Reduction and control of sediment-laden runoff near critical coral reef and other coastal ecosystems through the implementation of BMPs in Culebra, Puerto Rico FY-2015

FINAL REPORT

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1 PARTNERS AND COLLABORATORS FOR THIS PROJECT

Culebra Municipality

Yauco Municipality

Las Colinas Homeowner Association (CHA)

North View Homeowner Association (NVHA)

2 SUMMARY

The purpose of this Project was to implement three high priority Land Based Sources of Pollution (LBSP) restoration projects identified in the Culebra Watershed Management Plan (WMP), and to monitor performance of one of the installations. These projects have utilized green infrastructure practices to intercept stormwater runoff and utilize plants, soils, and natural processes to filter and reduce runoff pollution.

Efforts to support and implement the ***Culebra Community Watershed Action Plan for Coral Reefs and Water Quality*** has led to unprecedented collaborations between the Municipality of Culebra, the Department of Natural and Environmental Resources (DNER), National Oceanic and Atmospheric Administration (NOAA), the US Fish and Wildlife Service (FWS) through the Partners for Fish and Wildlife Program, local organizations, and the community in general. As part of the funding cycle from NOAA's Coral Reef Conservation Program (CRCP) for Fiscal Year (FY) 2015, and in collaboration with the Horsley Witten Group (HWG) and the USFWS, Protectores de Cuencas (PDC) carried out three high priority projects in Culebra to stabilize unpaved roads and to restore and protect coastal ecosystems.

The first project was developed following work started with FY-2014 NOAA funds in Punta Aloe, Fulladosa Ward, located in the Culebra Subwatershed (Figure 1). This project consisted of stabilizing the lower drainage area as well as implementing a series of additional practices in the upper drainage area of the work completed with previous FY-2014 NOAA funds. The second project was developed as part of the same dirt road system of Punta Aloe in the opposite drainage area on the Fulladosa Subwatershed, and the third project was done with the funding collaboration of the USFWS and the North View

Homeowner Association (NVHA) located in the Puerto del Manglar subwatershed (Figure 1). These projects represent major sediment and stormwater runoff control practices on unpaved road systems impacting Culebra's coastal and marine resources. The Punta Aloe sites drain to Culebra's main bay, Ensenada Honda, a bay recognized as critical habitat due to prevalence and abundance of seagrass beds and coral reefs. The Puerto del Manglar site drains to the Puerto del Manglar Bay (PMB), the second largest bay in Culebra. The PMB is an area of great ecological importance surrounded by mangroves, which form a unique habitat that is vital for coastal wildlife, seagrass beds and coral reefs. The goals of these projects were to address runoff from the adjacent roads and bare soil areas prior to being discharged to the marine environment. These efforts had the endorsements of the Municipality of Culebra, the Conservation and Development Authority of Culebra (ACDEC) and the support of the DNER, as well as from the local community. Furthermore, the Homeowner Associations as well as the Municipality of Culebra have agreed to provide long term maintenance to the stabilized roads.

It is important to point out that much of the labor for these efforts has been contracted locally from Culebra. These projects received technical assistance from the DNER, the USFWS and NOAA. The USFWS and DNER also provided native trees to be planted as part of the reforestation program. DNER provided logistical support and accommodation for the work team at their facilities in Culebra. Project sites were selected in coordination with agencies, Horsley Witten Group, NOAA CRCP, the Municipality of Culebra and homeowners from the area.

