Risk, Mitigation, & Planning

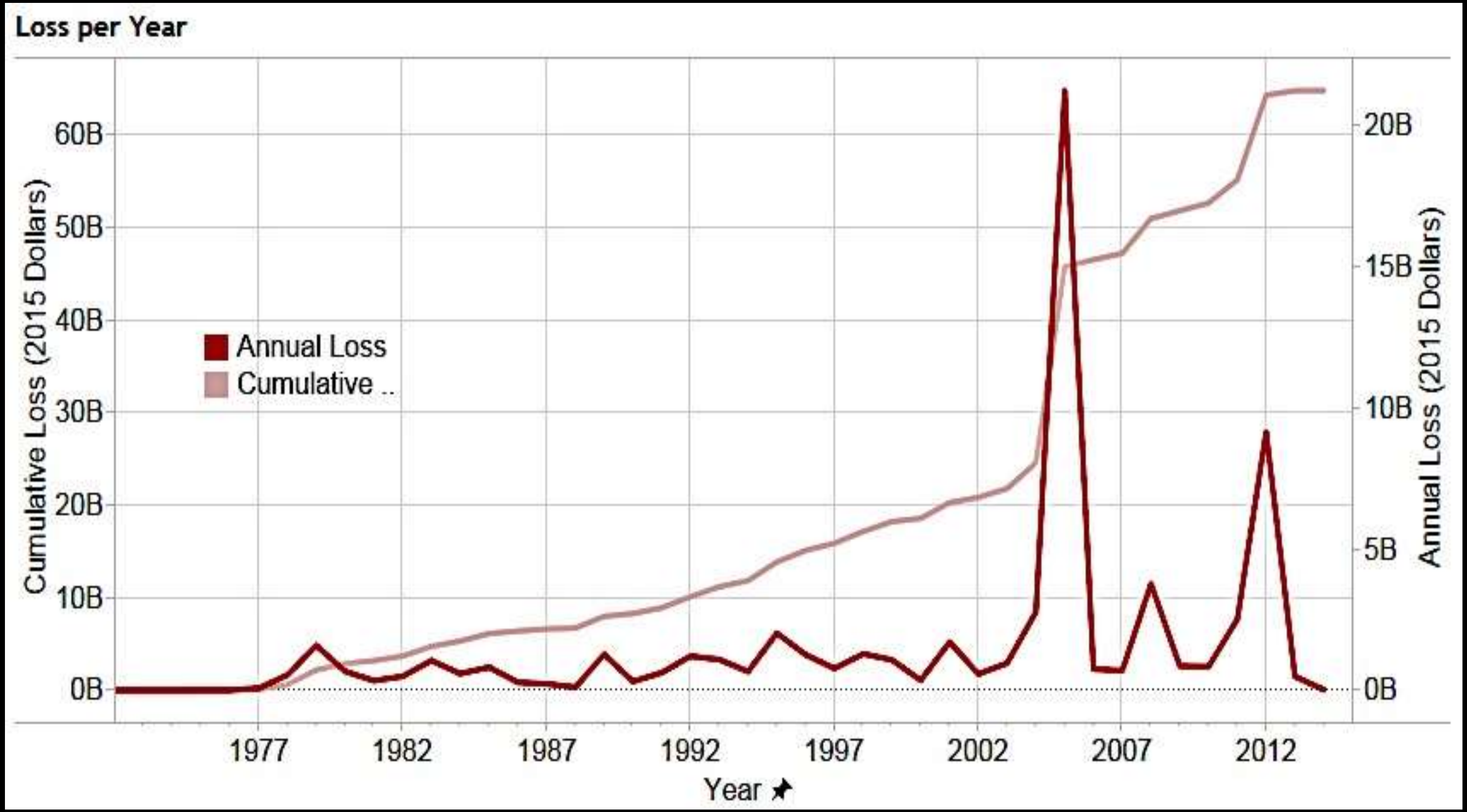
Lessons from Flooding in the Houston Area

Russell Blessing, Samuel Brody & Wesley Highfield

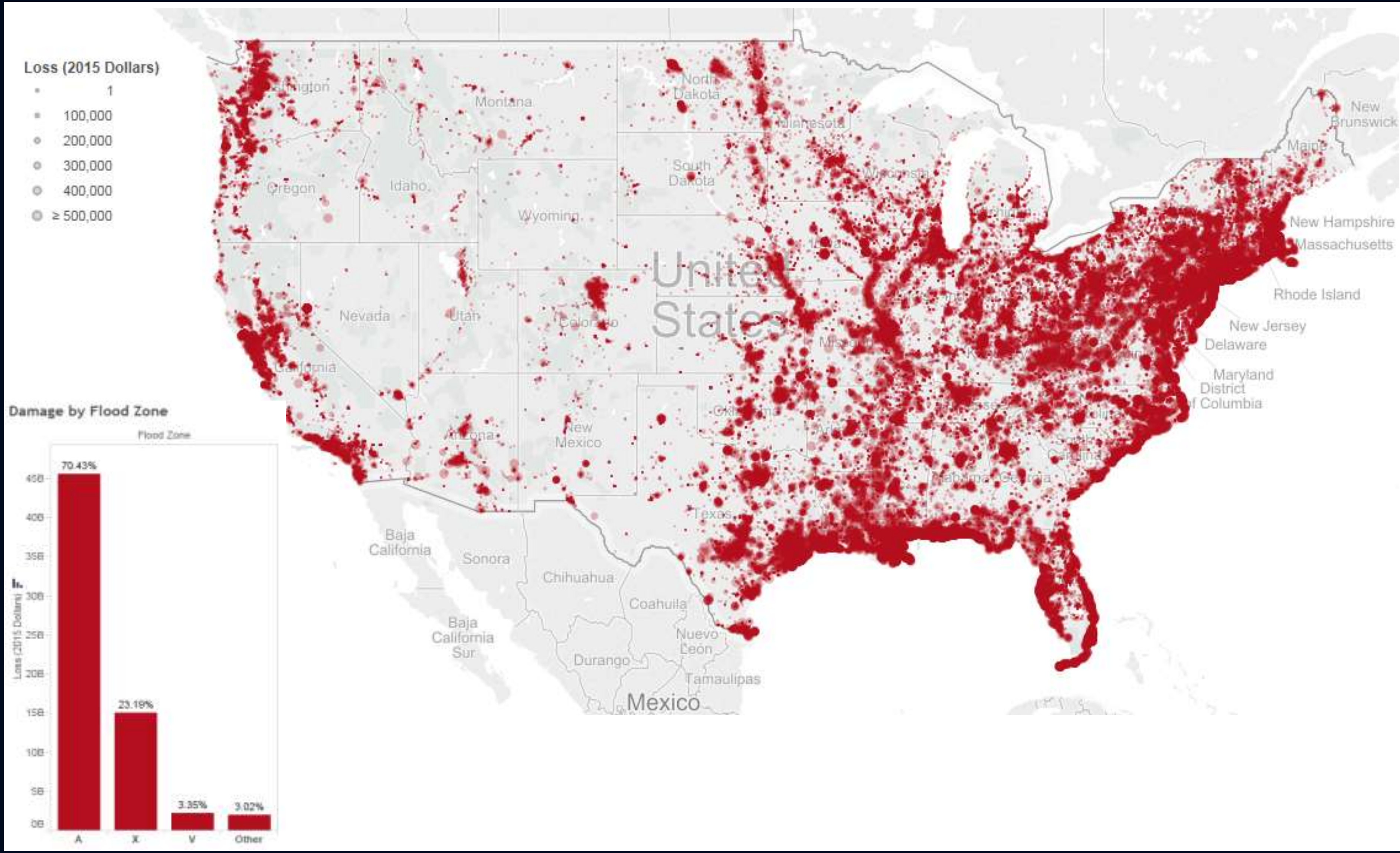
CTBS The Center for Texas Beaches and Shores

TEXAS A&M UNIVERSITY at GALVESTON

Cumulative Flood Loss: 1972-2015



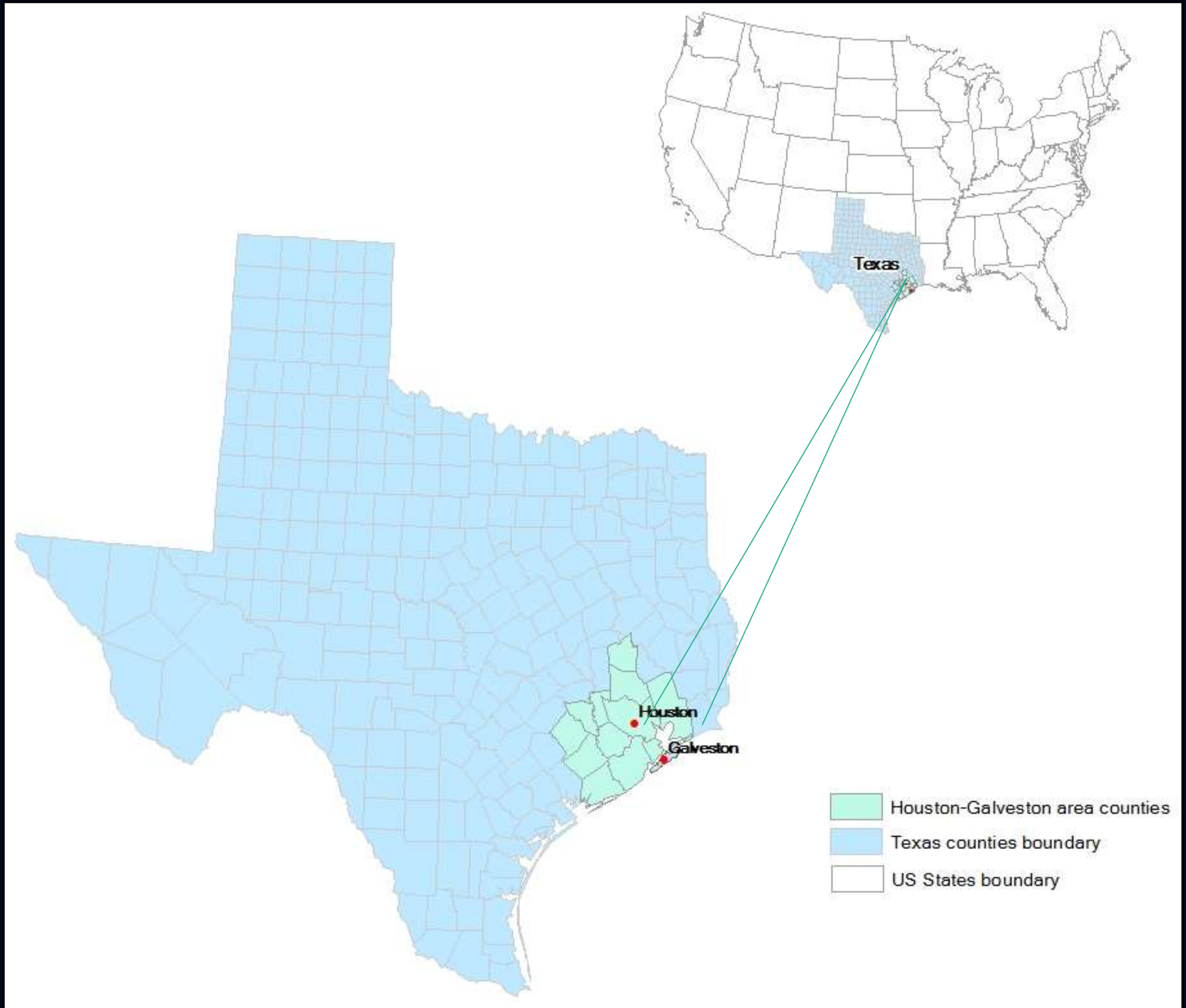
INSURED FLOOD LOSS: 1972-2015




Country Club
AUDUBON
Audubon Golf Club
Audubon Park
Audubon Park Zoo
WEST RIVERSIDE
Clarence Henry Truckway
Marrero
Westbank Expy
West Jefferson Medical Center

