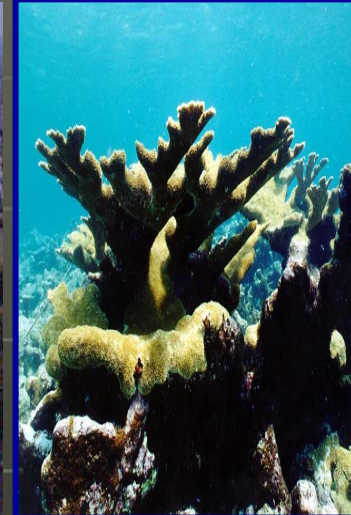


# Adapting to current and potential impacts of Climate Change in Puerto Rico



**Ernesto L. Díaz**  
**Natural Resources Administration**  
**Department of Natural and Environmental Resources**



April 2008

# OBJECTIVE

- Provide an overview of Puerto Rico's natural and socioeconomic system's vulnerability to climate change.
- Discuss potential adaptation strategies, challenges and coastal zone management priorities for the next decades.

# OVERVIEW

---

- Relevant socioeconomic statistics.
- Storm, Flooding, erosion and sea level trends
- Potential impact analysis (i.e. coastal)
- Adaptation strategies
- Biodiversity
- Challenges
- PRCMP Priorities

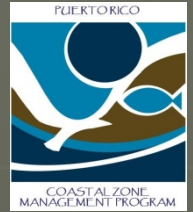






# Puerto Rico

## RELEVANT STATISTICS



<b>Emerged land area:</b>	9,497 km <sup>2</sup> (3,508 mi <sup>2</sup> )
<b>Territorial waters:</b>	9 nm (10.35 stat. mi)
<b>Population:</b>	3.9 million (26 <sup>th</sup> U.S. largest )
<b>Coastal Zone Population:</b>	2.73 million (70%) 40% urban land area
<b>GDP:</b>	~\$ 56.5 billion/yr
<b>Construction value:</b>	~\$ 6.4 billion/ yr <i>(Housing, Roads, schools, industrial, commercial buildings)</i>
<b>Industry:</b>	\$25.4 billion (45%)
<b>Tourism:</b>	\$4.1 % billion (7%) 12,900 hotel rooms 10,292,000 people used the San Juan Int'l airport 1,350,000 tourists arrived by cruise ships
<b>Agriculture:</b>	\$0.7 billion (1%)

# INFRASTRUCTURE WITHIN 1 KM OF THE COAST



- Eight ports

- Eight airports



- Five power plants

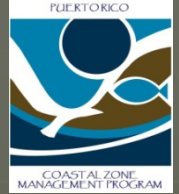
- 1080 miles of sanitary infrastructure

- 81 Industrial lots



- 114 miles of primary roads

# Why should a small island be concerned about climate change?

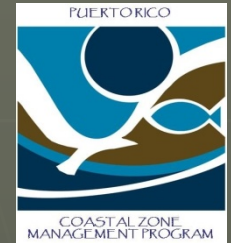


Over the next 100 years, small islands are likely to experience:

- Increase in Surface Temperatures between 1.4°C and 5.2°C
- Sea level Rise between 34 to 98 cm
- Changes in rainfall patterns and flooding during wet seasons.
- Increase in the frequency of extreme events
- Possible increase in the intensity of tropical cyclones and changes in their tracks.
- Increase in frequency of extreme temperatures.
- Less rainfall during dry seasons.
- Increase in sea surface temperature.
- Socioeconomic and environmental impacts

**Skepticism v. precautionary principle?**





## Is Puerto Rico vulnerable to CC-SLR?

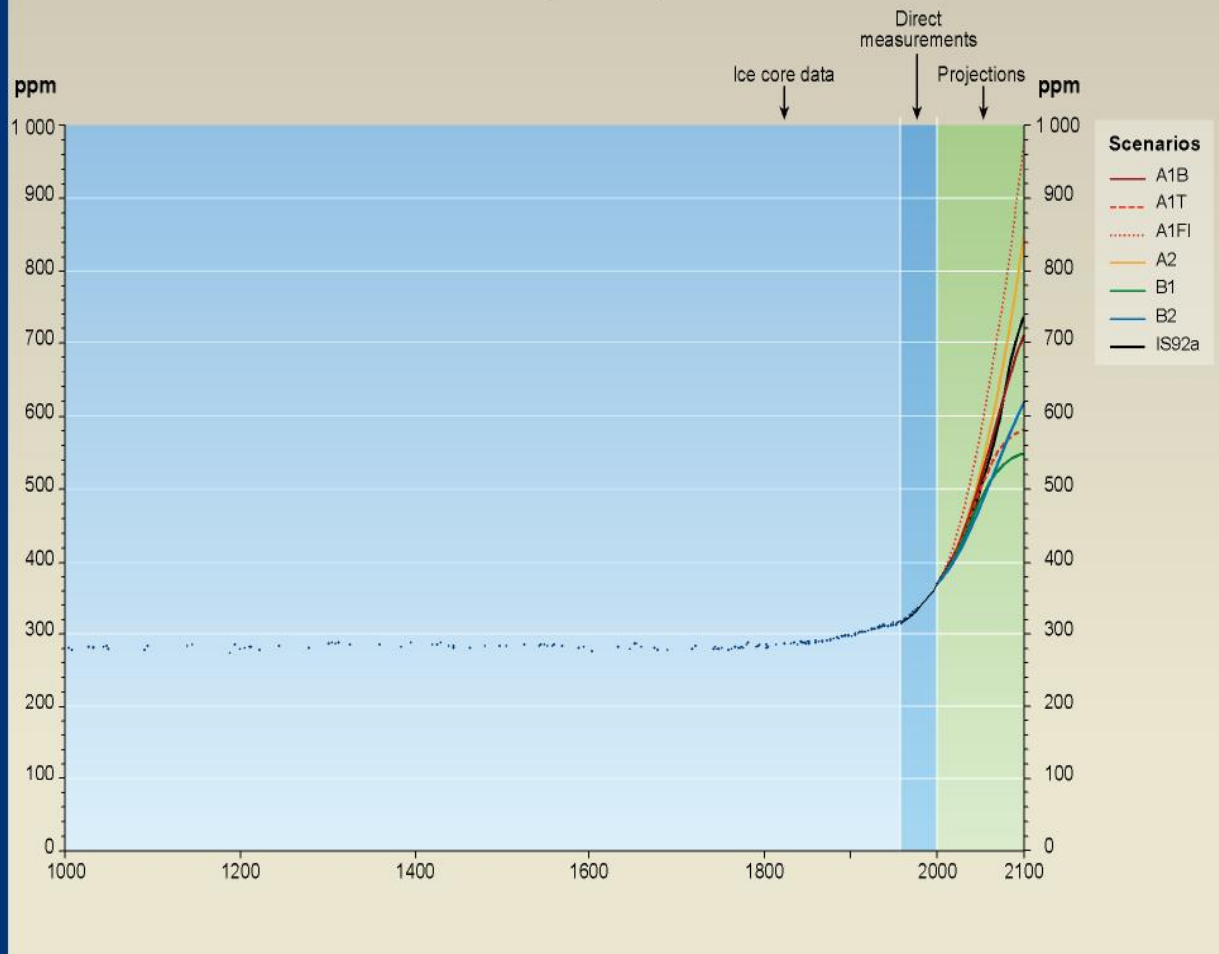
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*Vulnerability is a function of a system's sensitivity to climate and the capacity of that system to adapt to climate changes.*

*In other words, systems that are less able to adapt to changes are generally considered to be vulnerable to climate change impacts (i.e. coral reefs ...wetlands?, beaches ?)*

