# Hazen *Memorandum*

December 5, 2024

To: Broward County

From: Hazen and Sawyer
McKinsey & Company

Project: Broward County Risk Assessment and Resilience Plan

**Subject: Task 5.2.5 Calculation of Risk Reduction Benefits -FINAL**

## Authorization

This memorandum is provided as the deliverable under "Task 5.2.5 Calculation of Risk Reduction Benefits" of the Agreement between Broward County and Hazen and Sawyer, PC for Consultant Services for a Countywide Risk Assessment and Resilience Plan. The memorandum was prepared primarily by McKinsey as a subconsultant to Hazen and Sawyer.

## 1. Results summary

This memorandum summarizes the benefits of conceptual adaptation suites for the Broward County Risk Assessment and Resilience Plan effort. The economic impacts under each suite were compared to the impacts from the baseline (no action) condition to understand how effective the adaptation suites would be in mitigating the economic losses from flooding.

The future flood projections for the baseline (no action) and the adaptation suites incorporate sea-level rise, in addition to expected rainfall and storm surge. The future sea-level rise conditions evaluated during this study are 2.0 feet assumed to be reached by 2050 and 3.3 feet assumed to be reached by 2070.

The key findings are as follows.

- **Flood damage to residential and productive assets would be avoided** and the avoided damage, as measured by the repair and replacement cost savings, will vary depending on the measures pursued. With 2 feet of sea-level rise, adaptation suites could yield average annual savings of $500 million (M) to $2.0 billion (B) which would mitigate from 20% to 80% of baseline damages, respectively.

  Under 3.3 feet of sea-level rise, the average annual savings ranges from $126M to $4.3B which mitigates from 3% to 88% of baseline damages. These savings would be realized throughout the county, are concentrated in coastal areas, and represent flood events triggered by the most extreme rainfall levels as well as the more frequent, less extreme rainfall levels.

- **Lost economic production from flooding would be avoided**. The economic benefit modeled here is the increased gross value added (GVA) from avoided direct flooding impacts to businesses and reduced disruption to roads. Both types of flood impacts reduce the sales of goods and services as businesses are forced to close or reduce operations and customers are unable to access these businesses.

Under 2 feet of sea-level rise, GVA is estimated to be from $81M to $186M higher under the adaptation suites relative to baseline. Under 3.3 feet of sea-level rise GVA is estimated to be $77M to $660M higher, depending on the adaptation suite.

Not fully included in this measure are all the benefits of protecting critical infrastructure because only the short term direct effects were assessed. For example, flooding at the County's port and airport could slow or prevent the movement of people and goods with corresponding negative impacts to the economy. The adaptation suites were found to reduce downtime by at least 50% in key locations of the Fort Lauderdale-Hollywood International Airport and by 25% to 30% at Port Everglades potentially resulting in significant economic benefits to County residents and businesses.

- **More homes would be able to maintain their flood insurance.** All adaptation suites are expected to increase the number of NFIP (flood insurance) policies under 2 feet and 3.3 feet of sea-level rise relative to baseline. Under 2 feet of sea-level rise, the number of policies would be at least 60% higher than under the baseline. Under 3.3 feet of sea-level rise, the number of policies would be at least 70% higher than under the baseline. Premiums would be comparable to what they are today.

  However, none of the adaptation suites would maintain the number of policies that are currently held. While total flood insurance coverage is expected to be significantly higher than baseline under all suites when sea-level rise is 2 feet or 3.3 feet, only the most expensive suites can come close to maintaining today's current coverage of $44B.

- **Property values would be higher than under the baseline.** Under 2 feet of sea-level rise, only about $8B of the $24B in lost residential property value can be recovered under the less expensive adaptation suites. If more investment is made to increase drainage or create large flood control structures, almost all the $24B reduction can be recovered. Under 3.3 feet of sea-level rise, only about $3B in lost residential property value can be recovered unless additional drainage or flood control investments are made. This greater level of investment is expected to recover $30B of the $40B in lost residential property value.

- **Protect the county's fiscal position**. The County, its municipalities, and government agencies rely on property tax revenue and production-related tax revenue to finance public goods and services. Under 2 feet of sea-level rise, average annual property tax revenue is estimated to be $200M to $700M higher than under baseline depending on the adaptation suite. Under 3.3 feet of sea-level rise, average annual property tax revenue is estimated to be $100M to $1.0B higher than under baseline, depending on the suite. The adaptation suites are expected to reduce average annual production tax losses by $8M to $21M under 2 feet of sea-level rise and by $6M to $62M under 3.3 feet of sea-level rise, depending on the adaptation suite.

- **Reduce the flood impacts in vulnerable areas** as presented in this memorandum.

Taken together, the estimated benefit values demonstrate that the adaptation suites would be expected to materially mitigate the economic impacts of flooding caused by sea-level rise. However, as sea-level rise increases to 3.3ft, only the most ambitious adaptation suites provide substantial economic benefits.

Other benefits were not quantitatively estimated during this study but are important considerations. They include the increased economic activity (GVA) generated from the following flood-related impacts.

a) Avoided disruption to public services
b) Avoided population exodus
c) Avoided reduction in tourism
d) Increased investment
e) Favorable human capital impacts

Human capital impacts include improved physical and mental health, greater household wealth, and better education opportunities. These unmeasured benefits should be considered in future research related to quantifying the benefits of adaptation strategies.

These findings are described in detail herein, with methodology information contained in the *Task 4.1 Economic Modeling Methodology and Data Sources* memorandum, dated December 20 2023.

## 2. Introduction

The first phase of economic modeling in preparation for the Broward County Risk Assessment and Resilience Plan focused on the socioeconomic impacts of flooding given anticipated sea-level rise, ***assuming that no additional actions would be taken to mitigate these impacts***.

To facilitate the economic feasibility assessment of the proposed Resilience Plan, ***the economic benefits of adaptation suites were quantitatively estimated by examining the extent to which the baseline socioeconomic impacts could be mitigated within the county***. Seven different unique combinations of adaptation strategies were explored – each representing a different 'suite' of measures introduced to manage the effects of flooding.

The valuation of economic benefits presented in this memorandum assumes there are no changes in the economy of Broward County – including no changes in land use, gross domestic product, employment, or population from current levels. The results are best interpreted as the socioeconomic impacts of flooding that would occur today if faced with the flood conditions expected in 2050 and 2070. ***All dollar values are in 2022 dollars.***

This assessment can inform strategic and developmental planning, prioritization and implementation of interventions, and serve as critical input to the preparation of financing proposals. The results may also be used to support communication with stakeholders, particularly the residential and business communities in Broward County.

**As outlined in the *Economic Modeling Methodology and Data Sources* memorandum, analysis of the effects of the adaptation measures focused on quantitative modeling of four socioeconomic impact areas**, including:

1. **Reducing short-term economic losses.** Adaptation measures could reduce transport disruption and damage to productive assets. This analysis quantifies the short-term reduction (e.g. less than 1 year) in direct impacts to business downtime, including the indirect impacts to the county's sales, income, employment and tax revenue.

2. **Reducing property insurance impacts.** Under Risk Rating 2.0 property insurance could still be affected as flood risk increases. This analysis quantifies how adaptation measures could mitigate the negative impacts of sea-level rise on flood insurance affordability, insurance penetration rate, total purchased coverage, and rates of underinsurance.
3. **Reducing the impact on real estate values.** Increasing flood risk reduces the value of properties, as prospective buyers can expect to face higher repair and insurance costs, disruption to property use and higher insurance cost. This analysis quantifies how the flood adaptation suites could reduce these impacts.
4. **Reducing the fiscal risks to the County.** Ad valorem tax collections may fall as the value of properties decrease. This analysis quantifies how adaptation measures could mitigate downside impacts to tax collection.

In addition, the adaptation measures could also have benefits of reducing five other risks that were qualitatively assessed in the previous phase, including avoiding disruption to public services and critical infrastructure, lowering county investment risk, reducing demographic change such as out-migration, preserving tourism and avoiding physical and mental health impacts.

The memorandum's structure is as follows:

Section 1 describes the purpose of this memorandum.

Section 2 provides an introduction.

Section 3 provides definitions of frequently used terms used throughout this report.

Section 4 summarizes the key inputs to the socioeconomic modeling of adaptation, including outputs of the hydrologic modeling workstream and the adaptation suites.

Section 5 discusses the reductions in property-level flood damage under the adaptation suites.

Section 6 discusses the benefits of the adaptation suites as they mitigate short-term economic losses.

Section 7 discusses the benefits of the adaptation suites on NFIP insurance in Broward County.

Section 8 discusses the benefits of the adaptation suites on residential real estate value.

Section 9 discusses the benefits of the adaptation suites on tax revenue collection in Broward County.

Section 10 considers how impacts are distributed geographically across Broward County, including in vulnerable areas.

Section 11 assesses how adaptation can protect the operation of the Fort Lauderdale-Hollywood International Airport and Port Everglades.

Section 12 discusses uncertainties within the modeling effort and how they may affect the results contained in this memorandum.

Unless otherwise stated, all changes described in this memorandum are relative to impacts in the baseline.

## 3. Definitions

The following terms are used throughout this memorandum. Their definitions are provided below.

| | |
|---|---|
| Adaptation suite | Adaptation Suite (or strategy) is the bundle of adaptation measures intended to mitigate the socioeconomic impacts from flooding under baseline conditions of no action. |
| Adaptation measure | Adaptation measure refers to a single type of adaptation investment. The measures explored in this Resilience Study include converting two-lane roads to one-lane roads with storage areas, pumping stations, culvert improvements, seawalls, control-stations in canals and tidal barriers. |
| Average Annual Damage (AAD) | Average Annual Damage is the expected annual *financial loss from repairing or replacing physical damage* from flooding, accounting for the likelihood and severity of all the flood scenarios considered in the modeling process. |
| Average Annual Loss (AAL) | Average Annual Loss is the expected annual *macroeconomic loss* that would occur in any given year accounting for the likelihood and severity of all the scenarios considered in the modeling process. Macroeconomic losses the lost value of production resulting from damage to productive assets, business interruption caused by flooding of the road network, and indirect impacts to other businesses in the County. |
| Gross Value Added (GVA) | Gross Value Added measures the difference between the value of goods and services an economy, industry, region, or business produces, and the value of the raw materials required to produce them. It includes the income that residents receive, company profits, depreciation, interest payments and net subsidies (subsidies minus taxes). |
| High vulnerability census tract | Vulnerability data were obtained from the US Center for Disease Control's Social Vulnerability Index (CDC's SVI) dataset, at the census tract level. High vulnerability tracts were identified as those in the top quartile for a given vulnerability metric (e.g., elderly, disabled, housing burdened population) across Broward County. |
| Insurance affordability | A flood insurance policy is defined as affordable if the policy premium is less than 1% of the coverage of the policy, as per Homeowner Flood Insurance Affordability Act of 2014[1]. |
| Insurance coverage | Insurance coverage, as defined for this study, is the maximum payment amount that a property owner would receive from an insurance company to cover the repair or replacement of property assets in the event of a flood that damages the property. |
| Insurance penetration rate | Ratio between National Flood Insurance Program policy count and total number of housing units at the census-tract level |
| NFIP | The National Flood Insurance Program, administered by the Federal Emergency Management Agency, provides affordable insurance to property owners and encourages communities to adopt and enforce floodplain management regulations. |
| Risk Rating 2.0 | Risk Rating 2.0 is the NFIP's new pricing methodology, which was rolled out in late 2021. The methodology enables FEMA to deliver rates that are actuarily sound, equitable, easier to understand and better reflect a property's flood risk. |
| SFHA | Special Flood Hazard Areas (SFHA) are defined by FEMA as areas that will be inundated by flood events having a 1% annual chance of occurring. Residences within SFHAs typically are required to have NFIP flood insurance policies. |
| Sales | As used in this memorandum, "sales" is the commercial sales revenue by business type. |
| Stranded business | A stranded business is a business which is not physically connected to most of its consumers and suppliers (90%) via road, due to flooded roads being impractical to use for transportation (defined as roads with flood depths above 0.5ft). |
| SVI | The Social Vulnerability Index consolidates information on 16 vulnerability indicators in CDC/ATSDR's SVI database at the census track level, covering 4 key dimensions of |

[1] As per Affordability of National Flood Insurance Program Premiums Report 1, 2015; accessible at: https://nap.nationalacademies.org/read/21709/chapter/7#80

| | |
|---|---|
| | vulnerability: socioeconomic status, household characteristics, racial & ethnic minority status and housing type/transportation. |
| Underinsurance rate | Ratio between non-insured replacement costs and total replacement value. |

## 4. Key inputs to the socioeconomic modeling of adaptation

**Introduction to the inputs**. Outputs from the hydrologic modeling workstream were the core inputs into the socioeconomic modeling of adaptation. The hydrologic modeling workstream developed seven adaptation suites characterized by different combinations of measures and levels of protection offered.

Future flood projections for the baseline (no action) and the adaptation strategies incorporate sea-level rise, in addition to expected rainfall and storm surge. Sea-level rise scenarios of 2.0 feet (based on the 2017 NOAA Intermediate High Sea-Level Rise (SLR) projection) and 3.3 feet (using the same projection) were used. For each sea-level rise scenario, the hydrologic workstream provided the socioeconomic workstream with the following data:

1. Probability of the scenario occurring – same as the baseline in all adaptation suites
2. Maximum flood depth for each building – influenced by the adaptation suite
3. Duration of flooding above elevation thresholds for each building – influenced by the adaptation suite
4. Expected damages to each building, disaggregated between structural and content damages – influenced by the adaptation suite

The economics modeling team used these data to prepare two key inputs: (1) an analysis of road network disruption, and (2) damages to residential and productive assets.

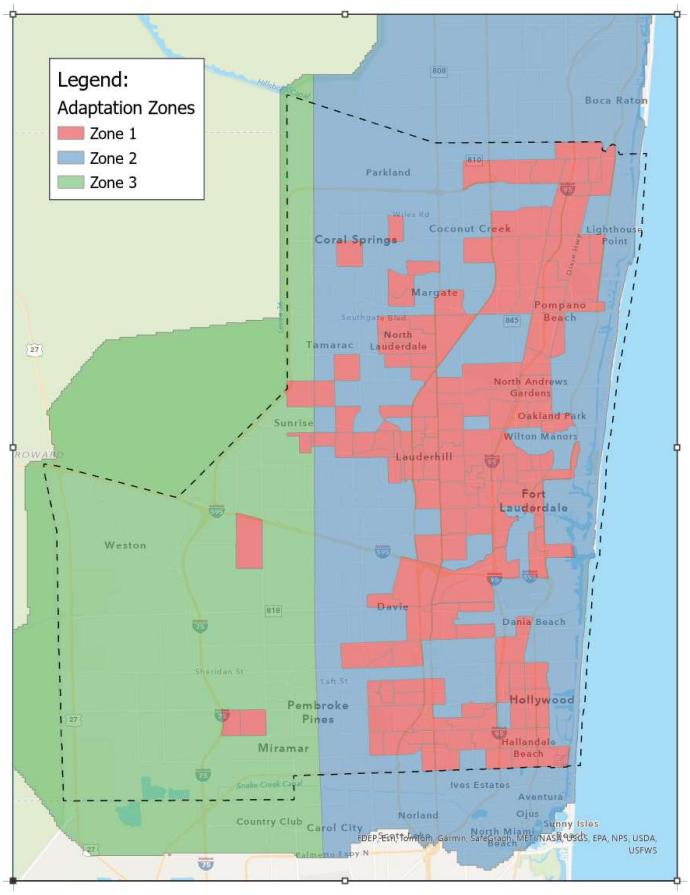
**Adaptation suites explored in this effort.** Seven different unique combinations of adaptation suites were explored – each representing a different ‘suite’ of measures to manage the effects of flooding. In general, the level of protection (and associated required investment) was designed to increase from the first to the last strategy. However, as can be seen in the results, this is not uniformly the case given the complex ways in which different types of measures, implemented in different parts of the county, afford different levels of protection in different flood conditions. The assumptions in each adaptation suite are summarized in **Exhibit 1**. Only the suite titled “Countywide with 7 foot walls and control elevation changes” includes drainage systems behind and through the seawalls to move stormwater away from the properties.