Pelican Island
Galveston Channel
Port of Galveston
Harborside Dr
Gulf of Mexico

The Houston-Galveston Region

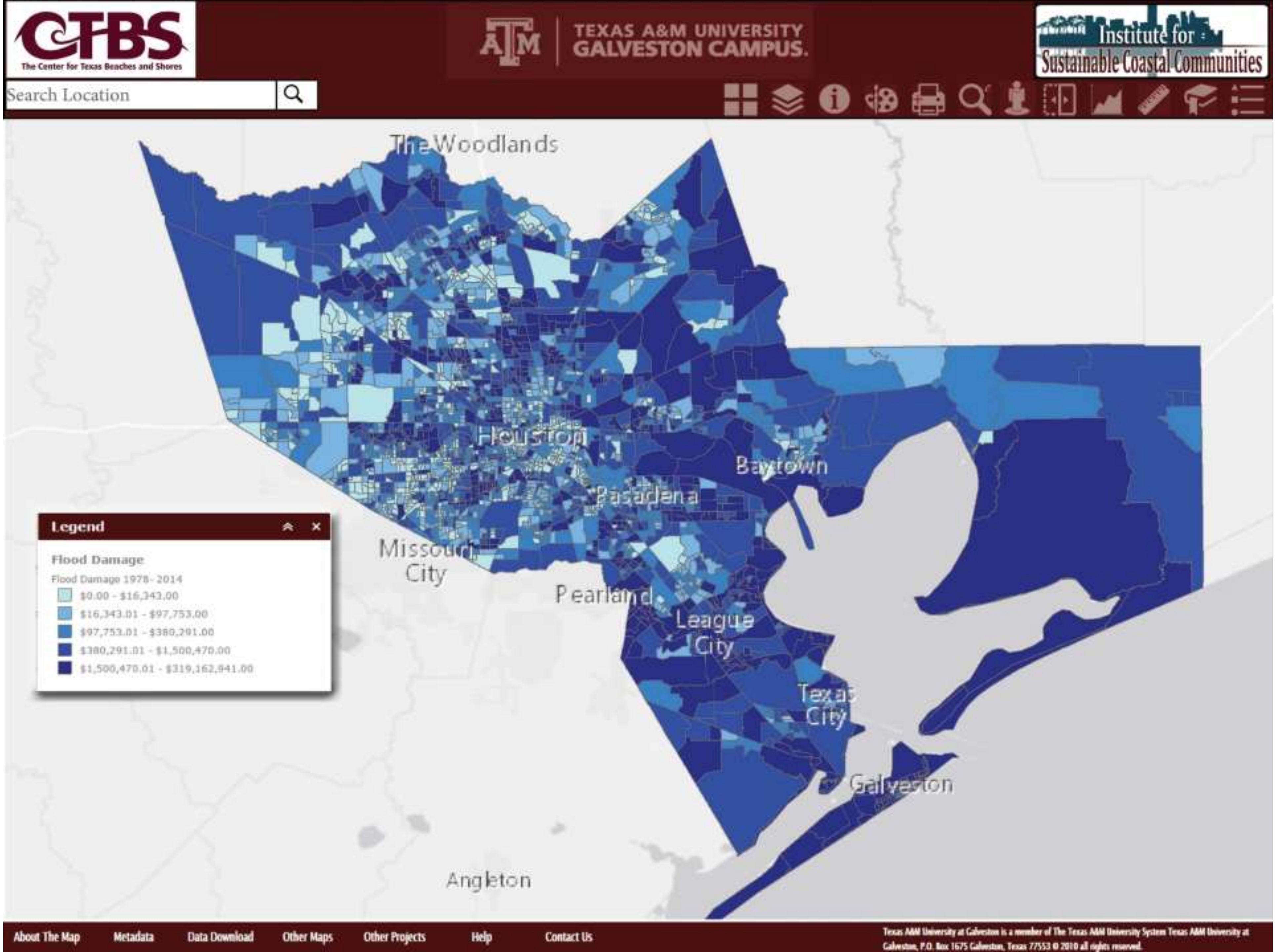


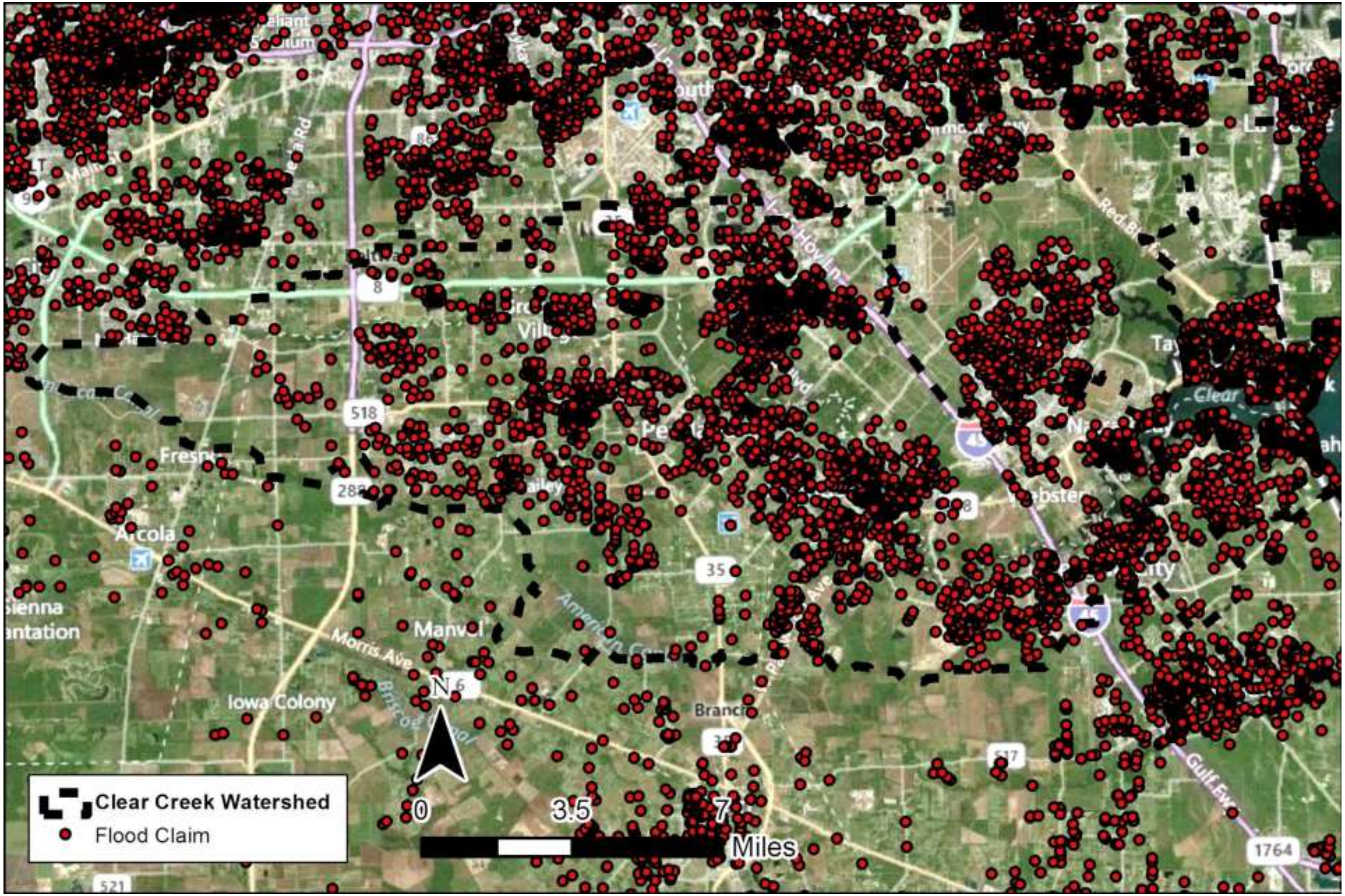
Galveston Bay Area Flooding

- Houston is one of most flood prone cities in U.S.
- Rapidly moving weather systems result in explosive rainfalls
- Little topographic relief, clay soils, and impervious surfaces contribute to large volumes of runoff and ponding
- Low lying coastal areas subject to surge
- Older homes with little elevation are subject to street flooding
- Population growth of 3.7 million people is expected in the region by 2040 (annual growth of ~100,000 people)

Chronic Flooding in Harris County

- 6/10 of the most flood-damaged coastal zip codes
- the most flood-related fatalities in the U.S. in the last 50 years
- 47% of all flood claims (1996-2007) were outside of the 100 year floodplain boundary


CTBS
The Center for Texas Beaches and Shores
TEXAS A&M UNIVERSITY
GALVESTON CAMPUS.
Institute for
Sustainable Coastal Communities
Search Location
The Woodlands
Houston
Baytown
Pasadena
Missouri City
Pearland
League City
Texas City
Galveston
Angleton
Legend
Flood Damage
Flood Damage 1978- 2014
$0.00 - $16,343.00
$16,343.01 - $97,753.00
$97,753.01 - $380,291.00
$380,291.01 - $1,500,470.00
$1,500,470.01 - $319,162,941.00
About The Map
Metadata
Data Download
Other Maps
Other Projects
Help
Contact Us
Texas A&M University at Galveston is a member of The Texas A&M University System Texas A&M University at Galveston, P.O. Box 1675 Galveston, Texas 77553 © 2010 all rights reserved.



Clear Creek Watershed
Flood Claim
0
3.5
7
Miles
N

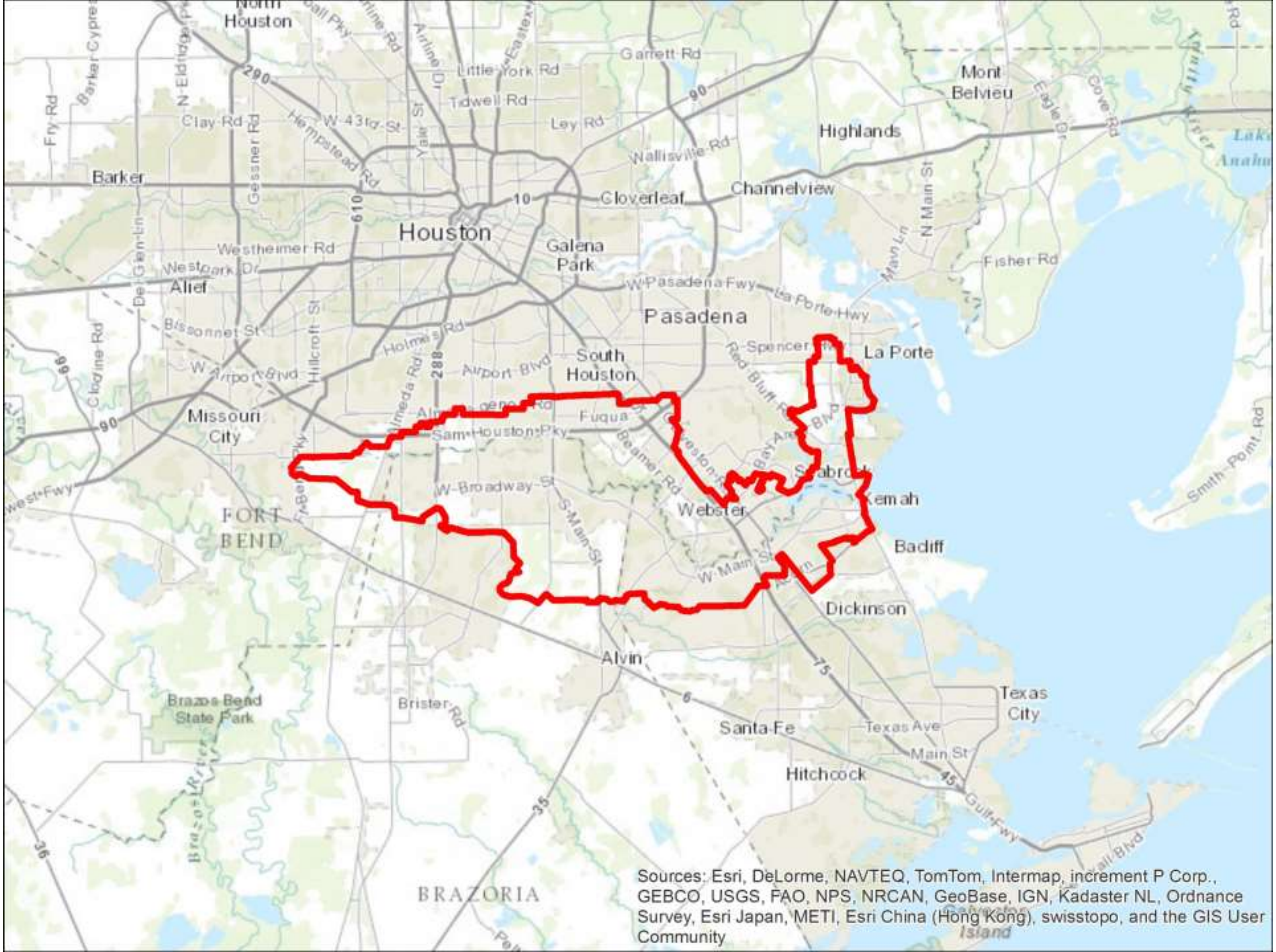
An Inadequate Indicator of Risk

The FEMA 100-year Floodplain

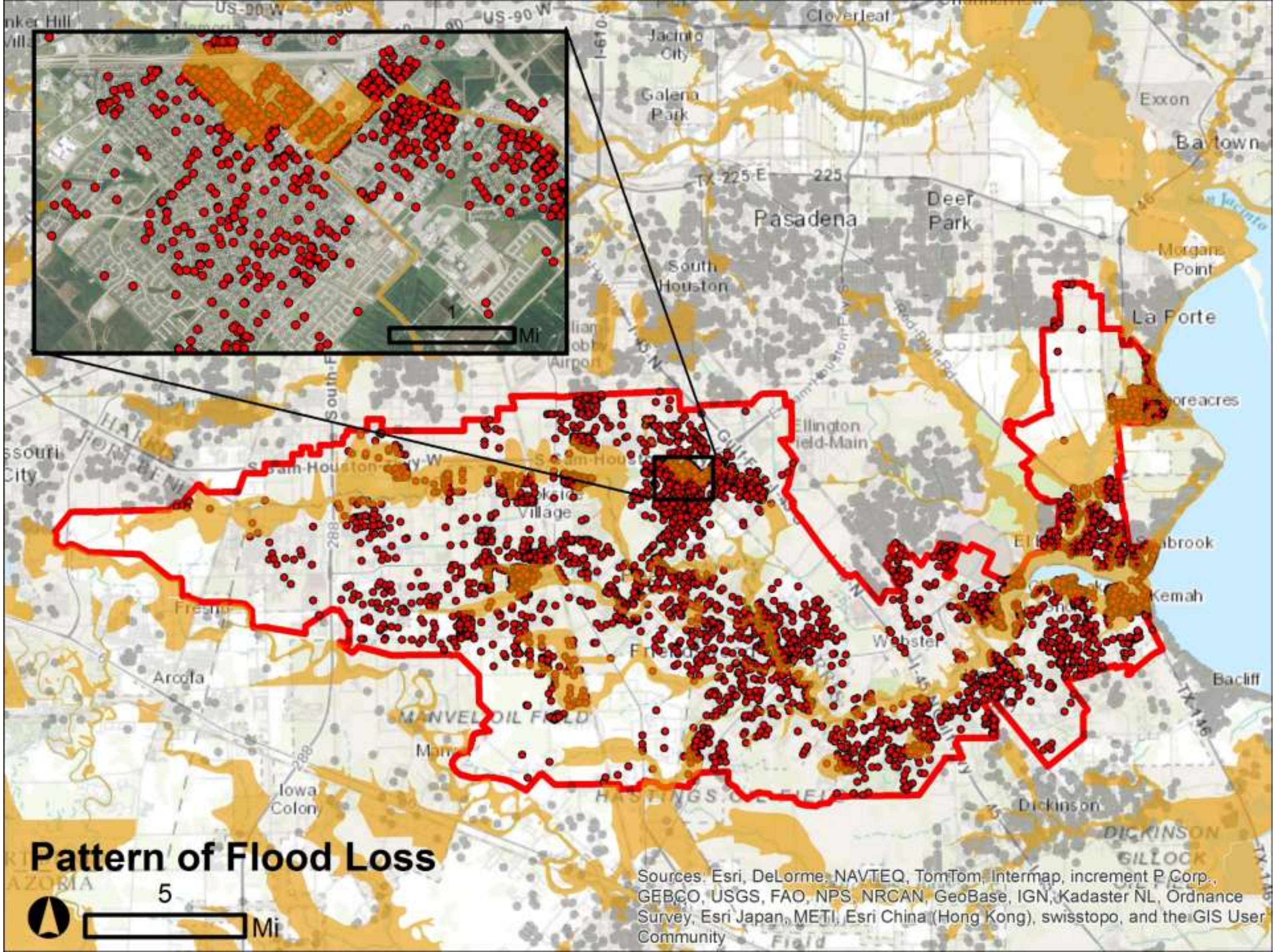
Two-Part Study

1. Examined the characteristics of flood loss occurring outside the floodplain.

2. Identified the drivers of flood loss outside the floodplain.



North Houston
Houston
Barker
Alief
Missouri City
FORT BEND
Galena Park
Cloverleaf
Channelview
Highlands
Mont Belvieu
Pasadena
South Houston
La Porte
Webster
Kemah
Dickinson
Alvin
Texas City
Santa Fe
Hitchcock
Brazos Bend State Park
BRAZORIA
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community


Pattern of Flood Loss
5
Mi
1
Mi
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community
US-90 W
Cloverleaf
Jacinto City
Galena Park
Exxon
Baytown
Pasadena
Deer Park
Morgans Point
South Houston
La Porte
Ellington Field-Main
Webster
Kemah
Bacliff
Dickinson
Arcola
Iowa Colony
MANVEL OIL FIELD
TX-225-E
225
288

Importance of Proximity

- Properties further away from floodplain experience less damage
  - 1 foot = $23.20 decrease in reported damage

…BUT…

- Living a quarter mile outside the floodplain still leaves an expected loss of **$12,972**.

Drivers of Flood Loss Outside the Floodplain

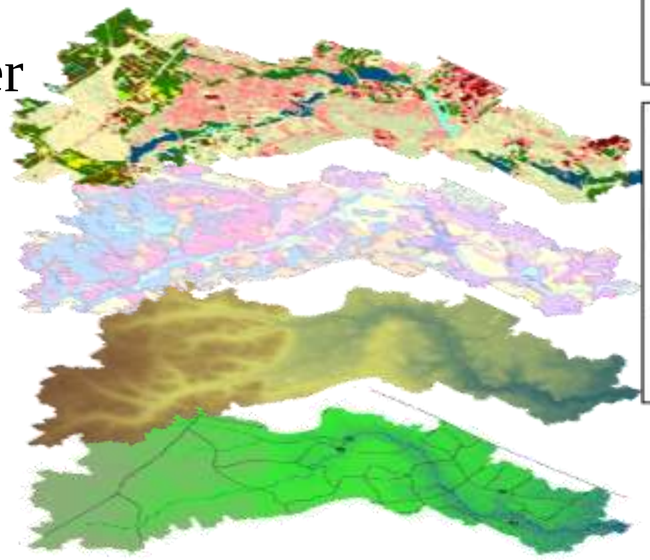
- **Disconnect b/w floodplains and actual loss**
  - Model uncertainty
  - Risk is a gradient
- **The 100-year flood is a moving target**
  - Changes in development
  - Changes in storm intensities and frequencies
- **Storm Characteristics**
  - Intensity
  - Duration
  - Antecedent rainfall

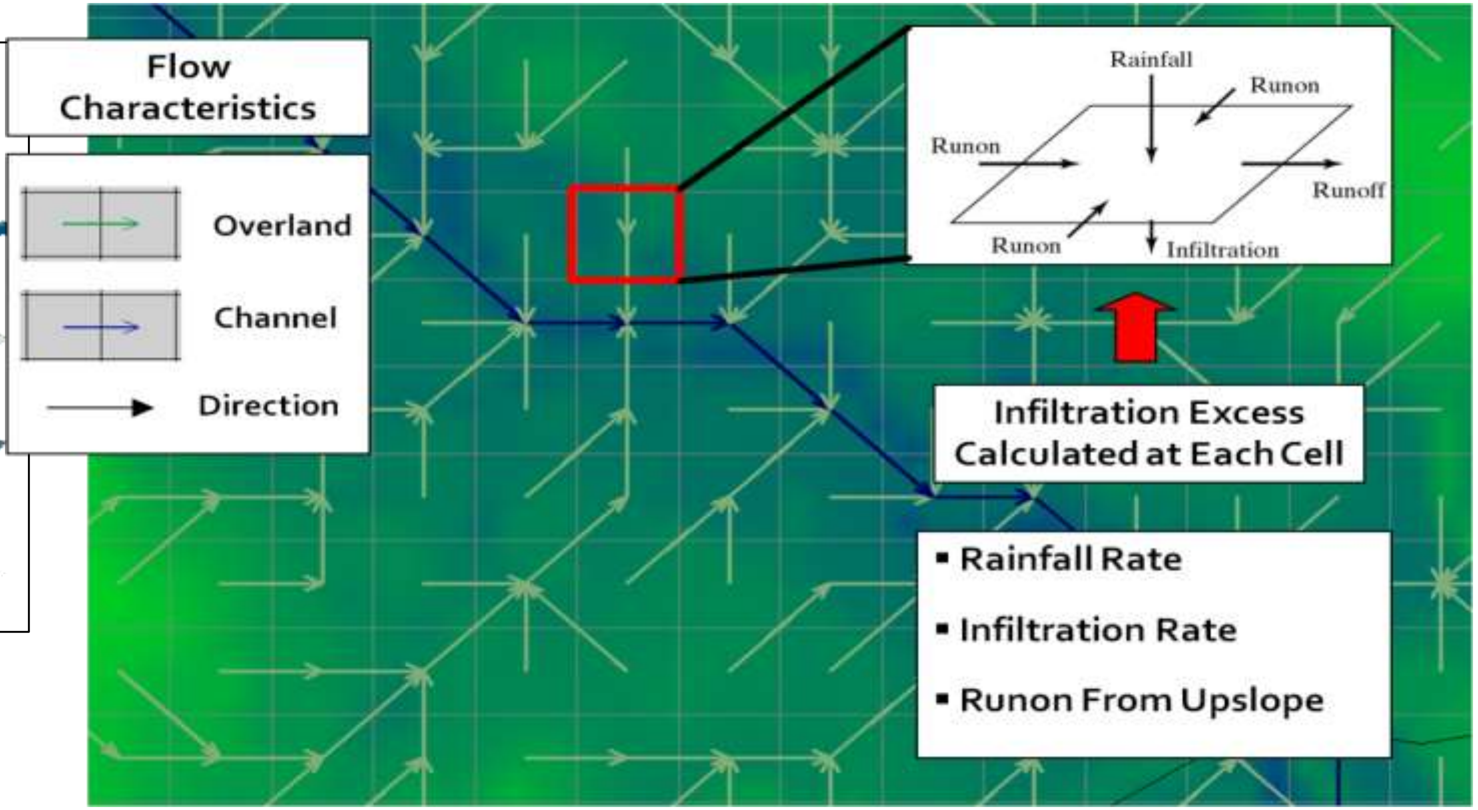
Comparing Models of Flood Risk

Can spatially distributed models better capture historical flood damage?

