

An aerial photograph of Miami, Florida, showing the city's coastline, waterways, and urban development. The image is used as a background for a title slide. A large white rectangular box with a black border is centered over the image, containing the title and subtitle text.

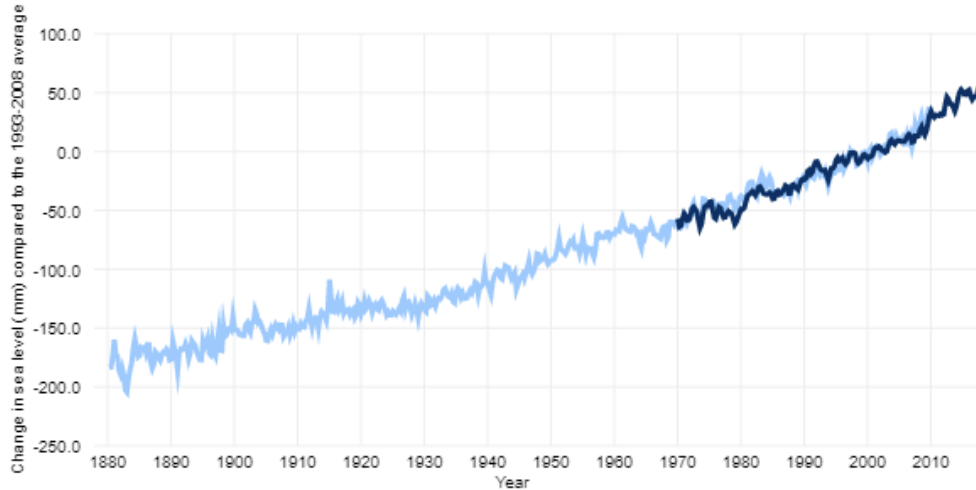
INFRASTRUCTURE ANALYSIS FOR SEA LEVEL RISE IN MIAMI, FLORIDA

ERI STERN
DIGITAL TERRAIN ANALYSIS
FALL 2017

ABSTRACT

Sea level rises due to melting glaciers and ice sheets, the expansion of the ocean as water warms, and to a lesser degree, because groundwater pumping has shifted water storage from aquifers, lakes, and reservoirs to the ocean. There has been a consistent rise in sea level since the later 1800s, and we have, in recent years, seen a more dramatic increase. While global sea level is rising, it is rising at different rates in some locations. The study area I focused on, which is the coastline along Miami, Florida, is experiencing a rapid sea level rise, and is vulnerable to environmental hazards such as storm surges. The purpose of this study was to compare two different estimates for sea level rise in 2100, and how they affect the infrastructure of Miami. To calculate the area of Miami that would be submerged with a sea level rise of 1 or 2 meters, I obtained a 5m DEM of the area which I subtracted to symbolize the submerged area. I also utilized some features such as evacuation routes, hospitals, schools, and Superfund sites to assess how significant the damage would be at 1 or 2 meters of sea level rise. Based on my results, I concluded that there would be significant infrastructural damage in Miami with the predicted level of sea level rise by 2100. Furthermore, when using the higher of the two estimates, the level of damage increased exponentially. I concluded that planners must begin working now to target these sites that fall in the flood zone, particularly when considering other causes of floods such as hurricanes and storm surges that are becoming increasingly prevalent in the area. To improve this project in the future, I would like to include models for storm surges and hurricanes to more accurately predict the effects of flooding in Miami.

