to assume that readings from a single location will be representative of conditions throughout the entirety of each estuary.

Our final criterion is similar to the previous one. In addition to requiring good geographic coverage for our measurement data, we also require good measurement coverage over time for each of the monitoring points chosen for inclusion in our models. We are looking for water quality metrics that are measured somewhat frequently and at regular intervals. We are, after all, trying to represent constantly evolving conditions across *continuous* periods of time with measurements that only give a glimpse of conditions at *specific* points in time. Hence, we desire frequent measurements so that we have a better chance of accurately representing perceived water quality in the models. Similarly, we need data that is measured at regular intervals because ambient water quality are effected by seasonal factors. For example, 20 water quality measurements spread out evenly throughout the year will be much more representative than 20 water quality measurements clustered together in one part of the year or another.

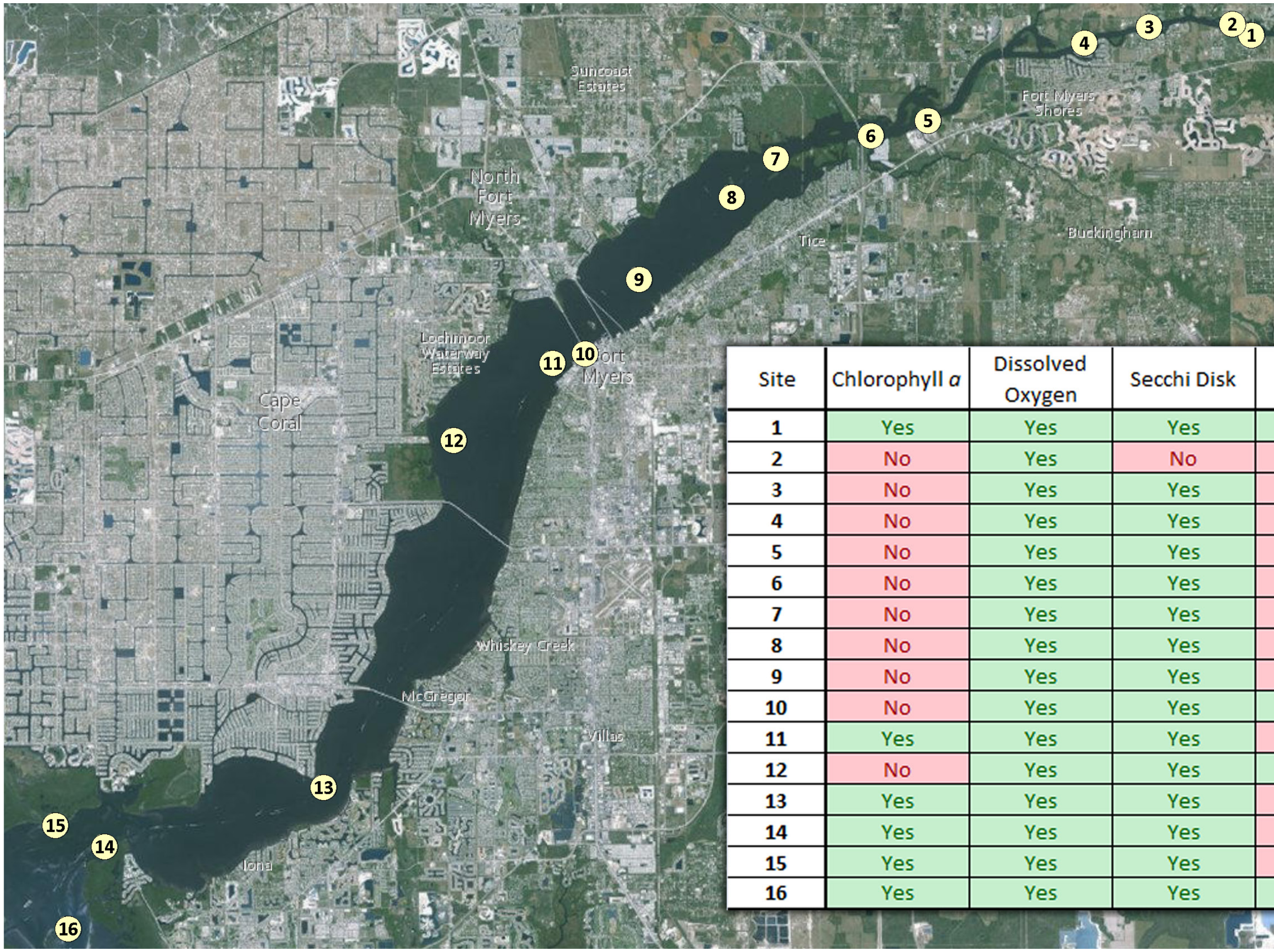
With the above criteria in mind, we have selected four different types of ambient water quality measurements for our Lee County models. These measurements are from the STORET database maintained by the Florida Department of Environmental Protection (FDEP), with each type of measurement collected roughly once per month at up to 16 separate monitoring sites in the Caloosahatchee River between the W. P. Franklin Lock and the mouth of the river at San Carlos Bay. The locations of the 16 monitoring points are displayed on the map in Figure 3.7, which also includes an inset table denoting which types of measurements were used at each monitoring point.

The first type of measure we use is micrograms per liter (μg/L) of chlorophyll *a* in the water, which captures the extent to which the water is populated by microscopic photosynthetic organisms that cause discoloration and murkiness in the water. As small as these organisms may be on an individual basis, their presence is certainly visible in large amounts. Some of these organisms are harmful to both aquatic life and humans, such as cyanobacteria (i.e. blue-green algae).[23]

The second type of measure we use is milligrams per liter (mg/L) of dissolved oxygen. A lack of oxygen in the water is associated with the presence of algae-friendly nutrients. Moreover, if dissolved oxygen levels remain too low for too long, most aquatic life will begin to die off, which of course can result in unpleasant sights and odors that may impact the perceptions of potential homebuyers. Like nitrogen and phosphorus, we consider dissolved oxygen to be a weak approximation of actual visible conditions in the water, but we nevertheless include it here because it was easily the most frequently measured characteristic that we came across in the various databases we looked at.

The third measure, turbidity, is a measure of the cloudiness of water due to any sort of tiny suspended materials, living or non-living. Turbidity is often measured by an instrument

[23] We actually analyzed two different chlorophyll *a* data series from the STORET database: "Chlorophyll *a* (corrected for pheophytin)" and "Chlorophyll *a* (uncorrected for pheophytin)." In terms of the results of our models, the difference between the two was negligible. Hence, we only report the results for one of them in this report—Chlorophyll *a* (corrected for pheophytin).



Site	Chlorophyll *a*	Dissolved Oxygen	Secchi Disk	Turbidity
1	Yes	Yes	Yes	Yes
2	No	Yes	No	No
3	No	Yes	Yes	No
4	No	Yes	Yes	No
5	No	Yes	Yes	No
6	No	Yes	Yes	No
7	No	Yes	Yes	No
8	No	Yes	Yes	No
9	No	Yes	Yes	No
10	No	Yes	Yes	Yes
11	Yes	Yes	Yes	No
12	No	Yes	Yes	Yes
13	Yes	Yes	Yes	No
14	Yes	Yes	Yes	No
15	Yes	Yes	Yes	No
16	Yes	Yes	Yes	Yes

Original monitoring point map file source: FDEP

Figure 3.7

Locations of Caloosahatchee Estuary water quality monitoring points used in the study. Inset table identifies which types of measurements were used from each site.

called a *nephelometer*, which captures its readings with a deflector that measures the way in which a light beam is deflected by particles suspended in the water. Nephelometer measurements are reported in Nephelometric Turbidity Units (NTUs). Higher NTUs mean that the water is more turbid.

The final metric is an older and seemingly less sophisticated—yet tried-and-true—method of measuring water clarity. For this measurement, an 8-inch wide disk, called a *Secchi disk*, is slowly lowered into the water until it is no longer visible to the naked eye, at which point the depth of the disk is recorded.[24] Secchi disk depth is most often measured in meters; we chose to convert to feet for explanatory purposes.[25]

Using GIS software, each Lee County home sale record in our data set was assigned to the nearest monitoring point for each of the four metrics. Using these assignments, we produced for each home sale record the average value of each metric's measurements over both the full month and the full year leading up to the sale's contract date.[26] For example, a home sale with a contract date of July 15, 2013 would first have been assigned the average of all chlorophyll *a* readings occurring between June 16, 2013 and July 15, 2013, and then the average of all chlorophyll *a* readings occurring between July 16, 2012 and July 15, 2013. The process would then be repeated for dissolved oxygen, turbidity, and Secchi disk depth. Because each metric in our Lee County data was measured only about once per month, the one-month averages were often simply the most recently recorded value of a metric. In the very few cases where there were no measurements in the month prior to the contract date for a particular home sale, the most recent measurement was substituted, which was never any more than 37 days prior to the contract date.

As for our Martin County models, the St. Lucie River data in FDEP's STORET database was inadequate for our purposes, so we instead used weekly dissolved oxygen and Secchi disk

[24] Secchi disk depth is the sole water quality measurement used in most of the existing published research wherein hedonic pricing models are used to calculate the effect of water quality on home prices. See, for example, Boyle et al. (1999), Michael et al. (2000), Boyle and Taylor (2001), and Walsh et al. (2010). Two exceptions are Leggett and Bockstael (2000), who use fecal coliform bacteria counts, and Poor et al. (2007), who use dissolved inorganic nitrogen and total suspended solids.

[25] In rare instances, the water was clear enough that the Secchi disk hit the bottom of the estuary without disappearing from view. To resolve these cases, we simply used the reported estuary depth at the monitoring site. While this approach underestimates the true clarity of the water, its impact is either minimal or result in slightly more conservative estimates.

