

**General assessment of the condition of the primary dune parallel to Road PR-187
and Parcelas Suárez both located on the municipality of Loiza, Puerto Rico**

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General remarks

Loiza is a municipality located on the north eastern coast of Puerto Rico and has the second largest line of sand dunes of this island (figure 1). The proximity of this area to the Luis Muñoz Marín International Airport (LMM) makes flying unmanned aerial vehicles (UAV) missions in this area almost impossible due to FAA restrictions. For this reason, we did not include this site on the coastal dune damage assessment that incorporated this technology.



Figure 1. Map of Puerto Rico showing the location of the municipality of Loiza.

Even though we have this technical limitation in this area, we did an “on-the-ground” assessment of the primary dune parallel to PR-187 on May 24, 2018. We were guided by Yeidi Escobar-Del Valle (planner) and Aquilino Pizarro (director of emergency management) from the municipal government of Loiza, during the visit. Our visual inspection of the area started near the large tidal pool in Piñones, next to Chatarras Beach, and finished on Vacía Talega beach (see figure 2). We also visited the highly eroded coast of Parcelas Suárez located to the east of this area. These areas experienced extensive flooding and destruction of private and public property as an effect of the strong action of waves during hurricanes Irma and María and winter storm Riley.

Our general impression is that green infrastructure and straightforward ecological restoration techniques can be implemented in this area as an alternative to more costly (and possibly less effective) engineering techniques that involve the installation of hard structures to protect the road and private and public property along road PR-187.

Our methods have had positive results in the western part of the island where we have successfully restored primary dunes in Isabela, Camuy and Arecibo since 2007 as part of several cooperative agreements with the U.S. Fish and Wildlife Service.

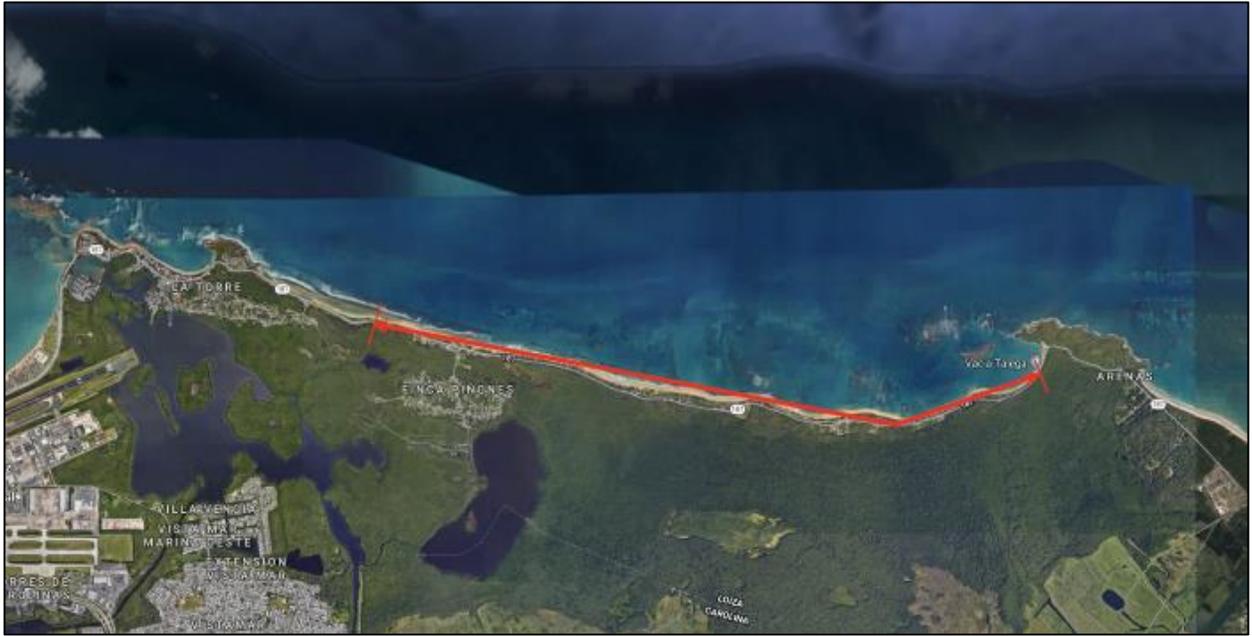


Figure 2. The red lines indicate the areas of primary dune that were assessed parallel to PR-187.

