# GREEN INFRASTRUCTURE
# PILOT PROJECT - CONDADO LAGOON ESTUARINE RESERVE
# FINAL REPORT

## I. Green Infrastructure Assessment at Condado Lagoon

### A. SUMMARY OF EXISTING CONDITIONS, FINDINGS & RECOMMENDATIONS


*Figure 1. Aerial photograph of Condado Lagoon Estuarine Reserve.*

**BACKGROUND**

**USES**

Water Resource

Located in the northwest side of the Condado neighborhood and east of Old San Juan, the Condado Lagoon Estuarine Reserve serves both as entrance and exit from the Old city and is a major amenity within the metropolitan San Juan area and one of the city's major hotel areas. Historically, it houses a minor Spanish fortress which constituted a first line of defense from ships attempting to reach the San Juan bay as part of a series of military strategies. A rock formation at this locale also forms part of a local legend by way of a rock resembling the shape of a dog waiting for its master's return from sea.

The confluence at this location of the estuarine resource, ocean, bay and lagoon, the Colonial fort, the dog's legend comprise, by virtue of its uses, a cultural landscape. According to the National Park Service "a cultural landscape is a geographic area, including both cultural and natural resources and the wildlife or domestic animals

therein, associated with a historic event, activity, or person, or exhibiting other cultural or aesthetic values." Furthermore, the uninterrupted views at this point upon which the fort's strategic dominance is predicated, conform a cultural viewshed. Both categories the cultural background and the viewshed should position this landscape as one to pursue international valuation and protection as a cultural landscape under NPS exigencies to further complement and underline its natural and economic attributes.

## ACCESS

Boardwalk & Park

The Lagoon is bordered by major roadways on three sides: to the north Condado Avenue and bridge, to the west the Expressway Las Americas, and to the south Baldorioty de Castro Avenue.


*Figure 2. Condado Lagoon north side access. [Google Earth]*

Access to the Lagoon and its waters can be attained formally in the north east side from Condado Avenue, and from Baldorioty de Castro on the south side. Access from the north is only viable for pedestrians. At the south east side, vehicular and pedestrian access from Baldorioty de Castro leads into a service road which offers users a way to unload equipment and limited parking opportunities. Access for pedestrians from the west results unsafe. Informal entry points into the boardwalk and water can be observed along the south edge by way of parking on grassed areas and opening up of mangrove "windows" in order to put boards in the water.

On the south side the existing Jaime Benítez Park offers a rotunda, a boardwalk and a discrete parking area. Stemming from the boardwalk, one of the major paddle board concessions offers official access to the water. Bike riding, skateboarding, walking, jogging, pet walking, or sitting by the water's edge constitute some of the uses that take place on this side of the Lagoon.

The Condado Lagoon's geographic location and the Governor's Executive Order allowing access to "water" areas exclusively for exercise purposes, have increased its popularity with individuals who have chosen to engage in said activities at the Lagoon in

2020. A series of concessionaires along the north and south sides rent equipment for paddle boarding, kayaking, among other uses, with visitors also bringing their own equipment. Swimming is also allowed at the southwest side of the Lagoon.

This increased popularity has caused a rise in the number of persons visiting, more equipment in the water, more soil compaction as people unload their personal belongings on shaded and grassed areas, and opening/thinning of red mangrove stands by folks entering the water at informally generated spots.

Use by individuals and families at the site, begs the question as to how much human pressure the site may sustain prior to eschewing the balance between habitat needs of the Lagoon and the recreational needs of Lagoon users. Carrying capacity for this resource requires evaluation and the development of a short and long term Plan in order to use it to its best ability.

## VEGETATION

Water's border

Red mangrove (*Rhyzophora mangle)* patches are present along the lagoon's shoreline, with spacing becoming further distanced on the south side of the water's edge. This vegetative buffer needs to be consolidated around the entire border, with emphasis on the south side of the Reserve's water edge in order to provide additional consolidated habitat for species. Resulting from hurricanes Irma and Maria this red mangrove buffer was debilitated by winds, rising coastal surge and excessive precipitations flowing from the surface run off located at higher points in Ponce de Leon Avenue. Also present along this edge are interspersed, however predominant, *Terminalia catappa* (almendro), *Eugenia borinquensis* (Eugenia) catalogued by Miller (2012) as vulnerable, *Thespesia populnea* (Emajagüilla), and *Coccoloba uvifera* (Uva de playa). Other species are also found on a more sporadic basis such as *Chrysobalanus icac*o (Icacos), *Laguncularia racemosa* (Mangle blanco), *Pithecellobim dulce* (Guama americano).

To the north, areas of the Lagoon where patches of vegetation are missing can be attributed to streets or recent/new construction along the water's edge. Those spots appear to coincide with area resident's complaints about presence of oil or greasy substances at the edge, as well as others. In addition, areas where the presence of red mangroves is also missing is attributed to wave energy which moves the new seedlings hampering their establishment along with constant removal of a planting substrate.

*Figure 3. Street edge and new construction at the water's edge. (photo courtesy M. Rodriguez)*

A succession of various mangrove species as a consolidated swath should additionally be added, where space allows, in order for the species to function as a system. Other types of endemic coastal fruit bearing shrubs or small trees should also be considered as part of a reforestation strategy and a habitat for coastal species. Additional plantings of tall grasses and groundcovers could constitute “stepping stone areas” for small birds and habitat for other species in the sector and aid in controlling erosion where possible.

Boardwalk

The boardwalk is lined with *Terminalia catappa*, a number of which were possibly lost as a result of hurricanes Irma and Maria. Even though this is a non-native species, it is locally naturalized and could provide much needed shade along the boardwalk area. Additionally, it would serve to consolidate the existing tree line along the south border of the boardwalk.

*Figure 4. Line of Terminalias missing several specimens to be replanted for shade. (Photo courtesy of M. Rodriguez)*

Several existing trees are dead but still standing in the area. These should removed or converted to mulch for area use as they constitute a risk to the safety of area users and/or property. As trees and branches decay and other organic detritus is collected at the site, these could be chipped by Park personnel in order to reuse as mulch on site or to be sold to the public.

*Figure 5. Examples of dead trees to be considered for removal and converted to mulch. (Courtesy of M. Rodríguez)*

## EROSION

The southern side of the Condado Lagoon presents areas of significant erosion, a partially collapsed concrete retaining wall and collapsed grassed areas. These constitute a risk to the safety of area users and need to be addressed immediately by the corresponding partner agency as a precautionary measure.

*Figure 6. Eroded embankment area and partial retaining wall collapse. (Courtesy of M. Rodríguez)*

Runoff

Following several visits to the site and observing the flow of water, it is considered highly probable that storm runoff stemming from streets located on higher ground to the south of the Lagoon, are contributing to the erosion found at critical points in the boardwalk. These highly eroded points appear to coincide with the topographic condition, runoff velocities, and the location of stormwater infrastructure. In several points along Baldorioty Avenue it was also noted that the height between the curb and the infrastructure grill did not exceed 3" as opposed to the regulatory 6", which may be causing water to flow more slowly thus accumulating sediment along these areas.

*Figure 7. Eroded points along the boardwalk's retaining wall both inland and in water's edge. (Courtesy of M. Rodríguez)*

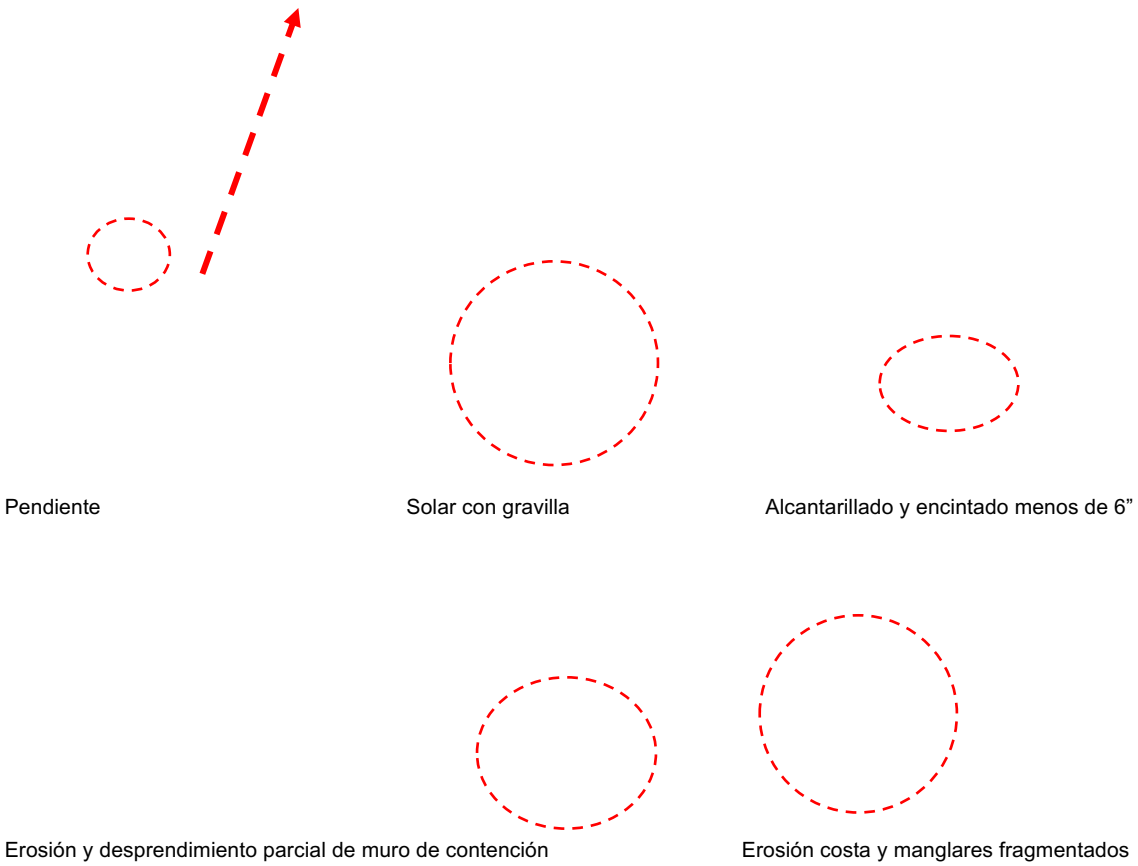



*Figure 8. Relationship with topographic changes on the southernmost side of Baldorioty Avenue. (Courtesy of M. Rodríguez)*

The eroded embankment is in direct perpendicular relationship with uphill sheet runoff which enters the Lagoon at this point.

Wave energy

At the northern side of the Lagoon it appears that erosion is being caused partly due to the energy of waves entering the lagoon on the northeastern edge, removing sand particles and depositing them on the southwestern side, the small beach area. Erosion heights differ anywhere from approximately 5'-0" to 6" depending on the area along the edge, the waves' energy, the level of erosion and the use by visitors. Therefore, reforestation on this side of the lagoon may need to consider various planting techniques which address embankment stabilization concomitantly.

*Figure 9. Eroded beach edge on the north side with discrete red mangrove plantings. (Photo courtesy of M. Rodriguez)*

People traffic & soil compaction

The area to the north of the Condado Lagoon runs a concessionary business operation of aquatic equipment. The concessionary has established movable structures and framework as storage for kayaks, paddle boards, among others along the built perimeter of the area buildings up to an enclosure with cyclone fencing. Pedestrian traffic over this grassed area has compacted the soil and eroded the most heavily trafficked sector. Redesigning the area to consider circulation and equipment storage should be reconsidered in order to mitigate the impact over this area.

*Figure 10. Compacted and eroded soils due to pedestrian traffic. (Photo courtesy of M. Rodriguez)*

On the south side, the formal entry point to the Lagoon is perhaps the most compacted and eroded. The area concessionary installed an astroturf carpet to diminish the erosion and sedimentation in the water. Both issues will require attention in order to stabilize the water's edge while still retaining the use for area participants.