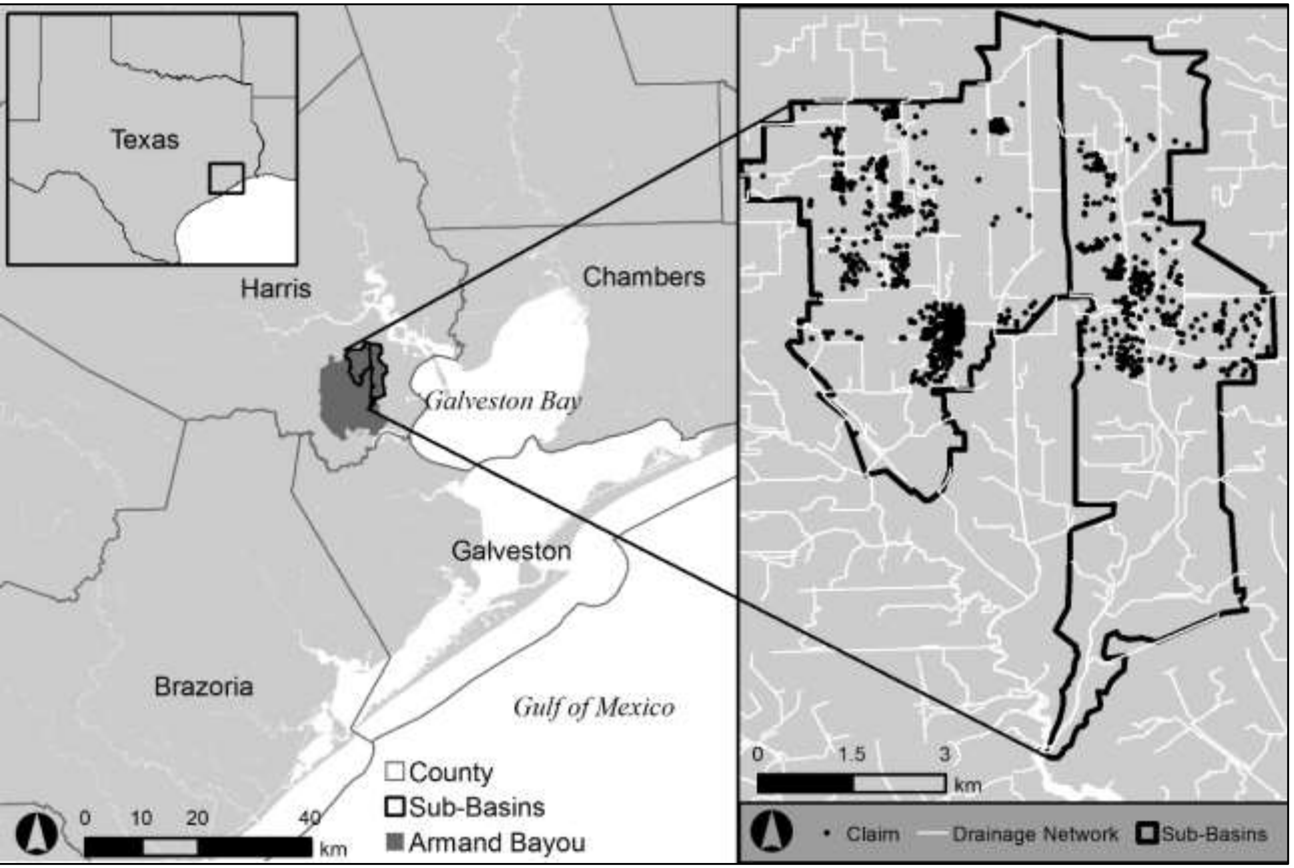
2D fully distributed hydrologic model **vs** FEMA's 100-year floodplain

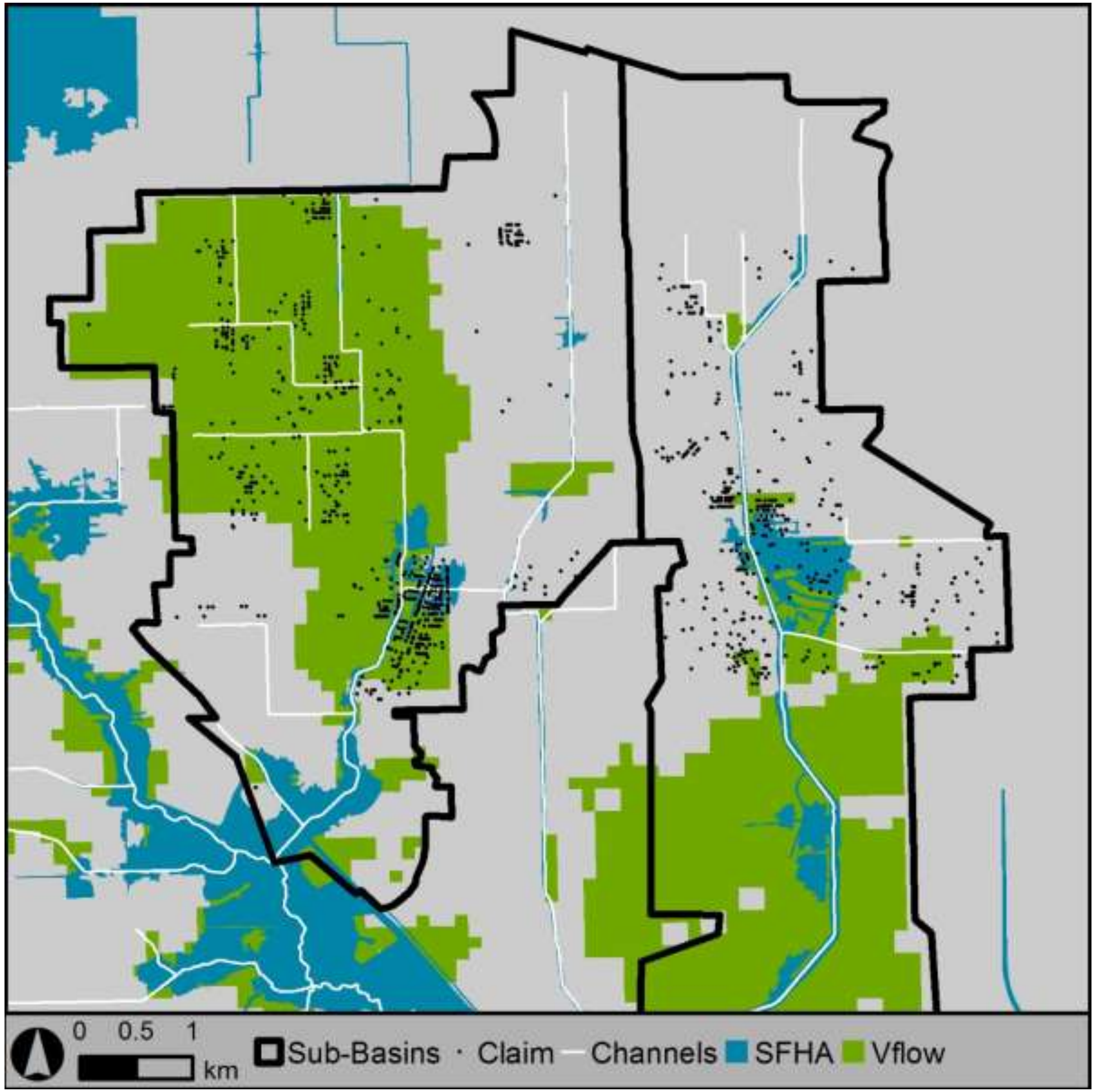
Land Use/Cover
+
Soils
+
Elevation
=
***Vflo*[TM] Model**





Green and Ampt Parameters:
USGS Soil Data Mart & NOAA CCAP 2006





	Captured Damage		Captured Claims	
	Vflo	**SFHA**	**Vflo**	**SFHA**
Allison	81.8%	29.8%	76.5%	24.5%
Erin	55.6%	13.0%	53.1%	15.3%
Ike	31.5%	18.0%	47.7%	7.3%
April	68.0%	13.0%	66.7%	12.8%
Oct	81.2%	48.9%	69.6%	21.7%
Other	38.2%	0.0%	80.0%	0.0%
Total	74.2%	25.5%	67.9%	19.9%

Two Key Points

1. Changing LULC is a key driver of flood loss outside the 100-year floodplain.

2. Even the most advanced model of flood risk will be undermined by changes in LULC.

Mitigating Flood Risk

The Community Rating System

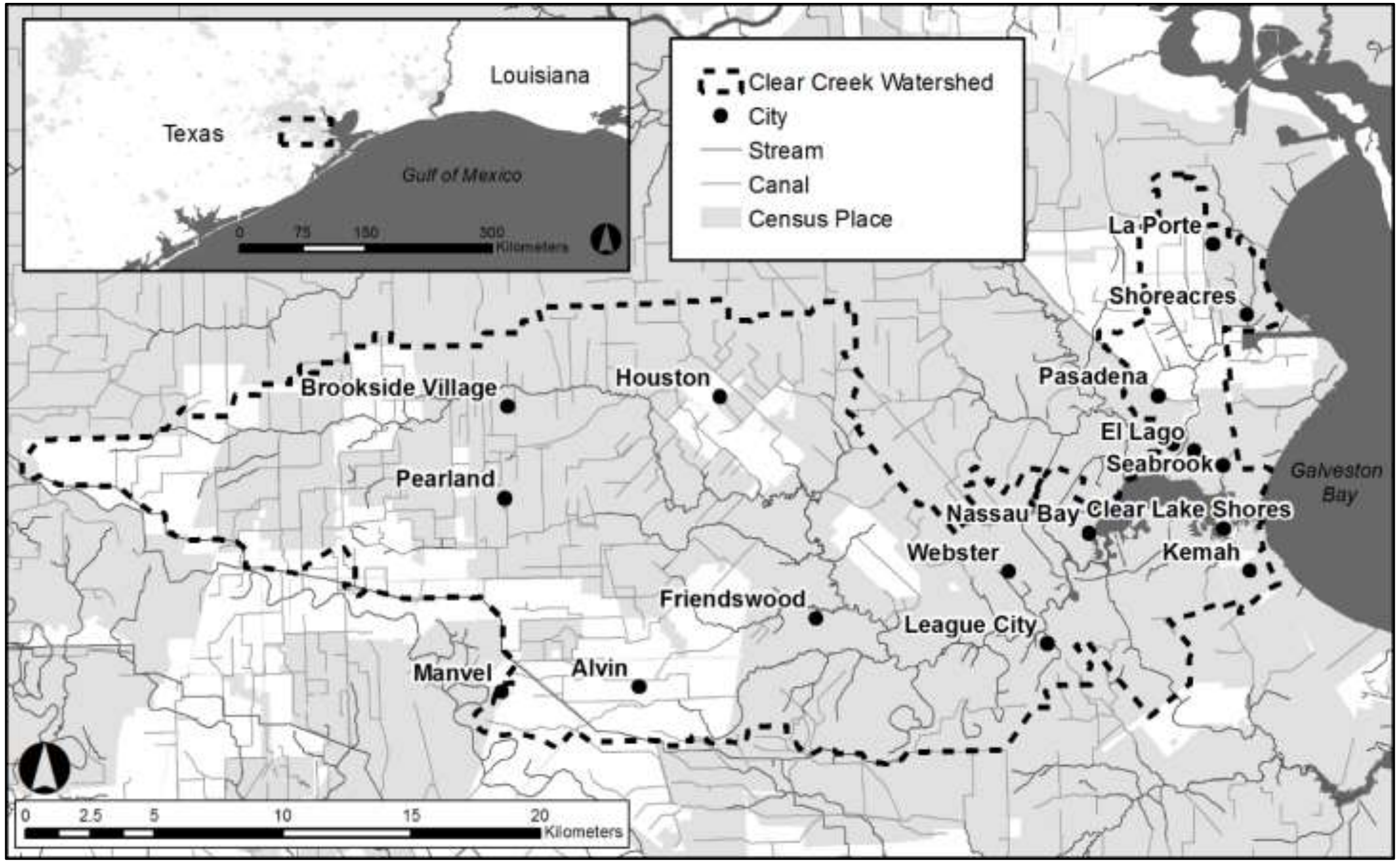
Two-Part Study

1. Examined the effect of CRS activities at reducing flood losses and insurance premiums.

2. Generated a scenario based cost benefit analysis of CRS avoidance based strategies.

Offsetting Rising Premiums

- Clear Creek Watershed: 1999-2009
- *How much would premiums have increased had HFIAA gone into effect?*

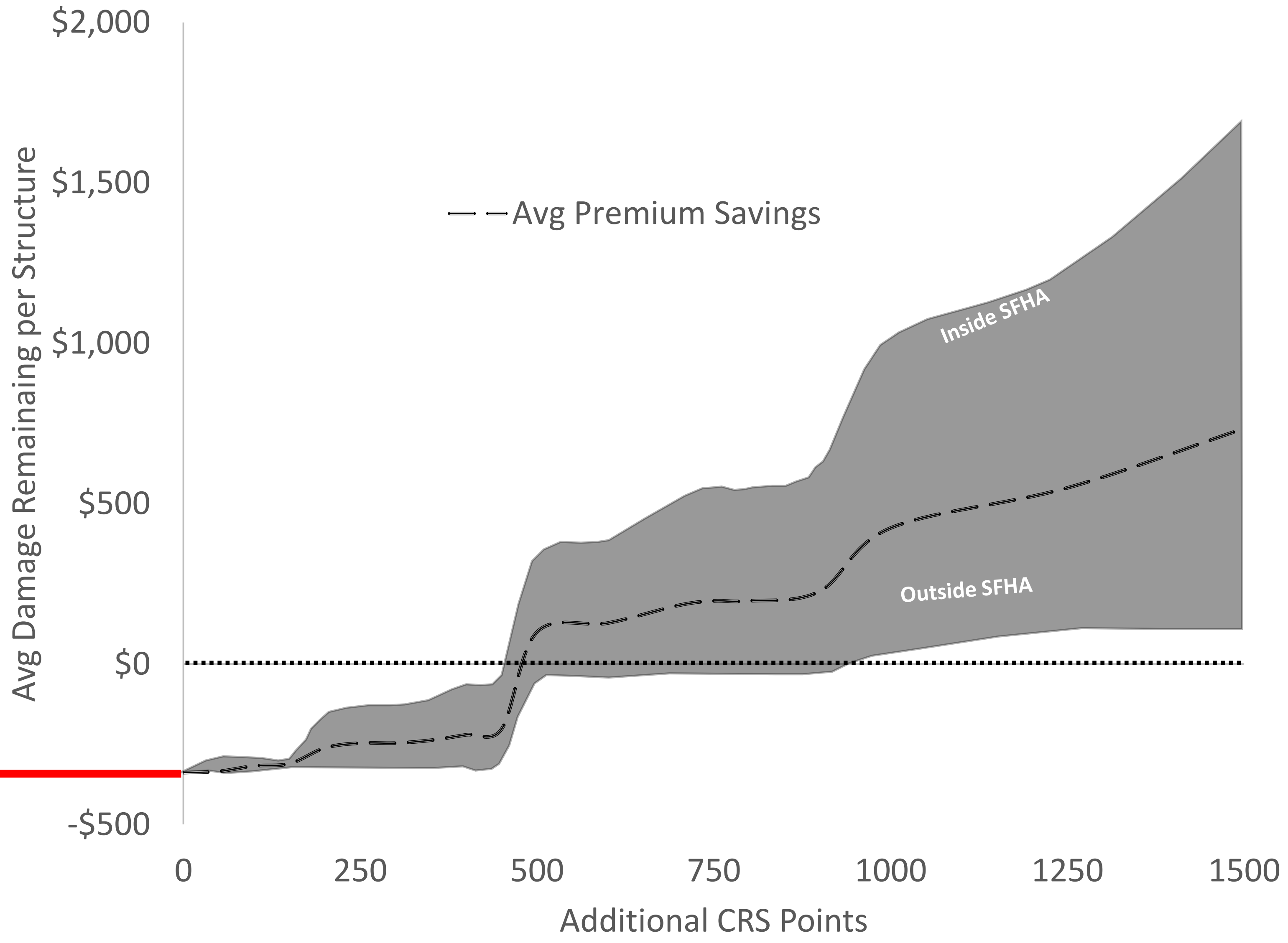


Average Premium Increase

City	Floodplain Inside	Floodplain Outside	All
Manvel	-	$96	$96
League City	$404	$149	$184
Webster	$280	$165	$192
Friendswood	$456	$213	$257
Alvin	$1,560	$156	$284
Brookside Village	$363	$245	$292
Pearland	$589	$205	$323
Houston	$482	$238	$325
Kemah	$449	$131	$364
El Lago	$558	$258	$373
Seabrook	$507	$289	$384
Shoreacres	$373	$536	$453
Clear Lake Shores	$463	-	$463
Nassau Bay	$610	$290	$473
Pasadena	$513	-	$513
La Porte	$586	$413	$531
Taylor Lake Village	$1,004	$244	$776
Watershed	$508	$227	$338

The Value of Avoiding Flood Risk

How many CRS points required to offset HFIAA premium increases?



