Benefit & Benefit/Cost Calculations for Two Everglades Restoration Projects

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THE EVERGLADES FOUNDATION

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© 2017. This study has been funded by the Congressional Office of (retired) Representative Curt Clawson and by the Everglades Foundation, but the Clemson University investigators are solely responsible for the content of the report. Thomas is Visiting Assistant Professor, De Los Santos is Assistant Professor, Sauer and Parker are Masters Students all in the Department of Economics, Clemson University. Hobbs (BS Clemson) is an industrial engineer at Perkins + Will in Atlanta. This project is the outgrowth of work done previously by researchers at and associated with Clemson University.

Abstract

We calculate economic benefits from two alternative Everglades restoration projects. We call one the South Reservoir, a reservoir south of Lake Okeechobee that would provide storage when the lake is too full. The other is called the North Reservoir, a storage area north of Lake Okeechobee that will capture water before it enters the lake. One purpose of the reservoirs is to mitigate the discharge of the excess water from Lake Okeechobee into the St. Lucie River and the Caloosahatchee where it damages the estuaries and negatively affects water quality. By investigating the effects of one reservoir at a time, hydrologists can estimate the reduction in discharges into the rivers attributable to a specific project.

Prior research clearly shows that reducing discharges improves water quality. Research also shows that improving water quality increases property values. We put these two pieces of scientific evidence together to calculate the expected economic benefits of the South Reservoir and of the North Reservoir compared to doing nothing.

The findings are dramatic. The South Reservoir outperforms the alternative of a North Reservoir, improving water quality by more than 45% in the Caloosahatchee and 64% in the St. Lucie River. This will cause property values of homes on or near the waterfront to increase by 18%, resulting in over $12 billion in increased value. Properties related to and serving those homes are also expected to increase in value, adding about $6.5 billion in value. There's also value in the water to be collected in the reservoir that would otherwise be dumped into the seas. Adding this to the increased real estate value, the benefits of the South Reservoir are expected to be over $20 billion. The cost of the South Reservoir is estimated to be about $2.5 billion, so the net benefits are over $17 billion with a benefit-cost ratio of 8.1.

The North Reservoir is not nearly so effective at reducing discharges to the estuaries, and, hence, will have economically less effect. It will only result in discharge mitigation of 5-6%. Benefits, counting the value of the water, would be $1.7 billion with a benefits-cost ratio of 1.5.

From a hydrological perspective, the South Reservoir is clearly a superior project and our economic analysis puts a dollar value on it that is conspicuously large. The beauty of doing a simple simulation of one project at a time is that we get a clear picture of the outcome. The hydrology is basic and the predicted economic outcome is definitive.

Introduction & Summary of Findings

The purpose of this inquiry and report is to analyze the economic benefits that would result from two alternative Everglades restoration projects. One is a reservoir north of Lake Okeechobee[1] and the other, a reservoir south of the lake.[2] Unlike previous research on Everglades restoration that has looked at a host of different projects, we compare two only in order to measure the outcomes using marginal analysis.[3] By looking at one project at a time, hydrologists can generate estimates of the hydrological outcomes attributable to a specific project. Basing the economic effects on these gives definitive conclusions about the benefits and benefits compared to costs of the projects.

The findings are:

- **The proposed South Reservoir has a benefit-cost ratio of 8.1 based on benefits of $20 billion.**
- **The proposed North Reservoir has a benefit-cost ratio of 1.5 with benefits of $1.7 billion.**

The South Reservoir project is undeniably cost effective. The North Reservoir is less so. Details of these findings are given below.

[1] Component A of CERP, henceforth called the North Reservoir.
[2] Component G of CERP, henceforth called the South Reservoir.
[3] It is like taking a partial derivative in calculus. This is a multi-faceted system, and what we want to know is the marginal impact of one project.

Background

The Everglades are fed by Lake Okeechobee, the largest freshwater lake in the State of Florida. In the 1890s, Lake Okeechobee was connected westward to the Caloosahatchee[4] which empties into the Gulf of Mexico in Lee County, Florida.[5] In the 1930s, Lake Okeechobee was connected eastward to the St. Lucie River which empties into the Atlantic Ocean in Martin County, Florida. These man-made connections have allowed for discharges from Lake Okeechobee into the St. Lucie River and the Caloosahatchee in order to control the lake's water levels and protect its levees after heavy rains. However, the freshwater discharged into these rivers from Lake Okeechobee has had adverse effects on river water quality because the discharges alter the rivers' nutrient levels and salinity where they meet the ocean.[6]

The South Reservoir is a 360,000 acre-foot reservoir south of Lake Okeechobee. The North Reservoir is a 200,000 acre-foot reservoir north of Lake Okeechobee. Both reservoirs are described in the Comprehensive Everglades restoration Plan.[7]

Benefits that the Reservoirs Would Create

There are innumerable benefits that would result from restoring water flow paths in the Everglades. Only two sets of benefits are explicitly analyzed here: (a) Increased value of existing real estate due to improved water quality along the rivers and estuaries east and west of Lake Okeechobee. (b) Value of the water captured in the proposed reservoirs that is currently being wastefully discharged into the ocean through the St. Lucie River and the Caloosahatchee.

It is important to note that this list of benefits is not exhaustive. Other potential benefits are important and arguably substantial. One is jobs. Standard analysis of projects such as this include an estimate of the number of jobs created by the project. We do this in a separate report. Other benefits include health effects. For example, the public health effects experienced during the 2016 algae blooms in Martin County cannot be taken lightly. Also, environmental amenities from the Everglades will increase in the event that more water flows there. While the benefit-cost analyses presented in this report focus on the benefits measured in real estate value, water, and jobs, the overall positive impact of the projects is expected to be substantially larger. In future research we hope to address these additional benefits quantitatively.

Hydrological Effects of the Reservoirs

Hydrologists at the Everglades Foundation have estimated the effect of each of the proposed reservoirs on discharges into the St. Lucie River and the Caloosahatchee. They generated time series of regulatory releases to the rivers based on simulations using historical rainfall, existing infrastructure and operations, etc.[8] The simulations forecast how much water would be released with and without each of the alternative reservoirs if the area continues to experience weather patterns similar to those that have occurred in the past. Our problem, then, is to identify the effect of these simulated discharges on water quality.

All this is given in Appendix A, but to summarize, there are multiple metrics for measuring the change in flow characteristics from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries. Volume, duration, and frequency are all defining characteristics. To maintain all of the characteristics, we use the modeled time series of monthly regulatory release totals and link these monthly flow totals to water quality metrics. To get the relation between monthly flows and water quality we use the relationships observed in past actual releases, thereby generating a time series of water quality.

We choose Secchi disk depth (SDD) as our water quality metric. SDD is a measure of water quality based on visual assessment of clarity. SDD has proven to be the most robust link between consumers' market-value expression of their appreciation of water quality and the water's underlying composition. That is, SDD is the metric of water quality most highly correlated with the market value of residential property.

We know from the hydrological literature that SDD responds negatively to pollution load. Specifically, as the phosphorus content of the water decreases, SDD goes up. We also know that discharges from Lake Okeechobee have high phosphorus content. To map these discharges into SDD we run regressions of SDD readings on the observed releases. The regressions show the predicted negative relation and are statistically significant.

From these regressions, we predict the water quality outcomes from the simulations of the two Everglades restoration projects. Table 1 shows the water quality effects for the two reservoirs and two rivers:

Table 1: Water Quality Improvements as a Result of Reservoirs

Percent Increase in Secchi Disk Depth		
	Caloosahatchee	**St. Lucie River**
South Reservoir	45.0%	67.3%
North Reservoir	3.2%	2.4%

[4] In this report, the term Caloosahatchee is preferred to Caloosahatchee River. The river is named for the Caloosa Indians and, in their native language, the term "hatchee" means river. Thus, it is somewhat redundant to say Caloosahatchee River. Natives often break the word: Caloosa Hatchee.

[5] Florida Department of Environmental Protection (2011) Brief History of Lake Okeechobee. Web page, retrieved on 5 Oct 2016 from http://www.dep.state.fl.us/evergladesforever/about/lakeo_history.htm.

[6] Buzzelli, C., Carter, K., Bertolotti, L., & Doering, P. (2015). St. Lucie and Caloosahatchee River Watershed Protection Plan Annual and Three-Year Updates. 2015 South Florida Environmental Report (10-1 - 10-108). Retrieved from http://my.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_sfer/portlet_prevreport/2015_sfer_final/v1/chapters/v1_ch10.pdf.