**Exhibit 1: Overview of the adaptation suites**

Existing conditions ✓ Additional measures

| Adaptation suite | County area where measures implemented, % | Two-way roads converted | Pumping stations | Storage areas | Control elevation changes | Sea walls | Surge & tidal coastal barriers |
|---|---|---|---|---|---|---|---|
| Baseline | ~0% | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| Priority areas | ~30% (Zone 1) | ✓ | ✓ | ✓ | ✗ | 5ft | ✗ |
| Coastal areas | ~60% (Zone 1&2) | ✓ | ✓ | ✓ | ✗ | 5ft | ✗ |
| Coastal areas w/ control elevation changes | ~60% (Zone 1&2) | ✓ | ✓ | ✓ | ✓ | 5ft | ✗ |
| Countywide | ~100% (Zones 1-3) | ✓ | ✓ | ✓ | ✗ | 5ft | ✗ |
| Countywide w/control elevation changes | ~100% (Zones 1-3) | ✓ | ✓ | ✓ | ✓ | 5ft | ✗ |
| Countywide w/7ft walls & control elevation changes | ~100% (Zones 1-3) | ✓ | ✓ | ✓ | ✓ | 7ft | ✗ |
| Large flood control structures | ~100% (Zones 1-3) | ✓ | ✓ | ✓ | ✓ | 5ft | ✓ |

The adaptation zones referenced in **Exhibit 1** refer to different parts of the county where certain measures – two-way road conversion to one-way roads, pumping stations, stormwater pumps, green infrastructure, culvert improvements and distributed storage (above and below ground) – would be implemented. Three zones were identified as follows and are depicted in **Exhibit 2**.:




- **Zone 1:** Census tracts identified as having the highest vulnerability
- **Zone 2**: Eastern portion of Broward County
- **Zone 3**: Western portion of Broward County

**Exhibit 2: Adaptation zones in Broward County**

**Flood scenarios evaluated.** The flood scenarios described in **Table 2** were modeled by Hazen and served as the base inputs to this economic modeling effort.

**Table 2. Flood scenarios used to estimate the economic benefits of adaptation suites**

| Scenario No. | Rainfall frequency | Sea-level Rise scenario | Antecedent Conditions | Tidal Conditions | Rainfall probability | Surge probability | Joint probability |
|---|---|---|---|---|---|---|---|
| RP-1 | 25-yr | 2.0 ft | Variable GW | No Surge | 4.00% | 100.00% | 4.00% |
| RP-2 | 50-yr | 2.0 ft | Variable GW | No Surge | 2.00% | 100.00% | 2.00% |
| RP-3 | 100-yr | 2.0 ft | Saturated System | No Surge | 1.00% | 100.00% | 1.00% |
| RP-4 | 25-yr | 2.0 ft | Variable GW | 20-yr Storm Surge | 4.00% | 5.00% | 0.20% |
| RP-5 | 50-yr | 2.0 ft | Variable GW | 20-yr Storm Surge | 2.00% | 5.00% | 0.10% |
| RP-6 | 100-yr | 2.0 ft | Saturated System | 20-yr Storm Surge | 1.00% | 5.00% | 0.05% |
| RP-7 | 25-yr | 2.0 ft | Variable GW | 100-yr Storm Surge | 4.00% | 1.00% | 0.04% |
| RP-8 | 50-yr | 2.0 ft | Variable GW | 100-yr Storm Surge | 2.00% | 1.00% | 0.02% |
| RP-9 | 100-yr | 2.0 ft | Saturated System | 100-yr Storm Surge | 1.00% | 1.00% | 0.01% |
| RP-10 | 25-yr | 3.3 ft | Variable GW | No Surge | 4.00% | 100.00% | 4.00% |
| RP-11 | 50-yr | 3.3 ft | Variable GW | No Surge | 2.00% | 100.00% | 2.00% |
| RP-12 | 100-yr | 3.3 ft | Saturated System | No Surge | 1.00% | 100.00% | 1.00% |
| RP-13 | 25-yr | 3.3 ft | Variable GW | 20-yr Storm Surge | 4.00% | 5.00% | 0.20% |
| RP-14 | 50-yr | 3.3 ft | Variable GW | 20-yr Storm Surge | 2.00% | 5.00% | 0.10% |
| RP-15 | 100-yr | 3.3 ft | Saturated System | 20-yr Storm Surge | 1.00% | 5.00% | 0.05% |
| RP-16 | 25-yr | 3.3 ft | Variable GW | 100-yr Storm Surge | 4.00% | 1.00% | 0.04% |
| RP-17 | 50-yr | 3.3 ft | Variable GW | 100-yr Storm Surge | 2.00% | 1.00% | 0.02% |
| RP-18 | 100-yr | 3.3 ft | Saturated System | 100-yr Storm Surge | 1.00% | 1.00% | 0.01% |
| RP-28 | 1-yr | Current | Variable GW | No Surge | 100.0% | 100.0% | 100.0% |
| RP-29 | 2-yr | Current | Variable GW | No Surge | 50.0% | 100.0% | 50.0% |
| RP-30 | 5-yr | Current | Variable GW | No Surge | 20.0% | 100.0% | 20.0% |
| RP-31 | 0 | 2.0 ft | Saturated | 100-yr Storm Surge | 100.00% | 1.00% | 1.00% |
| RP-32 | 0 | 3.3 ft | Saturated | 100-yr Storm Surge | 100.00% | 1.00% | 1.00% |
| RP-33 | 1-yr | 2.0 ft | Variable GW | No Surge | 100.00% | 100.00% | 100.00% |
| RP-34 | 2-yr | 2.0 ft | Variable GW | No Surge | 50.00% | 100.00% | 50.00% |
| RP-35 | 5-yr | 2.0 ft | Variable GW | No Surge | 20.00% | 100.00% | 20.00% |
| RP- 36 | 1-yr | 3.3 ft | Variable GW | No Surge | 100.00% | 100.00% | 100.00% |
| RP- 37 | 2-yr | 3.3 ft | Variable GW | No Surge | 50.00% | 100.00% | 50.00% |
| RP- 38 | 5-yr | 3.3 ft | Variable GW | No Surge | 20.00% | 100.00% | 20.00% |
| RP-40 | 1-yr | Current | Variable GW | 20-yr Storm Surge | 100.0% | 5.0% | 5.000% |
| RP-41 | 10-yr | Current | Variable GW | 20-yr Storm Surge | 10.0% | 5.0% | 0.500% |
| RP-42 | 25-yr | Current | Variable GW | 20-yr Storm Surge | 4.0% | 5.0% | 0.200% |
| RP-43 | 50-yr | Current | Variable GW | 20-yr Storm Surge | 2.0% | 5.0% | 0.100% |
| RP-44 | 100-yr | Current | Saturated | 20-yr Storm Surge | 1.0% | 5.0% | 0.050% |
| RP-45 | 1-yr | Current | Variable GW | 100-yr Storm Surge | 100.0% | 1.0% | 1.000% |
| RP-46 | 10-yr | Current | Variable GW | 100-yr Storm Surge | 10.0% | 1.0% | 0.100% |
| RP-47 | 25-yr | Current | Variable GW | 100-yr Storm Surge | 4.0% | 1.0% | 0.040% |
| RP-48 | 50-yr | Current | Variable GW | 100-yr Storm Surge | 2.0% | 1.0% | 0.020% |
| RP-49 | 100-yr | Current | Saturated | 100-yr Storm Surge | 1.0% | 1.0% | 0.010% |
| RP-50 | 1-yr | 2.0 ft | Variable GW | 20-yr Storm Surge | 100.00% | 5.00% | 5.00% |
| RP-51 | 1-yr | 3.3 ft | Variable GW | 20-yr Storm Surge | 100.00% | 5.00% | 5.00% |

The flood scenarios were translated into average annual flood metrics (for example, average annual flood damage and average annual changes in GVA) by integrating the area under the frequency/severity curve. This curve is based on each event's probability and the resulting flood metric. This integration provides the expected value of the flood metric or the average metric value among all event probabilities.

## 5. Property damage avoided


**Property-level damage.** The hydrologic modeling team modeled the average annual property damage associated with each flood scenario with and without each adaptation suite. In the baseline, average annual damage to residential assets could increase from close to $600M today to $1.8B with 2 feet of sea-level rise as indicated by the pink bars on the left hand side of **Exhibit 3a**.

Under 3.3 feet of sea-level rise, average annual baseline damage grows to an estimated $3.6B as indicated by the pink bar on the right hand side of **Exhibit 3a**. Damages to productive assets could increase from $240M today, to $645M with 2 feet of sea-level rise, and $1.4B with 3 feet of sea-level rise as indicated by the pink bars in **Exhibit 3b**.

**All but one adaptation suite would reduce property damage relative to the baseline**. For example, with 2 feet of sea-level rise, implementing measures in priority areas could avoid $400M to $1.5B in residential real estate damages, 21% to 82% of baseline damages (**Exhibit 3a**), and $100M-$400M in productive asset damages, 13%-63% of baseline damages (**Exhibit 3b**). The lower figure represents savings from implementing measures in priority areas, while the higher figure would involve implementing measures countywide with 7-foot NAVD seawalls and control-elevation changes.

**Exhibit 3a: Average annual damages to residential assets ($M damages)**

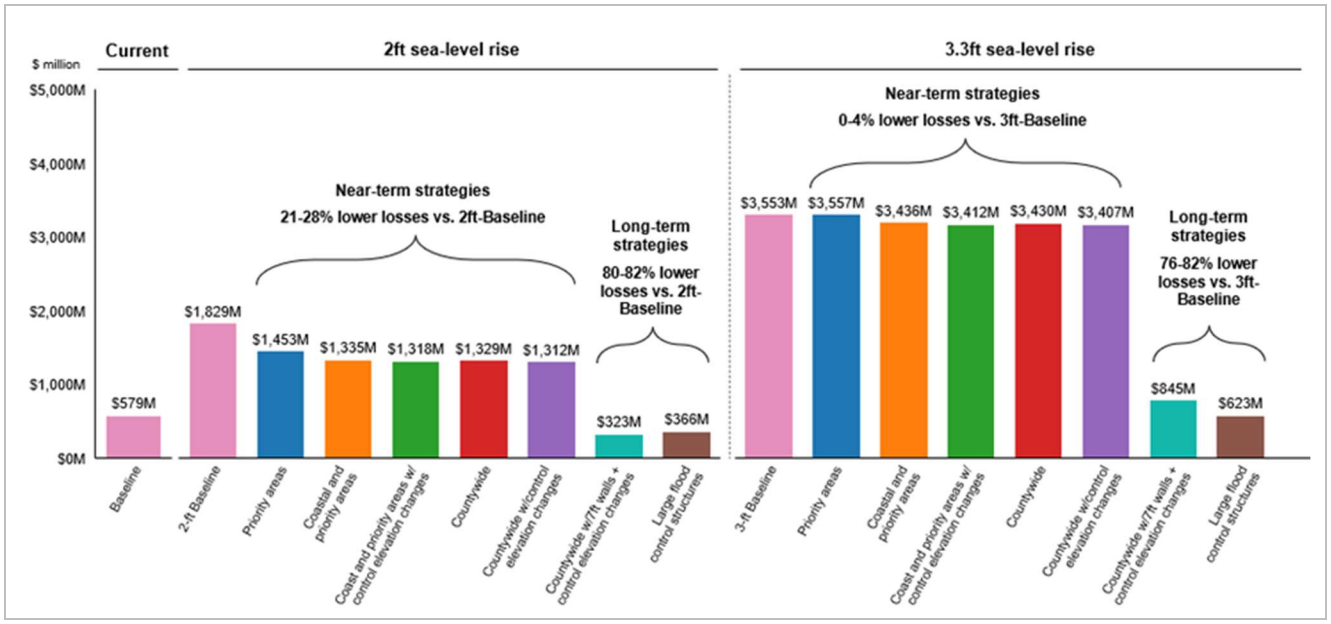
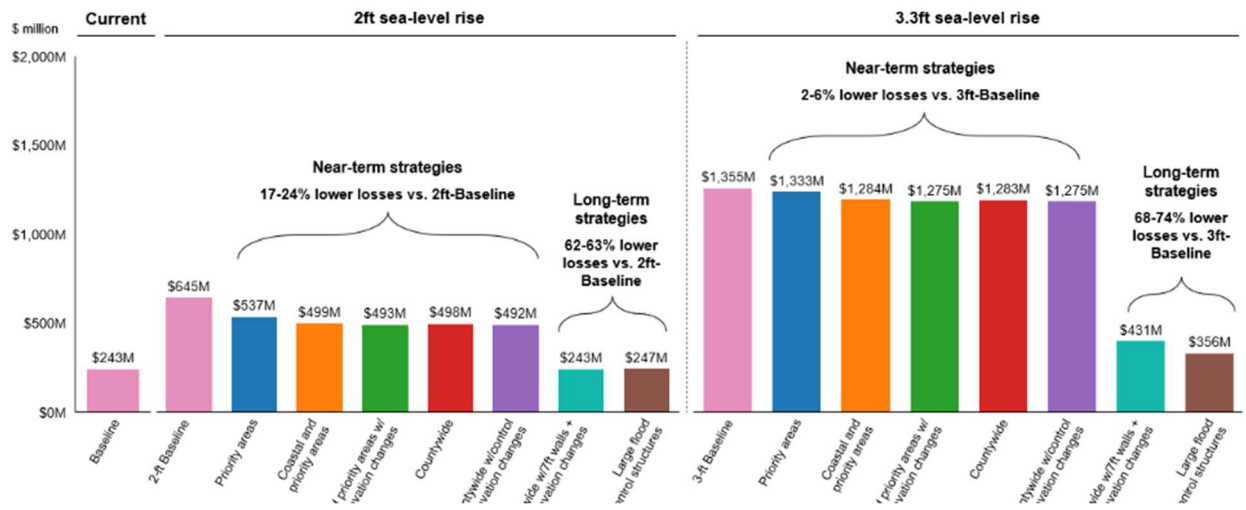
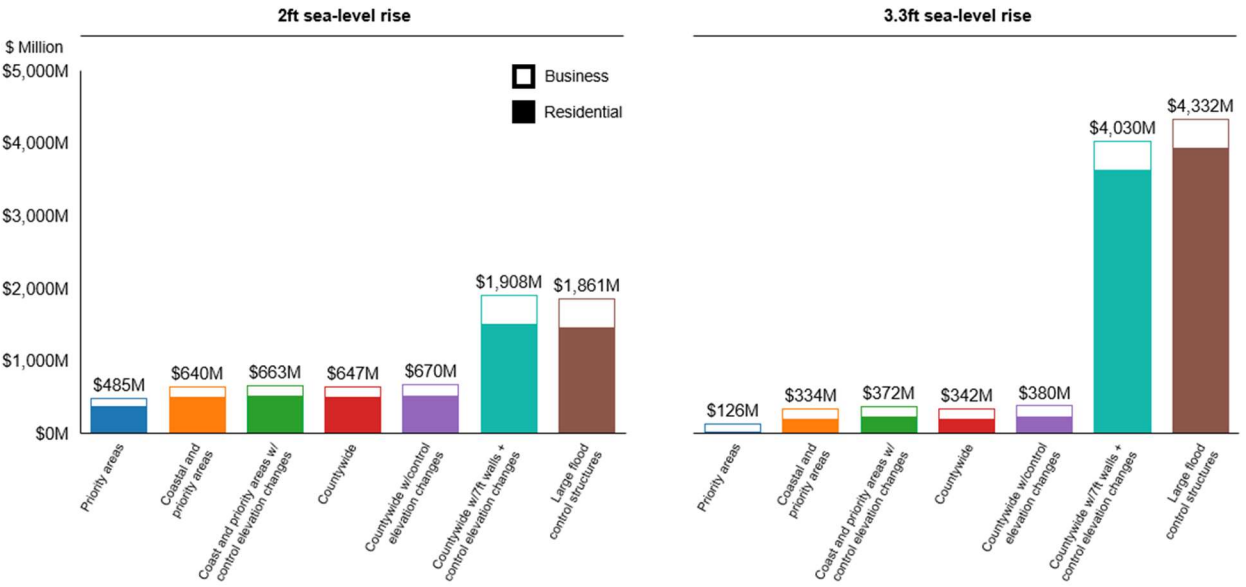


**Exhibit 3b: Average annual damages to productive assets ($M damages)**




With 3.3 feet of sea-level rise, higher seawalls and large flood control structures more materially mitigate flooding and the associated economic costs. The overall average annual savings associated with introducing these measures across residential and business assets would be $4.0B to 4.3B relative to the 3.3 foot baseline. The overall benefits of reduced asset damage associated with the adaptation suites are presented in **Exhibit 4.**

**Exhibit 4: Savings in average annual avoided flood damage to residential and productive assets relative to baseline ($M)**