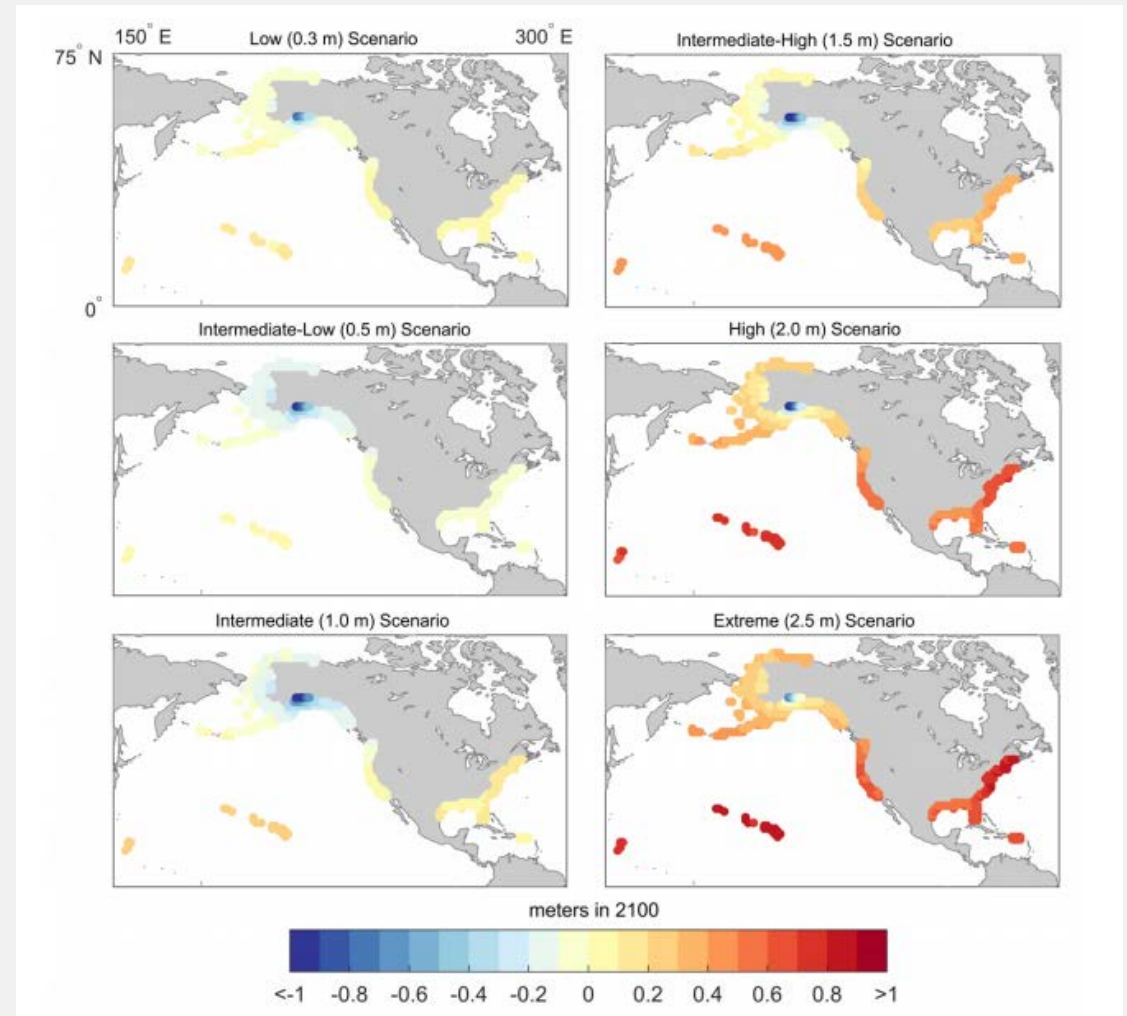
SEA LEVEL RISE: WHY IT IS OCCURRING AND WHO IS AFFECTED

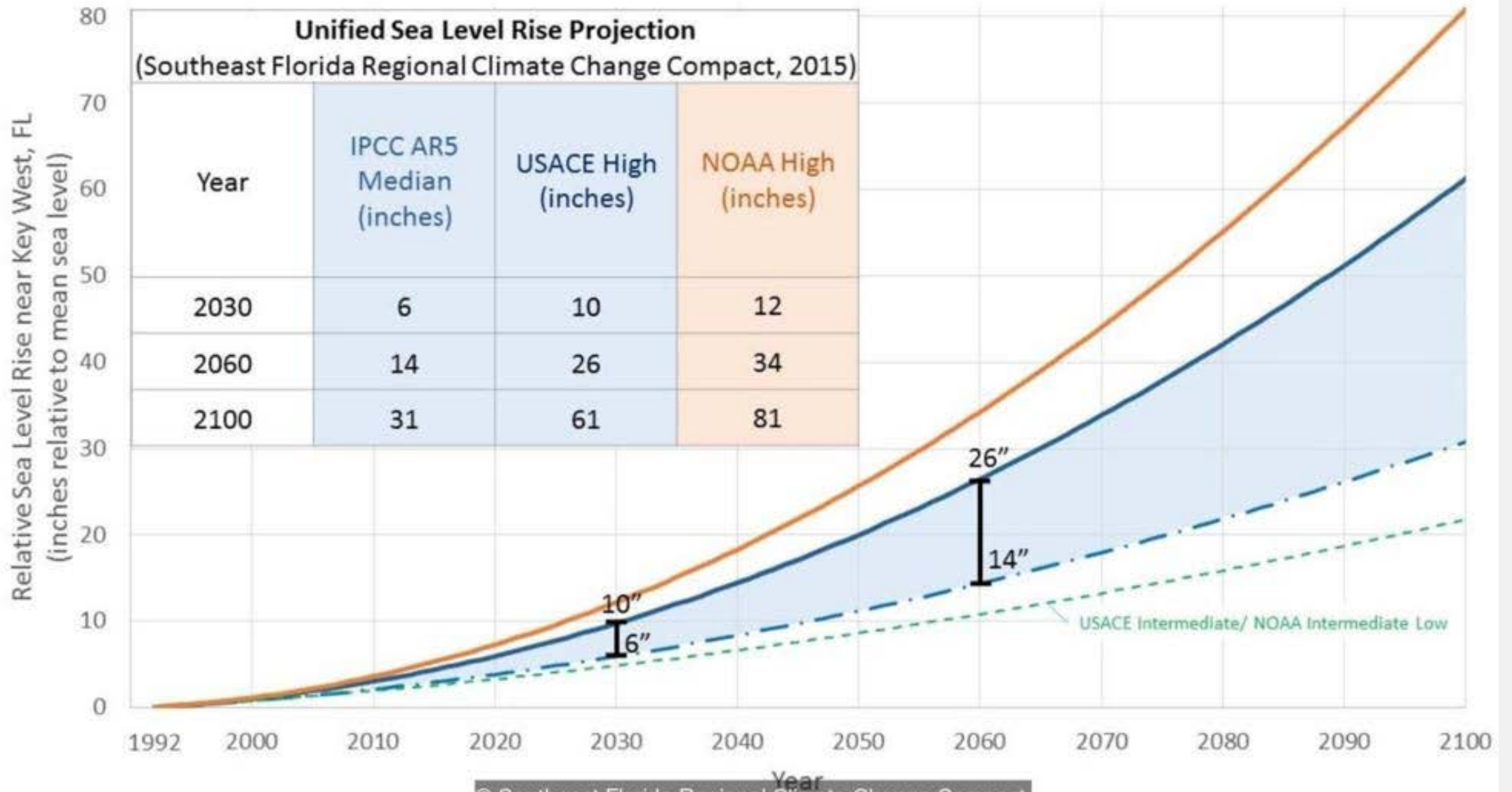


Graph from NOAA, (<https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level>)

Why sea level rise occurs

1. Melting glaciers and ice sheets
2. Ocean expands as water warms
3. Groundwater pumping shifts water storage from aquifers, lakes, and reservoirs to the ocean

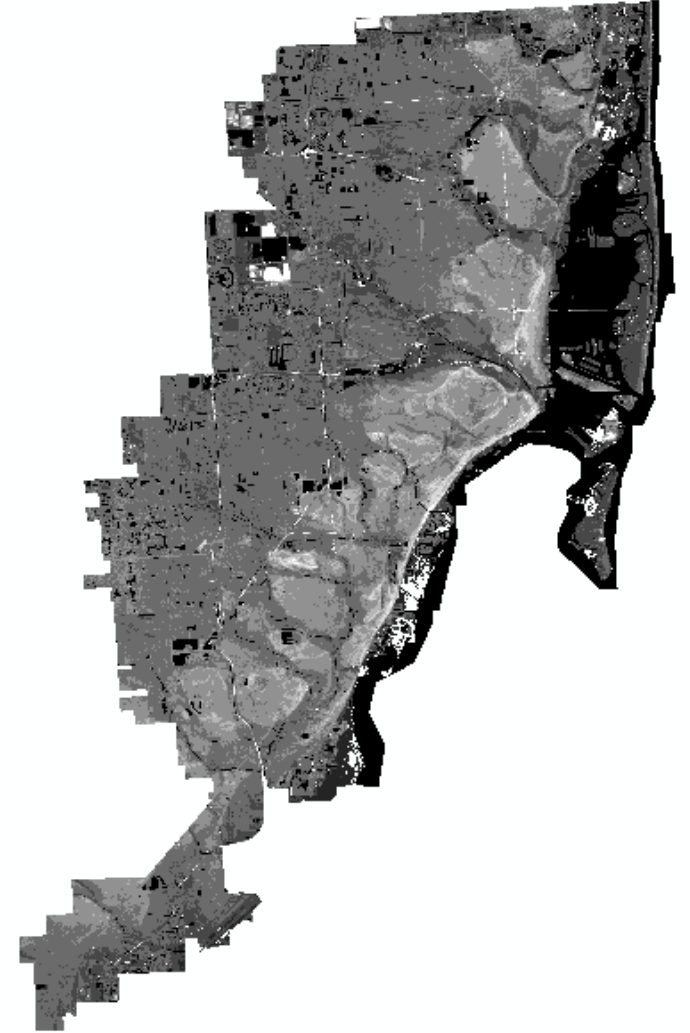
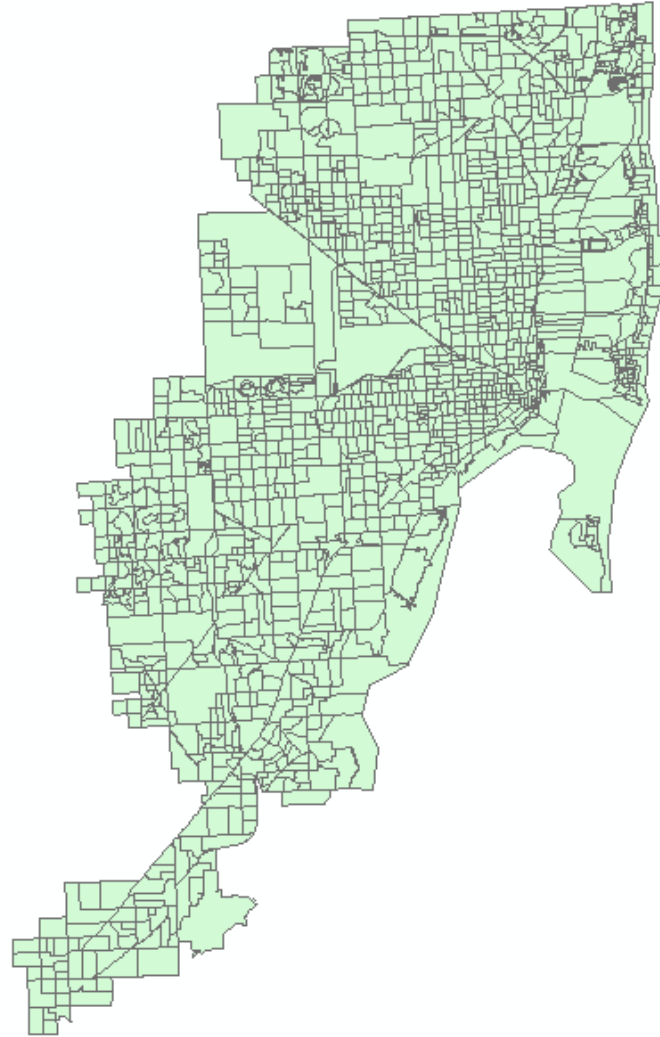
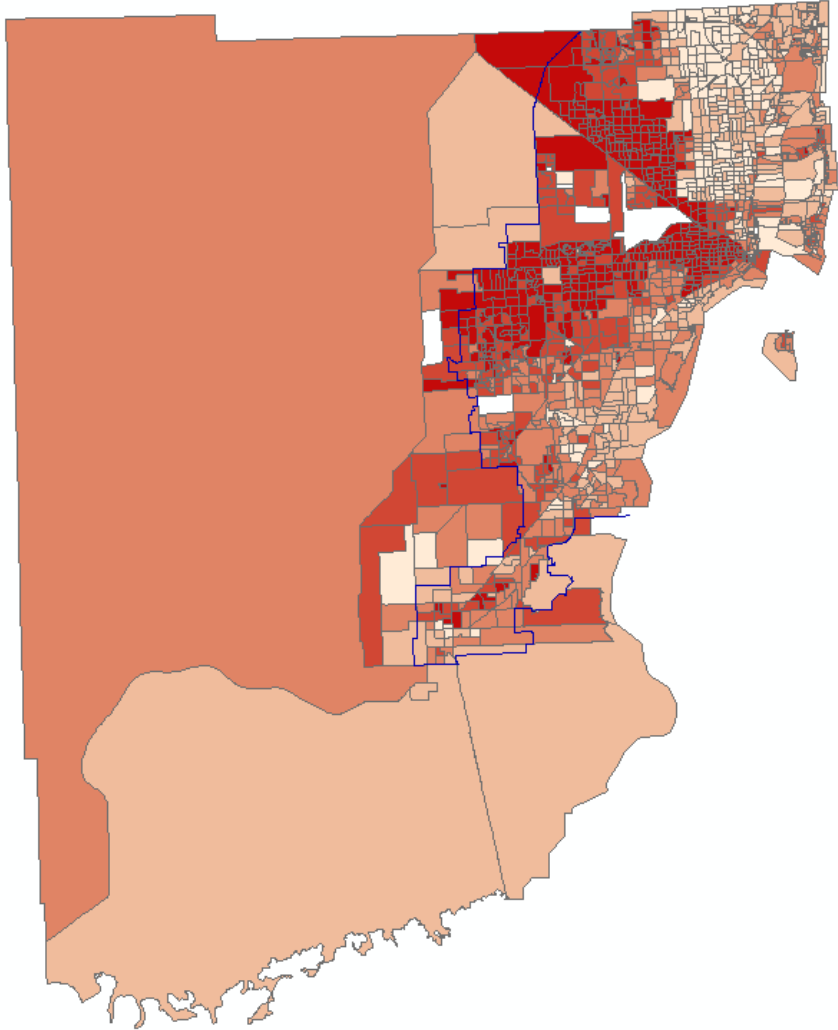




RESEARCH QUESTIONS

- How much land in Miami will be inundated by 2100 due sea level rise according to different predictions?
- How is infrastructure (such as roads and hospitals) affected by sea level rise based on different predictions?
- How much do the different predictions for SLR vary? What lessons can be learned for planners when considering different predictions?