[7] U.S. Army Corps of Engineers and the South Florida Water Management District. Central and Southern Florida Project Comprehensive Review Study. 1999. North Reservoir is described on page 9-2 and the South Reservoir is described on page 9-9. Retrieved from http://141.232.10.32/pub/restudy_eis.aspx

[8] See: Thomas Van Lent & Rajendra Paudel, "A Comparison of the Benefits of Northern & Southern Everglades Storage" October 26, 2016, The Everglades Foundation, http://www.evergladesfoundation.org/2016/10/26/a-comparison-of-the-benefits-of-northern-and-southern-everglades-storage/.

The hydrology simulations show that the South Reservoir completely eliminates 45% of the discharges into the St. Lucie River and 48% of the discharges into the Caloosahatchee, while the North Reservoir only eliminates around 5% of the discharges. We see in Table 1 that these reservoir characteristics translate directly into improved water quality. Again, Appendix A provides detailed discussion, statistical analysis, and citations for these hydrological conclusions.

Real Estate Value

Estuary waterfront residential real estate in Lee County and Martin County will increase in value due to improvement in water quality of the St. Lucie River and the Caloosahatchee, respectively.[9] This increase in waterfront property value will cause the value of adjacent and substitutable residential properties to increase. The value of commercial properties that service residential property will rise as well. We examine the effects on real estate values in Lee and Martin Counties only because hydrologists are very confident in their predictions about the effect of the reservoirs on water quality in the estuaries and waterways there. Other counties will almost certainly be positively affected by discharge reductions. Notably, Collier County has been plagued by algae blooms attributed to Caloosahatchee discharges. Nonetheless, hydrologists cannot be precise about the degree to which reduced discharges will translate into higher water quality there. In future work we may be able measure benefits beyond Lee and Martin Counties.

Many researchers have estimated the impact of improved water quality on waterfront and adjacent properties. Florida Realtors® conducted an exhaustive study controlling for almost all factors that affect residential property values.[10] Their statistical analysis finds that home values are positively affected by proximity to water and the quality of that water; that is, the closer a home is to water and the higher the quality of that water, the higher its value holding everything else constant. Florida Realtors use an exponential decay function to best fit the relation between distance from the water and the relative impact of water and water quality on the price of the property. The function quantifies how the relative amenity value of proximity to the water and its quality declines as distance from the water increases. We apply this model to measure the increase in real estate value from improved water quality caused by the North and South Reservoirs. The estimated coefficients from Florida Realtors (2015) for water quality effects are shown in Table 2.[11]

Table 2:
Percentage increase in property value for 20% increase in water quality based on distance from water

	Lee	Martin
Waterfront	0.1255	0.0702
1/8 of a mile from the waterfront:	0.0977	0.0547
1/4 of a mile from the waterfront:	0.0761	0.0426
1/2 of a mile from the waterfront:	0.0462	0.0258
1 mile from the waterfront:	0.017	0.0095
2 miles from the waterfront:	0.0023	0.0013
4 miles from the waterfront:	0.000042	0.000024

Note: From Florida Realtors (2015). Water quality measured by Secchi disk depth over the year before real estate sale.

To estimate the effects of improved water quality on property values in the areas to be affected by the construction of either reservoir, we apply these coefficients to residential real estate in Lee and Martin counties. The following types of residential real estate are considered: single family residential; condominiums; vacant residential (including undeveloped); multi-family dwellings like cooperatives, apartments, etc.; and mobile homes. The property designated as waterfront in Lee County is identified in the Lee County Tax Roll. The waterfront property distinctions affected by Lake Okeechobee discharges include those identified as located on the Gulf, Bay, Canal, River, or Creek.[12] The property designated as waterfront in Martin County is identified in the Martin County Tax Roll. The waterfront property distinctions affected by Lake Okeechobee discharges are listed in Table C1. Geographic information system (GIS) maps available through each county's property appraiser were used to measure distance from waterfront property to adjacent properties. The valuations used are the preliminary property tax rolls for 2016 for Lee and Martin Counties as of July 2016. Individual parcel value for each property in each county was measured by the appraiser's *just* value.[13] [14]

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[9] We used the term "estuary waterfront" to distinguish waterfront property that will be directly affected by reductions in discharges, as opposed to property on inland lakes.

[10] Florida Realtors (2015), "The Impact of Water Quality on Florida's Home Values," Florida Realtors: The Voice for Real Estate in Florida pp. 1-60.

[11] Using less exhaustive data than the proprietary information available to Florida Realtors, we have replicated their results but with less statistical precision. In particular, their analysis only uses single family housing, but we get similar results using all forms of residential parcels including undeveloped residential property. They and others (see Appendix B for references) find that Secchi disk measures of water quality are most informative of consumer preference. Note that the idea underlying the Florida Realtors estimates and our replication of them is that property 1/8 mile from the waterfront, or ¼ mile, or ½ mile, etc., is a substitute for property on the water, so if waterfront property becomes more valuable, so does property near but not on the water. This is the maintained hypothesis and statistically supported in the analysis.

[12] Hydrologists at the Everglades Foundation opined that since the tributaries of the Caloosahatchee and St. Lucie Rivere see the effects of Lake Okeechobee discharges these tributaries will be affected equally by discharge reduction.

[13] The amendment to Rule 12D-1.002(2), Florida Administrative Code, clarifies that just value and fair market value are legally synonymous as held by the Florida Supreme Court. The Florida Supreme Court has defined fair market value as: "The amount a purchaser willing but not obliged to buy, would pay to one willing but not obliged to sell."

[14] In some cases, the just value is lower than the last sales price. In alternative analyses, we used the last sales price, if "qualifying," and where the property was not subdivided after the sale. This increases the value estimates overall by about 10% for Lee County.
The law requires the Lee County Property Appraiser's Office to review every property transfer transaction and either qualify or disqualify it for use in setting values. Lee County Property Appraiser (2016). Frequently Asked Questions. Retrieved on 5 Oct 2016 from http://www.leepa.org/FAQ/FAQForm.aspx

Table 3 shows the total residential property values by parcel type and the increase in value that would result in Lee County from building the South Reservoir. Table 4 shows the same values for Martin County.

Table 3a shows the details of calculations that result in the values in Table 3. Table 3a represents calculations for Lee County single-family residential property separated by proximity to the affected waterfront. It shows the value and estimated increase in value that is expected from a reduction in lake water discharges by building the South Reservoir. In Table 3a, *Value Increase* is calculated by multiplying the value of property at each distance from the water by the adjusted coefficients in Table 2 relevant for property at each distance. The coefficients are adjusted for the 45% improvement in water quality along the Caloosahatchee expected to result from building the South Reservoir as shown in Table 1.[15]

The same calculations as shown in Table 3a are undertaken for both Lee and Martin Counties for each type of property. Only the calculations for Lee County are shown in detail for purpose of illustration. The values have been calculated for both the South Reservoir and the North Reservoir. Again, for the purpose of illustration, only the expected increase in value from the South Reservoir is shown in Tables 3, 3a, and 4.[16]

Table 3: Expected Residential Property Value Increase Lee County, South Reservoir

Residential Property Types	Total Property Value	Value Increase
Single Family Residences	$ 36,074,318,981	$ 6,815,261,613
Condos	9,530,175,449	2,375,987,588
Vacant Residential	2,384,066,131	444,059,566
Multi-family	3,933,236,710	579,623,118
Mobile Homes	1,443,169,043	175,089,158
Totals	**$ 53,364,966,314**	**$ 10,390,021,043**

Notes: Total Property Value is for properties within 4 miles of or directly on affected water. Value Increase is based on 35.3% increase in water quality as measured by Secchi disk depth and the real estate impact factors shown in Table 1. The value increases listed above are for Lee County only and the South Reservoir only.

Table 3a: Single Family Residences Value Increase Based on Proximity to Affected Waterfront Lee County, South Reservoir

Proximity to Affected Waterfront	Total Property Value	Value Increase
Caloosahatchee Estuary waterfront:	$ 17,500,476,709	$ 4,941,697,111
1/8 of a mile from the waterfront:	4,674,928,426	1,027,666,141
1/4 of a mile from the waterfront:	2,818,892,362	482,664,845
1/2 of a mile from the waterfront:	2,225,433,413	231,333,803
1 mile from the waterfront:	3,022,610,033	115,614,834
2 miles from the waterfront:	3,096,891,466	16,026,413
4 miles from the waterfront:	2,735,086,572	258,466
Totals	**$ 36,074,318,981**	**$ 6,815,261,613**

Notes: Value Increase is based on 35.3% increase in water quality as measured by Secchi disk and real estate impact factors shown in Table 1. The value increases listed above are for Lee County only and the South Reservoir only.