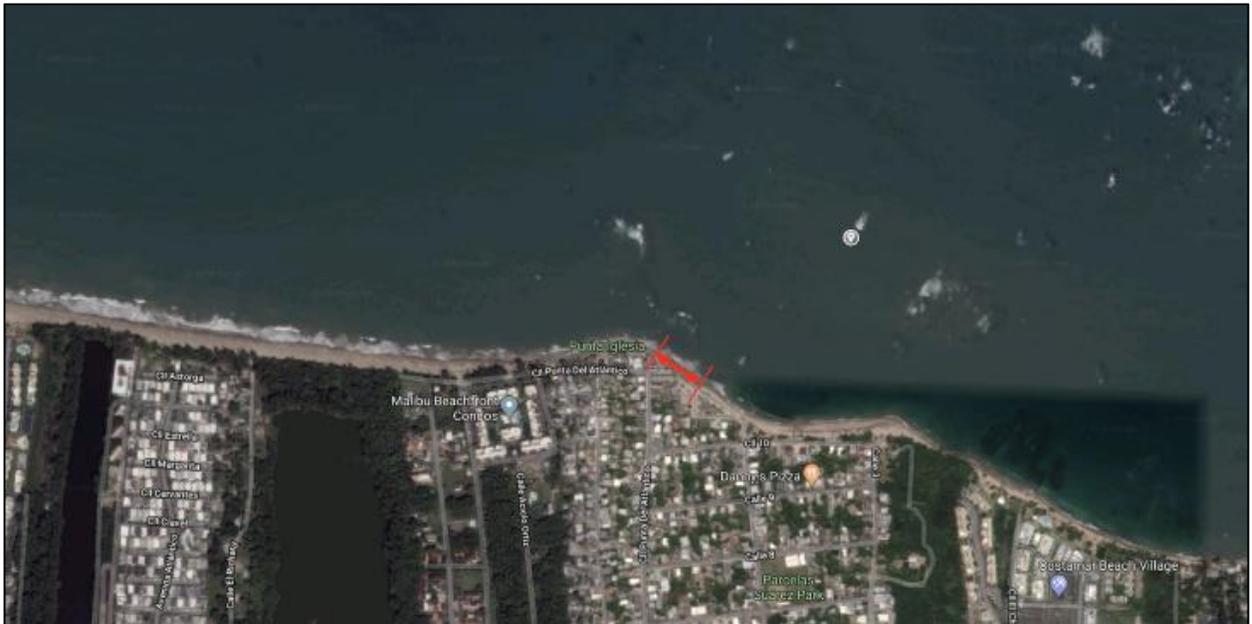


Figure 3. The red line indicates the area on Parcelas Suárez on which we assessed the condition of sand dunes.

Conditions of the sites

We found high volumes of **displaced sand** on both sides of road PR-187 especially on breached portions of the dune.



Figure 4. Displaced sand on the landward side of PR-187. This is very common along this route especially in areas where the dunes were breached.

We also identified many non-vegetated and highly eroded **breaches**, used as random beach accesses, on this line of primary dune. Areas of the dune that have significant vegetation cover withstood the effects of the strong wave action of the storms while the breached areas served as inlets of large volumes of sea water that caused massive flooding on this area (figure 5).



Figure 5. Stream of seawater flowing from the beach to PR-187 through a breached beach access on the primary dune during the week that winter storm Riley affected the Puerto Rico coast.

Many areas on these **random beach accesses** have no vegetation, a factor that reduces the stability of the dune (figure 6). We also found several **wooden boardwalks** that are in very bad (even dangerous) condition and should be repaired immediately. Additional better-designed and longer boardwalks should be installed along this area of dunes in order to re-direct foot traffic (which is heavy in some areas) away from vegetated areas. This simple measure would reduce flooding of this road significantly. If foot and sometimes vehicular traffic is not redirected the problem of flooding and massive sand displacement will not be resolved.



Figure 6. Two of the many random beach accesses along the primary dune parallel to PR-187.