CREATE STUDY AREA



5m DEM from University of Florida

CURRENT AREA AT OR BELOW SEA LEVEL

Con

Input conditional raster
raster_1

Expression (optional)
"VALUE" <=0

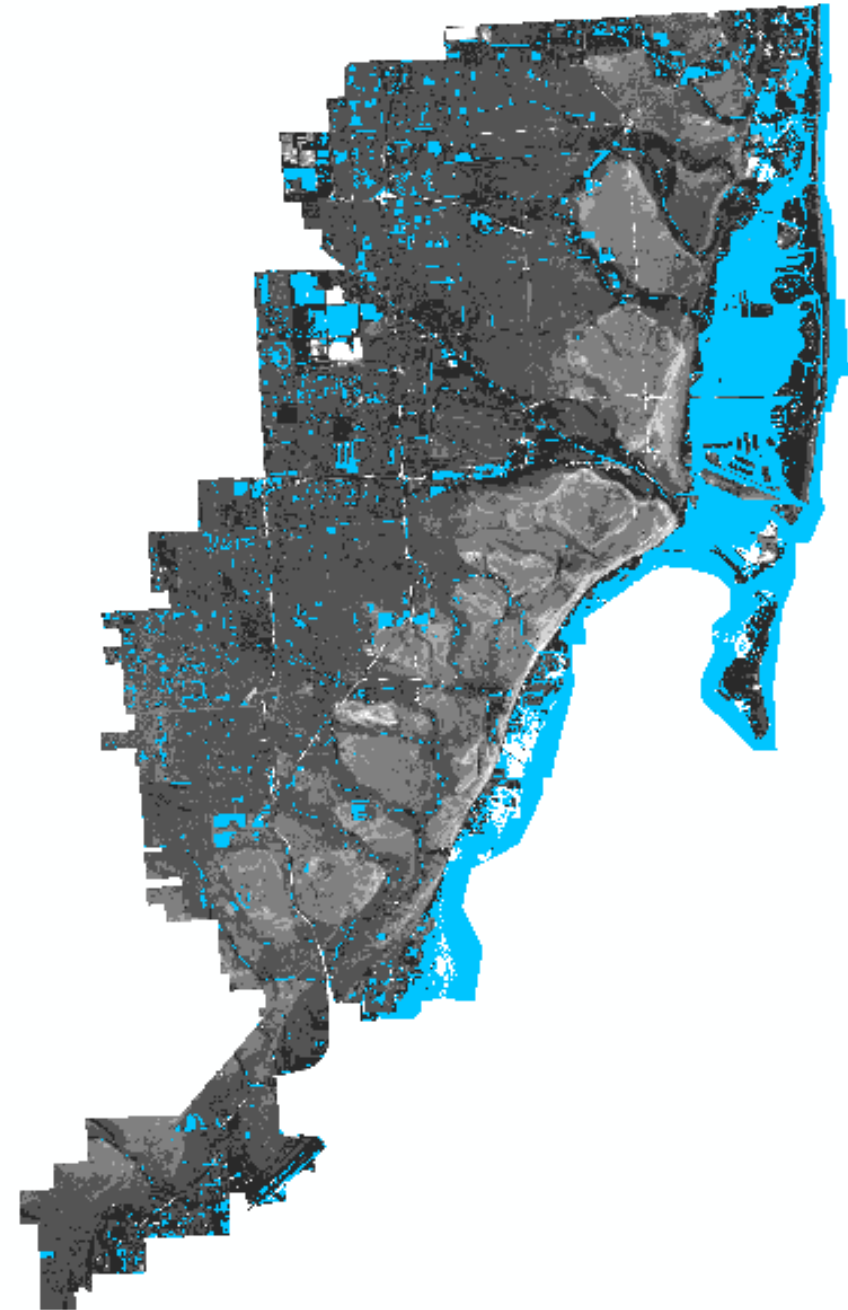
Input true raster or constant value
0

Input false raster or constant value (optional)
raster_1


Output raster
C:\Users\eri3\Documents\ArcGIS\Default.gdb\Con_raster_16



<http://www.bbc.com/future/story/20170403-miamis-fight-against-sea-level-rise>









LOW ESTIMATE FLOOD: SEA LEVEL RISE OF 1 METER

 Raster Calculator

Map Algebra expression

Layers and variables

-  raster_1m
-  con_raster_1
-  raster_1
-  raster_mask20
-  raster_mask2
-  dem


7	8	9	/	==	!=	&
4	5	6	*	>	>=	
1	2	3	-	<	<=	^
0	.	+	()	~	


Conditional

- Con
- Pick
- SetNull
- Math
- Abs
- Exp
- Exp10


"raster_mask20" - 1|

Output raster


C:\Users\eri3\Documents\ArcGIS\Default.gdb\rastercalc15 

 Con


Input conditional raster

raster_1 


Expression (optional)

"VALUE" <=0 


Input true raster or constant value

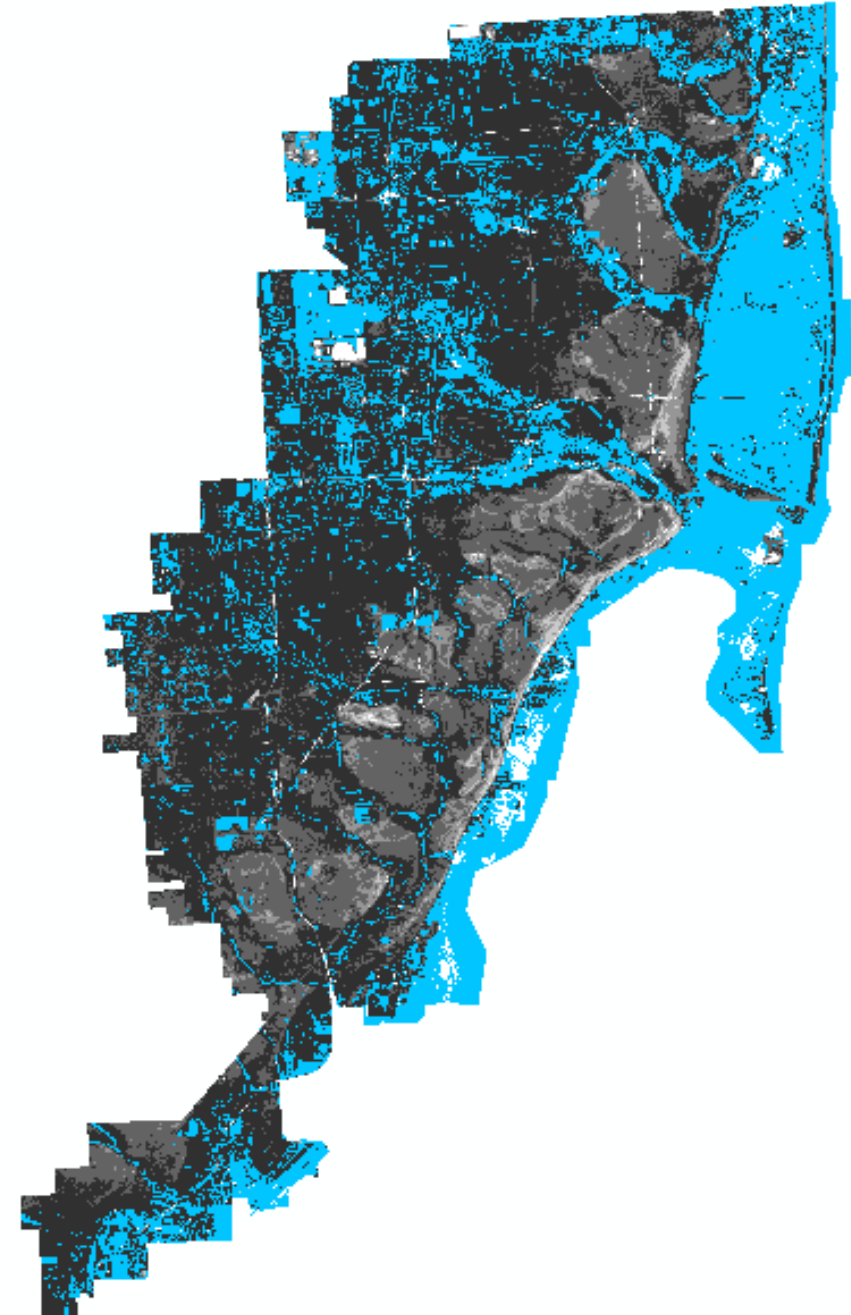
0 

Input false raster or constant value (optional)

raster_1 

Output raster

C:\Users\eri3\Documents\ArcGIS\Default.gdb\Con_raster_16 



HIGH ESTIMATE FLOOD: SEA LEVEL RISE OF 2 METERS

Raster Calculator

Map Algebra expression

Layers and variables

- 1mSLR
- raster_1
- 0mSLR
- raster_mask2
- dem

Conditional

- Con
- Pick
- SetNull
- Math
- Abs
- Exp
- Exp10

7 8 9 / == != &

4 5 6 * > >= |

1 2 3 - < <= ^

0 . + () ~

"0mSLR" - 2

Output raster

D:\DTA\final\raster_2

Con

Input conditional raster

raster_2

Expression (optional)