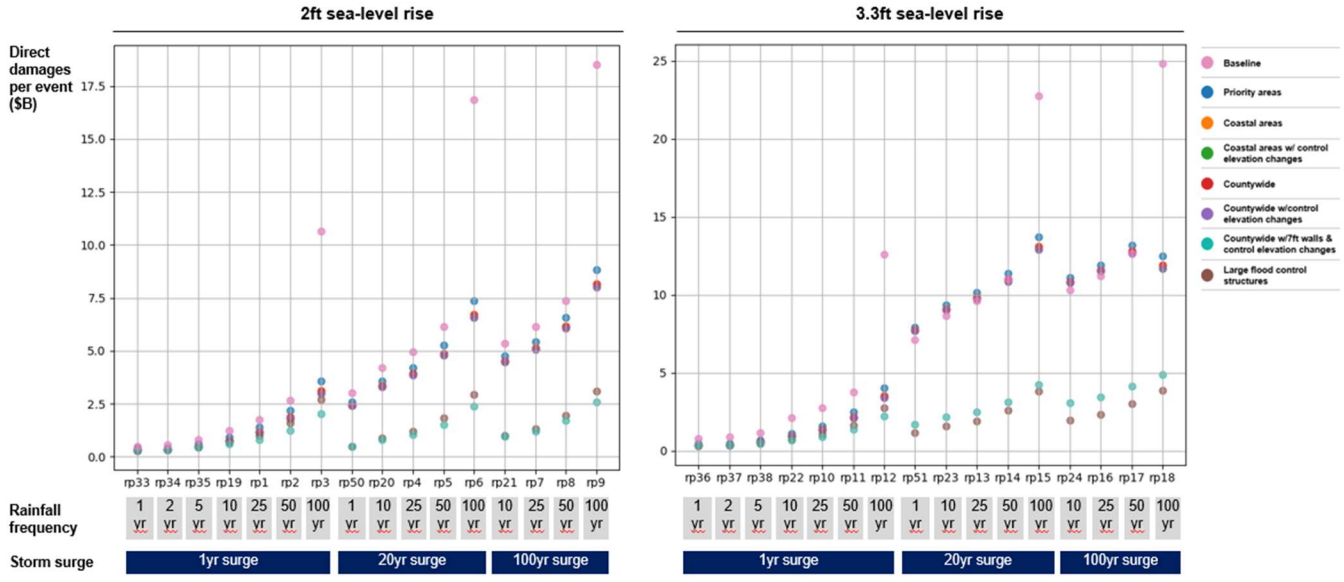

**Damages across different flood events.** Damages were calculated as the average annual damage based on probability weighted impacts of a range of rainfall and storm surge scenarios. This section considers how overall averages are built up from scenario-level impacts. Damages are highest for the scenarios that

include a 100-year rainfall event and a 100-year storm surge event (See Table 2 - Scenarios RP9 and RP18 under 2 feet and 3.3 feet of sea-level rise, respectively). However, because they are relatively rare, they contribute a small amount to the overall average annual damage.

**Exhibit 5** presents the extent to which each adaptation suite mitigates flood damage under each rainfall event / storm surge scenario. For 2 feet of sea-level rise, all adaptation suites reduce damages under all scenarios, but with mitigation benefits most pronounced for the most extreme rainfall events as indicated under the scenarios RP3, RP6, and RP9 in the left hand graph of **Exhibit 5**. Under 3.3 feet of sea-level rise, some adaptation suites do not mitigate flood damage under some of the scenarios while the two adaptation suites with the most comprehensive investments reduce damages under all scenarios. This is evident by examining the right hand graph of **Exhibit 5**.

Furthermore, the most comprehensive adaptation suites provide the greatest flood protection compared to the other suites under all rainfall and storm surge scenarios and they offer the greatest level of avoided flood damage benefits in scenarios involving 20-or 100-year storm surge events. Under 3.3 feet of sea-level rise, the other adaptation suites become ineffective at reducing flood damages in scenarios with 20- or 100-year storm surge events.

**Exhibit 5: Direct residential property damages across different rainfall and storm surge probabilities ($M) *(not probability weighted)***




**Damages across different cities. Table 3a and Table 3b** present the benefits by city of two adaptation strategies, assuming the adoption of a near-term adaptation suite under 2 feet of sea-level rise and a longer-term approach under 3.3 feet of sea-level rise. In this table the near-term strategy would be implementation of the adaptation measures listed in **Exhibit 1** under "Countywide with Control Elevation Changes" and the longer-term approach would be the Countywide approach with an increase in seawall height from 5 foot NAVD to 7 foot NAVD.

For these 29 cities, property damages are lower when the adaptation strategies are adopted versus the baseline for both the near-term and longer-term strategies. The amount of savings increases when sea-

level rise increases to 3.3 feet given the larger expected property damages that can be mitigated under the 3.3 feet sea-level rise baseline scenario. The largest benefits in reduced property damage are concentrated in the coastal cities and the lowest damages are in the cities that are in the more western portions of the County.

**Table 3a - Residential property damage avoided under two selected adaptation strategies among cities, sorted by $M in avoided property damage, average annual 2024 dollars**

| Average Annual Avoided Damage Range | Property Damage Avoided - Countywide with w/ control elevation changes at 2ft SLR | | | Property Damage Avoided - Countywide w/7ft NAVD seawalls + control elevation changes at 3.3ft SLR | | |
|---|---|---|---|---|---|---|
| | Number of Cities and Unincorporated County | $M / Year | %of Total Avoided Damage | Number of Cities and Unincorporated County | $M / Year | % of Total Avoided Damage |
| Greater than $100M | 2 | $337 | 54% | 5 | $2,436 | 85% |
| $20M to $100M | 4 | $145 | 23% | 5 | $342 | 12% |
| $10M to $20M | 6 | $81 | 13% | 3 | $32 | 1% |
| $5M to $10M | 5 | $36 | 6% | 5 | $49 | 2% |
| >$1 to <$5M | 8 | $19 | 3% | 8 | $20 | 1% |
| >$0 to $1M | 4 | $3 | 0.4% | 3 | $2 | 0.1% |
| **Total** | **29** | **$622** | **100%** | **29** | **$2,881** | **100%** |

*Note: Damages and savings by city were estimated as closely as possible because the analysis was conducted at the Census Tract level and the Census tracts mostly, but not completely, align with city boundaries.

**Table 3b - Residential property damage avoided under two selected adaptation strategies among cities, sorted by percentage of avoided property damage relative to baseline, average annual 2024 dollars**

| Average Annual Damage Avoided Range as percentage of baseline | Property Damage Avoided - Countywide with w/ control elevation changes at 2ft SLR | | | Property Damage Avoided - Countywide w/7ft NAVD seawalls + control elevation changes at 3.3ft SLR | | |
|---|---|---|---|---|---|---|
| | Number of Cities and Unincorporated County | $M / Year | % of Total Annual Avoided Damage | Number of Cities and Unincorporated County | $M / Year | % of Total Annual Avoided Damage |
| 70-99% reduction | 5 | $67 | 11% | 11 | $2,666 | 93% |
| 60-70% reduction | 6 | $53 | 9% | 7 | $87 | 3% |
| 40-60% reduction | 8 | $266 | 43% | 6 | $111 | 4% |
| 20-40% reduction | 6 | $77 | 12% | 3 | $12 | 0% |
| >0-20%reduction | 4 | $158 | 25% | 2 | $4 | 0% |
| **Total** | **29** | **$622** | **100%** | **29** | **$2,881** | **100%** |

*Note: Damages and savings by city were estimated as closely as possible because the analysis was conducted at the Census Tract level and the Census tracts mostly, but not completely, align with city boundaries.

The tables include all municipalities in Broward County except Lighthouse Point, which will experience a 112% increase in flooding under the near-term strategy relative to baseline conditions with 2.0 feet of sea-level rise. This amounts to an additional $66 million increase in average annual property damage above baseline conditions.

This increase in flooding occurs at the locations close to the Hillsboro Inlet where the water stages of the Intracoastal Waterway are more sensitive to sea-level rise than elsewhere. This sensitivity will be exacerbated by the effects of the adaptation strategies implemented upstream of the inlet (mainly the installation of 5 foot seawalls). Under the 2.0 foot sea-level rise baseline, in areas with low or no seawalls, the excess water would flow outside of channel banks during heavy rainfall or flood events. Once 5-foot seawalls are constructed under the near team adaptation strategy, more water will stay inside the channels, creating higher channel water depths downstream. These higher water depths would impede the proper drainage of the residential areas in Lighthouse Point and result in greater flooding than under baseline.

Once the drainage systems behind and through the seawalls are implemented under the long-term strategy, the city's drainage would significantly improve such that the property damage within the city would be expected to fall by 91% which amounts to $160 million in avoided average annual damages.

To counter the city's flood problem under the near-term approach, the economic analysis includes drainage improvements behind and through the seawalls in the City of Lighthouse Point in the near-term such that $106 million in property damages would be avoided in the near-term compared to the baseline which is a 70% reduction in damages under baseline.

The condition described here may also be present in other downstream areas. Although the economic effects in those areas are not expected to be significant enough to make a difference in the results presented in this document, the increased flooding that might occur in certain areas under the near-term strategy will be addressed during the formulation of the Resilience Plan.

The average annual avoided property damages for the individual cities in Broward County under the near-term strategy that includes the Lighthouse Point drainage features (later referred to as Tier 1) and under the longer-term strategy (later referred to as Tier 2) are provided in Appendix A-1.

## 6. Increased short-term economic activity


**Summary of key findings.** Gross Value Added (GVA) measures the contribution of business sectors to overall economic activity and includes the income produced within the county from all sources. Average annual avoided reductions in GVA resulting from each adaptation suite were assessed as the difference between the impact of the adaptation suite on average annual GVA and the impact under the baseline. The economic benefits modeled here were based on the increased GVA from:

- Lower direct flooding impacts to businesses, and
- Reduced disruption to roads.

The key findings of the short-term economic activity evaluation are as follows.

- The adaptation suites materially reduce modeled losses to economic production. Savings as measured by the avoided reduction in average annual GVA range from $81M to $186M under 2 feet of sea-level rise and between $77M and $660M under 3.3 feet of sea-level rise, depending on the adaptation suite. These suites could protect 1,000 to 2,500 jobs that would otherwise be at risk under 2 feet of sea-level rise, and as many as 8,300 jobs protected under 3.3 feet of sea-level rise.
- The avoided reduction in average annual GVA as a percentage of baseline GVA loss ranges from 19% to 43% while the avoided property damage as a percentage of baseline damage is higher at 21% to 82%, depending on the adaptation suite. The GVA losses are mitigated to a lesser extent because interruptions to the movement of goods and services are persistent over time.
- Outside of economic analysis, a more commonly used economic metric to residents and businesses is the "value of sales" or "sales" of a good, a service, or the total sales in an economy. Estimated county-wide average annual avoided sales loss is estimated to range from $310M and $850M under 2 feet of sea-level rise (31% to 83% of baseline sales losses) and $175M to $2.4B under 3.3 feet of sea-level rise (7% to 88% of baseline sales losses).

**Discussion of key findings.** The short-term economic loss modeling included two analyses:

- **Input-output modeling** – which provides estimates of the *expected* economy-wide impacts of flood damage and transport disruption.
- **Sales disruption** – which provides an estimate of a more familiar measure of economic activity.

**Mitigating expected economic losses (Input-output modeling).** The baseline analysis found the effects of flooding on economic production to be material, at $435M in average annual losses to GVA with 2 feet of sea-level rise, increasing to $947M with 3.3 feet of sea-level rise. This reflects business outages that result from damage to assets and interruptions to the road network, as well as the compounding impacts on other businesses in the county that trade with those that experience outages. Compared to the assessment of property damages, more extreme flooding scenarios cause proportionally greater losses to production, as large disruptions create bottlenecks in supply chains, increasing recovery times.

**All the adaptation suites substantively reduce short term losses to gross value added, profits, and jobs as risk. Exhibits 6a, 6b and 6c** demonstrate that, for all three economic measures, reductions could range from around 19% to 43% of the total expected baseline losses under 2 feet of sea-level rise, increasing to around 8% to 70% of the baseline when sea-level rise reaches 3.3 feet.

