

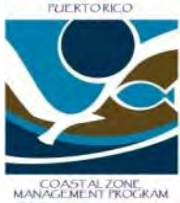
Puerto Rico
Department of Natural and Environmental Resources

Climate Change Vulnerability Assessment and Adaptation Strategies



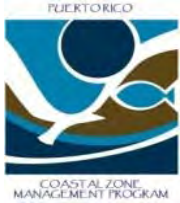
Ernesto L. Díaz, M.S., EEM
Marine Scientist - Director

2012



OVERVIEW

1. Puerto Rico Coastal Zone Management Program.
2. Climate variability and change in Puerto Rico.
3. Puerto Rico Climate Change Council.
4. Vulnerability Assessment
5. Future Scenarios and Adaptation Strategies.
6. Challenges (Planning, Design, Coastal Development and Biodiversity Conservation).



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2012

PRCZMP

The Puerto Rico Coastal Zone Management Program¹ is a partnership led by the Department of Natural and Environmental Resources to promote the protection, conservation and sustainable development of coastal and marine areas and resources.

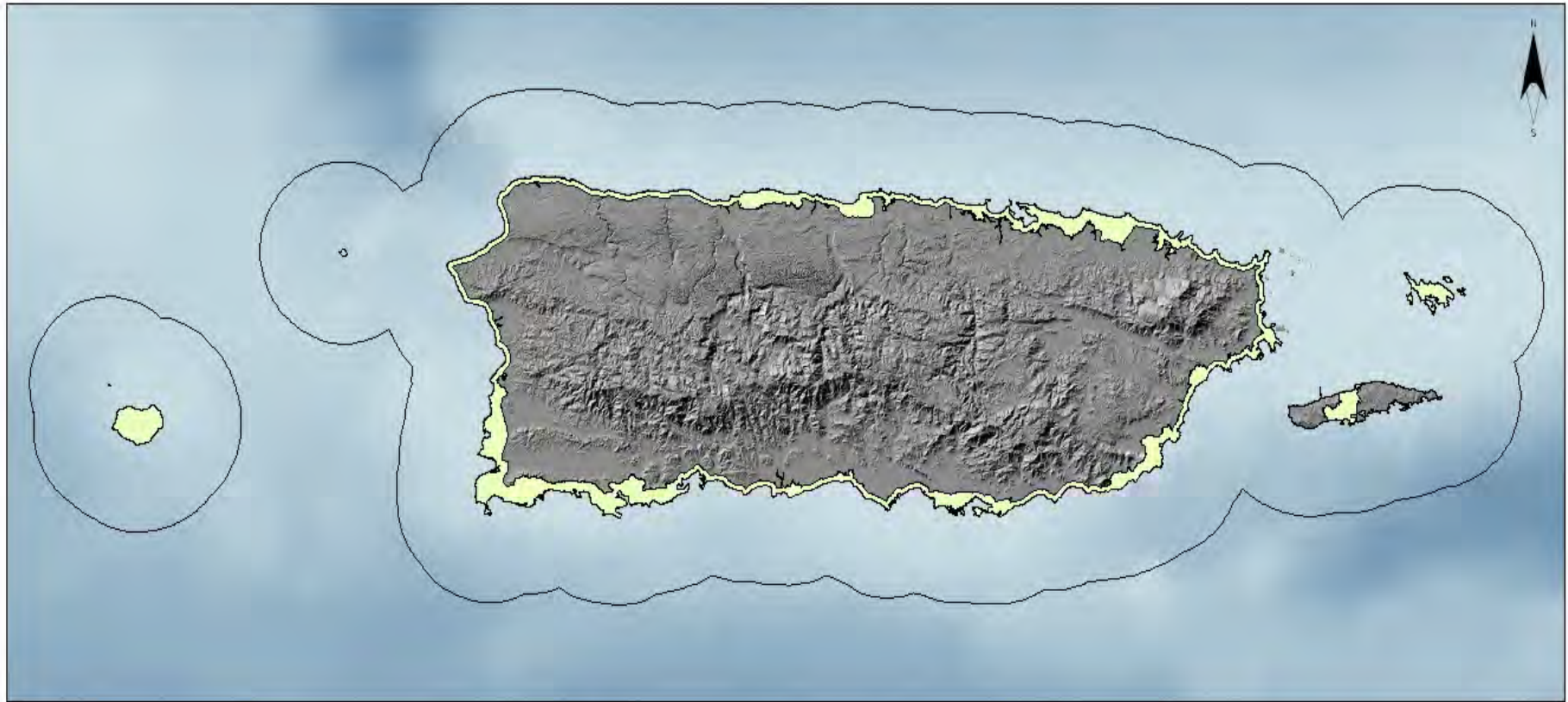
1. Adopted by Government of Puerto Rico and NOAA in 1978





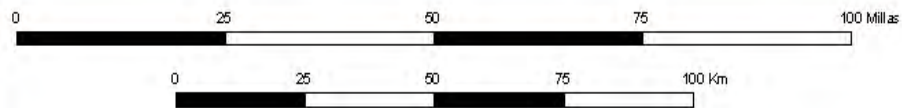
Goals and objectives:

- Guide public and private development in the coastal zone
- Conduct active management of coastal and marine resources.
- Foster scientific research, environmental education and public participation as key elements of sustainable development.

ÁMBITO DE APLICACIÓN DEL PROGRAMA DE MANEJO DE LA ZONA COSTANERA DE PUERTO RICO



-  Límite Terrestre
-  Límite Marino



RELEVANT STATISTICS

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2012

Emerged land area:	3,508 mi ² (9,497 km ²)
Territorial waters:	9 mn (10.35 mi)
Population:	~3.8 millones (26 th U.S.)
Coastal Population:	2.73 millones (70%)
Urban areas at CZ:	40%
Urban/coastline ratio:	24%
GDP:	~\$ 95.7 billion/yr

Economy (2009):

- **Manufacture: 45.5%**
- **Finances, Insurance and Real Estate: 19%**
- **Services: 12.8% (Turismo: 7%)**
- **Government: 9.7%**
- **Comerce: 7.8%**
- **Transportation and Services: 3.2%**
- **Construcction: 1.9%**
- **Agriculture: 0.7**

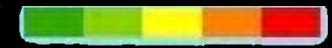
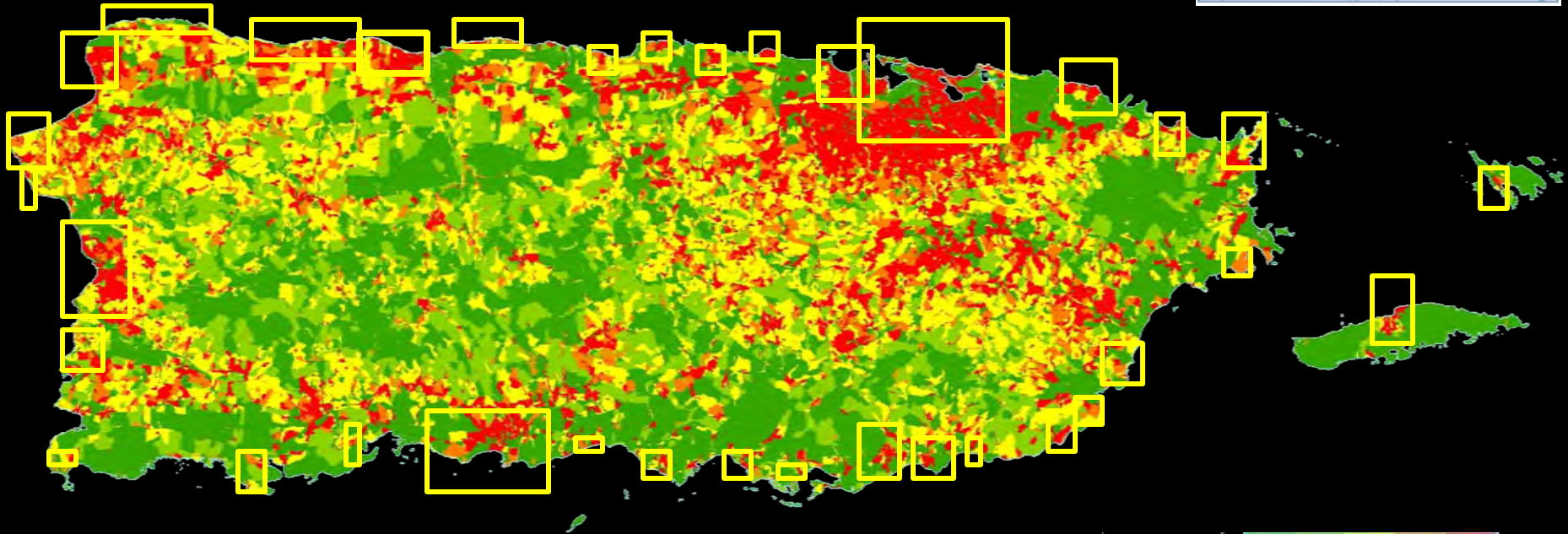


Critical Infraestructure (CZ jurisdiction: 1 Km)



- Eight ports
- Eight airports
- Six Power Plants
- 1,080 miles of sanitary infrastructure
- 81 industrial parks
- 114 miles of primary roads

Population density



0.0 - 31 (US Population Density)
31.1 - 100
100.1 - 310
310.1 - 500
Over 500

24% urban / coastline ratio



Climate Variability and Change in Puerto Rico

BACKGROUND:

- Scientific studies (Oceanography, Forestry, Wildlife biology, Marine biology, etc.)
- Greenhouse Gas Inventory (pre-Kyoto)
- Sea Grant roundtable
- Climate Change law and Executive Order creating a high level Advisory Commission.
- UPR- Carolina: Climate Change Summits
- **Puerto Rico Climate Change Council**



Puerto Rico Climate Change Council (PRCCC)