"VALUE" <= 0

Input true raster or constant value

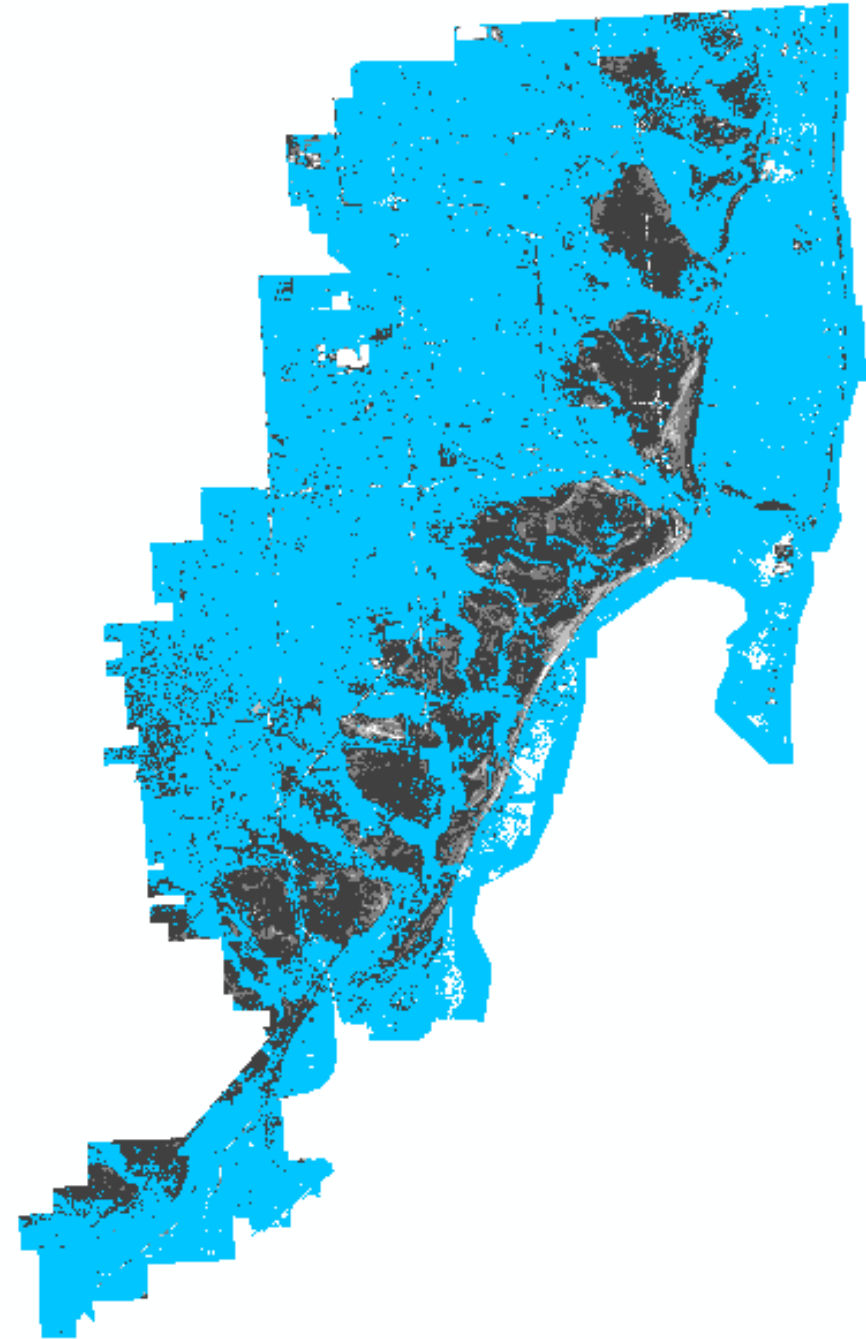
0

Input false raster or constant value (optional)