[26] For this purpose, we collected water quality data for 2009, as well as 2010-2013.

measurements compiled by the Florida Oceanographic Society (FOS).[27] Summary statistics for both the Lee County and the Martin County water quality measures are shown in Table 3.2.

While our use of FOS data prevented us from being able to estimate Martin County models for chlorophyll *a* and NTUs of turbidity, the FOS data was an upgrade in terms of how frequently it was collected (i.e. weekly instead of monthly). FOS data was also collected over the full five-year time period for the wide portion of the Indian River Lagoon in Martin County extending north from the mouth of the St. Lucie River. FOS reports its measurements by numbered zones. The zones used in our model are displayed in Figure 3.8.

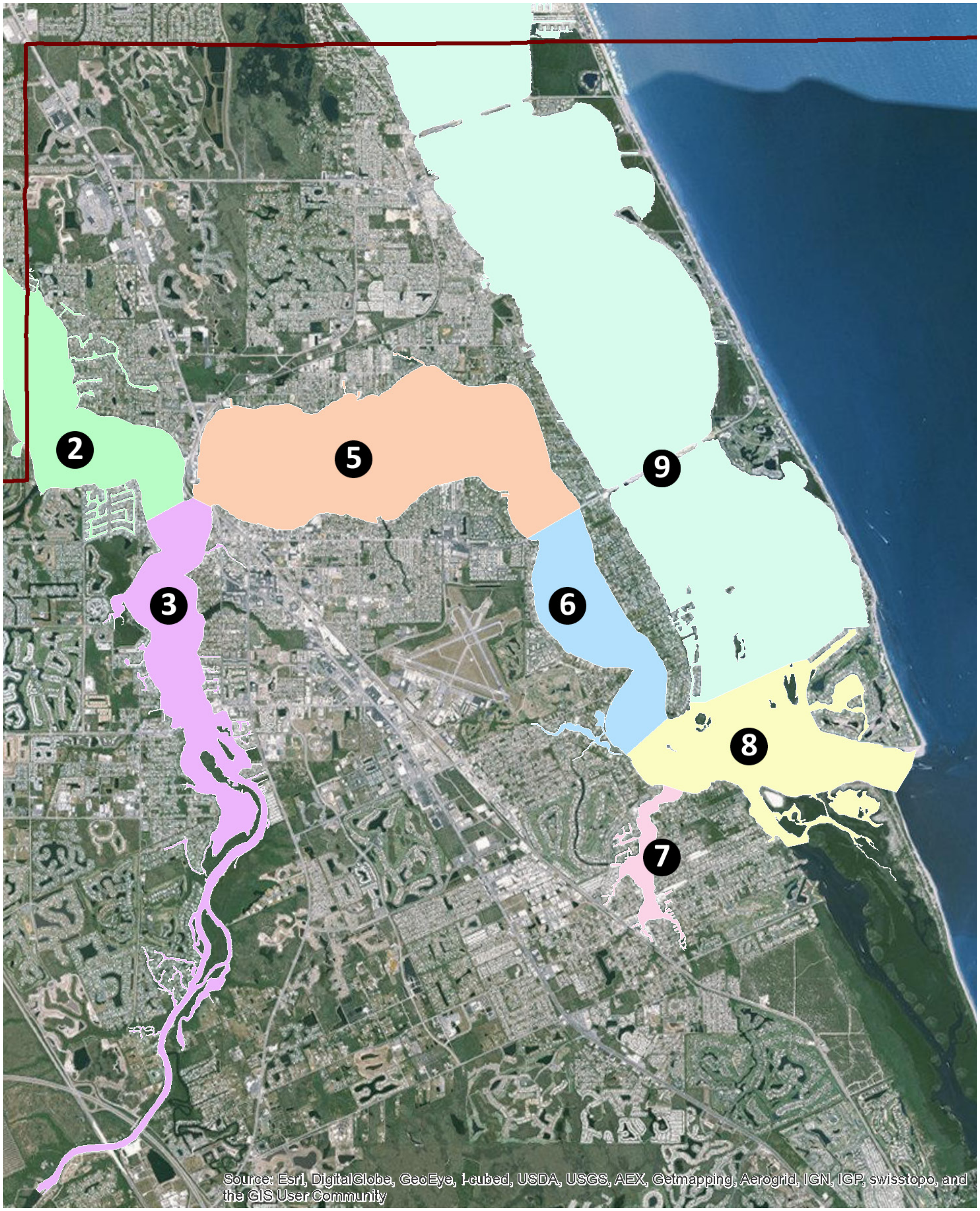
At the beginning of this passage we mentioned the need to answer a second question regarding water proximity and its relation to our water quality measurements. Recall that the amenity effect generated by a water body declines as the distance from the water body increases, which is represented in our model by the transformed distance measurements. Because our theory is that ambient water quality impacts this amenity effect, we multiply the water quality measurements for each home by the home's transformed distance measurement (which still enters into the model separately, as well). This effectively applies a distance-based discount to the impact of water quality; if we do not apply this discount, we are implicitly making the erroneous assumption that the effect of water quality is the same across all homes, regardless of how far away they are from the water body.

Table 3.2
Summary statistics for water quality variables*

		Lee County Stats: ***N*** = 48,572			Martin County Stats: ***N*** = 7,876		
	Units	***Mean***	***Std. Dev.***	***Source***	***Mean***	***Std. Dev.***	***Source***
Water Quality							
Chlorophyll* a *(1-month avg.)	µg/L	8.73	(12.2)	FDEP	—	—	—
Chlorophyll* a *(1-year avg.)	µg/L	8.30	(6.57)	FDEP	—	—	—
Dissolved O₂ (1-month avg.)	mg/L	6.99	(1.92)	FDEP	5.85	(0.960)	FOS; FDEP
Dissolved O₂ (1-year avg.)	mg/L	6.81	(0.541)	FDEP	5.94	(0.550)	FOS; FDEP
Turbidity (1-month avg.)	NTU	2.55	(2.88)	FDEP	—	—	—
Turbidity (1-year avg.)	NTU	2.44	(0.901)	FDEP	—	—	—
Secchi depth (1-month avg.)	feet	4.23	(1.86)	FDEP	3.39	(1.20)	FOS; FDEP
Secchi depth (1-year avg.)	feet	4.28	(0.890)	FDEP	3.40	(0.933)	FOS; FDEP

**Summary statistics calculated over all home sales and their associated water quality values*
Source abbreviations: **FDEP** – Florida Department of Environmental Protection STORET database, including measurements originally submitted by the City of Cape Coral, Lee County, the Loxahatchee River District, and the South Florida Water Management District ; **FOS** – Florida Oceanographic Society

[27] FDEP data did turn out to be available for the Loxahatchee River, located in the southern part of the county, so the full coverage area for our models included all estuarine waters of any significant width located in and around Martin County.



Original water body map file source: SFWMD AHED

Figure 3.8

A map of St. Lucie River and Indian River Lagoon zones for which the Florida Oceanographic Society reports water quality measurements. The map depicts only those zones from which we used measurements; FOS currently monitors three other nearby zones, as well.

Section 4. Model Results

In this section, we reveal the results of our model estimations. In Subsection 4.1, we give a brief overview of the overall performance of the models. Subsections 4.2 and 4.3 go into detail about the results of the models which respectively use the one-month and one-year water quality measures. Finally, in Subsection 4.4, we identify and demonstrate a useful application for our results: an estimation of water quality's effect on aggregate countywide property values.

4.1 Overview of Hedonic Pricing Model Performance

In all, we produced estimates for eight separate Lee County hedonic pricing models. The only difference between each of these models was the type of water quality measure we included (i.e. one-month and one-year averages for chlorophyll *a*, dissolved oxygen, turbidity, and Secchi disk depth). Because we did not have adequate chlorophyll *a* or turbidity data for the St. Lucie Estuary, we ran only four models for Martin County (i.e. one-month and one-year averages for both dissolved oxygen and Secchi disk depth). The raw estimates and other output from the models can be found in Appendix B.

All twelve models performed very well in terms of explanatory power. Each of the Lee County models explained about 88 percent of the variation in sale prices, while the Martin County models explained about 86 percent of sale price variation.[28] In addition, the estimated price effects of both the water quality measures and the control characteristics were, for the most part, strongly significant.[29] Among the water quality measures, only the estimated effects of dissolved oxygen on home prices failed to exhibit an acceptable level of statistical significance.

The dissolved oxygen result is not all that surprising since, as we noted in Section 3, dissolved oxygen levels are not a direct measurement of the appearance of a water body. As a

[28] Explanatory power in regression models such as these is measured by a statistic called the *coefficient of determination* (usually denoted $\boldsymbol{R}^2$). It measures how well the actual data fit the model.

[29] In the context of statistical estimation, the word *significance* does not refer to *importance*; rather, it refers to how reasonably sure we can be (based on the model results) that a characteristic we included in the model does indeed have a real effect, *regardless of how large or small that effect actually is.* Our results might yield, for instance, a larger estimated effect on home sale prices for Characteristic A than it does for Characteristic B—but if the margin of error associated with our estimate for Characteristic A is huge, then we can't really make a valid comparison with Characteristic B and can't even be sure whether Characteristic A has any effect on home prices at all.

predictor or indicator of algal growth, dissolved oxygen can be somewhat fickle. It is sensitive to changes in pressure and salinity, and it actually increases during the first stage of an algal bloom during the day when the algae are engaged in photosynthesis. The algae also, however, respire using oxygen, and even more oxygen is consumed when the short-lived algae organisms start to die off and begin to decay.

