Unpaved Road Assessment and Prioritization of NOAA Investments on Culebra Island, Puerto Rico

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Prepared for:
NOAA Coral Reef Conservation Program and Restoration Center

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Sustainable Environmental Solutions

Culebra's Integrated Watershed Management Plan (2013) identified unpaved roads as a primary contributor to sediment loadings in the nearshore coastal waters, which are threatening coral reef habitats in the region. Since then, NOAA has invested over $800,000 dollars to develop and implement cost-effective best management practices (BMPs) to stabilize these unpaved roads and reduce sediment loadings to coral reef habitats. This report was developed to provide: an inventory of unpaved roads on Culebra, summarize the impact of NOAA's investments in stabilizing unpaved roads on Culebra, and propose a method for prioritizing future NOAA investments in unpaved road stabilization projects on Culebra.

Inventory of unpaved roads in Culebra

A GIS desktop and field analysis was utilized to identify and characterize the unpaved road network in Culebra in 2017. Although this is intended to be a comprehensive inventory of the unpaved road network in Culebra, it is likely that it will change over time as new roads are created or existing roads are paved. To date, Culebra consists of a network of 50 miles of unpaved roads, which is spread across 32 subwatersheds on the island. Erosion of these unpaved roads contributes to nearly 400 metric tons of sediment delivery to the coast per year (Culebra Integrated Watershed Management Plan, 2013; Ramos-Scharron and Hernandez, 2015). Sediment contributions to nearshore coastal waters and habitats varies by subwatershed and is dependent on many factors including, but not limited to: mileage and density of unpaved roads, frequency of use and grading of unpaved roads, general slope of the watershed, proximity to nearshore coastal waters and habitats, and presence of a sediment delivery mechanism to the nearshore (i.e., ghuts, drainage systems).

Analyses from the 2013 Culebra Watershed Management plan indicate that annual sediment loadings from unpaved roads are greatest in the Fulladosa, Culebra, Aeropuerto, Coronel, Cemeterio, Cabra, Carenero, Mosquito, Manzanilla, Puerto Manglar, Almodovar, San Isidro, Zoni, and Larga watersheds (see Figure 1). However, the recent inventory of unpaved roads on Culebra indicates that the Aeropuerto, Cabra, Cayo Norte, Coronel, Culebra, Flamenco, Fulladosa, Mosquito, Puerto Manglar, and San Isidro subwatersheds have the greatest mileage of unpaved roads (Table 1). Of these subwatersheds, the Cayo Norte, Culebra, Fulladosa, Mosquito, Puerto Manglar, and San Isidro subwatersheds generally have unpaved roads with the greatest slopes suggesting that these roads are likely significant contributors to sediment loads (Figure 2, Table 1). Furthermore, the unpaved roads in the Cayo Norte, Mosquito, Puerto Manglar and San Isidro subwatersheds are the closest in proximity to good quality nearshore coral reef habitat (i.e., >50% cover and relatively large aerial extent) (Figure 3, Table 1). However, the Culebra and Fulladosa subwatersheds have extensive drainage systems which effectively conveys runoff from unpaved roads into similarly good quality nearshore coral reef habitats (Figure 4, Table 1). Given existing landuse plans, it seems that development and

unpaved roads will continue to remain a threat for these subwatersheds and therefore there is a need to invest in establishing sustainable unpaved road standards for these areas (Figure 5, Table 1).

Separate from the unpaved roads, the Aeropuerto subwatershed is a significant contributor of urban pollution such as hydrocarbons, heavy metals, leaking septic systems, etc. These pollutants are conveyed to the nearshore waters through the extensive stormwater drainage system in this subwatershed. The Cabra subwatershed is a significant source of fecal pathogens and nutrients from the Culebra wastewater treatment plant (WWTP). Electricity is used to pump sewage to and process sewage at the WWTP. Therefore, when the electrical grid is down sewage is not adequately treated (if at all) and is subsequently discharged directly to Ensenada Honda where it directly impacts seagrass and coral reef habitats.