*Figure 11.South side concessionary has installed a temporary astroturf covering in order to cover the eroded soil area at the launching zone. (Photo courtesy of M. Rodriguez)*

Active discharge point

During one of the visits a discharge point was observed stemming from one of the existing buildings. The event lasted briefly. The previous night the sector experienced a heavy downpour which, as explained by the Project Manager De

la Cruz, may explain that the building might have been pumping rainwater out of a basement.

*Figure 12. Direct discharge into Lagoon's water. (Photo courtesy of M. Rodriguez)*

**INFORMAL PARKING**

Currently the parking area at Jaime Benitez Park, which serves as entry point to the Lagoon, is not operating due to the Governor's Executive Order in response to COVID-19. Therefore, informal parking is pursued on the traffic median island at Baldorioty de CastroAvenue in order to accommodate more users at the site. This trend compacts the soil of the grassed strip causing erosion and sedimentation. Additionally, this sector receives direct pollutants from the vehicles, causing runoff and rain infiltration to be slower at these points and allowing pollutants to reach the service road and ultimately enter the Lagoon's water directly without filtering.

Sedimentation along this service road is a recurring problem which requires a multi-tiered approach in order to address the situation on a permanent basis.

*Figure 13. Findings located on map (vistas, erosion, deforestation areas, informal parking areas, access to water). (Photo courtesy of M. Rodríguez)*

## CONCLUSION

Based on the observations presented, a series of recommendations are proposed in order to address issues of water quality, safety, access, erosion and sedimentation control, reforestation, habitat reinforcement, and parking. By virtue of the Condado Lagoon's extension, the services it provides and the users it serves, it is recommended the work be organized in phases taking into consideration immediate, mid and long-term solutions, and by zones in order to minimize the disruption of place for public use. This is of particular relevance currently given the heightened use of the Lagoon resulting from COVID 19 governmental restrictions, which limits the use of other public spaces, mainly beaches as well as other recreational venues.

An understanding of the whole Condado Lagoon as a whole is necessary to be synthetized in one document, one drawing and one master plan, as all the initiatives are interdependent on one another, affecting each other.

## RECOMMENDATIONS

### Zone B - Southwest walkway

- Erosion control, habitat, runoff infiltration
    - Bio-swale garden @ collapsed eroded areas at water's edge - *Spartina patens, Laguncularia racemosa* (mangle blanco), *Avicennia marina* (mangle plateado),

- Sedimentation capture, pollution control, habitat food & nesting, runoff infiltration
    - Rain garden @ street edge aligned with eroded area - *Chrysopogon zizanioides* (vetiver), *Pennisetum rubrum* (pennisetum) grasses & *Chrysobalanus icaco* (icacos) shrubs

**Zone C - Southeast walkway**

- Sedimentation capture, pollution control, habitat food & nesting, runoff infiltration
    - Berm establishment to redirect stormwater runoff into the existing stormwater management inlets and avoid informal parking in the area
    - Rain garden @ entrance to service road (Marginal) at sedimentation prone area - *Wedelia trilobata* (wedelia**),** *Conocarpus erectus* (mangle boton)**,** *Chrysopogon zizanioides* (vetiver), and *Chrysobalanus icaco* (icacos)

**ADDITIONAL RECOMMENDATIONS:**

**SAFETY**

1. Cordon off the eroded and sunken areas on the boardwalk immediately by the appropriate agency.
2. Eliminate dead trees and grind stumps from the area to avoid a risk to the safety and welfare of users.

**ACCESS**

3. Maintain informal entry points into the water in areas where it is safe to enter. Partially formalized those points by providing a floating deck or a seating area at the water's edge to consolidate the red mangrove edge in areas most needed, but also recognizing people's use and appreciation of place.

**RESTORATION & HABITAT CONSOLIDATION**

4. Plant a succession of various mangrove species as a consolidated swath, where space allows, so that the summation of species function as a system.

    a. Use between 2 and 3 planting techniques/methodologies for red mangrove planting in order to test growth and consolidation responses vs. water energy and other establishment factors.
    b. Consider bio-rolls installation in areas with significant erosion as a way to plant the mangrove species and also to hold sand particulates to regain topography in those eroded points.

5. Consolidate the *Terminalia catappa* line of trees on the south edge to provide shade along the boardwalk area.

6. Plant endemic coastal fruit bearing shrubs and/or small trees as part of a reforestation strategy and to stimulate habitat for coastal species.

7. Plant grasses and groundcovers as “stepping stone areas” for small birds and habitat consolidation.

**EROSION CONTROL**

8. Use grasses and groundcovers as a mechanism to stabilize eroded coastal conditions at areas most affected.

9. Incorporate the use of mulch as cultural practice to cover patches of exposed soil and preventing the particulate from reaching the lagoon water.

10. Convert organic detritus generated in the park and Lagoon perimeter into mulch for internal use or external sale, possibly chipping materials 4 times a year and creating a storage area at the park.

**PARKING**

11. Extend the area along the service road for persons to be able to park temporarily during the pandemic period in order to curtail informal parking.

12. Aerate the soil where cars have been parking on the median in order to re-establish its percolation capacity and plant growth capability.

13. Establishment of a berm or a series of planted bio-swales which redirect runoff or collect and infiltrate it in the soil.

14. Clean the sedimentation from the curb side of the service road in order to prevent it from entering the storm sewers and the lagoon.

**CAPACITY STUDIES**

15. Conduct a carrying capacity study for this resource to determine best management practices.

**CULTURAL LANDSCAPE EVALUATION**

16. Perform a cultural landscape evaluation under National Park Service statutes in order to attain another level of recognition for the area and be able to seek funding for added protection.

# II. Green Infrastructure Proposal & Selected Sites

## A. FINDINGS & OPPORTUNITIES

The following sections present proposals for each of the issues identified previously in detail. Recommendations can be attained within different time frames, according to the ease and/or difficulty of each case. It is also recommended that a master plan design be conducted by a landscape architect firm as part of the ecological vision and future documentation for long term capital improvements at individual sites. An aerial photograph of the Condado Lagoon has been divided into four quadrants for ease of specific site identification.

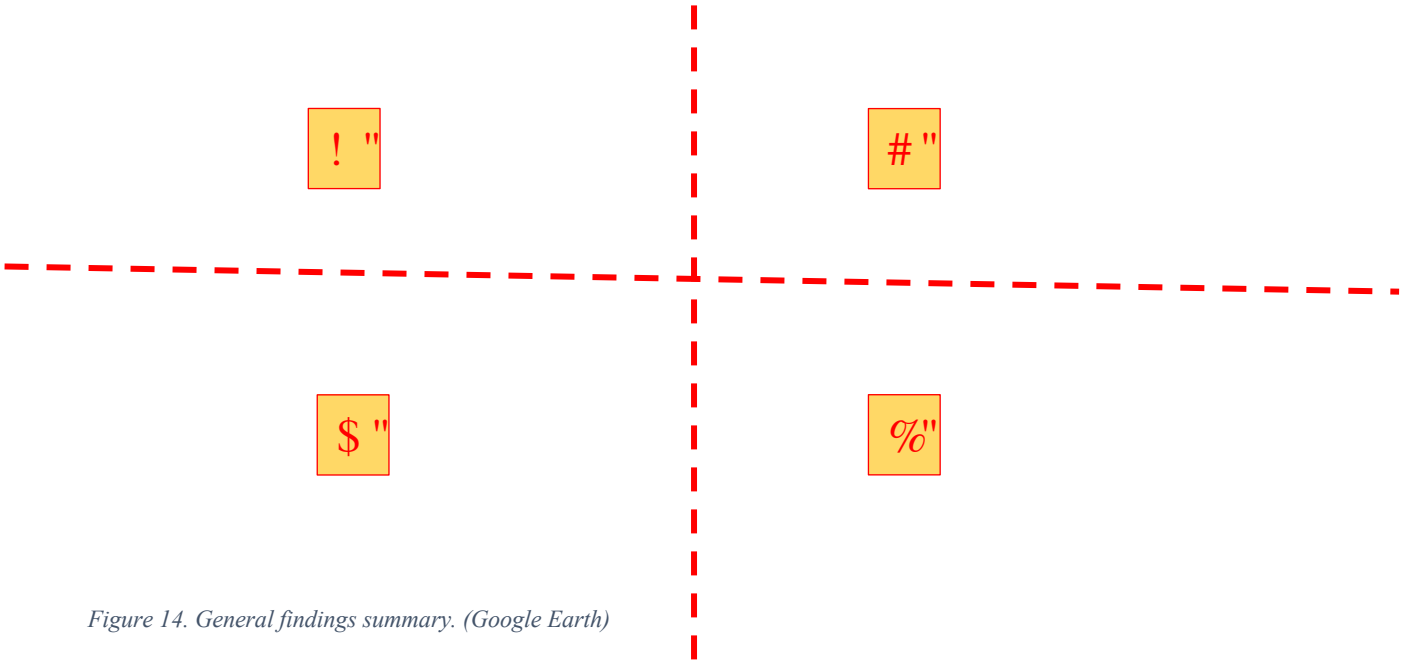



*Figure 14. General findings summary. (Google Earth)*

### 1. Zones A – D - Lagoon's water edge (entire water's perimeter)

- <u>Forest restoration</u>
- Red mangrove forest re-establishment and patch infill
- Erosion controls and storm water runoff management
- Mangrove forest succession re-establishment where space allows

### 2. Zone A - Lagoon's eroded edge (north access)

- <u>Erosion management and control</u>
- As stated earlier, topographic contour variations on the north side of the Lagoon, specifically in the Lomita sector, vary anywhere between 1'-0" to 6'-0", where the hillside erosion is exposed at said heights. Various factors come into play such as wave energy, coastal surge effects from hurricane Maria, soil compaction.

  In order for planting success across this sector, it is recommended that erosion control measures be put into place at the time of planting.

*Figure 15. Existing levels of erosion along the north east edge of the Condado Lagoon. (Photos courtesy M. Rodríguez)*

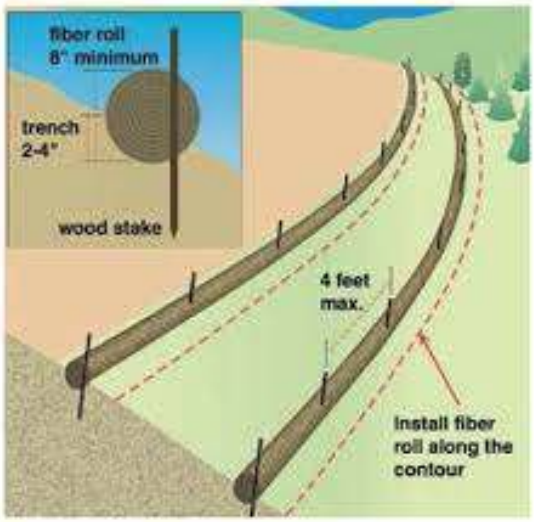
- **Proposal**
- Bio-rolls - Install bio-rolls in order to: a) allow for sand particles to collect behind the rolls and augment the presence and height of sand, b) wherever possible or practical, plant red mangroves inside or behind the bio-roll in order to stabilize roots, allow their systems to get established and create a mesh to retain needed substrate in the water's northern edge. This planting system could serve to manage wave energy while permitting plant growth and sand collection inside and behind the rolls, therefore stabilizing the embankment while the red mangroves establish themselves.
- Close monitoring practices is required in order to determine: plant growth, stability and soil/sand accumulation, thus erosion control levels. Tree height, dbh measurements, new growth in leaves and branches, root system growth process, amount of successfully established specimens, canopy area coverage is among the criteria proposed to be monitored at these sites. Likewise, monitoring of sand or soil augmentation is necessary as well in order to determine changes required to this technique as replication along the Condado Lagoon will allow documentation for use of this technique/strategy in other eroded coastal areas.