Figure 7. One of the wooden boardwalks on the primary dune along PR-187.

Recommended courses of action

The installation of **green infrastructure** in this area should be an alternative to hard structures to restore and sustain the valuable ecosystem functions and services offered by this system.

We have a method for the analysis of foot traffic patterns on highly visited areas allowing us to locate the new **wooden boardwalks** in the best possible locations. This integrates the use of a UAS and photogrammetry software (Pix4D and Sample Point). Our boardwalks have been very effective in redirecting foot traffic in the Isabela area and even withstood the recent storms. Our data from previous projects on the western coast of the island suggests that this is the only effective way to increase vegetation cover in areas of high foot traffic such as this one. We are recommending the installation of wooden boardwalks that will reduce the incidence of random foot traffic and plant trampling that promotes erosion of the primary dune. The **random accesses** should be closed with exclusion fencing and signs should be installed in these areas in order to make people aware of the problem that these breaches on the primary dune cause and the direction to the nearest designated beach access (walkover).

We also suggest the installation of **wooden sand-trapping structures** (wooden pallets or biomimicry matrices) on each of these sites to rapidly increase the height of the problem areas of these dunes especially in breached areas. The structures should be located on the crest of the existing dunes. This will be coupled to planting of **fast-growing pioneer vegetation** that will stabilize the accumulated sand.

Increased **law enforcement** and **information signage** along this route is also needed to inform visitors of the importance of protecting the dune system and the importance of its services.

A formal **sand relocation plan** for displaced sand needs to be designed and strictly implemented in this area. See figure 8 for an example of a sand relocation application form used on the mainland United States. The sand should be immediately relocated to the berm area of the beach.

The community in general also needs to be aware of the importance of these landforms. Increased **volunteer opportunities** during ecological restoration events on this area are also necessary. An **environmental education component** is also necessary. We are members of the UW-Madison Latino Earth Partnership Program and represent this program in Puerto Rico and are planning to offer a two-day K-12 teacher training institute in Loiza. These teachers will then integrate ecological restoration of dunes into their curricula. This will be coupled to oral presentations on the importance of ecological restoration of sand dunes that will be delivered in local schools as part of this project.

Integrating the community in the ecological restoration of this area is very important for the success of the project.

Sand volume, percent vegetation covers and patterns of beach use are key parameters that need to be closely monitored to assess the effectiveness of the ecological restoration practices. We would need to amend our current FAA Certificate of Authorization (COA) (2017-ESA-12) to be able to use the UAS in this area to gather the data that will allow us to measure the above parameters.

We estimate that a total of 6.8 km of the Loiza coastline requires the ecological restoration of dunes to increase the resiliency of the communities of this area to future extreme weather events in a cost-effective manner that will help sustain the fragile economy of this area.

See appendix for specific locations of recommended ecological restoration actions.



Town of Nags Head

Area of Environmental Concern (AEC) Land Disturbance Application (Sand Relocation)

This program is authorized under the Town's CAMA Major Permit for Beach Nourishment (CAMA Major Permit #45-10) for the purpose of clearing accumulating sand from structures located in the Ocean Hazard Area of Environmental Concern

DATE OF ON-SITE MEETING _____

PROJECT CONTACT INFORMATION (Contractor or Owner)

NAME _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

PHONE _____ EMAIL _____

AUTHORIZED AGENT _____

PROPERTY INFORMATION

PROJECT ADDRESS _____

PROPERTY OWNER NAME _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

PHONE _____ EMAIL _____

PROJECT DESCRIPTION

AREA OF DISTURBANCE _____ sq. ft.

VOLUME OF DISTURBANCE _____ cu. ft.

(Not including sand removal from paved surfaces)

DEPTH OF EXCAVATION _____ ft.

EQUIPMENT USED _____

PLACEMENT LOCATION _____

ROUTE FOR TRANSPORT _____

VEGETATION REMOVAL? YES NO

If so, how much? _____ sq.ft.