Given all the reasons listed above, in 2015, NOAA prioritized their investments in LBSP management in the Aeropuerto, Almodovar, Cabra, Coronel, Culebra, Mosquito, Manzanilla, Puerto Manglar, and Fulladosa subwatersheds.

Impact of NOAA investments

By the end of Fiscal Year 2018, NOAA will have funded the stabilization of over 15 miles of unpaved roads or roughly 30 percent of the entire unpaved road network (Figure 7, Table 2). Specifically, from 2013 to 2018, NOAA has provided over $830,000 to implement BMPs to stabilize over 15 miles of unpaved roads. Through Protectores de Cuenca's unrivaled approach to partnership building and interagency collaboration, this funding has been matched with over $900,000 from either direct funding or in-kind support from US Fish and Wildlife Service (USFWS), Puerto Rico's Department of Natural and Environmental Resources (DNER), Culebra's Municipal Government, Protectores de Cuencas (PDC), Horsley Witten Group (HWG), Para la Naturaleza, and homeowners associations (HOAs) that utilize these roads. Independent of these investments, private land owners on Culebra have begun to see the benefits of the stabilized unpaved roads (i.e., reduced maintenance, safer transit, more resilient to storms) and have started requesting the use of BMPs in the construction and/or maintenance of their roads.

Stabilizing an unpaved road costs approximately $116,000 per mile. Cost varies significantly depending on the site conditions (i.e., slope, number and type of BMPs implemented). To date, NOAA funding has covered $55,000 of the costs per mile, with the remaining costs leveraged from partners.

Since 2015, NOAA's investments have been prioritized in Aeropuerto, Almodovar, Cabra, Coronel, Culebra, Mosquito, Manzanilla, Puerto Manglar, and Fulladosa subwatersheds watersheds based on sediment contributions to nearshore coastal waters and coral reef habitats. Within these priority watersheds, 7 to 100 percent of the entire unpaved road

network per subwatershed has been stabilized (Table 1). Using loading estimates from the Culebra WMP[1] and assuming 50 percent efficiency of these BMPs, approximately 51 metric tons of sediment delivery to the nearshore coast has been prevented per year. This reduction in sediment load represents nearly 13 percent of the total unpaved road contributions across the island! Although this represents significant progress towards NOAA's goal of protecting and restoring coral reef habitats in this region, it is important to recognize that pollution prevention from these roads does not stop after implementation.

The BMPs implemented require long-term maintenance generally consisting of removing sediment from traps, regrading every 3 to 5 years, and replanting if needed. Storm surge damage from Hurricanes Irma and Maria required more significant repairs, including full reconstruction of unpaved parking lots in some locations. When NOAA funds stabilization of unpaved roads on Culebra, they require an MOA from the land-owner (public or private) to assure adequate long-term maintenance of the road. However, without a sustainable funding and maintenance plan, this requires continued education and enforcement. PDC has been able to establish funding mechanisms with private land owners, but long-term contributions to maintenance investments is more difficult from public entities given continued turn-over. Until a more sustainable funding mechanism can be established with our partners, continued education and enforcement will be needed to assure maintenance of the stabilized roads and ultimately protection of our investments.

There is also an additional need for monitoring at the project site and within the nearshore coastal waters to better understand the performance of the BMPs implemented. To date, funding for monitoring has been limited to approximately $3k per mile of unpaved road stabilized. This has allowed for very limited evaluation of our projects and even less of an ability to extrapolate that information into the nearshore habitat.

Prioritizing future NOAA investments

Utilizing the unpaved road inventory, an approach for prioritizing future NOAA funding is proposed that would maximize the sediment reduction benefit of NOAA funding to coral reef habitats. As such, stabilization of unpaved roads should be prioritized in subwatersheds where:

1. Slopes of the road are moderate to high, which means we are targeting those roads that are generally the greatest contributors to erosion and sediment loading.