Average Premium Increase = **$338**

How much can be saved?

Activity	Mitigation Activity	Mean Points	Maximum Possible	Per Point	Total Mean Savings
320	Map Information	124	140	-$140	**-$13,622**
330	Outreach Projects	110	315	-$164	**-$13,972**
340	Hazard Disclosure	12	81	-$324	**-$3,737**
350	Flood Protection Info.	32	66	-$873	**-$18,933**
360	Flood Protection Assistance	33	71	-$290	**-$8,386**
410	Floodplain Mapping	29	1373	-$518	**-$12,299**
420	Open Space Protection	106	900	-$68	**-$6,524**
430	Higher Reg. Stds.	259	2720	-$130	**-$21,358**
440	Flood Data Maint.	90	231	-$331	**-$19,895**
450	Storm water Management	69	670	-$157	**-$9,270**
510	Floodplain Planning	64	309	-$273	**-$13,622**
520	Acquisition/Relocation	317	3200	-$24	**-$6,788**
540	Drainage System Maint.	216	330	-$68	**-$11,937**

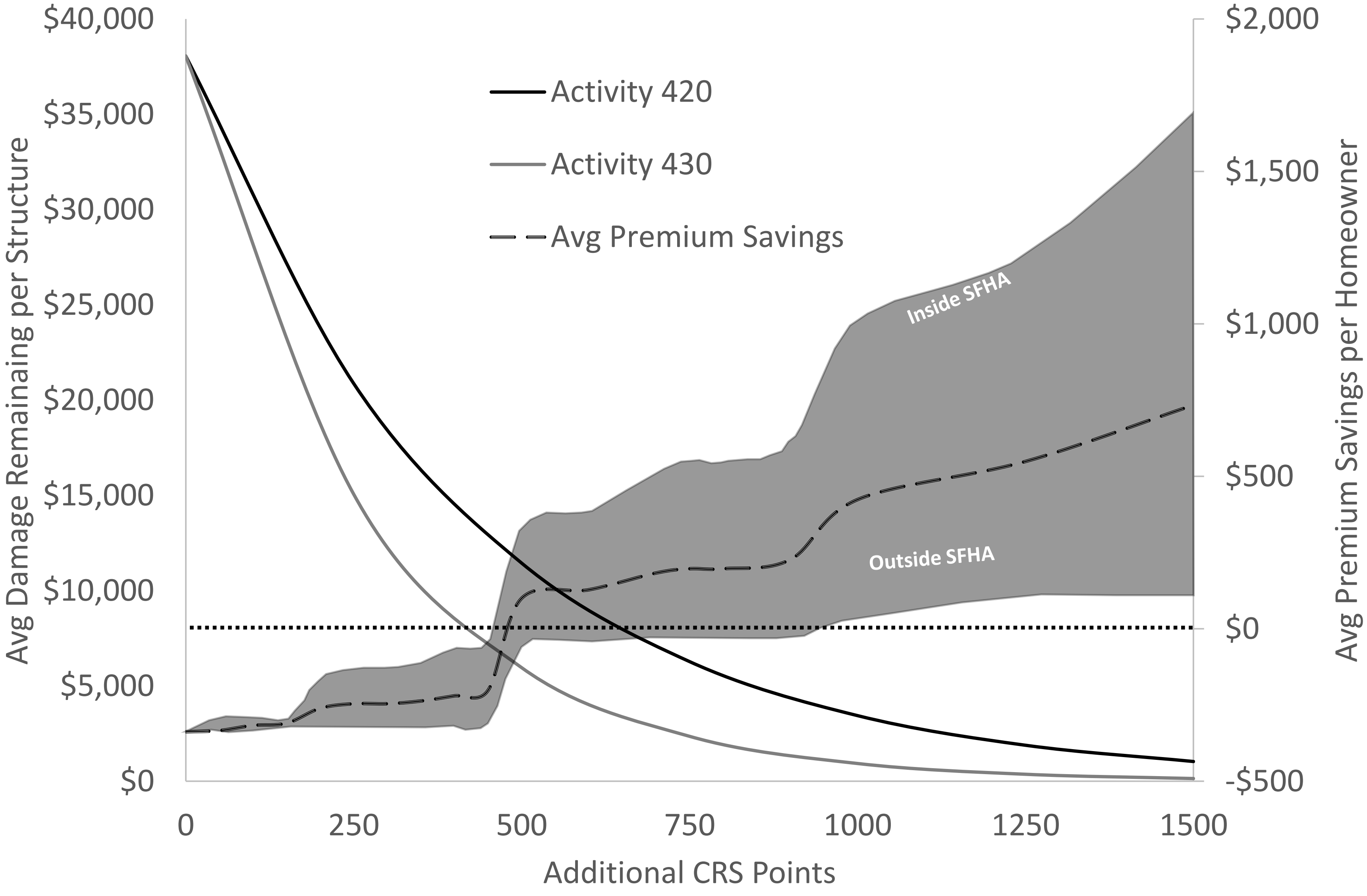
The Value of Avoiding Flood Risk

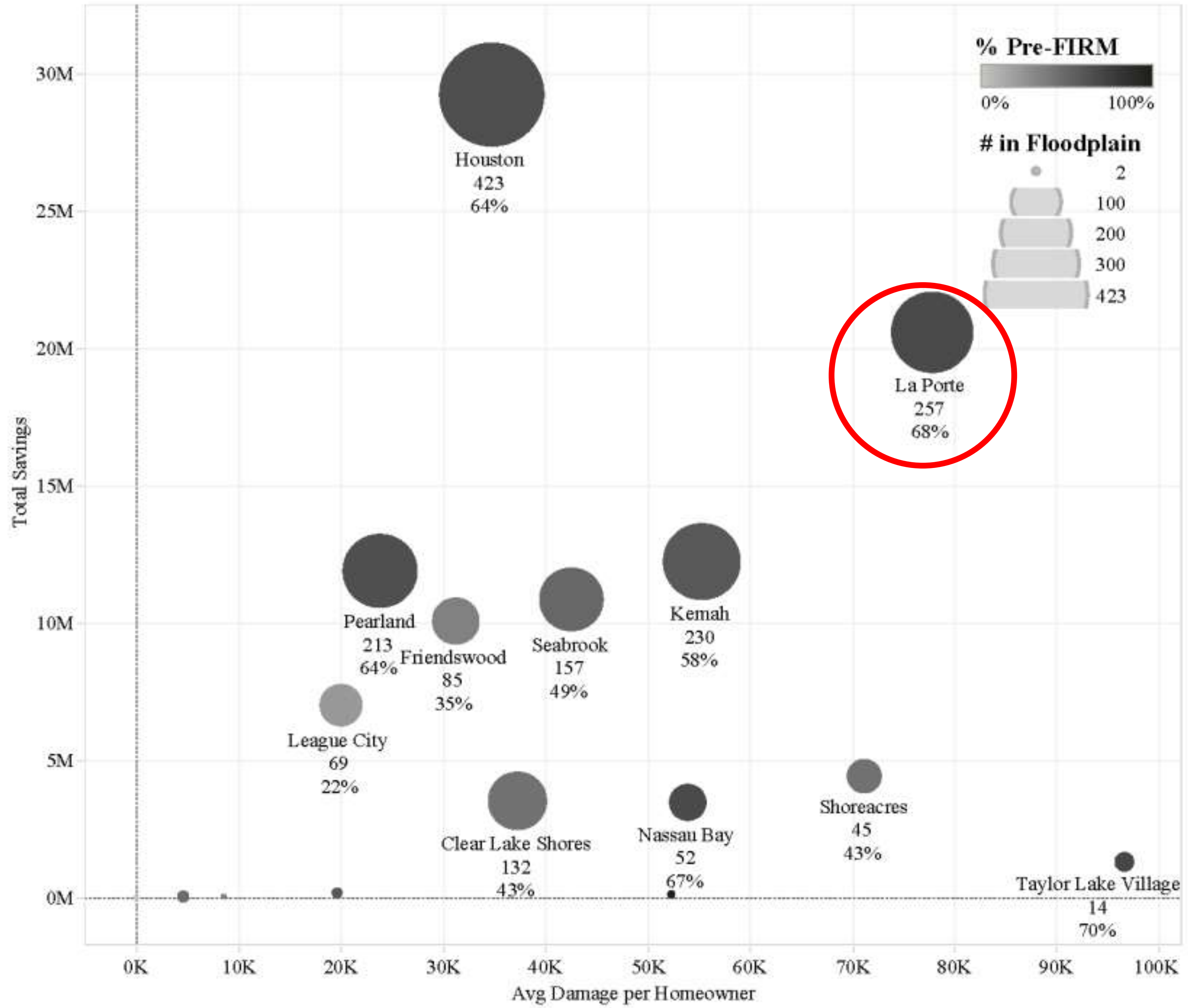
How much damage would have been avoided?

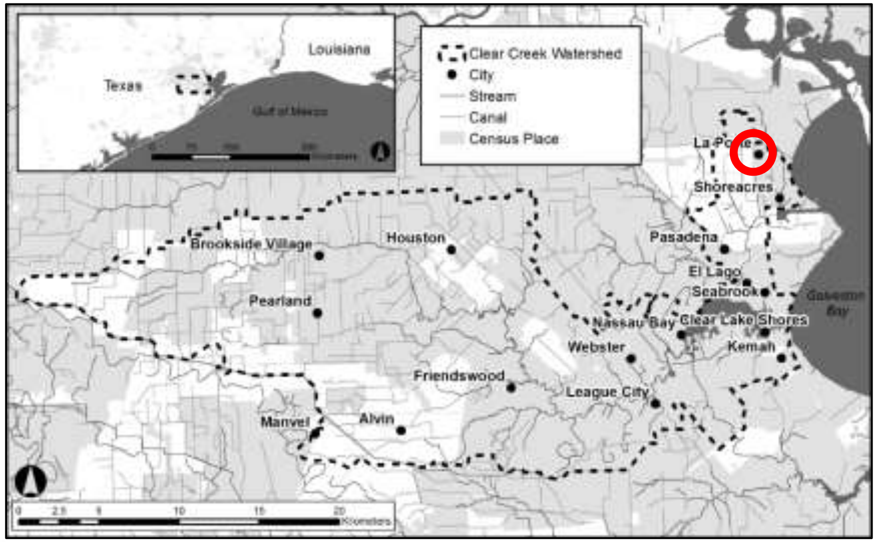
Time Period: 1999-2009

420: Open Space Preservation

430: Higher Regulatory Standards







500 point increase in avoidance based mitigation.

Who saves?

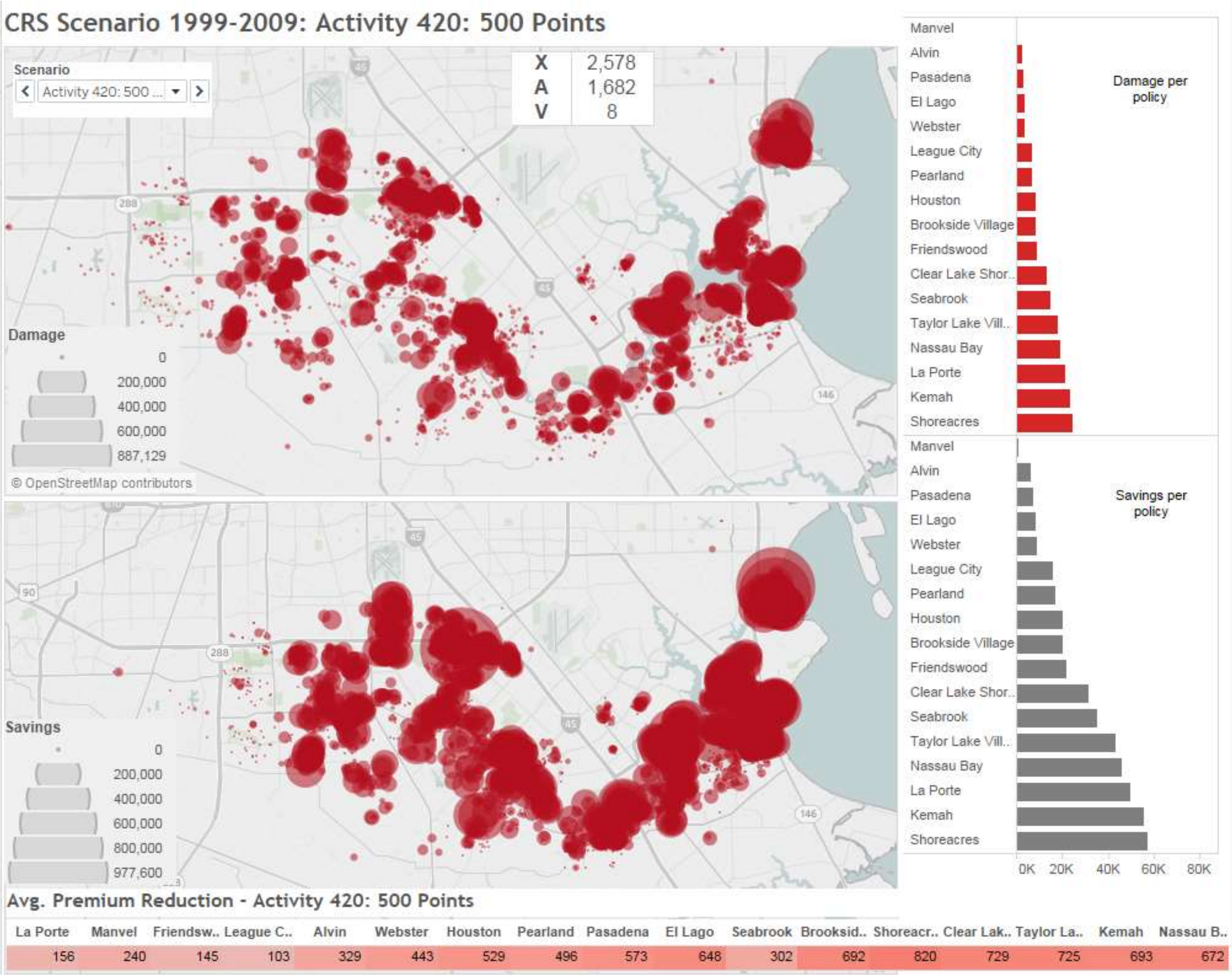
Those that were:

- Damaged the most
- Low-lying & coastal
- Cities with high development in the floodplain