PROJECT START DATE _____

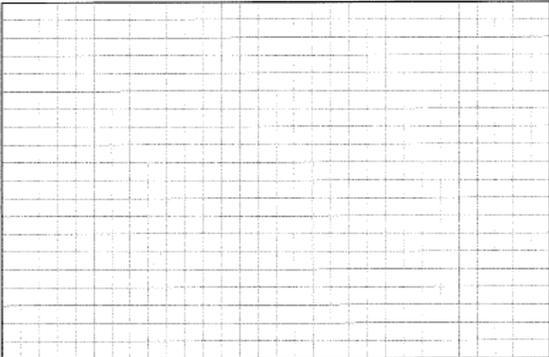
BEACH ACCESS TO BE USED FOR STAGING/ENTRY? N/A

(If necessary, a \$500 deposit will be required).

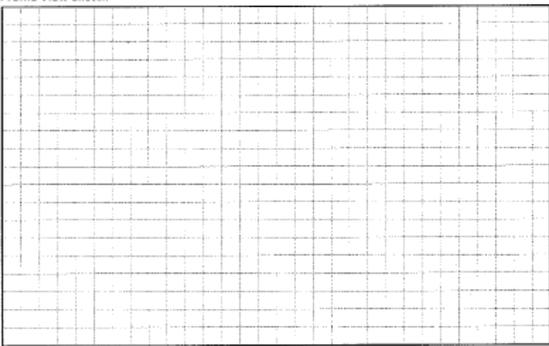
AUTHORIZATION CONDITIONS

1. The amount of sand removed from an existing dune must be the minimum necessary.
2. Land-disturbing activities within the AEC can ONLY be conducted between November 16th and April 30th annually.
3. Work shall ONLY be conducted Monday through Friday from 8:30 am to 5:00 pm.
4. NO "beach pushing"/bulldozing of beach sand.
5. Altered dunes shall be restored back to pre-disturbance conditions; maintain natural slope as closely as possible.
6. Sand placement on beach shall be no closer than 30 ft. to normal high water and must stay within property boundaries.
7. Stabilization Required.
 Sprigging Sand Fencing N/A
8. Please call for a final inspection.
9. _____
10. _____

Plan View Sketch



Profile View Sketch



CERTIFICATION AND STANDING. I certify that the information on this checklist and the site plan is complete and accurate.

DATE _____

SIGNATURE OF OWNER AGENT CONTRACTOR

Signature of Permit Official _____

This document constitutes authorization to complete *only* the activities described and shown herein. Any modification to the proposed work shall require approval from a Town of Nags Head Permit Official (please call 252-441-7016). Please keep a copy of this authorization on-site for the project duration.

White Copy – Town, Yellow Copy – Applicant

Figure 8. A sample application form for sand relocation from the town of Nags Head, North Carolina.

Appendix A

I. Breaches that need to be restored and closed (each picture has information including gps coordinates).

Breach 1.

Latitude: 18.451738

Longitude: -65.961220



Aerial map and on-the ground pictures of the location of a random breach on the primary dune. This site needs to be blocked with exclusion wooden fencing. Also an information sign should be placed in this area. Sand trapping devices should be installed in the area to promote sand accumulation and pioneer vegetation should be planted to help prevent further erosion.