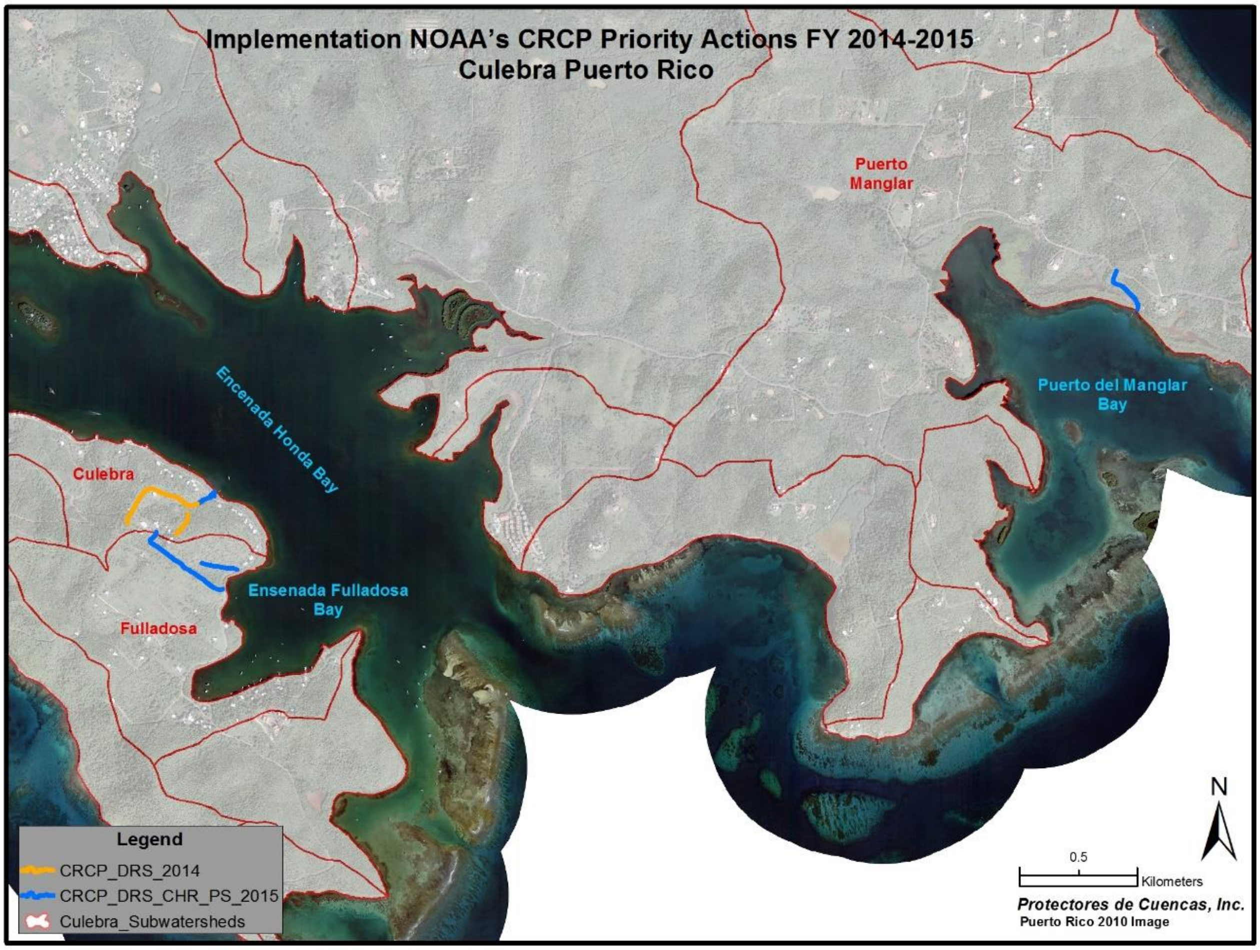

Figure 1. Culebra map with site locations where the yellow segments refer to the dirt road system project implemented in 2014, while the blue segments refer to the dirt road systems project implemented in 2015.

3 INTRODUCTION

3.1 BACKGROUND

Increased levels of land-based sediment loads associated with coastal development is one of the most important factors affecting coastal marine ecosystems in Puerto Rico. Puerto Rico coral reefs are among the most threatened marine ecosystems in the Caribbean. The degradation of coastal water quality in Puerto Rico has caused a decline in the population and health of coral reefs. The ability of reefs to survive is gradually being reduced as fine sediment and nutrient discharges from the land to the coastal waters increase. From the stand point of marine ecosystems conservation, degradation of water quality due to dispersed land-based sources of pollution has caused negative and sometimes irreversible damage to the integrity of the coral reef communities, sea grasses, mangroves, and other highly valued coastal ecosystems.