Table 4: Expected Residential Property Value Increase Martin County, South Reservoir

Residential Property Types	Total Property Value	Value Increase
Single Family Residences	$ 15,554,537,570	$ 1,826,012,549
Vacant Residential	457,092,260	62,226,621
Condos	1,739,980,490	388,591,960
Multi-family	426,884,640	58,342,641
Mobile Homes	152,742,210	6,478,857
Totals	**$ 18,331,237,170**	**$ 2,341,652,628**

Notes: Total property value on or within 4 miles of affected water. Increased Value based on 35.3% increase in water quality as measured by Secchi disk and the real estate impact factors shown in Table 1. The value increases listed above are for Martin County only and the South Reservoir only.

In Lee County, a considerable amount of inland waterfront property is not directly affected by discharges from Lake Okeechobee. However, it will be indirectly affected by improved

[15] The coefficients in Table 2 as reported by Florida Realtors (2015) are for an assumed 20% increase in water quality. So, for instance for the South Reservoir, the predicted increase in water quality is 45%, so the coefficients are increased in magnitude by the ratio of 45 to 20.

[16] All calculations available upon request.

water quality in the county because consumers often make the choice between different waterfront properties. Homes that are on golf courses or on inland lakes are properties that present a clear substitute for estuary waterfront properties in terms of consumer value. This argument is identically the same as asserting that property ¼ mile from the waterfront increases in value when the waterfront property increases in value, a proposition statistically supported in the Realtors' study.

To account for the relation in value between golf course and inland lake properties and the properties directly affected by discharges from Lake Okeechobee, a time-series regression model for sales data over the last 40 years is used. The full analysis is presented in Appendix D. The estimated relation factor between changes in value of these residential properties is 0.776. That is, whenever estuary waterfront property has gone up by 10% in a year, golf course and lake property has gone up by 7.76% in that year.

We did a similar analysis for commercial property such as supermarkets and shopping centers. This estimated relation factor is 0.655. That is, whenever estuary waterfront property has gone up 10% in a year, commercial property that can reasonably be expected to serve residential consumers has gone up 6.55% in that year.

Table 5 shows the total value of commercial, lake, and golf course property in Lee County related to waterfront property and the increase in the value of these properties that will occur due to an increase in the value of waterfront property because of improved water quality. Table 5 also shows similar analysis for Martin County. (The Martin County tax roll does not indicate when a property is located on lake front or golf course, so we only estimate the value increase for commercial property.) The estimated relationship between value changes in estuary waterfront property and changes in commercial property value is somewhat higher in Martin County compared to Lee. Regressions for Martin County are shown in Appendix E.[17]

Table 5:
Effects on Related Properties – South Reservoir

Types	Total Property Value	Factor 1	Factor 2	Value Increase
Lee County				
Golf Course & Lake Front	$ 22,306,962,395	0.776	0.282	$4,889,228,307
Commercial	5,692,580,438	0.655	0.282	1,052,553,284
Martin County Commercial	1,350,579,076	1.894	0.224	571,986,159
Totals				**$6,513,767,750**

Notes: Factor 1 is the time-series regression relation between Related Property and Estuary Waterfront Property (see Appendices D and E). Factor 2 is the increase in Estuary Waterfront Property value due to increased water quality. It is the ratio between Value Increases and Total Property Value for waterfront property shown in Table 3a. The value increases listed above are for the South Reservoir only. Rounding error may affect calculations.

[17] The regressions, shown in Appendices D and E, are qualifying property sales averaged by zip code and year. Qualifying sales are arms-length sales where the appraiser concludes that the sale price correctly indicates the value of the parcel. The Lee County Tax Roll for the current year shows the last 4 parcel sales; Martin County tax roll shows the last three. We took the first difference of average sale prices across years to account for autocorrelation. Factor 1 in Table 4 is the regression coefficient on estuary waterfront property as it affects these related properties.

The *Value Increase* totals from Tables 3, 4 and 5 are the total real estate property value increase due to reduced discharges from Lake Okeechobee that would result from the South Reservoir. It totals to $19.2 billion. We do exactly the same analysis for the North Reservoir. The totals for the two alternative reservoirs are shown in Table 6. The benefits from the North Reservoir are substantially smaller; they total $1.3 billion in increased real estate value. The benefits from the two alternative reservoirs differ because of their different hydrological effects.

The South Reservoir is predicted by hydrologists to mitigate discharges into the rivers much more than will the North Reservoir.

Table 6: Total Increases in Real Estate Value

	South Reservoir	North Reservoir
Lee Co Commercial	$1,052,553,284	$74,848,234
Lee Co Residential - Golf & Lake Front	4,889,228,307	347,678,457
Lee Co Residential - near/affected by Caloosahatchee	10,390,021,043	738,845,941
Martin Co Commercial	571,986,159	21,550,499
Martin Co Residential - near/affected by St. Lucie River	2,341,652,628	88,225,531
Total Real Estate Value Increases	**$19,245,441,421**	**$1,271,148,661**

Value of the Water Captured by the Reservoirs

The South and North Reservoirs, will capture a lot of water that is now harmfully wasted. Not only will the reservoirs improve the ecology of the rivers where this water would otherwise be dumped, but the reservoirs will also capture this valuable resource for use in productive ways. We know from hydrological simulations how much water will be saved. Here, we put a value on this salvaged water by valuing its use as potable water to residential consumers.

There are a lot of ways that this salvaged water might be valuably used. It could be used in agricultural irrigation or supplied to industrial users. It could be sent to the Everglades to enhance ecological conditions there. It could be used to supply potable water to residential and commercial customers. Probably the highest valued use would be restoring ecological balance in the Everglades. However, measuring this effect and accurately valuing the outcome is difficult. Less difficult is measuring the value of potable water that could be provided to residential consumers.

While we value the water based on its use as potable water for homes and businesses, that does not mean that this is the way it will be used if the reservoirs are built. Determining how the captured water will be used is a decision that will be made based on political considerations. Therefore, the water will be used in the way that provides the highest value politically, which may or may not be the same way that produces the highest value economically. Whether or not the water ever flows into a kitchen sink, the water in its potable use is a way to measure its value, and it is the value measured here.

In assigning a value to water, one has to know the expected use. The hydrologists did not investigate how to optimally allocate the water generated by the reservoirs. For the purposes of this investigation, it would seem that the highest value for the water generated by a reservoir would be if the water were designated for water supply for Palm Beach, Broward and Miami-Dade counties. It also is true that additional water supply is needed; Broward County states in its 2015 annual report that raw water supply is a serious problem. The report notes that they are hoping to partner to build reservoirs to create input water supply and that it may be necessary to tap into brackish ground water that will require desalination.[18] Moreover, as the water could be allocated using the existing infrastructure and the decision on water allocation belongs to the state of Florida, the water in these reservoirs is theoretically available for water supply. Based on this, we conclude that desalination of brackish groundwater is the opportunity cost of the water supply that can be created by the South and North Reservoirs.

There are several ways to measure desalination cost. One method measures observed desalination cost for existing plants in the U.S. and around the world. A second measures the differential costs between water systems in Florida that do and do not face brackish groundwater. The first method gives an estimate of $2 per 1000 gallons [$/kgal]. The second, $1.43/kgal. Details of these estimates are given in Appendix F.

To tally up the benefits of the water captured by the reservoirs we need to know how much water would be made available for potable purposes. Again, the function of the reservoirs is to take water out of Lake Okeechobee (or preventing water from reaching it) when the lake is excessively high and instead of dumping it into the rivers, holding it until it becomes valuable. Hydrologists model flows into the reservoirs and can estimate how much of this water would be usefully transferred from wet times to dry times. The South Reservoir is estimated to generate 11,370,000 kgal per year on average. The North Reservoir is estimated to generate 6,253,000 kgal per year on average. These are gallons of water potentially available at the wellheads of water districts. That is, these numbers are based on water released from the reservoirs into canals that then could find its way into the aquifers that are tapped by potable water suppliers.

Note that the South Reservoir will also supply water into the Everglades and this will have value. Environmentally beneficial water could occur in either a wet period or a dry period. Since there is no current way to separate water delivered in wet periods

[18] "The County CIP for the Utility includes provisions to construct reverse osmosis facilities to desalinate water from the Upper Floridan Aquifer to meet projected future potable water demands. The County, Palm Beach County, several municipalities, and the SFWMD are also evaluating the economic and environmental benefit of a regional water storage reservoir project located in Palm Beach County known as the C-51 Reservoir Project." Broward County Water and Wastewater Annual Report, 2015, p. 27.

and dry periods, we simply recognize that it has value, but do not attempt to quantify. We hope to measure this in future research.

The annual value of the flow is shown in Table 7 for both reservoirs. We value the flow at the historically observed average cost of desalination, $2/kgal, and at the average forecast rate differential between the high salinity counties and the rest of Florida, $1.43/kgal.