**Exhibit 6a: Average annual gross value added loss, $M, under the baseline and the adaptation strategies**

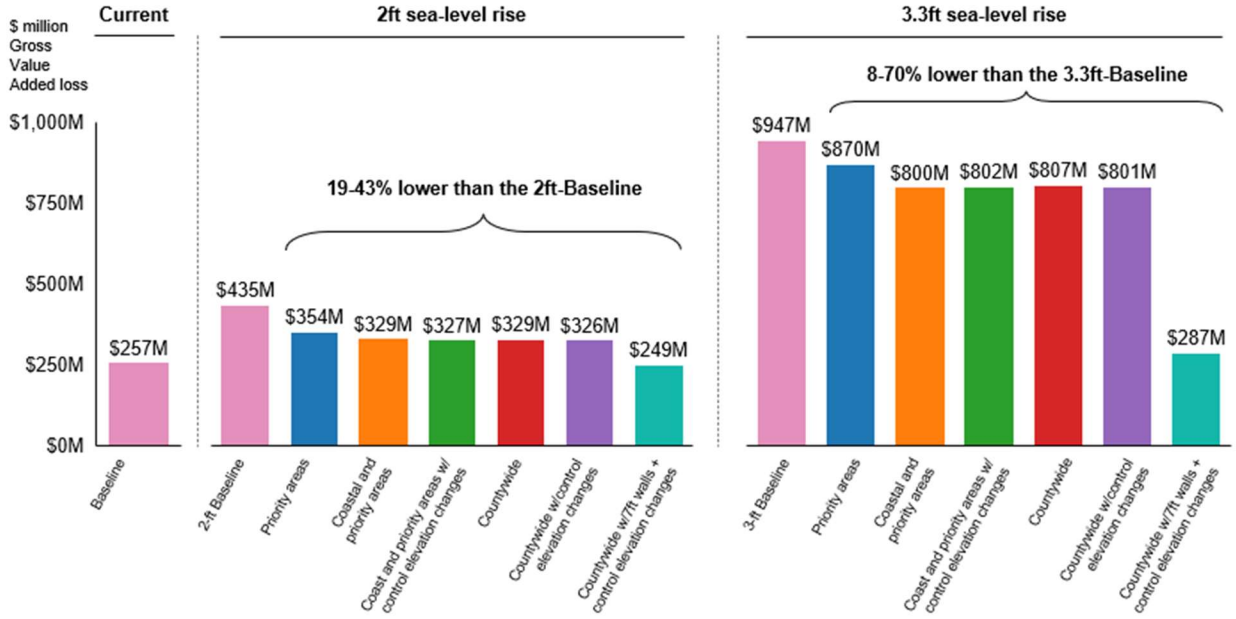



**Exhibit 6b: Average annual Profit loss, $M, under the baseline and the adaptation strategies**

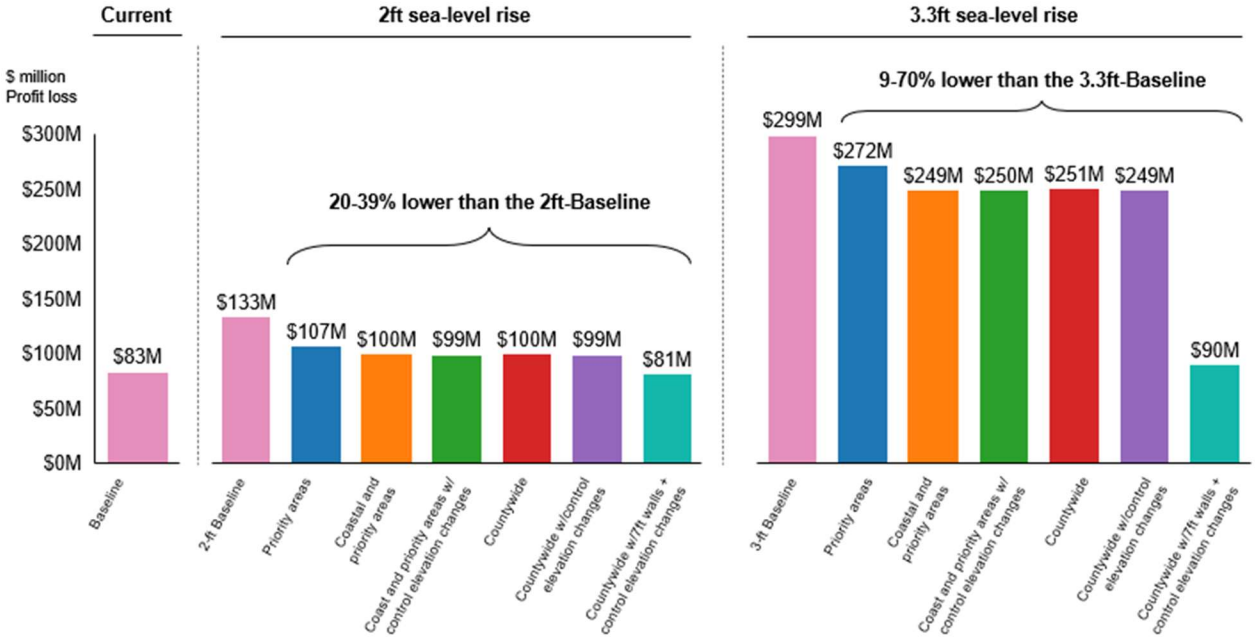
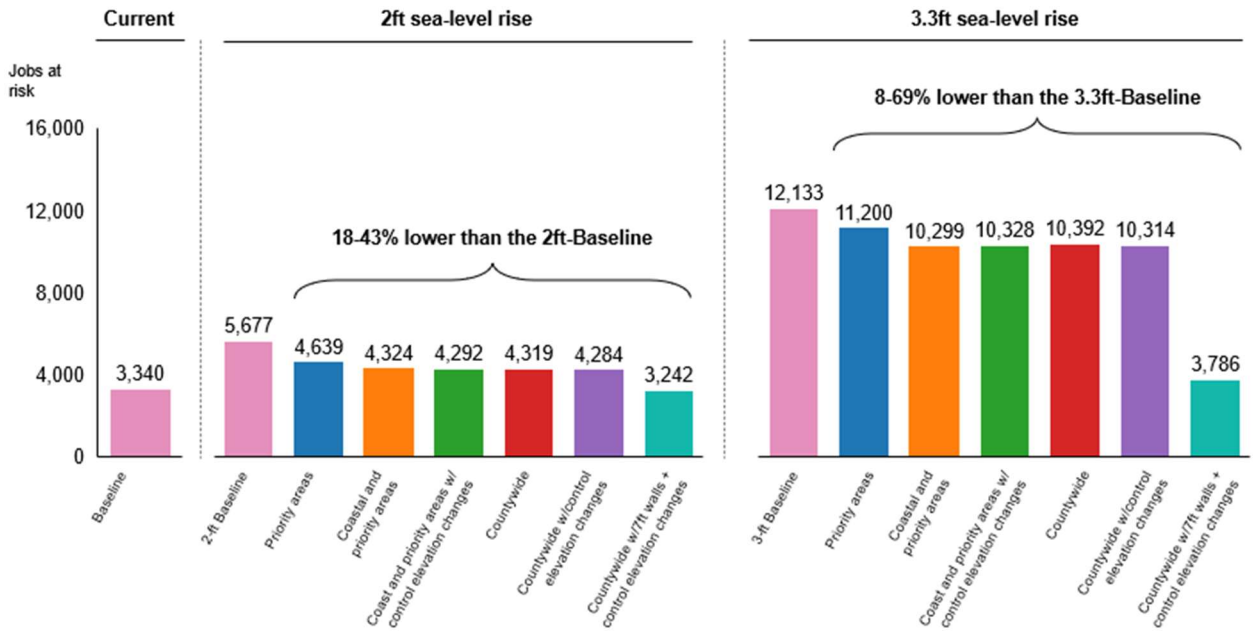
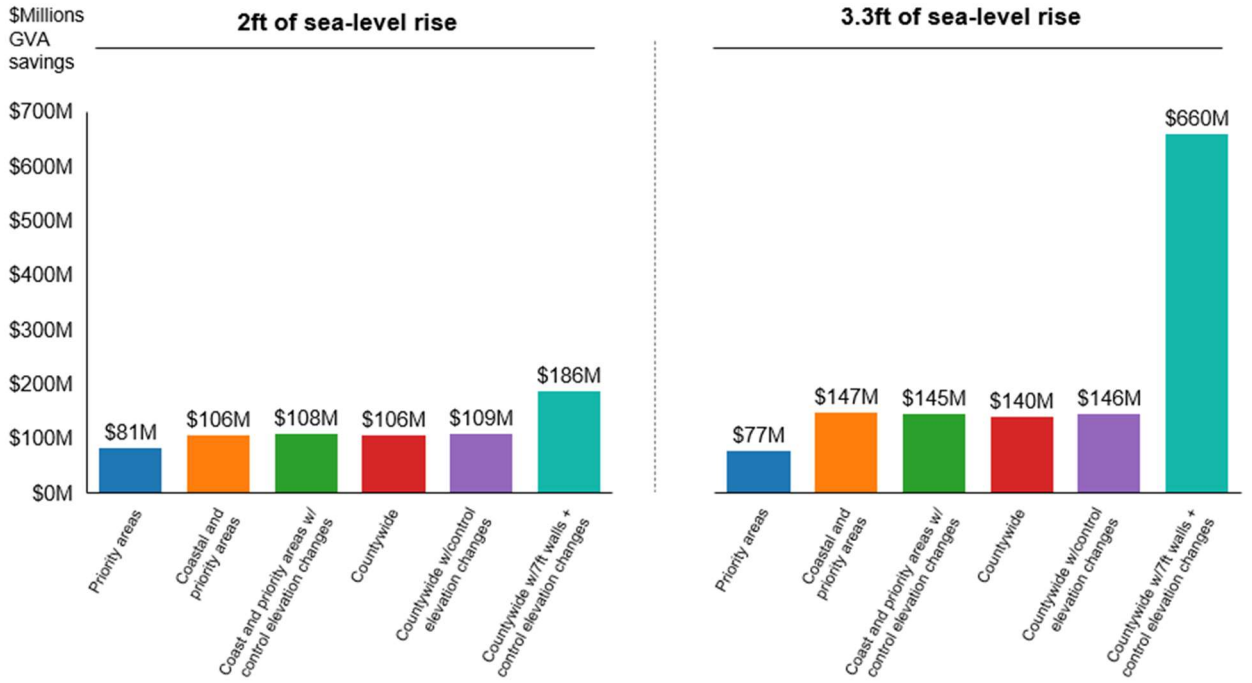


**Exhibit 6c: Average annual jobs at risk under baseline and the adaptation strategies**




The average annual increase in GVA from the adaptation strategies is provided in **Exhibit 7**. The benefits of the adaptation strategies as they mitigate short term economic losses range between an increase of $81M to $186M in GVA under 2 feet of sea-level rise, and $77M to $660M under 3.3 feet of sea-level rise.

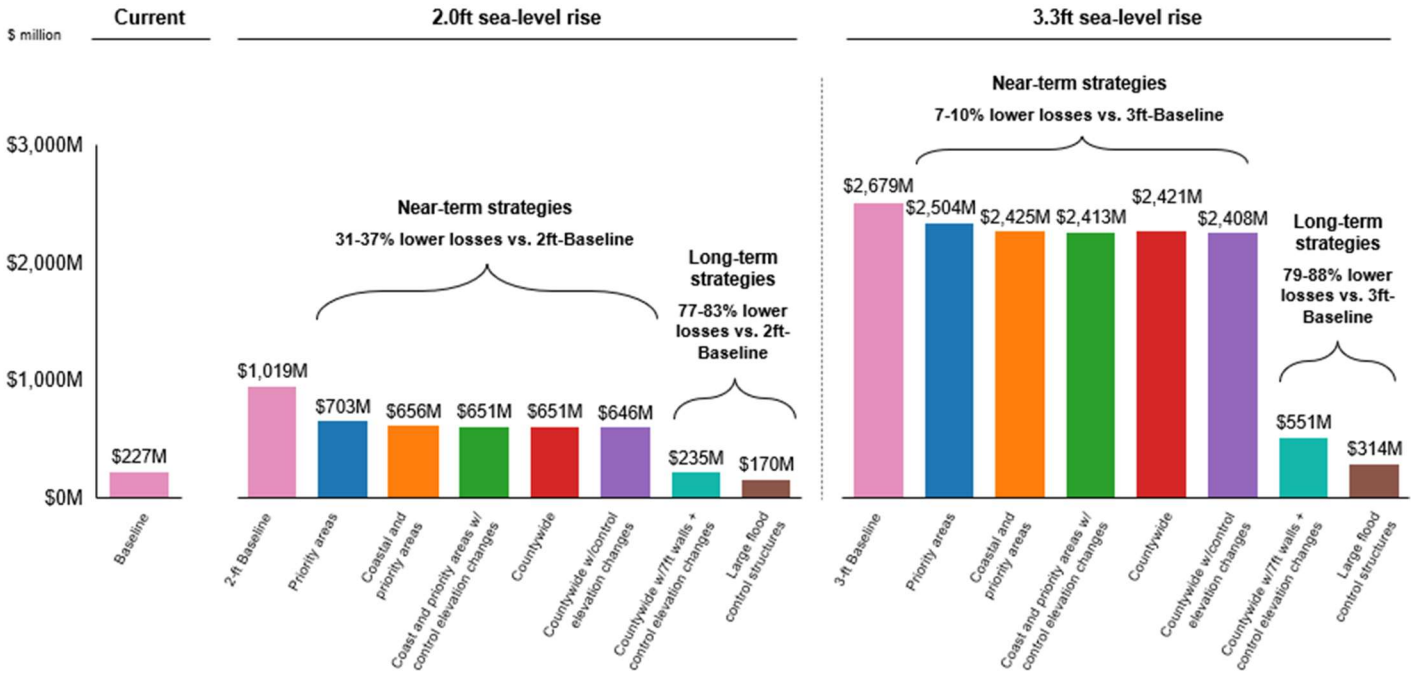
**Exhibit 7: Average annual increase in gross value added from the adaptation strategies, $M**



**Mitigating maximum potential sales losses.** Sales revenue is a metric that is routinely collected and reported by government agencies and private firms. The baseline analysis concluded that the average annual sales loss could increase between 4.5x and 11.8x the current sales losses from flooding absent adaptation actions with 2 feet and 3.3 feet of sea-level rise, respectively.

**Exhibit 8** demonstrates that under 2 feet of sea-level rise, the first five adaptation suites would still result in lower sales than today, but the loss would be between 31% to 37% lower than under baseline. The last two adaptation strategies, involving the construction of higher seawalls or large flood control structures would keep future losses at today's levels under 2 feet of sea-level rise. While sales loss under 3.3 feet of sea-level rise could not be kept at today's levels, the loss reduction would be high at 79% to 88% of baseline sales loss.

**Exhibit 8: Average annual sales loss across the baseline and the adaptation strategies, $M**



## 7. Greater flood insurance coverage


**Summary of key findings**. The key findings of the flood insurance market evaluation are as follows.

- **The number of NFIP policies in Broward County is expected to fall at a lower rate over time when adaptations suites are implemented relative to baseline.** Re-pricing of risk and growing damages from floods would still reduce the number of homes holding NFIP policies from the current level of 175,000 policies. However, assuming current NFIP policy criteria continue to be in place, from 1.6x to 3.3x as many people could maintain insurance where adaptation strategies are pursued. This represents an additional 32,000 to 113,000 additional policies relative to the baseline under the 2 foot sea-level rise scenario and 30,000 to 88,000 additional policies under 3.3 feet of sea-level rise, depending on the adaptation suite.

- **Premia for remaining policies could remain at levels more like today:** While some homes with higher risk profiles could still exit the market, premia for remaining homes could be the same, if not lower, with the adaptation suites in place.

- **Total NFIP coverage would still fall overall (because of changes in policy count and premia) but much less than in the baseline:** Current flood insurance coverage in Broward County is about $44B. Under 2 feet of sea-level rise with no adaptation (baseline), the amount of flood insurance coverage is expected to fall to $13B. The adaptation suites increase coverage to $21B to $41B relative to baseline, with the two most comprehensive suites facilitating the high end of this range at $38B and $41B. These two suites are expected to bring NFIP coverage close to its current level.

  Under 3.3 feet of sea-level rise with no adaptation, Countywide NFIP coverage falls to $11B from the current $44B level. The adaptation suites mitigate this drop resulting in $19B to $33B of coverage, with the two most comprehensive suites recovering to $31B and $33B or 70% to 75% of current coverage levels.

- **As a result, uninsured damages could be at 20% to 90% lower than under the baseline,** depending on which adaptation suite is pursued. The two most comprehensive suites provide the greatest benefits under both sea-level rise scenarios.

**Discussion of key findings.** All adaptation strategies would increase the number of residential housing units with NFIP policies relative to the baseline.

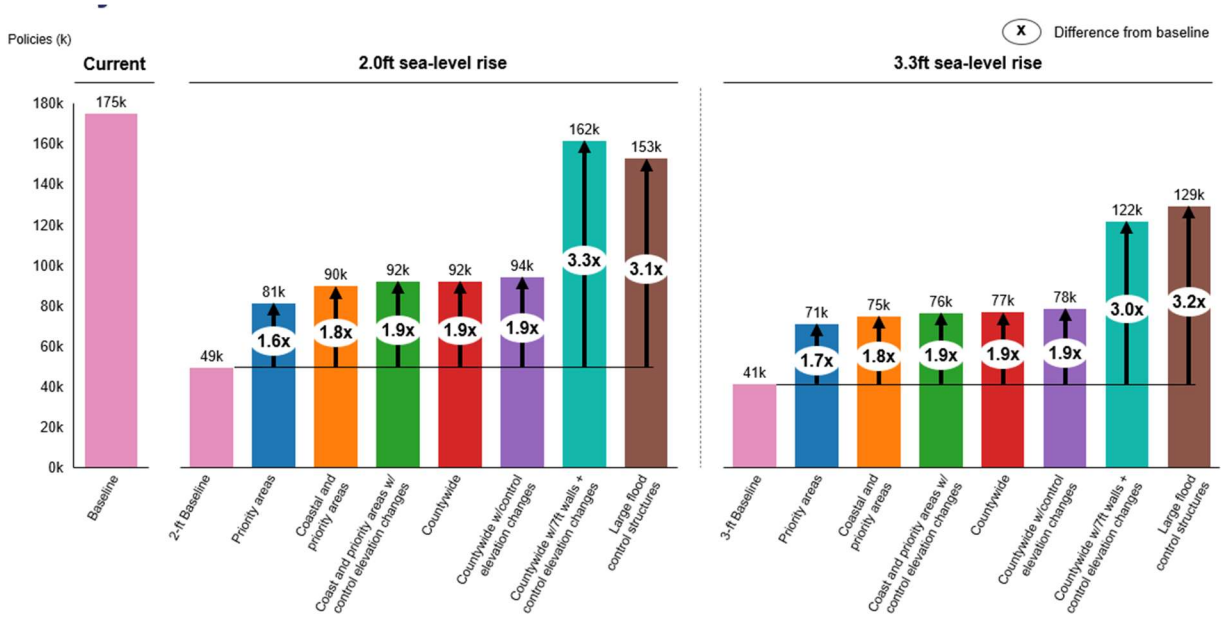
**With 2 feet and 3.3 feet of sea-level rise, respectively, the higher average annual damages per housing unit under baseline conditions could reduce the Countywide NFIP policy count by 70% to 75% relative to current conditions.** This assumes NFIP premia would increase in line with AAD (given the ambition of Risk Rating 2.0) which makes purchasing insurance less affordable absent adaptation measures. **Exhibit 9** presents the estimated NFIP policy count under current conditions and the estimated policy counts for the baseline and adaptation suites under each sea-level rise projection (2 feet and 3.3 feet). The exhibit shows how the Countywide NFIP policy count is expected to decrease from 175,000

policies currently to 49,000 policies under 2.0 feet of sea-level rise, and to 41,000 policies under 3.3 feet of sea-level rise.

**Implementing adaptation strategies could mean 1.6x to 3.3x times more residential homes would maintain their NFIP policies in 2050 and 2070.** This is primarily because each of the suites would lower a housing unit's average annual damage. This translates into a lower rise in risk-adjusted premiums, and a greater share of policies that remain affordable. The following observations are of note.

- While the adaptation suites result in higher NFIP policy counts relative to the baseline, they do not completely mitigate the reduction in the insurance penetration rate, and the policy count still falls overall. This is because the risk-adjusted premiums would be higher under the sea-level rise scenarios than they are currently, even if they would be significantly lower than under the baseline.
- Insurance penetration rates are much higher in the last two strategies depicted in **Exhibit 9** than in the baseline or the other adaptation suites. The adaptation measures implemented with higher seawalls (7ft) and/or large flood control structures offer increased flood protection in the longer term.

**Exhibit 9: Total NFIP policy count could fall less over time than the baseline if adaptation measures are pursued**




NFIP premia for the remaining policies could remain much closer to the current premia. After accounting for policy exits, premia for purchased NFIP policies may only rise modestly or even fall slightly in real terms. On the county level, **Exhibits 10a and 10b** demonstrate how the increase in premia due to 2 feet of sea-level rise could be significantly mitigated. Instead of the 1.9x increase from today's current premia, single-family home policy costs could range between 0.8x (lower) and 1.3x (higher) compared to current costs. Multi-family home policy costs range between 0.7x (lower) and 1.6x (higher) compared to current costs.