High rates of sedimentation, excess nutrients, urbanization, and sanitary sewage overflow, are the main causes of the degradation of marine ecosystems. This phenomenon is mainly due to the lack of sustainable management from the perspective of integrated watershed management. Erosion and habitat degradation are other serious problems that our wetlands, estuaries, and coastal waters face. The removal of vegetation and land clearing activities for construction without proper erosion and sedimentation control practices impact marine and coastal ecosystems and diminish the attractiveness of coastal areas for recreation and tourism. High sediment loads discharging to marine environments as a result of poorly maintained dirt roads without the installation of proper management practices is a very common problem in Culebra.

As mentioned by Ramos-Scharrón and Amador-Gutierrez (2011), experts agree that much improvement on coral reef conditions in Culebra can be achieved by decreasing sediment load rates into its coastal waters. It has been determined that unpaved roads are likely to generate sediment at a rate of up to four orders of magnitude greater than undisturbed lands. Increased loads caused by the continuously growing unpaved network in Culebra have increased the rate of sediment and nutrient delivery to the marine environment, threatening the island's fragile coral reef systems (Hernández-Delgado et al., 2006).

Geospatial Information System models suggest that sediment delivery rates in four general areas of Culebra including Punta Soldado, Bahía Mosquito, Puerto Manglar, and Zoní range between 20 and 120 tons km^{-2} yr^{-1} (tons of sediment divided by km^2 of land area per year) (Ramos-Scharrón, 2009), and this ranges from about half to up to 10 times higher than those estimated for three comparable watersheds on St. John, USVI. In the case of Puerto del Manglar watershed, a total of 9.4 km of unpaved roads are calculated with a total delivery 112 tons of sediment every year into the receiving coastal waters, representing 86% of the entire watershed surface area sediment yield. The data presented by the studies show that sediment pollution from particular road segments outweigh their counterparts in their relative contribution to watershed-scale sediment yields.

3.2 General Site Conditions

As part of the restoration projects completed, we continued to address issues of concern through the establishment of three restoration projects, two at Punta Aloe in the subwatersheds of Culebra and Fulladosa and one at the Puerto del Manglar subwatershed. PDC also made several improvements to Punta Aloe's project implemented in FY-2014, including a series of concrete swales along portions of the road.

The Punta Aloe site is composed of a municipal dirt road system. This dirt road is very steep and is one of the major sources of sediment runoff to Ensenada Honda. The homeowner association for this area provided matching contribution to pay for part of the costs of these projects. Approximately ½ mile of dirt road was stabilized to reduce sediment transport to the marine environment of Ensenada Honda.

The Puerto del Manglar site is composed of a community dirt road network with a bare soil parking lot that drains to a salt flat and mangrove wetland system managed by the USFWS as a National Wildlife Refuge. The NVHA had previously built a new parking area outside the salt flat, but it was not established correctly, and stormwater practices and sediment and erosion control measurements were not considered or wrongly implemented. This oversight caused significant amounts of sediment to fill most parts of the salt flat and discharge to coastal waters on the bay. In addition, the visitation in this area has resulted in an increased pressure on natural resources, therefore, increasing the need for implementation of management practices to ensure both the enjoyment of visitors to the area as well as the protection and conservation of this unique coastal resource. The lack of proper planning, management, and the absence of erosion and sediment control practices has led to an increase in sediment pulses that affects the adjacent bay and its resources.

3.3 Project Goal and Results

The primary goal of these projects was to stabilize bare soils in in high priority areas of Culebra by implementing sediment and erosion control measures to reduce sediment loads into the marine ecosystems. This will protect and build resilience of coral reef ecosystems in Culebra.

Prior to stabilization, in most parts of the dirt road networks, runoff was flowing down the center of the road causing erosive forces to transport sediments into the nearshore environment. After completing the installation of temporary sediment and erosion control measures, PDC stabilized approximately another 1 mile of dirt roads in three priority sites. Installed BMPs included sediment traps, check dams, swales, regrading, rip-raps, hydroseeding, Vetiver grass plantation and paving with concrete and granulate fill material and compacting. These projects will improve water quality and contribute to the health of adjacent coral reefs, and ultimately, support the Culebra local economy.