Table 7: Value of Flow of Water			
		South	North
Flow		11,370	6,253
Value of Flow			
@$/kgal	$ 1.43	$16,528,000	$9,089,000
	$ 2.00	$22,740,000	$12,505,000
Note: Flow in millions of gallons per year.			

The present discounted value [PDV] of this annual flow of benefits depends on the life of the project and the discount rate. We set the life of the project at 50 years. It remains to choose the discount rate.

We varied the discount rate used in our calculations to show the impact of different choices.[19] We use nominal rates of 1.66%, 2.625%, and 3.125%. Details of these alternative rates are given in Appendix F. Based on a forecast inflation rate of 1.66%, which is derived from the yield on inflation protected bonds, the nominal rates imply real discount rates of zero, 0.97%, and 1.47%, respectively. Nominal discount rates include the expected inflation rate. The nominal rate essentially says that a dollar next year is not worth as much as a dollar today because prices will go up due to inflation. However, this means that the value of water will also go up. So if we discount using the nominal rate, we have to increase the value of the water at the inflation rate as well. A mathematically equivalent calculation is to subtract the inflation rate from the nominal rate, call it the real rate, and use that for discounting.

The calculated PDVs of the reservoir water are shown in Table 8. The value of all the water in the South Reservoir is between $826 million and $1.14 billion discounting at the inflation rate. Using the government mandated rate of 3.125%, it varies between $583 and $802 million. The average over all these calculations is $817 million. Similarly, the overall average value of the water in the North Reservoir is $449 million.

Table 8: Present Discounted Value of Water Captured by South and North Reservoirs ($1000s)		
Nominal Discount Rate	Valuing Water at $1.43/kgal	
	South	North
1.660%	$826,393	$454,454
2.625%	$653,120	$359,167
3.125%	$582,969	$320,589
Average	$687,494	$378,070
Nominal Discount Rate	Valuing Water at $2/kgal	
	South	North
1.660%	$1,136,986	$625,256
2.625%	$898,589	$494,156
3.125%	$802,072	$441,079
Average	$945,882	$520,164
Notes: Calculations based on 50 years and real discount rates, i.e., the nominal rates listed minus the expected inflation rate, 1.66%.		

[19] Note that there is no discount applied to the increased value of real estate due to the reservoirs. Real estate is a capital asset. Its price is already a present discounted value.

Costs

The South Reservoir is estimated to cost approximately $2.47 billion. This cost was estimated by engineers using the same methodology employed by the U.S. Army Corps of Engineers. The total estimated cost includes land cost and other expenses related to building the reservoir, such as infrastructure development. The total cost per acre-foot is estimated at $6,869.79, and applying this cost to the proposed acre-footage of 360,000 acre-feet results in the estimated costs of $2.47 billion.[20]

The cost of the North Reservoir is taken from six projects analyzed by the U.S. Army Corps of Engineers and the South Florida Water Management District.[21] These projects range in size from 155,000 to 321,000 acre feet, with costs proportionally ranging from $896,000 to $1,802,000. Thus, a 200,000 acre-foot reservoir is estimated from these alternative projects to be $1.1 billion.[22]

Benefits Compared to Costs

Now we compare the increased real estate value and the value of the water to the cost of building the reservoirs. This is shown in Table 9. The cost of building the South Reservoir is estimated to be $2.47 billion and is estimated to generate $20 billion in benefits comprised of increased real estate value of $19 billion and water value of $817 million. This says that there would be a surplus of $17.6 billion from building the South Reservoir. This surplus is commonly characterized by the ratio of the benefits to costs. The benefit-cost ratio for the South Reservoir is 8.1.[23]

The benefit-cost ratio for the North Reservoir is substantially smaller; it is 1.5. Benefits are estimated to be greater than the costs by $596 million.

Table 9: Benefits, Costs, Surplus, and Benefit-Cost Ratios

	South Reservoir	North Reservoir
Real Estate Value Increases	$19,245,441,421	$1,271,148,661
Water Value	$ 816,688,000	$ 449,117,000
Reservoir Costs	$2,473,123,842	$1,124,423,881
Surplus (Benefits minus Costs)	$17,589,005,579	$595,841,781
Benefit-Cost Ratio	**8.1**	**1.5**

Jobs

The effect of the reservoirs will be to create jobs. They will create jobs in the actual construction of the reservoirs and in spillover effect from increased real estate values that we have discussed above. We present a detailed analysis of the jobs impact in a separate document. Here we simply note the job creation from the actual reservoir construction based on U.S. Army Corps of Engineer methodology.[24]

Table 10: Jobs Related to Increased Water Quality

Jobs per Million Dollars of Construction Activity based on Estimates by:		
	U.S. Army Corps of Engineers	19.974
Jobs Created by Everglades restoration		
	Reservoir Construction Cost	**Jobs**
South Reservoir	$1,963,220,682	39,213
North Reservoir	$1,124,423,881	22,459
Notes: The Corps of Engineers methodology for job creation includes direct construction jobs, indirect construction jobs, and jobs created from the economic impact of construction. Construction cost does not include land cost.		

[20] See: Thomas Van Lent & Rajendra Paudel, "A Comparison of the Benefits of Northern & Southern Everglades Storage" October 26, 2016, The Everglades Foundation, http://www.evergladesfoundation.org/2016/10/26/a-comparison-of-the-benefits-of-northern-and-southern-everglades-storage/; and Ardeshir Tehrani & Emmanuel Cruz, "Preliminary Engineering Report Design and Cost Analysis of the Comprehensive Everglades restoration Plan Southern Reservoir," Prepared for: The Everglades Foundation, July 2016.

[21] U.S. Army Corps of Engineers and South Florida Water Management District, "Lake Okeechobee Watershed Restoration, Initial Array of Alternatives Overview" October 25, 2016. No supplemental information on how these costs were developed is available.

[22] These estimates do not include the cost of land, as the South Florida Water Management District states they intended to construct on publicly-owned lands. However, in the Corps' cost estimation, even publicly-owned lands would have to be included in the cost.

[23] Note that if land cost for the South Reservoir were to double, the benefit/cost ratio would still be 6.7 with a surplus value of $17 billion.

[24] The estimate of jobs per million dollars of construction activity comes from McCormick (2010) citing a Corps of Engineer study. Robert E. McCormick, (2010) "Measuring the Economic Benefits of America's Everglades restoration: An Economic Evaluation of Ecosystem Services Affiliated with the World's Largest Ecosystem Restoration Project," www.everglades.org.

Discussion of Methodology

The results that we have presented are built on the basic hydrology of the proposed reservoirs. There seems to be little doubt that discharges from Lake Okeechobee cause degradation of the water quality down the St. Lucie River and the Caloosahatchee. Scientific research directly links pollution like phosphorus load to degraded water quality. We search for and find a direct statistical link between Lake Okeechobee releases and lower water quality measured by Secchi disk depth. From this, we translate the reduction in discharges predicted as a result of the reservoirs into water quality improvements.

The next step in our logic is that increased water quality increases residential real estate values. Our analysis is based on the idea that if water quality increases, the value of property on the water increases. And if the value of property on the water increases, the value of property across the street increases also, as does the property a block away, and two blocks away, and so forth. Arguably, the effect diminishes the further away from the water the property is located, and this is what has been found empirically. Colloquially, we say a rising tide raises all boats. The idea is that these properties are substitutes, so an effect that raises the value of one, raises the value of the other.

The basis of the argument is the same as saying that a new YMCA center will increase the value of all homes in a neighborhood, or a new metro stop will increase the value of homes within walking distance. Of course, the magnitude (and empirical significance) of these effects may vary, but the logic is the same.

Using this same principle, we identify properties that are specifically substitutes for estuary waterfront but are not necessary proximate. We posit that homes on golf courses and inland lakes are such properties; we statistically investigate and find this hypothesis to be consistent with the evidence. We also argue that some commercial properties like grocery stores and shopping malls are directly related in value to the value of residential property nearby, and we also test this hypothesis statistically and find support for it.

Again the argument for golf course, inland lake, and commercial property is the same as the argument that property across the street from estuary waterfront property increases as water quality increases. Many others have estimated the latter, and we use the estimates of the Florida Realtors in our analysis, but for the particular substitutes of golf course, inland lake, and commercial property, we do our own estimation which yields statistically and economically meaningful results.

To forecast increases in real estate values, we use percentage changes. We express improved water quality in percentage terms in Table 1. The Florida Realtors analysis is expressed in percentage changes in Table 2. We multiply these factors and then multiply the resulting product by current property values. This gives the dollar increase in waterfront and near waterfront property value increases.