Breach 2

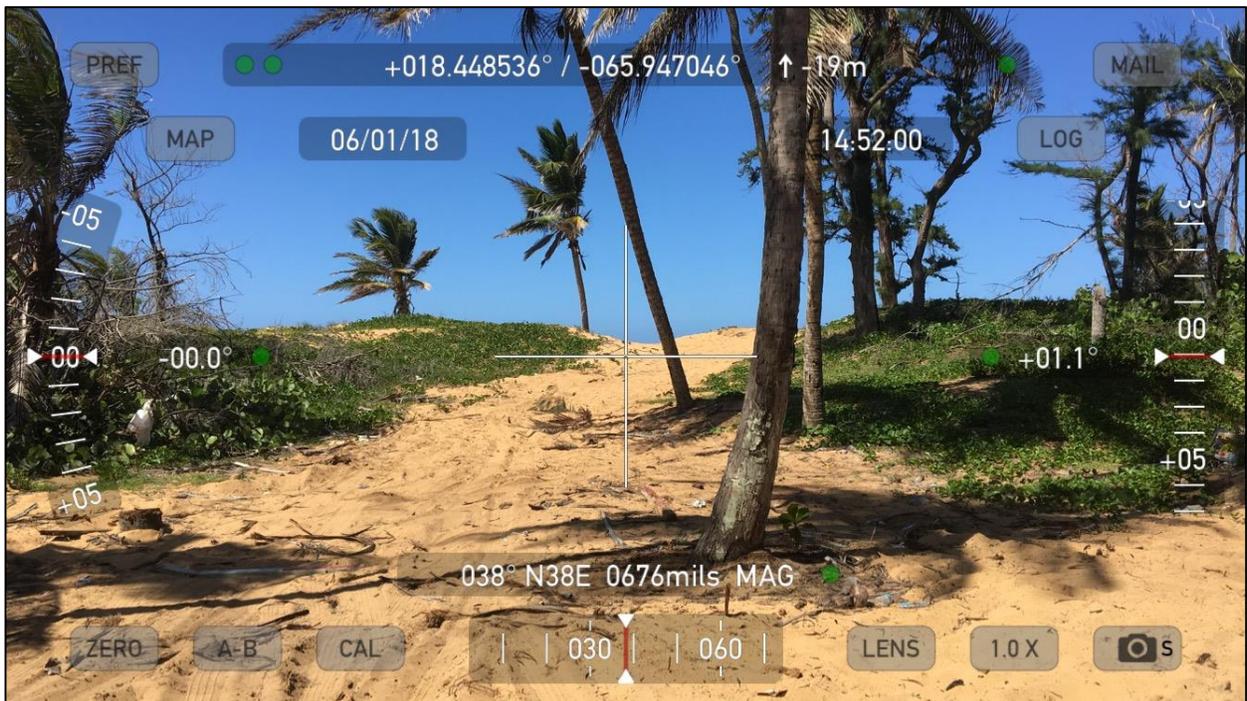
Latitude: 18.451629

Longitude: -65.960882



Aerial map and on-the-ground pictures of the location of a random breach on the primary dune. This site needs to be blocked with exclusion wooden fencing. Also an information sign should be placed in this area. Sand trapping devices should be installed in the area to promote sand accumulation and pioneer vegetation should be planted to help prevent further erosion.

Additional breaches that should also be repaired.







II. Areas where wooden boardwalks should be installed.

Site 1.

Latitude: 18.458946

Longitude: -654988606



Aerial map of the location. This area is located in front of a food business and a recreational path that we recommend be relocated closer to PR-187 to leave space available for sand accumulation on its original location. We also recommend the installation of a wooden boardwalk, information signs, planting of pioneer vegetation and sand trapping devices. We could detect significant sand transport in this area during our visit. The idea is to help the dune recover to the east of the segment of dune that is visible on the upper left of the picture.