In some instances, 2050 costs (in 2025 dollars) for the remaining policies could be lower than they are today for both single and multi-family homes. This is because properties that face high average annual damages drop out of the market under the baseline and under the adaptation suites, thus reducing the premia charged to those who keep their policies. This feature results in relatively modest differences in average premia between the adaptation suites.

To illustrate: for single-family homes, the average premia *among those households that buy insurance* is only 22% higher for the adaptation suite that introduces county-wide control elevation changes with 5 foot NAVD seawalls (purple bar in **Exhibit 10a**) versus the same suite but with 7 foot NAVD seawalls (aqua bar in **Exhibit 10a**) ([$766M - $627M] / $627M = 0.22). However, because insurance is more expensive in general, 42% fewer households can afford insurance with the former adaptation suite than the latter.

**Exhibit 10a: Average NFIP premia in Broward County – Single-Family**

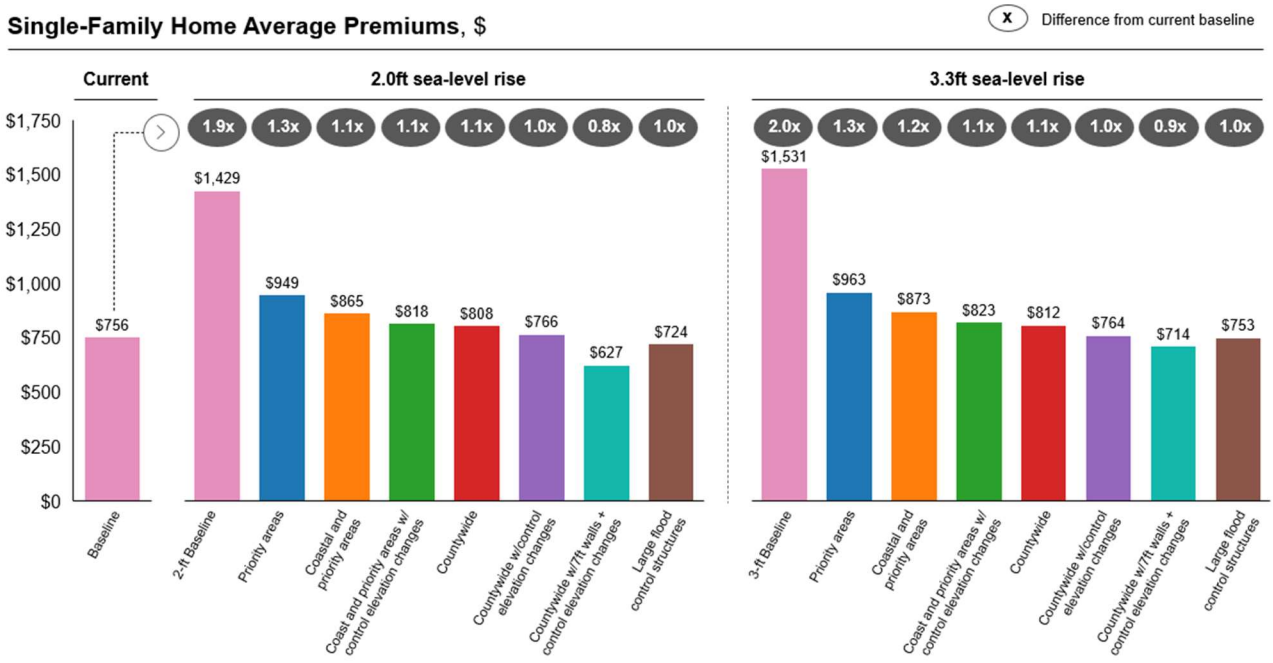
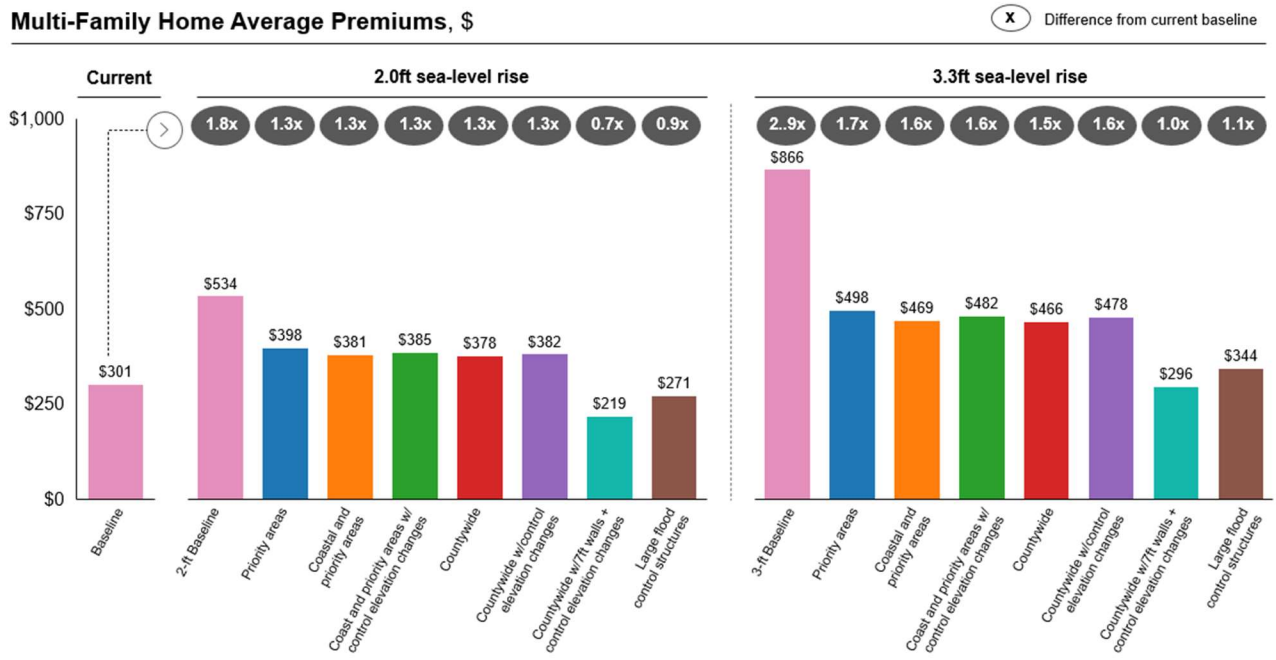


**Exhibit 10b: Average NFIP premia in Broward County – Multi-Family**




Compared to current conditions, total NFIP insurance coverage is expected to decrease under most adaptation suites but would still be higher than under the 2.0 foot and 3.3 foot baseline conditions. As a result of shifts in policy count and premia, total coverage could still decrease from $44B but with a wider range of potential outcomes. For example, in **Exhibit 11a**, total purchased coverage with 2.0 feet of sea-level rise could fall to between $21B and $41B but this would still be higher than under the baseline coverage of $13B.

Total insurance coverage, however, does not provide the full picture. Under the baseline, the share of census tracts with a 100% underinsurance rate (a measure of the amount of coverage relative to replacement value) is estimated to rise from the current 0% to about 30% under both sea-level rise scenarios. In all adaptation suites, the increase would be from 0% currently to no more than 15% and, correspondingly, the number of homes with at least 75% coverage would be higher.

**Exhibit 11a: Total flood insurance coverage under baseline and adaptation strategies**

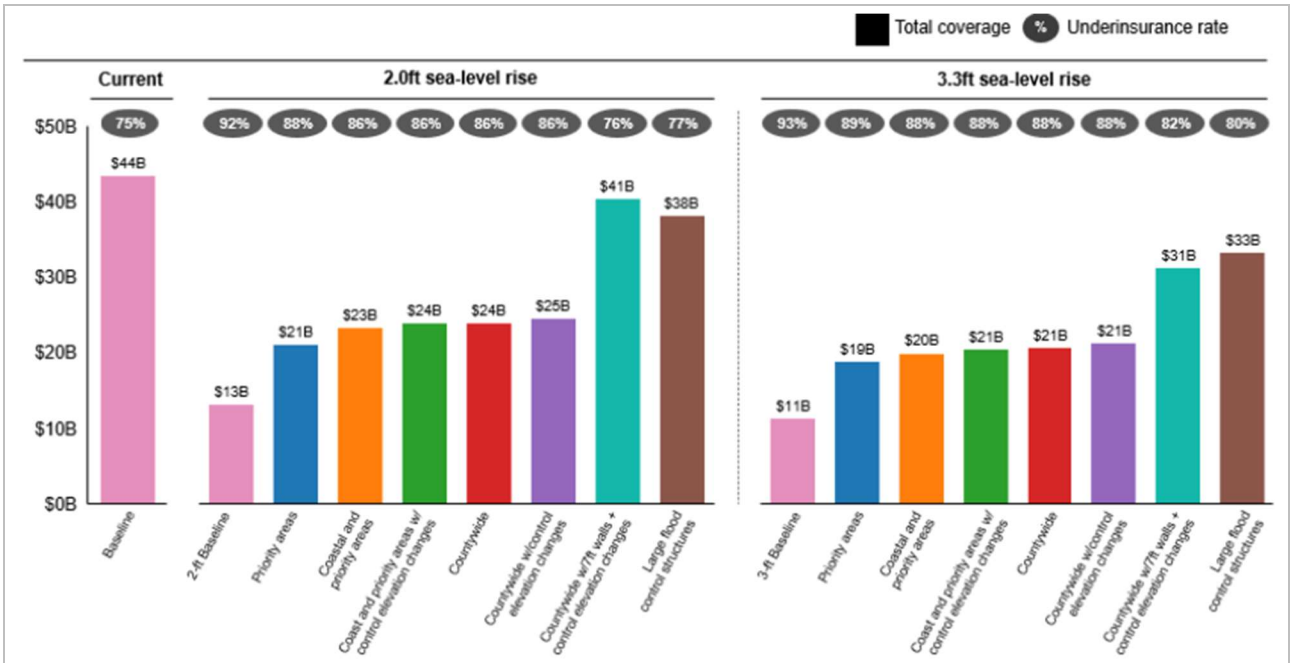
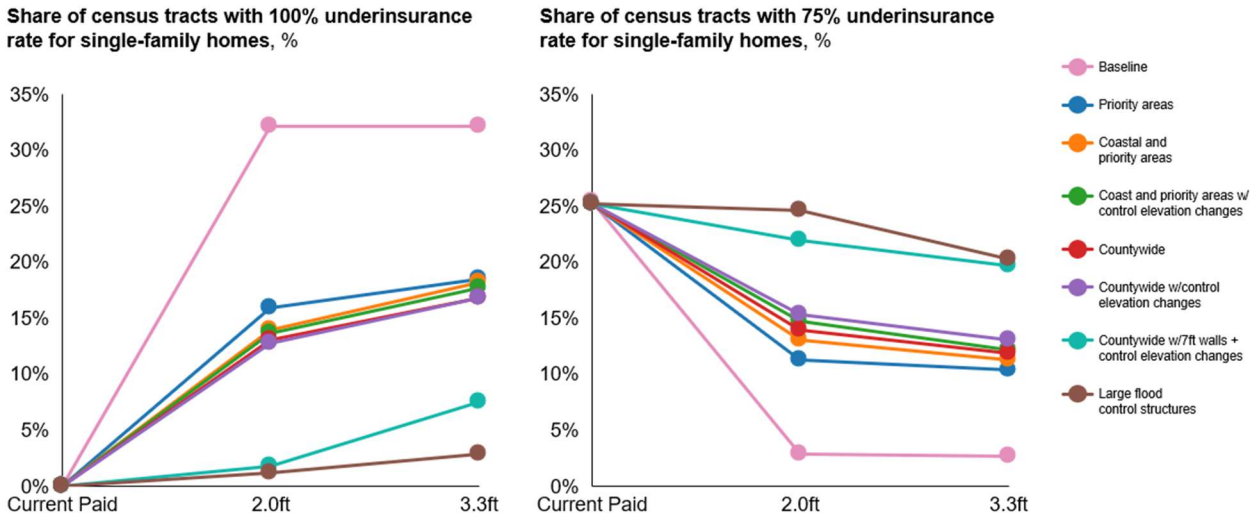



**Exhibit 11b: Underinsurance rates, defined as the value of uninsured assets as a proportion of the replacement value of assets**

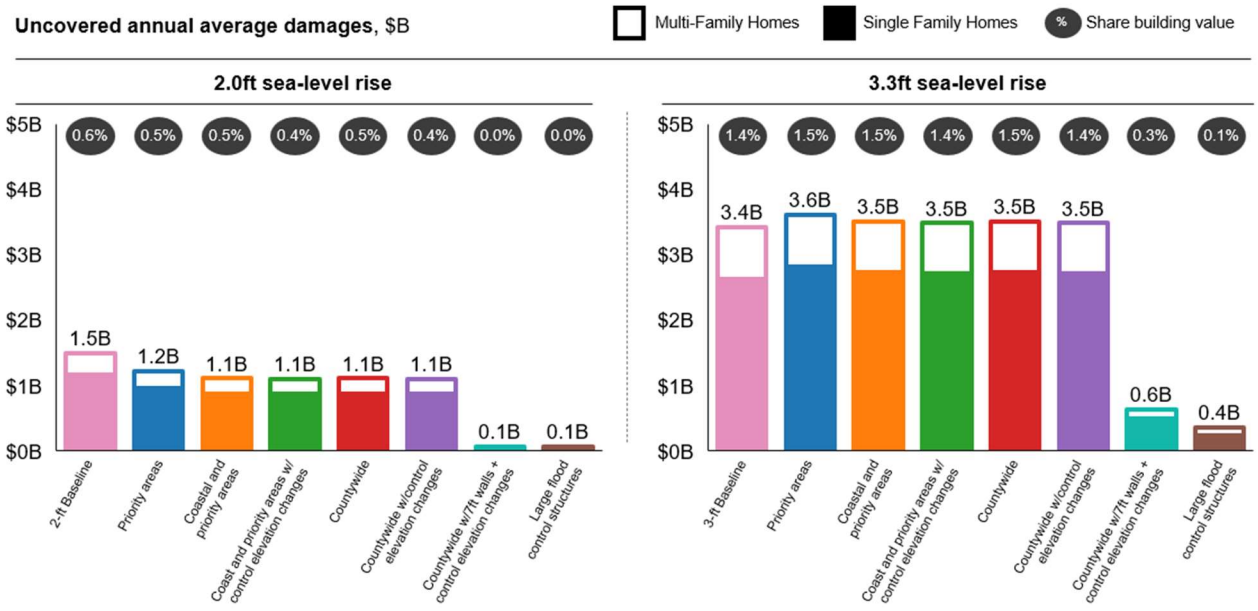



As a result of higher insurance coverage, annual uninsured damages are expected to be lower under the adaptation suites than under the baseline. As presented in **Exhibit 12**, annual uninsured damage in the baseline is estimated to be $1.5B by 2050 under 2 feet of sea-level rise and $3.4B under 3.3 feet of sea-level rise.

Under 2.0 feet of sea-level rise, most of the adaptation suites could reduce the uninsured damages by about 20% to 25% relative to baseline. The last two more comprehensive strategies mostly eliminate the uninsured damages under baseline. Under 3.3 feet of sea-level rise, only the last two more comprehensive

adaptation suites can reduce uninsured property damage but the reduction is an 80% elimination of the baseline uninsured damage (**Exhibit 12**).