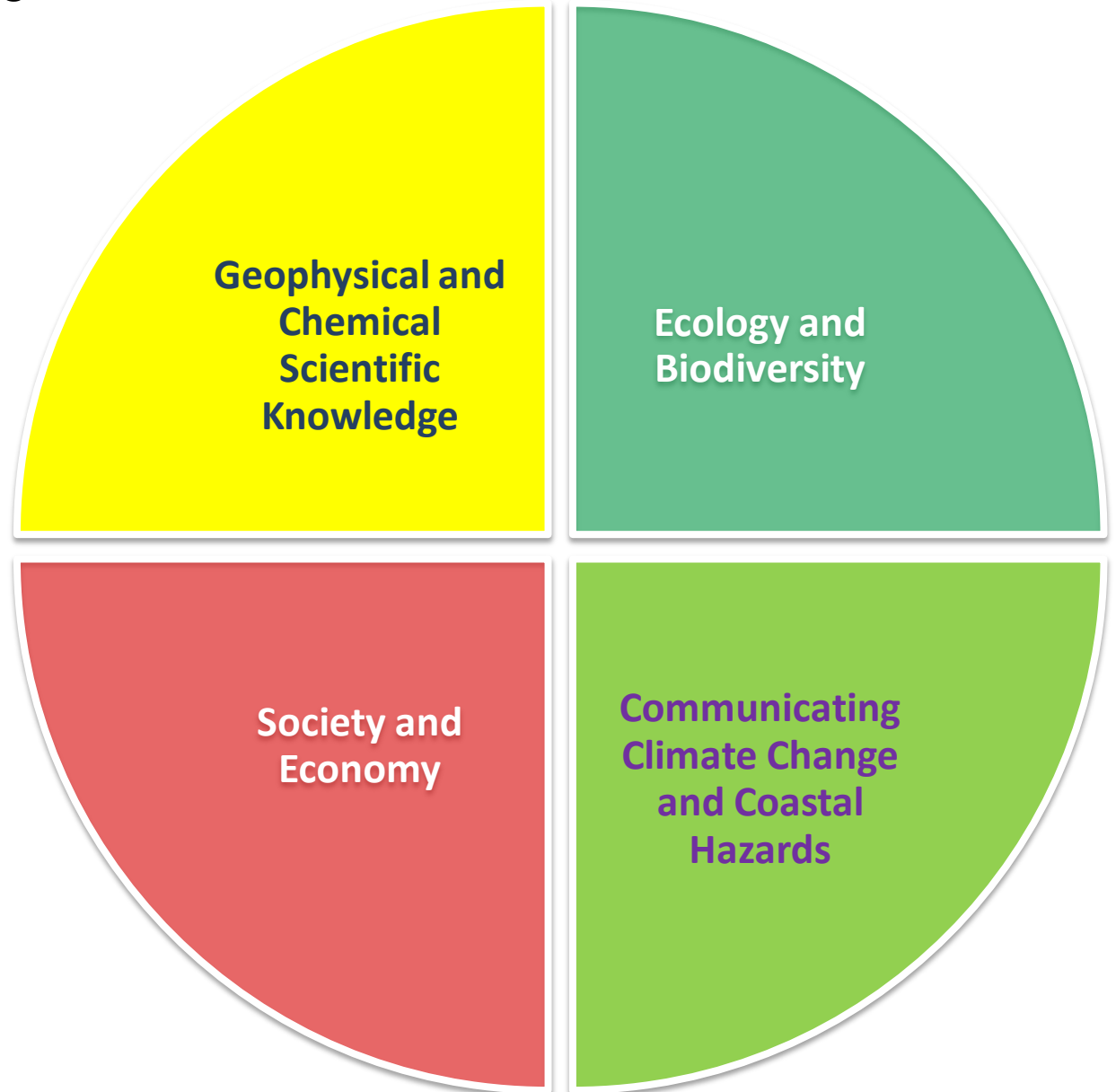
Climate Change Adaptation Project

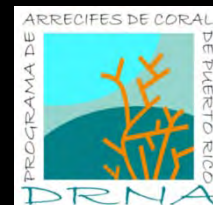
Submitted by PRCZMP approved by NOAA-CSC (2010)

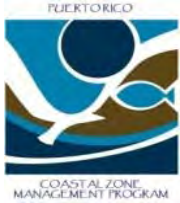
2010-2011: Vulnerability Assessment for three key sectors: coastal communities, critical infrastructure and coastal biodiversity.

2012: Adaptation Strategies (Recommendations, draft bills and proposed amendments to building codes and regulations)

**Four Working Groups
for the Puerto Rico
Climate Change
Council (PRCCC)**





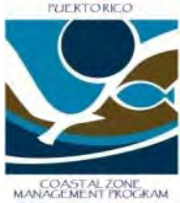


WG1: Historical trends and projections:

1. Atmospheric temperature
2. Precipitation
3. Extreme events (downpours)
4. Hurricanes
5. Sea surface temperature
6. Winter swells
7. Sea level rise
8. Ocean acidification

WG 2: Ecology and Biodiversity

1. Wetlands
2. Mangroves
3. Coral reefs
4. Beach systems
5. Submerged aquatic vegetation/sea-grasses (SAV)
6. Coastal lagoons
7. Estuaries
8. Keys and islets
9. Bioluminescent bays
10. Sea turtles
11. Fisheries
12. Marine mammals
13. Reptiles
14. Amphibians
15. Forests
16. Wildlife



WG 3: Economy and Society

- 1. Economic development**
- 2. Energy**
- 3. Tourism**
- 4. Industry**
- 5. Agriculture**
- 6. Infraestructure**
- 7. Coastal communities resiliency**
- 8. Water resources**
- 9. Historical and cultural resources**
- 10. Emergency management**
- 11. Health**



WG 4

Communicating climate change and coastal hazards

Air Temperature



- On average, the temperature has increased island-wide annually 0.014°C from 1948 to 2007
- 12 stations out of 16 located throughout the island expressed positive trends from ~1948 to 2007
- There is evidence of local trends within Puerto Rico as well. Velazquez-Lozano (2006) mention that the temperature of City of San Juan has grown at a rate of 0.06°C over the past 50 years.
- Therefore, Puerto Rico is becoming a little warmer which is consistent with regional (Caribbean) and global trends.

Precipitation

- Analyses of precipitation data (roughly 1948-2000):
- Precipitation trends analysis shows that clear trends can be established at the island, since most stations show a decrease (12 stations) and some do not show trends.
- Even with a single standard deviation, slight changes in precipitation distribution are observed.
- Southern Region of PR expressed trends in annual rainfall.
- Western Region of PR expressed trends in annual rainfall.
- Northeast and Eastern regions of the island – no clear pattern.
- The observed seasonal trends in precipitation show that summer rainfall has increased in almost 2/3 stations (70%) with significant changes in autumn and spring.