Summary of Findings

- The proposed South Reservoir has an overall benefit-cost ratio of **8.1**.
- The total benefits are **$19.25 billion** in the increased value of real estate due to improved water quality along the Caloosahatchee and St. Lucie River, and **$817 million** in the value of the water collected in the reservoir.
- The proposed North Reservoir has a benefit-cost ratio of **1.5**.
- The total benefits are **$1.27 billion** in the increased value of real estate due to improved water quality and **$449 million** in the value of the water collected in the reservoir.

Conclusions

These benefit-cost findings speak loudly. The South Reservoir is clearly a project with benefits vastly outweighing costs. The total benefits are estimated to be over $20 billion. At a construction cost of $2.47 billion, the South Reservoir is a no-brainer.

We speak so strongly because the fundamental structure of the analysis is sound. Nutrient-laden water that builds up in Lake Okeechobee is currently being dumped down rivers into the Atlantic Ocean and Gulf of Mexico causing algae blooms that ruin water quality as well as create malodorous effects for residents. Hard evidence has been amassed that people are willing to pay for clean water and less stink where they live. Hydrological studies and our own estimates show how much cleaner the water will be if excess water from Lake Okeechobee is not dumped down the rivers to the seas. Simple, straightforward, and technically sound calculations say the South Reservoir will increase the value of existing real estate in Lee and Martin Counties by more than $19 billion, not to mention the value of the water that is currently, harmfully wasted.

On the other hand, the North Reservoir is not as good of an investment economically speaking. Based on our estimates, the benefit-cost ratio is greater than one but cost increases (such as including land costs) could easily flip this. And, at all events, the North Reservoir's benefits pale in comparison to the South Reservoir. The hydrologic modeling of the North Reservoir shows that it eliminates Lake Okeechobee regulatory releases far less often than the South Reservoir.[25] The North Reservoir also captures less water. Hence, comparing the two proposed projects on a cost-benefit basis, the South Reservoir project dominates.

Comparing the benefit-cost ratio of South Reservoir to that of the North Reservoir is simple and direct, as the numbers show. The longer the project is put off, the more it will cost to build. We conclude the best option is to build the South Reservoir, and the sooner the better.

[25] See Table A2, Zero Flow.

Appendix A

The Effect of Water Discharges from Lake Okeechobee on Secchi Disk Depth Measures of Water Quality

Our empirical analysis of how water quality affects the value of Florida real estate uses Secchi disk depth (SDD) as the measure of water quality. SDD has proven to be the most robust link between consumers' appreciation of water quality and the water's underlying composition. (See Appendix B below.)

Hydrologists at the Everglades Foundation have provided us with predictions about how each proposed reservoir will affect water discharges into the Caloosahatchee and the St. Lucie River, relative to a baseline in which neither reservoir is built.[26] To assess each reservoir's impact on real estate values, we therefore must translate the predicted changes in discharges into predicted changes in SDD.

The relationship between water quality and discharges from the baseline revolves around the causal relationship between total phosphorus (TP) and chlorophyll (Chl) in the waterway, and the effects of these two on SDD. In an early examination of these underlying factors, Carlson (1977) estimates the following relationships:

$$\ln SDD = 2.04 - 0.68 \ln Chl \qquad \text{(equation 5, p. 364)}$$
$$\ln Chl = 1.449 \ln TP - 2.442 \qquad \text{(equation 7, p. 365)}$$
$$\ln SDD = 3.876 - 0.98 \ln TP \qquad \text{(equation 9, p. 365)}$$

The final equation indicates that SDD varies almost one-to-one with the water's phosphorus content. For example, a 10% reduction in total phosphorus corresponds to a 9.8% increase in SDD.

Carlson analyzed lakes. Concern that lakes differ from rivers and estuaries prompted similar research on other types of waterways. Hoyer, et al. (2002) compare the relationship between phosphorus and water quality measured by SDD in nearshore coastal waters on the west coast of the Florida peninsula.[27] Hence, their scientific analysis addresses precisely the issues and locale with which we are concerned.

Hoyer, et al., (2002) find that chlorophyll in the water has somewhat less effect on SDD measures of water quality in nearshore coastal waters compared to the estimated relationship in lakes. They report the following relationship in their Table 2 (p. 1027):

$$\log10\ SDD = 1.04 - 0.59 \log10\ TP$$

This says that a 10% reduction in phosphorus will result in a 5.9% increase in Secchi disk depth.

This published research shows that pollution in the form of phosphorus, reduces water quality as measured by SDD. We know that Lake Okeechobee releases contain high volumes of phosphorus. We must link Lake Okeechobee discharges into SDD measurements.

To do this, we use actual discharges from the lake and correlate these with observed SDD readings at the time of the releases. Daily discharge data are obtained from South Florida Water Management District's environmental database, DBHYDRO.[28] The weekly measured SDD data for the St. Lucie River is provided by Florida Oceanographic Society. Similarly, SDD data for the Caloosahatchee River is obtained from Florida Department of Environmental Protection's STORET database.[29] We have actual monthly discharges over the last 30 years. However, we only have SDD readings since 2009. We regress SDD on discharges from Lake Okeechobee separately for each river. We use a log transformation for SDD and for discharges. We use a linear specification. The summary statistics for these variables and the regression results are shown in Table A1. We use these regression results to predict SDD levels for the Everglades restoration simulations.

[26] See: Thomas Van Lent & Rajendra Paudel, "A Comparison of the Benefits of Northern & Southern Everglades Storage" October 26, 2016, The Everglades Foundation, http://www.evergladesfoundation.org/2016/10/26/a-comparison-of-the-benefits-of-northern-and-southern-everglades-storage/.

[27] See also, Garn, Herbert S., Rovertson, Dale M., Rose, William, J., & Saad, David A. (2010). Hydrology, Water Quality, and Response to Changes in Phosphorous Loading of Minocqua and Kawaguesaga Lakes, Oneida County, Wisconsin, With Special Emphasis on Effects of Urbanization. U.S. Geological Survey & U.S. Department of the Interior. Scientific Investigations Report 2010-5196.

[28] https://www.sfwmd.gov/science-data/dbhydro. Assessed on January 26, 2017

[29] http://prodenv.dep.state.fl.us/DearSpa. Assessed on January 26, 2017

Table A1: Regressions of River SDD Readings on Actual Lake Okeechobee Discharges		
Regressions		
	Caloosahatchee	**St. Lucie River**
Intercept	1.385	0.728
t-stat	5.77	2.91
Log Discharge	-0.099	-0.145
t-stat	-3.99	-4.91
R-sq	0.155	0.267
Obs	89	68
Sample Summary Statistics		
	Caloosahatchee	**St. Lucie River**
Log Secchi Disk Depth		
Mean	0.407	-0.443
Std Dev	0.438	0.429
Min	-0.693	-1.526
Max	1.253	0.811
Obs	102	93
Log Discharges		
Mean	8.712	8.417
Std Dev	2.007	1.695
Min	1.526	3.434
Max	12.462	12.322
Obs	500	373

Notes: SDD readings are not always available. Caloosahatchee SDD are taken from monitoring station CALUSA0012FTM from FDEP's STORET database. St. Lucie River SDD taken from monitoring station located at South Fork. Discharges are monthly totals.

The simulations predict flows from the lake into the rivers for three separate cases. The first is called the Existing Conditions Baseline (ECB). This is how much discharge would occur if nothing is done. The next is the amount of discharge into the Caloosahatchee and into the St. Lucie River if the North Reservoir is constructed. The third is the amount of discharge into the Caloosahatchee and into the St. Lucie River if the South Reservoir is constructed.

The regulatory discharges measured by the simulation model are defined by the model as harmful discharges. Much of the time the simulation model predicts zero flows. For instance, for the ECB discharges into the Caloosahatchee, discharges of zero are predicted over 50% of the time. This does not mean that there is no discharge half the time. It means that there is no harmful discharge half the time.

To measure the impact of an Everglades restoration project, we compare the regulatory discharges with a reservoir to the regulatory discharges in the baseline. The scenarios are described by the following 2x2 chart.

Impact of an Everglades Restoration Project		
	ECB River Discharge Positive	**ECB River Discharge Zero**
River Discharge with Reservoir Positive	(a)	(c)
River Discharge with Reservoir Zero	(b)	(d)

Panel (d) identifies the case where there are no discharges in the baseline and none with a reservoir. This is the most frequently occurring case. No harmful discharges happen either with or without the reservoir.

Panels (a) & (b) are the cases where Everglades restoration is having a positive impact. In panel (a) there would be river discharges from the lake without a reservoir and there are still discharges with a reservoir, but they are smaller. Panel (b) identifies the case where the reservoir completely eliminates the discharge that would have occurred. Panel (c) is an anomaly. This occurs when the model predicts that there would have been no discharge in the baseline but there is a discharge with a reservoir. While an anomaly, it does show the sophistication of the simulation model.