4.2 The Effect of Recent Water Quality on Home Sale Prices

The actual estimates produced by hedonic pricing models are a form of what economists call *marginal effects*. A marginal effect is simply the change in one value (in our case, sale price) in response to a small change in another value (the water quality measurements).[30] The marginal price effects that we estimated for the one-month averages of chlorophyll *a*, turbidity, and Secchi disk depth are displayed in Table 4.1. Because these effects decline as distance from the estuaries increases, we include estimates for various distances from the shoreline: on the waterfront, an eighth of a mile, a quarter of a mile, a half mile, one mile, two miles, and four miles.[31,32] Note that measured improvements in water quality are indicated by either *increases* to Secchi disk depth or *decreases* to chlorophyll *a* or NTUs of turbidity. As a result, in Table 4.1, where our intent is to show the marginal price effects of increasing water quality, we display the estimated effect of a *positive* change in Secchi disk depth and a *negative* change in both chlorophyll *a* and turbidity.

Note also that the design of our models is such that the results can be inverted; that is, the change in water quality and change in price associated with each marginal effect listed in Table 4.1 can both be multiplied by –1 and the result will still be true. For example, in Table 4.1 we indicate that a one-foot *increase* in Secchi disk depth is associated with an estimated 2.48 percent *increase* in the sale price of a home on the waterfront of the Caloosahatchee Estuary. But the inverse also works: if there is a one-foot *decrease* in Secchi disk depth, then there is an estimated 2.48 percent *decrease* in sale price.

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[30] In our hedonic pricing models, we followed the standard procedure of using the natural logarithm of sale prices rather than the raw sale prices. When the natural logarithm of sale price is used, the interpretation of the marginal effects changes from a set dollar amount to a percentage change in sale price.
[31] These distances, in feet, are respectively 0 ft; 660 ft; 1,320 ft; 2,640 ft; 5,280 ft; 10,560 ft; and 21,120 ft.
[32] Figure 3.5 from the previous section provides a good geographic frame of reference for the Lee County results. The boundaries of the mapped distance intervals in Figure 3.5 are identical to the distances reported in Table 4.1.

Table 4.1
Marginal price effects of changes in 1-month water quality measures at select distances

Location of Property	Water Quality Measure	Change in Water Quality	Resulting change in Property Value	Standard Error
Lee County				
Caloosahatchee Estuary waterfront	Chlorophyll *a*	−1 μg/L	+0.46%	0.092%
1/8 of a mile from the waterfront:	Chlorophyll *a*	−1 μg/L	+0.36%	0.072%
1/4 of a mile from the waterfront:	Chlorophyll *a*	−1 μg/L	+0.28%	0.056%
1/2 of a mile from the waterfront:	Chlorophyll *a*	−1 μg/L	+0.17%	0.034%
1 mile from the waterfront:	Chlorophyll *a*	−1 μg/L	+0.062%	0.012%
2 miles from the waterfront:	Chlorophyll *a*	−1 μg/L	+0.0084%	0.0017%
4 miles from the waterfront:	Chlorophyll *a*	−1 μg/L	+0.00015%	0.000031%
Caloosahatchee Estuary waterfront	Turbidity	−1 NTU	+1.07%	0.36%
1/8 of a mile from the waterfront:	Turbidity	−1 NTU	+0.84%	0.28%
1/4 of a mile from the waterfront:	Turbidity	−1 NTU	+0.65%	0.22%
1/2 of a mile from the waterfront:	Turbidity	−1 NTU	+0.40%	0.13%
1 mile from the waterfront:	Turbidity	−1 NTU	+0.15%	0.049%
2 miles from the waterfront:	Turbidity	−1 NTU	+0.020%	0.0067%
4 miles from the waterfront:	Turbidity	−1 NTU	+0.00036%	0.00012%
Caloosahatchee Estuary waterfront	Secchi disk depth	+1 foot	+2.47%	0.41%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+1.93%	0.32%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+1.50%	0.25%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+0.91%	0.15%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+0.34%	0.055%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.045%	0.0075%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.00083%	0.00014%
Martin County				
Waterfront on the St. Lucie Estuary, Loxahatchee Estuary, or Indian River Lagoon north of St. Lucie Inlet	Secchi disk depth	+1 foot	+5.41%	0.86%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+4.21%	0.67%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+3.28%	0.52%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+1.99%	0.32%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+0.73%	0.12%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.10%	0.016%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.0018%	0.00029%

Now, what does Table 4.1 actually tell us? First and foremost, all of the results in the table support the hypothesis that higher water quality in the month leading up to a sale has a positive impact on the sale price, regardless of the county or the measurement type. And as mentioned above, we can likewise infer from these same results that lower water quality means lower sale prices.

The differences between the two counties' estimated marginal price effects for Secchi disk depth are also interesting, in that the magnitudes of the estimated effects for Martin County are more than twice that of their Lee County counterparts. As interesting as this outcome is, however, it is difficult to draw a solid conclusion from it. This discrepancy could be due to differences in the innate supply or demand for estuarine water quality in each county, but there are many other potential reasons for it, including the fact that the Martin County model has different data sources and includes fewer control characteristics than the Lee County model.

The Secchi disk measurements themselves serve as an excellent example of how differences between data sources may give rise to the discrepancy between the results for the two counties. For each home sale, what we would ideally like to know is what the average Secchi disk depth at the nearest monitoring point would be over the course of the entire preceding month, as if it were being measured continuously over time. But Secchi disk depth is not measured continuously over time, so we have to settle with averaging whatever measurements were taken at single points in time over the course of the month.

Recall that the Secchi disk measurements for Lee County come from FDEP's STORET database, whereas most of the Martin County measurements are derived from data compiled by FOS. The FDEP measurements are taken approximately once per month in each location, whereas the measurements compiled by FOS for the St. Lucie Estuary and Indian River Lagoon are reported on a weekly basis. Therefore, in the month leading up to the sale contract date for a home in Lee County, we are typically only observing a single Secchi disk measurement, while in Martin County we are seeing about four measurements over the same amount of time. The greater number of measurements over the course of a month that we get from the Martin County data is akin to having a larger sample size in a survey. That is, the one-month Secchi disk averages that we calculated for the various monitoring locations in Martin County are statistically more likely to be representative of the typical clarity level exhibited by the water throughout the entire month.

When one of the variables of interest in a hedonic model is imperfectly measured, it can cause the estimated magnitude of the variable's effect to be lower than it really is. Among statisticians and econometricians, this phenomenon is known as *attenuation bias*. Perhaps, then, Lee County's Secchi disk effect is in reality closer to its counterpart in the Martin County model than our results indicate. Unfortunately, we cannot know for certain.

Be that as it may, the difference between the magnitudes of the two estimates is not an important result here. What is important, on the other hand, is that Secchi disk depth's impact on the sale prices of nearby homes was found to be positive and strongly significant in the models for both counties, just as we had hypothesized it would be. The fact that this result was found in models of two different housing markets that were built using different data sources further verifies the robustness of this result. Simply put, our model clearly shows that ambient water quality affects housing prices.

Now, what about the differences between the estimated effects for the three measurement types used in the Lee County models? Can we make valid comparisons between these results? The answer is "yes," although this task is difficult to accomplish based on how the data are presented in Table 4.1 because a one-unit change in NTUs of turbidity, for example, is not the same thing as a one-foot change in Secchi disk depth. We can get closer to making a meaningful comparison, however, if we think in terms of percentage changes rather than single unit changes in the water quality measurements.

In order to do this, we first need to acknowledge that our model results explicitly describe relationships between *unit* changes in water quality measurements and percentage changes in sale prices. These results hold regardless of the initial (i.e. pre-change) values for the water quality measurements. That is, it doesn't matter if the current Secchi disk depth is 2 feet or 8 feet; our model results simply indicate that an additional foot of Secchi disk depth will result in a price increase of 2.48 percent for waterfront homes.

But what if Secchi disk depth increases by 20 percent instead of by one foot? If the current depth is 2 feet, this will be an increase of 0.4 feet, but if the current depth is 8 feet, a 20 percent increase is a change of 1.6 feet. For waterfront homes, then, the resulting price changes would be $0.4 \times 2.48\% = 0.992\%$ and $1.6 \times 2.48\% = 3.968\%$, respectively. If we are going to analyze percentage changes in the water quality measurements, then we need to be aware that the resulting price effects will change depending on the initial level of water quality.

Our best option, then, is to compare the effects of a percentage change where we assume the initial value is the *average* value (across all home sales in a county over all four years of the study) of each of the one-month water quality measurements.[33] Table 4.2 shows

[33] These average measurement values are displayed in Table 3.2 in the previous section.