Southern Region of PR

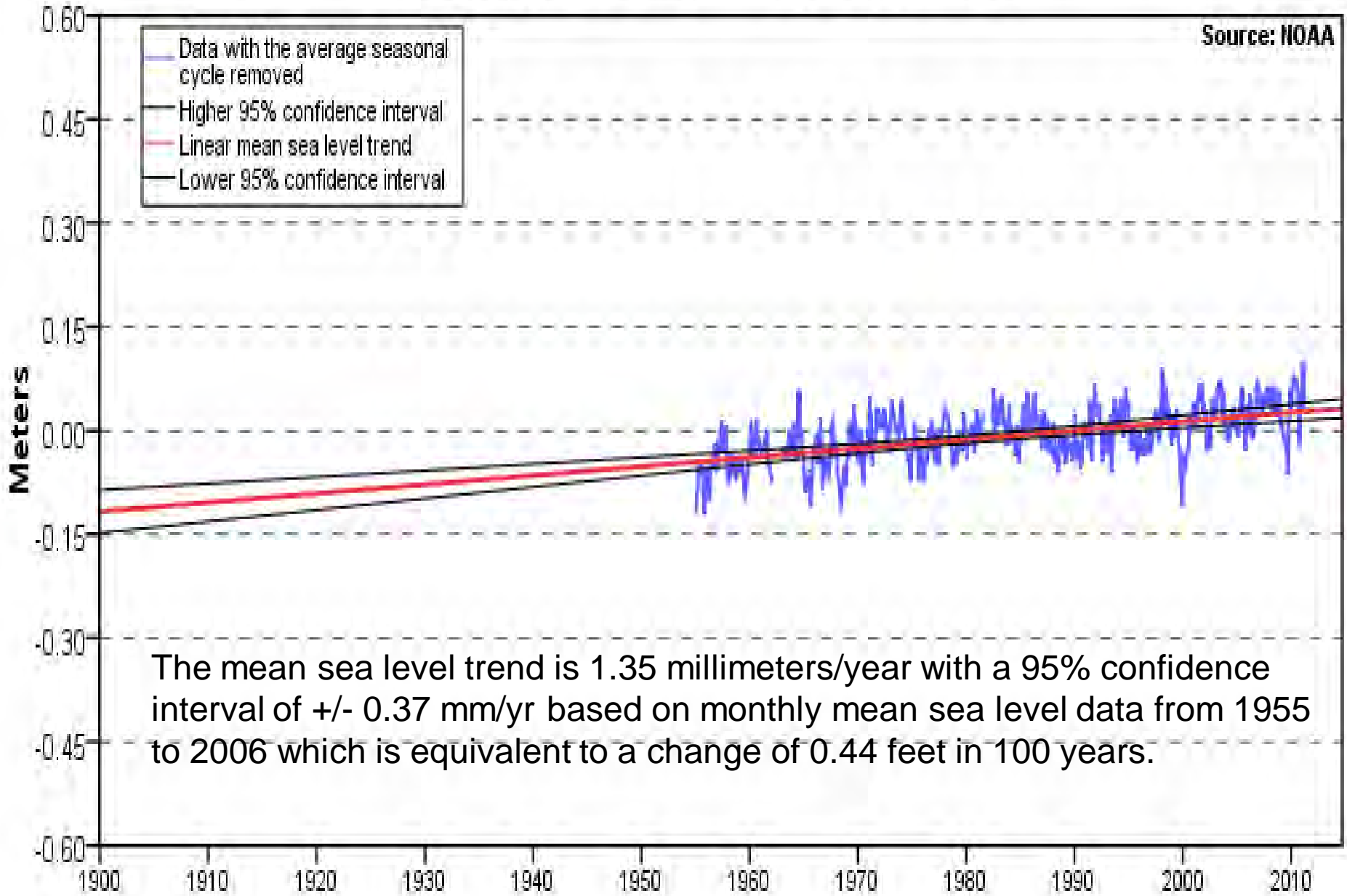
Western Region of PR

Northeast and Eastern

Magueyes Island, PR

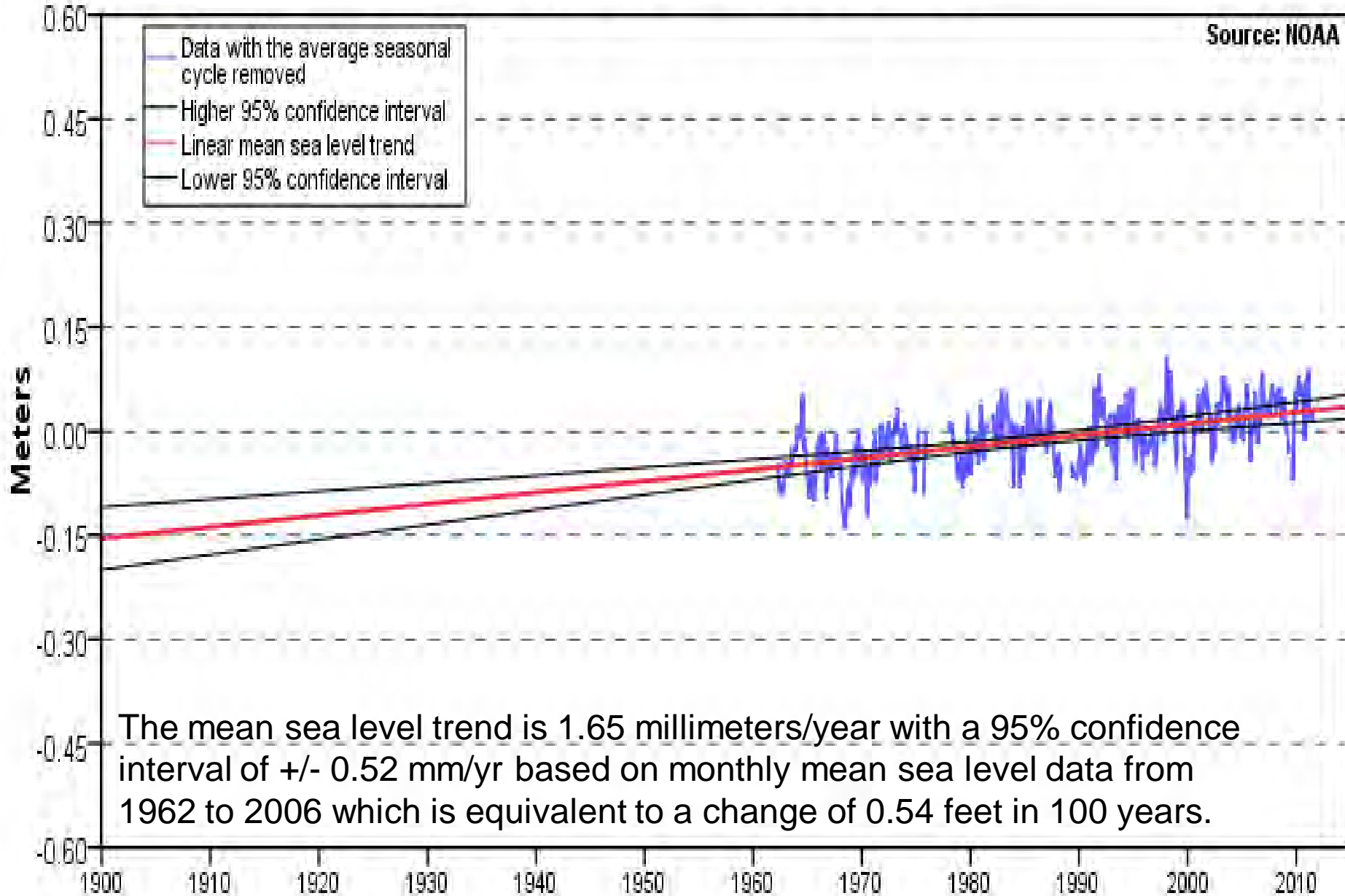
1.35 +/- 0.37 mm/yr

Source: NOAA

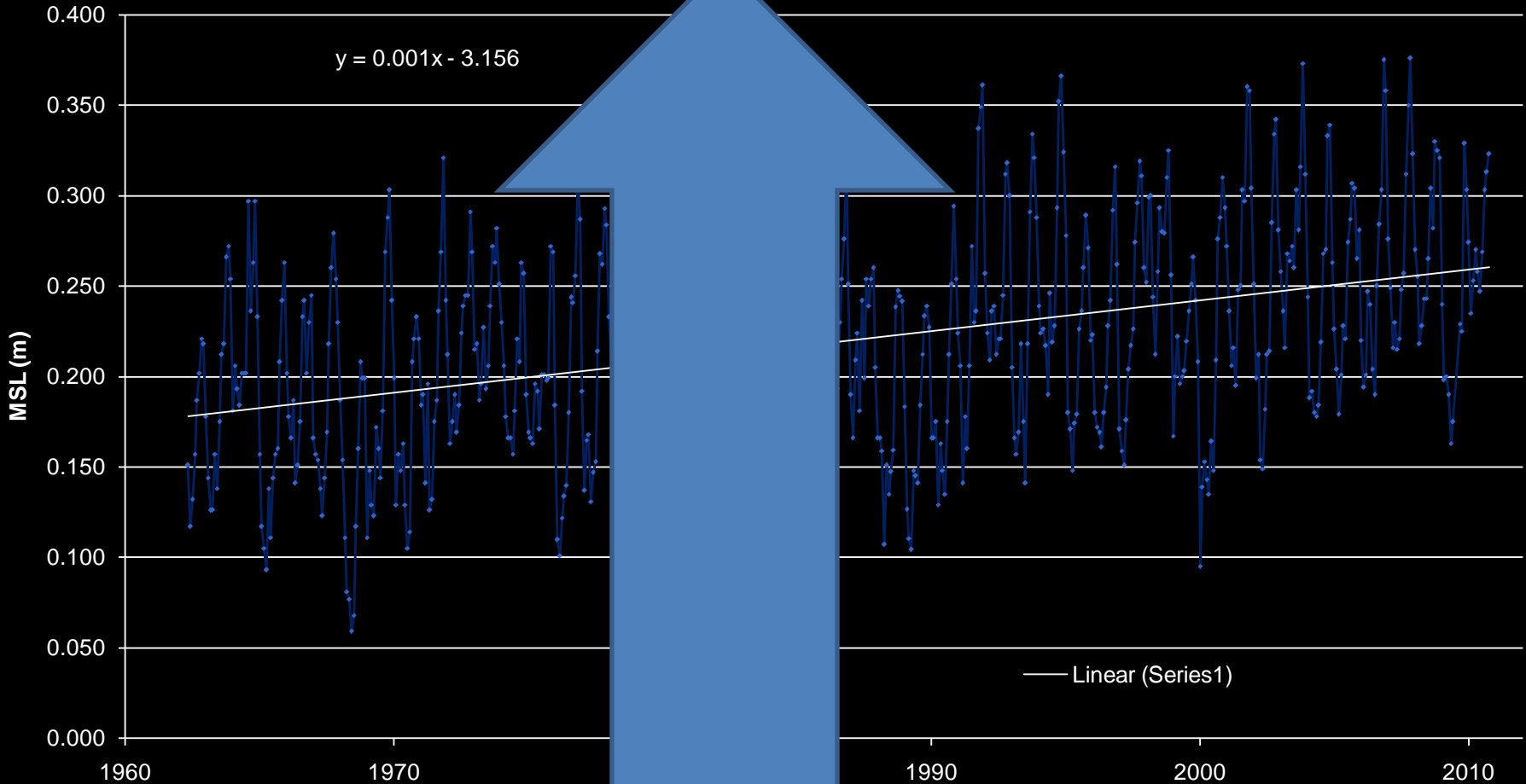


San Juan, PR 1.65 +/- 0.52 mm/yr

Source: NOAA

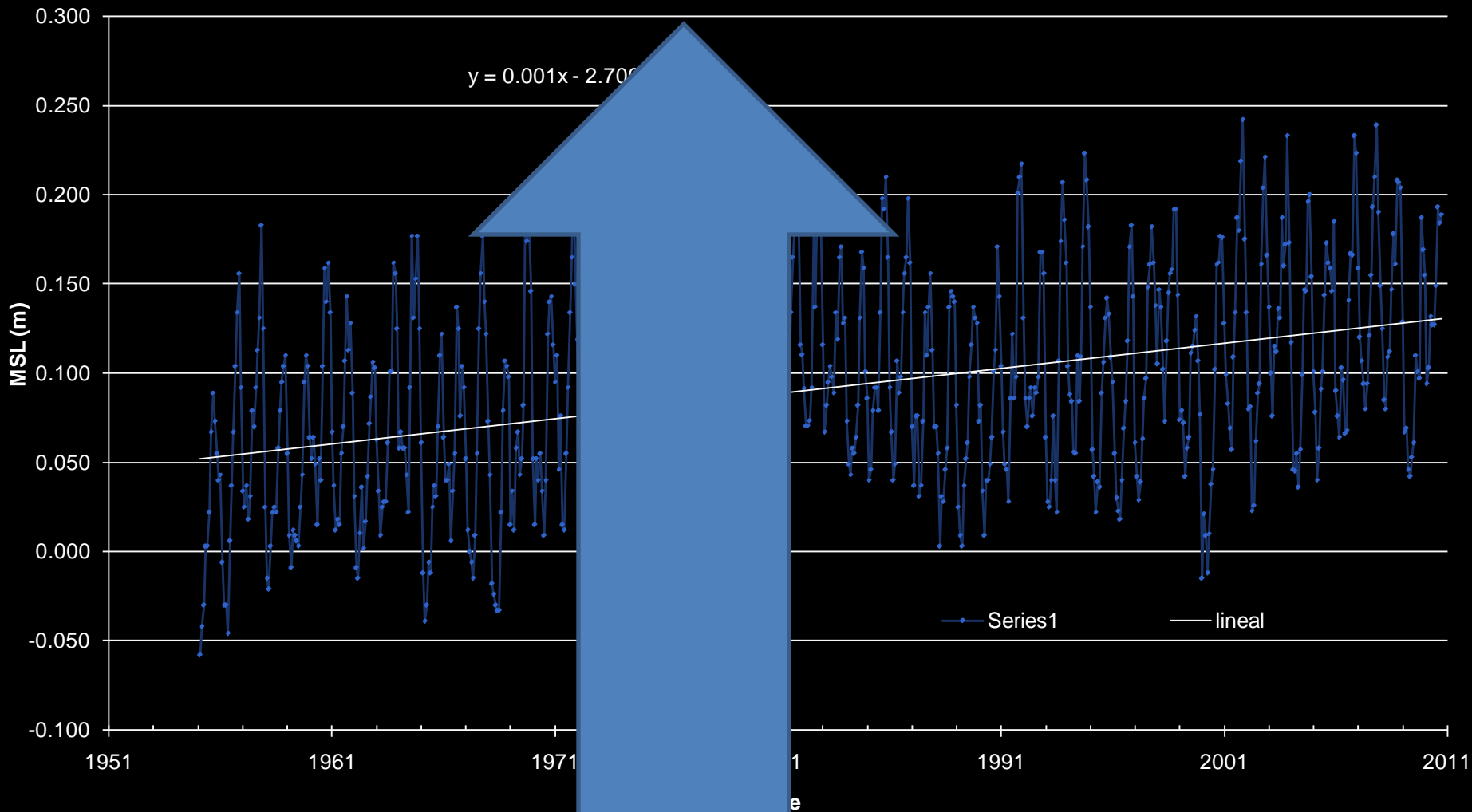


San Juan Monthly Mean Sea Level 1962-2010



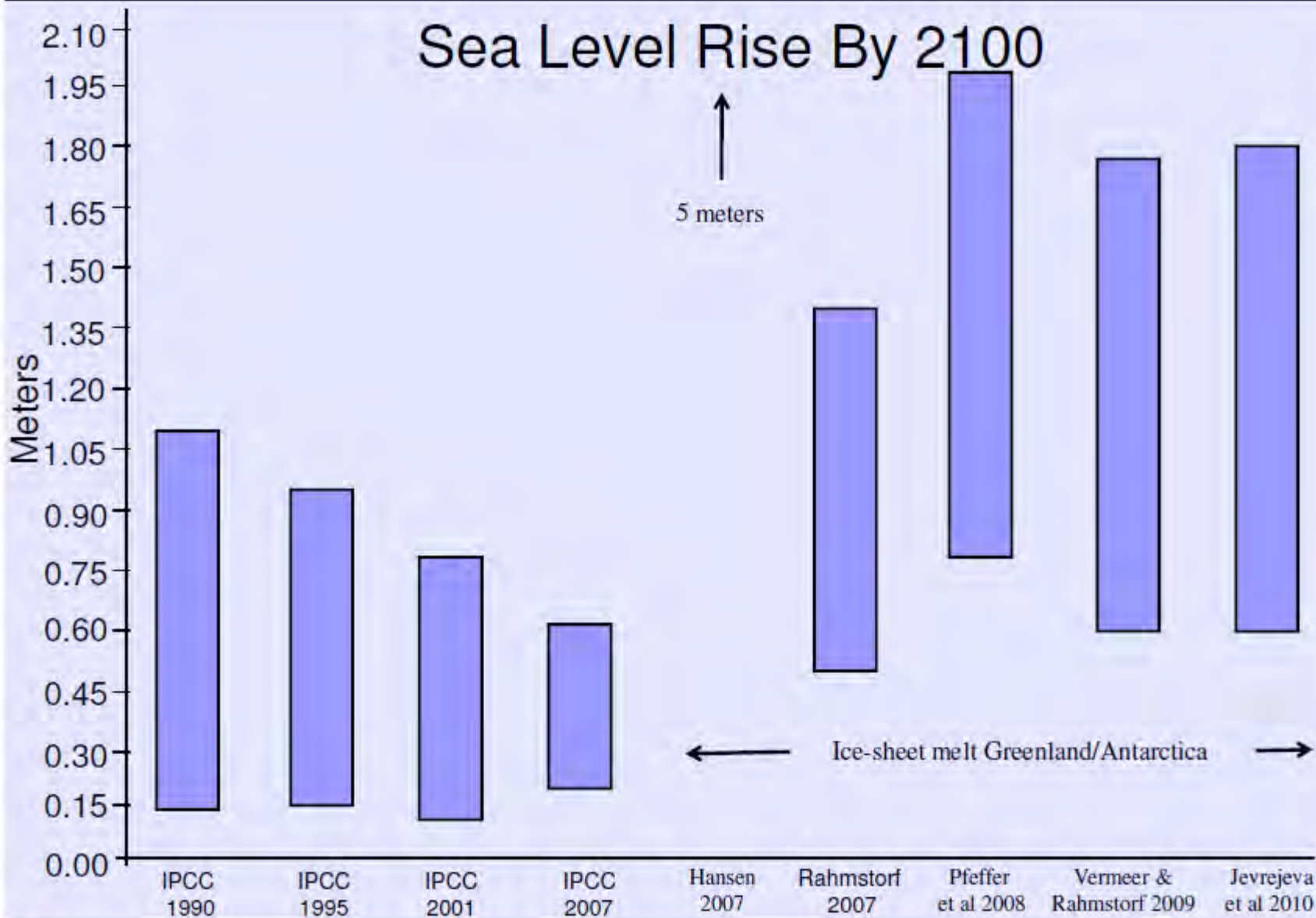
0.414 m (2100)