- **Technology**

  BioRolls consist of a technology where natural fiber is bound into cylindrical coils or logs of varying lengths and widths. The coils are set in the ground following topographic contours and serve to collect soil, controlling erosion and generating a growth medium. The materials from which the rolls are formed are considered suitable for installing plant species either within the coil or at its higher point.

The technology is predominantly used in large scaled projects that entail areas where topographic gradients and erosion issues are being managed in roadway development and agricultural fields. The product's durability, as per manufacturer specifications, extends between 36 – 48 months. Under tropical conditions such as Puerto Rico's climate, this product's life expectancy could be estimated to be shorter and adjustments to that effect should be taken into consideration at the time of installation. Due to the nature of the material, it is expected to decompose naturally while allowing sufficient time for plant establishment.


ASDCO – STRAW BIO-ROLL




File:Install biorolls or other sediment ...

*Figure 16. Bio-roll technology and installation illustration as part of green infrastructure technologies to handle erosion. (Agency, 2016)*

If the life expectancy were to be considered at a 50% reduction, a 24-month span would allow for a significant period of time in order for root systems to be established. Monitoring of this data would form part of an experimental phase for the red mangrove reforestation initiative and would assist in documenting restoration initiatives for consideration in tropical conditions along coastal lands experiencing systematic erosion and deforestation due to wave energy and hurricane surge (Maria 2017).

These materials have been used to experiment with the establishment of aquatic plants in pond-like conditions where water energy is limited.

Bio-rolls | SISALL

(2021)

- **Methodology**
- The number of bio-rolls will vary depending on the elevation variation.
- Sectors between 1 – 2 feet in elevation change.
  - Gradient change is up to 1 foot – 1 bio-roll
  - Gradient change is up to 2 feet – 2 bio-rolls, with a horizontal distance of 1 foot between them
- Sectors between 2 – 3 feet in elevation change.
  - Gradient change is up to 3 feet – 3 bio-rolls, at a horizontal distance of 8” between them.
  - In both instances, plants will be installed within the bio-roll system in order to partially control the water’s energy, therefore offering the plantules a better chance at being established.

- Sectors between 1 – 2 feet in elevation change.

*Figure 17. Eroded edges in the Lomita area. (Photos courtesy M. Rodríguez)*

*Figure 18. Significantly eroded edges in the Lomita area. (Photos courtesy M. Rodríguez)*

- Sectors between 2 – 3 feet in elevation change.

*Figure 19. Severely eroded edges in the Lomita area. (Photos courtesy M. Rodríguez)*

- Proposed Plantings and Attributes
    - Mangroves or *manglar* in Spanish, constitute a community of trees or shrubs located in coastal peripheries. From a structural standpoint, the variety of their root systems – aerial and in-ground - offers an anchoring system for each species depending on their level of salinity tolerance or substrate stability needs. Most importantly, the roots serve as the evapotranspiration system for these plants which produce large amounts of oxygen. This fact renders mangroves as the great sequestration plants of C02, therefore part of their relevance in managing climate change.
    - Furthermore, mangrove systems act as a first line of defense regarding hurricane winds and tidal surge during these events, protecting activities, people and property inland.
    - Therefore, we propose plantings of various mangrove species (mangle rojo, mangle blanco, mangle negro) is proposed as a measure for erosion control and embankment stabilization close to the water's edge. This strategy is also proposed to evidence the ecological succession of these species, where space allows.

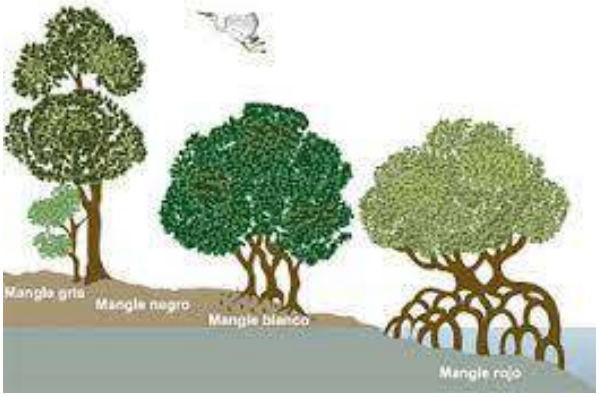



*Figure 20. Vegetation at linear park including red mangroves, Terminalias, Coccos nucifera. (Photo courtesy M. Rodríguez). Material recovered from internet. (EcoExploratorio, 2021)*

*Rhizophora mangle* – mangle rojo

Tolerates salinity
Roots tolerate the energy of ocean waves therefore they thrive in intertidal zones of varying salinity
Aerial stilt roots stabilize this species in intertidal zones and waterlogged soils of varying salinity
Roots: play important role in gas exchanges; sequester CO2; dissipate the energy of coastal storms; provide habitat as nursery for young fish
Leaves serve as habitat for various aquatic species
Canopy offers a temperature change in the water
Height – 20 m (approx. 66 feet) – small shrub to medium sized tree

*Figure 21. Red mangrove root system and propagules. (The Nature Conservancy, n.d.; The Nature Conservancy, 2020) (Refra, 2019)*

*Avicennia germinans* - mangle negro
Tolerates highest level of salinity
Excretes excess salt through its leaves
Roots prefer stable soils or substrate; therefore, it is located further inland than red mangroves
Generates numerous pneumatophors for the exchange of oxygen
Height - up to 15 m (approx. 45' ft.) – shrub or small tree


*Figure 22. Black mangrove trees and seedlings. (Blanco, 2020)*

*Laguncularia racemosa* - mangle blanco
Tolerates high levels of salinity
Even though it tolerates wet roots, its preference is for areas where its root system can be stable and not submitted to the energy of water.
Amenable to different soil types
Height - up to 25 m (82 ft.) – shrub or small tree


*Figure 23. White mangrove tree and leaves detail. (San Diego Natural History Museum, n.d.) (Ross, 2021)*

- <u>Surfacing</u>
    - The entrance area and water's edge on the northeastern side evidences eroded pathways created by the increase in the amount of foot traffic by Lagoon users as well as concession stand businesses.
    - Commercial users have introduced a series of impermanent structures which house rental equipment, shelter users and employees from the rain and sun, and locate garbage bins, (sheds, tarps, plastic storage houses, wooden platforms). These features belong to different design expressions,

materials, and colors, underscoring a sense of disarray to the area. The soil adjacent to those appurtenances shows compaction and erosion caused by the foot traffic.

- It is highly recommended that the Municipality of San Juan set boundaries as to the types of appurtenances that concessions may and may not bring to natural reserves and the types of improvements required of the businesses when their clientele's usage disrupts the property's features.

- **Proposal**
- Install an elevated wooden walkway/platform leading to the water's edge, thereby liberating the pressure from the compacted soil. This walkway will be part of a system which includes platforms or decks for the concession stands. Areas for garbage disposal will be incorporated into the design, as well as a place for collection formally established.
- Concession usage of the resource of the Lagoon's sandy perimeter will be restricted only to the use of said space. Bi-annual maintenance of said decking will be part of the concessionary's responsibilities as per contractual agreement with the MSJ/DNR.

*Figure 24. Compaction and erosion along main pedestrian path. (Photo courtesy M. Rodríguez)*

*Figure 25. Outdoor furniture and appurtenances with dissimilar materials. (Photos courtesy M. Rodriguez)*

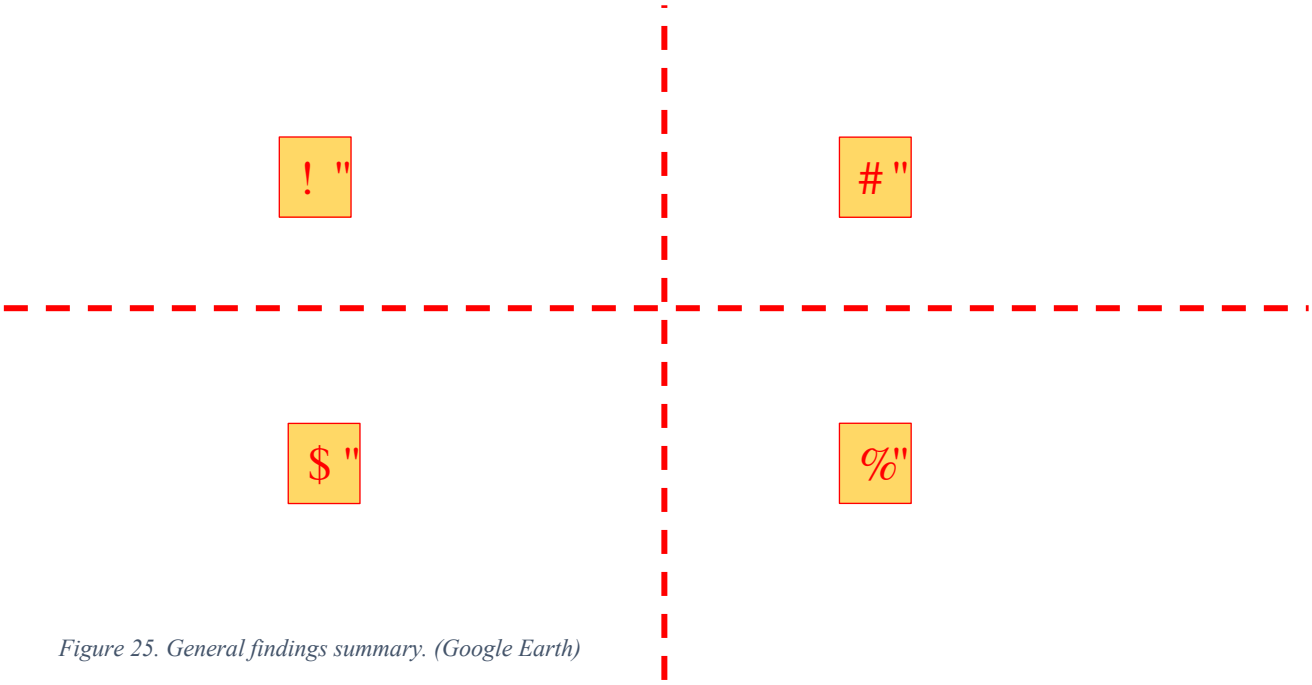



*Figure 25. General findings summary. (Google Earth)*

## 3. Zone C– East access to water (previous formal entrance)

- Erosion control, aeration to loosen soil compaction
  - Entrance surface releveling with pea gravel
- CO2 capture
  - Consolidate red mangrove forest - east and southeast lagoon borders
  - Red mangrove planting in discrete areas to reinforce existing mangrove forest areas, thereby consolidating the forest
- Maintenance practice
  - Establish a composting/mulching area where organic detritus, leaves, dry palm tree branches can be collected to decompose the material and other organic debris to convert to compost. Use the resulting compost to nourish soil along the Lagoon's edge. In lieu of this option, wooden detritus may be chipped to create mulch for internal use.

- Potential siting for this could be in close proximity to the existing dumpster.

- Monitoring of planting initiatives
  - Removal of debris from the area surrounding young plantings in the interest of facilitating their visibility, and therefore not to be trampled by area users, and for oxygen and rain to infiltrate as close to the root systems as possible.

*Figure 26. Organic detritus collects around areas of new planting making their visibility difficult. (Photos courtesy M. Rodríguez)*

## 4. Zone C – South East current access to water activities

- Erosion control and embankment stabilization

    - Entrance and egress from the water will require the creation of a decking structure to complement the existing boardwalk or other type of hard surfacing to mitigate soil erosion. This surface should be connected to the existing park boardwalk and lead to the floating dock to decrease the pressure of human traffic and its result on soil compaction, erosion which in turn causes sedimentation in the Lagoon. Given the scale of this project, consideration should be given into incorporating it into the capital improvement plans for various agencies.
    - A landscape architecture master plan for the Condado Lagoon Reserve is recommended to develop a comprehensive vision which captures existing initiatives and future restoration initiatives to serve as a guiding and planning document.
    - Given the fact that the surrounding soil has been previously impacted by infill material, anchoring points should be pursued inland in this area to avoid disturbing the Lagoon's substrate.