Data Visualization

<u>Enables:</u>

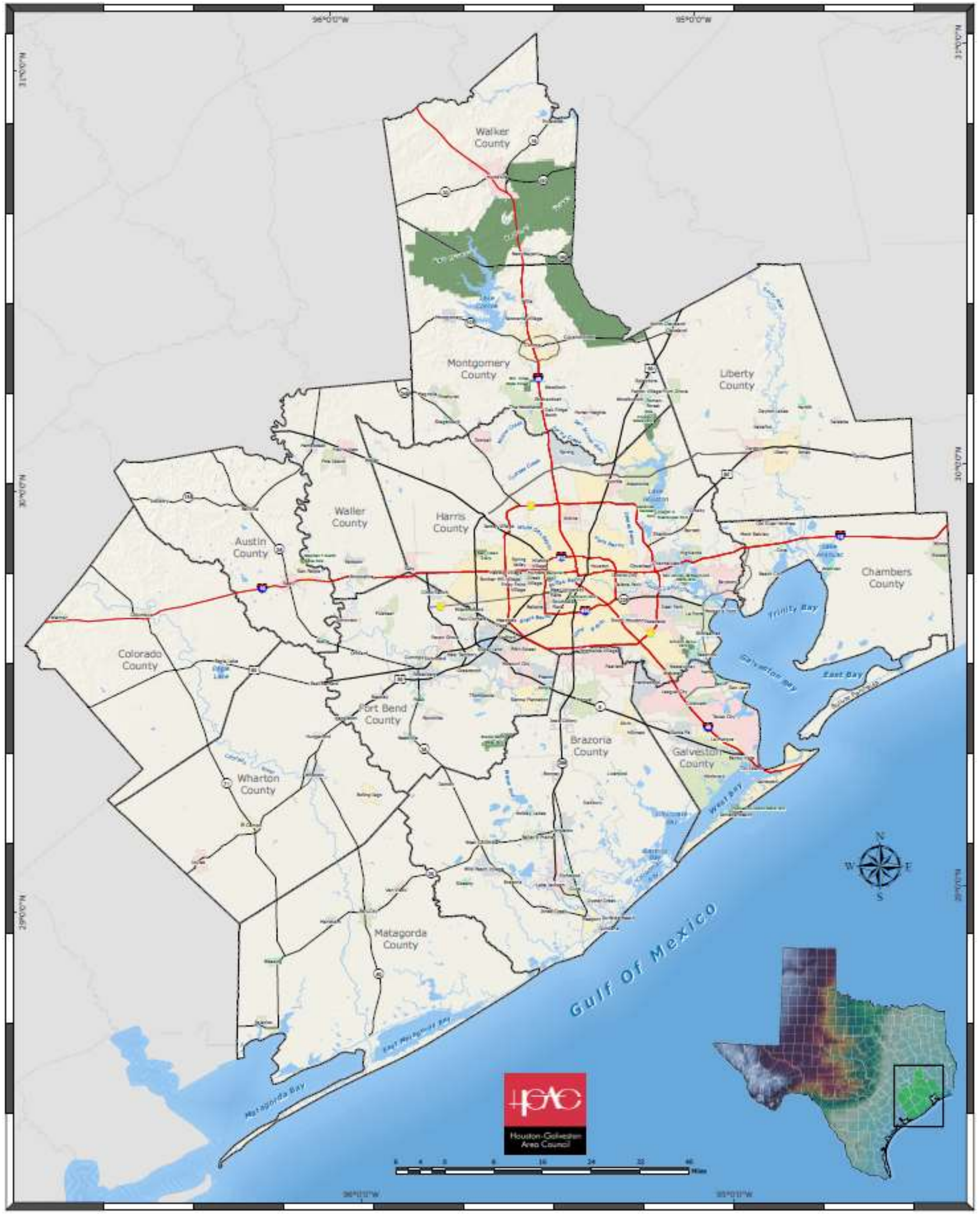
- Outreach
- Exploration
- Dynamic “story-telling”



Looking Forward

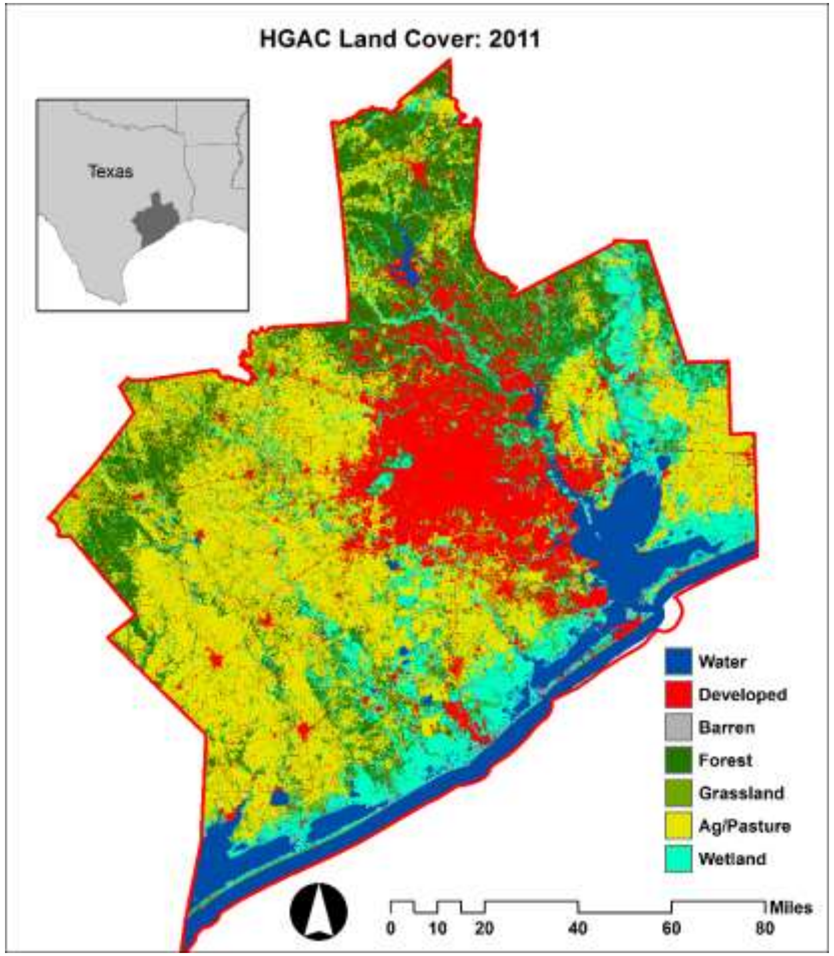
Future Development, Moving Floodplains, & Sea Level Rise

- Flood risk reduction is a moving target:
  - Storm event characteristics
  - Land Use/Land Cover change
  - Existing mitigation
  - Sea level rise
- What do regional-scale scenarios of future flood damage look like?
  - Forecast land cover change/development
  - Model the distribution of structures in future scenarios.
  - Estimate future storm surge damages



Land Cover Data

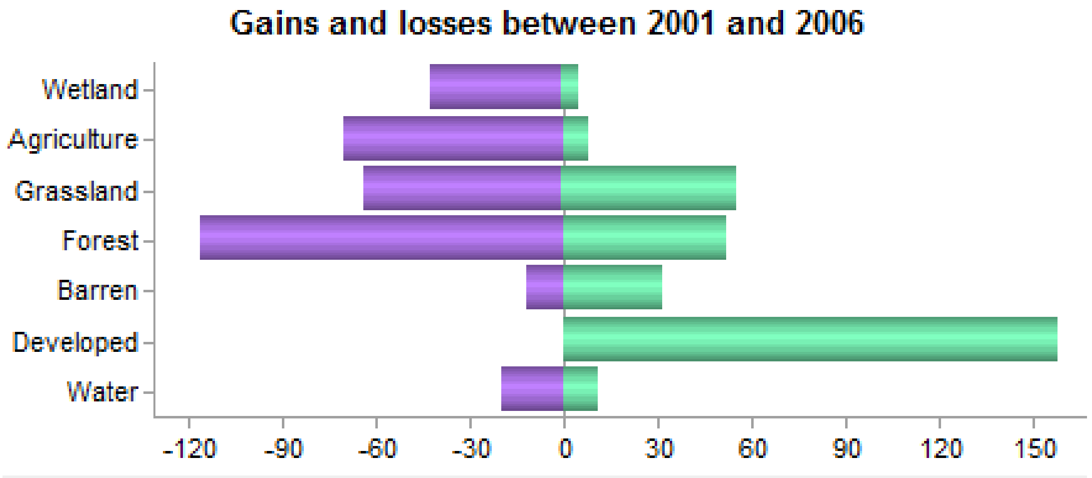
- National Land Cover Dataset
  - 30 meter: 2001, 2006, & 2011
  - Reclassified to improve model accuracy



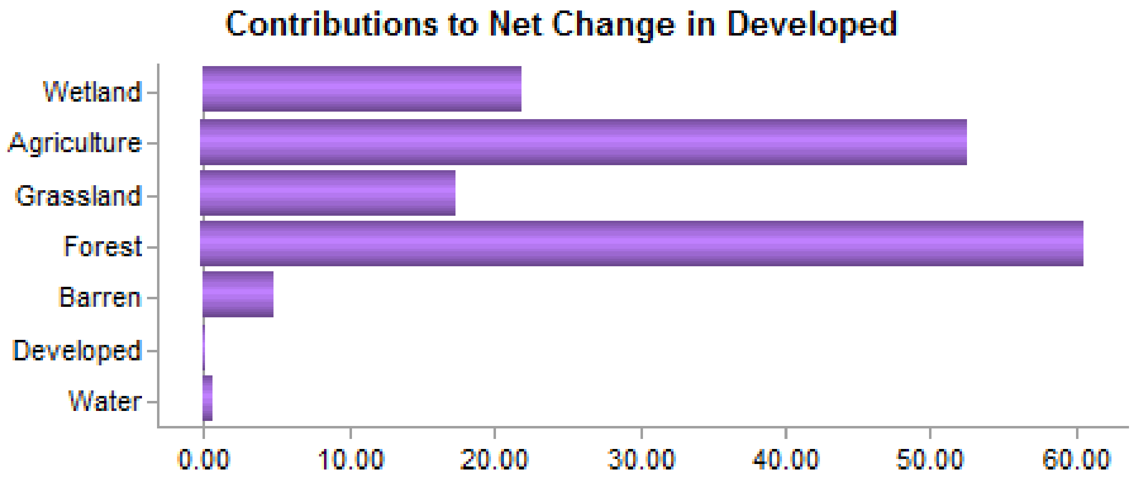
NLCD	Reclassified
Developed, Open Space	Developed
Developed, Low Intensity	
Developed, Medium Intensity	
Developed High Intensity	
Barren Land	Barren
Deciduous Forest	Forest
Evergreen Forest	
Mixed Forest	
Dwarf Scrub	
Shrub/Scrub	
Grassland/Herbaceous	Grassland
Sedge/Herbaceous	
Pasture/Hay	Ag/Pasture
Cultivated Crops	
Woody Wetlands	Wetland
Emergent Herbaceous Wetlands	
Open Water	Water

HISTORICAL CHANGE ANALYSIS

- Analyze past land cover change
- Change assessed from 2001 to 2006



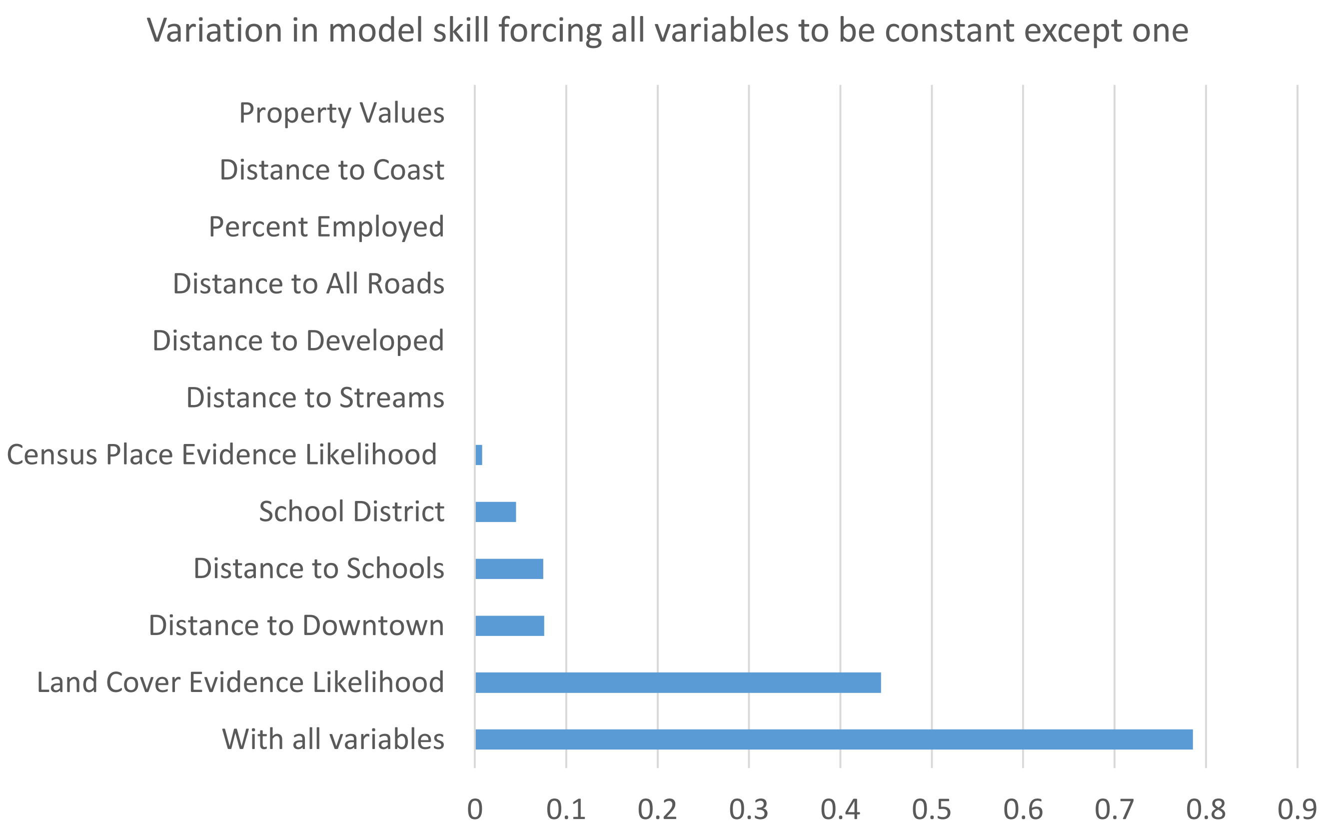
sq miles



sq miles

MODELING DEVELOPMENT PROBABILITIES

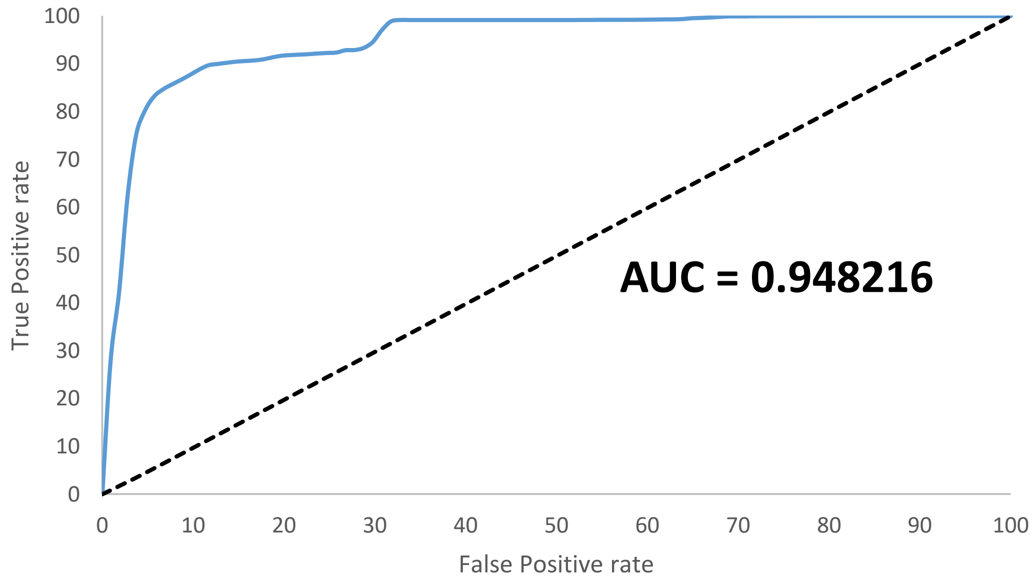
- Change probabilities are developed using an artificial neural networks (ANNs)
  - Can model complex, non-linear relationships between drivers and development
  - Drivers + Transitions (2001-2006)
  - Network of weights formed using an iterative learning process (i.e. training)