*Are impacts associated to vulnerability?*

# Past and future CO<sub>2</sub> atmospheric concentrations

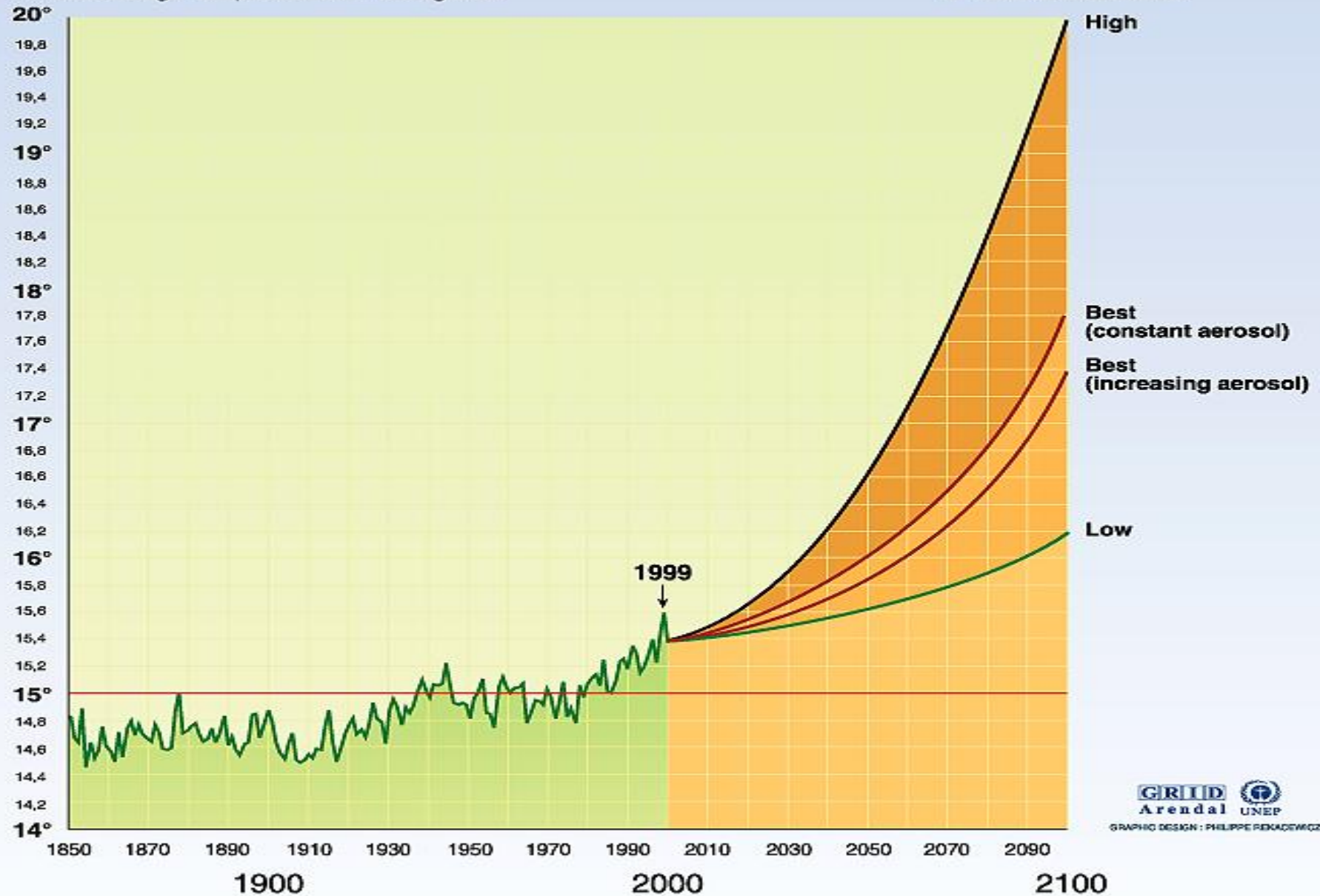


SYR - FIGURE 9-1a

# Projected changes in global temperature: global average 1856-1999 and projection estimates to 2100

Global average temperature in °centigrade

IPCC estimate

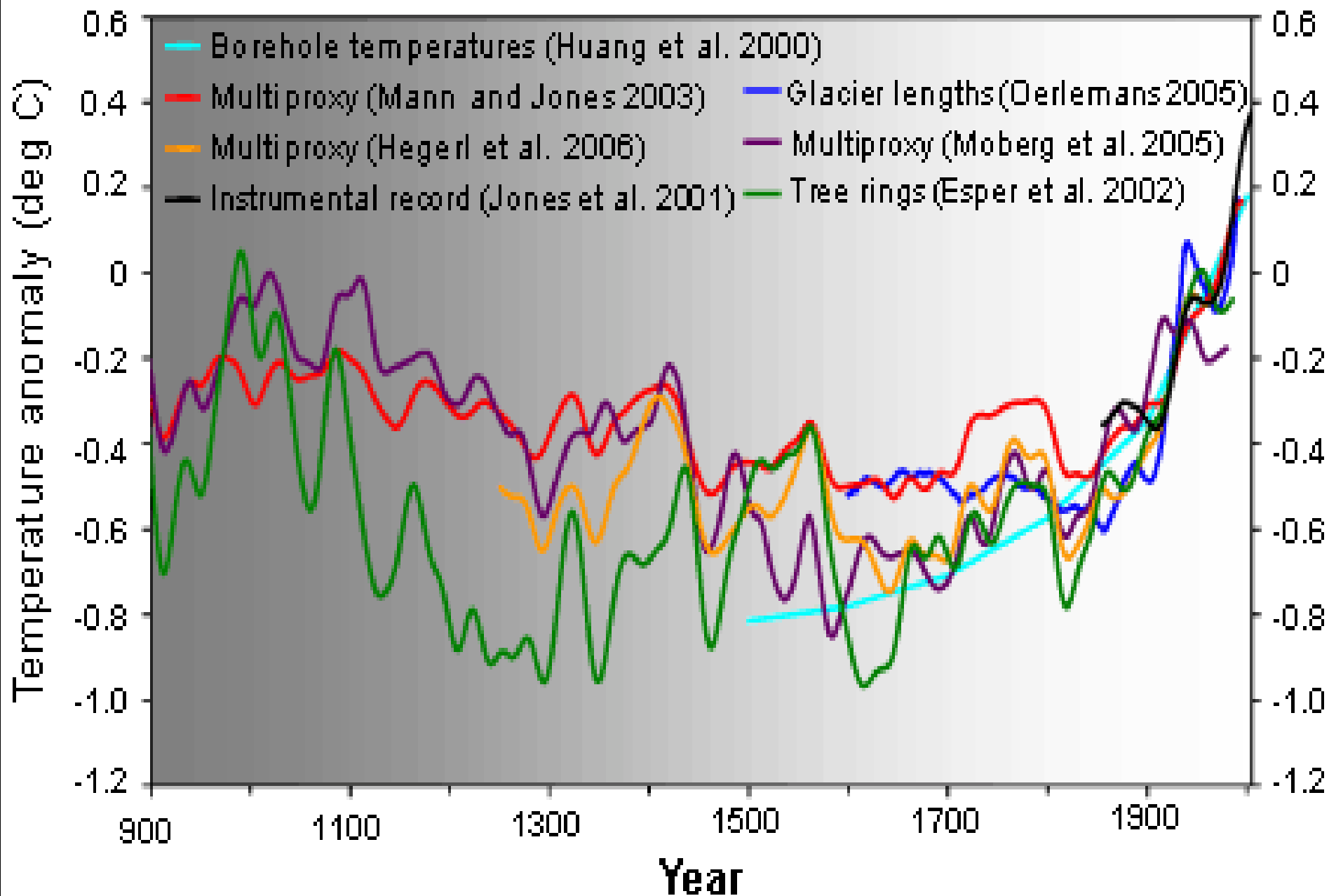


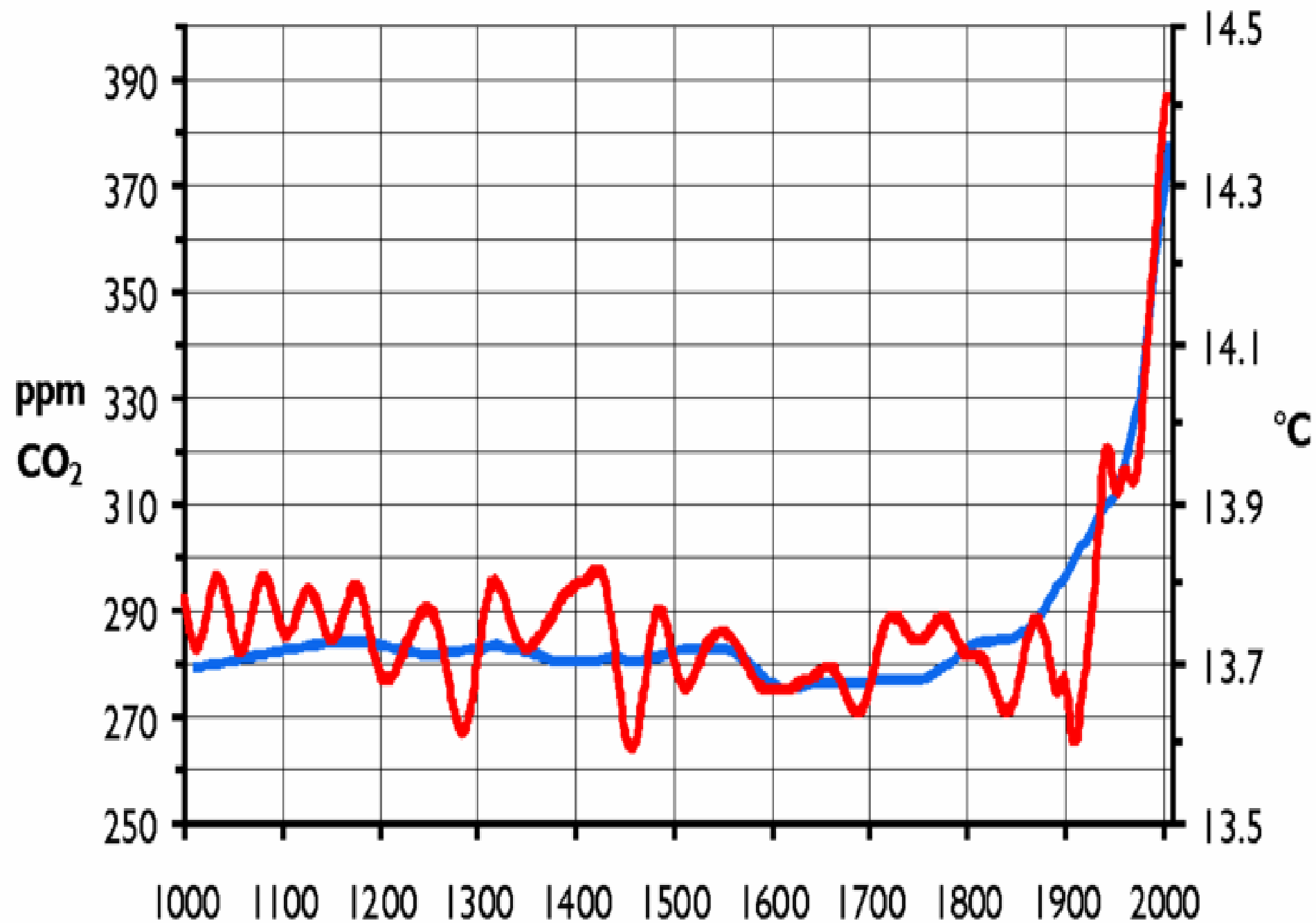
GRID  
Arendal UNEP

GRAPHIC DESIGN: PHILIPPE REKADOWICZ



**Figure 2: Surface Temperatures over the last 1,100 Years**





Rank	Country	Annual CO <sub>2</sub> emissions (x10 <sup>6</sup> tons/yr)	Percentage of total emissions
-	<u>World</u>	27,245,758	100.0 %
1	<u>United States</u> <sup>[5]</sup>	6,049,435	22.2 %
2	<u>China</u>	5,010,170	18.4 %
-	<u>European Union</u>	3,115,125	11.4 %
3	<u>Russia</u>	1,524,993	5.6 %
4	<u>India</u>	1,342,962	4.9 %
5	<u>Japan</u>	1,257,963	4.6 %
6	<u>Germany</u>	808,767	3.0 %
7	<u>Canada</u>	639,403	2.3 %
8	<u>United Kingdom</u>	587,261	2.2 %
9	<u>South Korea</u>	465,643	1.7 %
10	<u>Italy</u> <sup>[6]</sup>	449,948	1.7 %
11	<u>Mexico</u>	438,022	1.6 %
12	<u>South Africa</u>	437,032	1.6 %
13	<u>Iran</u>	433,571	1.6 %
14	<u>Indonesia</u>	378,250	1.4 %
15	<u>France</u> <sup>[7]</sup>	373,693	1.4 %
16	<u>Brazil</u>	331,795	1.2 %
17	<u>Spain</u>	330,497	1.2 %
18	<u>Ukraine</u>	330,039	1.2 %
19	<u>Australia</u>	326,757	1.2 %
20	<u>Saudi Arabia</u>	308,393	1.1 %



**What is driving climate change**



**GHG**

Increase in greenhouse gas emissions

**How the climate responds**

Sea level rise

Increase in air/sea surface temperatures

Increase in climatic variability, e.g. rainfall, tropical cyclone intensity

**Examples of impacts**

- Beaches submerged
- Coastal lands inundated
- Salinisation of coastal aquifers
- Salt water intrusion into mangroves and estuaries

- Coral bleaching
- Increased incidences of biotoxins and algal blooms can contaminate fish

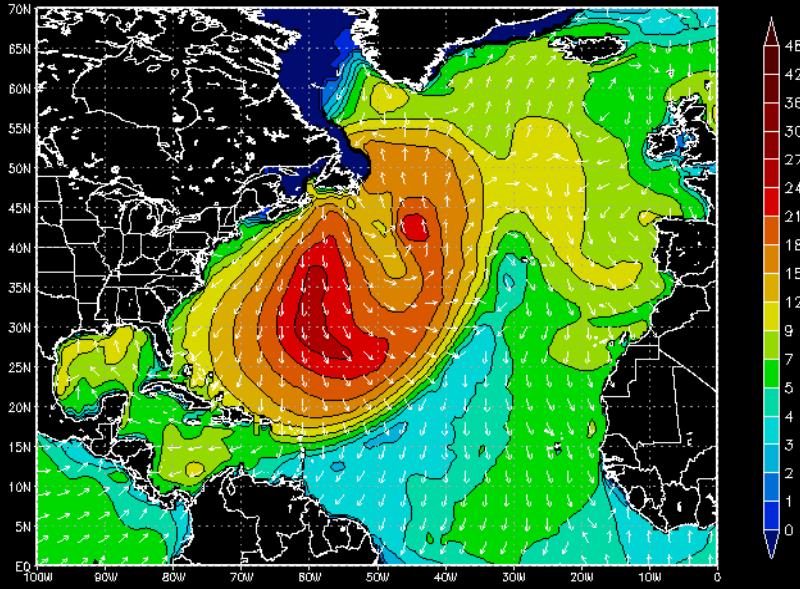
- Submergence, silting and loss of sea-grass beds
- Damage to mangroves impairing their function
- Physical damage to coral reefs caused by storms
- Structural changes in the fisheries sector

**Examples of resulting hazards and implications**

Mangrove shoreward retreat  
loss of fresh water aquifers  
Increased incidence of fish poisonings  
Damage to dive tourism  
Coastal lands inundated  
Destruction of human settlements

**Many economic, social and environmental impacts and implications**

WW3\_GLOBAL Wave Height [ft] and Direction for 17MAR2008 00Z  
Valid 19MAR2008 12Z Forecast Hour 60



GRADS: COLA/IGES

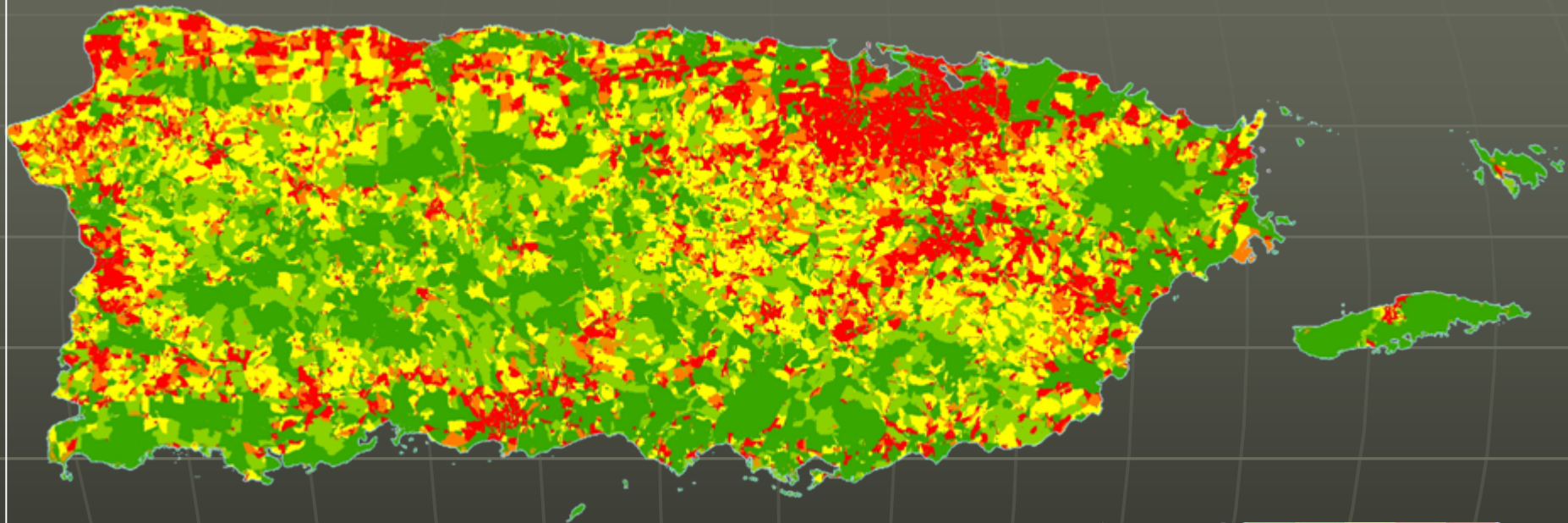
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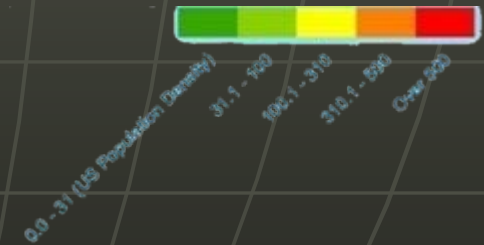


# POPULATION

~ 3.9 million

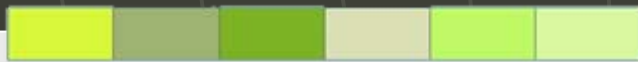
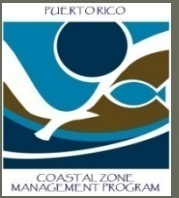


- *Aprox. 1,100 people/mi<sup>2</sup>*
- *Increased 8% over last decade*





# BIODIVERSITY



Dry Forest

Moist Forest

Rain Forest

Wet Forest

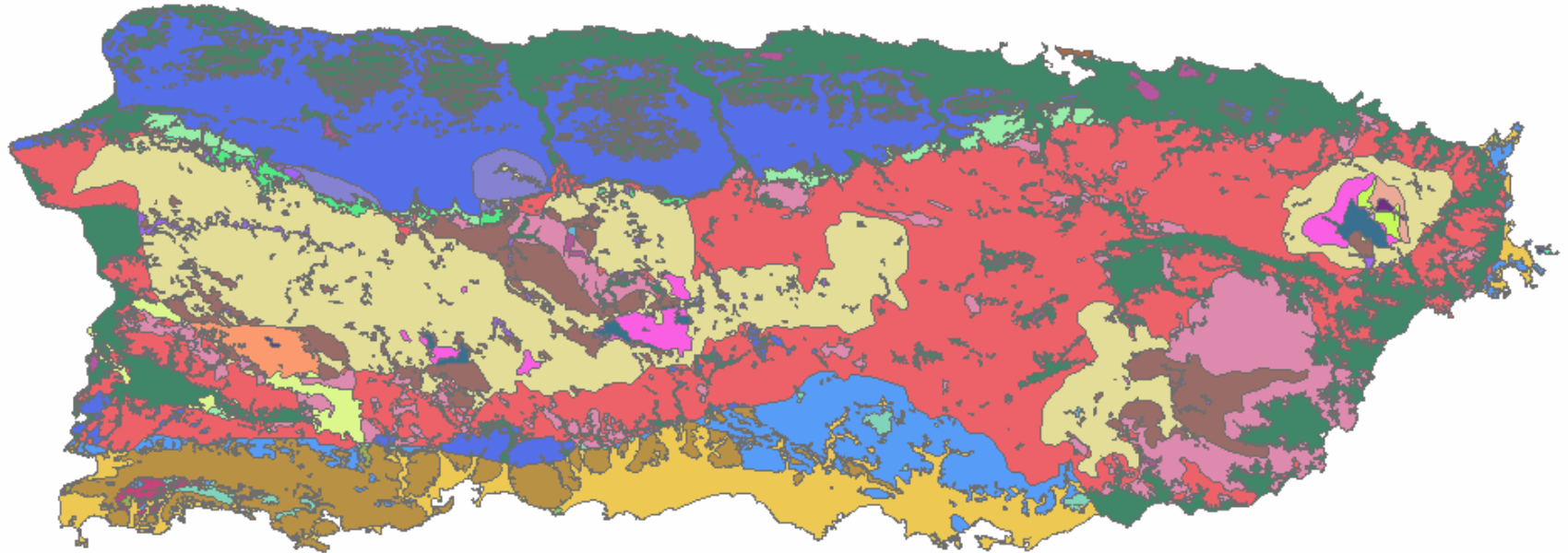
Rain Forest (Lower Montane)