*Figure 27. Existing access to the water uses astroturf covering to prevent erosion. (Photos courtesy M. Rodríguez)*

    - Upon examination of the DRNA's Management Plan for the Condado Lagoon, discrete floating dock structures have been proposed in said Plan as a way to gain access to the water. It is additionally recommended to attain ADA compliance.

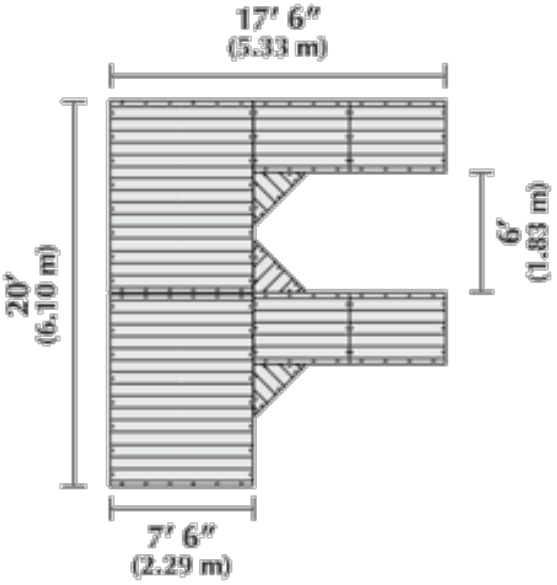



*Figure 28. Dimensioned floating dock to provide access to water reducing compaction to the marine bottom; Connect—Dock 1000 Series Low Profile Packages.*

## 5. Zone C - Southeast informal access and vistas

- Erosion and soil compaction
    - Create a series of small decks and/or floating docks elevated from the soil to mitigate soil compaction and allowing for passive means of recreation. A Few locations are proposed, guided by persons' use of the space.

*Figure 29. Family enjoying views and people watching at the Lagoon's south side.*

*Figure 30. Various points along the vegetated border offer vistas to area users. (Photos courtesy M. Rodríguez)*

## 6. Zone C - Southeast service road & street parking entrance

- <u>Erosion management, sedimentation mitigation and runoff infiltration</u>
  The southeast boardwalk's parking lane and service road (Marginal Baldorioty Avenue) confronts a sedimentation issue resulting from various factors: the stormwater infrastructure's low point, infrastructure in need of maintenance (roots, debris), runoff velocity factor stemming from Baldorioty Avenue at the entrance to the service road. These compounded runoff factors cause the water to back flow into the service road leaving sediments behind as the water slowly percolates the soil.

*Figure 31. Existing parking access to park and lagoon amenities. (Photos courtesy M. Rodríguez)*

*Figure 32. Baldorioty Expressway service road and entrance to Jaime Benitez Park. (Photos courtesy M. Rodríguez)*

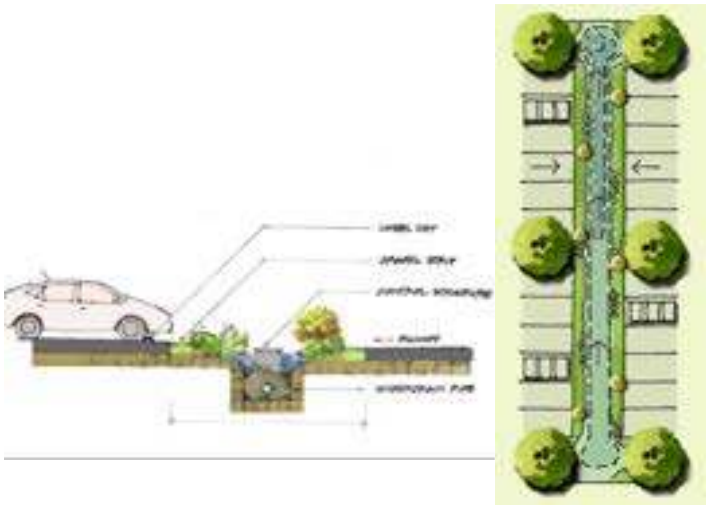
- Sedimentation capture, pollution control, habitat food & nesting, runoff infiltration
    - Bio-swale to capture surface stormwater runoff along the service road which flows in two directions.
    - Installation of speed bumps to redirect the water flow into the bio-swale.
    - Planting strip establishment to redirect stormwater runoff into the existing stormwater management inlets and avoid informal parking in the area (south side)

- **Technology**
    - Install bio-swales in order to: a) capture partial runoff prior to reaching the storm-water infrastructure, b) infiltrate runoff at these points, c) capture sedimentation, D) conveyance. According to the Environmental School of Forestry at New York State University,

        > "Traditionally, the water runs off the asphalt into a storm gutter or along a curb until it reaches the inlet to storm sewer drain. A bioswale replaces the traditional concrete gutter with an earthen one. The vegetation reduces the water's velocity allowing for treatment and infiltration. Because they behave like a gutter, these trenches are best suited along roadsides or parking lots…"

      The bio-swale strip, may be planted with fruiting shrubs for part of its length and in others merely by a ground cover, both with the intent to control erosion, while also providing food and habitat for some species and interest for pollinators.

*Figure 33. Bio-swale example in upstate New York. (City og Binghamton, 2021)*



*This bioswale cross section (left) depicts the swale with an underdrain, which may not be necessary in naturally well drained soils. Surface runoff from the adjacent impervious area enters the swale diffusely through an energy reducing gravel strip and then flows through vegetative buffers along the edge of the bioswale. Swales can be designed with swale blocks (dashed lines perpendicular to flow arrows in plat view (right)) if there is a significant slope or by setting the discharge elevation of the control structure higher than the swale bottom if the swale has little relief.*

*Figure 34. Bioswale cross section and plan views. (University of Florida, 2008)*

- **Proposed Plantings**

Plantings proposed for use at the bio-swales and berms at this sector include *Chrysobalanus icaco* (icacos), *Wedelia trilobata* (wedelia). These plantings will serve to prevent erosion as their root systems establish in the area, while providing textural interest from its leaves, fruits for diverse species and interest to pollinators. Maintenance will be necessitated by way of irrigation, specifically during the three months of establishment and the first year for irrigation and trimming of shrubs and ground covers.

- *Chrysobalanus icaco* (icacos) – woody shrub natural to coastal ecosystems/environments planted to serve as barrier and avoid people from entering restoration areas; its fruits offer food to various species as well as for human consumption.
    - Small to medium shrub with height ranging between 3’ – 10’ (91.4 cm – 304.8 cm)
    - Tolerates salinity
    - Tolerates high winds
    - Tolerates full sun
    - Medium tolerance to drought
    - Densely foliated growth habit from the ground – help prevent erosion
    - Flowers between January and August, attracting pollinators
    - Mature fruit is edible to wildlife and humans


*Figure 35. Chrysobalanus icaco, icaco (Pinterest, 2021)*

- *Sphagneticola trilobata (formerly Wedelia trilobata* (wedelia) – low lying dense ground cover creeper whose root system serves to prevent erosion
    - Height ranges from 12” – 18” (.3 to 1.5 m)
    - Low lying creeping habitat stems
    - Flowers create interest for pollinators
    - High salt-tolerant species
    - Part shade/part sun tolerance
    - Medium drought tolerance
    - Flowers provide interest to pollinators

*Figure 36. Sphagneticola trilobata, wedelia (Denton, n.d.)*

## 7. Zone D - Southwest boardwalk

- <u>Erosion management, control, conveyance and runoff infiltration</u>
  The southwest boardwalk confronts sheet runoff volumes at two points, both which experience erosion and embankment collapse. This runoff is compounded by that generated by Baldorioty Avenue, which add significant pressure at the

two sites identified. These two “pressure points” appear to have been further impacted by hurricane Maria’s winds and the storm surge born of it, debilitating and eroding the substrate at the water’s perimeter.

Although a longer term intervention will be required in order to stabilize this border, the south side of the boardwalk (abutting Baldorioty de Castro Avenue) can be conceived to slow the runoff’s energy stemming from Ponce de Leon Avenue, the northern hillside and Baldorioty Avenue, and redirect it to the stormwater infrastructure more pointedly.

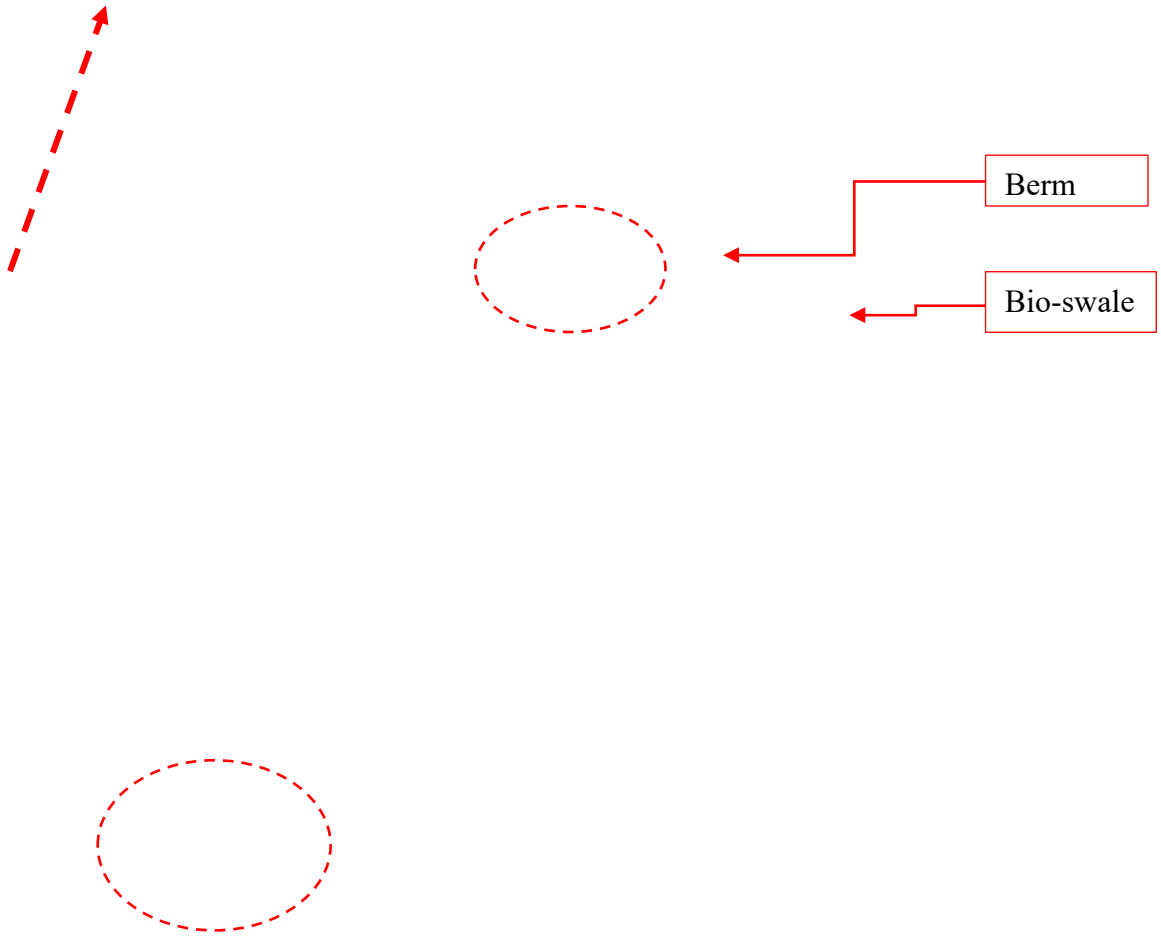



*Figure 37. Collapsed retaining wall infrastructure will necessitate reinforcement from the water’s edge in order to stabilize the soil prior to implementing other green infrastructure strategies at these points. Plantings of coastal grasses is proposed as their root systems will serve as another layer of embankment stabilization. (Photos courtesy M. Rodríguez)*

- **Proposal**

Various interlaced strategies will be necessitated at this area in order to address the issues aforementioned. A blend of green infrastructure technologies and more traditional forms will also be needed. A Green Infrastructure approach to problem-solving will serve to ameliorate volumes of runoff and speed from uphill points and to capture and infiltrate into the soil prior to reaching the lagoon's water. From the vantage point of green infrastructure two strategies will be implemented.