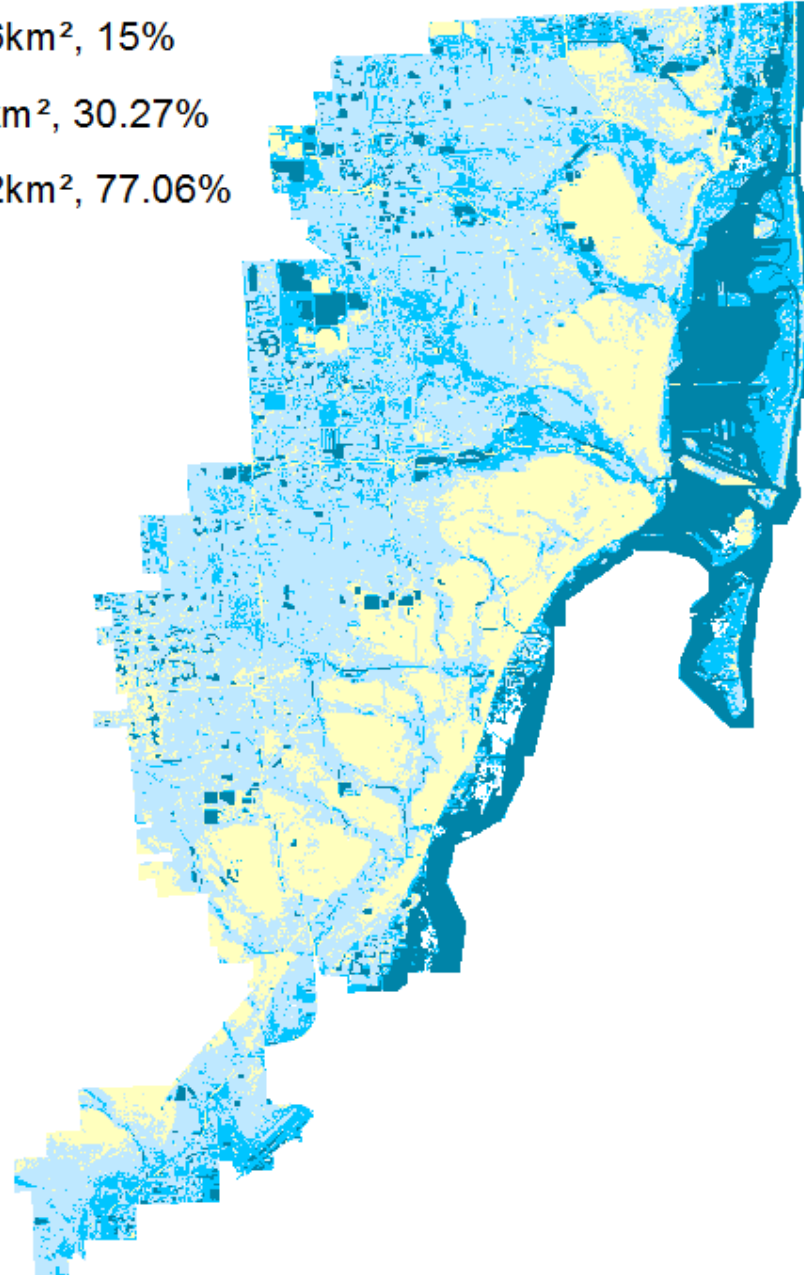
raster_2

Output raster

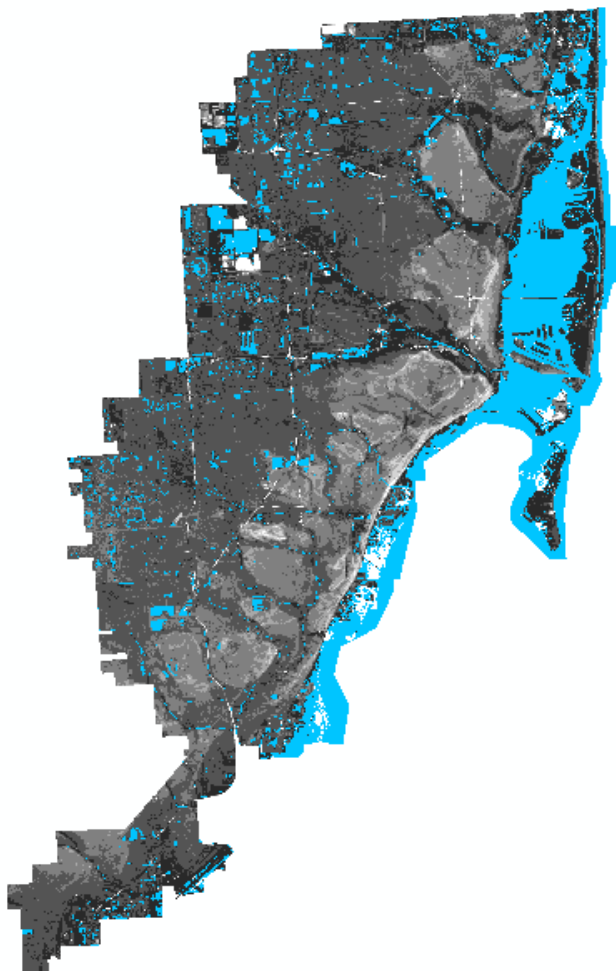
D:\DTA\final\raster_2con



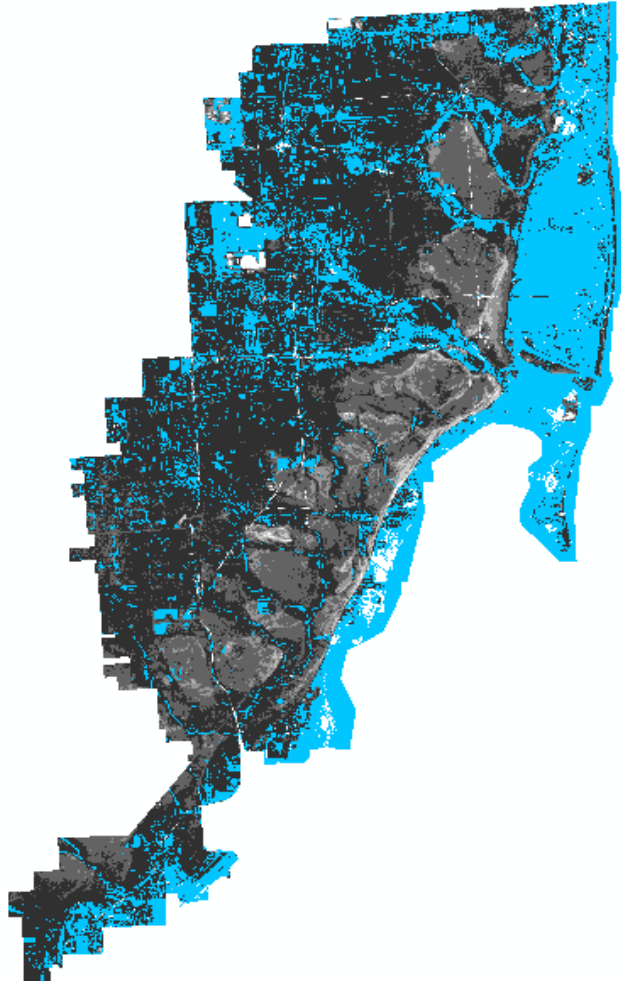
Amount underwater per sea level rise



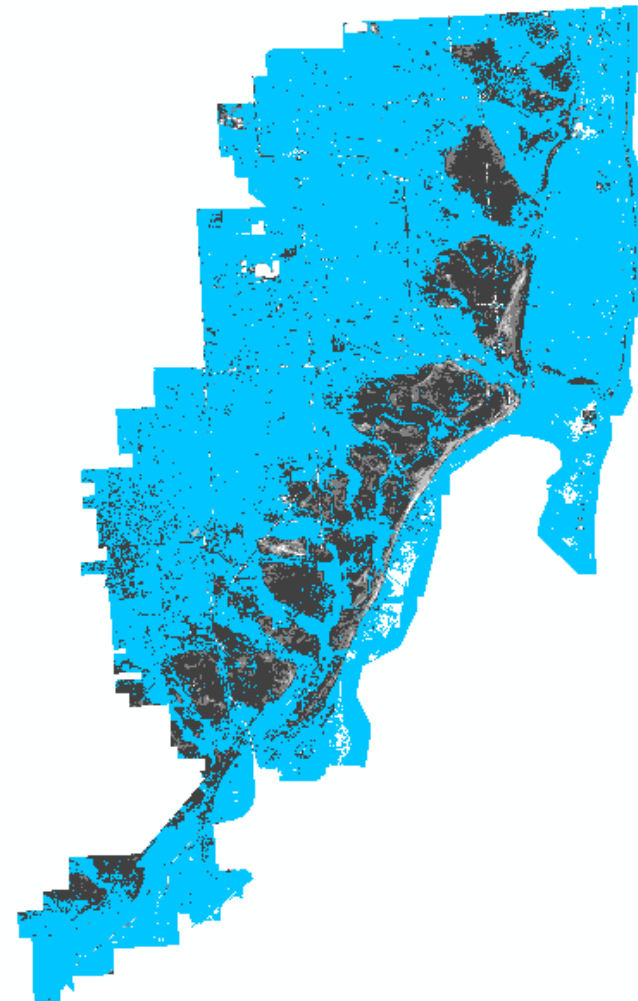
COMPARISON OF SEA LEVEL RISE



Original sea level: 15%



1m SLR: 30.27%, (15.27% increase)