4 IMPLEMENTATION

4.1 PUNTA ALOE PROJECTS

This site includes a municipal dirt road for which half was stabilized and regraded during Phase I with FY-2014 NOAA funds. The main problem of this dirt road system was that it was constructed in the flow patterns of two natural dry channels. Most of the runoff that drained naturally through the dry channels during storm conditions had been intercepted by the road, resulting in runoff flowing on the top of the road before discharging directly to the Bay without passing through the mouth of the natural dry channel. During Phase II of these efforts, we improved the previous work by adding several concrete swales and Vetiver grass lines, paved a steep segment of the dirt road with concrete, and stabilized a dirt boat launching area near the coastal zone with gravel and vegetative buffers. We also built a series of raingardens downhill of the implemented road stabilization practices. The use of concrete crossing swales was implemented to ensure proper conveyance of runoff to its natural course into the dry channel after passing through a series of treatments. Also, the second half of the Punta Aloe dirt road network that drains to the Fulladosa Bay was stabilized.

Punta Aloe projects received the financial support from NOAA, Culebra residents and the Municipality of Culebra, with in-kind contributions of heavy equipment. Before starting any restoration work in the area, we installed a series of temporary sediment and erosion control practices at the current road and near the coastal zone and where work was going to take place. Sediment control practices included installing silt fences and planting Vetiver grass to redirect runoff to forested areas.

The steepest segment of this dirt road network was stabilized by paving it with concrete. A stone swale was built on the side of the concrete to reduce the energy of the runoff prior to discharging into a raingarden, and hydroseeding was used to stabilize the remaining bare soil areas. Up gradient of the concrete stretch, the road segment was regraded towards the outside of the road and compacted. A rain garden system was constructed at the end of the dry channel before it discharges to the marine environment. Part of the channel was clogged with big piles of sediment; this was a product of the construction of the road and previous maintenance procedures. This problem was causing the natural flow to cut through these piles of sediment and through the main road, transporting them to the sea.

As part of this project, the sediment piles were removed along with other sediments that had built up upstream over the years, and the natural channel was restored pack to natural conditions. A series of check dams were built inside the channel to reduce runoff energy and trap some of the sediments. Downstream of the channel, where a boat launching area exists, a significant amount of sediment had also piled over the years. This sediment was removed and the bare soil was stabilized by paving it with gravel, hydroseeding and other vegetative buffers (See Figures 2 to 7). Removed sediments were appropriately disposed in a local landfill.

On the upper part of the road that was stabilized with FY-2014 funds, we added a series of concrete swales where runoff needed to cross the road (Figure 8). Concrete swales have been demonstrated to be a very reliable and effective practice on these roads.

On the other half of the Punta Aloe dirt road network that drains to the Fulladosa Bay, a total of approximately ½ mile (using ArcGIS tools) of dirt road was stabilized to reduce sediment transport to the marine environment. All the dirt road stabilized was regraded to the desired hydrological patterns, and runoff was conveyed into a continuous swale with check dams at intervals of approximately 25-30 ft., depending on the slope. The regrading process was conducted using a bulldozer, and soil was compacted with a 15-ton compacting roll. A series of concrete crossing swales was constructed to cross runoff from one side of the road to another into forested areas. Sediment traps were constructed to help filter stormwater that was causing erosion problems and discharging sediments. The traps were formed by excavating an area across a low portion of drainage swale, and berms were constructed and compacted with the small compacting roll. After compacting, the sediment traps were covered with 2-8 inch stones as rip-rap to prevent erosion from the berms, the bottom was punched through with the backhoe to promote infiltration, and Vetiver grass half-moons were planted to help trap sediment and promote infiltration and evapotranspiration. A rip-rap overflow was constructed with bigger 1-2 ft. stones to reduce energy of the water. The final segment of the road was paved with compacted gravel to reduce the sediments entering the raingarden that eventually drains to the Bay (See Figures 9 and 10).

For this project, we had an in-kind contribution from the Las Colinas Homeowner Association (CHA) for part of the cost associated with the concrete. Other contributions from land owners include space for storing heavy equipment, water for irrigation, and maintenance of green areas restored.

Figure 2. Sediment accumulation along dirt road at Punta Aloe prior to stabilization.

Figure 3. Sediment accumulation along boat launching area at Punta Aloe before the area was stabilized.