Wet Forest (Lower Montane)

# PUERTO RICO

## Ecozones (6)

## Geoclimatic Units

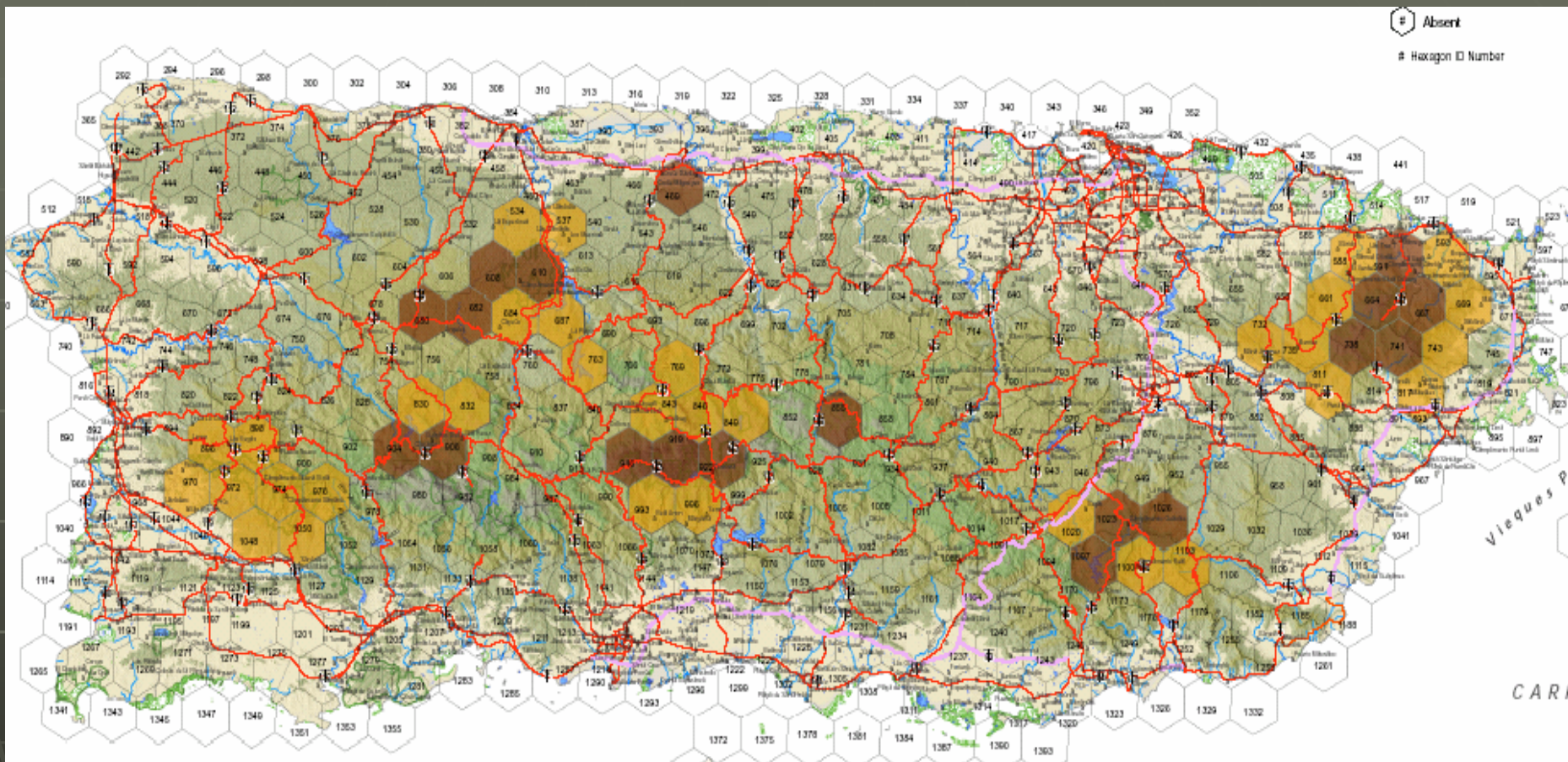


**GEOCLIMATIC ZONES: 28**

**WOODY VEGETATION FORMATIONS: 21**



# PR-GAP



Vertebrate Species Hexagon Range Map - Pre-review

Map Date: 12 January, 2004

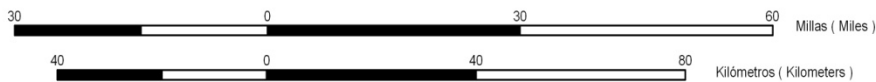
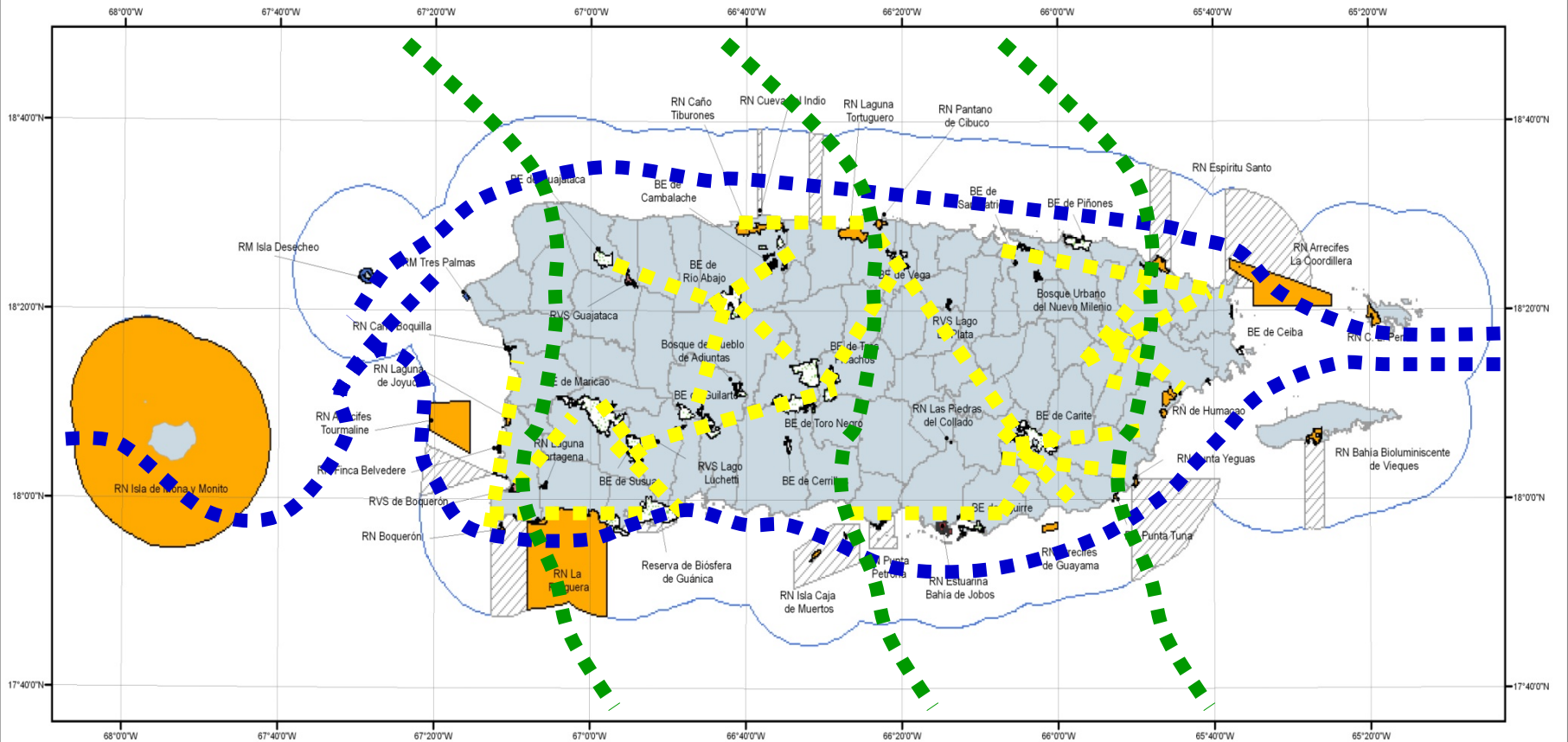
PRGAP Scientific Name: *Buteo platypterus brunnescens*  
PRGAP Common Name: Puerto Rican Broad-winged Hawk  
PRGAP Species ID: **ABNKC19052**  
Taxonomic Class: **Aves**  
Taxonomic Order: **Falconiformes**

Residency Status: **Breeding Endemic**  
Occurrence Status: **Rare**  
NatureServe Global Rank: **G5T2Q (species level)**  
Federal U.S. ESA Status: **Listed Endangered (LE)**  
PR Natural Heritage Status: **Critically Endangered (CR)**

Leyenda - Map key:

- Bosques estatales - State forests
- Reservas naturales - Nature reserves
- Reservas marinas - Marine reserves
- Refugio de Vida Silvestre Estatal - State wildlife refuge
- Extensiones marinas - Marine extensions
- Reserva Nacional de Investigación Estuarina - National Estuarine Research Reserve
- Límite de la zona costanera marina (9 millas náuticas) - Coastal zone maritime boundary (9 nautical miles)

  
 Escala - Scale: 1: 850,000



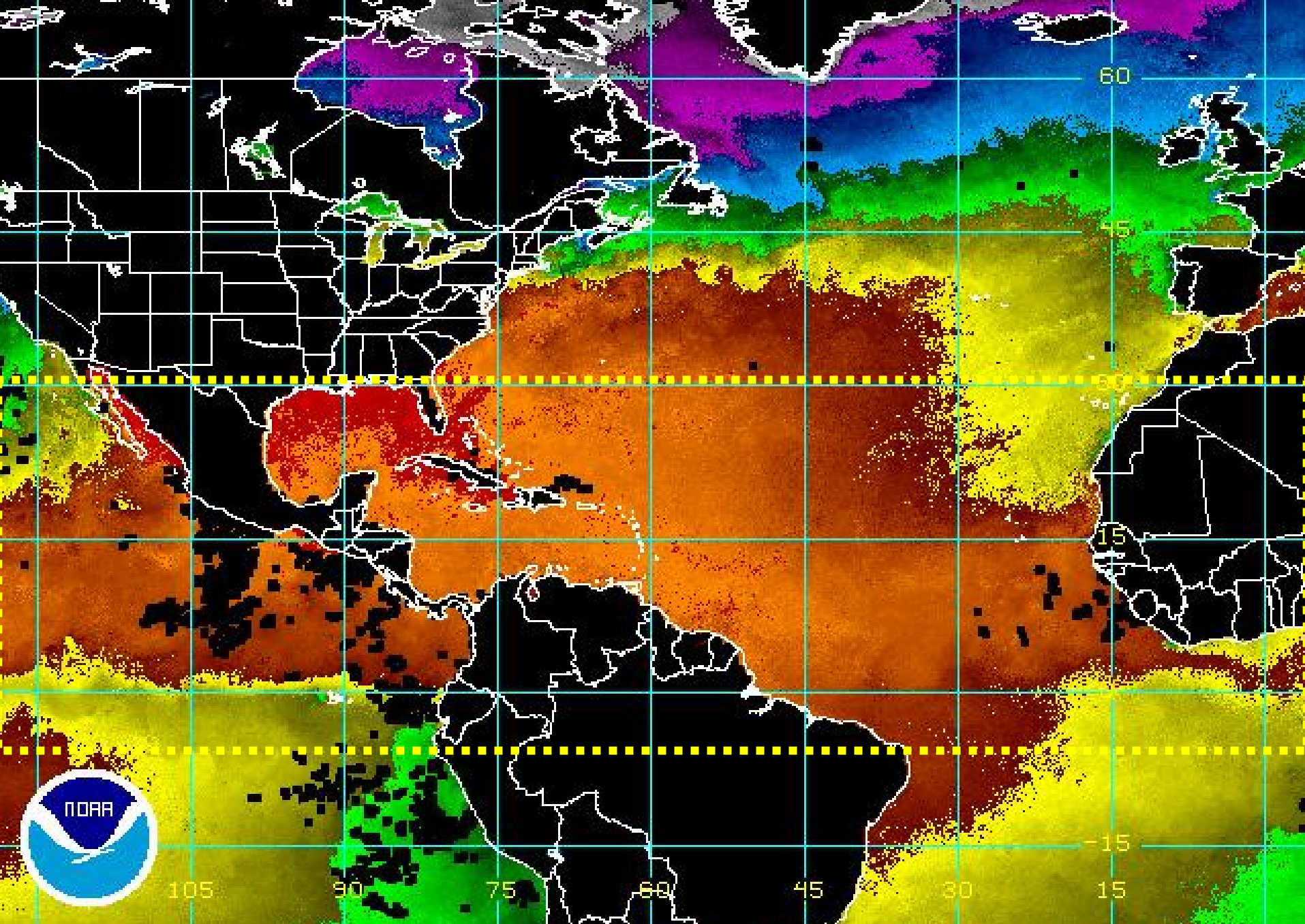
Departamento de recursos naturales y Ambientales  
 Programa de Manejo de la Zona Costanera

## Áreas naturales protegidas administradas por el DRNA

### Natural Protected Areas under the DRNA administration

Fuente de información - Source:  
 Departamento de Recursos Naturales y Ambientales  
 IITF