Magueyes - Monthly Mean Sea Level 1955-2008

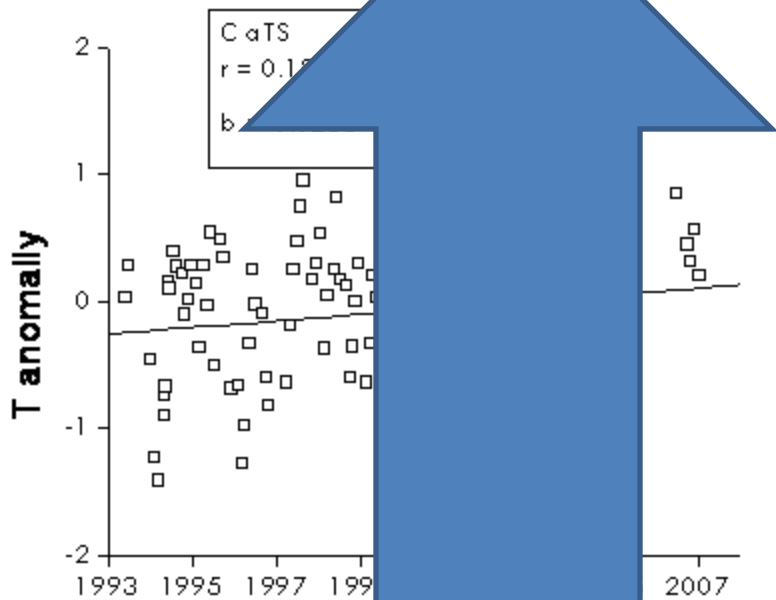


0.256 m (2100)

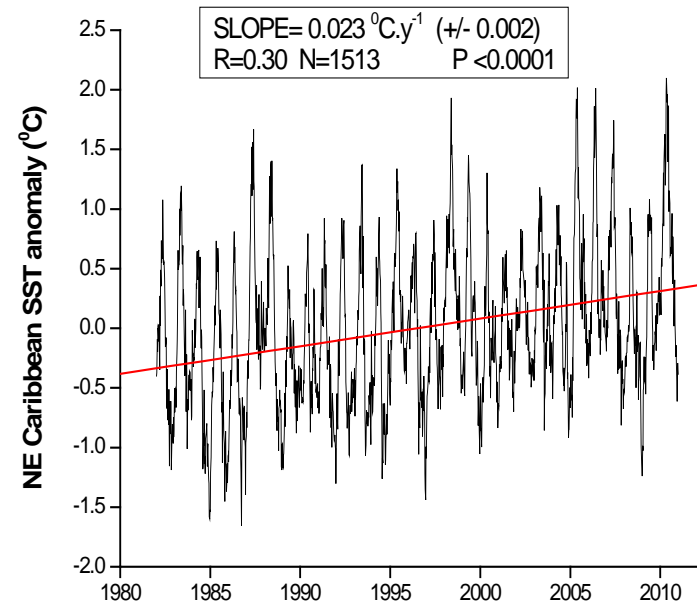
Sea Level Rise By 2100



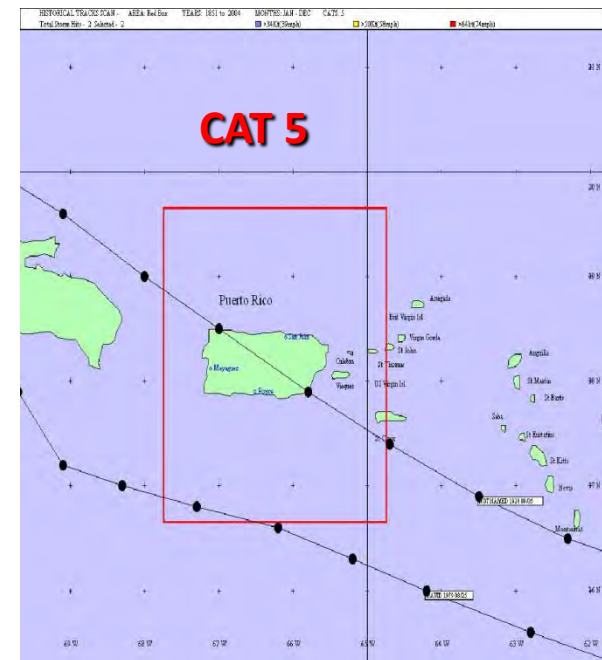
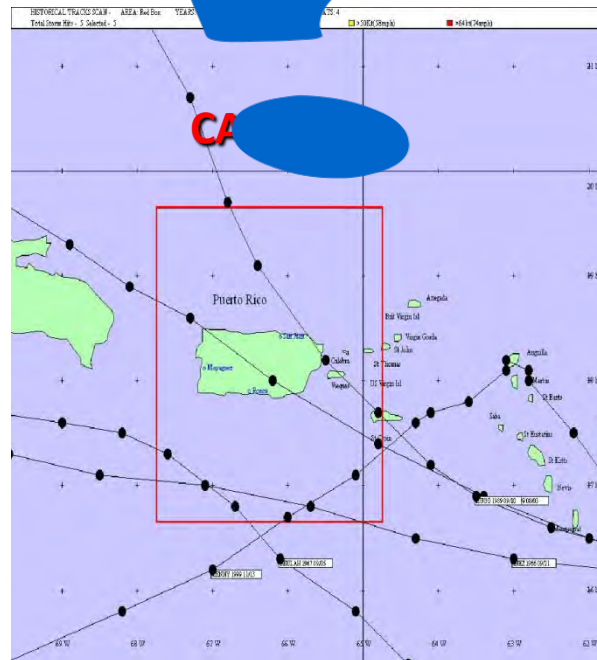
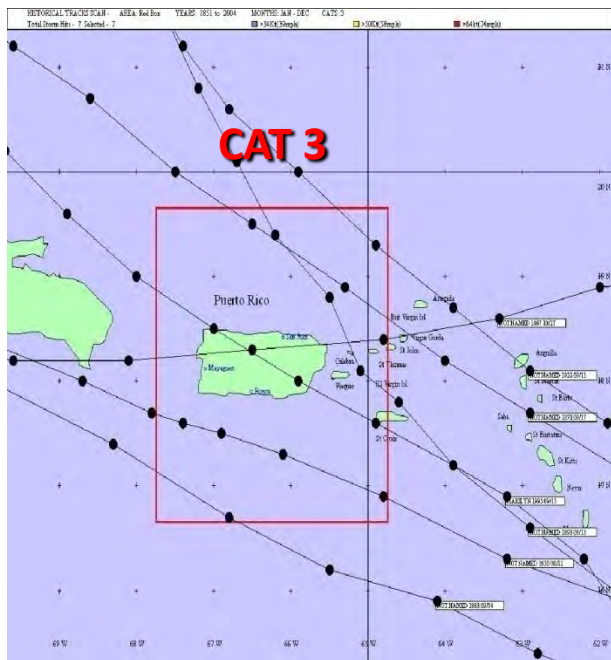
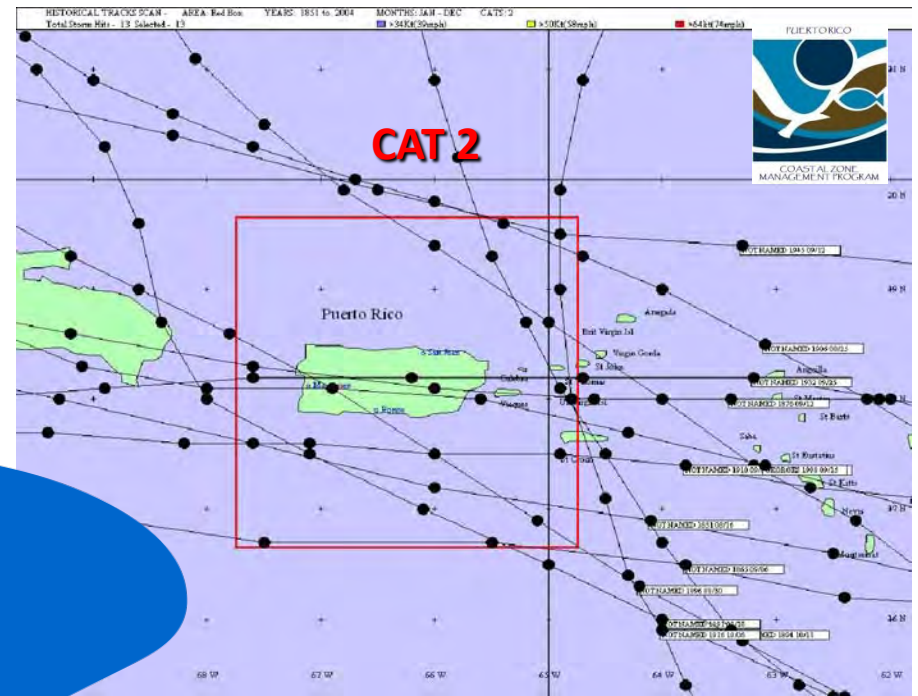
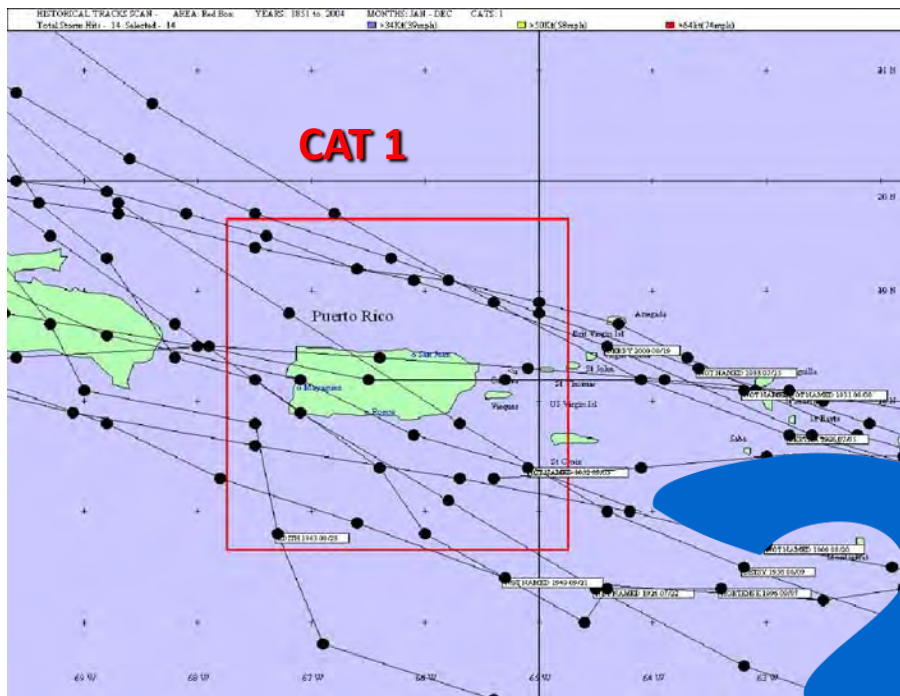
Sea Surface Temperatures (SSTs) - CariCOOS



SST data from CaTS. SST trend between 1993 and 2007 is linearly estimated at 0.026 (+/- 0.002) Celcius per year



SST anomaly data from OI.v2 SST product for the CaTS region (Northeastern Caribbean) from 1982 to 2011. A linear fitting of the data yields a slope of 0.023 degrees (+/- 0.002) Celcius per year.