Figure 4. Sediment accumulation removal at Punta Aloe.

Figures 5. Dirt road stabilization at Punta Aloe including the removal of piled sediments and restoration of the natural waterway.

Figures 6. Dirt road stabilization, concrete paving and hydroseeding application along road at Punta Aloe.

Figures 7. Completed project implementation along road at Punta Aloe.

Figures 8. Construction process of concrete crossing swales along dirt road at Punta Aloe improvements of work completed with FY-2014 funds.

Figures 9. Regrading and compaction activities, construction process of concrete crossing swales, check dams and sediment trap along dirt road at Punta Aloe Phase II.

Figures 10. Before and after of completed work at second portion of Punta Aloe.

4.2 Puerto del Manglar Project

The Puerto del Manglar site is composed of a community dirt road network with a bare soil parking lot that once was on a salt flat and mangrove wetland system managed by the USFWS. The NVHA had previously built a parking area outside the salt flat, but it was not established correctly and stormwater practices and sediment and erosion control measurements were not considered or wrongly implemented (Figures 11 and 12). This problem caused a significant amount of sediment to be deposited, which filled most parts of the salt flat, on mangrove areas and, consequently, discharged to coastal waters on the Puerto del Manglar Bay.

The high visitation in this area has resulted in an increased pressure on natural resources, therefore, increasing the need for implementation of management practices to ensure both the enjoyment of visitors to the area as well as the protection and conservation of this unique coastal resource. The lack of proper planning, management and the absence of erosion and sediment control practices has led to an increase in sediment pulses that affect the adjacent bay and its resources. The surrounding wetland is an important habitat for marine birds, including the endangered Brown Pelican. This site was selected as a priority for restoration due to the huge sediment load produced by the dirt road and parking area.

Work completed consisted of stabilizing the access road and parking area by regrading and compaction (See Figures 13 and 14). Before starting any restoration work in the area, we installed a series of temporary sediment and erosion control practices at the current road and near the coastal zone and where work was going to take place. Sediment control practices included installing silt fences and planting Vetiver grass to redirect runoff to forested areas. A series of swales and check dams were installed to direct part of the runoff from the main access roads to a sediment trap. The parking area and all the road segments that run parallel to the wetland system were then paved with gravel after the installation of geotextile to serve as a filtration system. The gravel infill will allow vehicle support and drainage of all storm water.

The old parking lot that was utilized by visitors was located on the terrestrial maritime zone, and motor vehicles had direct access to the beach area. As part of this project, this area was closed with boulder rocks to ensure soil stabilization and vegetation recovery. The new parking area was developed using green infrastructure techniques to help with the sediment load reduction process. The parking, as well as all the flat sections of the dirt road, was designed to capture and infiltrate rainwater and runoff from the adjacent hillsides into the subsoil. Parking was also regraded and designed to convey the excess runoff produced in larger storm events into a rain garden system without directly discharging into the mangrove and subsequently into the marine environment.

The salt flat wetland area was restored by removing the piles of sediment that had accumulated from the adjacent road and parking areas. This sediment accumulation was preventing natural hydrological flow patterns of tidal process. After the sediment was removed and natural hydrologic conditions were reestablished, we reforested the area with mangroves and other coastal forest. A wooden boardwalk was constructed to provide pedestrian access while protecting the surrounding restored area. Hydroseeding was used to stabilize remaining bare soil areas of the restored site (See Figures 15 to 16).

This project was possible thanks to a partnership between NOAA, the USFWS and the NVHA. A conservation agreement was established between NOAA, USFWS, PMHS and PDC for the long-term conservation and maintenance of this area. The USFWS provided additional funding for the habitat conservation component of the project, the NVHA provided in-kind funds to cover the efforts of removing accumulated sediment on the wetlands, and NOAA CRCP provided the funds for the soil stabilization component and the implementation of BMPs. The USFWS also provided a total of 100 native coastal forest native trees that were planted on the restored areas.

Figures 11. Wetland existing conditions before project started at Puerto del Manglar.

Figures 12. Wetland restoration process and boardwalk at Puerto del Manglar.

Figures 13. Dirt road stabilization by regrading and compaction at Puerto del Manglar.