Table 4.2
Marginal effects of a 20% improvement over the mean value of the 1-month water quality measures

Location of Property	Water Quality Measure	Change in Water Quality from Average Value	Equivalent Change in Units	Resulting Change in Property Value
Lee County				
Caloosahatchee Estuary waterfront	Chlorophyll *a*	−20%	−1.75 μg/L	+0.80%
1/8 of a mile from the waterfront:	Chlorophyll *a*	−20%	−1.75 μg/L	+0.62%
1/4 of a mile from the waterfront:	Chlorophyll *a*	−20%	−1.75 μg/L	+0.49%
1/2 of a mile from the waterfront:	Chlorophyll *a*	−20%	−1.75 μg/L	+0.29%
1 mile from the waterfront:	Chlorophyll *a*	−20%	−1.75 μg/L	+0.11%
2 miles from the waterfront:	Chlorophyll *a*	−20%	−1.75 μg/L	+0.015%
4 miles from the waterfront:	Chlorophyll *a*	−20%	−1.75 μg/L	+0.00027%
Caloosahatchee Estuary waterfront	Turbidity	−20%	−0.51 NTU	+0.55%
1/8 of a mile from the waterfront:	Turbidity	−20%	−0.51 NTU	+0.43%
1/4 of a mile from the waterfront:	Turbidity	−20%	−0.51 NTU	+0.33%
1/2 of a mile from the waterfront:	Turbidity	−20%	−0.51 NTU	+0.20%
1 mile from the waterfront:	Turbidity	−20%	−0.51 NTU	+0.074%
2 miles from the waterfront:	Turbidity	−20%	−0.51 NTU	+0.010%
4 miles from the waterfront:	Turbidity	−20%	−0.51 NTU	+0.00018%
Caloosahatchee Estuary waterfront	Secchi disk depth	+20%	+0.85 feet	+2.09%
1/8 of a mile from the waterfront:	Secchi disk depth	+20%	+0.85 feet	+1.63%
1/4 of a mile from the waterfront:	Secchi disk depth	+20%	+0.85 feet	+1.27%
1/2 of a mile from the waterfront:	Secchi disk depth	+20%	+0.85 feet	+0.77%
1 mile from the waterfront:	Secchi disk depth	+20%	+0.85 feet	+0.28%
2 miles from the waterfront:	Secchi disk depth	+20%	+0.85 feet	+0.038%
4 miles from the waterfront:	Secchi disk depth	+20%	+0.85 feet	+0.00070%
Martin County				
Waterfront on the St. Lucie Estuary, Loxahatchee Estuary, or Indian River Lagoon north of St. Lucie Inlet	Secchi disk depth	+20%	+0.68 feet	+3.69%
1/8 of a mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	+2.86%
1/4 of a mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	+2.23%
1/2 of a mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	+1.35%
1 mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	+0.50%
2 miles from the waterfront:	Secchi disk depth	+20%	+0.68 feet	+0.067%
4 miles from the waterfront:	Secchi disk depth	+20%	+0.68 feet	+0.0012%

the estimated impact of a 20 percent change in these average values.[34] Clearly, the strongest effects are associated with increases in Secchi disk depth. Why is this the case?

For one, the diagnostic tests we ran on our models tell us as much. The Secchi disk measurements were easily the most statistically significant water quality measures in our

[34] Our choice of 20 percent here is arbitrary; the choice of percentage is actually irrelevant for this type of comparison—what is important is that the same percentage is used for all three measurement types.

models.[35] This could very well be due to the ability of Secchi disk depth to capture the essence of perceived water quality in ways that chlorophyll *a* and turbidity cannot.

The relative weakness of chlorophyll *a* as a measure is that it ignores inorganic impediments to water clarity, whereas Secchi disks and turbidity meters more directly measure clarity itself. The fact that chlorophyll *a* is still statistically significant in our models is possibly a testament to the very unpleasant nature—and frequency—of algal blooms occurring in the Caloosahatchee in recent years.

As for turbidity, the source of its underperformance in our model might actually be something that is more generally considered to be one of its advantages as a measure of water quality, relative to Secchi disks. For limnologists and other water quality experts, Secchi disks have their drawbacks. The readings can be affected by a number of factors such as choppy water or the amount of sunlight hitting the water. If we imagine two rivers that are identical in every way except that one is measured on a windy, cloudy day and the other is measured on a calm, sunny day, we might not be surprised to find a difference in the recorded Secchi disk depths. Nephelometers, on the other hand, produce their own consistent source of light. For many scientific applications, this might be considered an advantage.[36] But in our case, we are trying to measure water clarity as perceived by someone who is looking at it from above—and this person is subject to the same environmental effects as the person taking the Secchi disk measurements.

There are other potential explanations for the greater impact of Secchi disk depth versus chlorophyll *a* and turbidity, as well. As we show in Figure 3.7 in the previous section, our Lee County data set includes turbidity measurements taken from 4 different monitoring sites and chlorophyll *a* measurements from 6 different sites. In contrast, our Secchi disk depths are drawn from 15 different sites within the Caloosahatchee Estuary, so the Secchi disk measurement that we attach to any particular home sale is much more likely to come from a nearby station, thus better representing water conditions in the home's immediate vicinity. This leaves our estimated Secchi disk depth effects less susceptible to attenuation bias compared to the other two measurement types.

[35] See the *t*-statistics reported in the model output tables in Appendix B.

[36] There are several disadvantages associated with nephelometry, as well. First, nephelometers are not the only instruments used to measure turbidity; other instruments are sometimes used and their results are converted—imperfectly—into NTUs. Additionally, some turbidity meters use infrared light while others use white light, which can lead to different readings. Lastly, nephelometers and other turbidity meters produced by different manufacturers often fail to produce the identical results.

As before, though, we would point out that the exact differences between the magnitudes of the estimated effects of the three measurement types is not as important as the notion that they all were found to be highly significant with the hypothesized signs (i.e. positive for Secchi disk depth, negative for chlorophyll *a* and turbidity).

4.3 The Effect of Long-Term Water Quality on Home Sale Prices

We turn now to the results for the long-term models, which feature nearby water quality measurements averaged over a full year leading up to each home sale. The marginal price effects for unit changes in one-year average water quality measurements are reported in Table 4.3. In Table 4.4, we present the estimated price changes associated with a 20 percent increase in the value of a home facing average water quality conditions for the county in which it is located. What is immediately quite evident from these tables is that the marginal effects for these models are appreciably greater in magnitude than those estimated using only the average over the most recent month—especially in the case of Secchi disk depth in Lee County.[37] Unlike most of the one-month measures for Lee County, the one-year measures are constructed from multiple observations over time, which means they are not nearly as prone to measurement error and potential attenuation bias. More importantly, the results strongly suggest that long-run ambient water quality plays a more significant role in determining home sale prices than the water quality conditions immediately prior to the contract date.

This is not to say that the events surrounding, for instance, the Lake Okeechobee releases in the summer of 2013 did not impact the local housing markets in Lee and Martin counties. They likely did—but they did so as part of a long-term, ongoing sequence that was already established and well known to most market participants. In other words, if the summer of 2013 had been the first time in recent history that either estuary experienced an acute decline in ambient water quality following discharges from Lake Okeechobee, then the level of public outrage and enduring concern for the health of the local economies would likely have been considerably less. But this was not the case. The events of 2013 were the latest incidents in a chain that goes back for decades.

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[37] The *t*-statistics for the one-year models indicate a substantial improvement in statistical significance, as well. See Appendix B.

Table 4.3
Marginal price effects of changes in 1-year water quality measures at select distances

Location of Property	Water Quality Measure	Change in Water Quality	Resulting change in Property Value	Standard Error
Lee County				
Caloosahatchee Estuary waterfront	Chlorophyll *a*	-1 μg/L	+1.03%	0.16%
1/8 of a mile from the waterfront:	Chlorophyll *a*	-1 μg/L	+0.80%	0.12%
1/4 of a mile from the waterfront:	Chlorophyll *a*	-1 μg/L	+0.62%	0.096%
1/2 of a mile from the waterfront:	Chlorophyll *a*	-1 μg/L	+0.38%	0.058%
1 mile from the waterfront:	Chlorophyll *a*	-1 μg/L	+0.14%	0.021%
2 miles from the waterfront:	Chlorophyll *a*	-1 μg/L	+0.019%	0.0029%
4 miles from the waterfront:	Chlorophyll *a*	-1 μg/L	+0.00034%	0.000053%
Caloosahatchee Estuary waterfront	Turbidity	-1 NTU	+7.94%	0.91%
1/8 of a mile from the waterfront:	Turbidity	-1 NTU	+6.18%	0.71%
1/4 of a mile from the waterfront:	Turbidity	-1 NTU	+4.82%	0.55%
1/2 of a mile from the waterfront:	Turbidity	-1 NTU	+2.92%	0.33%
1 mile from the waterfront:	Turbidity	-1 NTU	+1.07%	0.12%
2 miles from the waterfront:	Turbidity	-1 NTU	+1.45%	0.017%
4 miles from the waterfront:	Turbidity	-1 NTU	+0.0027%	0.0030%
Caloosahatchee Estuary waterfront	Secchi disk depth	+1 foot	+14.66%	1.02%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+11.42%	0.80%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+8.89%	0.62%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+5.39%	0.38%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+1.98%	0.14%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.27%	0.019%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.0049%	0.00034%
Martin County				
Waterfront on the St. Lucie Estuary, Loxahatchee Estuary, or Indian River Lagoon north of St. Lucie Inlet	Secchi disk depth	+1 foot	+10.32%	1.14%
1/8 of a mile from the waterfront:	Secchi disk depth	+1 foot	+8.03%	0.89%
1/4 of a mile from the waterfront:	Secchi disk depth	+1 foot	+6.26%	0.69%
1/2 of a mile from the waterfront:	Secchi disk depth	+1 foot	+3.80%	0.42%
1 mile from the waterfront:	Secchi disk depth	+1 foot	+1.40%	0.15%
2 miles from the waterfront:	Secchi disk depth	+1 foot	+0.19%	0.021%
4 miles from the waterfront:	Secchi disk depth	+1 foot	+0.0035%	0.00038%

Prospective homebuyers who already live in these counties or who have spent a lot of time there are probably well aware of the history behind these events. Their willingness to pay might be somewhat influenced by the current water conditions, but if they have lived in the area long enough they probably know how the water looks under better conditions. Their

Table 4.4
Marginal effects of a 20% improvement over the mean value of the 1-year water quality measures