To estimate the impact of the Everglades restoration projects on water quality, we line up the data in the simulations by months. That is, for each month in the simulation we have the baseline discharge and the discharge with a reservoir. This is done for each reservoir separately and separately for each river. We then forecast the SDD measure, in logs, for the baseline discharge and for the discharge with a reservoir. For each month, we take the difference in the forecast logs. This is a percentage change in SDD predicted by the model due to the existence of a reservoir. We average these log differences across the months. This gives our predicted percentage improvement in SDD from the reservoir. When the predicted discharge is zero, we set the log discharge to zero. When the predicted SDD is deeper than the maximum observed, we restrict it to the maximum observed.

The results of this exercise are shown in Table A2. The first thing to notice in Table A2 is that the ECB discharge levels are different for each reservoir for each river. This is because we delete observations when there is no harmful discharge predicted.

Ultimately there are four values of interest. These are the Avg Difference in Log SDD, which is the percentage improvement in water quality as measured by SDD, for the Caloosahatchee and St. Lucie River, for the South Reservoir and for the North Reservoir. These values shown in Table A2 are {0.45, 0.637, 0.032, 0.024} respectively.

Table A2: Comparison of River Discharges with and without Reservoirs		
Caloosahatchee		
(n=130)	**ECB**	**North Reservoir**
Avg Monthly Flow	54,458.42	51,132.67
Difference in Log Flow		-0.272
Flow Zero (% of time)		0.053
Avg Log SDD	0.344	0.376
Difference in Log SDD		0.032
Caloosahatchee		
(n=126)	**ECB**	**South Reservoir**
Avg Monthly Flow	56,187.22	30,715.61
Difference in Log Flow		-5.023
Flow Zero (% of time)		0.484
Avg Log SDD	0.315	0.765
Difference in Log SDD		0.450
St. Lucie River		
(n=131)	**ECB**	**North Reservoir**
Avg Monthly Flow	20,752.18	19,441.59
Difference in Log Flow		-0.165
Flow Zero (% of time)		0.053
Avg Log SDD	-0.598	-0.574
Difference in Log SDD		0.024
St. Lucie River		
(n=126)	**ECB**	**South Reservoir**
Avg Monthly Flow	21,576.63	11,094.56
Difference in Log Flow		-4.388
Flow Zero (% of time)		0.460
Avg Log SDD	-0.65	0.013
Difference in Log SDD		0.637

Notes: ECB is exiting conditions baseline. Observations only include months where ECB discharges and river discharges with a reservoir in place are not both zero. SDD is the predicted value from the regressions in Table 1. Difference in Log SDD is the percentage improvement in water quality that we use to predict real estate value increases. The unit of measure for Avg Monthly Flow is CFS.

The South Reservoir shows clear hydrological superiority in improving water quality. This has already been reported by hydrologists.[30] They reported (among other things) the simple ratio of the Avg Monthly Flows and the discharges with a reservoir, which can be calculated from Table A2. Alternatively, we look at the data on a month-by-month basis because this is the way we map the data into SDD measures. On a month-by-month basis, the average difference in the log of discharges is -5 for the Caloosahatchee and -4.4 for the St. Lucie as a result of the South Reservoir compared to 0. 27 and -0.16, respectively, for the North Reservoir. Looking month by month exaggerates the difference between the two reservoirs because the South Reservoir has the effect of reducing the predicted ECB discharge to zero in many more months than the North Reservoir. This statistic is shown in Table 2. The South Reservoir completely eliminates harmful discharges nearly 50% of the time for both rivers while the North Reservoir only produces this result around 5% of the time. Big discharges do the most damage to water quality and reducing them to zero has the most beneficial effect.

The water quality improvements for the two reservoirs and the two rivers that we use in our real estate value calculations are given in Table A3.

Table A3: Water Quality Improvements as a Result of Reservoirs		
Percent Increase in Secchi Disk Depth		
	Caloosahatchee	**St. Lucie River**
South Reservoir	45.0%	67.3%
North Reservoir	3.2%	2.4%

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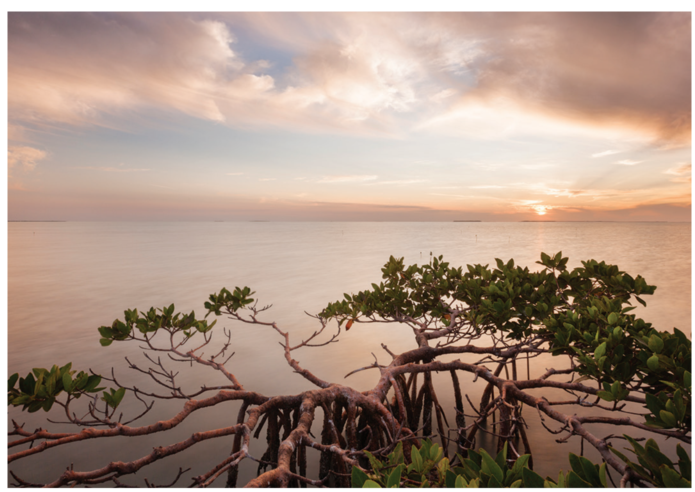

[30] Van Lent & Paudel (2016).

Appendix B

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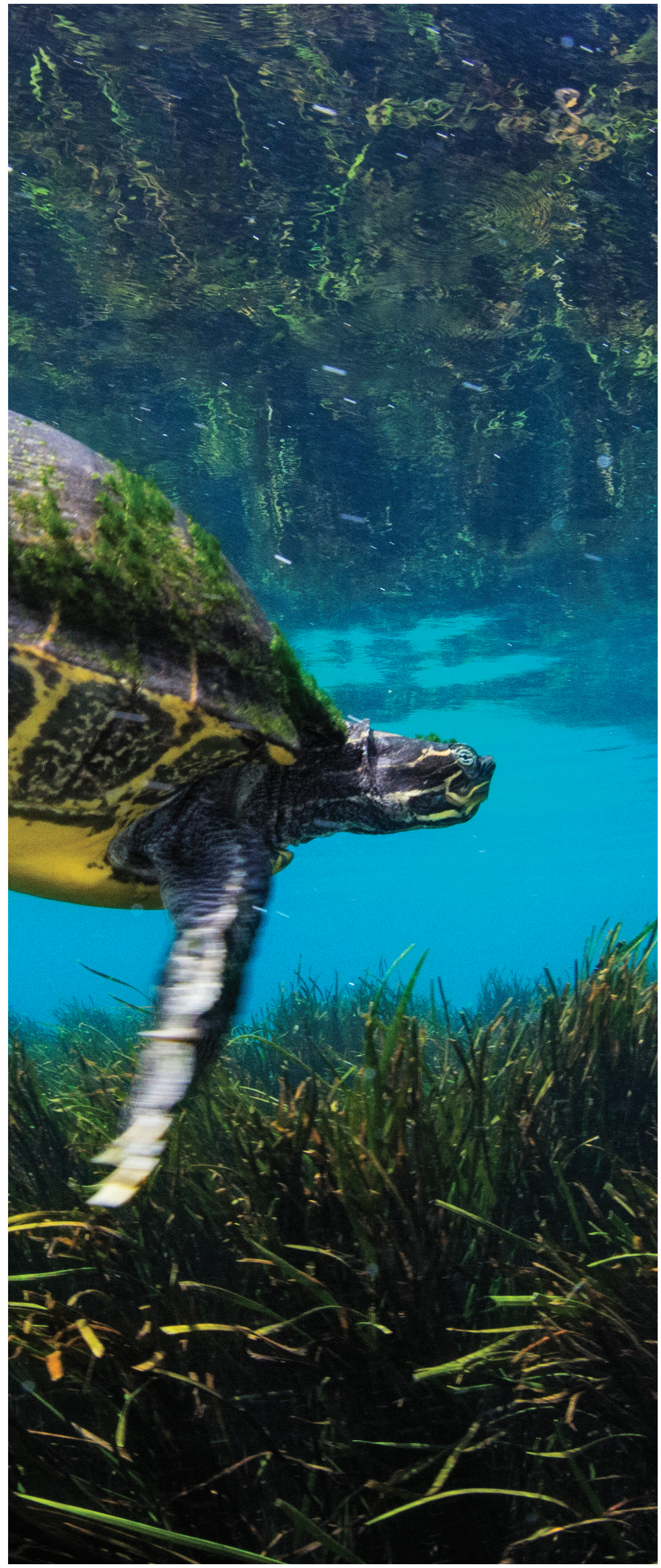
Appendix C

Martin County Property Designations

Table C1: Waterfront Property Designations in Martin County
Boatslip site
Canal frontage site
Beach access strip
Commercial – Waterfront
Dock site
Excess Indian River fronta
Excess St Lucie Rivr front
Indian River frontage site
Intracoastal Waterwy Front
Loxahatchee River frontage
Manatee Pocket frontage si
Marina Sites
Oceanfront Site
St. Lucie Inlet frontage s
St. Lucie River frontage s



Appendix D

Regressions of Changes in Other Property Values on Changes in Estuary Waterfront Values in Lee County

The regressions are based on qualifying property sales averaged by zip code and year. Qualifying sales are arms-length sales where the appraiser concludes that the sale price correctly indicates the value of the parcel. The Lee County Tax Roll for the current year shows the last 4 parcel sales. We took the first difference of zip-code average sale prices across years to account for autocorrelation. Factor 1 reported in the main text Table 4 is the regression *Coefficient* on waterfront property shown below.