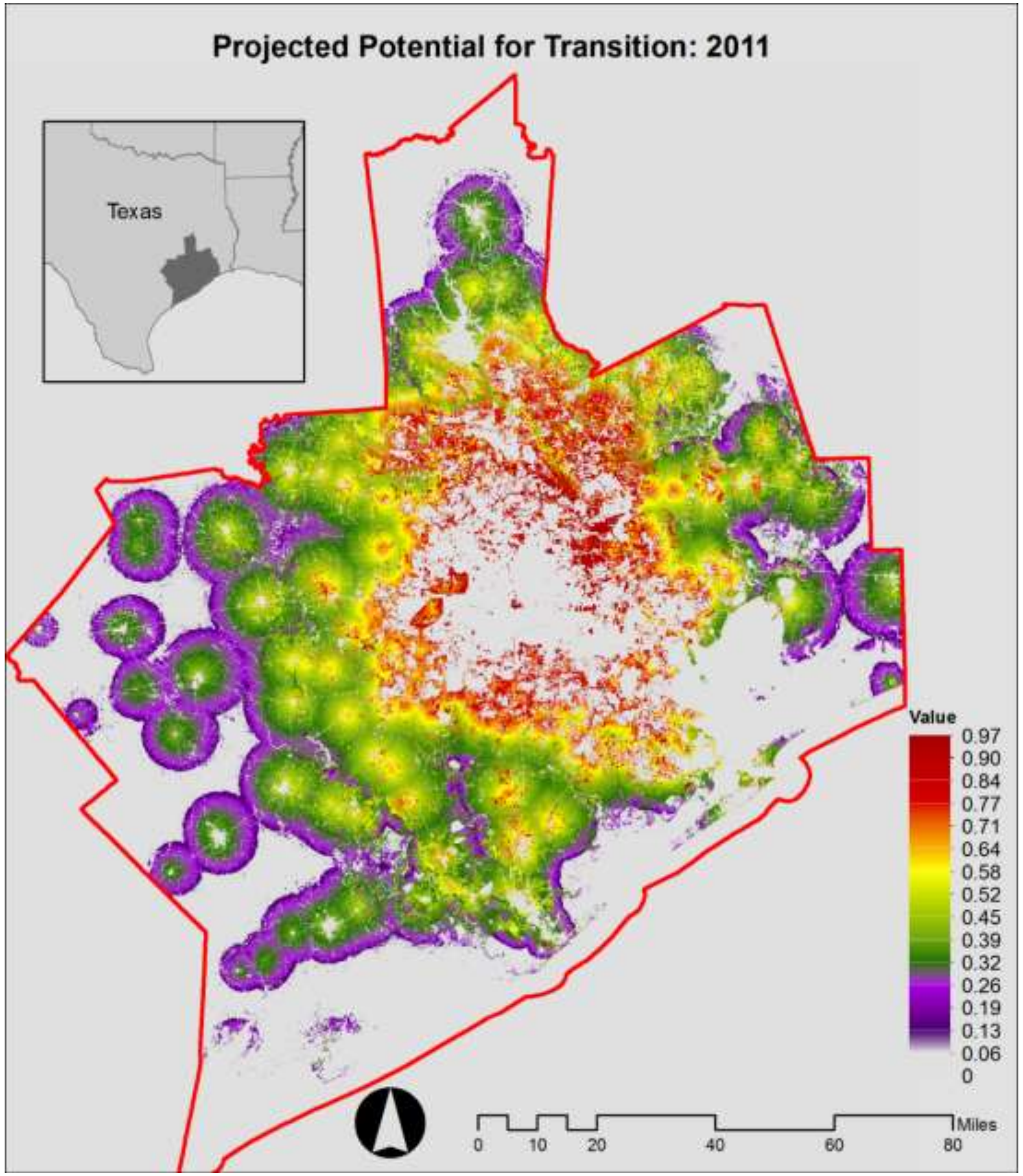


Validation

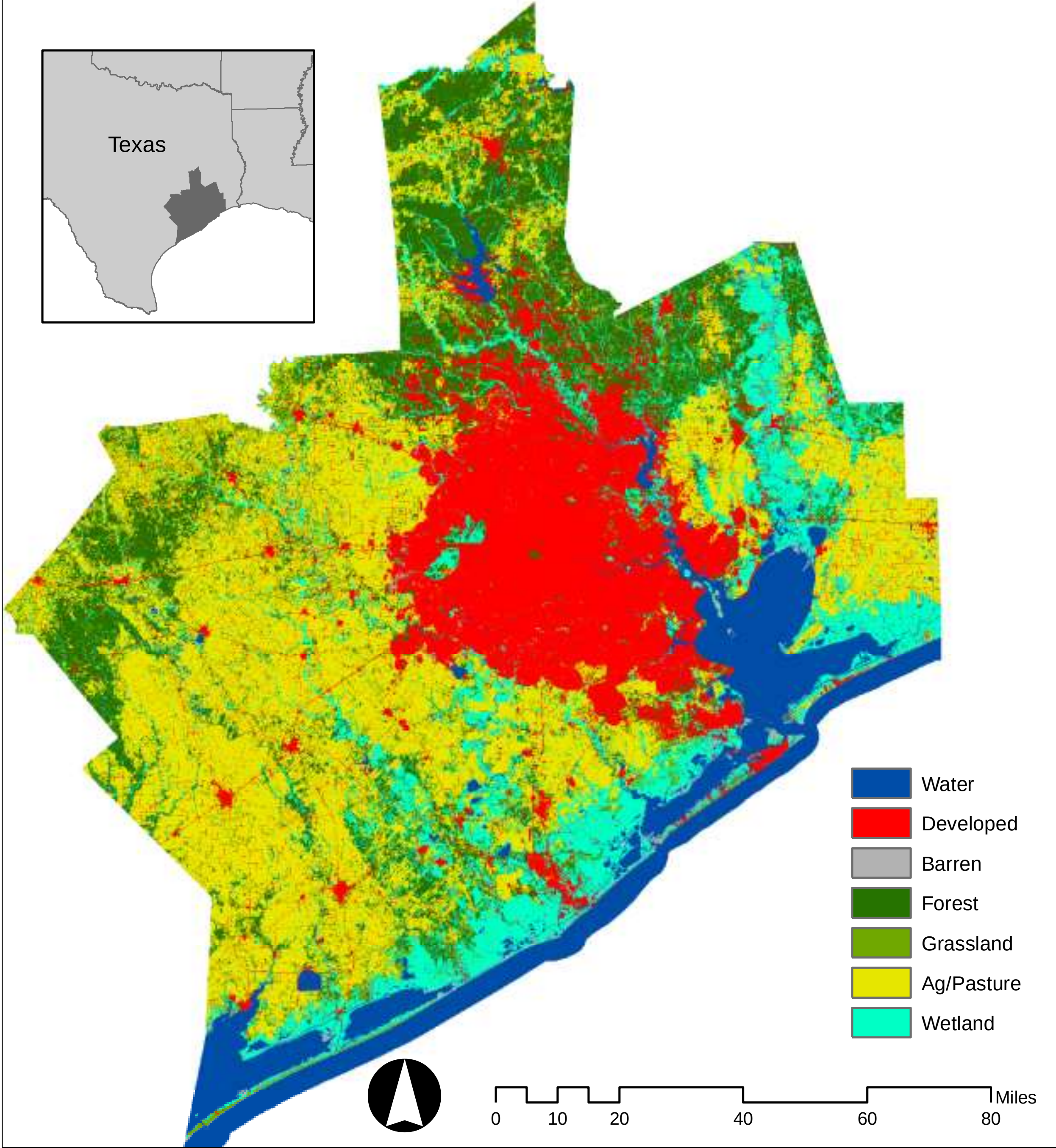
- Forecast 2011 land cover from 2006 changes
- Compare with actual 2011 change
  - Soft prediction of 2011
  - Overlaid on top of what actually changed