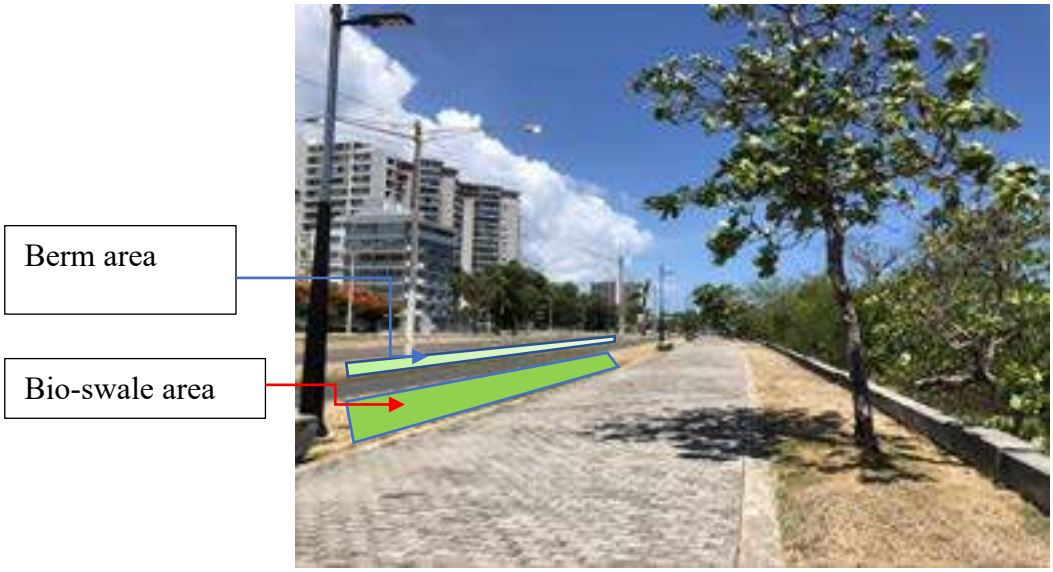



*Figure 38. Proposed green infrastructure strategies. (Photos courtesy M. Rodríguez)*

- **Technology**

  In order to maintain a cohesive vocabulary of practices, it is recommended that along those parts of the boardwalk where akin conditions exist, similar green infrastructure strategies be pursued in order to impact a larger area, thus making results more easily quantifiable.

  - Install raingardens to: a) capture partial runoff and thus relieve pressure from existing storm-water infrastructure, b) infiltrate runoff at these points, c) capture sedimentation, d) conveyance and as complement to the bio-swale strategy.
  - Along this stretch, erosion is critical and requires immediate attention, particularly in areas where collapses and minor landslides have occurred. The use of simultaneous strategies and types of best management practices is recommended in this segment to address the varying issues occurring at the site.

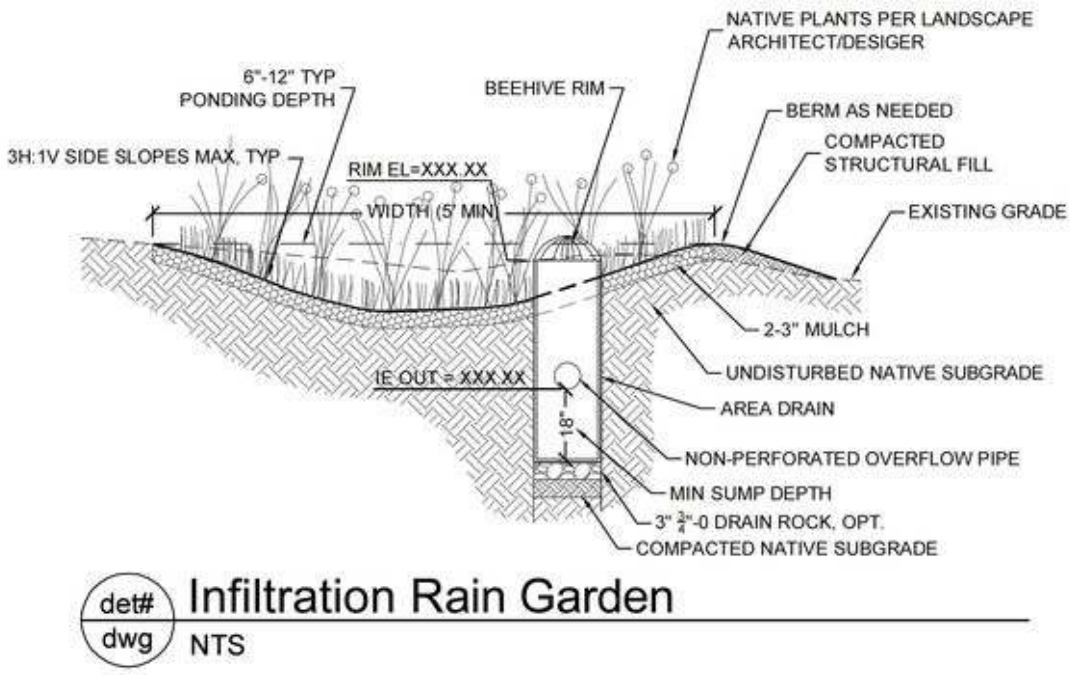



*Figure 39. Raingarden design construction detail (typ.). (Ohio Rain Garden Design, 2021)*

- Install bio-swales – Refer to pages 29 – 30.

- **Proposed Plantings**

Suggested plantings for the west side stretch of the linear park serve to strengthen existing forested areas which were impacted by hurricanes Irma and Maria, specifically the red mangrove forest and the *Terminalia catappa*, almendro trees in this segment.

A variety of species, trees, understory shrubs, marsh grasses, and ground cover are also recommended in places where the space allows as a measure to expand ecosystemic succession. Given the issues of erosion found in this segment, the use of grasses is also proposed. Once established, the root system of these plants will help retain soil particles in place, thus reducing erosion. In the case of vetiver, it additionally captures pollution that may be caused by metals. The following species are suggested:

- *Laguncularia racemose,* mangle blanco
- *Avicennia marina,* mangle plateado
- *Thespesia populnea*, emajagüilla
- *Andira inermis*, moca
- *Citharexylum fruticosum*, péndula
- *Eugenia foetida,* eugenia
- *Chrysobalanus icaco*, icaco
- *Spartina patens*, saltmeadow cordgrass
- *Chrysopogon zizanioides,* vetiver
- *Pennisetum rubrum,* pennisetum

- *Sphagneticola trilobata,* wedelia

- *Spartina patens*, saltmeadow cordgrass
  - Height ranges from 1 – 2 ft (30 to 60 cm)
  - Grows in clump form
  - Tolerates partial salinity and being covered by high tide
  - Provides habitat for crustaceans, mollusks and birds
  - Provides nutrients to the estuary
  - Serve as pollution filters

*Figure 40. Spartina patens grasss is proposed to mitigate erosion and as habitat for various species. (Science, 2021)*

- *Conocarpus erectus* (mangle botón)
  - Height ranges from 15 – 20 ft (.x to 1m)
  - Grows in tidal lagoons and inland
  - Tolerates salinity


*Figure 41. Conocarpus erectus, magle boton proposed planting as part of mangrove succession in the area. (National Parks, 2020)*

- *Chrysopogon zizanioides,* vetiver
    - Height ranges up to 5 ft (150 cm)
    - Root system grows downward 13 feet Deep (4 m)
    - Highly drought tolerant and to floods
    - Protects soil from sheet erosion
    - Absorbs disolved nutrients (nitrogen, phosphorous and magnesium, aluminum and manganese)

*Figure 42 Vetiver plant and its root system. (Vetiver Grass UK, 2021)*

    - Bio-swale @ collapsed eroded areas at water's edge - *Spartina patens, Laguncularia racemosa* (mangle blanco), *Avicennia marina* (mangle plateado), or
    - habitat
- Install bio-swales in order to: Sedimentation capture, pollution control, habitat food & nesting, runoff infiltration
    - Rain garden @ street edge aligned with eroded area - *Chrysopogon zizanioides* (vetiver), *Pennisetum rubrum* (pennisetum) grasses & *Ch*
    -

Boardwalk

The boardwalk is lined with *Terminalia catappa*, a number of which were possibly lost as a result of hurricanes Irma and Maria. Even though this is a non-native species, it is locally naturalized and could provide much needed shade along the boardwalk area. Additionally, it would serve to consolidate the existing tree line along the south border of the boardwalk.

*Figure 43. Line of Terminalias missing several specimens to be replanted for shade. (Photo courtesy M. Rodríguez)*

Runoff

Following several visits to the site and observing the flow of water, it is considered highly probable that storm runoff stemming from streets located on higher ground to the south of the Lagoon, are contributing to the erosion found at critical points in the boardwalk. These highly eroded points appear to coincide with the topographic condition, runoff velocities, and the location of stormwater infrastructure. In several points along Baldorioty Avenue it was also noted that the height between the curb and the infrastructure grill did not exceed 3" as opposed to the regulatory 6", which may be causing water to flow more slowly thus accumulating sediment along these areas.

*Figure 44.Eroded points along the boardwalk's retaining wall both inland and in water's edge. (Photos courtesy M. Rodríguez)*

## SELECTED INTERVENTION SITES

Phasing of projects

The trajectory of work by the Estuario at the Condado Lagoon Estuarine Reserve sets the tone in which to proceed in the future: a series of discrete interventions constitute the parts which added up make the whole. Consideration should be given to the development of a landscape architecture master plan to maintain the integrity of a wholistic vision and approach for interventions at this Reserve from the vantage point of natural, ecological, cultural and fiscal resources found at this place while underscoring a controlled use for the Reserve.

Presently, four areas have been selected for green infrastructure interventions at the Condado Lagoon Estuarine Reserve: a) access point to the water on the south side at Jaime Benítez Park, b) north east side along the Le Rivage building, c) water's access point on the north side at Ashford Avenue entrance, d) service road entry point at Baldorioty de Castro Expressway.

1. Lagoon Access at Jaime Benítez Park - A restoration initiative was conducted at the south side at Jaime Benítez Park, on January 23rd, 2020. Endemic tree species (*Libidibia monosperma, Thespesia populnea, Annona glabra*) and red mangroves (*Rhizophora mangle*) were planted with the support of a group of community volunteers at this site as a strategy to consolidate the existing forest along this area. Prior to this restoration a red mangrove planting had also been conducted by a troop of Girl Scouts, furthering the continuity of the red mangrove forest.

   The two restorations held at this site have had different results. On the one hand, the Girl Scouts site appears to respond positively as specimens planted all seem to have survived, with some reaching 96 cm (38") in height and showing healthy leaves.

   In the case of the restoration held on January 23rd, five (5) specimens of *Libidia Monosperma* remain and not the other species planted. Albeit the fact that this is a slow growing species, little to no growth seems apparent their height at 48 cm (19") A series of factors may have influenced the results in both instances.

   1.1. Lessons learned

      1.1.1. Maturity of plant material – In the case of the red mangroves, young plantules were used and appear to have established themselves with success. Individual specimens were planted under "*nodriza*" contitions with mature trees providing shade. This hardening strategy intended to facilitate establishment.
      Endemic species planting included young trees out of which the *Libidibia monosperma* appears to have a higher transplant success and resilience rates.

      1.1.2. Irrigation - Irrigation presented a challenge at this public area because no mechanical system is in place. Given the total area of this mid-sized park, the

most cost-effective strategy would be to install a solar powered irrigation system, particularly in turf areas to ensure survival of investment in plant material.

1.1.3. COVID-19 related non-operation periods caused an added stress over the recent planting as irrigation and monitoring visits could not be conducted during two-week periods at a time.