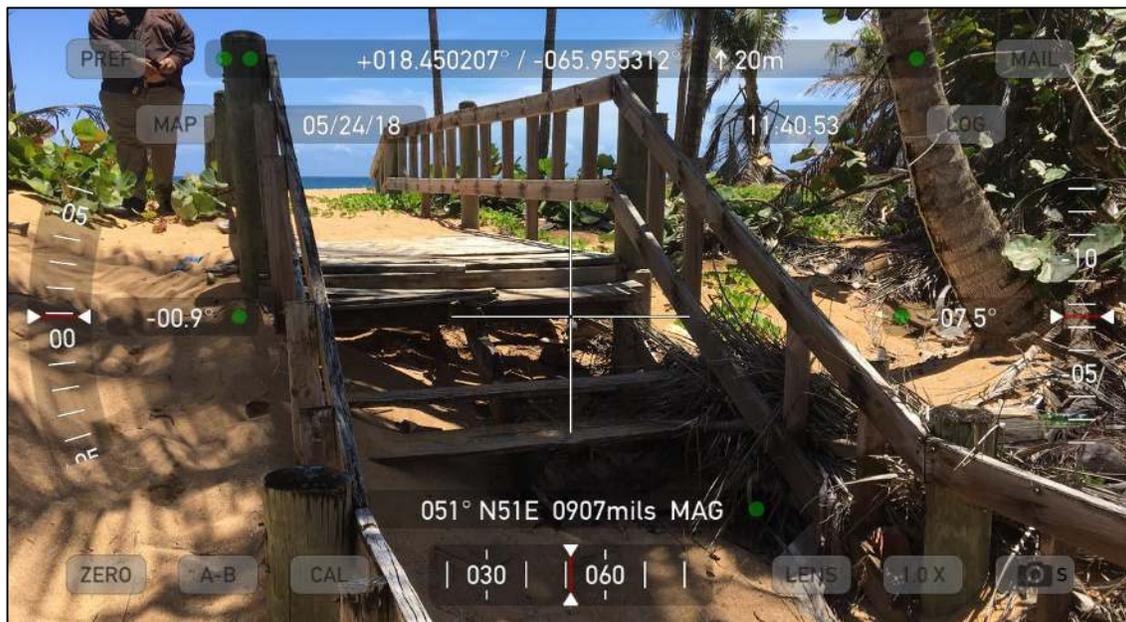


Additional pictures of this area.

Site 2.

Latitude: 18.450185

Longitude: -65.955218



This is one of the existing wooden boardwalks that need to be repaired and modified to be made longer and oriented on a different angle (not perpendicular to ocean) to reduce the influx of water to PR-187 during storms. Exclusion fencing should be installed to block foot traffic on the periphery of this structure also an information sign should be installed on the road side of this structure. Sand trapping devices and pioneer vegetation should be used to restore the seaward side of this structure. The longer boardwalk will help move foot traffic from the vegetated areas and will promote sand accumulation.

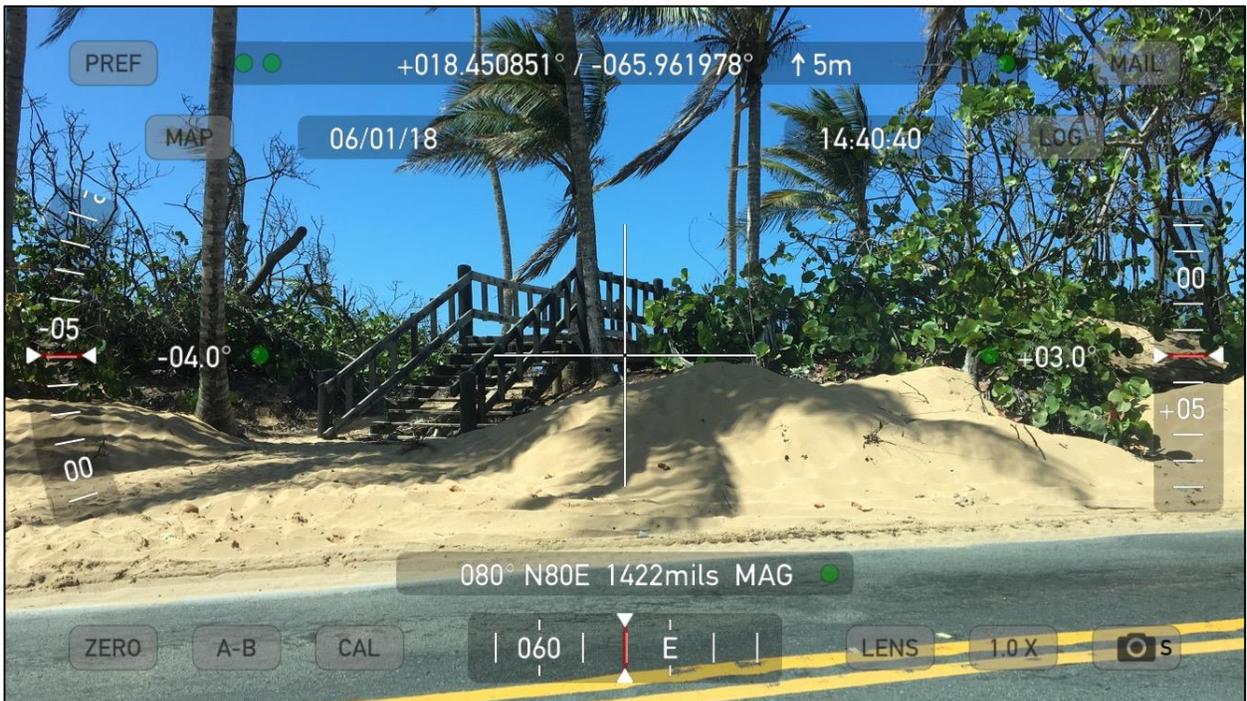


The same boardwalk viewed from another angle.