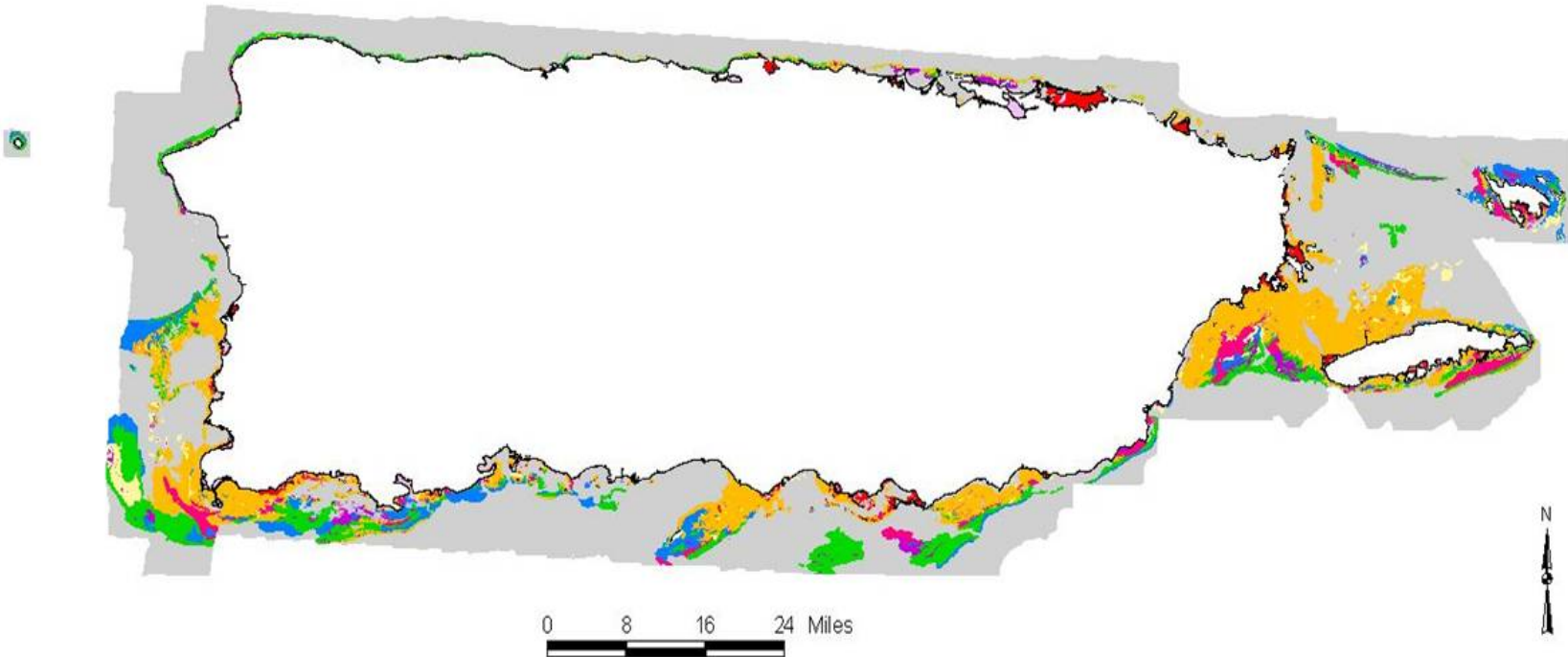
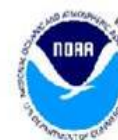




SST IN DEGREES C 0 5 10 15 20 25 30 +35

1 POES COMPOSITE ATLANTIC/EAST PACIFIC SST 27 AUG 05





Distribución de Arrecifes de Coral(1)

MEstades/03

Leyenda:

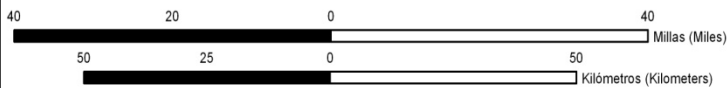
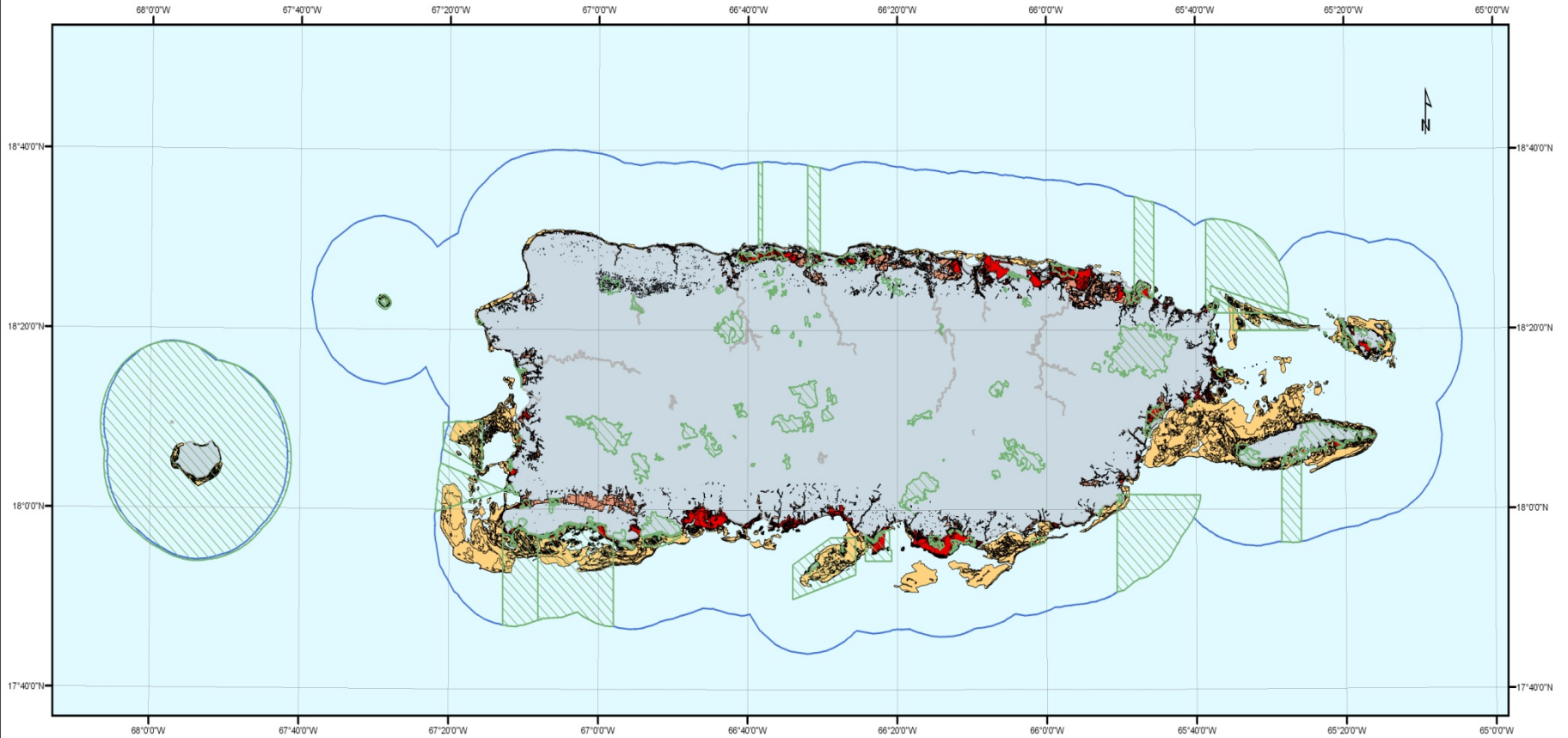
- Artificial
- Colonized Bedrock
- Colonized Pavement
- Colonized Pavement with Sand Channels
- Land
- Linear Reef
- Macroalgae
- Mangrove
- Mud

- Patch Reef (Aggregated)
- Patch Reef (Individual)
- Reef Rubble
- Sand
- Scattered Coral/Rock in Unconsolidated Sediment
- Seagrass
- Spur and Groove Reef
- Uncolonized Bedrock
- Unknown

(1)Fuente: NOAA/NOS

Legenda - Map key:

- Humedales palustres - Palustrine wetland
- Humedales estuarinos - Estuarine wetland
- Áreas Naturales Protegidas - Natural Protected Areas
- Humedales marinos - Marine wetland
- Límite de las aguas territoriales de Puerto Rico (9 millas náuticas) - Coastal zone maritime boundary ( 9 nautical miles)

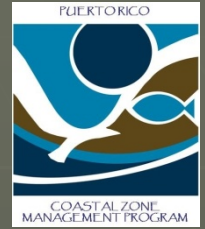


Fuente de información - Source:  
Departamento de Recursos Naturales y Ambientales  
Wetlands Inventory  
NOAA Benthic Mapping

# Humedales protegidos de Puerto Rico Protected wetlands of Puerto Rico



Departamento de Recursos Naturales y Ambientales  
Programa de Manejo de la Zona Costanera

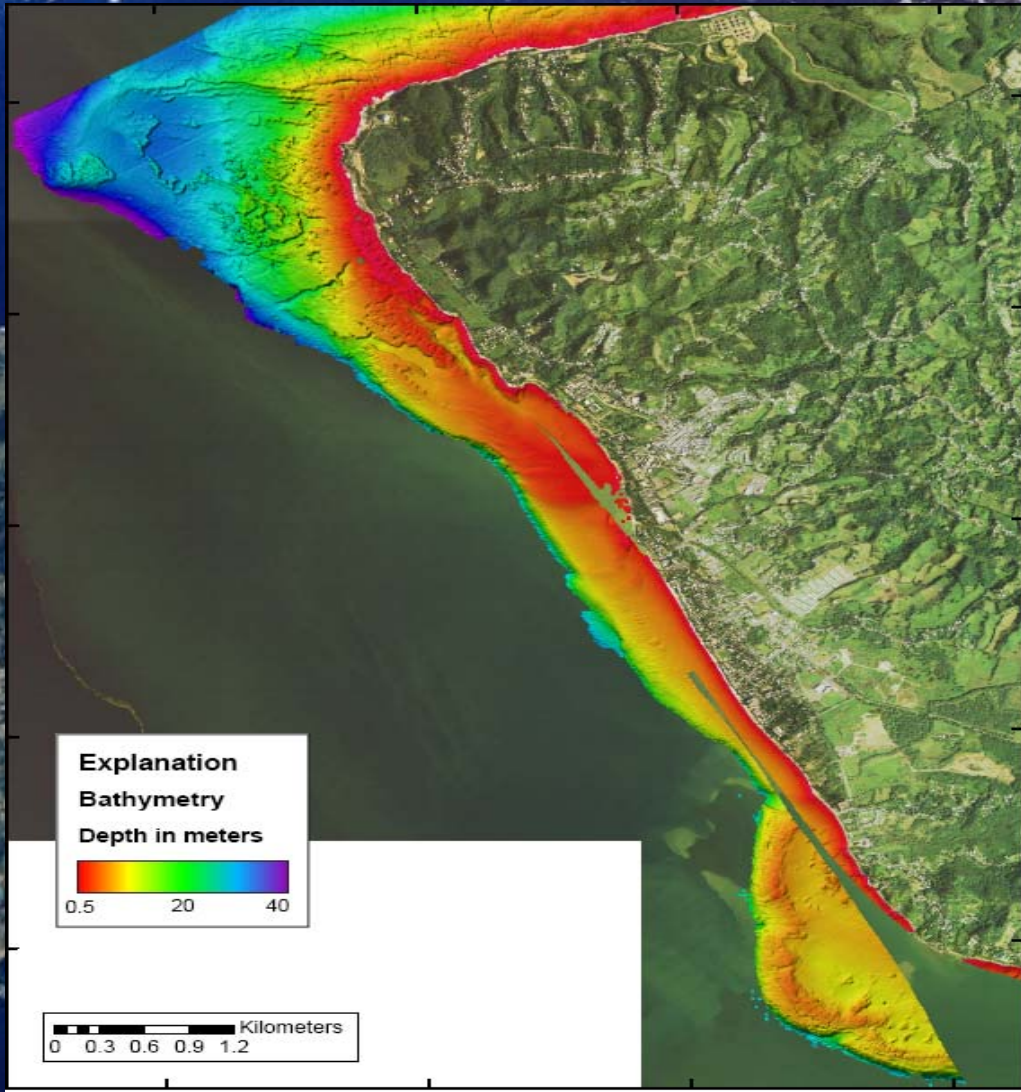
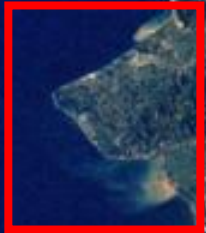


# Natural Protected Areas Statistics

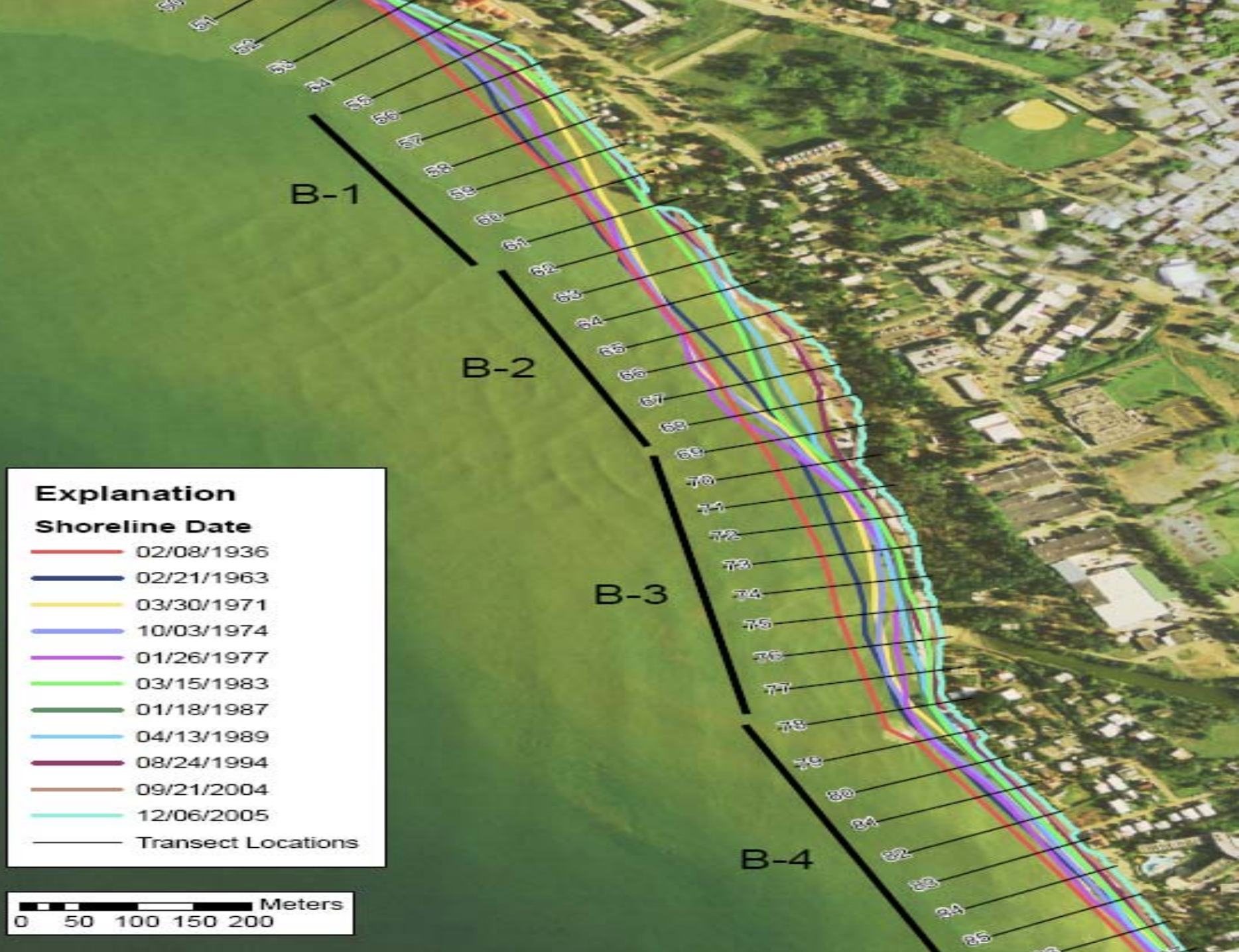
---

- **Total protected areas (land)** **8.24%**
- **Total protected estuarine wetlands** **31.80%**
- **Total protected reefs** **51.49%**
- **Total protected sea grasses** **49.24%**