Location of Property	Water Quality Measure	Change in Water Quality from Average Value	Equivalent Change in Units	Resulting Change in Property Value
Lee County				
Caloosahatchee Estuary waterfront	Chlorophyll *a*	−20%	−1.66 µg/L	+1.70%
1/8 of a mile from the waterfront:	Chlorophyll *a*	−20%	−1.66 µg/L	+1.33%
1/4 of a mile from the waterfront:	Chlorophyll *a*	−20%	−1.66 µg/L	+1.03%
1/2 of a mile from the waterfront:	Chlorophyll *a*	−20%	−1.66 µg/L	+0.63%
1 mile from the waterfront:	Chlorophyll *a*	−20%	−1.66 µg/L	+0.23%
2 miles from the waterfront:	Chlorophyll *a*	−20%	−1.66 µg/L	+0.03%
4 miles from the waterfront:	Chlorophyll *a*	−20%	−1.66 µg/L	+0.00057%
Caloosahatchee Estuary waterfront	Turbidity	−20%	−0.49 NTU	+3.88%
1/8 of a mile from the waterfront:	Turbidity	−20%	−0.49 NTU	+3.02%
1/4 of a mile from the waterfront:	Turbidity	−20%	−0.49 NTU	+2.35%
1/2 of a mile from the waterfront:	Turbidity	−20%	−0.49 NTU	+1.43%
1 mile from the waterfront:	Turbidity	−20%	−0.49 NTU	+0.52%
2 miles from the waterfront:	Turbidity	−20%	−0.49 NTU	+0.071%
4 miles from the waterfront:	Turbidity	−20%	−0.49 NTU	+0.0013%
Caloosahatchee Estuary waterfront	Secchi disk depth	+20%	+0.86 feet	+12.55%
1/8 of a mile from the waterfront:	Secchi disk depth	+20%	+0.86 feet	+9.77%
1/4 of a mile from the waterfront:	Secchi disk depth	+20%	+0.86 feet	+7.61%
1/2 of a mile from the waterfront:	Secchi disk depth	+20%	+0.86 feet	+4.62%
1 mile from the waterfront:	Secchi disk depth	+20%	+0.86 feet	+1.70%
2 miles from the waterfront:	Secchi disk depth	+20%	+0.86 feet	+0.23%
4 miles from the waterfront:	Secchi disk depth	+20%	+0.86 feet	+0.0042%
Martin County				
Waterfront on the St. Lucie Estuary, Loxahatchee Estuary, or Indian River Lagoon north of St. Lucie Inlet	Secchi disk depth	+20%	+0.68 feet	7.02%
1/8 of a mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	5.47%
1/4 of a mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	4.26%
1/2 of a mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	2.58%
1 mile from the waterfront:	Secchi disk depth	+20%	+0.68 feet	0.95%
2 miles from the waterfront:	Secchi disk depth	+20%	+0.68 feet	0.13%
4 miles from the waterfront:	Secchi disk depth	+20%	+0.68 feet	0.0024%

home purchase decisions are going to be based less, then, on whether an event is currently happening, and more on their knowledge of how often these sorts of events occur. The one-month models we estimated have short memories compared to the one-year models, so they fail to capture any aspect of this important part of the decision process.

The important result here is that the true danger to the housing markets in both counties is not from the immediate effects of algal blooms or other sorts of unpleasant conditions caused by releases from Lake Okeechobee and local runoff. Certainly, there is the potential for prospective homebuyers to back out of sales or for sellers of near- or on-waterfront homes to keep holding on to their properties for a few extra weeks. For these people, the delay in the sale of their home could cause economic hardship or undue stress. But the fact remains that these homes will eventually sell, and our one-month models indicate that these short-term price effects subside as soon as these events clear up.[38]

The greater direct danger to home values in these markets is the continuing recurrence of these types of events, and the increasing frequency with which they are occurring. This effect is longer lasting and does not go away when the algal blooms and murky waters clear up after each incident. In other words, while the short-term price effect might subside, the larger, long-term effect does not.

[38] We attempted to estimate the effects of water quality on the length of time homes were on the market, but our models yielded highly inconclusive results. According to Johnson et al. (2007), this is not an unusual result in the economics literature. Economists have had considerable trouble building models for market duration, which relative to sale price is much more dependent on unobservable characteristics of buyers and sellers. We also found little evidence that the number of sale contracts for homes near the water is dependent on nearby water quality.

Section 5. Applying the Results: Aggregate Countywide Effects

One of the motivating factors behind our decision to go forward with this study was that we anticipated our models would provide concrete results that could supplement future research on the water quality's aggregate impact on property values in an area. Such research would be of great benefit to both policymakers and the general public.

We suspect that very little research currently exists on this matter simply because the value placed on water quality at the micro (i.e. individual) level has not been well quantified. As far as we can tell, our study is the first to provide such quantitative measurements for the estuaries of Lee and Martin counties, and only the second to use hedonic methods to provide quantitative measurements of the impact of water quality on real estate throughout any part of Florida.[39]

In this section we offer a simple, intuitive approach to measuring the aggregate property value impact of changes in average estuarine water quality in Lee and Martin counties, based on our estimates from Section 4. We follow our description of this approach with two separate examples of its application.

5.1 A Simple Approach

Our approach relies on the just values of single family homes, as reported in the 2013 FDOR-certified tax rolls for each county. The just value of a property is simply the county property appraiser's estimate of the market value for the property. It is estimated and tracked by Florida county property appraisers because it forms the basis for determining a property's assessed and taxable values.

Apart from just values, the only other property-level data our approach requires is the distance of each single family home in each county to the nearest estuary shoreline. As before, we use GIS parcel maps of the two counties in conjunction with the AHED water body maps from SFWMD to calculate these distances.

[39] Walsh, Milon, and Scrogin (2011) use hedonic pricing models to determine the effect of lake water quality on nearby homes in the Orlando area.

The basic premise of our approach is that our previously estimated marginal effects of water quality on price can also be interpreted as estimated marginal effects of water quality on just values, since just value is itself an estimate of the market price a property would fetch if it were on the market. The just values of homes rise when they, or similar nearby homes, sell for higher prices. Most anything that affects the sale prices of homes essentially affects the property value of nearby homes that are not currently on the market.

Using this logic in conjunction with our model results from Section 4, we would estimate that the change in a home's value resulting from a change in the nearest monitoring point's average measured Secchi disk depth over the past year is:

$$\Delta Value = JustValue \times \Delta Secchi \times MarginalEffect \tag{5.1}$$

where Δ*Value* is the change (in USD) in the home's market value, *JustValue* is the pre-change market value of the home as determined by the county property appraiser's office, Δ*Secchi* is the change (in feet) in the average Secchi disk depth over the past year, and *MarginalEffect* is the estimated marginal effect of a one-foot change in the average Secchi disk depth over the past year.

The value of *MarginalEffect* varies based on the distance of the home to the nearest estuary waterfront. It is equivalent to the marginal effect for a waterfront property multiplied by the distance-based *RelativeImpact* value we described in Section 3. That is,

$$MarginalEffect = MarginalEffect_0 \times RelativeImpact, \tag{5.2}$$

where $MarginalEffect_0$ is the estimated marginal effect of a one-foot change in average Secchi disk depth over the past year on the value of a waterfront home. $MarginalEffect_0$ is estimated by our models and can be found in Table 4.3 in the previous section.[40] We know how to calculate *RelativeImpact* from Equation 3.1 in Section 3. This yields the following equation:

$$MarginalEffect = MarginalEffect_0 \times e^{-2 \times Distance}. \tag{5.3}$$

[40] In Table 4.3, these values have been rounded to the nearest hundredth of a percentage point. For this analysis, we use the raw full output from our statistical software package since it offers more precision: 14.66204% for Lee County and 10.32006% for Martin County.

If we substitute the right-hand side of Equation 5.3 for *MarginalEffect* in Equation 5.1, we get

$$\Delta Value = JustValue \times \Delta Secchi \times MarginalEffect_0 \times e^{-2\,\times\,Distance}. \qquad (5.4)$$

In Equation 5.4, only the values *JustValue* and *Distance* are specific to each property, and they are predetermined by the tax rolls and GIS measurements, respectively. $MarginalEffect_0$ only differs by county, not by property. To calculate an aggregate countywide effect, we assign a value for Δ*Secchi* to each Secchi disk monitoring point in the county, use Equation 5.4 to calculate Δ*Value* for each individual single family home in the county, and then simply sum the results.

5.2 Example: A Uniform Change in Water Quality

For our first example, we assume each water quality monitoring point in each county has experienced a one-foot increase in its average Secchi disk depth measurements over the past year.[41] Under this scenario, $\Delta Secchi = 1$ across all monitoring points, which simplifies Equation 5.4 to

$$\Delta Value = JustValue \times MarginalEffect_0 \times e^{-2\,\times\,Distance}. \qquad (5.5)$$

For our calculations, we use the single family home just values reported in the 2013 FDOR-certified tax rolls for Lee and Martin counties. The results are as follows:

- *Other things equal, we find that a one-foot increase in average Secchi disk depth throughout the Caloosahatchee Estuary* ***raises Lee County's aggregate property value by an estimated $541 million****.*

- *Other things equal, we find that a one-foot increase in average Secchi disk depth throughout the St. Lucie Estuary, Loxahatchee Estuary, and the portion of the Indian River Lagoon north*

[41] We use Secchi disk depth for our analysis here because it is available for both counties and we have established that it is a superior measure of perceived water quality relative to chlorophyll *a* and turbidity. Additionally, it is much easier for to visualize a one-foot change in Secchi disk depth than it is a one-µg/L change in chlorophyll *a* or a one-NTU change in turbidity.

of the St. Lucie Inlet ***raises Martin County's aggregate property value by an estimated <u>$428 million</u>***.