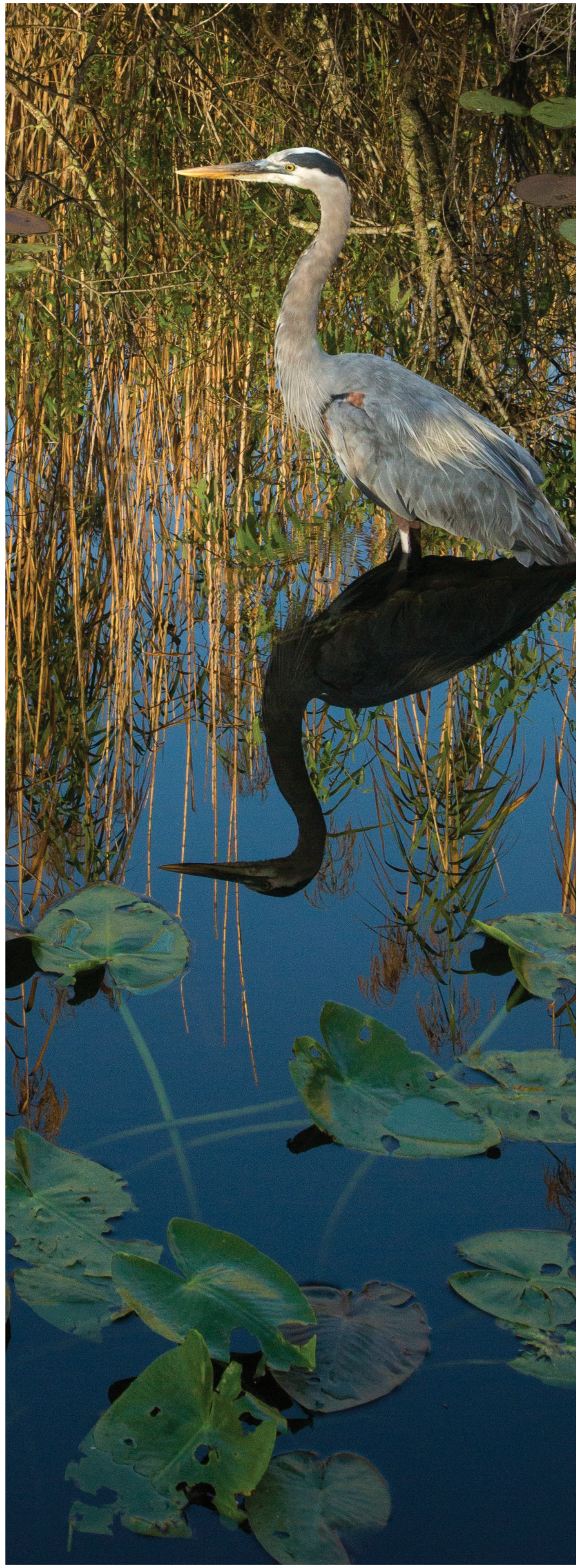
Table D1: Regressions of Change in Other Property Values based on Changes in Estuary Waterfront Property Values

Dependent Variable	Effect of Change in Estuary Waterfront Value		
Property Type:	**Intercept t-stat**	**Coefficient t-stat**	**R-sq *N***
Golf & Lakefront	0.266	0.776	0.362
	3.27	13.64	330
Commercial	0.102	0.655	0.208
	1.28	11.42	499
Notes: Variables are percent changes year to year in the average sales by zip code			

Table D2: Means of Variables used in Table D1

Variable	Mean	Std Dev	Min	Max
Golf and Lakes Property Regression				
Year	2001		1976	2016
Golf and Lakes	$ 891,380	$ 3,404,594	$ 4,700	$ 50,055,871
Estuary	$ 444,731	$ 997,712	$ 6,317	$ 13,004,118
Commercial Property Regression				
Year	1997		1973	2016
Golf and Lakes	$ 1,037,833	$ 2,626,559	$ 600	$ 41,000,000
Estuary	$ 405,206	$ 863,891	$ 3,225	$ 13,004,118

Table D3: Commercial Property Types Assumed to vary with Waterfront Property in Lee County
Commercial, Vacant
Convenience Store
Department Store
Golf Course
Home For The Aged, Alf
Hotel
Marina
Motel
Restaurant
Restaurant, Drive-In
Shopping Center, Communit
Shopping Center, Neighbor
Shopping Center, Regional
Store, One (1) Floor
Supermarket



Appendix E

Regressions of Martin County Commercial Property Valuation Changes on Changes in Estuary Waterfront Values

The regressions are based on qualifying property sales averaged by zip code and year. Qualifying sales are arms-length sales where the appraiser concludes that the sale price correctly indicates the value of the parcel. The Martin County Tax Roll for the current year shows the last 3 parcel sales. We took the first difference of sale prices, averaged by zip code, across years to account for autocorrelation. Factor 1 reported in Table 4 is the regression *Coefficient* on waterfront property shown below.

Table E1: Change in Value of Commercial Property based on Change in Waterfront Property in Martin County 1972 through 2016			
Dependent Variable: Change in Commercial Property Value	**Effect of Change in Estuary Waterfront Property Value**		
Sample	**Intercept t-stat**	**Coefficient t-stat**	**R-sq *N***
All observations	1.37	4.30	0.092
	1.85	4.33	177
Commercial Obs > 2; Residential Obs >10	0.75	1.89	0.042
	3.34	2.05	99
Notes: Percentage change by year in commercial and waterfront residential property values averaged by zip code.			

The estimated coefficient between waterfront property and commercial property values is sensitive to one or two observations when all observations are used. Hence, we re-estimated using only observations where the change between years within a zip code was based on an average of more than two commercial property sales and more than ten residential property sales. This lowered the estimated coefficient somewhat, and this lower value is what we show in Table 4 in the main text.

Table E2: Summary Statistics on Martin County Commercial Property Analysis				
Variable	**Mean**	**Std Dev**	**Min**	**Max**
Sales Year	**1998**		**1972**	**2016**
Commercial Property				
Average	$ 837,344	$ 1,272,455	$ 2,520	$ 9,525,840
Number of Parcels	4.0	3.2	1	16
Waterfront Residential				
Average	$ 222,205	$ 190,237	$ 13,805	$ 1,247,705
Number of Parcels	184.7	166.4	3	712
Percentage Change				
Commercial	2.12	10.06	-1.00	121.34
Residential	0.17	0.73	-0.82	6.47
Notes: Property value are averaged by zip code and sales year. Number of Parcels is the number of sales in a given zipcode and year. Values used are qualifying sale prices.				

Table E3: Commercial Property Types in Martin County	
Property Description	**Number in Sample**
Vacant Commercial	347
Stores (1 story)	243
Department Store	1
Community shopping center	115
Restaurant/cafeterias	54
Drive-in Restaurants	17
Golf Course/Driving Range	20
Hotels/Motels	27
Homes for the aged	9

Appendix F

Water Valuation

There are several ways to measure the cost of desalination. In broad terms we can look at the cost of desalination that has been observed for existing plants in the U.S. and around the world. A second method is to look at the differential cost, in Florida, between water systems facing brackish groundwater and those not.

Looking at historical experience one observer says: "A thousand gallons of freshwater from a desalination plant costs the average US consumer $2.50 to $5 […] compared to $2 for conventional freshwater."[31] Another says: "While there are many variables related to the cost of desalinated water, a good rule of thumb is $2–4 per 1,000 gallons for brackish water and $3–6 per 1,000 gallons for seawater desalination."[32] Yet another says, "Total production cost of water ranges from $1.09 to $2.40 per thousand gallons[.][33] The newest technology that is being exploited in Israel has a cost of $2.20/kgal for desalination of seawater, but it is not clear when this technology will made generally available and at what price.[34] Our own calculations of the cost of water from the mammoth Carlsbad plant in San Diego put the cost at $3 per 1000 gallons [$/kgal] for energy and capital only, which seems to be right in line with the seawater estimate cited above when maintenance is added in. Taken together, these data say desalination cost is around $2/kgal.