**Exhibit 12: Average annual uninsured property damages assuming no re-mapping of special flood hazard areas**




## 8. Increased real estate values


**Summary of key findings**. The key findings of the real estate benefits evaluation are as follows.

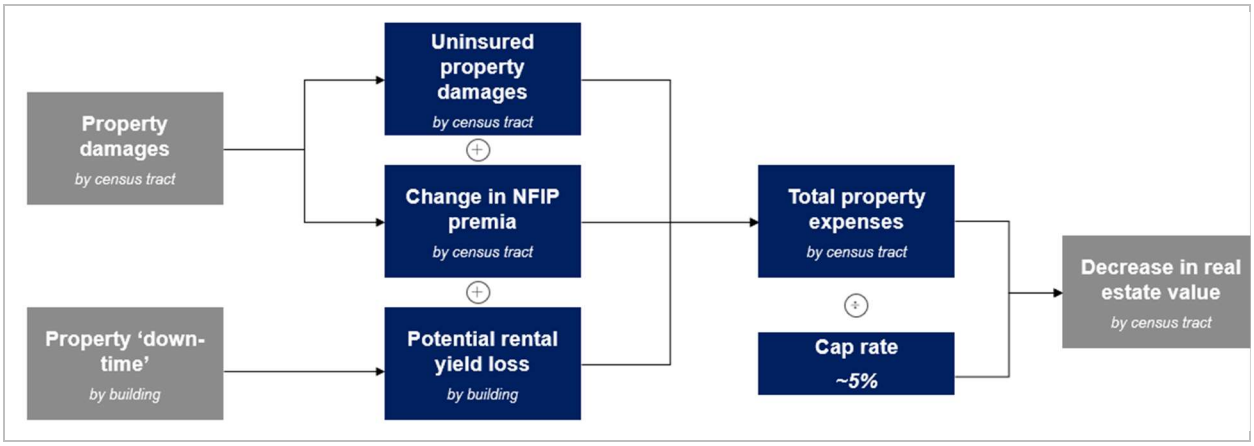
The real estate analysis assessed the benefits of adaptation on the valuations of homes and the associated fiscal tax impacts to the county. This is a first order analysis that focuses on the real estate directly affected by floods and does not consider market effects. For example, losses in certain parts of neighborhoods that are affected could depress real estate prices of other properties in the vicinity. On the flip side, migration to other parts of the county from affected areas could increase prices elsewhere.

The method used to estimate the impact of the baseline and adaptation strategies on real estate values is summarized in **Exhibit 13**. The estimated increase in real estate values are to be interpreted as how much more the property would be worth if the adaptation suite were implemented. Property values could be higher or lower over time and not track this estimated increase because other factors also influence property values, including mortgage interest rates, nationwide economic activity, and the propensity of people and businesses to move to south Florida independent of the effects of sea-level rise.

The previous baseline analysis found that the increased flood risk relative to current conditions could reduce the value of a residential property in Broward County by 18% under 2.0 feet of sea-level rise if no adaptation actions are taken. This could amount to $24B in dollar terms, with the primary driver being the

direct effect of uninsured property damages (see **Exhibit 13**). Changes in policy premia costs and loss of use are also factored into the analysis but tend to play a smaller role (**Exhibit 13**).

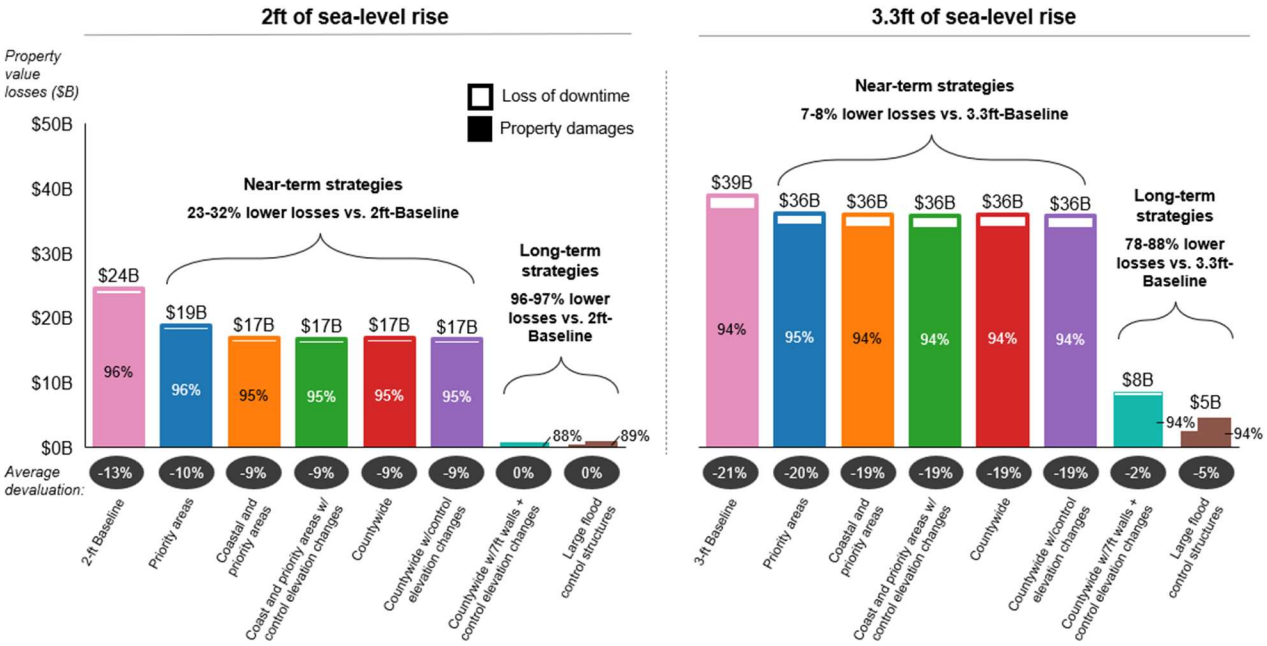
**Exhibit 13: Costs of Increased Flooding are Expected to Devalue Residential Properties**




As presented in **Exhibit 14**, five of the adaptation suites could mitigate the baseline reduction in residential real estate prices by 23% to 32% under 2 feet of sea-level rise, with the two more ambitious adaptation suites all but eliminating the baseline reduction in property value. Under 3.3 feet of sea-level rise, only about 7% to 8% of the baseline real estate value reduction under baseline be mitigated when five of the adaptation suites are implemented. When the last two more comprehensive suites are implemented, then about 78% to 88% of the baseline real estate value losses could be mitigated.

**Exhibit 14: Residential real estate property value losses across adaptation suites**

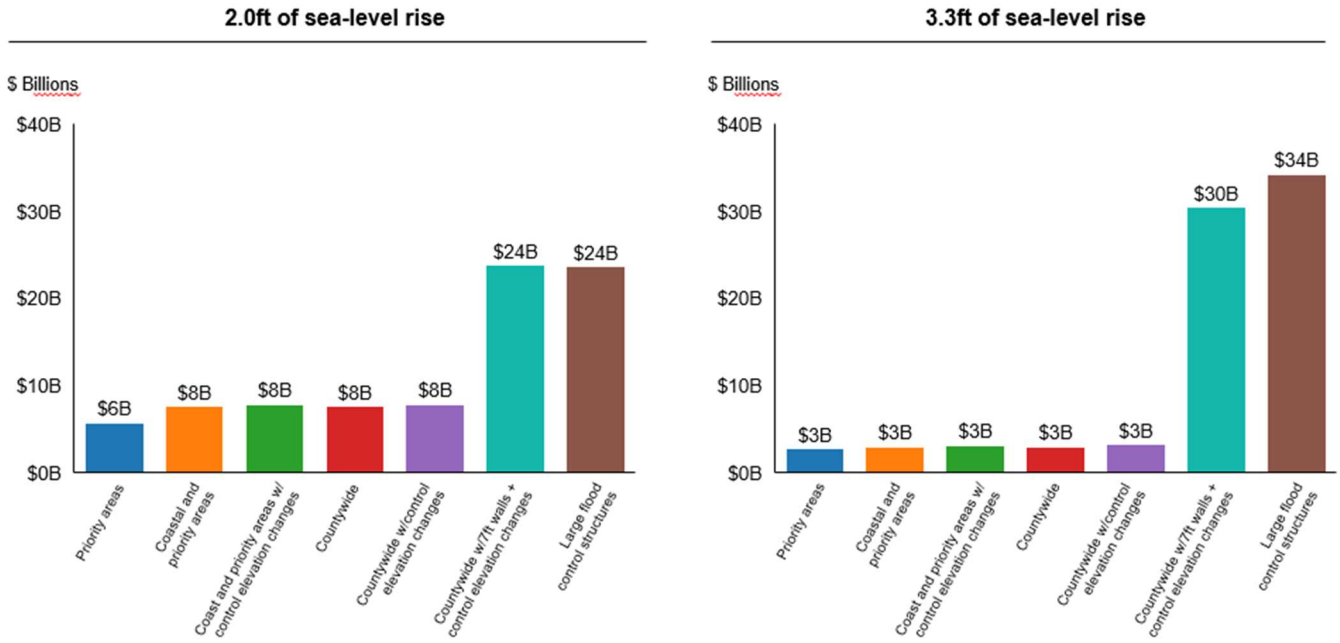
Inside each bar is the % of the property value reduction driven by average annual property damage



As with the baseline results, property value reductions are primarily driven by uninsured property damage (about 95%+ of the damages) and this impact on household cost is assumed to affect the valuation of the property. These potential losses under the baseline and under the adaptation suites are not evenly distributed across the county – they are particularly concentrated in areas that could be subject to higher flood risk under any conditions.

This evaluation found that the adaptations suites are expected to save about $6B to $24B in residential real estate value under 2feet of sea-level rise, and $3B-$34B in value under 3.3 feet of sea-level rise. **Exhibit 15** presents the potential savings for each adaptation suite. The losses broadly reflect the same trend as the direct flood damages (which are the key input) and are sensitive to assumptions regarding the capitalization rate.

**Exhibit 15: Savings in residential real estate property values across adaptation suites**



## 9. Increased tax collections

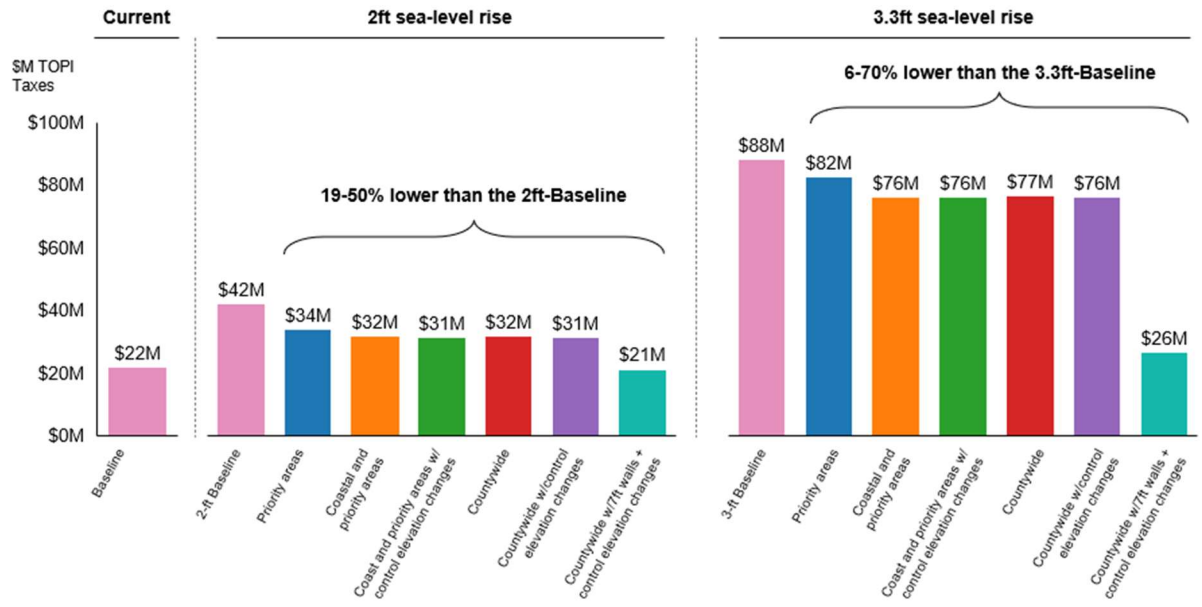

**Summary of key findings**. The reduction in tax revenue collected in Broward County due to increased flood risk was estimated. This tax revenue includes the reduction in production-related tax revenue associated with disrupted economic activity, and the reduction in ad valorem tax revenue associated with reduced real estate values. Production-related taxes include sales and excise taxes, customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and assessments.

Currently, average annual production-related tax revenue loss from flooding is estimated to be $22M countywide. Under the baseline condition with 2 feet of sea-level rise, the average annual tax revenue loss is $42M which is an additional loss of $20M relative to current conditions. The adaptation suites would mitigate the baseline loss of production-related tax revenue by $8M to $21M under 2 feet of sea-level rise and by $6M to $62M under 3.3 feet of sea-level rise, depending on the suite, with the more comprehensive suites providing the most savings in production tax revenue.

Under 2 feet of sea-level rise, average annual ad valorem tax revenue could be $200M to $800M higher than under baseline, depending on the adaptation measures pursued, with the most comprehensive suites maintaining tax revenue at current levels (in 2022 dollars). The results are similar under 3.3 feet of sea-level rise, where average annual property tax revenue would be $100M to $1.0B higher than baseline, with the two most comprehensive suites maintaining almost all (94%) of today's property tax revenue.

**Production-related tax revenue.** The average annual production-related tax revenue losses currently and under baseline and the adaptation suites for both sea-level rise scenarios are provided in **Exhibit 16**. The baseline assessment found that the average annual production tax revenue loss could increase from $22M to $42M under 2 feet of sea-level rise. The baseline average annual revenue loss increases to $88M under 3.3 feet of sea-level rise.

**Exhibit 16: Production-related tax revenue losses, average annual in 2022 dollars**



The adaptation suites are expected to reduce average annual production-related tax revenue losses by about $8M to $21M at 2 feet of sea-level rise, and about $6M to $62M at 3.3 feet of sea-level rise. The change in tax revenue is directly related to the change in economic activity caused by flood damage and transport disruption.

**Impacts on ad valorem tax revenue.** The ad valorem tax collected in the County is based on the assessed value of the property which is based on its market value. Also, other factors determine a property's ad valorem tax bill including existence of a Homestead Exemption and 13 other exemptions that provide tax advantages to homeowners, military veterans, seniors, active military and the disabled.

Homestead Exemptions are provided to residential property owners who permanently live in their homes and apply for the exemption. For properties with a Homestead Exemption, the Save Our Homes (SOH) provision under Florida Statutes limits the annual increase in the assessed value of a property to no more than 3% of the home's assessed value in the previous year (called the SOH value).

If the home's value falls from one year to the next, the home's SOH value is increased by 3% per year until the SOH value is equal to its market value. This is called the "recapture" rule. Once the assessed value reaches the market value of the home, the recapture rule no longer applies and the assessed value is adjusted downward when its market value falls resulting in a lower tax bill.

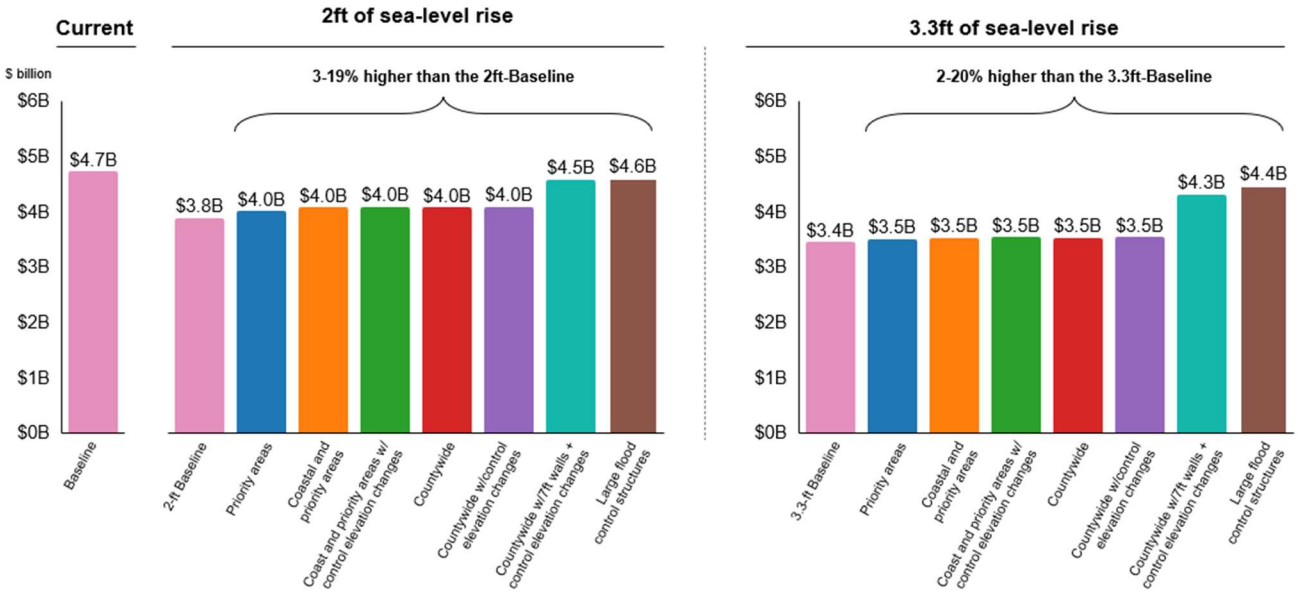
The method used to calculate the impact of sea-level rise on market value captures the distribution of the exemptions countywide but does not account for the impact of the SOH statute on ad valorem taxes when property values fall for Homesteaded properties. Thus, in the short-term, the estimated impacts of sea-level rise on ad valorem tax revenue will be lower than reported in this memorandum.