[1] The Watershed Treatment Model (WTM) was calibrated by regional data (Ramos-Scharron, 20xx) and used to estimate sediment loading contributions from unpaved roads across the island. On average, unpaved roads were estimated to contribute 6.9 tons per year.

2. Proximity to coral is either near and has low to high hydrologic connectivity OR proximity to coral is far but has high hydrologic connectivity, which means that the stabilization of unpaved roads would benefit coral reef habitat.
3. Quality of corals in the drainage area is good, which suggests the projects would benefit corals of the greatest value near the island.
4. Future land protection in the watershed is low and therefore unpaved road stabilization is needed to promote sustainable development within these subwatersheds.
5. Potential partnerships is moderate to high to allow for the greatest ability to leverage funding with NOAA funds.

Accordingly, NOAA should continue to fund the stabilization of unpaved roads in the Coronel, Culebra, Fulladosa, Manzanillo, Mosquito, and Puerto Manglar subwatersheds (see Table below). In addition, NOAA should consider the addition of the Larga and San Isidro subwatersheds to their priority list given the sediment contributions of these unpaved roads and the proximity of good quality coral reef habitat. Furthermore, all of the unpaved roads in the Almodovar subwatershed have been stabilized and no additional NOAA funding is needed to stabilize unpaved roads in the Aeropuerto and Cabra subwatersheds. Therefore, it is suggested that these subwatersheds are removed from the priority list for unpaved road

CURRENT PRIORITIES		**PROPOSED NEW PRIORITIES**	
Subwatershed	Miles remaining	Subwatershed	Miles remaining
Aeropuerto	4.7	Coronel	0.7
Almodovar	0.0	Culebra	1.7
Cabra	3.9	Fulladosa	1.7
Coronel	0.7	Larga	1.5
Culebra	1.7	Manzanillo	0.3
Fulladosa	1.7	Mosquito	1.7
Manzanillo	0.3	Puerto del Manglar	4.1
Mosquito	1.7	San Isidro	1.7
Puerto del Manglar	4.1		
TOTAL	18.7	TOTAL	13.3

stabilization. That being said, it is suggested that NOAA should continue to coordinate with municipal and jurisdictional partners and fund the implementation of demonstration projects in

the Aeropuerto and Cabra subwatersheds to reduce urban pollutants from stormwater runoff and nutrient loadings[2] from the Culebra WWTP.

If NOAA adopts this new list of priorities that would shift the total miles of unpaved road remaining in the priority subwatersheds from 18.7 to 13.3 miles, from the current to the new list, respectively. As such, the total funding needed to stabilize all remaining priority unpaved roads will range from approximately $730,000 to $1.5 million depending on how much funding we are able to leverage from our partners. Given the history of PDC's success in leveraging partnership funds, it is likely that the costs for project implementation would be closer to $730,000. It is important to note that this cost estimate does not include the costs for maintenance, monitoring, or the LBSP management needs highlighted for Aeropuerto and Cabra subwatersheds.

[2] PRASA is not mandated to remove nutrients from the sewage prior to discharging to the nearshore coastal waters. However, the Culebra WWTP is designed to provide tertiary treatment of nutrients. NOAA and their partners have been working with PRASA to update the existing treatment wetlands to enhance nutrient sequestration through the use of floating treatment wetlands. Continued investments in these partnerships and this technology could provide significant benefits to NOAA trust resources which, otherwise, are not mandated.