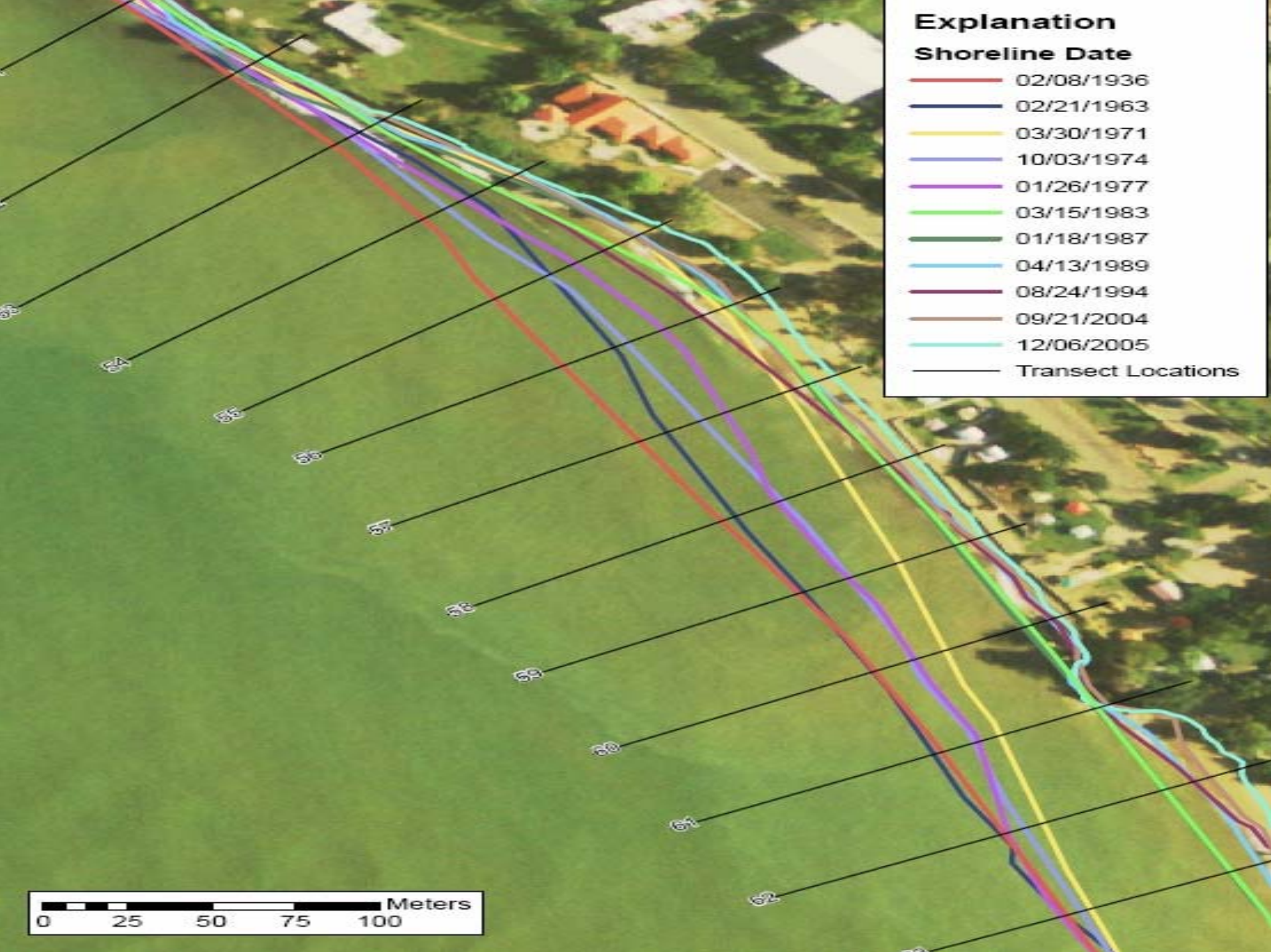
### Explanation

#### Shoreline Date

- 02/08/1936
- 02/21/1963
- 03/30/1971
- 10/03/1974
- 01/26/1977
- 03/15/1983
- 01/18/1987
- 04/13/1989
- 08/24/1994
- 09/21/2004
- 12/06/2005
- Transect Locations

0 50 100 150 200 Meters





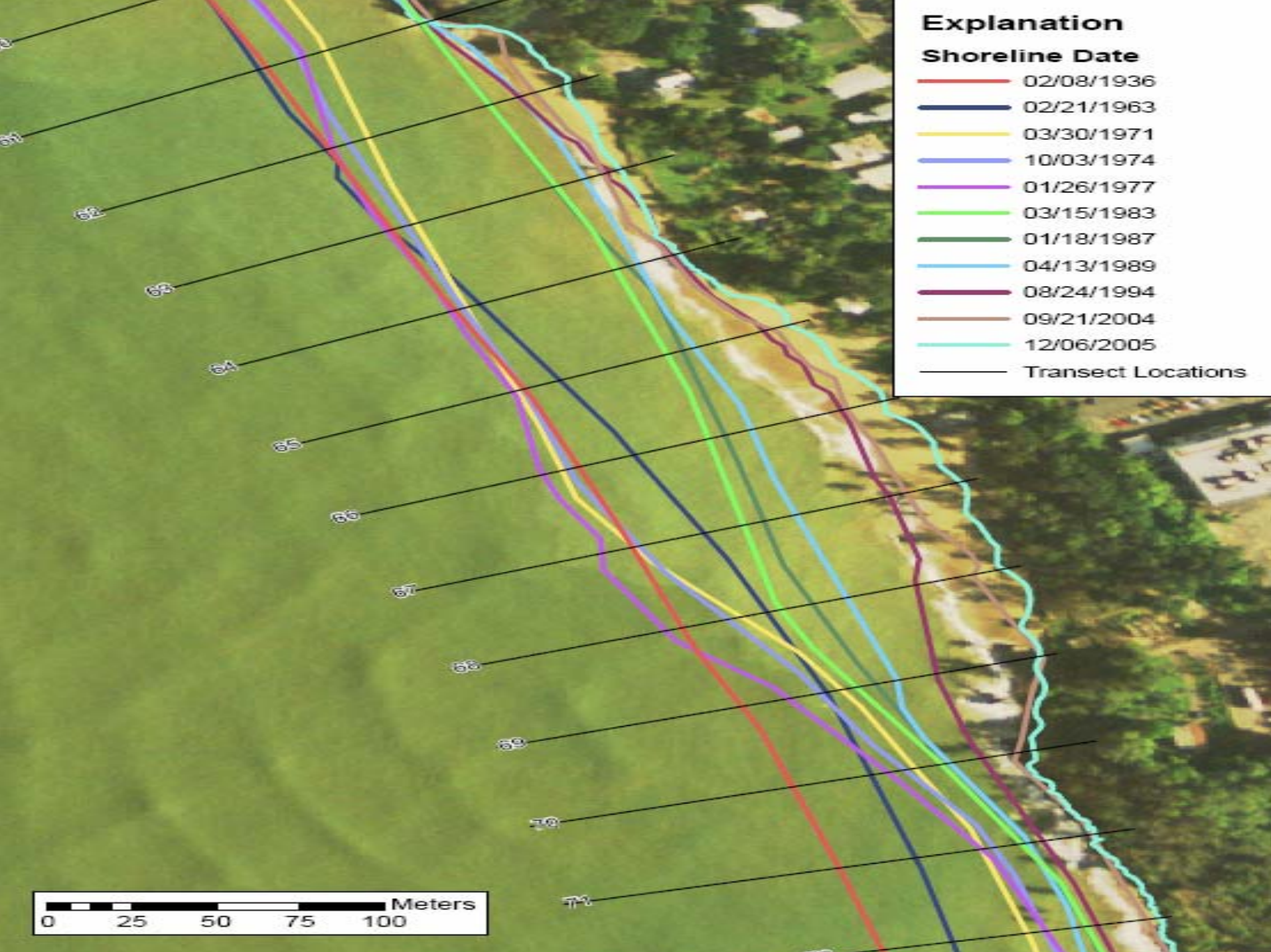
## Explanation

### Shoreline Date

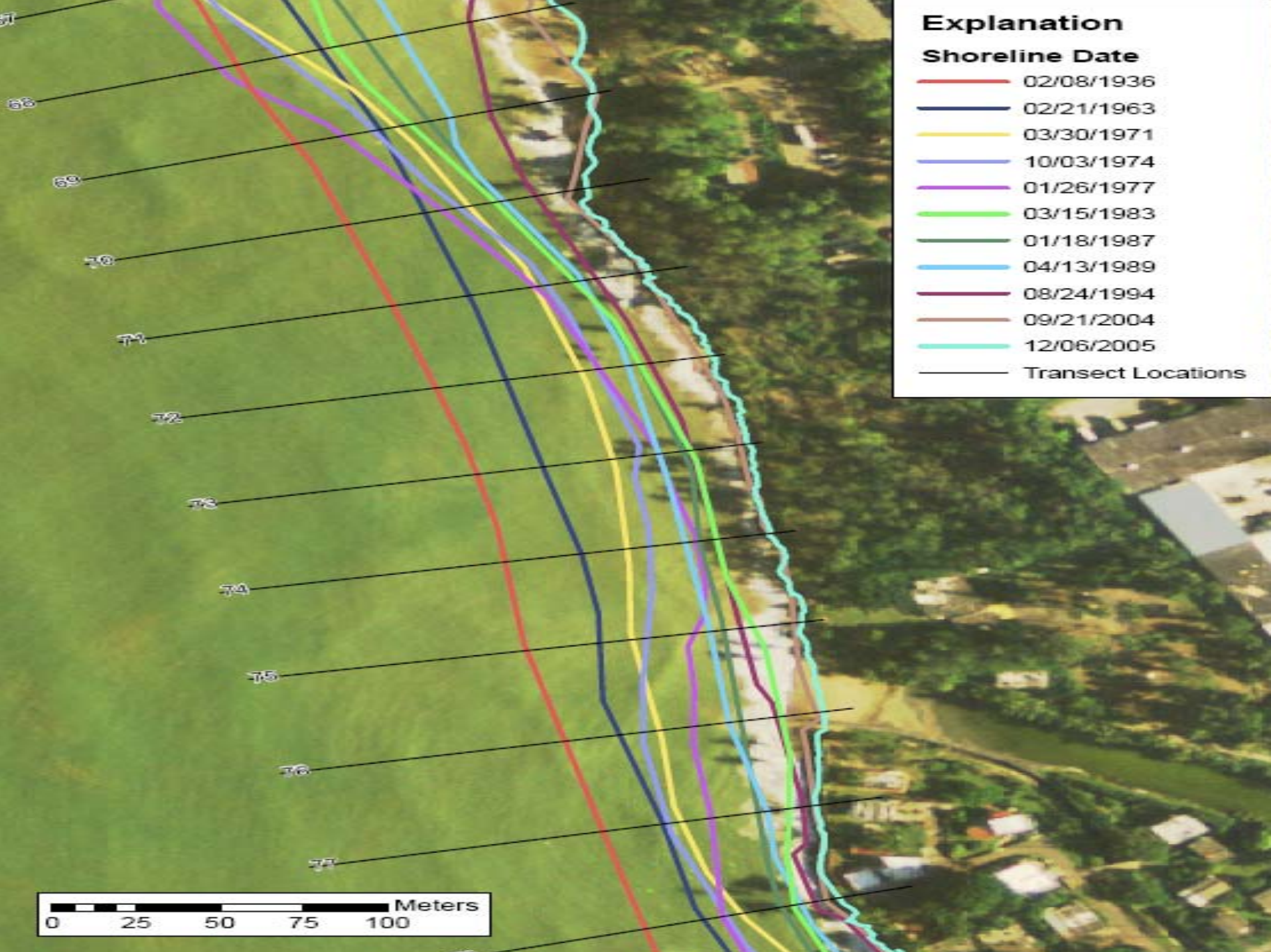
- 02/08/1936
- 02/21/1963
- 03/30/1971
- 10/03/1974
- 01/26/1977
- 03/15/1983
- 01/18/1987
- 04/13/1989
- 08/24/1994
- 09/21/2004
- 12/06/2005
- Transect Locations