Relative Operating Characteristic Curve

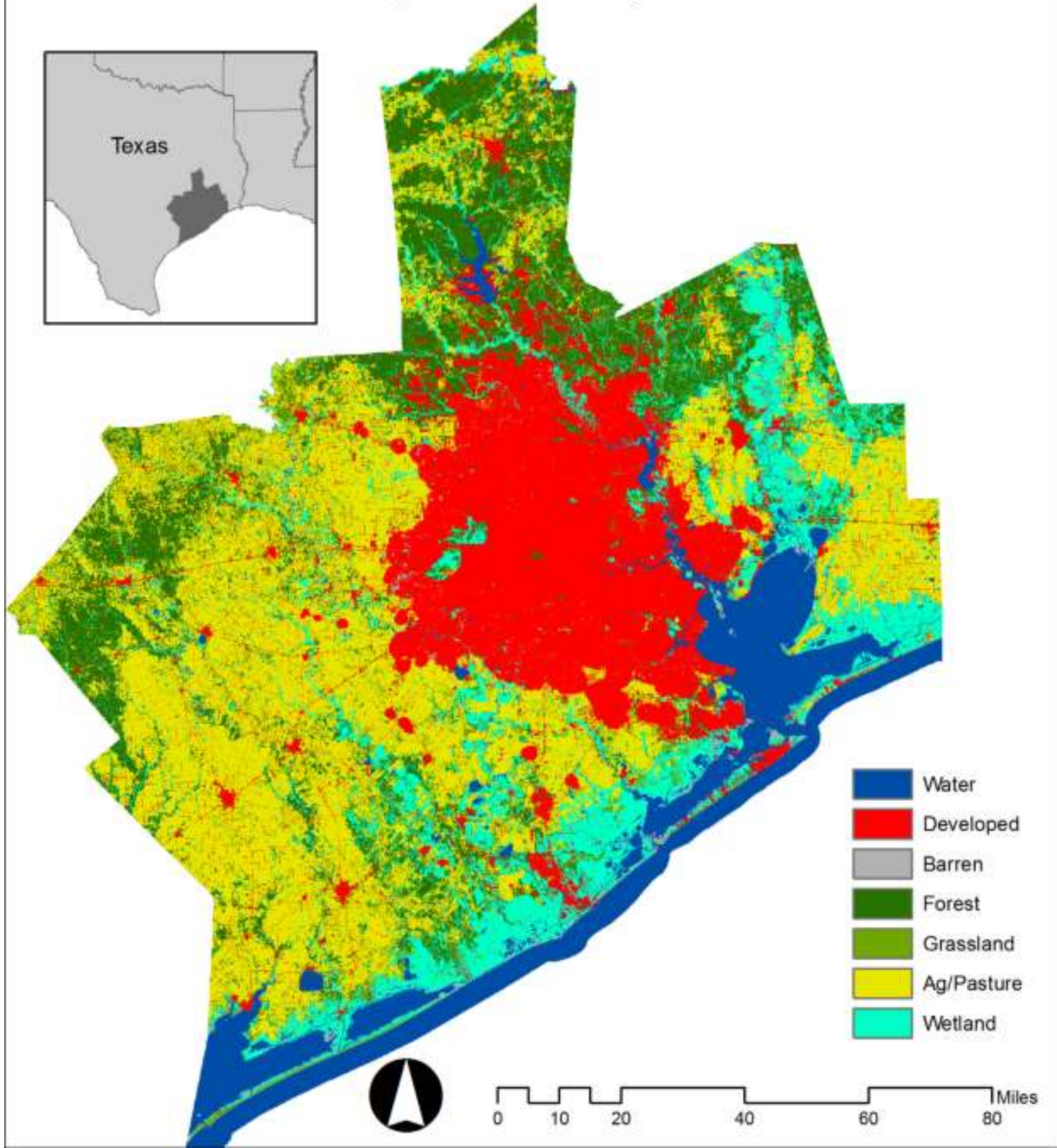




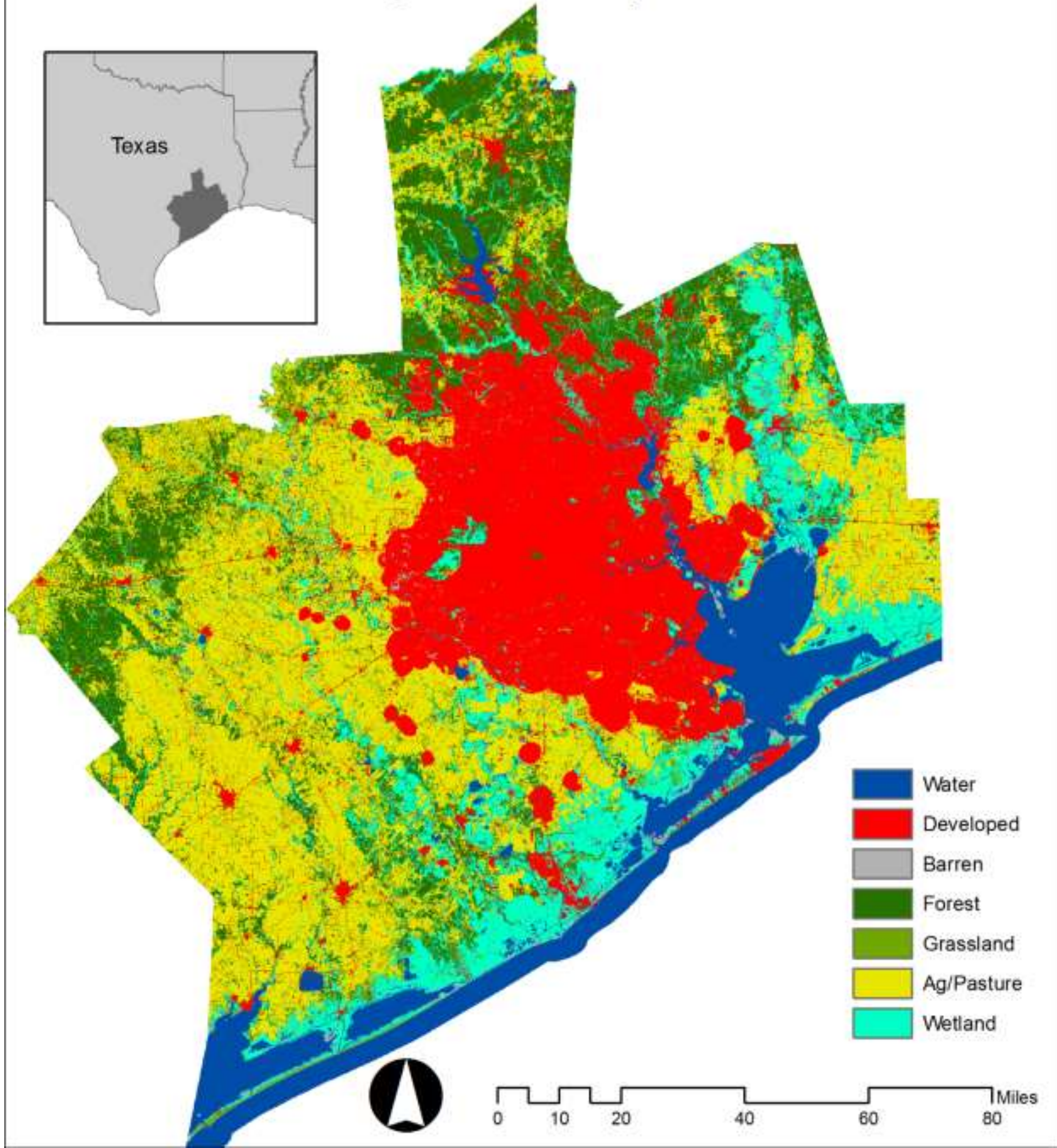
HGAC Projected Development: 2025



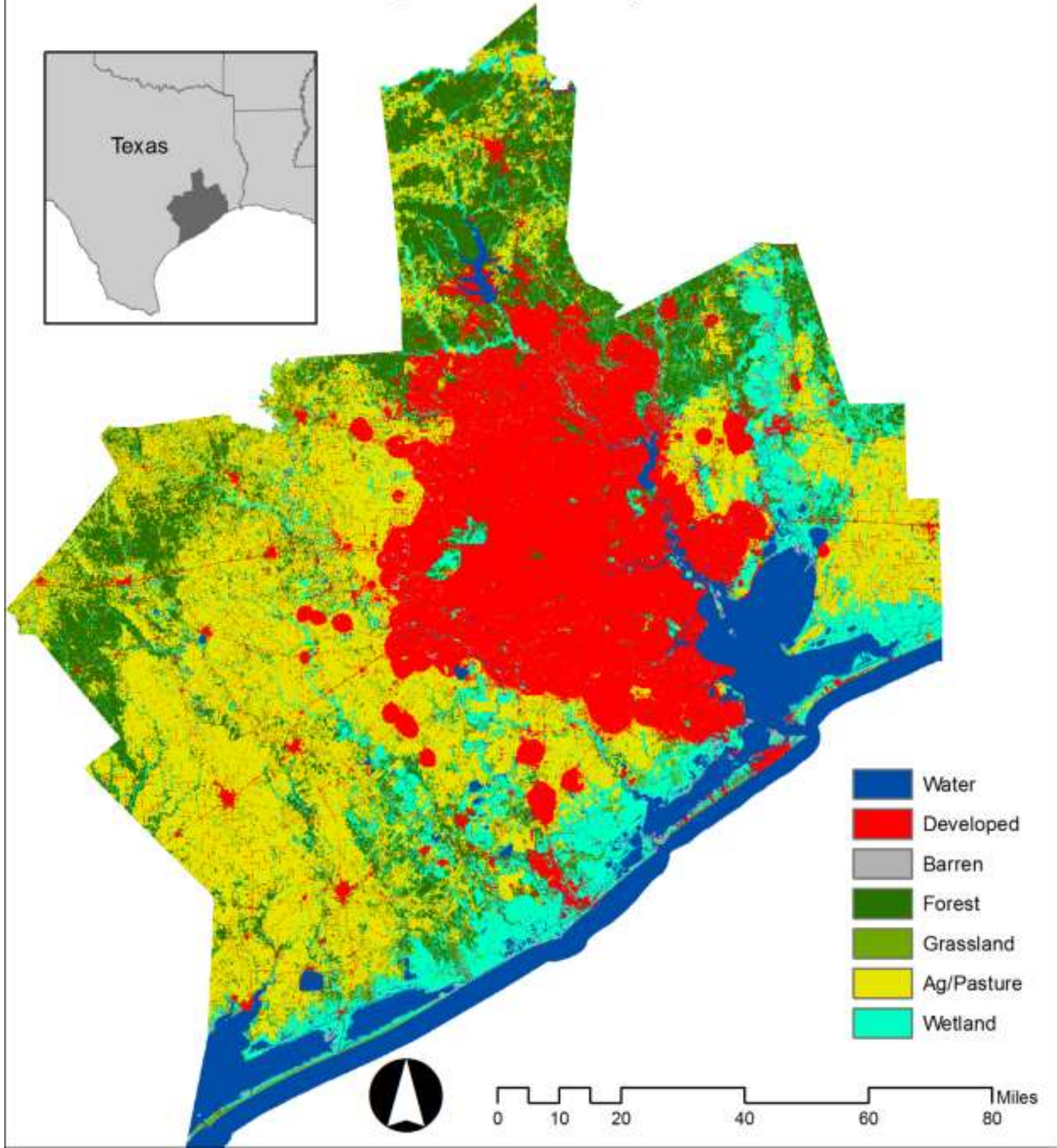
HGAC Projected Development: 2035



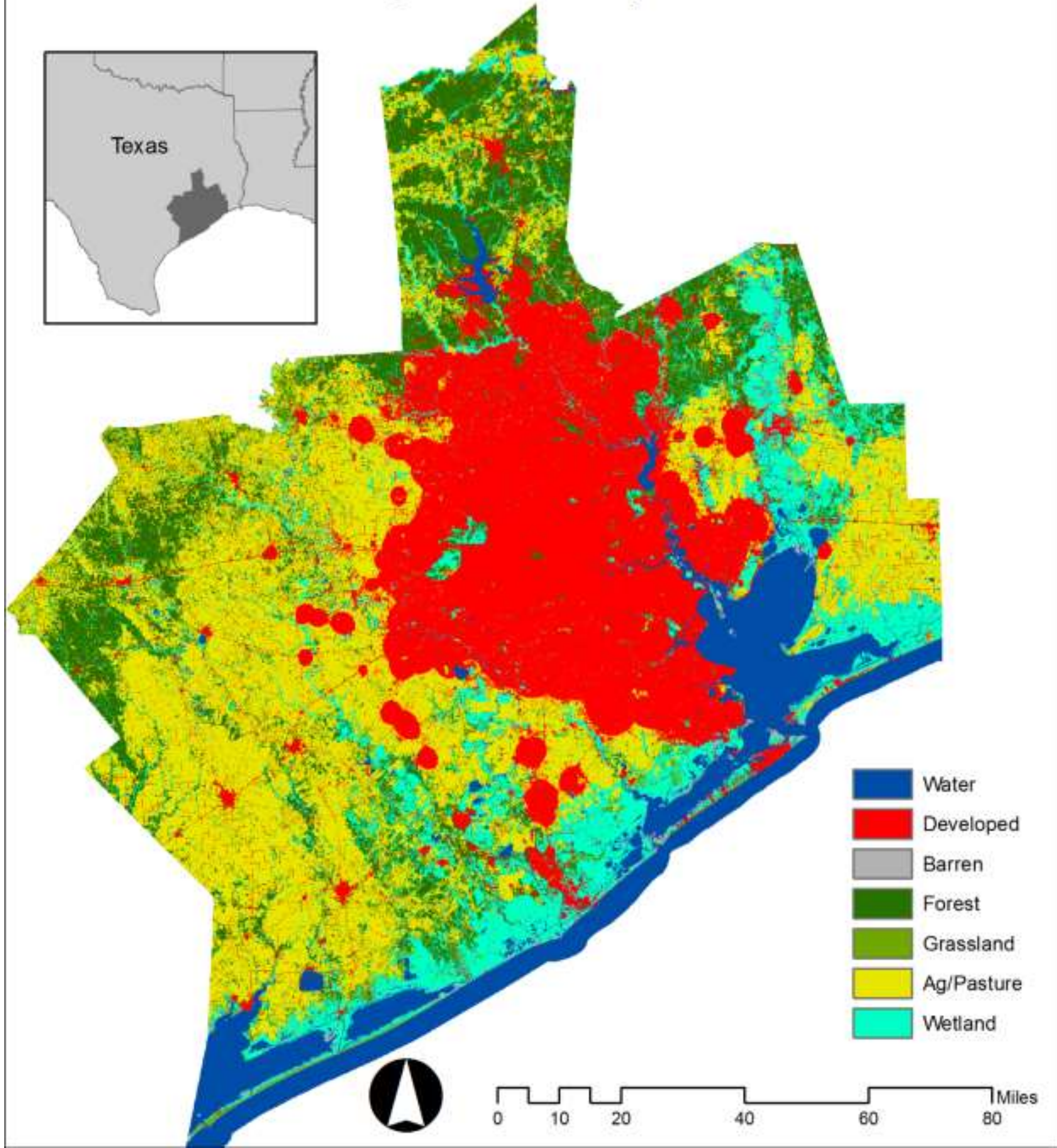
HGAC Projected Development: 2044



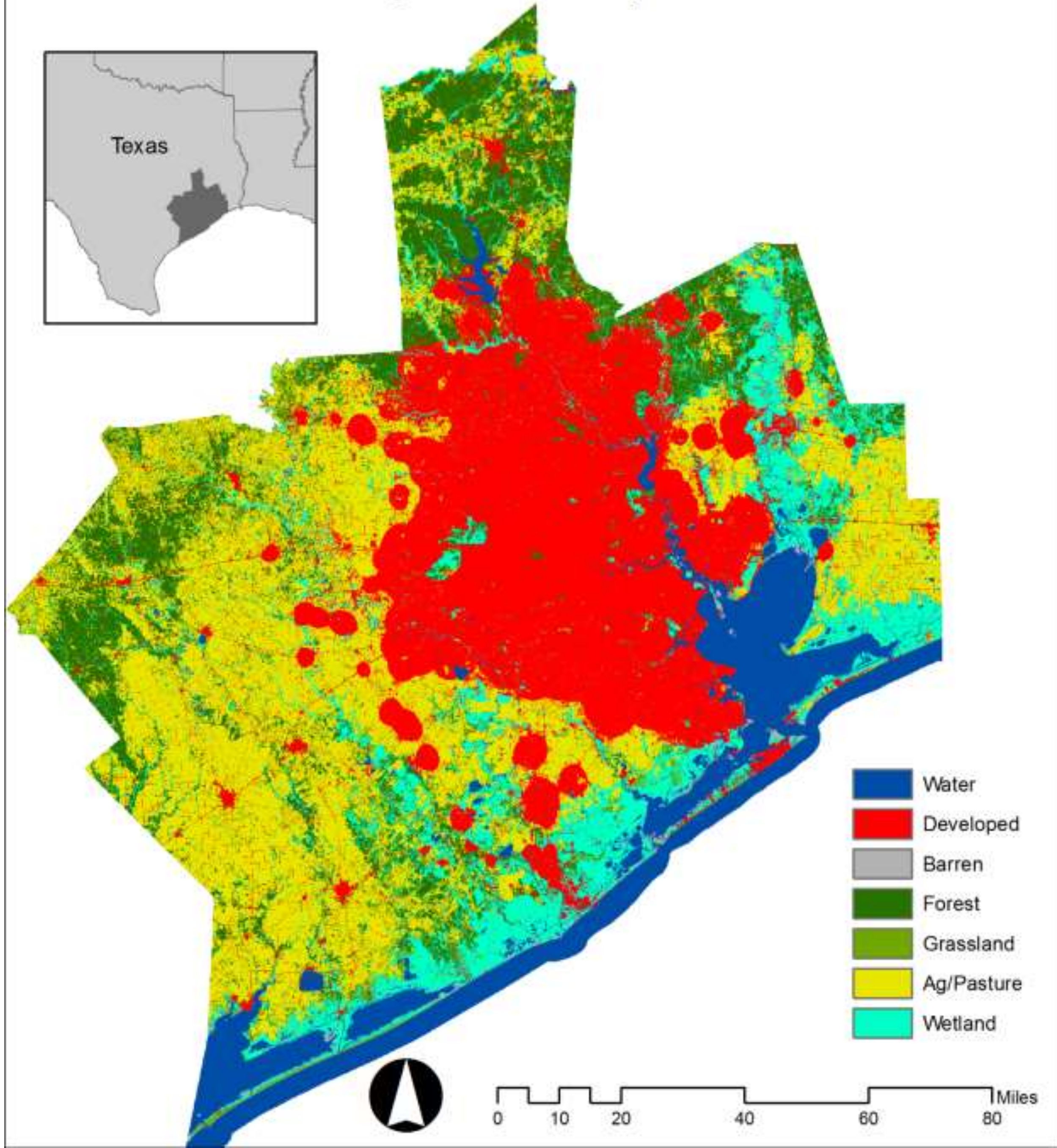
HGAC Projected Development: 2054



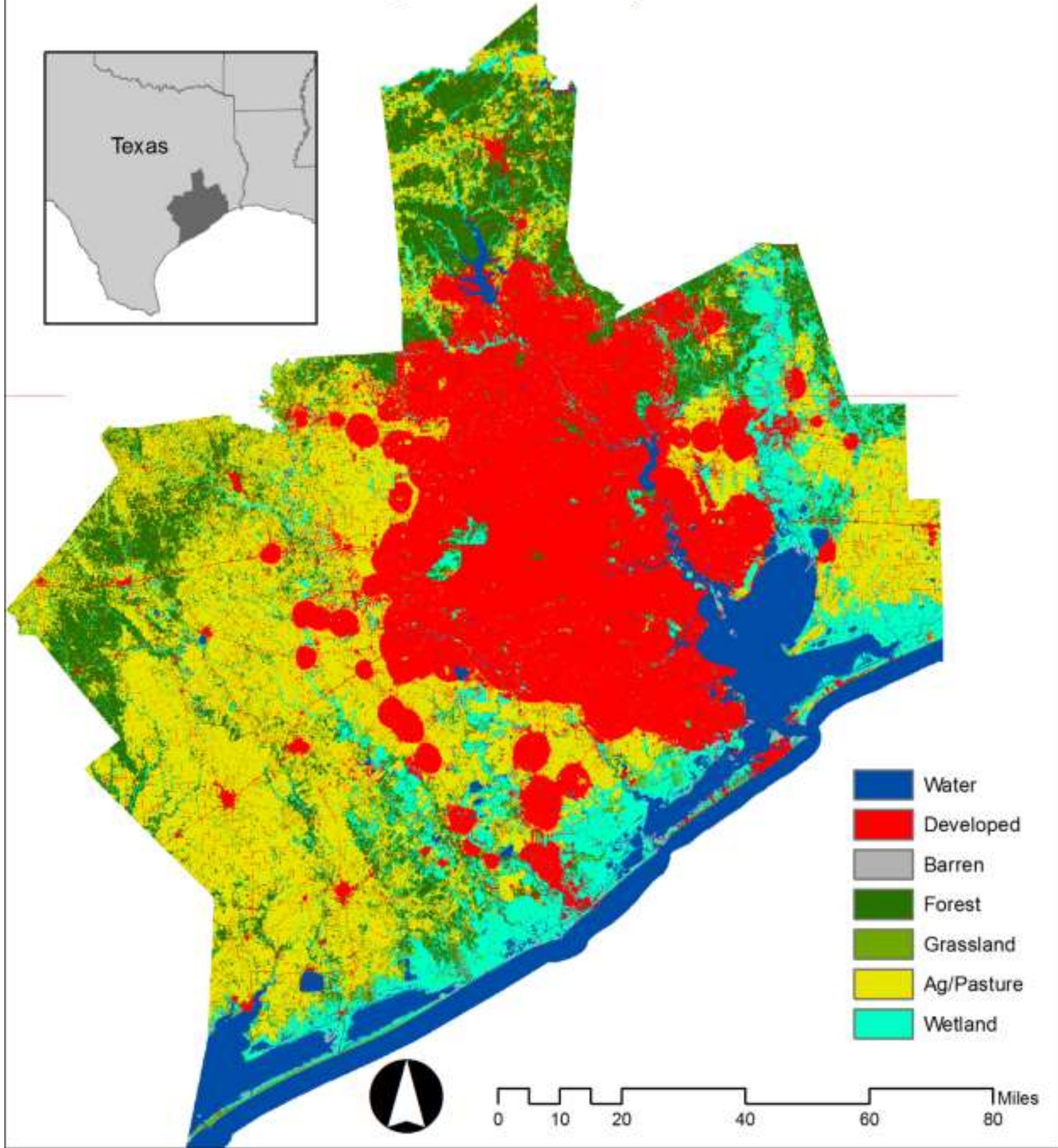
HGAC Projected Development: 2063



HGAC Projected Development: 2073



HGAC Projected Development: 2083

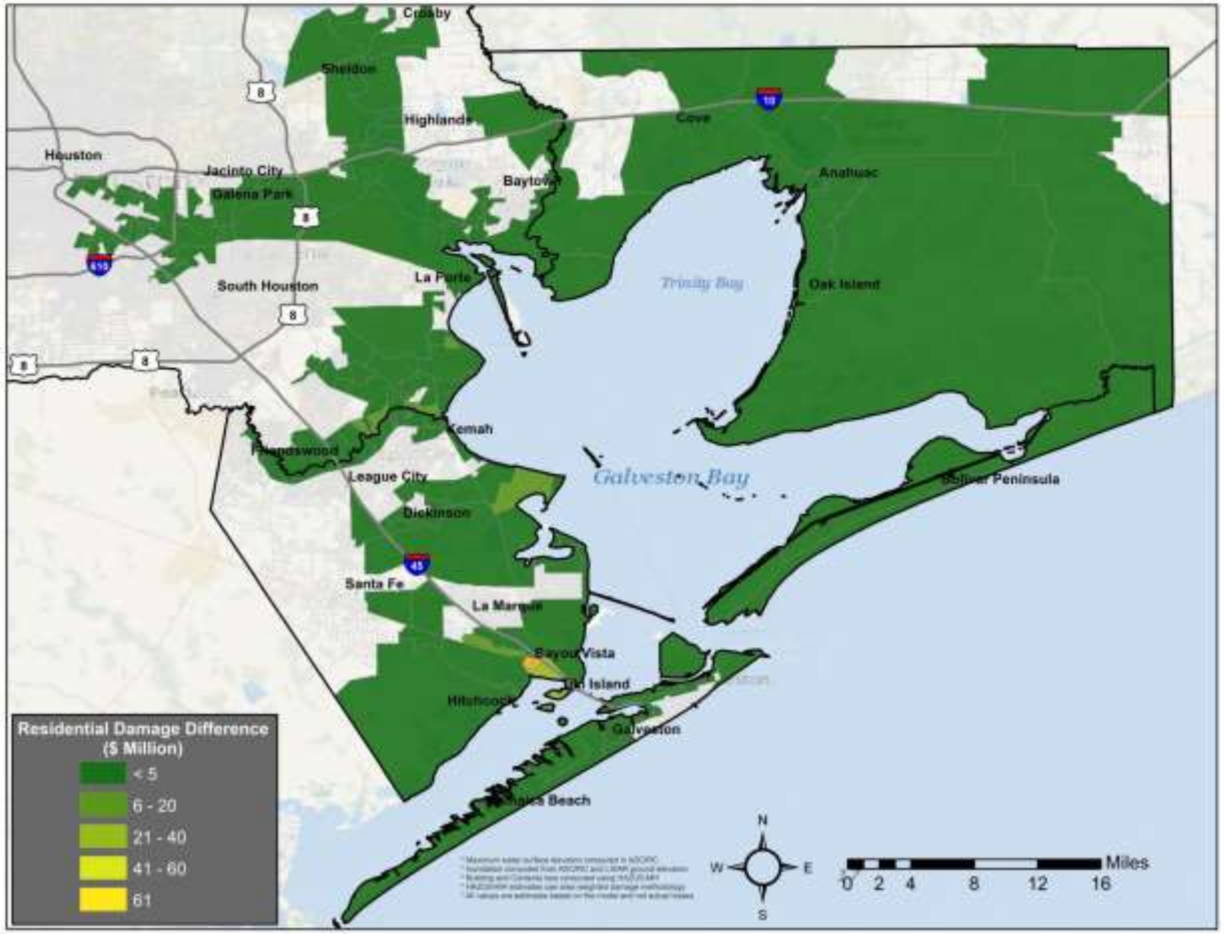


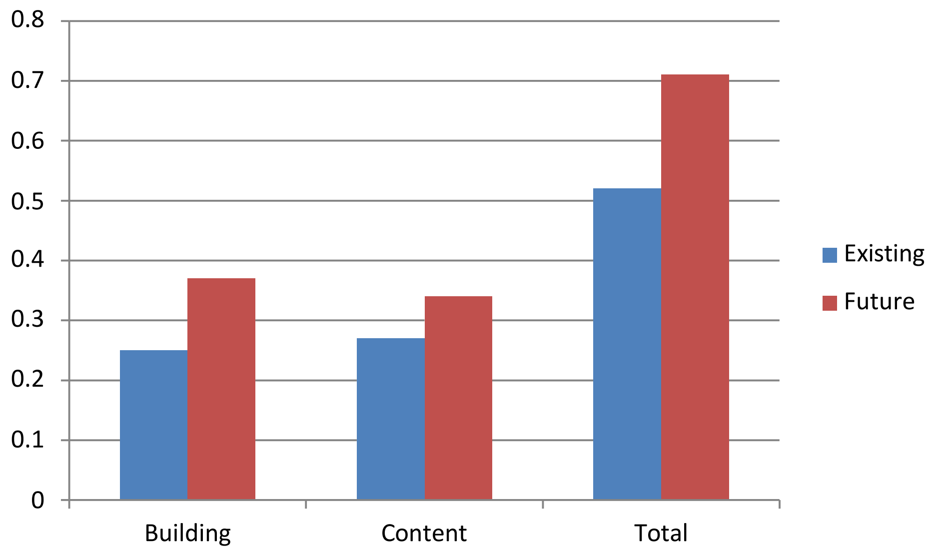
Integrating Future Development and Flood Damage