1.1.4. Circulation areas - Distance from people's circulation areas played a crucial role at this site. At this specific locale various circumstances occur proximity to the Park's entrance from the parallel parking, loading, and unloading of sports equipment (paddle boards, kayaks, etc.) and personal belongings, walking and seating in open spaces underneath trees, locating equipment in those areas. As mentioned earlier, the height of the young plant material presented a visibility issue to park visitors, judging from the number of bent trees or by barks impacted by trimmers. *Libidia* trees further apart from the walkways edge (over 8 feet) appear in better conditions.

1.1.5. Open Areas Maintenance Practices – Maintenance crews assigned to the sector collect leaves and palm tree leaves (*pencas*) in the understory parts of the forest, towards the water. Albeit the fact that this practice could assist in the creation of compost, due to the height and tenderness of the plant material, specimens were covered by debris which led to their demise.

Given the amount of organic material present it is proposed that composting be pursued close to the existing garbage bins. Composted material could be used at this site or others managed by DNRA.

2. Consolidation of *Rhizophora mangle* forest - Another restoration initiative was conducted at the south side of Jaime Benítez Park, on January 30th, 2020 as part of a collaborative venture with Earth Echo on the part of the Estuario's Restoration Unit and the support of Green Infrastructure by way of partial plant material and time.

The forest at this segment of the Park appears robust. An in-fill strategy was pursued to strengthen this border further. Three discrete areas were selected directly adjacent to mature mangroves and propagules were located at the intertidal zone to ensure sufficient hydration. *Rhizophora mangle* was planted following the Bauzá planting technique methodology, with four propagules per stake for a total of 92 specimens.

The Green Infrastructure Unit started monitoring of this and other plantings following this activity. The recordings of planting survival rates for the months of February and April were found at 61% and 48%, respectively. This reduction of over 50% of the material planted may be due to a series of factors which will require adjustments to ensure a higher success rate at future planting/restoration efforts: a) Plant material quality at collection time, b) hydration level, c) depth of propagules at planting, d) proximity to people circulation.

2.1. Lessons learned

2.1.1. Plant material quality – Propagules for this volunteer activity were collected both at the Condado Lagoon Estuarine Reserve and at the Piñones Forest seeking diversity in the material. At the time of collection, mid to late January, propagules had already fallen to the ground rather than being hand-picked from the plant. There is a level of uncertainty as to how long they had been in the ground, their level of maturity and hydration.

BMP recommendation - When considering red mangrove restoration projects, planning needs to factor in scheduling activities around the propagules maturity season to ensure their freshness and increase their survival rate.

2.1.2. Hydration level – As mentioned, the level of hydration of some of the propagules was uncertain at the time of collection. On the other hand, at the time of planting the Lagoon was experiencing high tide. Propagules were planted at the intertidal zone on that date. However, a week later the intertidal zone had retreated approximately 1.5m from the planting areas. Two months later, that zone was located approximately 3m away. Even though the propagules possibly receive some level of hydration trough capillary action, this might probably not be enough to guarantee their survival.

BMP recommendation - When considering red mangrove restoration projects, monitor tidal movements to ascertain areas best suited for planting survival.

2.1.3. Depth of propagules at planting – Planting took place with a group of volunteers inexperienced about plant propagation.

BMP recommendation - When considering red mangrove restoration projects, consider preparing and sharing educational material (videos) regarding red mangroves health, depth of planting, planting zone requirements, etc.

2.1.4. Proximity to people circulation – The three planting sites selected for restoration performed in similar fashion regarding the factors exposed, except the one closest to people “traffic”. At this particular site, three stakes were removed by persons in the area, which resulted in the loss of those propagules. The distance from this area and people circulation is approximately 1m.

BMP recommendation - When considering restoration or reforestation projects locate planting areas at least 3m away from circulation zones.

2.1.5. Open Areas Maintenance Practices – Leave detritus and palm tree leaves (*pencas*) are being collected in the understory parts of the forest, towards the water. Albeit the fact that this practice could assist in the creation of compost, due to the height and tenderness of the plant material, specimens are covered by debris which may lead to their demise.

BMP recommendation - Given the amount of organic material present it is proposed that composting be pursued close to the existing garbage bins. Composted material could be used at this site or others managed by DNRA.

Given the level of maintenance required at this locale it is recommended that a person be dedicated to these functions to support restoration success.

3. Northeast - expansion of red mangrove restoration

   As part of the consolidation phases of the red mangrove forest along the south east border of the Lagoon, expansion towards the northeast side is proposed, abutting Le Rivage building. A fragmented segment of established red mangrove forest exists at the end of Joffre Street which can be connected with a planting activity.

   Three zones of 8 stakes with 4 propagules each are proposed at each of the sectors which are missing vegetation currently. Some propagules at the site are establishing themselves under the shade of more mature red mangroves suggesting that their root system is receiving sufficient water through capillary action when the tide is low. Planting additional “seedlings” is proposed to reinforce the existing red mangrove growth in this segment and to continue expanding, where possible, to the northwest.

*Figure 45. Embankment area along Le Rivage building with patches of red mangrove; propagules spontaneously getting established in area. (Courtesy of M. Rodríguez)*

4. North Access point at Ashford Avenue

The formal north entrance to the Condado Lagoon Estuarine Reserve serves as gateway to Old San Juan, to the tourist area of Condado and is part of the cultural legacy of historic Spanish military value. The juncture of culture, economy and a heavily trafficked road system renders the site with a myriad of interests/needs to satisfy.

Currently the entrance has gained prominence as COVID 19 restrictions have limited the use of beaches in the metropolitan area and individuals have recurred to the Lagoon as a recreational amenity. The space is shared with recreational concession stands for paddle boats, kayaks, bicycle rentals, food kiosks, activities rentals (carpas – up to 5 @ 12 persons each) and local swimmers. A capacity regarding the number of persons using this site at one time has not been determined and the Management Plan for the Reserve calls for a carrying capacity study to be conducted at the Lagoon (PM-RNELC, p. 201). Site observations indicate an approximate 100 individuals using this site.

*Proyecto 10. Determinar el Límite de Cambio Aceptable de esta ANP*

*Identificar las condiciones biológicas, físicas y sociales que son aceptables para esta ANP*
*Manejar efectivamente a los usuarios y el recurso para el aprovechamiento sostenible de esta ANP - RNELC*

> Plan de Manejo para la Reserva Natural Estuarina Laguna del Condado, Octubre 2016, DNRA, ELA (Plan de Manejo Reserva Natural Estuarina Laguna del Condado, 2016)

*Figure 46. Various existing uses at the Condado Lagoon's north entrance. (Photos courtesy of M. Rodríguez)*

As mentioned earlier, the number of persons using this entrance and the increased level of pedestrian traffic have caused the grass and some understory shrubs to “die-out”, the soil to become compacted, which in turn has created eroded areas where the foot traffic occurs. The area impacted by individuals has increased as evidenced by the dead grass or understory shrubs being used to hang signage or to shelter other concession stand belongings. Therefore, eroded particulate stemming from these zones is likely to reach the Lagoon’s waters during heavy rainfalls and causing sedimentation.

Surfacing

It is recommended that formal pathways be defined to avoid further soil compaction and erosion. Given the site’s attributes, sectionally sliced fallen palm tree trunks can be installed as pathways or, more long term, a wooden walkway could be considered. The porosity of the palm tree trunks provides a safe non-slip surface. Although a wooden walkway would constitute the most cost-effective alternative in the long-run, due to local maintenance budgetary concerns, the recommendation would be to pursue the fallen palm tree trunks option. This same treatment is proposed for installation in sectors where concession stands are additionally compacting and eroding the soil.

Other alternatives should also be considered following decisions informed by the carrying capacity study. Loose aggregate or mulching options are not considered appropriate as those materials will be washed by rainfall into the lagoon’s bottom and impact water quality.

*Figure 47. Eroded path caused by pedestrian use and ensuing soil compaction. (Photos courtesy of M. Rodríguez)*

*Figure 48. Cross sectional cut of palm tree trunk and pathway constructed using cuts. (Kate, 2015)*

Restoration/Reforestation

Another phase of red mangrove restoration is proposed on the northeast side, to reinforce the existing forest adjacent to area buildings. As area users look for shaded places in which to recreate, the red mangrove forest has been impacted.

Planting of understory shrubs or small trees is proposed in areas along the main pathway with re-sodding behind them, as a short-term strategy to clearly define the pathway for users. Nonetheless, a more permanent solution will be required depending on the desired levels of individuals using the space.

To maintain a cohesive palette of plant material used in the Lagoon's restoration, of *Chrysobalanus icaco*, icacos, *Coccoloba uvifera*, uva playera. *Conocarpus erectus*, mangle botón and *Spartina patens*, saltmeadow cordgrass are suggested with the former being an addition to the succession of mangrove forest and to provide pollinator interest and food for wildlife. The saltmeadow cordgrass is proposed to mitigate erosion once the root systems get established and as habitat for birds. Shade will be provided eventually by this vegetation where individuals can take cover from the sun. The understory shrubs, trees and grasses will define edges along the path's perimeter and guide the user to remain within the path to control further erosion.

*Figure 49. Eroded and compacted soil as result of pedestrian circulation. (Photos courtesy of M. Rodríguez)*

## Proposed vegetation selection

*Figure 50. Proposed understory woody vegetation, Chrysobalanus icaco, icaco to provide habitat and food.*

*Figure 51.Conocarpus erectus (mangle botón)*

*Figure 52. Spartina patens, saltmeadow cordgrass*

5. Service road entry point at Baldorioty de Castro Expressway and Jaime Benitez Park (PHYTOREMEDIATION & SEDIMENTATION CONTROL bioswale)

   The southeast Jaime Benítez Park entrance and service road (Marginal Baldorioty Avenue) confronts a sedimentation issue resulting from various factors: the stormwater infrastructure's low point, infrastructure in need of maintenance (roots), runoff velocity factor stemming from Baldorioty Avenue at the entrance to the service road. These compounded runoff factors cause the water to back flow into the service road leaving sediments behind as the water slowly percolates the soil.

*Figure 53. Baldorioty Expressway service road and entrance to Jaime Benítez Park. (Photos courtesy M. Rodríguez)*

A multi-tiered approach is proposed to control sedimentation, water pollution control, and runoff infiltration by using a bio-swale at the existing planting strip, formal plantings at the planting strip and install speed bumps to redirect the water flow into the bio-swale. The bio-swale intends to: a) capture partial runoff prior to reaching the storm-water infrastructure, b) infiltrate runoff at these points, c) capture sedimentation, d) provide conveyance. The planting strip establishment seeks to redirect stormwater runoff into the existing stormwater management inlets and avoid informal parking in the area (south side).

The bio-swale may be planted with fruiting shrubs for part of its length and in others merely by a ground cover, both with the intent to control erosion, while also providing food and habitat for some species and interest for pollinators.

Proposed Plantings

Plantings proposed for use at the bio-swales and berms at this sector include *Chrysobalanus icaco* (icacos), *Wedelia trilobata* (wedelia). These plantings will serve to prevent erosion as their root systems establish in the area, while providing textural interest from its leaves, fruits for diverse species and interest to pollinators. Maintenance will be necessitated by way of irrigation, specifically during the three months of establishment and the first year for irrigation and pruning of shrubs and ground covers.

- *Chrysobalanus icaco* (icacos) – woody shrub natural to coastal ecosystems/environments planted to serve as barrier and avoid people from

entering restoration areas; its fruits offer food to various species as well as for human consumption.