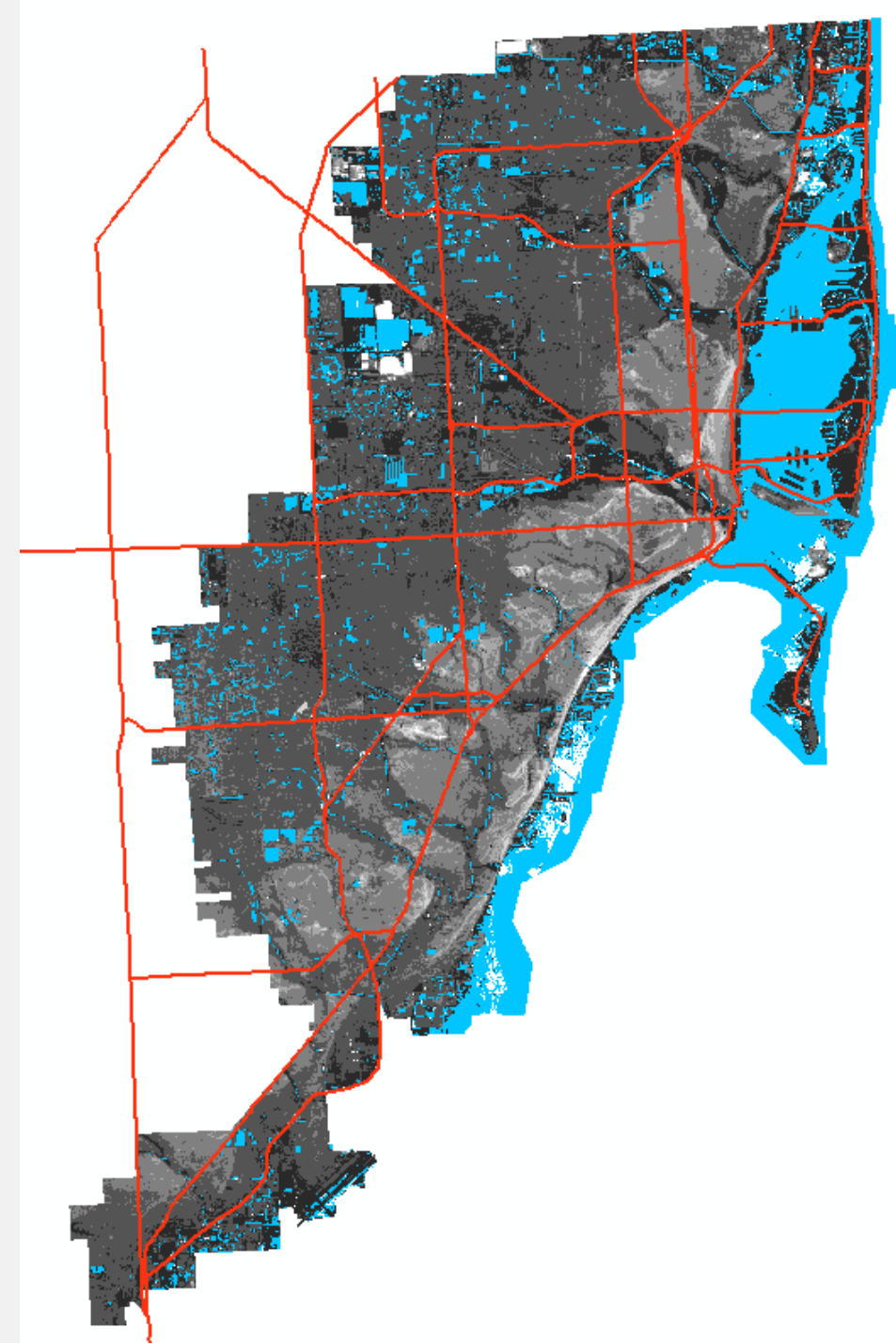


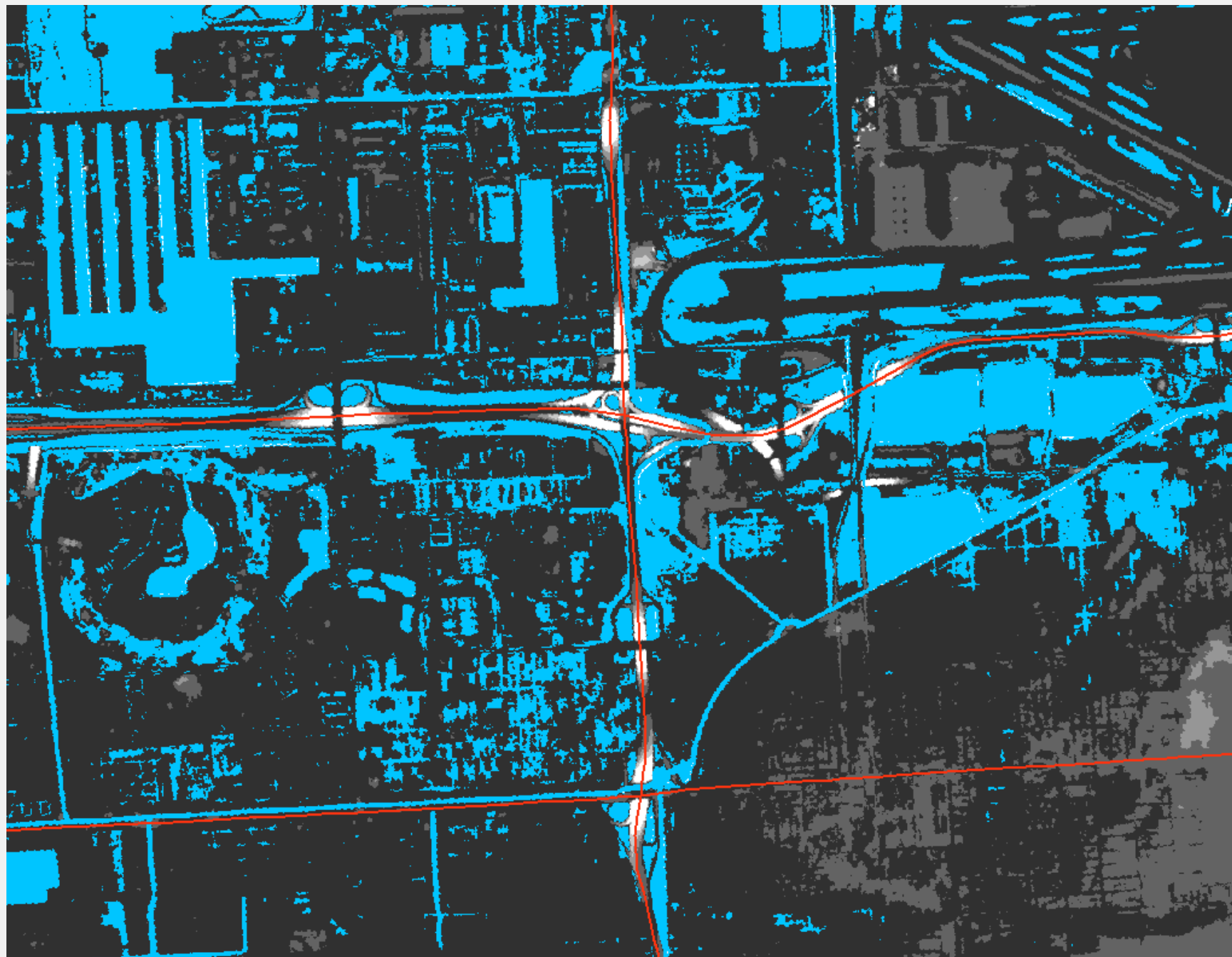
2 m SLR: 77.06% (62.06% increase)

INFRASTRUCTURE ANALYSIS: PRIMARY EVACUATION ROUTES

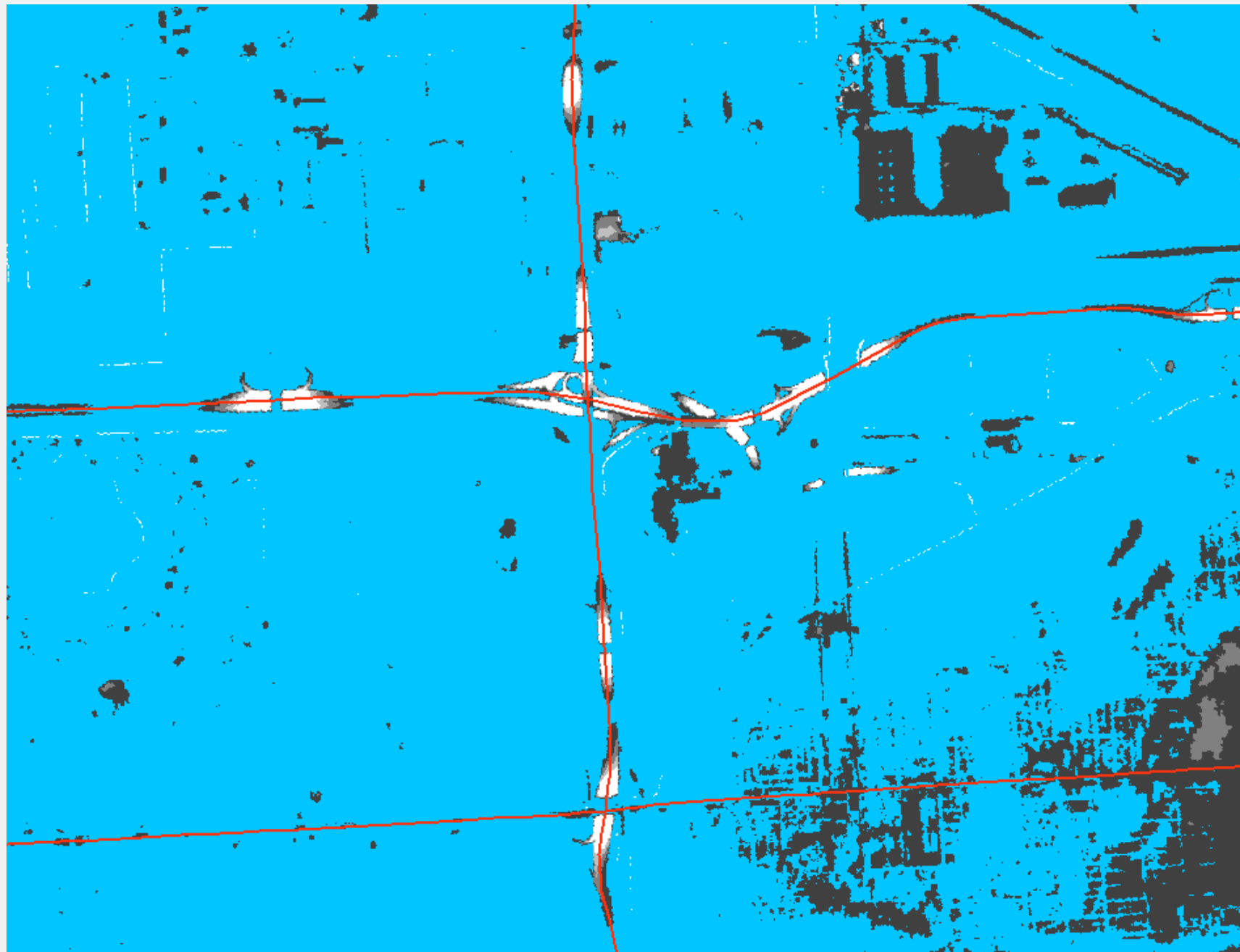


<http://www.bbc.com/future/story/20170403-miamis-fight-against-sea-level-rise>





1 meter sea level rise



2 meter sea level rise

INFRASTRUCTURE ANALYSIS: HOSPITALS

Select By Location

Select features from one or more target layers based on their location in relation to the features in the source layer.

Selection method:

select features from

Target layer(s):

- ☒ Hospital
- ☐ line2
- ☐ 0m SLR: 172.06km², 15%
- ☐ 1m SLR: 344.2km², 30.27%
- ☐ 2m SLR: 876.22km², 77.06%
- ☐ polygon
- ☐ intersect0slr
- ☐ census
- ☐ Urban_Development_Boundary
- ☐ simp2_0slr
- ☐ Primary_Evacuation_Route

☐ Only show selectable layers in this list

Source layer:

0m SLR: 172.06km², 15%

☐ Use selected features (0 features selected)

Spatial selection method for target layer feature(s):

are within the source layer feature

☐ Apply a search distance

6000.000000

Meters

[About select by location](#)