Coastal Inundation



Increased salt water intrusion to
ground water aquifers



Impacts to water supply – water insecurity
Damage to roads

Impacts to port and airport operations
Temporary or permanent interruption of operations



High replacement cost of infrastructure or
permanent loss of infrastructure



Erosion



Beach loss



Damage/potential loss of beach front properties, hotels, etc.



Loss or revenue from Tourism and Real Estate

Effects of relative sea level rise: climate and non-climate factors (from Nicholls, 2002).

Biogeophysical effect		Other relevant factors	
		Climate	Nonclimate
Inundation, flood and storm damage	Surge	Wave and storm climate, morphological changes, sediment supply	Sediment supply, flood management, morphological changes, land claim
	Backwater effect (river)	Runoff	Catchment management and land use
Wetland loss or change		CO ₂ fertilization Sediment supply	Sediment supply, migration space, direct destruction
Beach Erosion		Sediment supply, wave and storm climate	Sediment supply
Saltwater intrusion	Surface waters	Runoff	Catchment management and land use
	Groundwater	Rainfall	Land use, aquifer use
Rising water tables/impaired drainage		Rainfall	Land use, aquifer use



Coastal Features and Ecosystems Update



Ecotone Identification Sampling Points

Lidar Coastal Profiling



National Wetland Inventory Review

















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16 U.S.C. § 1541 Coastal Zone Management Act, 1972 : Section 302 (L)

Currently, not enough is being done to manage and protect our coastal resources.

"(7) Global warming results from the accumulation of man-made gases, released into the atmosphere from such activities as the burning of fossil fuels, deforestation, and the production of chlorofluorocarbons, which trap solar heat in the atmosphere and raise temperatures worldwide.

Global warming could result in significant global sea level rise by 2050 resulting from ocean expansion, the melting of snow and ice, and the gradual melting of the polar ice cap.

Sea level rise will result in the loss of natural resources such as beaches, dunes, estuaries, and wetlands, and will contribute to the salinization of drinking water supplies.

Sea level rise will also result in damage to properties, infrastructures, and public works.

ESTUDIO SOBRE LA PERCEPCIÓN PÚBLICA DE LOS
**CAMBIOS CLIMÁTICOS Y
LOS RIESGOS NATURALES**
SEGMENTO OESTE DE PUERTO RICO



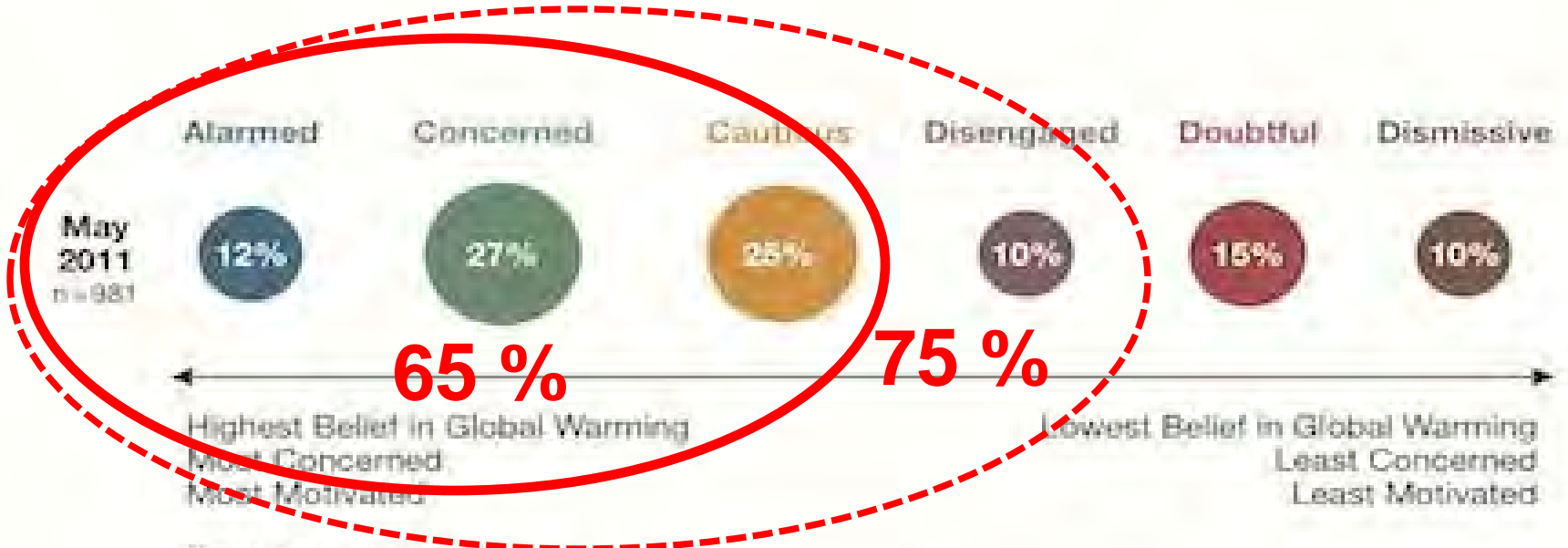
Sea Grant
Puerto Rico



SEPTIEMBRE 2009

Percepción pública:

- Krosnick: 1997,1998, 2008
- UMET: 1997
- PMZC: 2009 (8 municipios)
- Caribbean Business-WOSO-Gaither: 2011
- Yale-G.Mason: 2011



Proportion represented by each

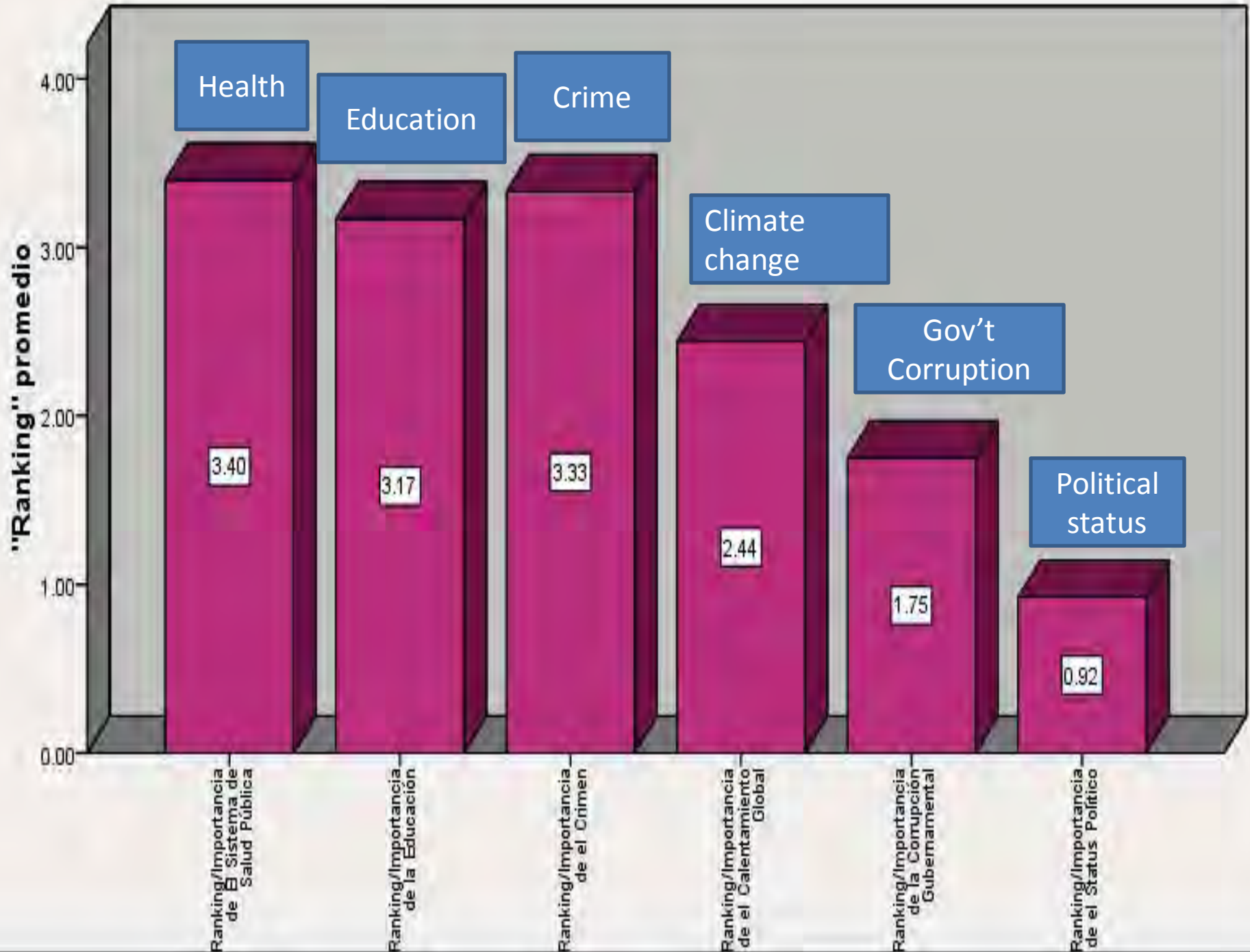
Source: Yale Project on Climate Change Communication

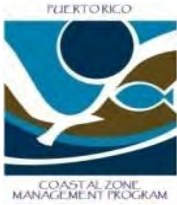
82.8 %



86 %

CARIBBEAN BUSINESS
Knowledge is Profit.





Puerto Rico is at risk from:

- Continuing development in high hazard areas
- Elimination of dunes, reefs, mangroves and other naturally protective features
- Poor maintenance of existing shoreline stabilization structures
- Poor maintenance and dredging of rivers, canals, and reservoirs
- Poor maintenance of storm-water management systems
- Poor soil management practices on land and coastal watersheds.



Recommendations and challenges

Ernesto L. Díaz
2012

Natural ecosystems at risk from sea-level rise are undervalued or ignored in traditional economic analyses (i.e., wetlands, dune loss or beach changes) - Improved methods for future studies are needed.

Local governments should conduct detailed studies to better understand the potential impacts of sea-level rise in their communities.

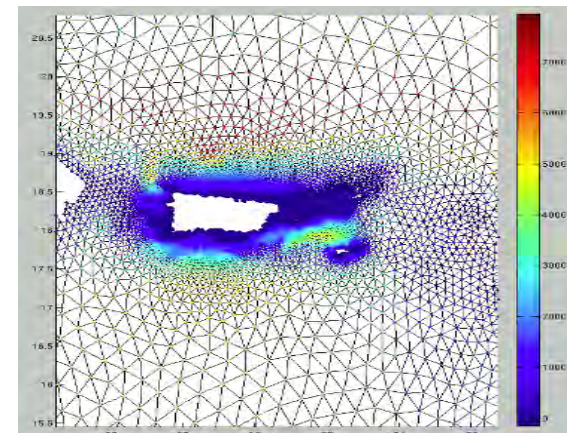
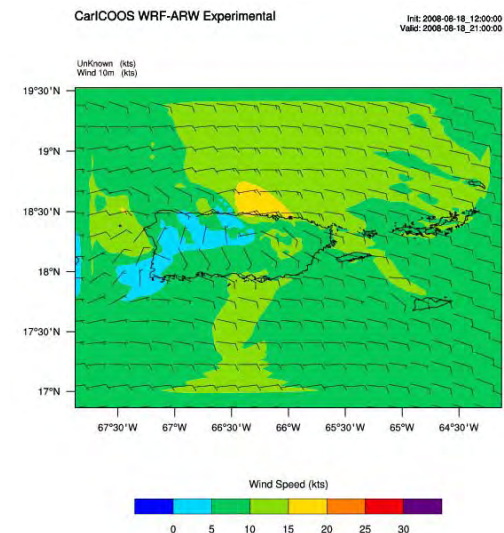
Future development should be limited in areas that are at risk from rising seas.