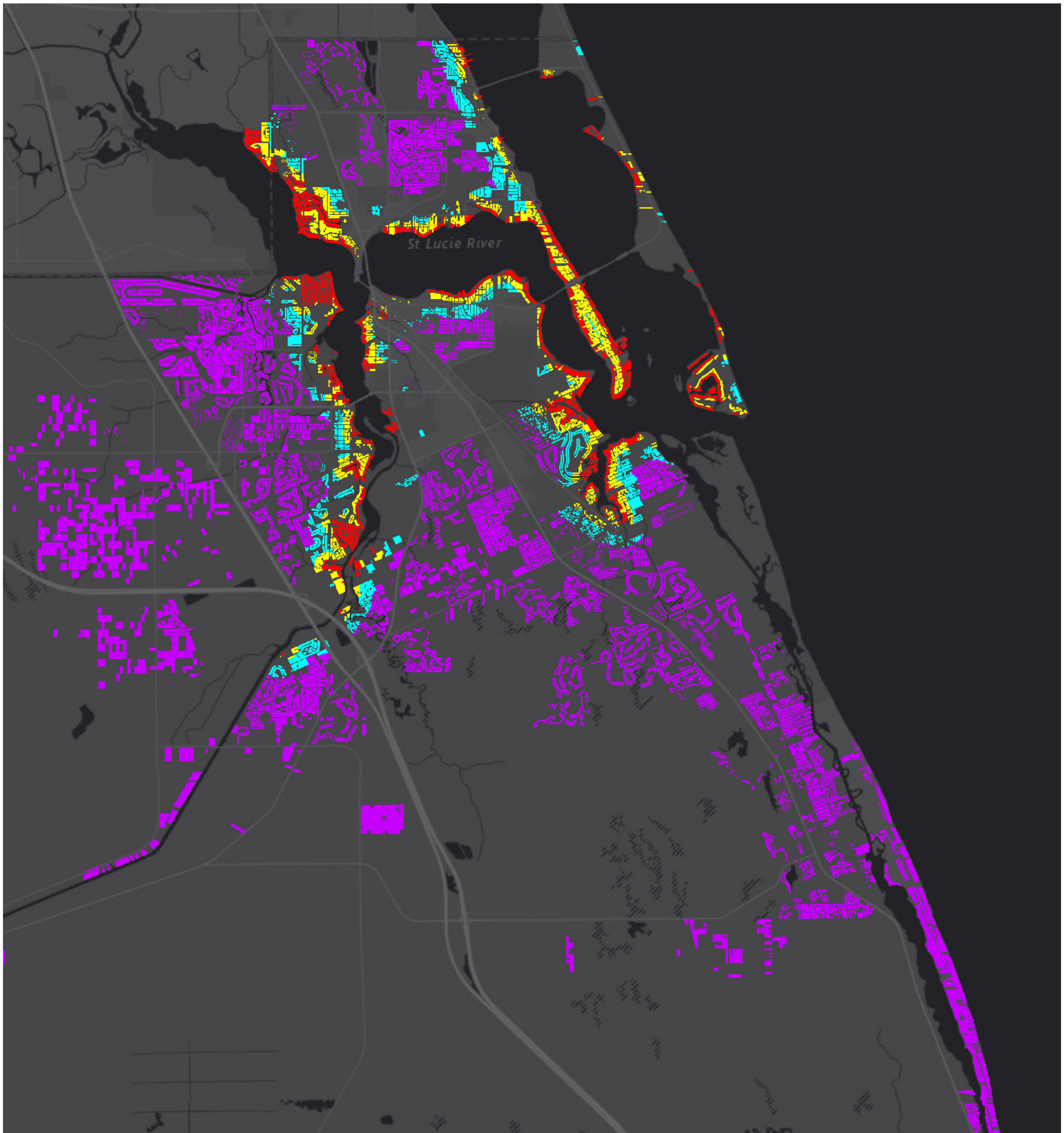
Figure 5.1 serves to illustrate that the impact of water quality on property values is not limited to the waterfront. It shows Martin County's single family home parcels, color-coded according to their distances from estuary shorelines. Red parcels include waterfront and near-waterfront properties, up to the distance at which 25 percent of the $428 million of estimated added value has been accounted for. Yellow parcels account for the next quarter of added value, so combined, the red and yellow parcels account for half of the $428 million estimate. Cyan-colored parcels account for the third quarter of generated aggregate value, and the remaining parcels, colored purple, account for the final 25 percent.

We should note that the estimated changes to each county's aggregate property value are entirely due to estimated increases in the value of each county's stock of single family home properties. Since we made no attempts in our study to estimate the effects of improved water quality on other types of properties, we made no assumption that the values of these properties would increase. In reality, given that the single family home effects we estimated were so strong and significant, it is probably safe to assume that improved water quality will at the very least have similar effects on values of condominiums and other residential properties. So in this respect, our estimates may be a bit conservative. That said, in the 2013 tax roll data we are using, single family homes account for 55 percent of total just value in Lee County and 61 percent of total just value in Martin County.

As we mentioned previously in Section 4, our model results are applicable to both increases *and* decreases in measured water quality. Just as a one-foot increase in the average annual Secchi disk depth at each monitoring station respectively leads to $541 million and $428 million improvements in the aggregate market value of single family homes in Lee and Martin counties, a one-foot *decrease* in average annual Secchi disk depth results would—other things constant—be associated with estimated *losses* of $541 million and $428 million.

5.3 Example: Martin County in the Summer of 2013

In the summer of 2013, major water releases from Lake Okeechobee into the St. Lucie River resulted in a significant decline in observed water quality throughout the St. Lucie



Original parcel map source: MCPA

Figure 5.1

Map of Martin County single family home parcels, color-coded according to distance from the “Estuary” class of water bodies as defined in Section 3.2. Each color accounts for one quarter of the aggregate change in Martin County property values resulting from a one-foot change in average Secchi disk depth in the St. Lucie Estuary, Loxahatchee Estuary, and the Indian River Lagoon (north of the St. Lucie Inlet).

Estuary and adjoining portions of the Indian River Lagoon. Because water quality data was collected over this time period, we can produce a more precise estimate of the impact to Martin County's single family home values. For this estimate, we use Equation 5.4 because we know how much the one-year average Secchi disk depth changed at each Martin County monitoring point over the summer. That is, we do not need to make any assumptions about the values of Δ*Secchi* in Equation 5.4 (as we did in the previous example, where we assumed a uniform one-foot change across all monitoring points) because in this case, these values were actually measured.

In this example, we specifically define Δ*Secchi* for each monitoring point as the change (in feet) in the one-year average Secchi disk depth between May 1, 2013 and September 1, 2013. After calculating Equation 5.4 for each single family home in Martin County and summing the results, we arrive at the following estimate:

- *We find that changes in the water quality of the St. Lucie Estuary, Loxahatchee Estuary, and the portion of the Indian River Lagoon north of the St. Lucie Inlet—as measured by changes to one-year average Secchi disk depth at each monitoring point—resulted in an estimated* ***<u>$488 million reduction</u> in Martin County's aggregate property value between May 1, 2013 and September 1, 2013****.*

As in the previous example, this assessment is derived entirely from estimated changes in the value of Martin County's stock of single family homes; we did not estimate changes in the values of other property types. We would also emphasize that our result does not imply that there was an *overall* reduction of $488 million in Martin County's aggregate property value between May 1 and September 1. Water quality is not, after all, the only factor that affected home prices over that time span. In fact, 2013 was actually a banner year for real estate in Florida, marked by a significant statewide recovery in home prices, so it is quite possible that Martin County's aggregate property value increased during the summer.[42] Our result simply reflects the notion that any overall recovery of property values was significantly dampened by poor water quality, and would have been much stronger otherwise.

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[42] In the price index shown in Figure 3.1 in Section 3, this increase in the statewide price level for single family homes is clearly evident.

Section 6. Concluding Remarks

In this study, we compiled an extensive database of water quality measurements and control characteristics, which we used to produce robust estimates of the effect of water quality on single family home prices in two metropolitan Florida counties. The statistical significance, direction, and magnitude of these estimates leave little doubt that water quality plays an important role in the determination of home sale prices. The results also corroborate those of the only similar Florida-based study, published by Walsh, Milon, and Scrogin in 2011.

Our methodology and our results for these models (or similar models) can be used as a building block for future studies on the effect of water quality on housing prices elsewhere in Florida, although this is largely dependent on whether the appropriate water quality data are available. The lack of water quality metrics that are tracked or reported consistently and frequently over time and across multiple locations in various markets is the major limiting factor here. That is, in order to further our understanding of water quality's effect on real estate markets elsewhere in the state, more comprehensive monitoring will be required.

The examples we provide in Section 5 are rather simple; future research may provide more precise aggregate estimates through more complex, nuanced approaches. As we noted, our models and our approach focuses solely on single family homes. Effects on other property types should be explored, as well. Our own aggregate estimates show, at the very least, that these effects are significant in both size and scope.

Policy makers and the public would also benefit from research into the possible effects of Everglades restoration on water quality in the estuaries of Martin and Lee counties. If such estimates could be obtained, the future benefit to the real estate markets in these counties could be estimated through our methodology, as well.

Finally, we should note that our estimates merely reflect the impact of water quality on home prices near the water, and we suspect that the estimates we have produced are merely a drop in the bucket compared to the overall economic impact of water quality on the leisure, recreation, and marine industries in these counties.