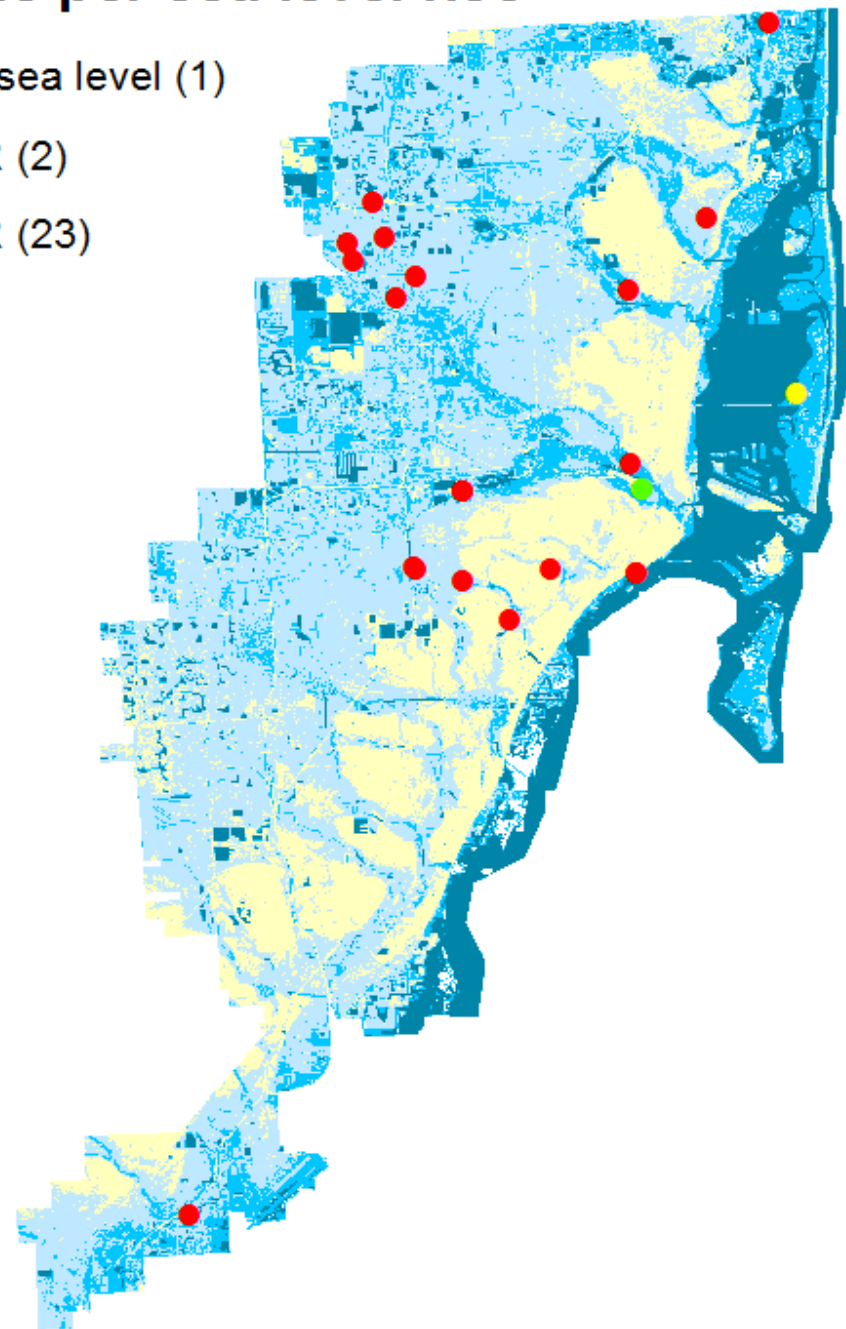
OK

Apply

Close

Number of hospitals per sea level rise

- Hospitals at current sea level (1)
- Hospitals at 1m SLR (2)
- Hospitals at 2m SLR (23)





[http://ak4.picdn.net/shutterstock/videos/5596124/thumb/1.jpg?i10c=img.resize\(height:160\)](http://ak4.picdn.net/shutterstock/videos/5596124/thumb/1.jpg?i10c=img.resize(height:160))

According to The Washington Post, Mt Sinai Hospital, Mercy Hospital, and Sister Immanuel Hospital were evacuated prior to Hurricane Irma. These are all in the 2m SLR flood zone, and Mt. Sinai is also in the 1m SLR flood zone.



INFRASTRUCTURE ANALYSIS: PUBLIC SCHOOLS

Public schools per sea level rise

- Public Schools at 1m SLR (23, 5.2%)
- Public Schools at 2m SLR (261, 59%)

Select By Location ×

Select features from one or more target layers based on their location in relation to the features in the source layer.

Selection method:
select features from ▼

Target layer(s):

- ☒ Public_School
- ☐ Hurricane_Bus_stop
- ☐ Primary_Evacuation_Route2
- ☐ rte0SLR
- ☐ Primary_Evacuation_Route
- ☐ Hospitals at current sea level (1)
- ☐ Hospitals at 1m SLR (2)
- ☐ Hospitals at 2m SLR (23)
- ☐ Hospital
- ☐ line2
- ☐ 0m SLR: 172.06km², 15%

☐ Only show selectable layers in this list

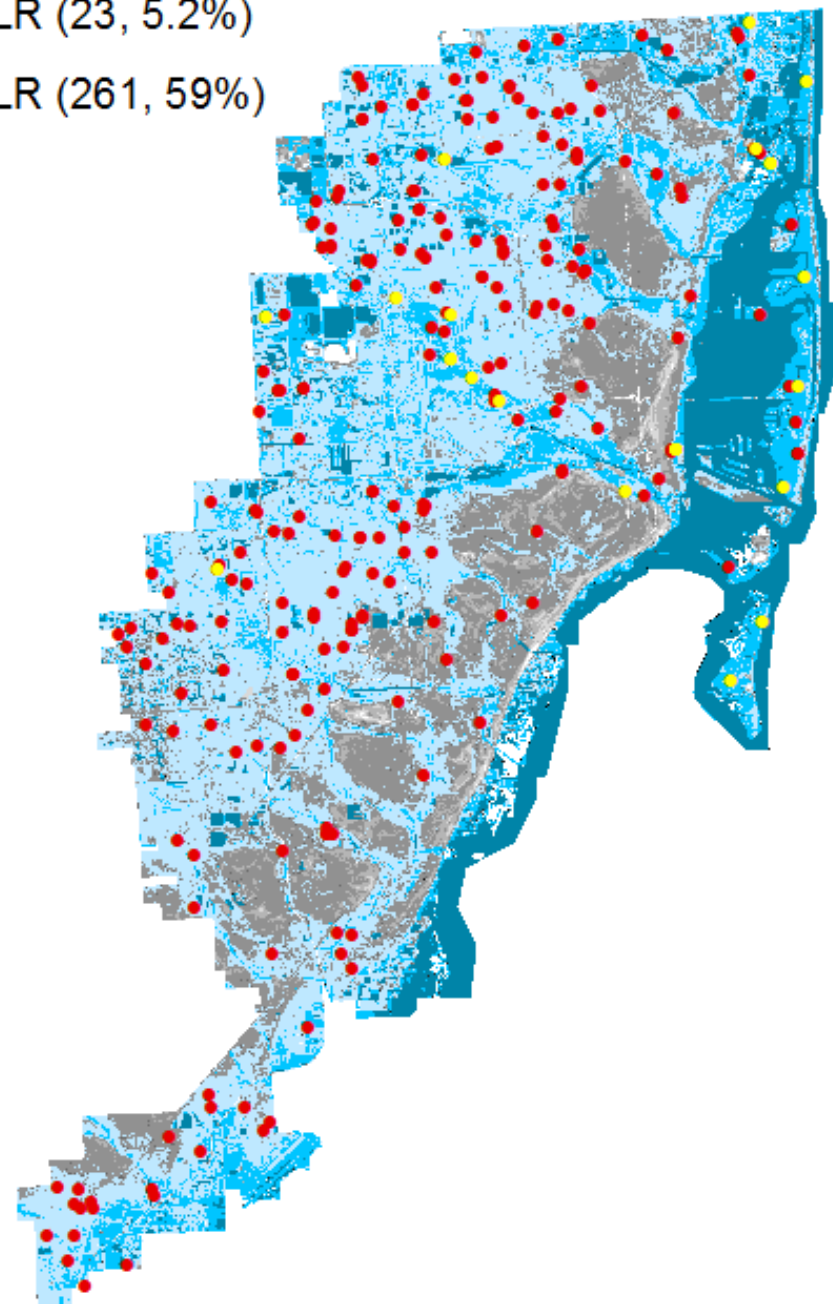
Source layer:
0m SLR: 172.06km², 15% ▼

☐ Use selected features (0 features selected)

Spatial selection method for target layer feature(s):
are within the source layer feature ▼

☐ Apply a search distance
6000.000000 Meters ▼

[About select by location](#) OK Apply Close



INFRASTRUCTURE ANALYSIS: SUPERFUND SITES

Superfund sites are areas identified as containing hazardous toxic waste. They are targeted for remediation by the EPA.

After Hurricane Sandy, the Gowanus Canal overflowed into people's homes, resulting in massive contamination and cleanup. After Hurricane Katrina, increased chemical exposure in the groundwater and soil were traced back to the flooding of Superfund sites.