Figures 14. Completed dirt road stabilization project at Puerto del Manglar.

Figures 15. Construction of sediment trap at Puerto del Manglar.

Figures 16. Completed dirt road stabilization project at Puerto del Manglar.

4.3 MONITORING EFFECTIVENESS

In order to quantify the effectiveness of the work that has been completed in Culebra to reduce erosion and sediment into the nearshore environment, we have partnered with Carlos E Ramos-Scharrón, PhD from the University of Texas in Austin to develop the following Monitoring Protocol. FY-2015 funds were used to prepare this monitoring protocol, and sampling will continue with subsequent NOAA funding.

GENERAL EROSION MITIGATION APPROACH

The general approach being followed by the erosion mitigation actions to be taken at one road segment by PDC is designed to reduce erosion rates along unpaved roads, reroute road runoff for it to more closely mimic natural flow paths, and to prevent untreated sediment-laden runoff from directly entering water bodies (i.e., natural ephemeral streams [''quebradas''] and coastal waters). Actions to be taken include insloping roads through grading, digging ditches, installing energy dissipating structures, decreasing the spacing between road drainage points, and building several types of sediment retention structures. The sketch accompanying this document summarizes some of the actions expected to be taken as part of mitigation. The locations of the sites where these actions are to be implemented are shown here.

It is anticipated that FY16, FY17 and FY18 NOAA funding will implement similar erosion mitigation strategies in other priority subwatersheds. Therefore, the monitoring approaches proposed here will serve as a model for future monitoring efforts in the following years. Furthermore, the pre-mitigation monitoring established with FY16 funding will serve as baseline for all post-mitigation work (including FY17 and FY18).

GENERAL MONITORING APPROACH

Given the multiple activities and objectives of the mitigation strategy and its imminent implementation in the coming months, it is impossible to establish a simple pre-mitigation and post-mitigation monitoring effort. Therefore, we will follow a more indirect approach to evaluate the effectiveness of the mitigation efforts in reducing sediment production and delivery. Our objectives are:

1) *Quantify unpaved road sediment production rates*. Although similar work has been conducted in the nearby island of St. John, no previous empirical quantification of erosion rates has been conducted previously in Culebra. This will be achieved by measuring plot-scale erosion rates through rainfall simulation experiments and road-segment scale erosion rates with sediment traps during natural rainfall events.
2) *Quantify runoff response at the plot, road-segment, and catchment scale*. The rerouting of road runoff is in part expected to reduce the frequency of runoff delivery to coastal waters. This will be measured with the aid of the rainfall simulation experiments at the plot scale, peak crest gauges located within sediment retention structures, and a combination of peak crest gauges and automated water level recorders located along the stream network for determining the presence of runoff at the catchment scale.
3) *Quantify the direct impact of road runoff delivery into streams in suspended sediment concentration and estimate annual sediment yields into coastal waters*. This objective will be achieved through a combination of suspended sediment samplers (single-stage samplers) and automated water level recorders.

METHODS

1) **Rainfall simulations**: A number of rainfall simulation experiments will be conducted in order to quantify the rate of both runoff and sediment production from unpaved roads in Culebra. Carlos has conducted a series of experiments of this sort in combination with PDC, therefore, we have an already established logistical protocol[1]. The results will allow us to make estimates on the amount of runoff and sediment produced given different storm events, to estimate how often an untreated road delivering runoff directly to coastal water is effectively connected to the marine environment, and to estimate the concentration of suspended sediments being carried and delivered by unpaved roads in Culebra.
2) **Rainfall intensity**: Two automated, tipping bucket style rain gauges will be installed in the vicinity of the work area to document rainfall patterns during monitoring. All erosion rates will be established in conventional units of Mg of sediment produced per hectare of road surface area per mm of rainfall.
3) **Sediment traps**: Sediment detention structures built with the purpose of trapping road-derived sediment will be used as monitoring sites to quantify road erosion rates. The method entails setting a grid of at least 15 pieces of rebar inserted vertically into the bottom of each structure. The elevation from the bottom of each pond to the top of each rebar is measured during setup and at least once a month.