Appendix A

Table A.1
Description of Lee County flood insurance risk map zone types

Zone Name	Zone Description
X	An area of minimal flood hazard that is determined to be outside the Special Flood Hazard Area and higher than the elevation of the 0.2-percent-annual-chance (or 500-year) flood.
X02	An area of minimal flood hazard that is determined to be outside the Special Flood Hazard Area between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood.
A	Areas subject to inundation by the 1-percent-annual-chance flood event generally determined using approximate methodologies. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply. (In unincorporated Lee County, the county has estimated BFEs in these areas.)
AE	Areas subject to inundation by the 1-percent-annual chance-flood event determined by detailed methods. Base Flood Elevations (BFEs) are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.
VE	Areas subject to inundation by the 1-percent-annual-chance flood event with additional hazards due to storm-induced velocity wave action. Base Flood Elevations (BFEs) derived from detailed hydraulic analyses are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Source: Lee County
All properties in the study fell into one of these categories, so Zone X was omitted as an indicator variable in the models

Table A.2
Description of Martin County flood insurance risk map zone types

Zone Name	Zone Description
X	Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level. Zone C may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood.
X500	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.
A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones.
AE	Areas with a 1% or greater annual annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. The base floodplain where base flood elevations are provided.
AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
VE	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

Source: Martin County
All properties in the study fell into one of these categories, so Zone X was omitted as an indicator variable in the models

Appendix B

Table B.1
Results of 1-month and 1-year regressions for Martin County

	(1)		(2)		(3)		(4)	
Structural Characteristics								
Effective age of home	−0.0194**	[−34.30]	−0.0194**	[−34.28]	−0.0195**	[−34.23]	−0.0196**	[−34.13]
ln(lot acreage)	0.177**	[28.95]	0.177**	[28.97]	0.178**	[29.11]	0.178**	[29.20]
Total finished area	2.51E−04**	[21.67]	2.51E−04**	[21.68]	2.51E−04**	[21.71]	2.51E−04**	[21.91]
Bedrooms	0.0522**	[6.52]	0.0524**	[6.53]	0.0516**	[6.47]	0.0505**	[6.37]
Boat dock	0.343**	[12.79]	0.344**	[12.81]	0.348**	[12.84]	0.351**	[13.08]
Swimming pool	0.191**	[20.18]	0.191**	[20.06]	0.190**	[20.07]	0.187**	[19.89]
Located on golf course	0.114**	[9.62]	0.113**	[9.61]	0.115**	[9.78]	0.117**	[9.97]
Sale Characteristics								
Short sale	−0.197**	[−20.54]	−0.198**	[−20.63]	−0.196**	[−20.37]	−0.195**	[−20.32]
Foreclosure/REO	−0.349**	[−23.40]	−0.350**	[−23.44]	−0.349**	[−23.43]	−0.349**	[−23.32]
Neighborhood Characteristics								
Pct. of residents 18 & under	−0.0124**	[−9.81]	−0.0123**	[−9.72]	−0.0125**	[−9.89]	−0.0122**	[−9.68]
Pct. of residents age 65+	7.99E−04	[1.59]	7.92E−04	[1.57]	7.11E−04	[1.41]	6.95E−04	[1.37]
Median household income	0.0254**	[12.01]	0.0252**	[11.78]	0.0250**	[11.86]	0.0245**	[11.51]
Jurisdictional Characteristics								
Millage rate	0.0474**	[3.39]	0.0470**	[3.36]	0.0660**	[4.76]	0.0835**	[6.01]
Primary School Score	1.96E−04	[1.10]	1.84E−04	[1.03]	2.07E−04	[1.17]	2.31E−04	[1.31]
Middle School Score	3.54E−04	[1.68]	3.69E−04	[1.74]	0.00506*	[2.37]	5.91E−04**	[2.75]
High School Score	0.00112**	[3.40]	0.00111**	[3.37]	6.73E−04*	[2.05]	2.50E−04	[0.76]
Regional Characteristics								
Statewide home price index	0.00609**	[5.57]	0.00632**	[5.80]	0.00721**	[6.66]	0.00659**	[6.12]
Flood risk characteristics								
Risk type X500	−0.00632	[−0.49]	−0.00667	[−0.52]	0.00680	[0.53]	0.0222	[1.72]
Risk type A	0.144**	[5.27]	0.145**	[5.29]	0.159**	[5.78]	0.173**	[6.29]
Risk type AH	0.0441*	[2.00]	0.0449*	[2.04]	0.0646**	[2.92]	0.0873**	[3.94]
Risk type AE	−0.0143	[−0.47]	−0.0171	[−0.56]	−0.0175	[−0.58]	−0.0106	[−0.35]
Risk type AE × AE elevation	0.00104	[0.40]	0.00126	[0.49]	0.00181	[0.71]	0.00207	[0.81]
Risk type VE	−2.261	[−1.48]	−2.247	[−1.49]	−2.33	[−1.70]	−2.537	[−1.89]
Risk type VE × VE elevation	0.238	[1.58]	0.237	[1.59]	0.243	[1.79]	0.262	[1.96]
Water Proximity and Quality								
Intracoastal waterway waterfront	0.222**	[4.03]	0.224**	[4.05]	0.217**	[3.95]	0.207**	[3.79]
exp(−2 × distance to I.C.W.)	0.245**	[6.31]	0.244**	[6.28]	0.266**	[6.82]	0.284**	[7.29]
exp(−2 × distance to ocean)	0.763**	[6.88]	0.766**	[6.93]	0.737**	[6.68]	0.714**	[6.52]
Estuary waterfront	0.350**	[10.57]	0.348**	[10.52]	0.341**	[10.18]	0.332**	[10.02]
exp(−2 × distance to estuary)	0.199**	[3.11]	0.311*	[2.53]	−0.0978**	[−2.72]	−0.267**	[−5.96]
exp(−2 × distance to estuary) × dissolved O_2 (1–month)	−0.0200	[−1.80]	—	—	—	—	—	—
exp(−2 × distance to estuary) × dissolved O_2 (1–year)	—	—	−0.0387	[−1.85]	—	—	—	—
exp(−2 × distance to estuary) × Secchi depth (1–month)	—	—	—	—	0.0541**	[6.26]	—	—
exp(−2 × distance to estuary) × Secchi depth (1–year)	—	—	—	—	—	—	0.103**	[9.06]
Constant	9.994**	[34.56]	9.974**	[34.68]	9.615**	[33.92]	9.510**	[33.65]
N	7,975		7,975		7,975		7,975	
***R*-squared**	0.8566		0.8566		0.8576		0.8587	

Dependent variable in all models is **ln(*sale price*)**; estimation by ordinary least squares with heteroskedasticity-robust clustered standard errors
Month and year fixed effects omitted from table; available upon request
t-statistics in brackets
* $p < 0.05$, ** $p < 0.01$

Table B.2
Results of 1-month regressions for Lee County

	(1)		(2)		(3)		(4)	
Structural Characteristics								
Effective age of home	−0.0109**	[−53.06]	−0.0109**	[−52.99]	−0.0109**	[−53.00]	−0.0109**	[−52.96]
ln(lot acreage)	0.0475**	[10.59]	0.0471**	[10.50]	0.0472**	[10.52]	0.0471**	[10.51]
Heated area	3.88E−04**	[32.68]	3.88E−04**	[32.79]	3.88E−04**	[32.71]	3.88E−04**	[32.74]
Bedrooms	−0.0264**	[−5.14]	−0.0264**	[−5.14]	−0.0264**	[−5.14]	−0.0263**	[−5.12]
Bathrooms	0.0753**	[13.85]	0.0757**	[13.92]	0.0756**	[13.89]	0.0755**	[13.91]
Number of stories	−0.0823**	[−10.25]	−0.0826**	[−10.30]	−0.0826**	[−10.28]	−0.0827**	[−10.31]
Garage	0.268**	[32.40]	0.268**	[32.40]	0.268**	[32.40]	0.267**	[32.28]
Carport	0.0222*	[2.19]	0.0219*	[2.16]	0.0220*	[2.17]	0.0224*	[2.22]
Sea wall	0.158**	[10.65]	0.159**	[10.76]	0.159**	[10.70]	0.158**	[10.60]
Boat dock	0.115**	[12.45]	0.115**	[12.45]	0.115**	[12.44]	0.115**	[12.44]
Swimming pool	0.258**	[60.80]	0.258**	[60.87]	0.258**	[60.83]	0.258**	[60.83]
Located on golf course	0.230**	[28.10]	0.229**	[28.01]	0.230**	[28.03]	0.230**	[28.11]
Sale Characteristics								
Short sale	−0.270**	[−72.83]	−0.270**	[−72.80]	−0.270**	[−72.84]	−0.270**	[−72.79]
Foreclosure/REO	−0.321**	[−94.00]	−0.321**	[−93.94]	−0.321**	[−93.97]	−0.321**	[−93.99]
Neighborhood Characteristics								
Pct. of residents 18 & under	−0.00421**	[−17.29]	−0.00419**	[−17.18]	−0.00419**	[−17.19]	−0.00420**	[−17.23]
Pct. of residents age 65+	0.00363**	[20.09]	0.00365**	[20.22]	0.00364**	[20.18]	0.00363**	[20.11]
Median household income	0.0516**	[47.94]	0.0517**	[48.06]	0.0516**	[48.03]	0.0517**	[48.07]
Jurisdictional Characteristics								
Millage rate	−0.0230**	[−21.88]	−0.0230**	[−21.89]	−0.0230**	[−21.92]	−0.0229**	[−21.79]
Primary School Score	0.00211**	[10.45]	0.00213**	[10.52]	0.00211**	[10.45]	0.00210**	[10.38]
Middle School Score	0.00739**	[60.61]	0.00740**	[60.63]	0.00740**	[60.68]	0.00740**	[60.70]
High School Score	−0.00396**	[−21.33]	−0.00393**	[−21.10]	−0.00393**	[−21.18]	−0.00394**	[−21.24]
Regional Characteristics								
Statewide home price index	0.00813**	[20.02]	0.00815**	[20.05]	0.00814**	[20.04]	0.00831**	[20.41]
Flood risk characteristics								
Risk type X02	0.0597**	[12.88]	0.0589**	[12.70]	0.0588**	[12.69]	0.0590**	[12.72]
Risk type A	−0.208**	[−6.25]	−0.208**	[−6.27]	−0.208**	[−6.28]	−0.208**	[−6.26]
Risk type AE	0.0361**	[4.23]	0.0354**	[4.14]	0.0353**	[4.13]	0.0345**	[4.04]
Risk type AE × AE elevation	0.00671**	[8.90]	0.00678**	[8.99]	0.00678**	[8.99]	0.00680**	[9.03]
Risk type VE	−0.201	[−0.69]	−0.205	[−0.71]	−0.203	[−0.70]	−0.196	[−0.67]
Risk type VE × VE elevation	0.00950	[0.45]	0.00983	[0.47]	0.00966	[0.46]	0.00911	[0.43]
Water Proximity and Quality								
Bay waterfront	0.378**	[6.92]	0.377**	[6.90]	0.378**	[6.90]	0.378**	[6.90]
exp(−2 × distance to bay)	0.358**	[17.36]	0.357**	[17.30]	0.357**	[17.34]	0.358**	[17.40]
Gulf waterfront	0.696**	[7.54]	0.696**	[7.53]	0.696**	[7.53]	0.696**	[7.54]
exp(−2 × distance to Gulf)	0.877**	[25.82]	0.876**	[25.78]	0.876**	[25.81]	0.877**	[25.84]
Canal waterfront	0.224**	[15.64]	0.223**	[15.59]	0.224**	[15.62]	0.224**	[15.62]
River (non−estuary) waterfront	0.319**	[4.71]	0.310**	[4.58]	0.312**	[4.60]	0.311**	[4.60]
Lake waterfront	0.248**	[44.01]	0.247**	[43.89]	0.248**	[43.93]	0.248**	[43.97]
Estuary waterfront	0.642**	[17.89]	0.642**	[17.91]	0.642**	[17.72]	0.643**	[17.80]
exp(−2 × distance to estuary)	0.256**	[18.14]	0.161	[4.90]	0.248**	[16.89]	0.112**	[4.96]
exp(−2 × distance to estuary) × chlorophyll a (1−month)	−0.00459**	[−5.01]	—	—	—	—	—	—
exp(−2 × distance to estuary) × dissolved O_2 (1−month)	—	—	0.00818	[1.89]	—	—	—	—
exp(−2 × distance to estuary) × turbidity (1−month)	—	—	—	—	−0.0107**	[−2.95]	—	—
exp(−2 × distance to estuary) × Secchi depth (1−month)	—	—	—	—	—	—	0.0248**	[6.04]
Constant	8.170**	[126.63]	8.154**	[126.53]	8.159**	[126.63]	8.140**	[126.42]
N	48,572		48,572		48,572		48,572	
***R*-squared**	0.8767		0.8766		0.8766		0.8767	