- Small to medium shrub with height ranging between 3’ – 10’ (91.4 cm – 304.8 cm)
- Tolerates salinity
- Tolerates high winds
- Tolerates full sun
- Medium tolerance to drought
- Densely foliated growth habit from the ground – help prevent erosion
- Flowers between January and August, attracting pollinators
- Mature fruit is edible to wildlife and humans

*Figure . Chrysobalanus icaco*, icaco

- *Sphagneticola trilobata (formerly Wedelia trilobata* (wedelia) – low lying dense ground cover creeper whose root system serves to prevent erosion
  - Height ranges from 12” – 18” (.3 to 1.5 m)
  - Low lying creeping habitat stems
  - Flowers create interest for pollinators
  - High salt-tolerant species
  - Part shade/part sun tolerance
  - Medium drought tolerance
  - Flowers provide interest to pollinators

*Figure 54.. Sphagneticola trilobata, wedelia*


*Figure 55. Conceptual green infrastructure design, berms and bio-swales, at Baldorioty Avenue at entrance to Jaime Benitez Park.*

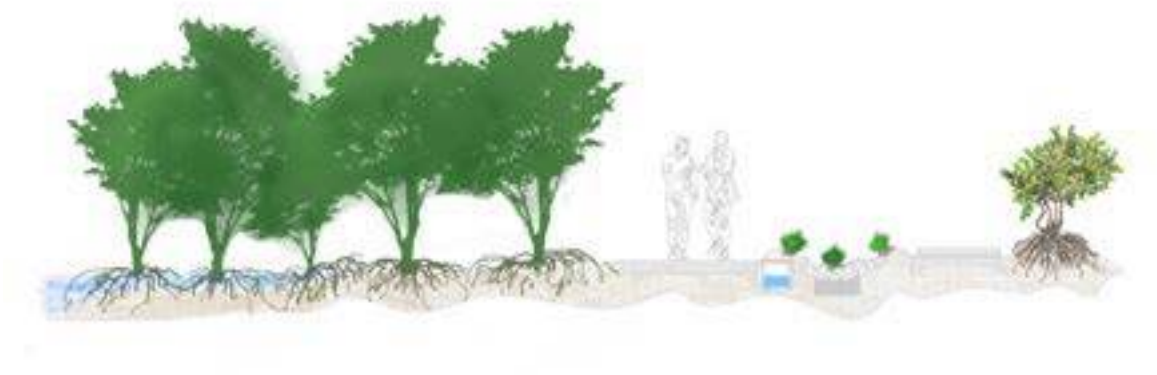


*Figure 56. Illustrative rendering of bio-swale intervention at Condado Lagoon.*

*Figure 57. Illustrative rendeing of berm strategy proposed.*

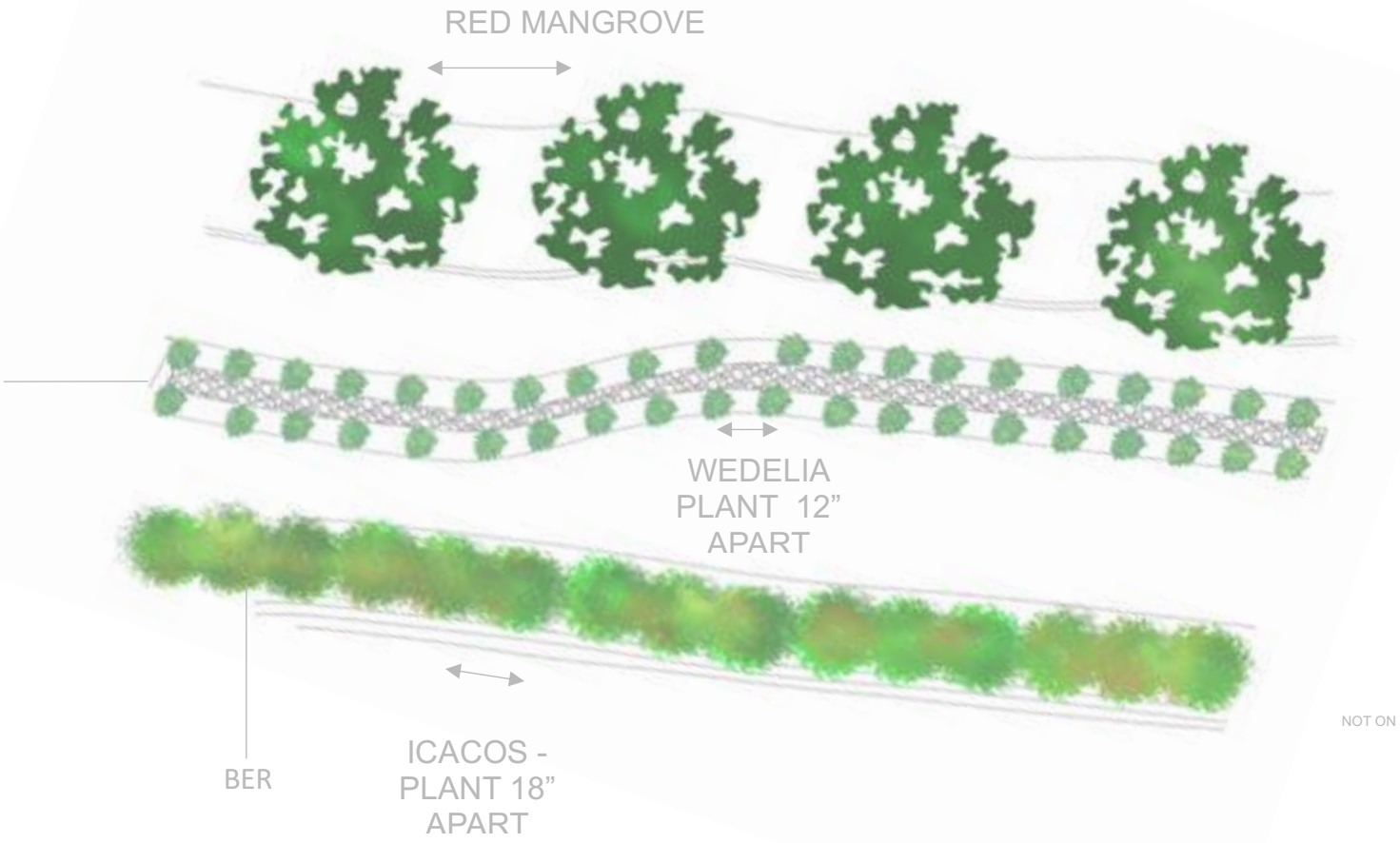



*Figure 58. Illustrative rendering of bio-swale segment.*

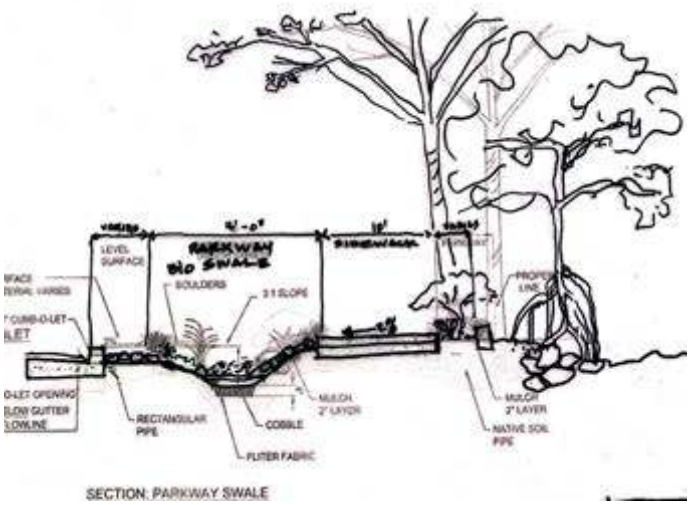
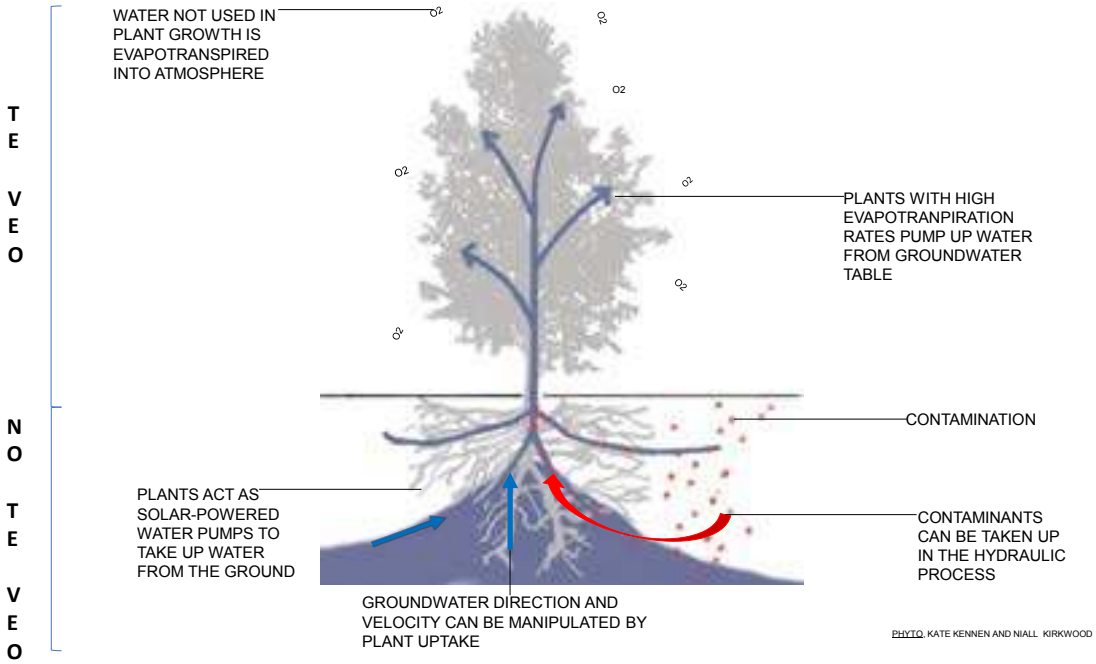
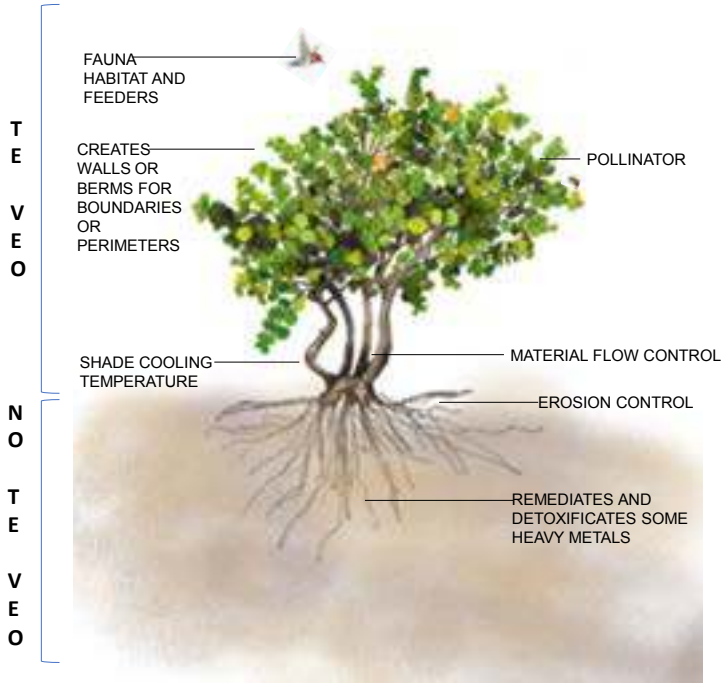



*Figure 59. Illustrative section elevation for bio-swale strategy.*




*Chrysobalanus icaco*, icaco

Arbusto mediano o árbol pequeño cuya altura ronda entre 3’ – 10’ (6.6m – 19.7m)
Tolerante a la salinidad
Tolerancia alta ante el viento
Tolerante al sol pleno
Medianamente tolerante a la sequía
Hábito de crecimiento tiende a ser densamente foliado desde el suelo, lo cual ayuda a **prevenir la erosión**
Florece entre enero y agosto **atrayendo a polinizadores**
Fruto maduro y la semilla son comestibles para los humanos y la vida silvestre