0 25 50 75 100 Meters

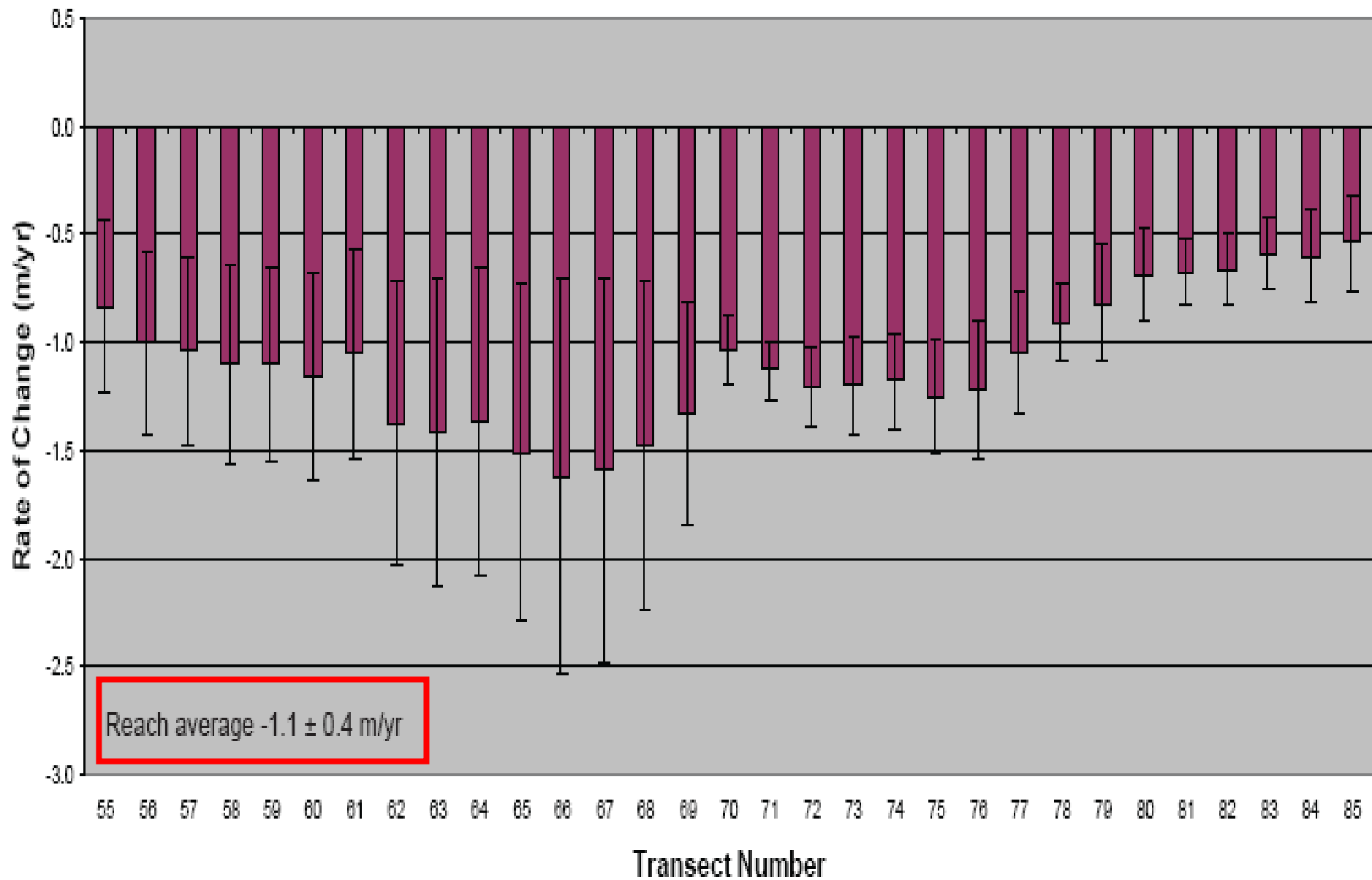




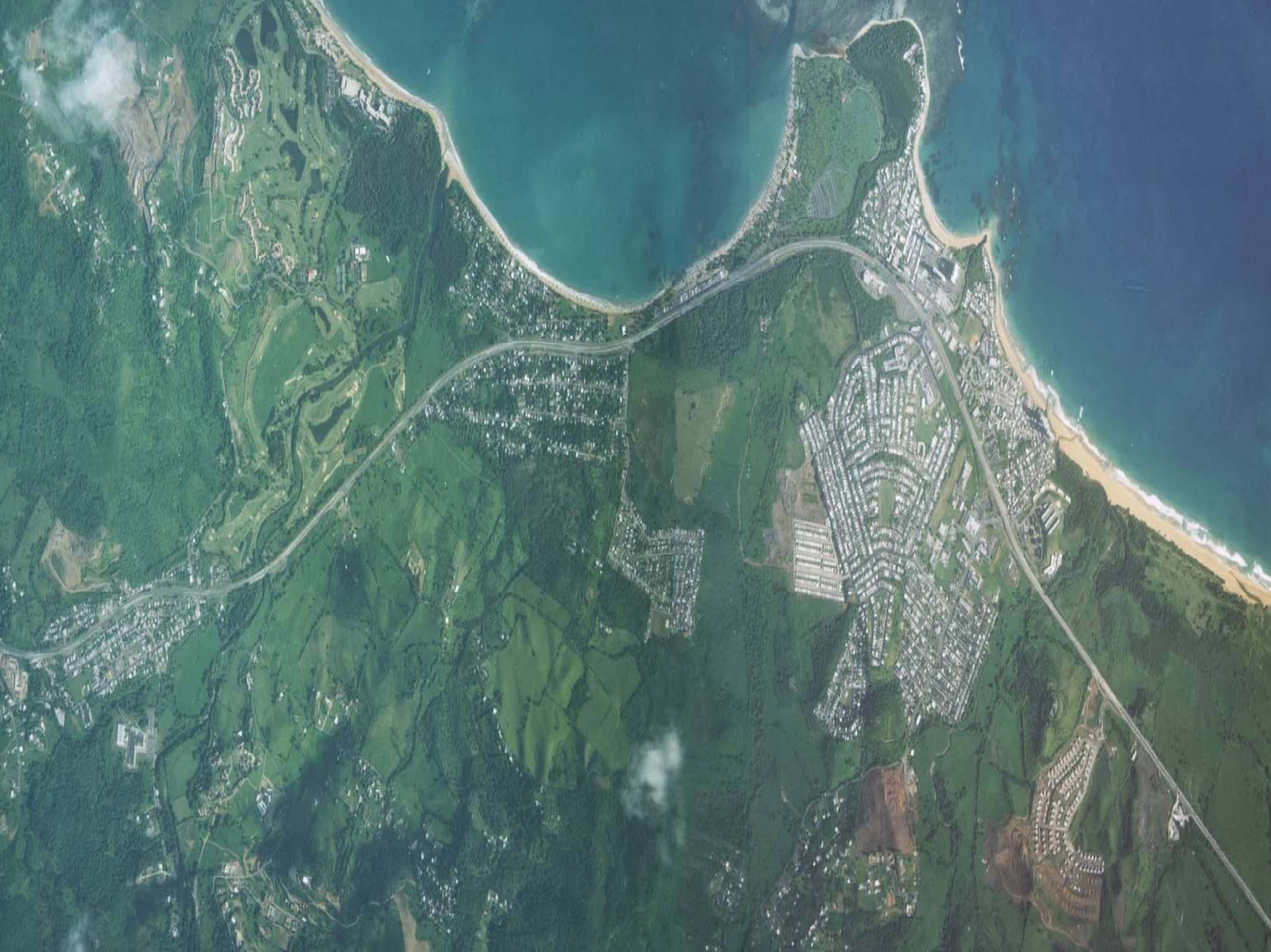




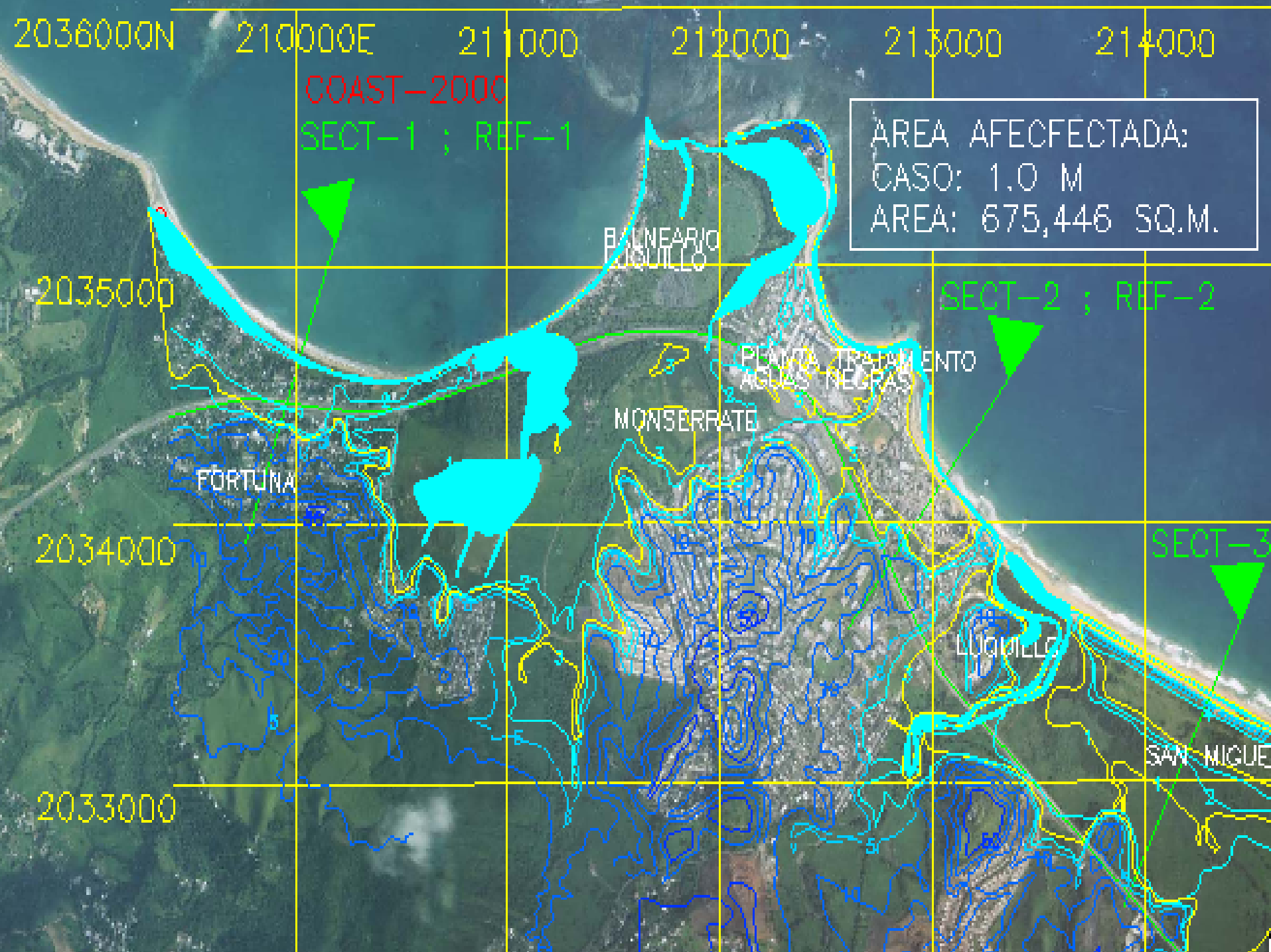
# Reach B











2036000N

210000E

211000

212000

213000

214000

COAST-2000  
SECT-1 ; REF-1

AREA AFECTADA:  
CASO: 1.0 M  
AREA: 675,446 SQ.M.