Dependent variable in all models is **ln(*sale price*)**; estimation by ordinary least squares with heteroskedasticity-robust clustered standard errors
Month and year fixed effects omitted from table; available upon request
t-statistics in brackets
* $p < 0.05$, ** $p < 0.01$

Table B.3
Results of 1-year regressions for Lee County

	(1)		(2)		(3)		(4)	
Structural Characteristics								
Effective age of home	−0.0109**	[−53.14]	−0.0109**	[−52.98]	−0.0109**	[−53.27]	−0.0109**	[−53.02]
ln(*lot acreage*)	0.0484**	[10.76]	0.0472**	[10.50]	0.0478**	[10.66]	0.0478**	[10.66]
Heated area	3.87E−04**	[32.65]	3.88E−04**	[32.72]	3.88E−04**	[32.70]	3.88E−04**	[32.76]
Bedrooms	−0.0264**	[−5.12]	−0.0264**	[−5.13]	−0.0264**	[−5.14]	−0.0260**	[−5.07]
Bathrooms	0.0747**	[13.73]	0.0757**	[13.92]	0.0747**	[13.75]	0.0731**	[13.49]
Number of stories	−0.0816**	[−10.17]	−0.0826**	[−10.27]	−0.0819**	[−10.21]	−0.0813**	[−10.14]
Garage	0.268**	[32.38]	0.268**	[32.43]	0.265**	[32.09]	0.260**	[31.67]
Carport	0.0223*	[2.20]	0.0217*	[2.14]	0.0231*	[2.28]	0.0249*	[2.47]
Sea wall	0.157**	[10.59]	0.160**	[10.75]	0.156**	[10.54]	0.153**	[10.31]
Boat dock	0.115**	[12.42]	0.115**	[12.46]	0.114**	[12.33]	0.114**	[12.42]
Swimming pool	0.258**	[60.79]	0.258**	[60.80]	0.258**	[60.75]	0.257**	[60.77]
Located on golf course	0.230**	[28.17]	0.229**	[28.01]	0.231**	[28.22]	0.233**	[28.64]
Sale Characteristics								
Short sale	−0.270**	[−72.84]	−0.270**	[−72.81]	−0.270**	[−72.91]	−0.270**	[−73.01]
Foreclosure/REO	−0.321**	[−93.94]	−0.321**	[−93.97]	−0.321**	[−94.08]	−0.321**	[−94.20]
Neighborhood Characteristics								
Pct. of residents 18 & under	−0.00427**	[−17.48]	−0.00418**	[−17.18]	−0.00421**	[−17.27]	−0.00426**	[−17.48]
Pct. of residents age 65+	0.00360**	[19.92]	0.00365**	[20.19]	0.00364**	[20.15]	0.00355**	[19.65]
Median household income	0.0514**	[47.78]	0.0517**	[48.04]	0.0513**	[47.75]	0.0516**	[48.09]
Jurisdictional Characteristics								
Millage rate	−0.0229**	[−21.82]	−0.0230**	[−21.88]	−0.0229**	[−21.86]	−0.0221**	[−21.20]
Primary School Score	0.00210**	[10.39]	0.00213**	[10.54]	0.00205**	[10.16]	0.00193**	[9.57]
Middle School Score	0.00739**	[60.57]	0.00740**	[60.74]	0.00740**	[60.73]	0.00743**	[61.09]
High School Score	−0.00400**	[−21.55]	−0.00393**	[−21.15]	−0.00394**	[−21.25]	−0.00397**	[−21.49]
Regional Characteristics								
Statewide home price index	0.00812**	[19.99]	0.00813**	[19.96]	0.00792**	[19.43]	0.00793**	[19.57]
Flood risk characteristics								
Risk type X02	0.0601**	[12.96]	0.0589**	[12.70]	0.0590**	[12.74]	0.0587**	[12.72]
Risk type A	−0.207**	[−6.23]	−0.208**	[−6.28]	−0.208**	[−6.25]	−0.206**	[−6.18]
Risk type AE	0.0373**	[4.36]	0.0354**	[4.14]	0.0351**	[4.11]	0.0316**	[3.70]
Risk type AE × AE elevation	0.00661**	[8.77]	0.00678**	[8.99]	0.00676**	[8.96]	0.00689**	[9.14]
Risk type VE	−0.196	[−0.68]	−0.207	[−0.71]	−0.170	[−0.59]	−0.152	[−0.53]
Risk type VE × VE elevation	0.00918	[0.44]	0.00993	[0.47]	0.00735	[0.35]	0.00587	[0.28]
Water Proximity and Quality								
Bay waterfront	0.378**	[6.93]	0.377**	[6.90]	0.378**	[6.93]	0.377**	[6.93]
exp(*−2 × distance to bay*)	0.359**	[17.43]	0.356**	[17.29]	0.360**	[17.54]	0.368**	[17.88]
Gulf waterfront	0.696**	[7.55]	0.696**	[7.53]	0.697**	[7.56]	0.698**	[7.61]
exp(*−2 × distance to Gulf*)	0.878**	[25.86]	0.876**	[25.78]	0.878**	[25.94]	0.881**	[26.08]
Canal waterfront	0.225**	[15.66]	0.223**	[15.57]	0.226**	[15.83]	0.227**	[15.78]
River (non−estuary) waterfront	0.320**	[4.71]	0.311**	[4.60]	0.316**	[4.66]	0.322**	[4.76]
Lake waterfront	0.248**	[44.08]	0.247**	[43.92]	0.249**	[44.21]	0.249**	[44.29]
Estuary waterfront	0.654**	[18.36]	0.644**	[17.86]	0.646**	[17.59]	0.658**	[17.32]
exp(−2 × distance to estuary)	0.298**	[17.34]	0.170	[1.29]	0.420**	[16.85]	−0.421**	[−8.87]
exp(−2 × distance to estuary) × chlorophyll a (1−year)	−0.0103**	[−6.46]	—	—	—	—	—	—
exp(−2 × distance to estuary) × dissolved O_2 (1−year)	—	—	0.00719	[0.38]	—	—	—	—
exp(−2 × distance to estuary) × turbidity (1−year)	—	—	—	—	−0.0794**	[−8.77]	—	—
exp(−2 × distance to estuary) × Secchi depth (1−year)	—	—	—	—	—	—	0.147**	[14.32]
Constant	8.189**	[126.58]	8.158**	[126.41]	8.213**	[126.56]	8.236**	[127.70]
N	48,572		48,572		48,572		48,572	
***R*-squared**	0.8767		0.8766		0.8769		0.8774	

Dependent variable in all models is **ln(*sale price*)**; estimation by ordinary least squares with heteroskedasticity-robust clustered standard errors
Month and year fixed effects omitted from table; available upon request
t-statistics in brackets
* $p < 0.05$, ** $p < 0.01$

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