Current efforts to build, maintain, or modify structures in coastal areas at risk of sea-level rise should be based on estimates of SLR.

Climate change knowledge and projections must be integrated into the design of all coastal structures.

MODELING ASSETS (NOWCASTS AND FORECAST),

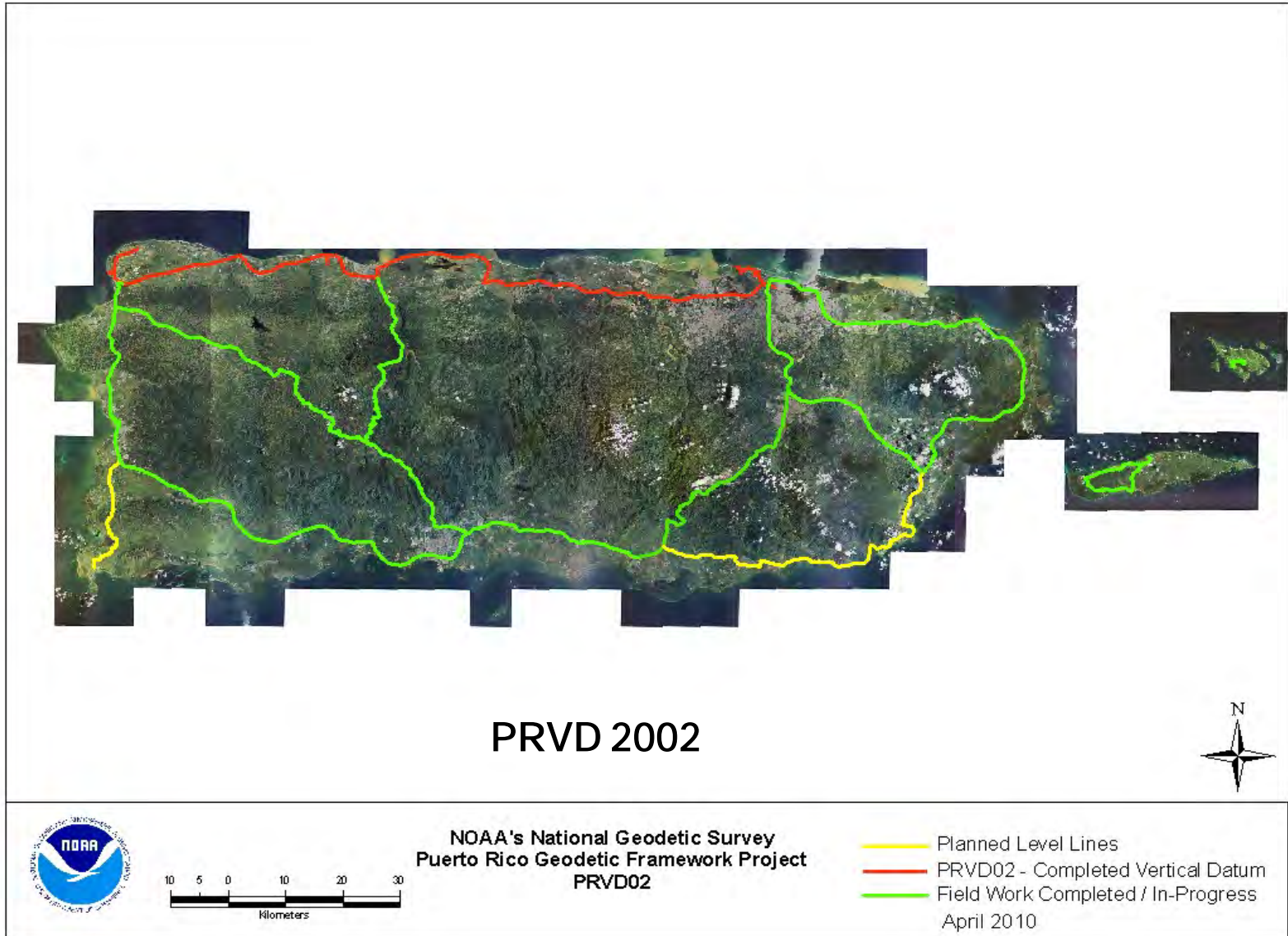
- CaRA and UPRM have jointly established the Alliance for Numerical Modeling and Coastal Forecast. DNER-PRCZMP has contracted the Alliance to perform Coastal Zone inundation modeling using ADCIRC, SWAN and COULWAVE.
- Coastal winds, WRF -CaRA/UPRM, S. Strippling NWS-SJ)
- Coastal waves, SWAN (CaRA-UPRM, – UniNorte)
- Storm surge-inundation ADCIRC (CaRA-UPRM);UPRM, Renaissance Institute and DNER-PRCZMP.



SENADO DE PUERTO RICO

R. C. del S. 797

26 de abril de 2011



PUERTO RICO
Department of Natural and Environmental Resources

How have we gotten here?
...and next steps!



Ernesto L. Díaz, M.S., EEM
Marine Scientist - Director

2012

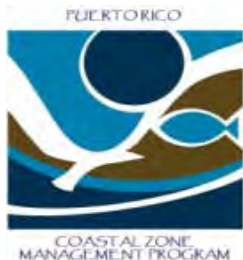


Coordination Techniques of the Puerto Rico Climate Change Council

Kasey R. Jacobs

NOAA Coastal Management Fellow

kjacobs@drna.gobierno.pr



NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY



Puerto Rico Cambios Climáticos/Climate Chang Listserv (PR-CC-L)

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[First document for April 6th Meeting](#)

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[Save the Date - April 6 - Puerto Rico Climate Change Meeting](#)

By Kasey Jacobs - Mar 23 - 2 authors - 1 reply

[A Growing Role for Social Sciences in Climate Change Dialog](#)

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[Free Webinar by FWS-OUT8041: Intro to Communicating Climate Change - A Webinar Series for Communicators](#)

By lilibeth_serr...@fws.gov - Feb 14 - 1 author - 0 replies

[Fw: New report released: The State of Marine and Coastal Adaptation in North America: A Synthesis of Emerging Ideas](#)

By kjac...@dma.gobierno.pr - Feb 9 - 1 author - 0 replies

[RealClimate Blog by Climate Scientists](#)

By Kasey Jacobs - Feb 1 - 1 author - 0 replies

[Video Talk on Climate Change and Ocean Ecosystems by Ove Hoegh-Guldberg for NCSE](#)

By Kasey Jacobs - Jan 27 - 1 author - 0 replies

[New PR Coral and Global Warming article in Ecosphere](#)

By Kasey Jacobs - Jan 25 - 1 author - 0 replies

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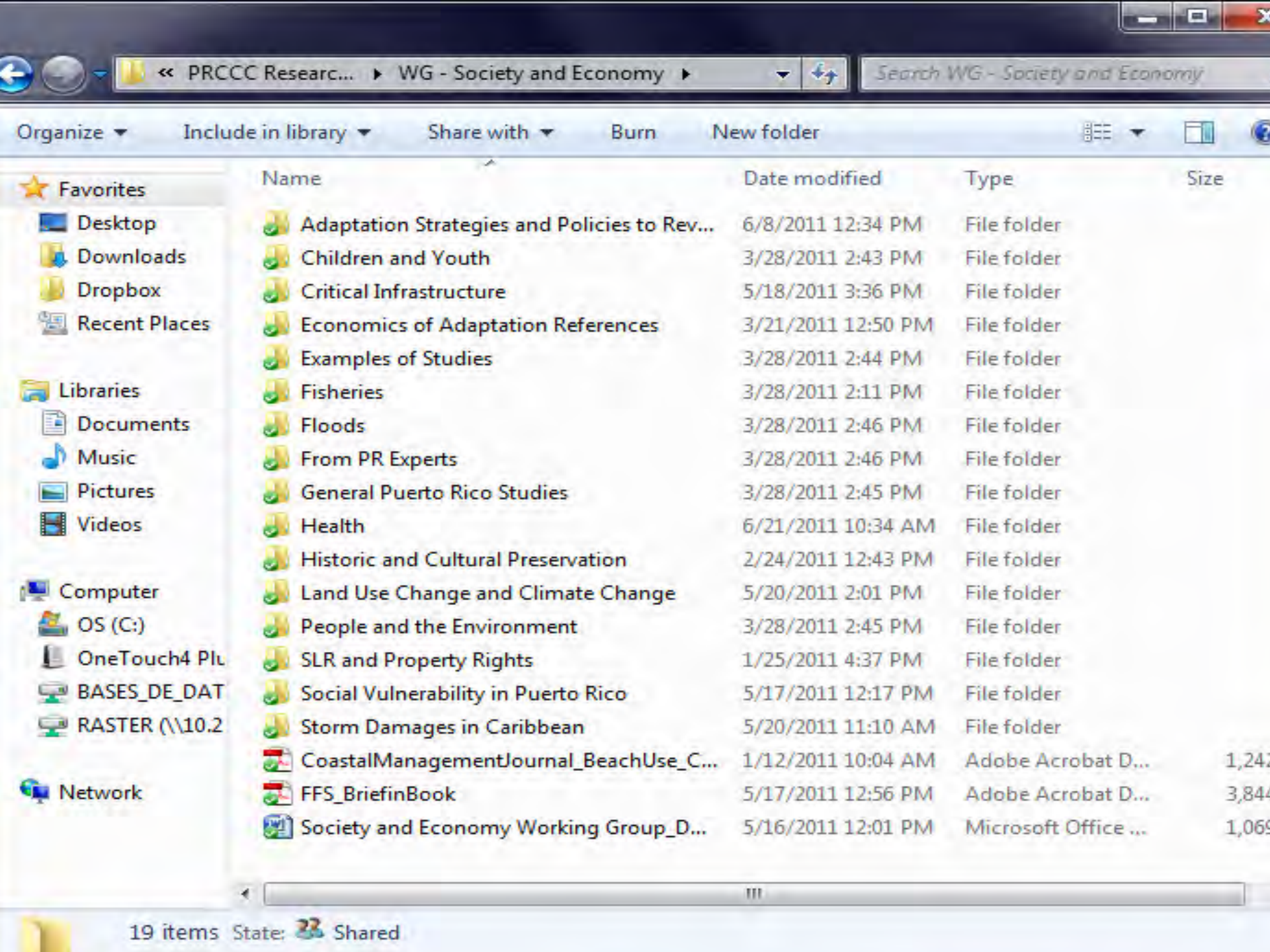
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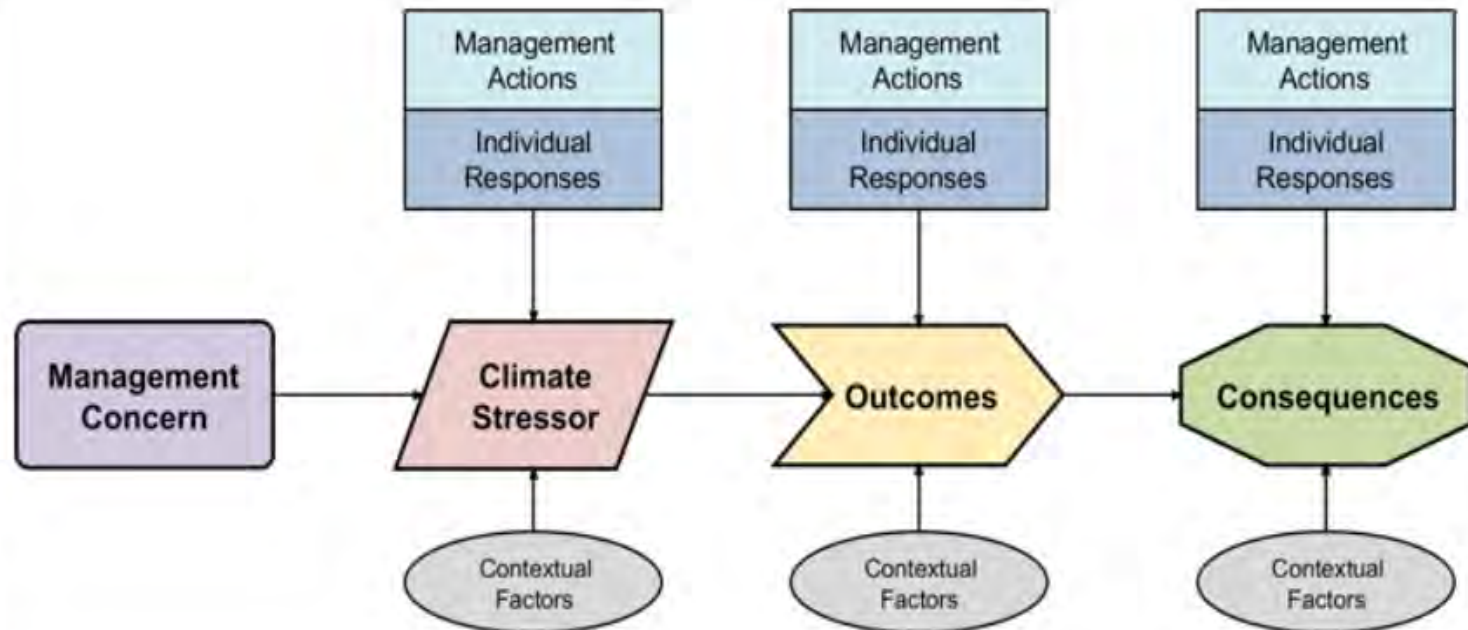
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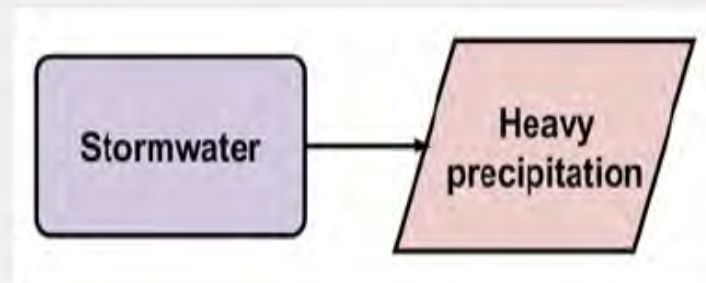
Network