(Atkin, 2017)



Photo from a flooded Superfund site during Hurricane Harvey in Texas.

https://media.nbcdfw.com/images/1200*675/toxicwastewaterEPAharvey_1200x675.jpg

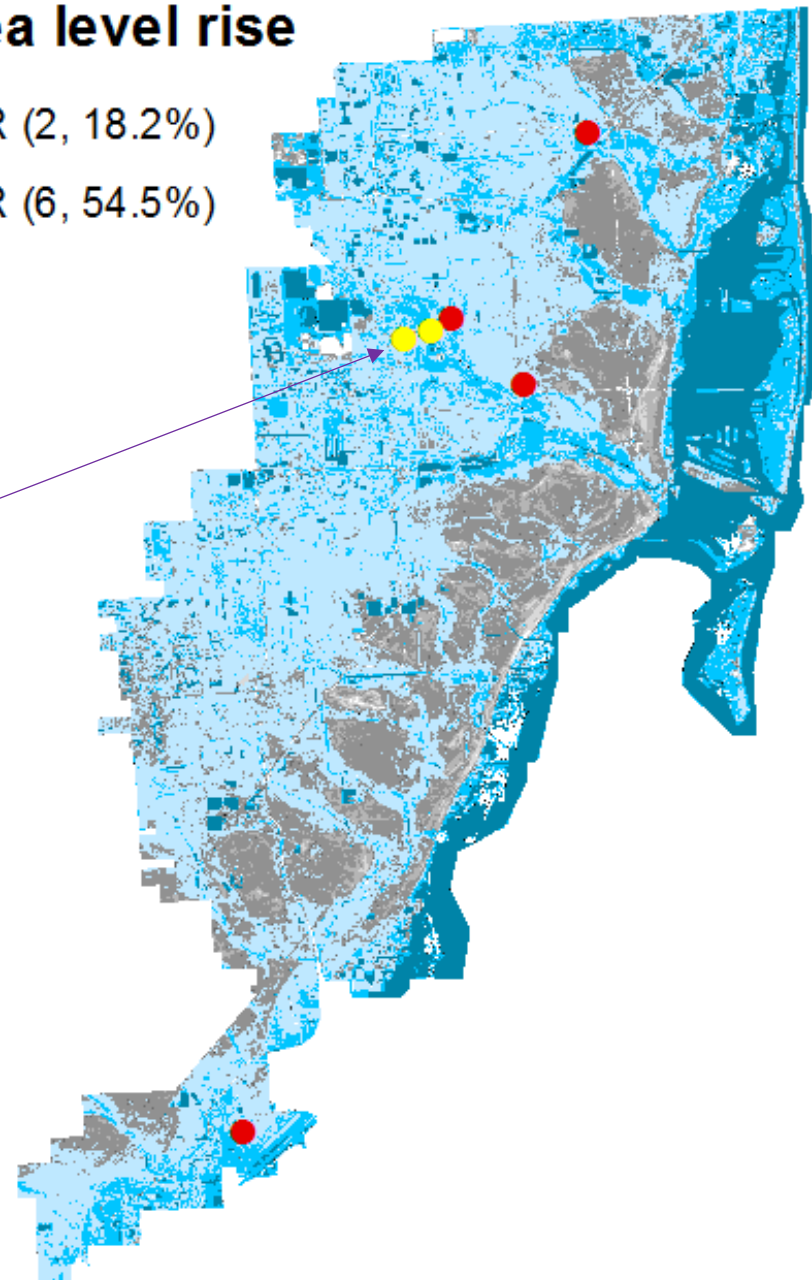
Barrels of IDW “Investigation Derived Waste” at Miami Drum Service, one of the Superfund Sites located at 1m SLR. This site is located over a drinking-water aquifer. (Kennedy, 2017)



<http://www.chicagotribune.com/news/nationworld/ct-irma-toxic-waste-sites-20170909-story.html>

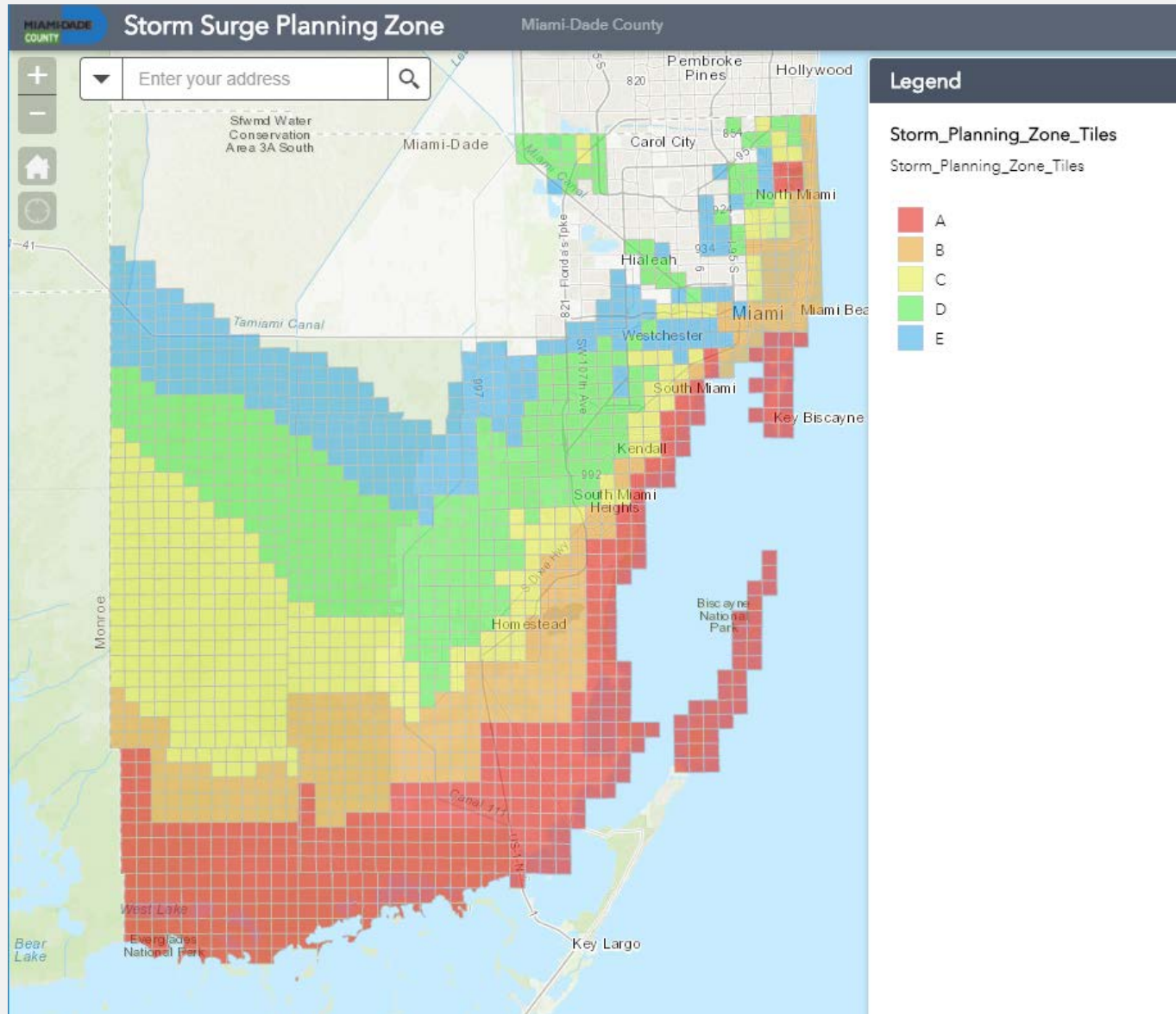
Superfund sites per sea level rise

- Superfund Site at 1m SLR (2, 18.2%)
- Superfund Site at 2m SLR (6, 54.5%)



LIMITATIONS AND IMPROVEMENTS

- DEM resolution
- Storm surges
 - SLOSH Model (Sea, Lake, and Overland Surges from Hurricanes)
 - Accounts for physical factors like coastal area, bay, river shape, water depth, bridges, canals, etc.



<http://mdc.maps.arcgis.com/apps/webappviewer/index.html?id=4919c85a439f40c68d7b3c81c3f44b58>



Canal (from Miami-Dade County Open Data)
 Shared by MDPublisher
 Line feature class that graphically displays Miami-Dade County Canals for mapping purposes
 Projected Coordinate System: WGS_1984_Web_Mercator_Auxiliary_Sphere
 Projection: Mercator_Auxiliary_Sphere

4 attributes | 1754 locations | [Download](#) [Star](#)



Lake (from Miami-Dade County Open Data)
 Shared by MDPublisher
 Polygon feature class of lakes within Miami-Dade-County
 Projected Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
 Projection: Mercator Auxiliary Sphere
 False Easting: 0.00000000
 False Northing: 0.00000000
 Central Meridian: 0.00000000
 Standard Parallel_1: 0.00000000
 Auxiliary Sphere Type: 0.00000000
 Linear Unit: Meter

8 attributes | 1936 locations | [Download](#) [Star](#)



Stream (from Miami-Dade County Open Data)
 Shared by MDPublisher
 A line feature class of streams located within Miami-Dade County.

http://gis-mdc.opendata.arcgis.com/datasets?q=Hydrology&sort_by=name&sort_order=asc

WORKS CITED

Atkin, E. (2017, September 8). America Has a Toxic Waste Hurricane Problem. *The New Republic*. Retrieved December 7, 2017, from <https://newrepublic.com/article/144737/america-toxic-waste-hurricane-problem>

Biesecker, M., & Dearen, J. (2017, September 9). Flooding threatens toxic waste sites as Hurricane Irma nears. *Chicago Tribune*. Retrieved December 7, 2017, from <http://www.chicagotribune.com/news/nationworld/ct-irma-toxic-waste-sites-20170909-story.html>

FGDL Metadata Explorer. (n.d.). Retrieved December 07, 2017, from <https://www.fgdl.org/metadataexplorer/explorer.jsp>

Lindsey, R. (2017, September 11). Climate Change: Global Sea Level. Retrieved December 04, 2017, from <https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level>

Miami-Dade County GIS Open Data. (n.d.). Retrieved December 07, 2017, from <http://gis-mdc.opendata.arcgis.com/>

Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group (Compact). October 2015. *Unified Sea Level Rise Projection for Southeast Florida*. A document prepared for the Southeast Florida Regional Climate Change Compact Steering Committee. 35 p.