- Preliminary “back of the envelope” estimates
  - Extrapolate residential structure types and counts
    - developed land cover – density relationships
- Re-estimate damage with HAZUS and updated counts
- ADCIRC inundation layers as inputs
  - Storm surge for 10%/1%/0.02% percent storms and Hurricane Ike
  - Only residential structures

Preliminary damage estimates: 2080

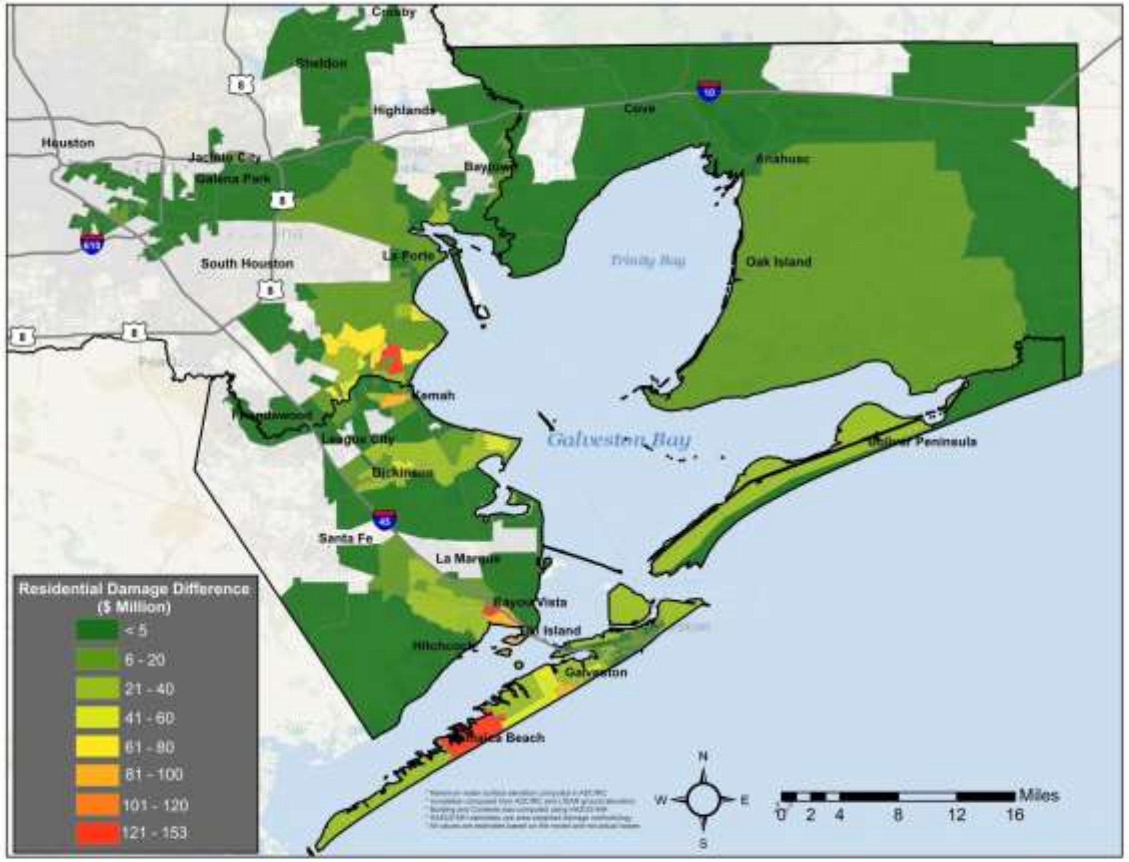
- 10-year surge event: increases damage from ~$500m to ~$700m

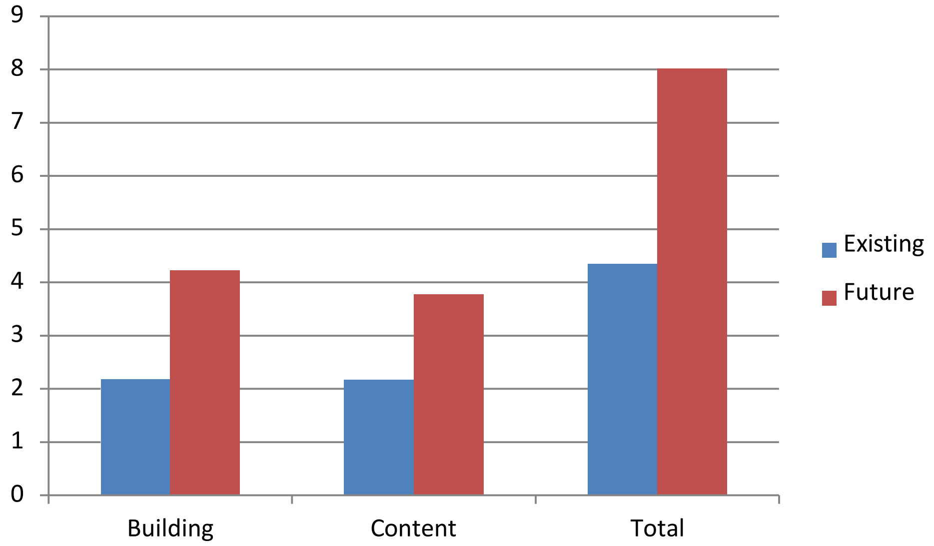




Preliminary damage estimates: 2080

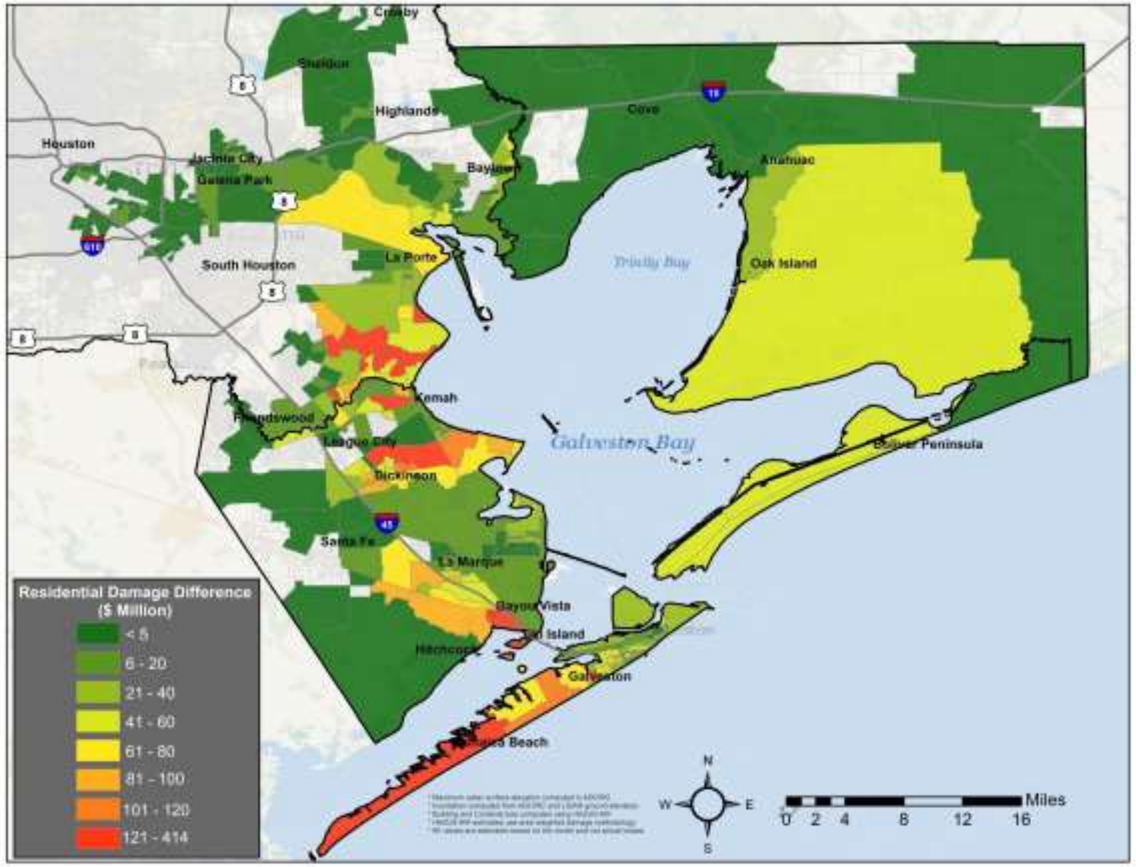
- 100-year surge event: increases damage from ~$4.3b to ~$8b;

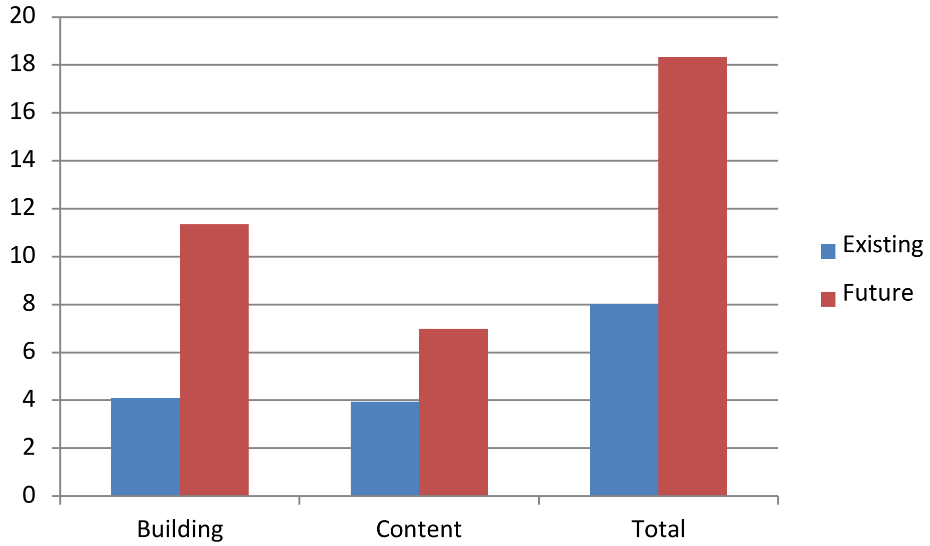




Preliminary damage estimates: 2080

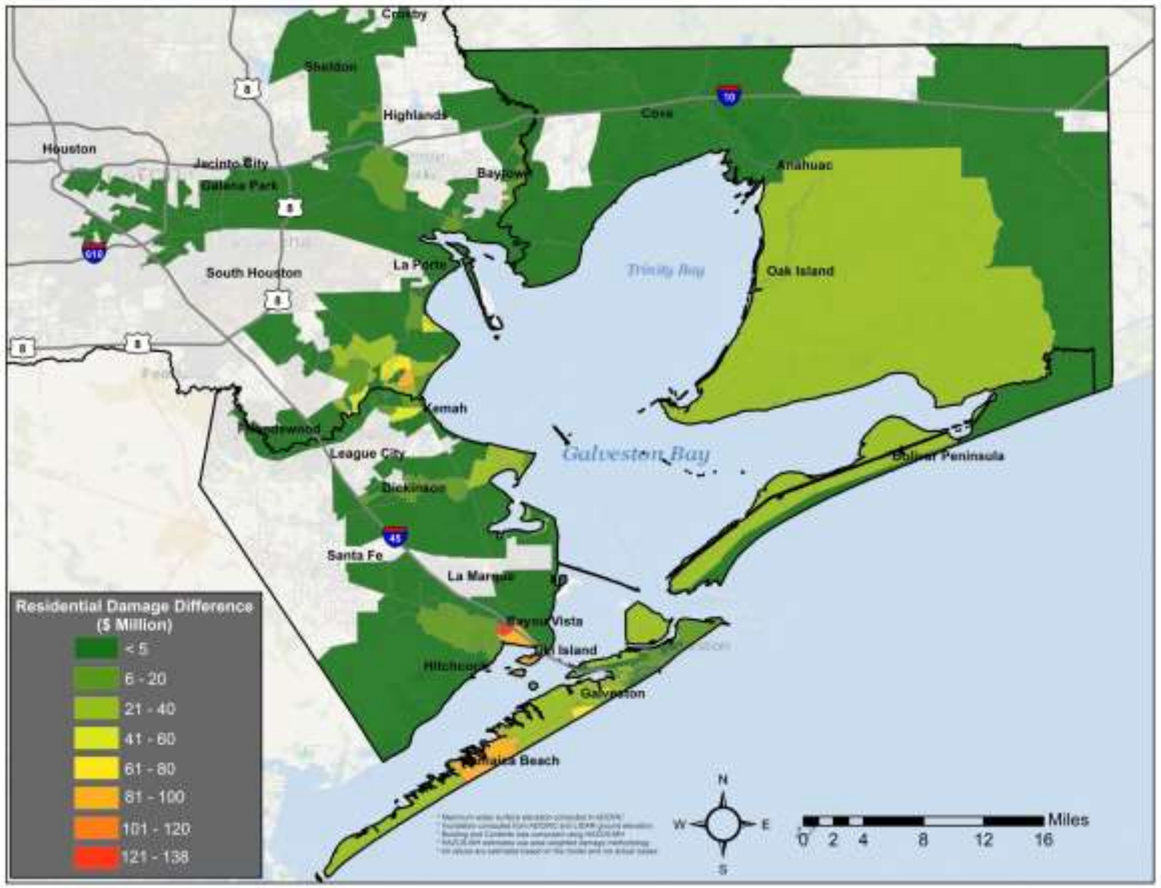
- 500-year surge event: increases damage from ~$8b to ~$18.3b;

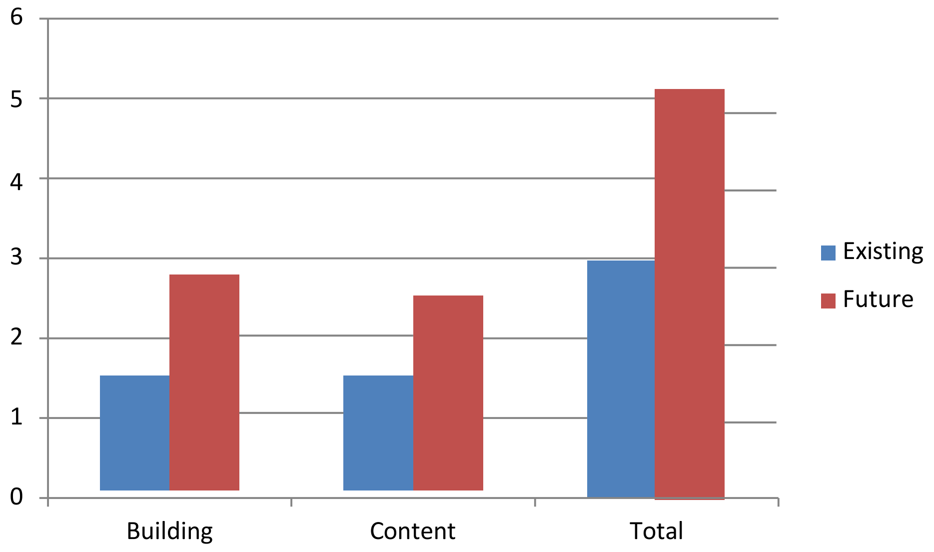




Preliminary damage estimates: 2080

- A repeat of Hurricane Ike: increases damage from ~$2.97b to $5.33b





Future Work

- Flood risk is a constantly moving target
- Higher reg’s and floodplain avoidance are cost effective in the face of dynamic risk
- Visualizing historic losses can be leveraged to improve risk communication
- More thorough cost-benefit analysis of specific mitigation activities
  - Especially on the “cost” side
- In-depth future flood risk assessment over a range of scenarios:
  - Sea level rise into surge models
  - H&H with forecasted land cover change
  - Future floodplain delineations
  - Mitigation scenarios

Thank You

CTBS
The Center for Texas Beaches and Shores

NSF
National Science Foundation

TEXAS A&M
UNIVERSITY at GALVESTON