2035000

SECT-2 ; REF-2

BALNEARIO  
ESCOBILLO

PLANTA TRATAMIENTO  
AGUAS NEGRAS

MONSERRATE

FORTUNA

2034000

SECT-3

LUCILLE

2033000

SAN NIGUE

2036000N 210000E 21 000 212000 213000 214000

COAST-2000  
SECT-1 ; REF-1

AREA AFECTADA:  
CASO: 2.0 M  
AREA: 3,075,832 SQ.M

BALNEARIO  
LOQUILLO

SECT-2 ; REF-2

PLANTA TRATAMIENTO  
AGUAS NEGRAS

MONSERRATE

FORTUNA

2035000

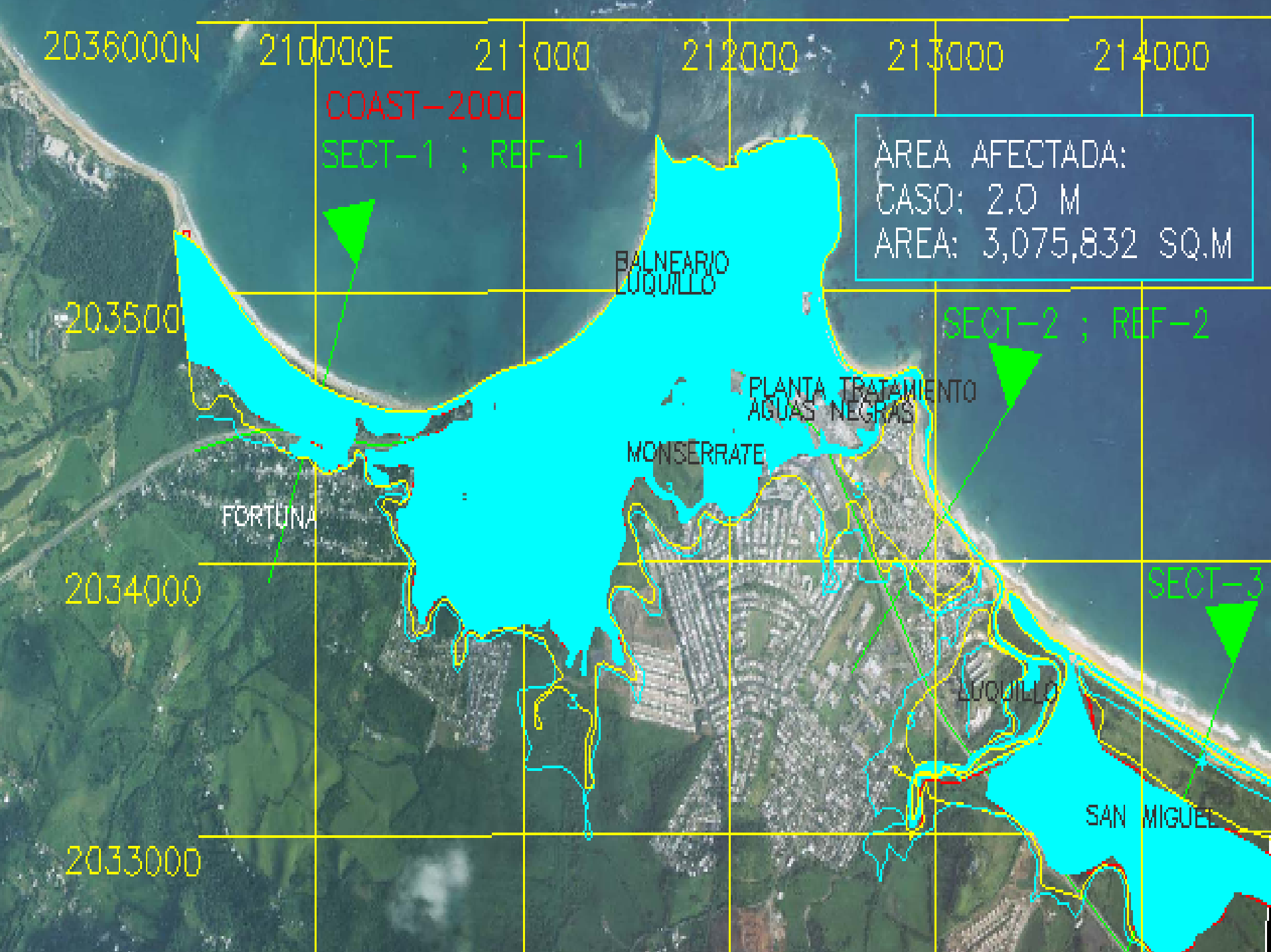
2034000

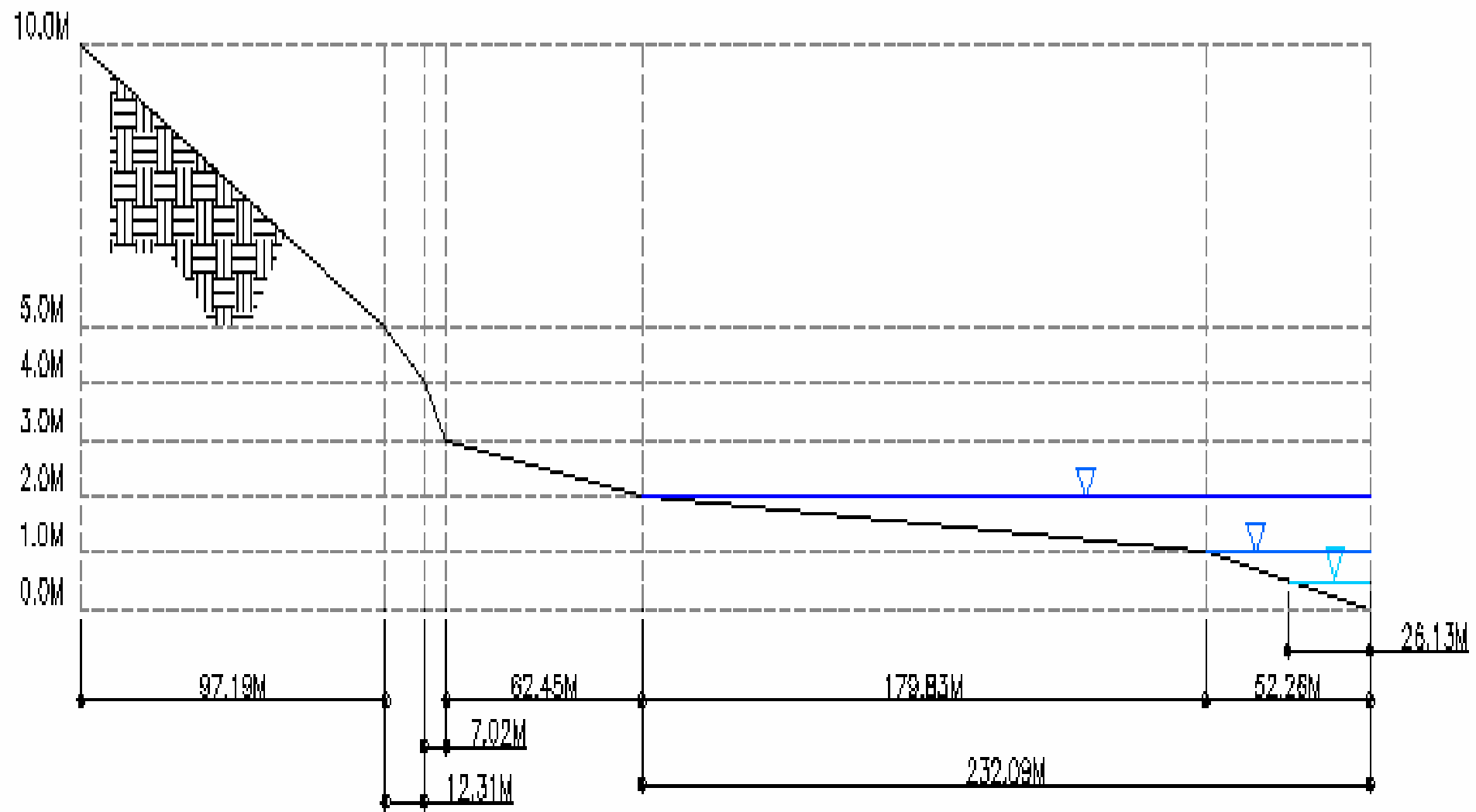
SECT-3

LOQUILLO

2033000

SAN MIGUEL

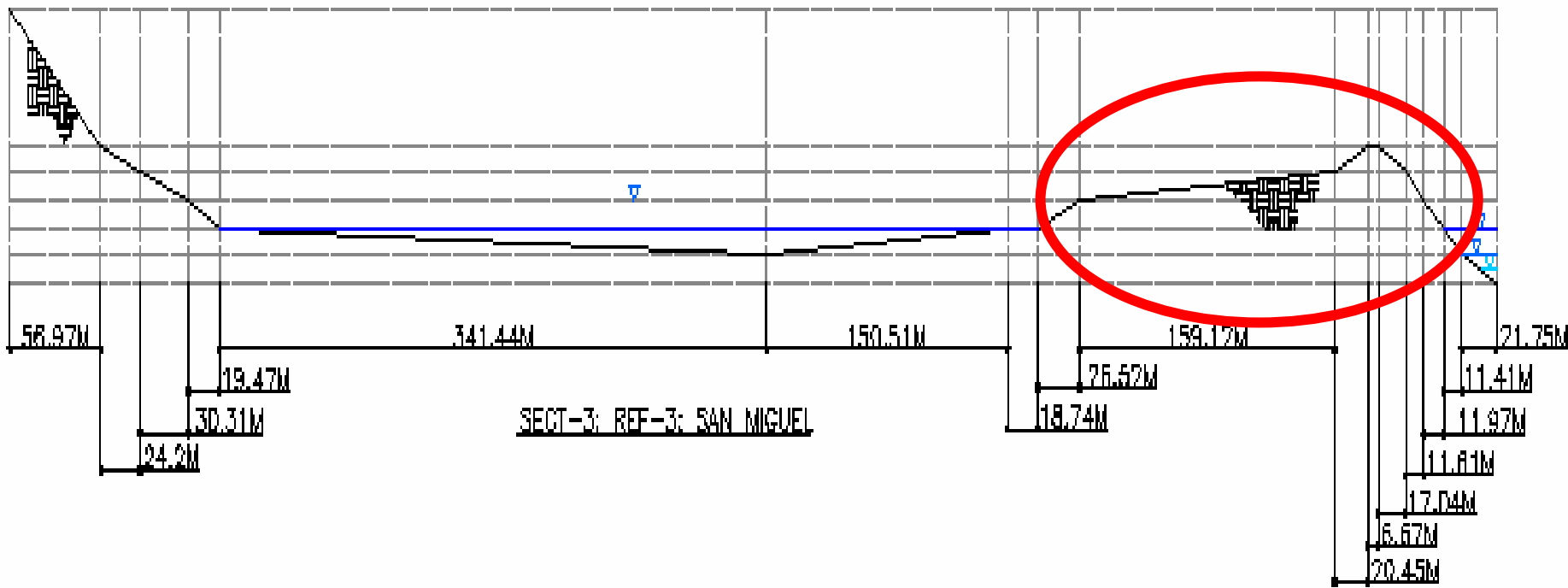




SECT-1; REF-1; FORTUNA

10.0M

5.0M  
4.0M  
3.0M  
2.0M  
1.0M  
0.0M



SECT-3: REF-3: SAN MIGUEL



# Adapting to CC-SLR in Puerto Rico

Adaptive responses:

Retreat



Accommodation



Protection



## 1. RETREAT

New vs. Existing structures

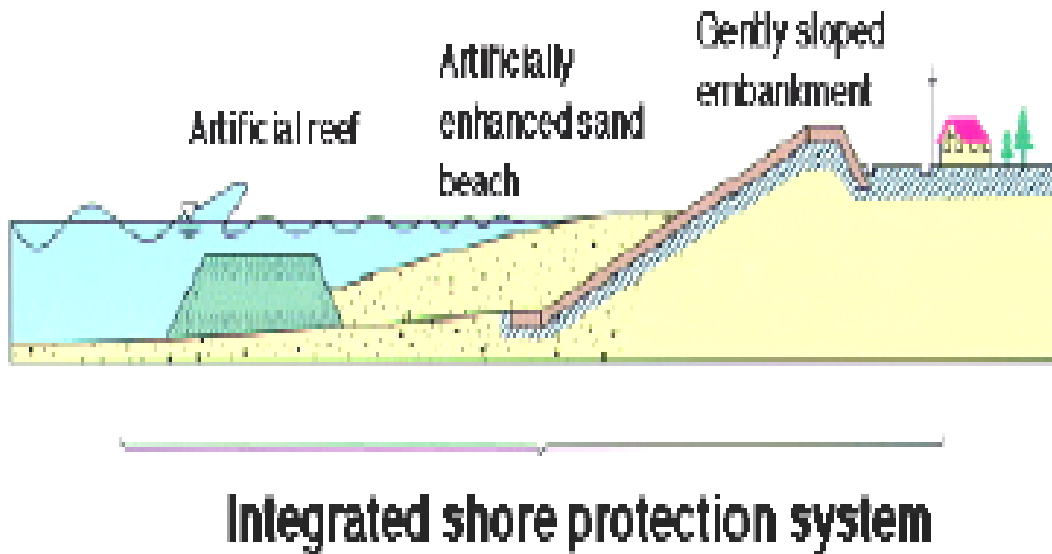
## 2. ACCOMMODATION

- Water or coastal dependant structures
- Port operations, airports, public infrastructure, access roads

## 3. PROTECTION

Structural, non-Structural and integrated solutions

# PROTECTION STRATEGIES:



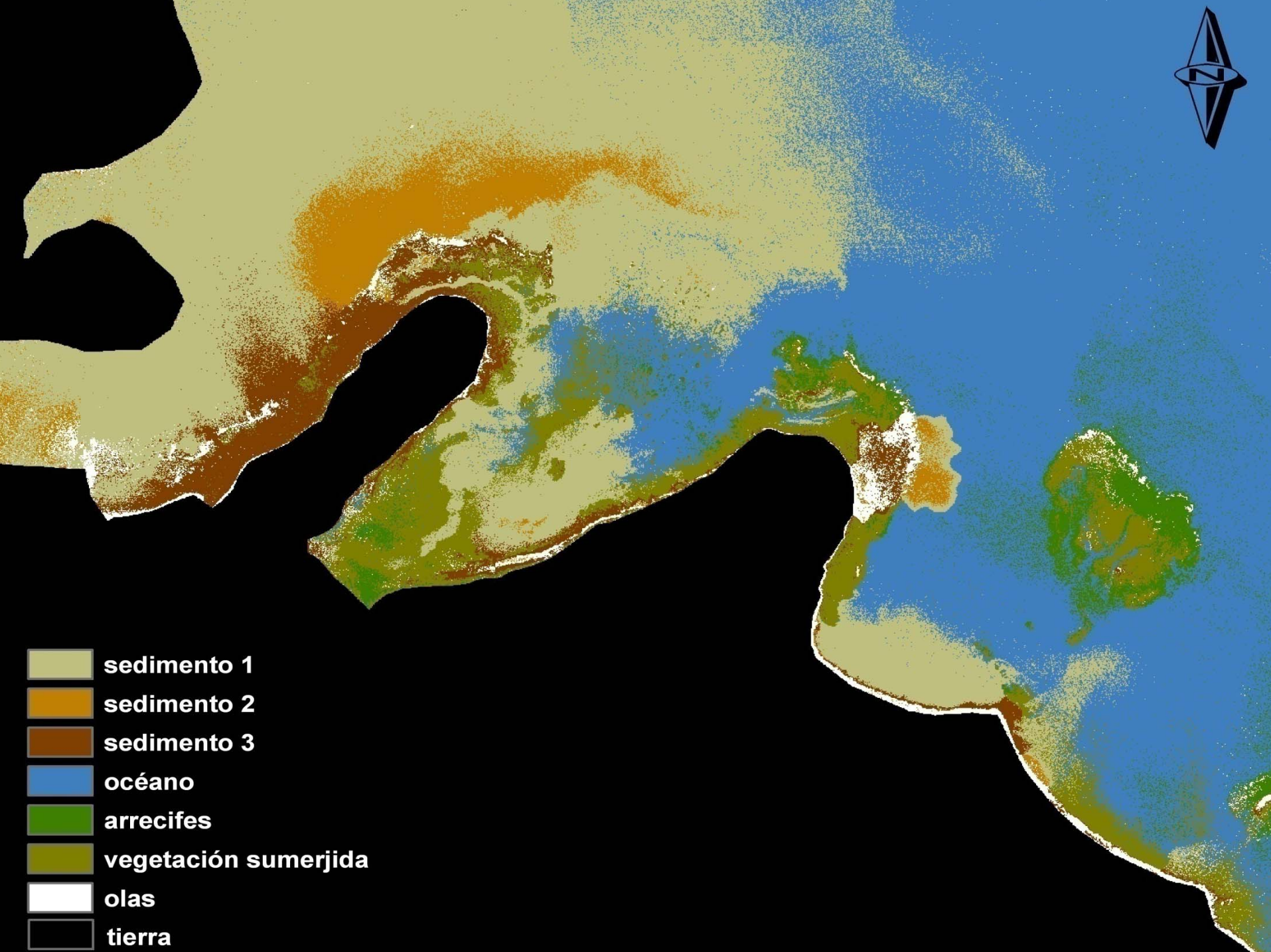
- Mangrove and dune systems protection
- Wetlands protection, restoration and enhancement
- Artificial reefs
- Integrated options











-  **sedimento 1**
-  **sedimento 2**
-  **sedimento 3**
-  **océano**
-  **arrecifes**
-  **vegetación sumerjida**
-  **olas**
-  **tierra**









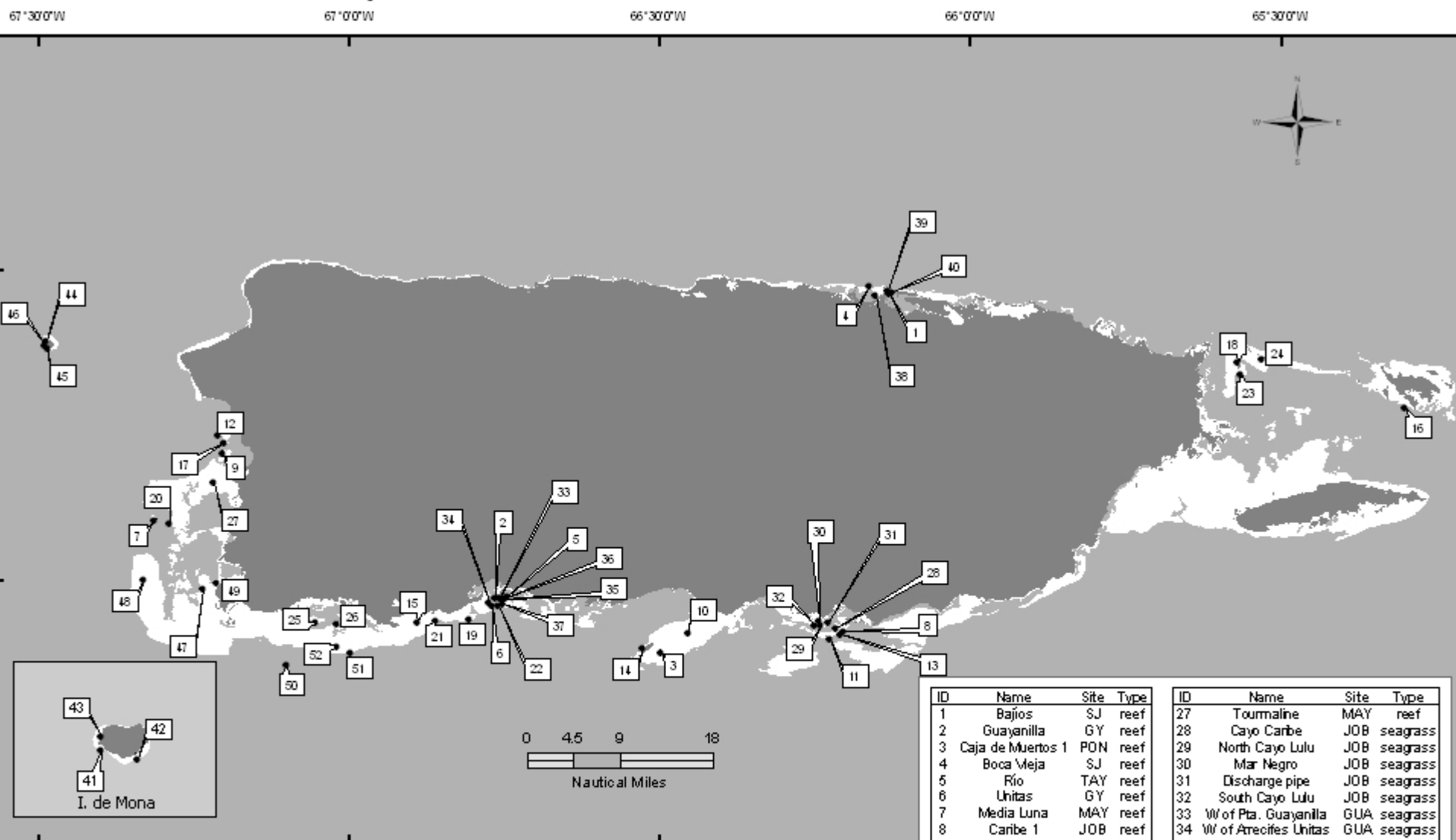




## ARRECIFES DE CORAL: SEDIMENTACION

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*La degradación de los arrecifes de coral de borde es mayor en aquellas cuencas y áreas costeras donde la población es mayor y las descargas y fuentes terrestres de sedimentos son más altas.*