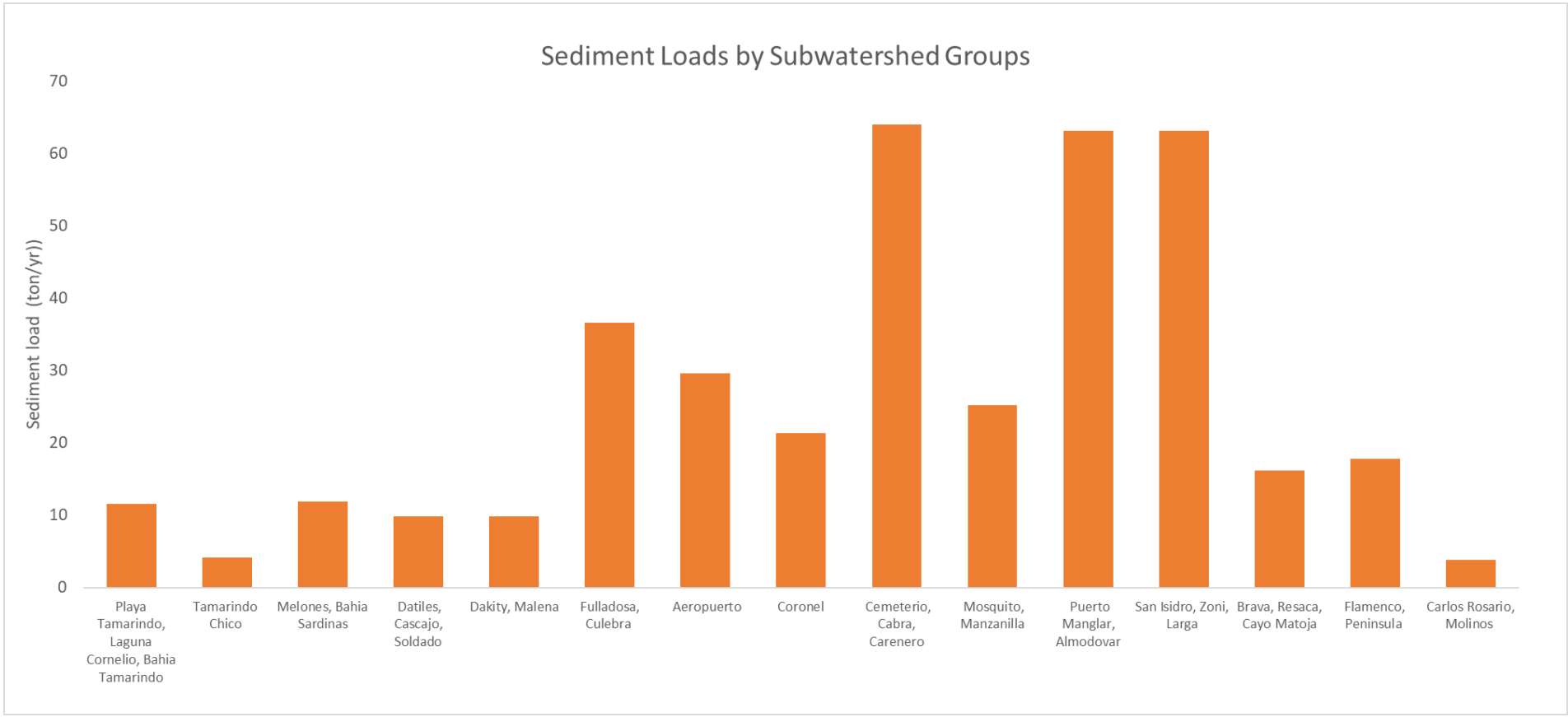

Figure 1. Unpaved road contributions to sediment load per subwatershed group (Culebra Watershed Management Plan, 2013).

Table 1. Subwatershed characteristics used to develop a method for prioritizing NOAA funding for unpaved road stabilization. Methods for defining subwatershed characteristics are described in the subsequent figures.