Name	Date modified	Type	Size
Adaptation Strategies and Policies to Rev...	6/8/2011 12:34 PM	File folder	
Children and Youth	3/28/2011 2:43 PM	File folder	
Critical Infrastructure	5/18/2011 3:36 PM	File folder	
Economics of Adaptation References	3/21/2011 12:50 PM	File folder	
Examples of Studies	3/28/2011 2:44 PM	File folder	
Fisheries	3/28/2011 2:11 PM	File folder	
Floods	3/28/2011 2:46 PM	File folder	
From PR Experts	3/28/2011 2:46 PM	File folder	
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Social Vulnerability in Puerto Rico	5/17/2011 12:17 PM	File folder	
Storm Damages in Caribbean	5/20/2011 11:10 AM	File folder	
CoastalManagementJournal_BeachUse_C...	1/12/2011 10:04 AM	Adobe Acrobat D...	1,24
FFS_BriefinBook	5/17/2011 12:56 PM	Adobe Acrobat D...	3,84
Society and Economy Working Group_D...	5/16/2011 12:01 PM	Microsoft Office ...	1,06

VCAPS diagrams: Building blocks



Start with the management concern and the climate stressor



Add outcomes

- There are many **outcomes** associated with *heavy precipitation*
 - What happens to the socio-ecological system?
 - Ask, “Why does the town care about heavy precipitation?”
 - If we simply drew a diagram that went from *precipitation to flooding*, we’d be ignoring opportunities to manage causes of flooding or erosion (e.g., run-off).

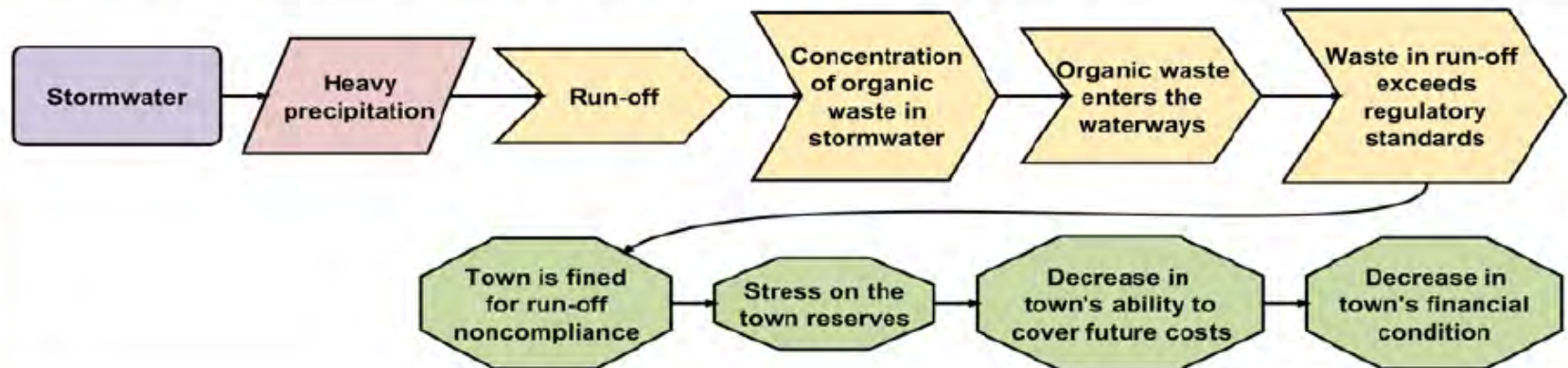


-
- The more detailed the causal chain, the easier it will be to identify and envision possible **management actions**.



Continue by adding consequences

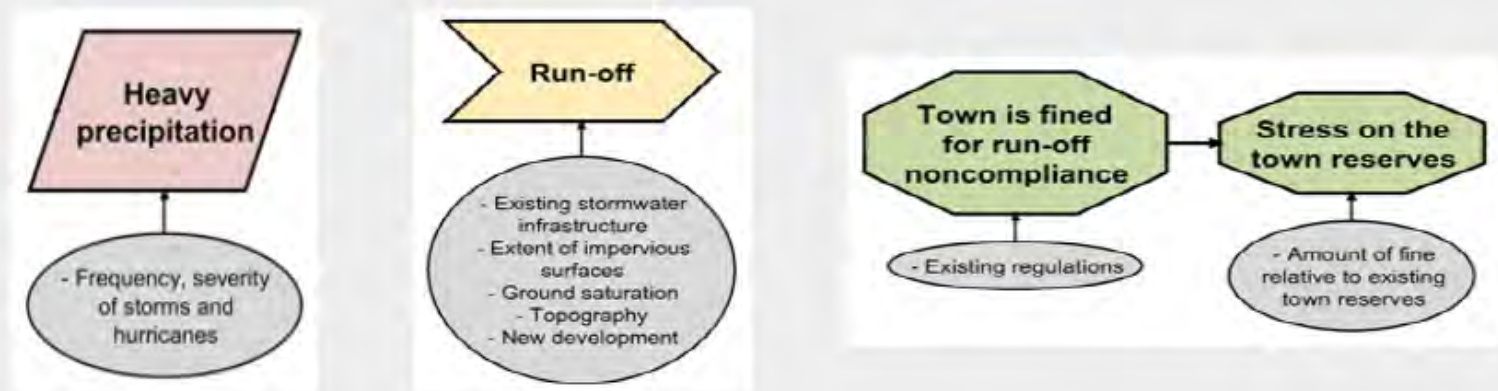
- **Consequences** are implications of the **outcomes** that affect things that people care about. They exert some sort of loss or cost to things that people value.
 - individuals, communities, institutions, or ecosystems.
- Sometimes the distinction between outcomes and consequences is fuzzy. That's OK!

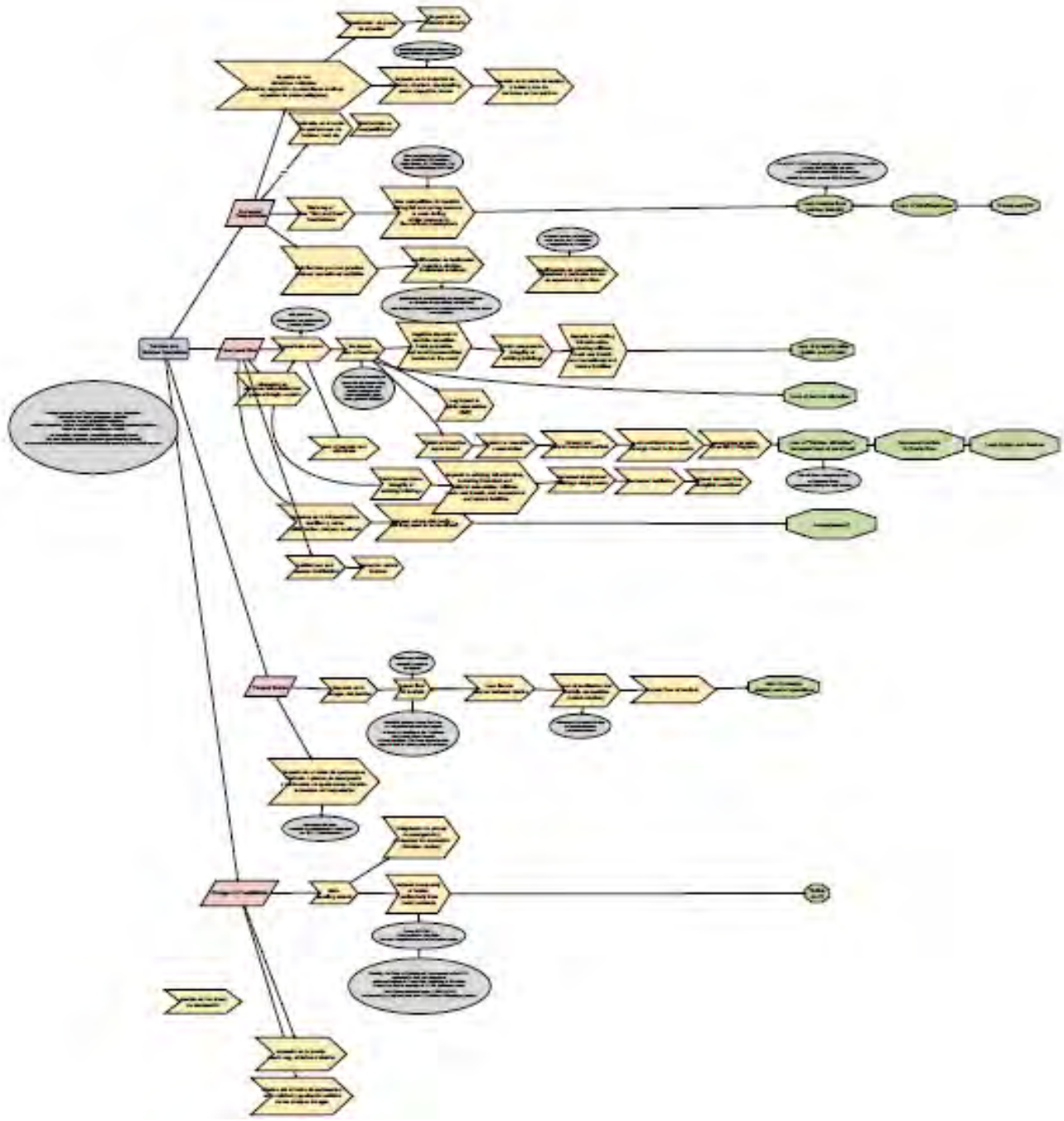


Localize the diagram with contextual factors

□ Start asking:

- What about this place makes the town more or less vulnerable to these outcomes and consequences?
- What makes this (**climate stressor, outcome, or consequence**) better, worse, stronger, larger...?