A second way to estimate the value of the water captured in the reservoirs is by looking at the experience of water systems in Florida that have clean input water supplies versus brackish ground water to deal with. The USGS records the various sources and uses of water around the country.[35] From their report for Florida counties, we calculate the percentage of groundwater used for public supply that is saline. Six counties have percentages in excess of 5%: Charlotte, Collier, Indian River, Lee, Martin, and St. Lucie. We compare the water rates charged customers in these counties to the rates for customers in the rest of the state. The rate data come from Faftelis Financial Consultants, 2012, Florida Water Rate Survey, that reports data for 177 water suppliers in the state.[36] The difference in water rates ($/kgal) is the value of clean water.

Table G1 shows the simple means of the water rates charged by suppliers in the state. The estimates are based on two measures of the price of water charged to residential consumers. The first is based on the household charge for 8000 gallons per month. The data report the "Monthly Bill @ 8000 Gallons." We divide this by 8 to get $/kgal. In the second measure is the same except for a monthly bill calculated for 4000 gallons. In the second measure we lose 4 observations because the minimum charge allows more than 4000 gallons of use per month, which makes the 4000 gallon bill an overstatement of the price per gallon. As expected, the high salinity counties do charge more.

To get the best measure of the differential in rates across the state we use linear regression where we can account for other factors such as the size of service population and other factors. These regressions are shown in Table G2. The regressions are the log of the water rate on a dummy variable for providers in the high salinity counties, the log of the service population, and county fixed effects. What we find is that water rates in the high salinity counties are, at the margin, between 79% and 82% higher than the rest of the state. These estimates are significant statistically. The regressions have a good fit. Service area population is negatively related to rates indicating economies of scale. The county fixed effects account for unobserved factors that vary within the county and they account for much of the goodness-of-fit in the model.[37]

Table G3 shows the range of the forecast rates across the state taken from our regressions.[38] The differential in the rates in the high salinity counties and the rest of the state is one measure of the value of the water from the reservoirs. It averages $1.43/kgal.

Table G1: Simple Means of Water Bills ($/kgal)

Counties	4000 gal/mo	8000 gal/mo
High Salinity Counties	$6.493	$5.004
Rest of State	5.012	3.919
Notes: 18 suppliers in high salinity counties, and 159 suppliers in the rest of the state.		

[31] http://www.pri.org/stories/2015-05-15/desalination-expensive-energy-hog-improvements-are-way

[32] http://www.texasdesal.com/about-us/desal-faqs/ downloaded, 10/31/2016.

[33] http://www.twdb.texas.gov/innovativewater/desal/doc/Cost_of_Desalination_in_Texas.pdf, downloaded, 10/31/2016

[34] https://www.technologyreview.com/s/534996/megascale-desalination/ downloaded, 10/31/2016

[35] Maupin, M.A., Kenny, J.F., Hutson, S.S., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2014, Estimated use of water in the United States in 2010: U.S. Geological Survey Circular 1405, 56 p., http://dx.doi.org/10.3133/cir1405.

[36] http://www.raftelis.com/static/images/2012-Florida-Water-Rate-Survey.pdf, downloaded, 10/31/2016.

[37] We tried other variables that characterize the billing structure such as impact fees and fixed charges, and these are significant in the absence of the fixed effects but are absorbed in the fixed effects when they are included.

[38] The logs to levels forecast mean is adjusted for the mean squared error (MSE).

Table G2: Regression of Household Rates across Water Suppliers with Dummy for Suppliers in High Salinity Counties				
	Dependent Variable: log($/kgal) based on:			
Independent Variables	4000 gal/mo		8000 gal/mo	
	Coefficient	stat. sig.	Coefficient	stat. sig.
Intercept	2.215	<.0001	1.838	<.0001
High Salinity {0.1}	0.818	0.0276	0.794	0.0394
log(Population)	-0.106	<.0001	-0.090	<.0001
County Fixed Effects	3.180	<.0001	3.250	<.0001
(F value)	0.605		0.585	
R-sq	0.087		0.095	
MSE	173		177	
Obs	1.564		1.312	
Notes: Mean of log(pop) is 10 with a s.d. of 1.66.				

Table G3: Forecast Water Bill from Regressions ($/kgal)		
Counties	4000 gal/mo	8000 gal/mo
High Salinity Counties	$6.522	$4.787
Rest of State	4.851	3.604
Difference	$1.671	$1.183

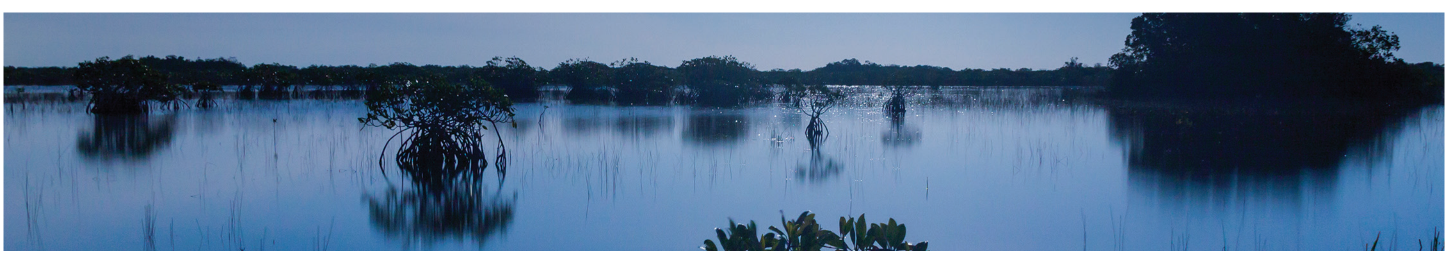
Choice of the Discount Rate

The discount rate reflects the fact that usually $1 today is worth more than $1 tomorrow, but this is not necessarily true. It may be that $1 today and $1 a year from now are identically valuable. Many economists argue exactly this, i.e., that the social rate of discount is zero. The argument is, we as a society imagine that we will live forever, as a society. Therefore, what we do today for those tomorrow is 1:1. This may be too strong a belief for many reasons, but the basic idea is sound. The social discount rate should be considered lower than the private or commercial discount rate.

On the other hand, public law identifies a discount rate to be used for water resource planning. For 2016, that rate is 3.125%.[39] The rate is based on a calculation using long term Treasury Bonds. The prescribed average of these gives a rate of 2.625%. However, public law mandates that the official discount rate cannot change by more than 0.25% between years.

Note that these rates are nominal rates as opposed to real rates. They include an estimate of inflation. Inflation also affects the value of the flow of benefits. For simplicity in calculations, most economists do not inflate the benefits but rather subtract the expected inflation rate from the assumed nominal interest rate to get a real rate. The expected inflation rate can be conveniently calculated by subtracting the yield on Treasury Inflation Protected Securities from the yield on identical Treasuries that are not inflation protected. The expected inflation rate at the end of October 2016 was 1.66%.

With these thoughts in mind, we varied the discount rate used in our calculations.[40] We use nominal rates of 1.66%, 2.625%, and 3.125%, which imply real discount rates of zero, 0.97%, and 1.47%.



[39] https://www.federalregister.gov/documents/2015/12/17/2015-31717/change-in-discount-rate-for-water-resources-planning, downloaded, 11/8/2016. "This rate has been computed in accordance with Section 80(a), Public Law 93-251 (88 Stat. 34), and 18 CFR 704.39, which: (1) Specify that the rate will be based upon the average yield during the preceding fiscal year on interest-bearing marketable securities of the United States which, at the time the computation is made, have terms of 15 years or more remaining to maturity (average yield is rounded to nearest one-eighth percent); and (2) provide that the rate will not be raised or lowered more than one-quarter of 1 percent for any year. The U.S. Department of the Treasury calculated the specified average to be 2.6511 percent. This rate, rounded to the nearest one-eighth percent, is 2.625 percent, which is a change of more than the allowable one-quarter of 1 percent. Therefore, the fiscal year 2016 rate is 3.125 percent."

[40] Discussions about the proper discount rate are complicated mathematically and philosophically heady. They can quickly lead to confusion if not frustration. This is why we present calculations using several different discount rates. These show the impact of the different choices. Also note that there is no discount applied to the increased value of real estate due to the reservoirs. Real estate is a capital asset. Its price is already a discounted present value.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