The average annual ad valorem tax revenue collected currently and under the baseline and adaptation suites with 2 feet and 3.3 feet of sea-level rise is presented in **Exhibit 17**. Without the adaptation suites, the current annual ad valorem tax revenue of $4.7B could fall to an average annual revenue of $3.8B, a 19% reduction, under 2 feet of sea-level rise. Under 3.3 feet of sea-level rise, average annual revenue could fall to $3.4B, a 27% reduction. Ad valorem tax revenue is an important source of government revenue, accounting for 37% of the County's total revenue in FY22.[2]

Under the adaptation suites, most of the ad valorem tax revenue losses can be recovered under the two most comprehensive suites. Under 2 feet of sew-level rise, average annual ad valorem tax revenue increases by $200M to $800M relative to the baseline tax revenue, with the most significant mitigation provided by the two more comprehensive suites. Under 3.3 feet of sea-level rise, average annual ad valorem tax revenue increases by $100M to $1.0B, with the more comprehensive suites providing the largest tax revenue savings.

[2] Based on Broward County's FY22 Annual Comprehensive Financial Report, page 7, total property tax revenue received by the County, most of which includes ad valorem tax revenue, was $1.2 billion. This amount is 37% of the $3.3 billion in total Broward County government revenue collected in FY22. This amount does include the $3.6 billion of property tax revenue allocated to the County's municipalities, school board, and other state and local government agencies.

**Exhibit 17: County-wide average annual ad valorem tax revenue across adaptation suites**




## 10. Benefits across the county, including vulnerable areas

In general, adaptation strategies reduce impacts in vulnerable areas as well as other parts of the county. The charts in **Exhibit 18** present these results through the lens of four types of impacts including residential damages, sales revenue loss, average premiums for single-family homes, and impacts on property values. Vulnerable areas are outlined in black and include census tracts with higher socio-economic vulnerability and census tracts located in areas of high flood risk.

For the 2-foot sea-level rise scenario, the baseline map can be compared to the adaptation suite that includes countywide adaptations with control elevation changes under the current 5-foot NAVD seawalls requirement. For the 3.3-foot sea-level rise scenario, the baseline map can be compared to the county-wide coverage with 7-foot NAVD seawalls.

Across the county, impacts are lower for all four metrics when moving from the baseline map to the adaptation suite map. The impacts are lower across the Zone 1 priority areas for vulnerability analysis and across the county more generally. The benefits tend to be more pronounced in the Zone 1 priority areas (as shown by the number of black outlined squares that are no longer shaded).

**Exhibit 18a: Average annual damages to residential assets as share of property value across the county – Direct residential damages**

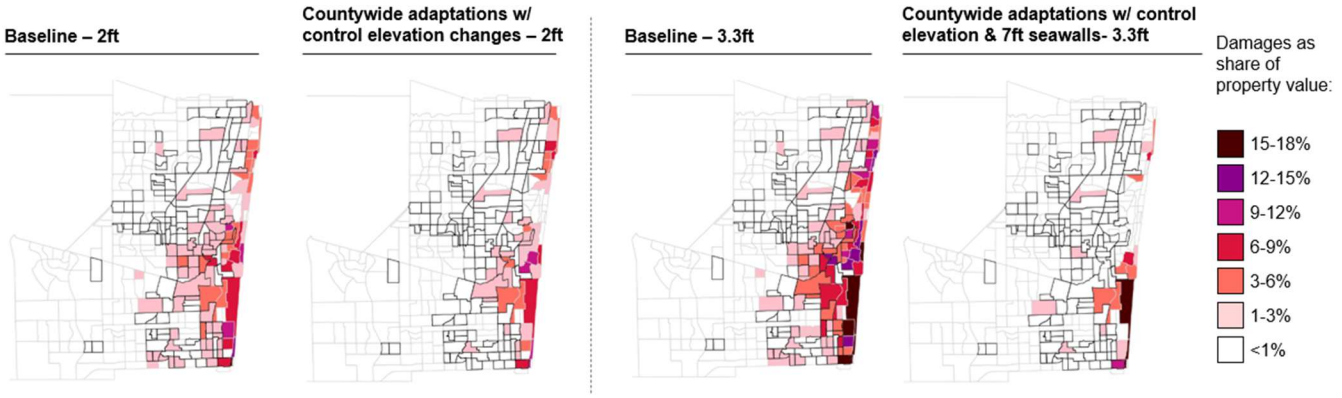



**Exhibit 18b: Average annual sales revenue loss ($M)**

**Exhibit 18c: Initial single-family home premiums across the County before considering their impact on affordability and the corresponding adjustments to coverage and premia**

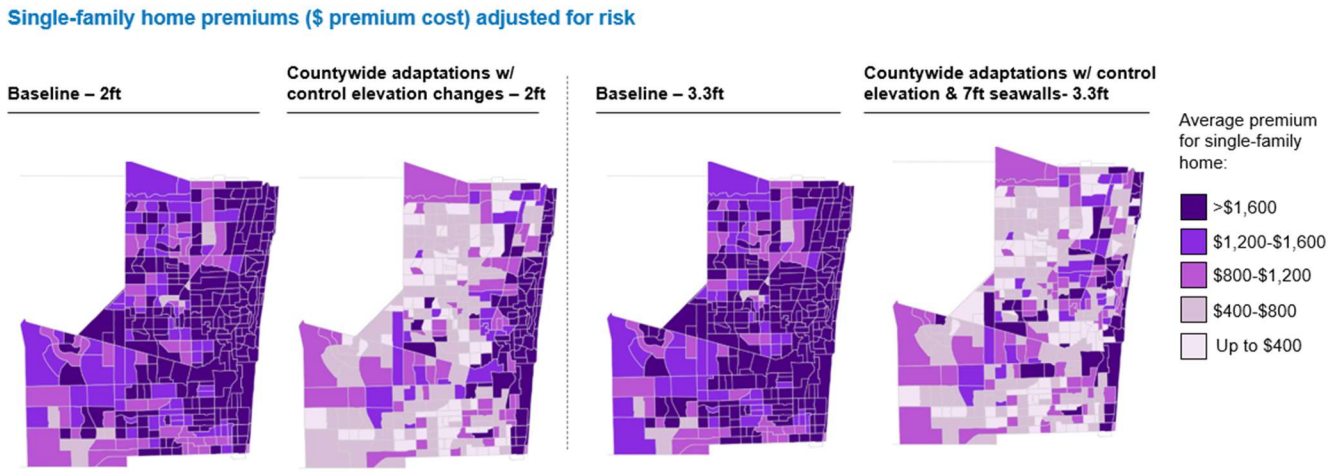
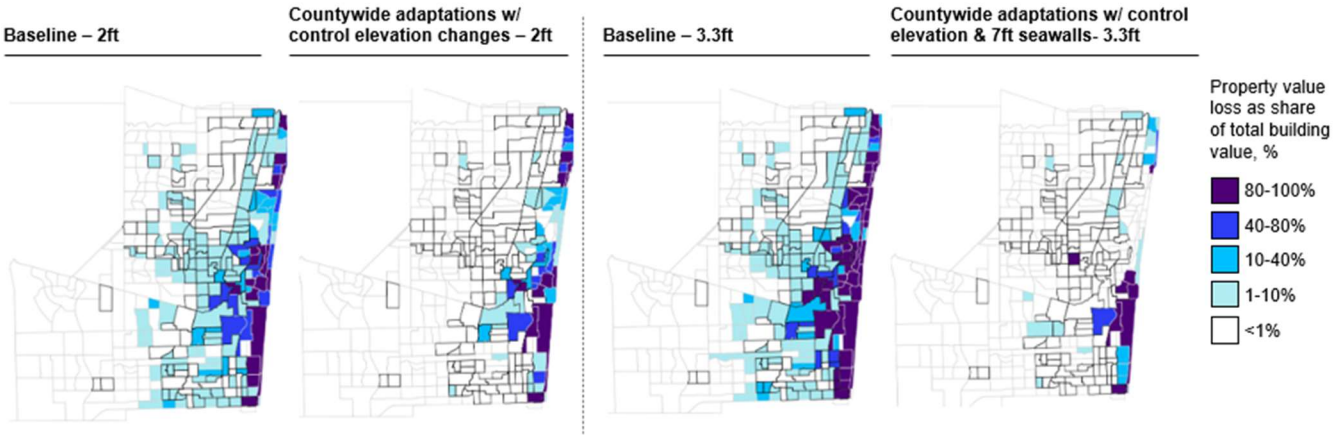



**Exhibit 18d: Real estate value losses across the County ($M losses)**

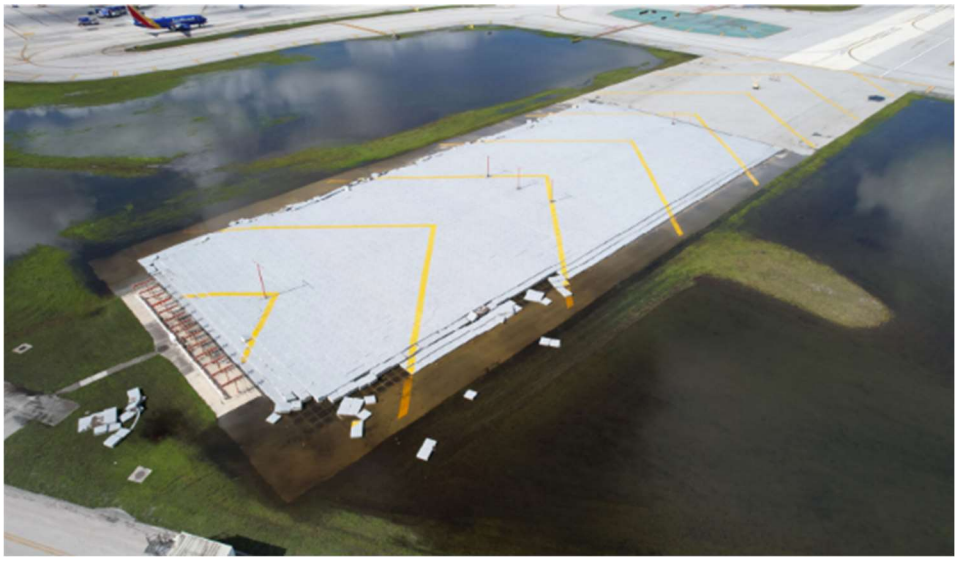



## 11. Sea-level Rise impacts on the County's airport and port

**Fort Lauderdale-Hollywood International Airport.** In April 2023, Fort Lauderdale-Hollywood International Airport experienced an extraordinary weather event, recording around 26 inches of rainfall in 12 hours. This unprecedented event, classified as a 1-in-1000-year occurrence, resulted in rainfall levels exceeding those typically observed during hurricanes.

The severe weather caused significant disruption to both the airfield and surrounding roadways, necessitating the closure of the airport by the Aviation Department. The estimated cost of direct damages was $17.5 million, primarily attributed to the extensive damage sustained by the EMAS (Engineered Materials Arrestor System) beds.

**Photo taken at FLL International Airport on April 13th 2023 (View of East end EMAS)**



The three main types of disruption and losses that the airport could face in the future are: (1) direct damages to terminal buildings, (2) disruption to access roads, and (3) disruption to flight traffic due to flooding on the airfield, especially runways and taxiways. Of these, the largest economic loss from a flood event (not just the airport, but air carriers and the public) would likely come from disrupted flight traffic.

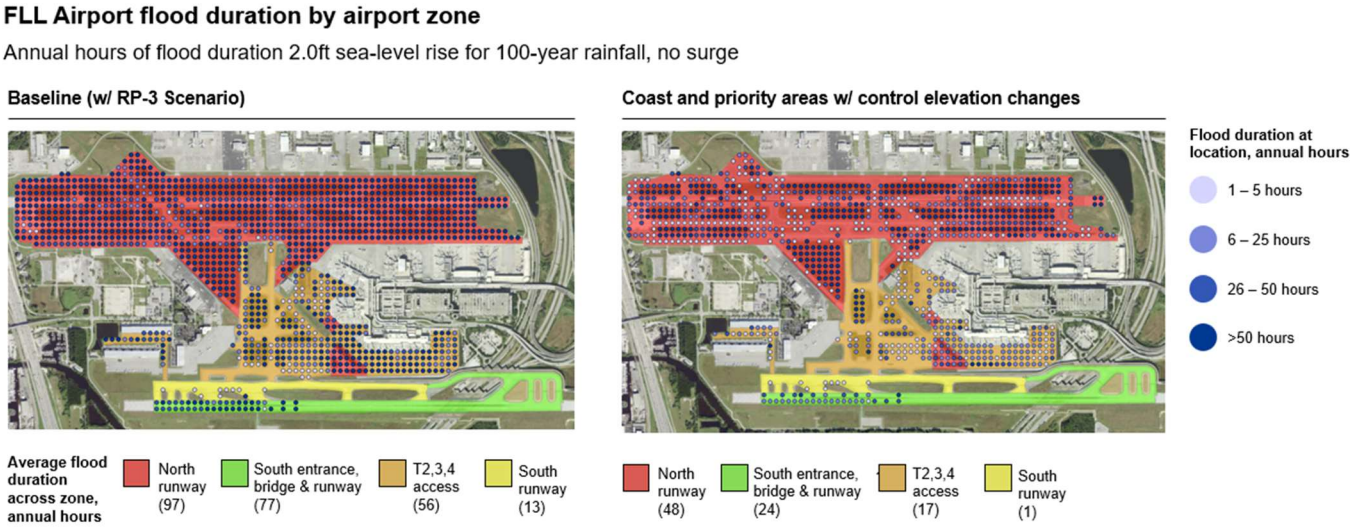
Estimating the annual average loss in airport sales and profits due to more frequent and severe flooding is challenging due to the complex nature of airport operations. For example, flooding in certain areas may only close one runway, or only selected taxiways or hangers. Flooding of access roads to the airport can impede passengers and crew.

The airlines can reallocate their fleets to other airports under a four to six month lead time or even faster, as network planning conditions warrant. Potentially, the increased frequency and extent of flooding has the potential to increase airport costs and reduce airport revenue. When considering potential reductions in flight activity as a function of reputational disruptions caused by unmitigated flood impacts, a five percent reduction in commercial operations could result in about a $12 million annual reduction in revenue and a fifteen percent reduction could result in about a $35 million annual revenue reduction.

Further losses to the economy are possible if businesses and tourists decide to use airports and stay at locations outside of Broward County because of airline reallocation or to avoid flood-induced airport disruptions. The GVA and job losses associated with this impact were not estimated during this study.

In **Exhibit 19**, the impacts of the adaptation strategies were compared to the baseline for an RP-3 flood event (2.0 feet of sea-level rise and 100-year rainfall with no storm surge). The metric is the number of hours of annual flood duration above 6 inches.

**Exhibit 19: Fort Lauderdale-Hollywood International Airport average annual hours of maximum flood duration by airport zone**



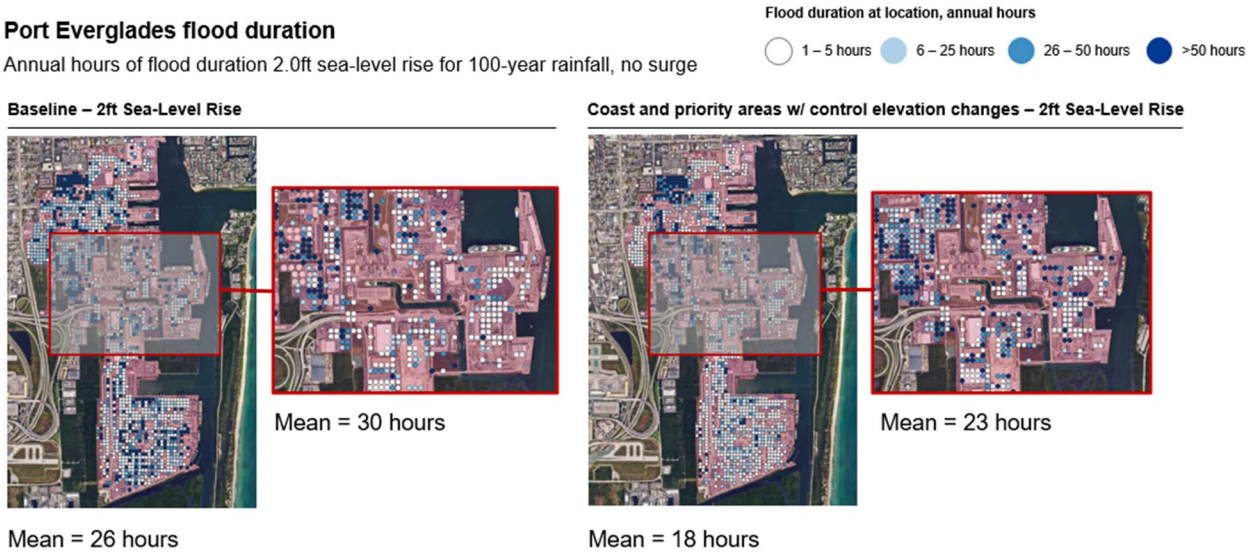

The exhibit shows that the area marked in red associated with the north runway could experience a significant reduction in flood duration of approximately 50% with the implementation of adaptation measures in *Coastal and Priority Areas w/Control Elevation Changes*, decreasing from around 100 hours in the baseline to around 50 hours under adaptation. The south runway is relatively less affected. In the baseline only the eastern edges are flooded, and this is mostly mitigated using the same adaptation strategy.