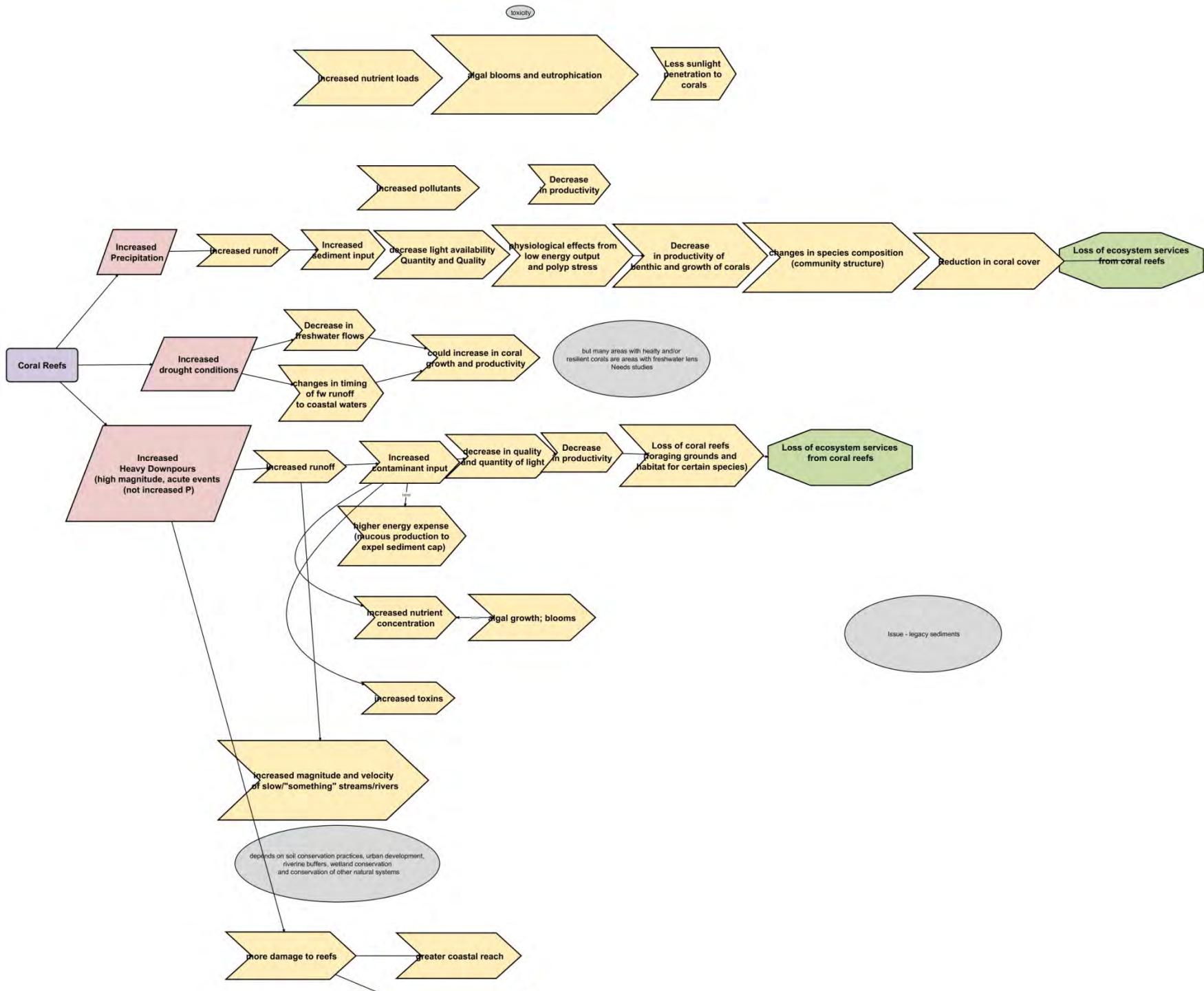


WG 2 Coral Meeting



WG 2 Coral Meeting





TALLERES PARA LA EVALUACIÓN DE RIESGOS ACTUALES Y FUTUROS EN LA ZONA COSTANERA

- Erosión
- Tormentas y marejadas
- Inundaciones fluviales y costeras
- Lluvias y sequías más intensas
- Efectos del cambio climático
- Estrategias de adaptación

6 de marzo de 2012

(Municipios costeros del norte)
Embassy Suites, Dorado

8 de marzo de 2012

(Municipios costeros del sur)
Ponce Hilton, Ponce

Ambos talleres serán de 8 a.m. a 4 p.m.

RSVP: 787-999-2200 x.2729 / 2730



Examples of Outputs from Stakeholder/Expert Workshops

Table 4. Risk assessment results from the infrastructure risk assessment workshop.

Planning Area	Feature	Average Likelihood	Average Magnitude	Most Often Risk Category Answer	Average Risk Score	Climate Driver	Most Often Given Time Answer
Coastal Flood Control and Protection		3.30	2.70	High	8.73	Sea Level Rise	2020
Dams and Levees	Hazards	2.64	2.82	High	7.36	Precipitation	2020
Stormwater	Collection, Storage and Treatment	2.84	2.42	High	7.29	Precipitation	2020
Transportation	Airports, Ports, Rail, Roads and Bridges	2.79	2.41	High	6.90	Precipitation	2050
Facilities and Buildings	Cultural Resources, Private and Public	2.62	2.38	High	6.48	Precipitation, Sea Level Rise	2020
Wastewater	Collection, Treatment	2.58	1.92	High	5.15	Precipitation	2080
Water Supply	Sources, Treatment, Distribution	2.40	1.67	Low and High	4.21	Precipitation	2080

Habitat	Sensitivity Risk (likelihood x severity)	Average Risk Score	Climate Driver	Time Urgency Action
Cold Water Streams & Associated Riparian Zones	High	10.2	Temperature	2020
Tidal Marsh	High	9.7	Sea Level Rise	2020
Talus Slopes	High	9.0	Temperature	2050
Open Water Marine	High	8.9	Temperature	2020
Beaches and Dunes	High	8.2	Sea Level Rise	2020
Herbaceous Freshwater Wetlands	High	7.6	Precipitation	2020
Offshore Islands	High	7.3	Sea Level Rise	2020/2050
Intertidal Flats and Shores	High	6.4	Sea Level Rise	2050
Major Rivers & Associated Riparian Zones	High	5.9	Precipitation	2050
Forested Swamps	High	5.2	Precipitation & Temperature	2050
Subtidal Aquatic Beds	High	5.0	Sea Level Rise	2050
Lakes, Ponds, Impoundments & Shorelines	Medium	4.4	Temperature	2080
Upland Forest Complex	Medium	4.3	Temperature	2080
Coastal Uplands	Low	3.7	Temperature	2080
Rocky Outcrops & Summits	Low	3.4	Precipitation	2080
Warm Water Streams & Associated Riparian Zones	Low	3.3	Precipitation	2050
Bogs and Fens	Low	3.1	Precipitation	All Dates equal
Early Successional Shrublands/Forests	Low	2.0	Precipitation	2080
Sand Barrens & Warm Season Grasses	Low	1.8	Precipitation & Temperature	2080

Pre-Workshop Survey

ENCUESTA DE RIESGOS COSTEROS DE PUERTO RICO

* Required

*Nombre de su municipio **

*Población de su municipio **

*Actividades económicas de su municipio **

Climate Change in the Caribbean: Puerto Rico & the U.S. Virgin Islands

November 15-16, 2011

San Juan, Puerto Rico

Inter American University of Puerto Rico

School of Law





Communicating Climate Change and Coastal Hazards

PRCCC Working Group 4 Meeting

Friday, December 16th, 2011

9:00AM – 12:00PM

National Weather Service Office, Carolina, PR

RSVP by December 8th to kjacobs@drna.gobierno.pr

Come to discuss, learn, and decide on
important issues for the
Puerto Rico Climate Change Council

Special Guest Speaker: Andrew Revkin, *The New York Times* and *Dot Earth Blog* author will be video conferencing with us to offer advice and take questions on communicating climate change to decision makers and the public. Andy is one of the most respected and influential journalists covering climate change and other global environmental issues in the world.



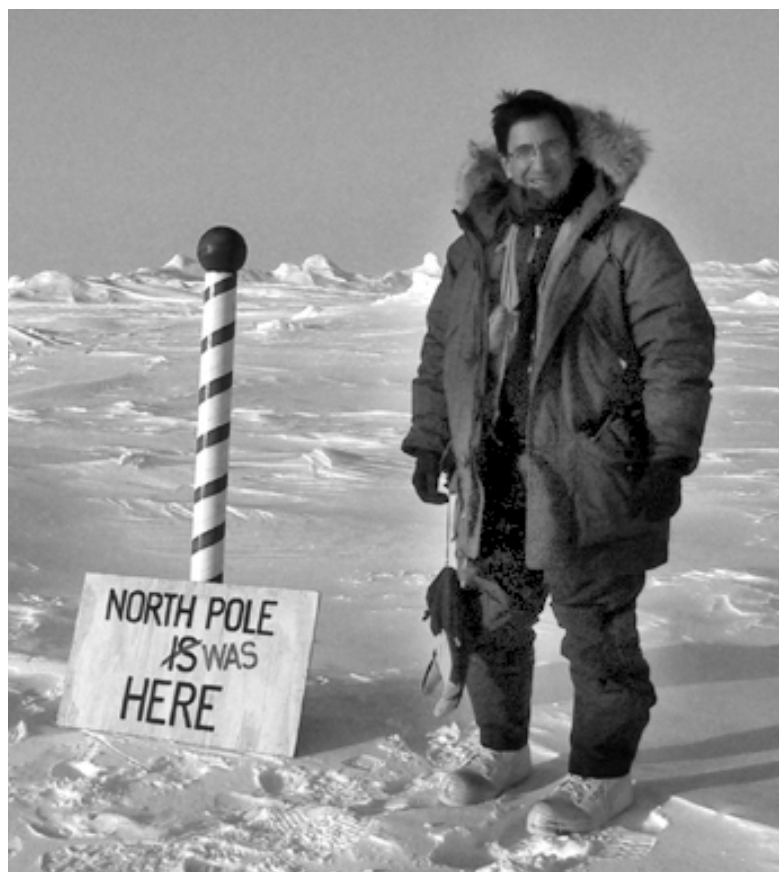
Purpose:

To develop the communication's plan for Puerto Rico's climate change vulnerability assessment and decide on the next steps of Working Group 4

Desired Outcomes: *By the end of this meeting, we will have:*

- Agreed upon main message, audience, and frame of a communication's plan
- A collective understanding of where Puerto Rico needs to go in terms of communicating climate change and hazards
- Agreed upon types of information and graphics to be included in the final reports of the PRCCC
- Next steps of Working Group 4 to be conducted in 2012

Andrew Revkin



Conexión Natural - Parte 2

<http://vimeo.com/27002734>