J. Alvarez 2004



Estado Libre Asociado Puerto Rico  
 Departamento de Recursos Naturales y Ambientales  
 Programa de Manejo de la Zona Costanera

ID	Name	Site	Type	ID	Name	Site	Type
1	Bajios	SJ	reef	27	Tourmaline	MAY	reef
2	Guayanilla	GY	reef	28	Cayo Caribe	JOB	seagrass
3	Caja de Muertos 1	PON	reef	29	North Cayo Lulu	JOB	seagrass
4	Boca Meja	SJ	reef	30	Mar Negro	JOB	seagrass
5	Río	TAY	reef	31	Discharge pipe	JOB	seagrass
6	Uhtas	GY	reef	32	South Cayo Lulu	JOB	seagrass
7	Media Luna	MAY	reef	33	W of Pta. Guayanilla	GUA	seagrass
8	Caribe 1	JOB	reef	34	W of Atrecifes Uhtas	GUA	seagrass
9	Manchas Grandes	MAY	reef	35	SW Cayo Palomas	GUA	seagrass
10	Berbería	PON	reef	36	W of Cayo Palomas	GUA	seagrass
11	La Barca	JOB	reef	37	N of Maria Langa	GUA	seagrass
12	Manchas Ext.2	MAY	reef	38	Ensenada Boca Meja	SJ	seagrass
13	Caribe 2	JOB	reef	39	W Bajo Colnas	SJ	seagrass
14	Caja de Muertos 2	PON	reef	40	Bajo Santa Bena	SJ	seagrass
15	Cayo Coral	GUA	reef	41	Playa Mujeres	MON	reef
16	Pta. Maguey	CUL	reef	42	Playa Pajaros	MON	reef
17	Manchas Int.2	MAY	reef	43	Carmelitas	MON	reef
18	Isla Palomino	FAJ	reef	44	North Reef	DES	reef
19	Pta. Ventana 2	GY	reef	45	Puerto Canoas	DES	reef
20	Las Coronas	MAY	reef	46	Puerto Botes	DES	reef
21	Pta. Ballena	GUA	reef	47	Resuellos	BOQ	reef
22	Fanduco	GY	reef	48	Gallardo	BOQ	reef
23	Isla Palominitos	FAJ	reef	49	El Palo	BOQ	reef

# Impacts of Sedimentation on coral reefs

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## Major impacts of river-derived sediment and nutrients:

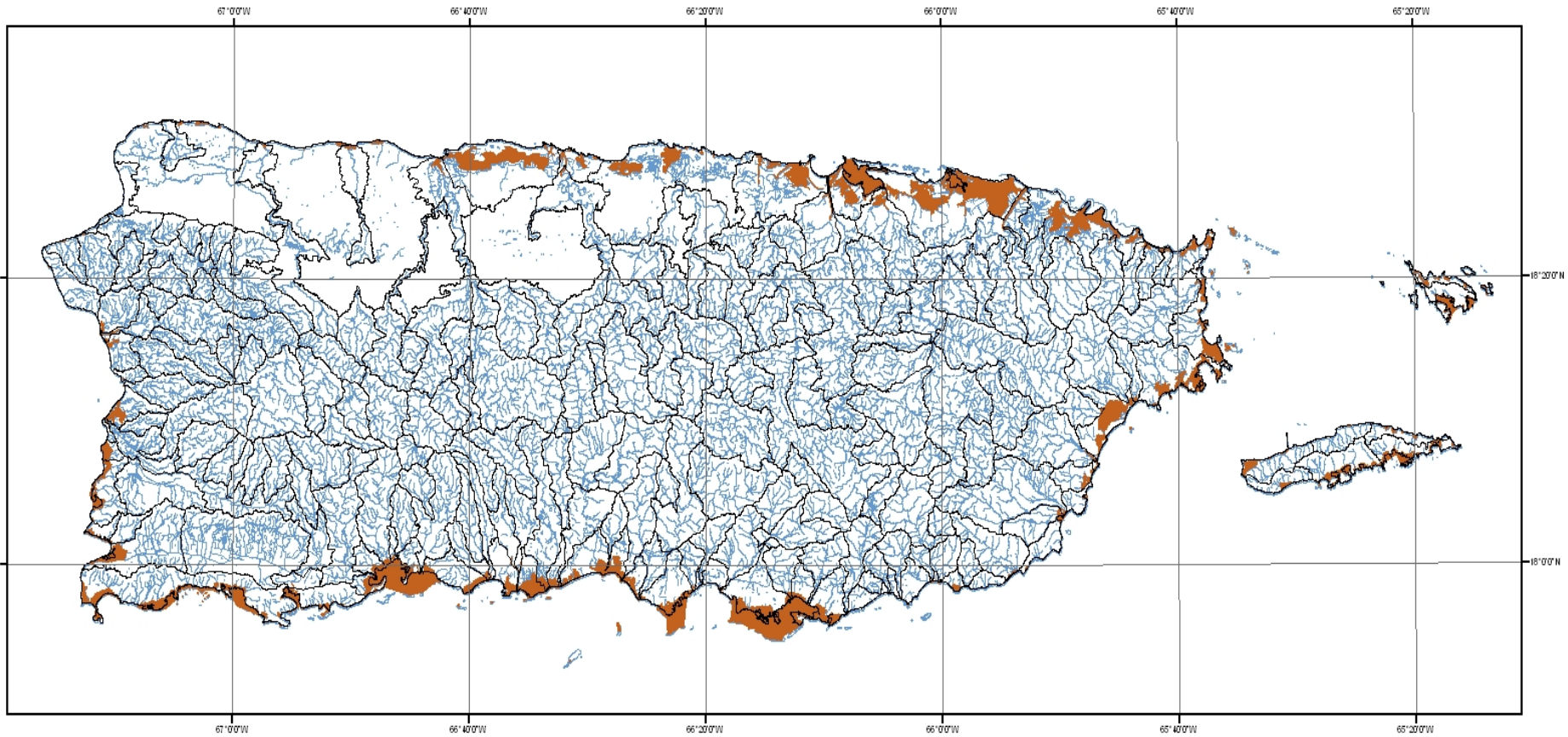
- Reduced light penetration
- Reduced live coral cover,
- reduced coral abundance and diversity
- increased algal and sponge density and diversity.



# Leyenda

- Cuencas hidrográficas
- Humedales estuarinos
- Hidrografía

Bruta - Scale : 1:850,000



## Cuencas hidrográficas e hidrografía de Puerto Rico

Fuente de información - Source:

Departamento de Recursos Naturales y Ambientales

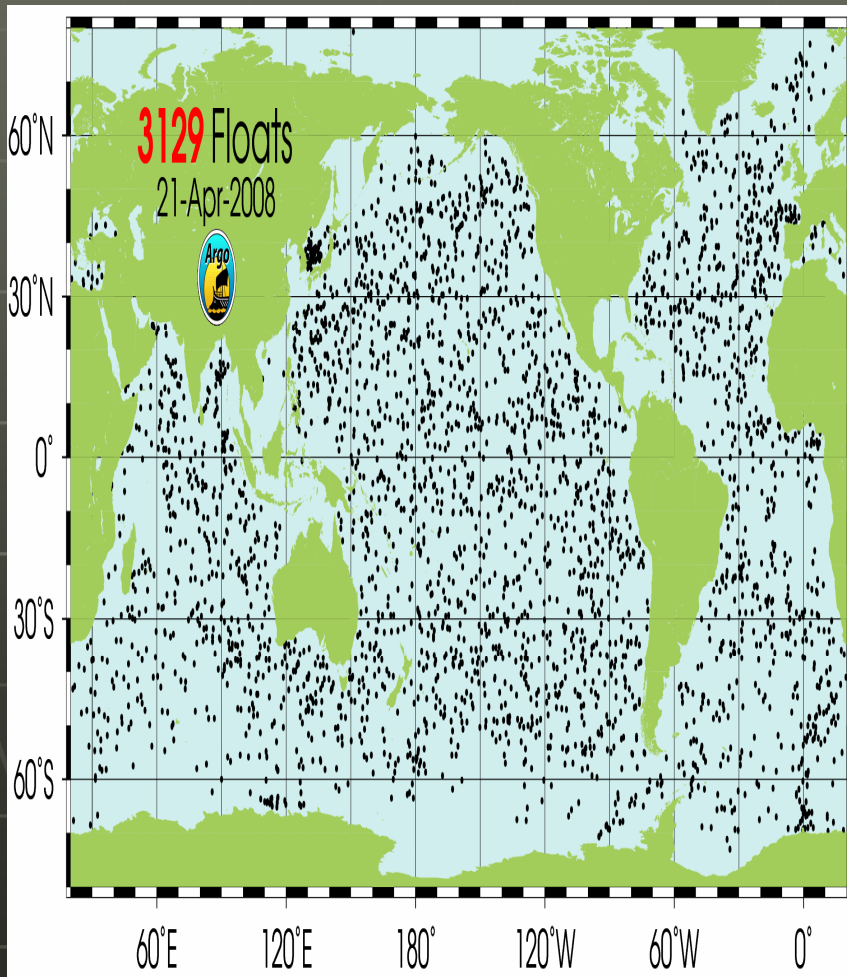
Departamento de Recursos Naturales y Ambientales  
Programa de Manejo de la Zona Costanera







# GLOBAL SYSTEMS MONITORING

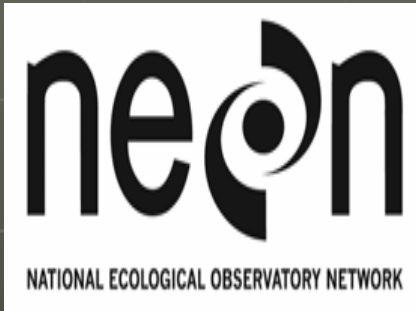


**ARGO** is a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean.

This allows, for the first time, continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours after collection.



# GLOBAL SYSTEMS MONITORING



The **National Ecological Observatory Network** is a research platform designed to advance understanding of how ecosystems and organisms respond to variations in climate and changes in land use.

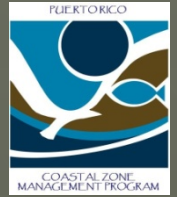
**NEON** is the first long - term **ecological** observatory conceived as a continental - scale research network; equipped with standardized sensors, cyber-infrastructure, and data - collection protocols across the network; and designed to **address simultaneously a common set of research questions and support investigator - driven** ecological research in all regions of the United States.

# **Puerto Rico CHALLENGES**

- **Increase knowledge about trends of resource abundance and distribution**
- **Increase understanding of interspecies and species-habitat relationships**
- **Contribute to increase knowledge about climate change, sea level rise and their impact on terrestrial, coastal, marine and socioeconomic systems.**
- **Effectively address human use patterns that may affect resource sustainability and biodiversity**

# **Puerto Rico CHALLENGES**

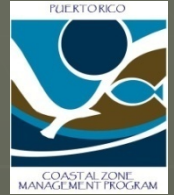
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- **Improve predictions of weather and climate change and their effects on coastal communities**
- **Reduce public health risks**
- **Protect healthy coastal marine ecosystems (i.e. wetlands and coral reefs systems) and support habitat restoration projects.**
- **Enable the sustainable use of marine and coastal resources.**
- **Develop better tools and techniques for coastal hazards protection (i.e. Early warning systems)**



# PRIORITIES:



- **Strengthen and ensure access to the best information available in order to support decision making (in both the Public and Private sectors.)**

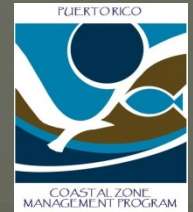
- **Establish the Island-wide baseline for the Public Domain Maritime Zone (Setback plus conservation easement).**

- **Identify and protect key geomorphic features that reduce coastal communities vulnerability to hazards.**

- **Protect coastal wetlands and coral reef systems from stressors such as nonpoint pollution (i.e. Sedimentation) through land acquisition and active management.**

- **Conduct coastal communities vulnerability assessments.**

- **Identify adaptation mechanisms for communities at risk.**



## COMMONWEALTH PARTNERS

- PR Planning Board
- DNER
- PR Environmental Quality Board
- Department of Agriculture
- Housing Department
- Department of Health
- Cultural Heritage Institute
- Puerto Rico's Tourism Company
- University of Puerto Rico
- Sea Grant
- Coastal Municipalities (43)

## FEDERAL PARTNERS

- NOAA OCRM
- NOAA NOS
- NOAA National Geodetic Survey
- US Geological Survey
- US Environmental Protection Agency
- Caribbean Fisheries Management Council
- International Institute of Tropical Forestry
- Natural Resources Conservation Service

## Other Commonwealth partners:

- University of Puerto Rico – Marine Sciences Department
- University of Puerto Rico – Health Sciences Department
- Puerto Rico Water Resources Institute
- Puerto Rico Forest and Natural Reserves Systems
- Community based organizations and NGOs
- Other Universities and Research Institutions

## TECHNOLOGY:

**GIS**  
Remote sensing  
Mass education  
and outreach



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