**Port Everglades.** Port Everglades is also at risk of flooding events due to its coastal position. During the 1-in-1000 year flood occurrence in April 2023, the pump systems used at the petroleum terminals were impacted, leading to severe disruption in fuel distribution. All 12 petroleum terminals were closed for 1 day, with the last one returning to service 9 days after the flood. While direct damage to the facilities was relatively minor, the disruption to fuel distribution was felt throughout the region.

**Exhibit 20** presents the results of a similar analysis conducted for Port Everglades under a 100-year rainfall event with no storm surge at 2.0 feet of sea-level rise. The annual number of hours flooded in the baseline at 2.0 feet of sea-level rise could be about 30 hours at the main access, and 26 hours across all port facilities including storage areas.

Under 2 feet of sea-level rise, annual flood duration would be approximately 25% to 30% lower if adaptation measures were pursued in the adaptation suite called “Coastal and Priority Areas w/ Control Elevation Changes”. The average annual number of hours flooded could be reduced from 30 hours to 23 hours at the main access and from 26 hours to 18 hours across all port facilities.

**Exhibit 20: Port Everglades annual hours of max flood duration**




## 12. Discussion of uncertainty

Climate change is an ongoing process with a variety of outcomes possible in the 21st century and beyond, as the world works to decarbonize and limit the impacts of greenhouse gas emissions on the Earth's climate. As a result, this analysis provides a view of possible scenarios in which a warming world could cause sea-levels to rise and storm surge and rainfall to increase in severity. For the purposes of this analysis, local sea-level rise scenarios of 2.0 feet and 3.3 feet were chosen, which correspond approximately with 2050 and 2070 estimates using NOAA's 2017 sea-level rise projections under the medium-high emissions scenario. Under other emission scenarios, these sea-level rise scenarios could occur at different times in the future. Uncertainty around timing and magnitude of sea-level rise is the largest uncertainty included in this analysis.

This analysis used a case study of 2.0-foot sea-level rise by 2050 and 3.3-foot sea-level rise by 2070. Significant deviations in sea-level rise will affect the need for and timing of the measures that comprise each Adaptation Strategy. Given these sea-level rise scenarios, the best available information was used to assess the benefits of the adaptation strategies.

Other uncertainties are those typical when evaluating conceptual projects and include the following.

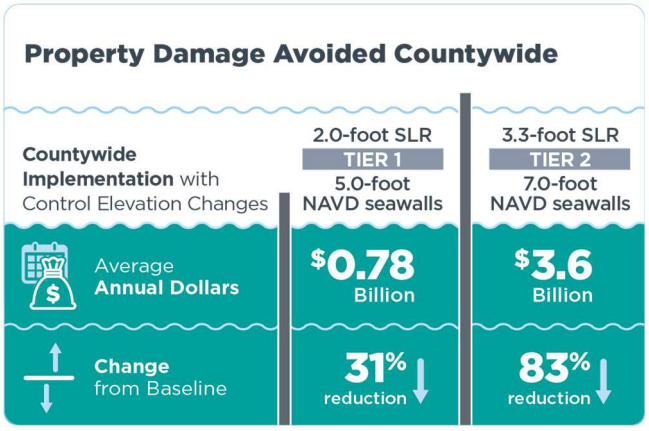
- Land uses, economic conditions and drainage infrastructure existing at the time of this study could be different during engineering design and construction of the adaptation suites resulting in differences in benefits and costs than those reported during this study.
- While the data used to assess damages and economic activity are of good quality, human and business responses to emergencies, regulations, incentive systems, and prices do not always mimic their past behaviour as reflected in the historic and current data used in this study.

For these reasons, the economic feasibility of adaptation measures and strategies should be revisited on a regular basis as investment decisions are being contemplated.

The estimated economic benefit values reported in this memorandum provide actionable information for the County to conduct resiliency planning. Because these analyses are based on scenarios, they do not require that the future is known. Rather, they allow leaders to plan for a range of possible futures and act now with the best information available at the time of analysis.

## 13. Benefit values of the Tier 1 and Tier 2 adaptation strategies

Given the benefit values presented in this memorandum, the adaptation suites with the greatest total benefits are the Countywide measures with control elevation changes. This adaptation strategy, where the current seawall height requirement of 5 feet NAVD is maintained but additional drainage features behind the seawalls in Lighthouse Point are added, is called Tier 1 and for the purposes of this study would be fully implemented by the year 2050 when sea-level rise is expected to be 2.0 feet higher than today.




By 2070, sea-level rise is expected to be 3.3 feet higher than it is today. To mitigate the increased flooding impacts, the flood control capabilities of Tier 1 would be enhanced by adding an additional 2 feet to the existing seawalls to achieve 7 foot NAVD seawalls in place of the 5 foot NAVD seawalls reflected in the Tier 1 strategy.

In addition, additional drainage features would be added, as needed, to protect property behind the seawalls from additional flooding caused by the higher sea levels. This adaptation strategy is referred to as Tier 2 and, for the purposes of this study, would be fully implemented by 2070.

Another adaptation strategy that includes large flood control structures delivered even greater benefit values. However, these structures would be relatively expensive and intrusive to the natural and aesthetic environment and are not further considered at this time.

A summary of the benefit values estimated during this study are provided in **Table 4**.

**Table 4 Summary Countywide Tier 1 and Tier 2 Benefit Estimates in 2022 Dollars**

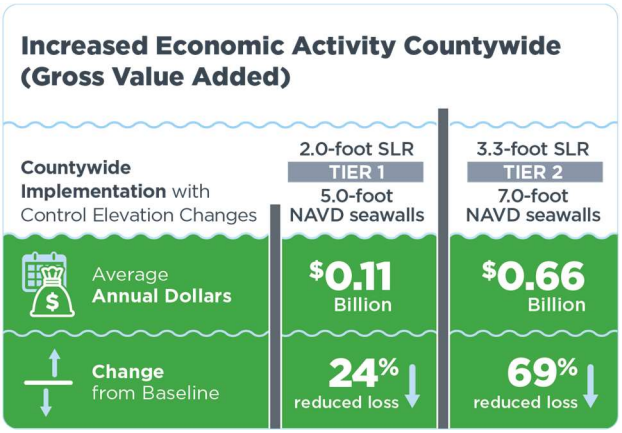
| Benefit Category | Tier 1 Adaptation Strategy to Mitigate 2-foot SLR | Tier 2 Adaptation Strategy to Mitigate 3.3-foot SLR |
|---|---|---|
| Property Damage Avoided, average annual | $776,000,000 | $3,600,000,000 |
| Increased Short term Economic Activity, average annual | $109,000,000 | $660,000,000 |
| Increased Property Tax Collected, average annual | $211,000,000 | $962,000,000 |
| Increased Real Estate Value | $8,000,000,000 | $30,000,000,000 |
| Increased Flood Insurance Coverage | $12,000,000,000 | $20,000,000,000 |

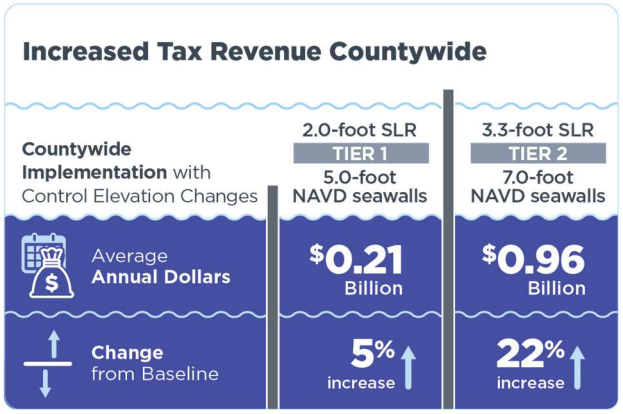
The average annual benefits of the Tier 1 adaptation strategy when sea-level rise is 2.0 feet include an estimated $776 million in avoided property damage, $109 million in short term economic activity (gross value added), and a $211 million increase in property taxes collected. Property values are estimated to be $8 billion higher and flood insurance coverage is expected to be $12 billion larger than the baseline strategy of no action.

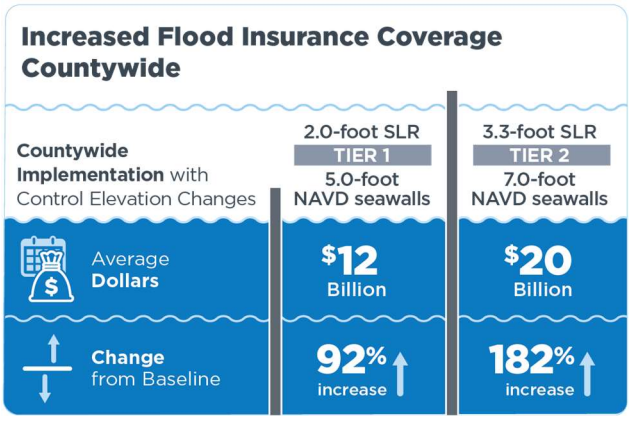
The average annual benefits of the Tier 2 adaptation strategy when sea-level rise is 3.3 feet include an estimated $3.6 billion in avoided property damage, $660 million in short term economic activity (gross value added), and a $962 million increase in property taxes collected. Property values are expected to be $30 billion higher and flood insurance coverage is expected to be $20 billion larger than in the absence of flood mitigation action.

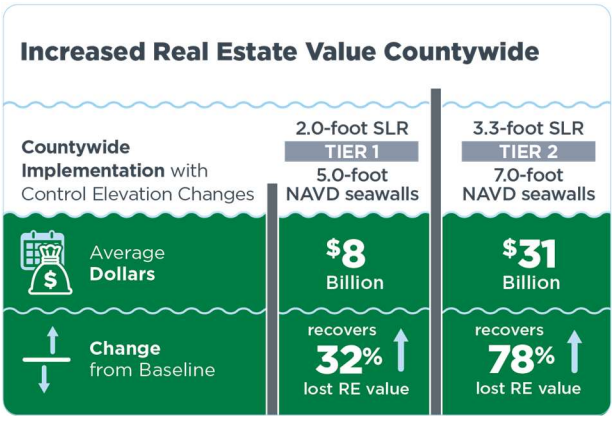
The values for property damage avoided, increased economic activity, and increased real estate value will be included along with the capital and annual cost of Tier 1 and Tier 2 to assess the economic feasibility and economic internal rate of return of these two suites of adaptation strategies.

Other benefits whose dollar values were estimated will not be included in the economic feasibility evaluation because they would be double counting the benefits. These benefit values are the increased flood insurance coverage and the reduced flood insurance premia which are included in the estimated property damages and the increased property tax revenue which is included in the real estate benefit value. However, these other benefits do have meaning to residents and businesses as the cost of everyday expenses are mitigated when flood adaptation strategies are implemented.



There are other benefits of the Tier 1 and Tier 2 Adaptation Strategies that should also be included in the economic feasibility evaluation but could not be estimated during this study. These benefits would further stabilize the County's wellbeing and economy by reducing the negative impacts of sea-level rise. Many of these impacts would increase economic activity as measured by gross value added and could, therefore, be included in the economic feasibility evaluation. These other benefits are as follows.

- **Reduced disruption to public services.** Mitigating flood damage to critical infrastructure such as power grids and road networks can reduce the negative impacts to other services (e.g. communication and health care) with cascading benefits to health and wellbeing.
- **Increased investment.** Mitigating property damage from flooding is expected to reduce perceived investment risk resulting in lower borrowing costs, and potentially improving economic investment, growth and wellbeing relative to the baseline.
- **Avoided demographic disruptions.** Decreases in the frequency and extent of flooding caused by sea-level rise could improve the quality of life and public safety that could reduce or prevent out-migration, increase or stabilize in-migration, and incentivize people to continue to live in areas that would have experienced higher flood risks. The results of these benefits would be an increase in population, higher consumer demand, higher employment, and greater tax revenue relative to baseline.
- **Increased tourism**. Flood mitigation can stabilize and possibly increase tourism capacity and improve the County's attractiveness as a vacation destination, resulting in economic growth relative to baseline.
- **Human capital benefits**. Flood mitigation can improve physical and mental health, increase household wealth, and improve education relative to baseline.

These benefits could be further evaluated in future studies as the adaptation strategies are refined.

The estimated economic benefit values reported in this memorandum provide actionable information for the County to conduct resiliency planning. These benefit values were based on certain assumptions and circumstances that could change over time, including future drainage investments by other entities, changes in economic conditions, and future climate change and its effects. For these reasons, the benefit values and economic feasibility of adaptation measures and strategies should be revisited on a regular basis as investment decisions are being contemplated.

**Appendix A-1: Average annual percentage change in flood damage to residential properties relative to baseline under Tier 1 and Tier 2 adaptation strategies by municipality**

| Municipality | Baseline average annual flood damages and Tier 1 and Tier 2 percentage changes Relative to Baseline (negative % means reduction in property damage) | | | |
|---|---|---|---|---|
| | Baseline under 2ft SLR ($M in damages to residential homes) | Tier 1 % change - Countywide w/ control elevation changes under 2ft SLR | Baseline under 3.3ft SLR ($M in damages to residential homes) | Tier 2 % change - County-wide measures, w/ control elevation changes and 7ft seawalls under 3.3ft SLR |
| Coconut Creek | $3,690,000 | -40% | $3,710,000 | -40% |
| Cooper City | $6,190,000 | -55% | $6,660,000 | -58% |
| Coral Springs | $15,160,000 | -61% | $15,290,000 | -61% |
| Dania Beach | $44,850,000 | -20% | $94,890,000 | -78% |
| Davie | $43,540,000 | -34% | $45,060,000 | -23% |
| Deerfield Beach | $69,920,000 | -2% | $157,630,000 | -81% |
| Fort Lauderdale | $822,250,000 | -19% | $1,751,330,000 | -79% |
| Hallandale Beach | $68,940,000 | -23% | $164,910,000 | -49% |
| Hillsboro Beach | $25,680,000 | -10% | $37,180,000 | -10% |
| Hollywood | $322,520,000 | -57% | $610,540,000 | -72% |
| Lauderdale By The Sea | $40,610,000 | -58% | $99,250,000 | -99% |
| Lauderdale Lakes | $2,350,000 | -75% | $2,590,000 | -69% |
| Lauderhill | $15,990,000 | -67% | $17,800,000 | -48% |
| Lighthouse Point | $58,620,000 | -69% | $176,000,000 | -91% |
| Margate | $13,170,000 | -40% | $13,270,000 | -40% |
| Miramar | $45,230,000 | -57% | $56,380,000 | -63% |
| North Lauderdale | $2,100,000 | -87% | $2,170,000 | -88% |
| Oakland Park | $42,440,000 | -41% | $72,060,000 | -75% |
| Parkland | $3,680,000 | -26% | $3,800,000 | -28% |
| Pembroke Park | $580,000 | -90% | $670,000 | -89% |
| Pembroke Pines | $15,500,000 | -67% | $16,100,000 | -67% |
| Plantation | $20,470,000 | -60% | $21,740,000 | -51% |
| Pompano Beach | $180,240,000 | -20% | $385,220,000 | -82% |
| Southwest Ranches | $2,920,000 | -17% | $2,950,000 | -18% |
| Sunrise | $4,830,000 | -67% | $5,290,000 | -68% |
| Tamarac | $3,890,000 | -72% | $4,170,000 | -70% |
| Unincorporated | $16,190,000 | -55% | $28,030,000 | -73% |
| West Park | $10,700,000 | -68% | $11,170,000 | -67% |
| Weston | $2,590,000 | -29% | $2,680,000 | -31% |
| Wilton Manors | $85,740,000 | -70% | $165,030,000 | -98% |