Site 3 (Chatarra Beach).

Latitude: 18.453048

Longitude: -65.965542



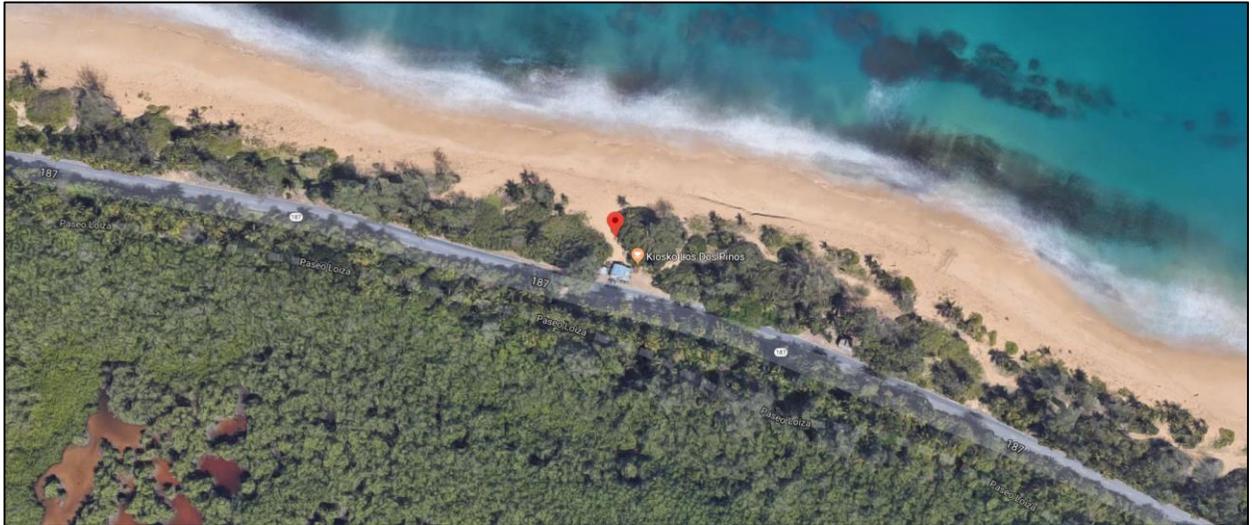
This is one of the existing wooden boardwalks that need to be repaired and modified to be made longer and oriented on a different angle (not perpendicular to ocean) to reduce the influx of water to PR-187 during storms. Exclusion fencing should be installed to block foot traffic on the periphery of this structure also an information sign should be installed on the road side of this structure. Sand trapping devices and pioneer vegetation should

be used to restore the seaward side of this structure. The longer boardwalk will help move foot traffic from the vegetated areas and will promote sand accumulation.

Site 4.

Latitude: 18.449125

Longitude: -65.947903



A wooden boardwalk should be installed in this area behind this small business. Sand trapping devices and pioneer vegetation should be installed on the periphery of this structure.

Site 5.



There are three accesses between the buildings. We suggest the access on the top picture be closed with exclusion fencing and that a wooden boardwalk be installed between the buildings on the lower picture.