## III. Green Infrastructure Pilot Project Implementation

| | |
|---|---|
| Project Summary | The purpose of this project is to mitigate soil compaction and erosion in the northern access point of the Condado Lagoon Estuary Reserve. In so doing it is intended to decrease the level of sedimentation reaching the Lagoon's water and affecting water quality. The use of green infrastructure by way of understory shrubs in already eroded areas and to reduce the width of the major pedestrian thoroughfare and reduce pedestrian impacted areas will prevent further erosion. The chosen material, whether endemic or naturalized, seeks to provide shelter, food, and interest to pollinators, increase bird population and other wildlife already present in the Lagoon. |
| Project objectives: | Decrease sedimentation levels at the Lagoon<br>Enhance water quality at the Lagoon<br>Connect fragmented patches of red mangrove forest<br>Decrease soil compaction and erosion<br>Augment diversity of ecosystems & understory species<br>Increase wildlife species, birds, aquatic life and pollinators<br>Upsurge of CO2 sequestration by red mangrove coverage |
| Issues addressed: | Water quality, erosion, compaction, sedimentation, reduction in stormwater volume reaching Lagoon, coastal ecosystem habitat increase for existing species, interest for pollinators, increase in diversity of species, consolidation of fragmented patches of red mangrove forest, CO2 sequestration |
| Project type: | Green Infrastructure |
| Location: | Ashford Avenue, San Juan, Puerto Rico, Lagoon access |
| Latitude/Longitude: | 18.4602701, -66.0825617 |
| Climatic Zone: | Sub Tropical |
| Total Area Size: | 77,500 sf / 1.78acre |
| Impact Area Size: | 15,500 sf (20%) / .35 acre - 2000 sf / .046 acre |
| Impacted Area: | 2,000 square miles / 7.17 square miles |
| Budget: | $5,600 |
| Completion Date: | May 21, 2021 |
| Number of Volunteers: | 10 ($1,200.00 in kind) |
| Irrigation donation by MSJ: | 10 days ($1,000.00 in kind) |
| Property ownership: | Public |
| Partner Agencies: | Municipality of San Juan (co-manager)<br>Department of Natural Resources (co-manager)<br>San Juan Bay Estuary Program (co-manager) |

# IV. Project Benefits

## A. Environmental

- Added habitat and food source types to current 46 species of birds, 36 aquatic species found at the Lagoon
- Reduce erosion and compaction areas by 20%.
- Reduces stormwater runoff by 32% (36 gallons per minute) and sedimentation from reaching the Lagoon's water.
- Connect fragmented patches of red mangrove forest
- Increase wildlife species, birds, aquatic life and pollinators

## B. Social

- Augment public participation opportunities for learning about native coastal species and the ecological services associated to them through connection to webpage by QR codes.
- Increased opportunities for learning about green infrastructure strategies available in the protection of water quality.

# V. Pilot Project – Selected Site

The selected site locates at the northeastern pedestrian access to the Condado Lagoon Estuarine Reserve. This place constitutes the juncture at which the Atlantic Ocean, the San Juan Bay and the Condado Lagoon waters meet. Additional site attributes include: serving as an ecological, social, cultural and economic fulcrum functioning as gateway between the Old City and the contemporary one. Therefore, a vast array of issues, opportunities and needs converge at this site.


*Figure 60. Opportunities identified at the Condado Lagoon Estuarine Reserve.*

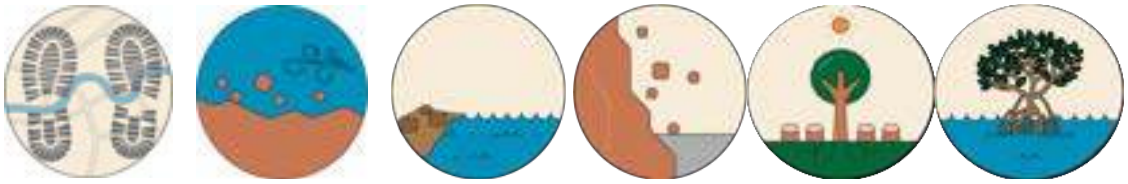



*Figure 61. Issues addressed: human impact, erosion, sedimentation, deforestation, red mangrove restoration.*


*Figure 62. Total area of impact. Google Earth*

*Figure 63. Area of direct impact. Google Earth*

# VI. Pilot Project Installation

## A. Site conditions prior to installation


*Figure 64. Red mangrove area patches to be consolidated. (Photos courtesy of M. Rodríguez)*

*Figure 65. Eroded sector to be planted with Chrysobalanus icaco to prevent further erosion and mitigate sedimentation at the Lagoon and strengthen wildlife habitat, food and pollination. (Photos courtesy of M. Rodríguez)*

*Figure 66. Areas to define the limit of pedestrian circulation to mitigate soil erosion and compaction. (Photos courtesy of M. Rodríguez)*

## B. Site conditions during installation

*Figure 67. Planting of Ryzophora mangle propagules to connect fragmented patches of red mangrove forest at the water's edge. (Photos courtesy of L. Medina)*

*Figure 68. Planting of Ryzophora mangle propagules following Bauzá technique to anchor areas of propagules and facilitate planting establishment. (Photos courtesy of L. Medina)*


*Figure 69. Planting of Chrysobalanus icaco to control soil erosion and eventual sedimentation affecting water quality. This understory woody shrub will provide a habitat for wildlife and its flowers attract pollinators and provide food to birds and humans. (Photos courtesy of L. Medina)*


*Figure 70. Planting of understory native coastal woody shrubs serves to direct persons using the space and keep them along a designated path area, thus reducing the soil compacted by people's steps. (Photos courtesy of L. Medina)*

*Figure 71. Planting of Coccoloba uvifera to control soil erosion and sedimentation. This understory native coastal woody shrub will provide a habitat for wildlife and its flowers attract pollinators and provide food to birds and humans. The selection of plantings will serve to diversify the plant material currently at this site and ecological relationships throughout the Condado Lagoon. (Photos courtesy of L. Medina)*

## C. Site conditions after installation

*Figure 72. A covering of mulch was added to the soil around the base of this existing tree as a humidity retention mechanism and to prevent the soil around the root system to be exposed and thus, partially controlling the erosion. (Photos courtesy of L. Medina)*

## VII. Conclusions

The green infrastructure pilot project addressed three major areas: water quality enhancement, coastal ecosystems and wildlife strengthening and CO2 sequestration. The reduction of pedestrian thoroughfares has an immediate effect on soil compaction, erosion and the subsequent amount of sediment that reaches the natural body of water. The definition of walkable areas using native shrub species adds habitat spaces for wildlife on land while also increasing species types at this location, which is lacking an understory cover to its forest. At the water's edge, planting red mangrove to fill in disconnected patches allows for forest connectivity and for the increase of spawning areas for fish amidst the root systems. In addition, consolidation of the red mangrove forest increases the capacity to sequester CO2 and mitigate wave energy at this highly urbanized juncture, as part of the proven functions of red mangroves.

Short and mid term results for this initiative will need to be measured and revisited within a year span. As part of the short term metrics, two strategies are recommended: water quality monitoring and planting monitoring plan. The use of the existing Planting Monitoring Plan should be pursued on a monthly basis. This Plan documents the development of recently planted material, registers height and caliper development, leave characteristics, and also collects photographic documentation. Area coverage by the new branch growth on coastal shrubs should constitute part of the metrics used to consider soil coverage in the mitigation of soil erosion. Water quality measurements should additionally be pursued monthly at this particular site.

For the long term, metrics should be developed to establish the relationship between new planting areas to increases in bird viewings, the number and/or aquatic species and other wildlife presence in order to establish the economic value of green infrastructure strategies in natural areas.

## VIII. Monitoring Plan

A Planting Monitoring Plan has been developed and is in current use for new red mangrove plantings along the Condado Lagoon Estuarine Reserve. The Plan is in place and has been used to monitor red mangrove plantings completed in January of 2021 on a monthly basis. The Planting Monitoring Plan has been expanded to include other plants.

## IX. Maintenance and Irrigation Plan

The Irrigation Plan calls for daily irrigation for the understory shrub planting during a two week period in order to surpass the transplant shock period. For subsequent weeks (weeks 3-6), the Irrigation Plan indicates irrigation twice a week and weekly from there on through week through week 12 (weeks 7-12).

The plant choice took into account expanding diversity of the existing coastal ecosystem so that after the third month these plants will be established and acclimated to this locality within the estuarine ecosystem and be able to tolerate conditions without further irrigation. However, this strategy should be evaluated during the fourth month following planting, i.e. in September 2021.

It is recommended that plants be fertilized once a month, with organic slow release fertilizer in pellet form.

Given the purpose of providing shelter and food for wildlife, continuous pruning is discouraged to allow plants to develop fruits and have an opportunity to self propagate.

# X. Appendices

A. Budget (Appendix)
B. Invoices
C. Letters to partner agencies (Appendix)
D. Calendar for Implementation (Appendix)
E. Agreements/permits by MSJ
F. Attendance sheet
G. Monitoring Plan

# XI. Works Cited

ADSCO Construction Supply. (n.d.). *www.asdcosupply.com.* Retrieved May 2021, from https://www.asdcosupply.com/collections/sediment-control/products/straw-bio-rolls

Agency, M. P. (2016, February 29). *Minnesota Stormwater Manual*. Retrieved from https://stormwater.pca.state.mn.us/index.php?title=File:Install_biorolls_or_other_sediment_controls_along_the_contour_of_the_slope.PNG

Blanco, L. (2020, December 18). *Mangle negro: características, taxonomía, hábitat y usos*. (Lifeder, Producer) Retrieved May 2021, from https://www.lifeder.com/mangle-negro/: https://www.lifeder.com/mangle-negro/

City of Binghamton. (2021, May). Retrieved from www.binghamton-ny.gov: http://www.binghamton-ny.gov/sites/default/files/files/2%20Bioswale%20Brochure%20May%202016.pdf

Denton, S. (n.d.). (F. I. Keys, Producer) Retrieved May 2021, from regionalconservation.org: https://regionalconservation.org/ircs/database/plants/PlantPageFK.asp?TXCODE=Sphatri

EcoExploratorio. (2021, May). *ecoexploratorio.org*. Retrieved from https://ecoexploratorio.org/vida-en-el-mar/ecosistemas-marinos/manglares/

National Parks. (2020, April 20). *National Parks Flora and Fauna Web*. Retrieved from https://www.nparks.gov.sg/FloraFaunaWeb/Flora/3/3/3372

Ohio Rain Garden Design. (2021, May). *www.pinterest.com*. Retrieved from https://www.pinterest.com/pin/816699713645791887/

Pinterest. (2021, May). Retrieved from https://www.pinterest.com/pin/685180530777856543/

Plan de Manejo Reserva Natural Estuarina Laguna del Condado. (2016, Octubre). (Departamento de Recursos Naturales) Retrieved May 2021

Refra. (2019). (Refra, Producer) Retrieved May 2021, from http://www.refra.eu/Live-Aquarium-Plants/904909-Hydroponics-Aquarium-Rhizophora-mangle/

Ross, M. (2021, May). *Naturalista*. Retrieved from https://colombia.inaturalist.org/observations?verifiable=true&taxon_id=62854&place_id=7196&preferred_place_id=7196&locale=es

San Diego Natural History Museum. (n.d.). Retrieved May 2021, from https://www.sdnhm.org: https://www.sdnhm.org/oceanoasis/fieldguide/lagu-rac-sp.html

The Nature Conservancy. (n.d.). *TNC.org*. Retrieved May 2021, from https://www.nature.org/en-us/about-us/where-we-work/united-states/florida/stories-in-florida/why-mangroves-important/

University of Florida. (2008). *buildgreen.ufl.edu*. (U. o. Florida, Producer) Retrieved May 2021, from http://buildgreen.ufl.edu/fact_sheet_bioswales_vegetated_swales.pdf

Vetiver Grass UK. (2021, May). Retrieved from https://vetivergrassuk.com