Subwatershed	Area (acres)	Unpaved roads (miles)	Stabilized (miles)	% Stabilized	General slope of roads	Proximity to Corals	Hydrologic Connection	Quality / Density of Coral	Land protected	Partnership potential
Aeropuerto	646	5.0	0.3	6.75	Moderate	Far	High	Good	Low	Moderate
Almodovar	66	0.7	0.7	100.00	High	Near	High	Good	Low	High
Bahía Sardinas	90	1.3	0.2	17.60	Moderate	Near	High	Fair	Low	Moderate
Bahía Tamarindo	93	1.2	0.1	8.54	Moderate	Near	High	Fair	Low	High
Brava	407	0.2	0.0	0.00	Low	Near	Low	Fair	High	Low
Cabra	1033	7.0	3.1	44.18	Moderate	Far	High	Good	Low	High
Carenero	98	1.5	0.0	0.00	Moderate	Far	Moderate	Good	Low	Low
Carlos Rosario	147	0.0	0.0	0.00	n/a	Near	Low	Good	High	Low
Cascajo	111	1.0	0.0	0.00	Moderate	Near	Low	Fair	Low	Low
Cayo Norte	299	2.2	0.0	0.00	Moderate/High	Near	Moderate	Good	High	Low
Cementerio	58	0.4	0.0	0.00	Low	Far	High	Good	Low	Moderate
Coronel	415	2.7	2.0	74.45	Moderate	Far	High	Good	Low	High
Culebra	90	2.3	0.6	26.67	High	Far	High	Good	Low	High
Dakity	108	0.0	0.0	0.00	n/a	Near	Moderate	Good	High	Moderate
Dátiles	28	0.5	0.0	0.00	Low	Near	Moderate	Fair	Low	Moderate
Flamenco	657	2.5	0.0	0.00	Low	Near	High	Fair	High	High
Fulladosa	169	3.3	1.7	50.03	High	Far	High	Good	Low	High
Laguna Cornelio	96	0.6	0.0	4.58	Low	Near	Moderate	Fair	Low	High
Larga	121	1.5	0.1	3.90	Moderate	Near	High	Good	Low	High
Malena	60	0.4	0.4	100.00	Moderate	Near	High	Good	High	High
Manzanillo	43	1.1	0.8	75.58	High	Near	High	Good	Low	High
Melones	48	0.7	0.0	0.00	Moderate	Near	Moderate	Fair	Low	Moderate
Molinos	37	0.0	0.0	0.00	n/a	Near	Low	Good	Low	Low
Mosquito	193	2.5	0.8	30.74	High	Near	High	Good	Low	High
Península	159	0.0	0.0	0.00	n/a	Near	Low	Good	High	Low
Playa Tamarindo	49	0.2	0.0	0.00	Low	Near	Low	Fair	Low	Moderate
Puerto Manglar	725	7.1	3.0	42.87	Moderate/High	Near	High	Good	Low	High
Resaca	378	0.3	0.0	0.00	Moderate	Near	Low	Fair?	High	Low
San Isidro	219	2.1	0.4	81.33	High	Near	High	Good?	Low	High
Soldado	18	0.0	0.0	100.00	Low	Near	Low	Good?	High	High
Tamarindo Chico	50	0.5	0.0	0.00	Low	Near	Moderate	Fair	Low	Low
Zoní	191	1.0	0.6	65.04	Low	Near	High	Fair	Low	Moderate