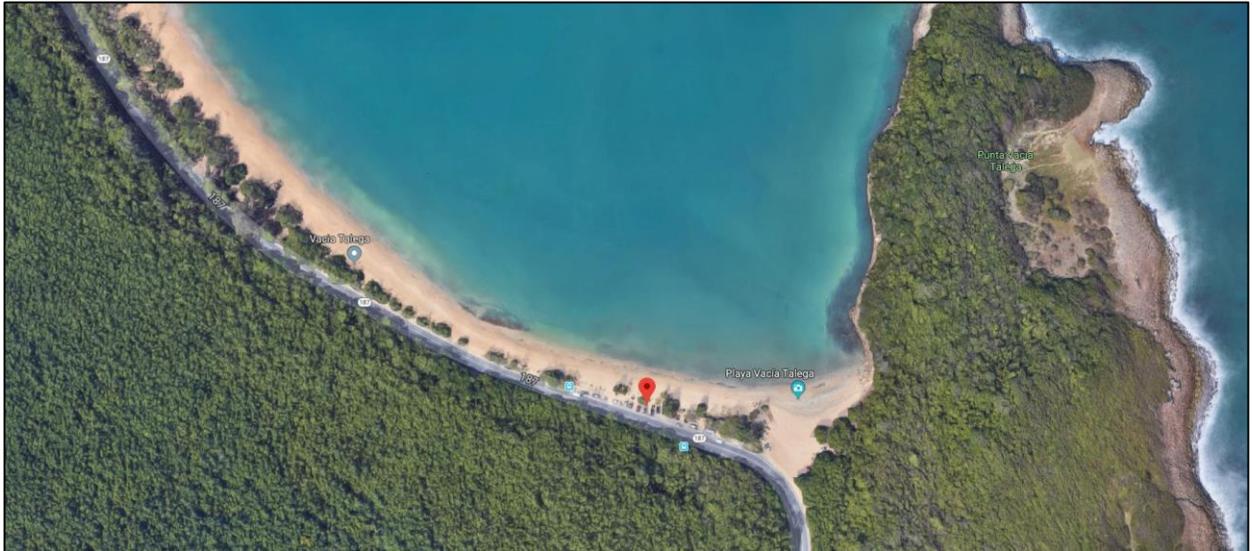


The access on the left of the building on the top picture should also be blocked. The beach area behind the buildings (bottom picture) should be restored with sand trapping devices and pioneer vegetation such as the beach bean thriving on the same picture. The growth of this plant in this area is limited by the heavy foot traffic (note footprints) and dragging of coolers.

Site 6 (Vacía Talega).

Latitude: 18.449988

Longitude: -65.904683



This is Vacía Talega Beach is an area of heavy recreational use. This area experiences heavy foot and vehicular traffic specially during weekends and holidays. We recommend exclusion fencing in the area to reduce vehicular damage to an incipient dune and pioneer vegetation. Information signs and at least two wooden boardwalks could significantly contribute to at least some sand accumulation (the morphology of the coast does not

promote sand transport – personal communication with Dr. Rosana Grafals and Dr. Maritza Barreto from UPR) but excluding traffic from the beach could promote the growth of stabilizing plants and some sand accumulation that would make this area more resilient to extreme weather events.



This unprotected beach leaves road PR-187 exposed to heavy wave action and flooding during strong storms. This area experienced heavy flooding during winter storm Riley (see below).



Site 7.



This is one of the existing wooden boardwalks that need to be repaired and modified to be made longer and oriented on a different angle (not perpendicular to ocean) to reduce the influx of water to PR-187 during storms. Exclusion fencing should be installed to block foot traffic on the periphery of this structure also an information sign should be installed on the road side of this structure. Sand trapping devices and pioneer vegetation should be used to restore the seaward side of this structure. The longer boardwalk will help move foot traffic from the vegetated areas and will promote sand accumulation.

Road Punta del Atlántico in Parcelas Suárez was severely affected by wave action during the extreme events of 2017 and early 2018. The road was closed and there are plans to install hard structures to protect the coast. Our recommendation is to immediately demolish the extremely dangerous Centro Comunal Parcelas Suárez building and install experimental sand trapping devices in the area as well as exclusion vegetation followed by the planting of pioneer vegetation. Even though Dr. Maritza Barreto thinks there is no significant landward sand transport we were able to witness a significant amount of sand (brought in from nearby areas of the coast by winter storm Riley?) being constantly blown on-shore. We also saw ripples on the sand suggesting sand accumulation and significant amounts of sand being accumulated on the yards of nearby houses. The pavement of the closed road should be removed and the area should be planted with pioneer dune vegetation combined with biomimicry matrices as a last alternative before installing hard structures on this area. We perceived more support to green infrastructure by the municipal government and community members. This is something to be seriously considered. We can monitor sand accumulation closely using our UAV system and photogrammetry software.







Sand being transported landward and being accumulated on the road and houses in Parcelas Suárez.

Appendix B

Additional pictures of the flooding along PR-187