[1] Ramos-Scharrón and Thomaz. 2016. Runoff development and soil erosion in a wet tropical montane setting under coffee cultivation. Land Degradation & Development. Doi: 10.1002/ldr.2567

Differences in elevation between measurements amount to the depth of sediment accumulation and the combination of measurements leads into a volumetric estimate of the amount of sediment that has settled at the bottom of the structure[2]. Converting those volumetric units into a mass-based estimate requires determining the dry bulk density of the accumulated sediments and these samples will be collected and determined in the lab following standard protocols[3]. Samples will also be used to determine the texture of the eroded sediment through standard dry sieving methods. Accumulation rates will also be useful in prescribing a frequency of dredging maintenance requirements.

4) **Peak crest gauges**: These gauges are an inexpensive way to determine the maximum elevation of the water surface[4]. These encompass a pair of PVC tubes with different diameters inserted into one another and capped. The outer tube is placed vertically on the bottom of the streambed or detention structure and secured to pieces of rebar. The outer tube is slit to allow water to flow into it. Powdered cork is placed at the bottom of each gauge so that when water enters the gauge, the cork marks the height of the water surface. These gauges will be used to determine periods when each road segment draining into the sediment detention structures has generated any runoff and if the runoff has overtopped the outlet of each structure.

[2] Dissmeyer. 1982. How to use fabric dams to compare erosion from forestry practices. Forestry Report SA-FR 13, USDA, Forest Service, Southeast Areas, 11p.

[3] Blake & Hartge. 1986. Bulk density. In Methods of Soil Analysis, Part I – Physical and Mineralogical Methods, Agronomy Monograph No. 9.

[4] Sauer & Turnipseed. 2010. Stage measurement at gaging stations: US Geological Survey Techniques and Methods, Book 3, Chapter A7, 45 p.

Some peak crest gauges will be located at the bottom of streambeds to determine when runoff has occurred along these portions of the streams.

5) **Hobo water level recorders**: Water levels in streams will be used to determine when runoff is present and if the hydraulic conditions of the stream permit, then they can also be used to estimate discharge rates[5]. The water level recorders will be placed as close to the outlet of the stream as possible.
6) **Single stage runoff samplers**: Single stage samplers are an economical way of collecting runoff samples in remote locations[6]. These will be placed just upstream and downstream of important road runoff delivery points to determine the localized impact on suspended sediment concentration. Suspended sediment concentration will be determined based on the evaporation method[7]. Those located near the outlet of the streams will be combined with automated water level recorders to estimate sediment yields following standard sediment rating curve protocols[8].

7) **Sampling Frequency**: We will sample 3 times per month for 12 months.

[5] Dalrymple & Benson. 1967. Measurement of peak discharge by the slope-area method. Techniques of Water-Resources Investigations of the US Geological Survey. Book 3, Applications of Hydraulics.

[6] Edwards & Glysson. 1999. Field Methods for Measurement of Fluvial Sediment. Techniques of Water-Resources Investigations of the US Geological Survey, Book 3, Applications of Hydraulics, Chapter 2

[7] American Society for Testing and Materials. 2000. Standard test methods for determining sediment concentration in water samples. D 3977-97.

[8] Potterfield. 1972. Computation of fluvial sediment discharge. Techniques of Water-Resources Investigations of the US Geological Survey. Book 3, Applications of Hydraulics.

5 PERIOD OF PERFORMANCE

The total period of performance was from October 24, 2015 to December 12, 2016 for a total of 14 months, approximately. Most the work was completed from October, 24, 2015 to July 30, 2016 with the NOAA funding. From August to September, work was continued using funds from the CHA, and from October until December, 2016, with funds from the USFWS and the NVHA.

6 COSTS

The work completed in Culebra at Punta Aloe and Puerto del Manglar subwatersheds was performed for a total combined cost of $221,540 including $134,640 (cash, Table 1) and $86,900 (non-cash, Table 6). From this amount, $106,640 was provided by NOAA CRCP (Table 2), $20,000 was provided by the USFWS (Table 3) Partners for Fish and Wildlife Program, $5,000 was provided by the NVHA (Table 4), and $3,000 by the CHA (Table 5). A total in-kind (non-cash) match of $86,900 was estimated on this effort from contributing entities including the DNER, PDC, Culebra Municipality, Yauco Municipality, local community volunteers as described in Table 6.

Cash costs of the Punta Aloe project on the Culebra subwatershed were a total of $29,400 ($26,400 NOAA funds and $3,000 from CHA). The costs of the Punta Aloe project on the Fulladosa subwatershed were a total of $45,740 (NOAA funds), with an additional $14,500 (NOAA funds) dedicated for monitoring effectiveness of practices installed. The Puerto del Manglar project costs were a total of $45,000 ($20,000 NOAA funds, $20,000 USFWS funds and $5,000 from NVHA).

Table 1. Summarized Global Costs

CATEGORY	COST
Labor and Manpower	$16,965
Rental Equipment and Materials Transportation	$14,011
Materials	$33,250
Project Management, Coordination, Design and Engineering	$31,060
Travel (gas, flights, ferry, per diem, etc.)	$12,887
Monitoring	$14,500
Indirect (10%)	$11,967
TOTAL	**$134,640**

Table 2. Summarized NOAA Funding Costs

CATEGORY	COST
Labor and Manpower	$11,315
Rental Equipment and Materials Transportation	$10,800
Materials (costs include 8-12", 2-4', ¾/1 ½", size stones, Vetiver plants, Hydroseeding sup, other mis.)	$25,000
Project Management, Coordination, Design and Engineering	$24,340
Travel (gas, flights, ferry, per diem, etc.)	$10,990
Monitoring	$14,500
Indirect (10%)	$9,695
TOTAL	**$106,640**

Table 3. Summarized USFWS Funding Costs

CATEGORY	COST
Labor and Manpower	$4,800
Rental Equipment and Materials Transportation	$2,461
Materials (Vetiver plants, concrete, lumber, soil enhancements and other mis. materials)	$4,125
Project Management, Coordination, Design and Engineering	$5,200
Travel (gas, flights, ferry, per diem, etc.)	$1,597
Indirect (10%)	$1,818
TOTAL	**$20,000**

Table 4. Summarized NVHA Funding Costs

CATEGORY	COST
Labor and Manpower	$850
Rental Equipment and Materials Transportation	$750
Materials (Geotextiles, lumber, and other mis. materials)	$1,125
Project Management, Coordination, Design and Engineering	$1,520
Travel (gas, flights, ferry, per diem, etc.)	$300
Indirect (10%)	$455
TOTAL	**$5,000**

Table 5. Summarized CHA Funding Costs

CATEGORY	COST
Labor and Manpower	$0
Rental Equipment and Materials Transportation	$0
Materials (costs include 8-12", 2-4', ¾/1 ½", size stones, Vetiver plants, and other mis. materials)	$3,000
Project Management, Coordination, Design and Engineering	$0
Travel (gas, flights, ferry, per diem, etc.)	$0
Indirect (10%)	$0
TOTAL	**$3,000**

Table 6. Estimated In-Kind Match Contributions from Project Partners

ENTITY	ACTIVITY	UNITS	COST/UNIT	TOTAL COST
USFWS	Trees at a cost of $20/tree	100	$20	$2,000
DNER	Lodging for 8 persons at a rate of 1500/Month	12	$1,500	$18,000
Culebra Municipality	HD Hammer for Bob Cat at a rate of $1,450/month	2	$1,450	$2,900
Culebra Municipality	Hours labor	40	$30	$1,200
Yauco Municipality	Dump Truck at a rate of $450/day	14	$450	$6,300
Omar Villanueva	Backhoe at a rate of $400/day	42	$400	$16,800
PDC	Dozer at a rate of $650/day	8	$650	$5,200
PDC	Dump truck at a rate of $450/day	10	$450	$4,500
PDC	Small water truck at a rate of $350/day	40	$350	$14,000
PDC	Skid Loader at a rate of $250/day	10	$250	$2,500
PDC	Uncompensated hours at a team mean cost/hour	80	$75	$6,000
PDC	Office space and materials at a cost of $1,500/year	1	$1,500	$1,500
PDC	Landscaping Supplies (hand tools, soil enhancements, auger drill, generator, etc.)	60	$100	$6,000
			TOTAL ESTIMATED	***$86,900***