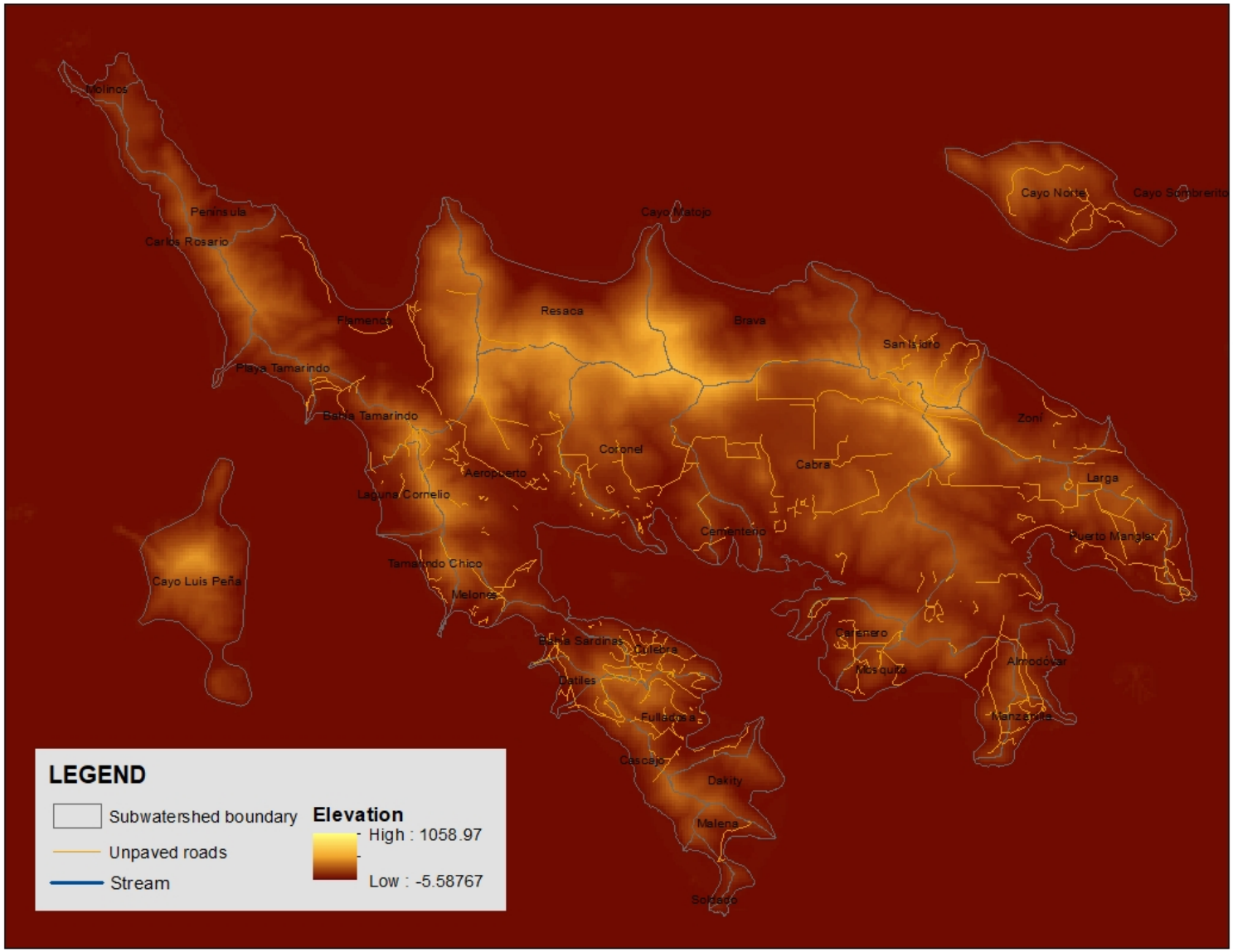

Figure 2. National elevation maps and the unpaved road inventory were used to characterize 'general slope of roads' in each subwatershed. Method generally consisted of qualifying slope by 'Low', 'Moderate', or 'High' by comparing the average difference in elevation on roads within each subwatershed. Subwatersheds characterized as 'Low' either had relatively low elevations across the subwatershed or the roads were generally positioned within the watershed to limit changes in elevation across their length. Subwatersheds that were characterized as 'High' typically had relatively significant elevation changes across the watersheds and across the length of the roads. Lastly, subwatershed that were characterized as 'Moderate' were those that either had moderate changes in elevation across the watershed or consisted of roads with a mixture of slopes throughout the subwatershed. All slope categories were field verified.

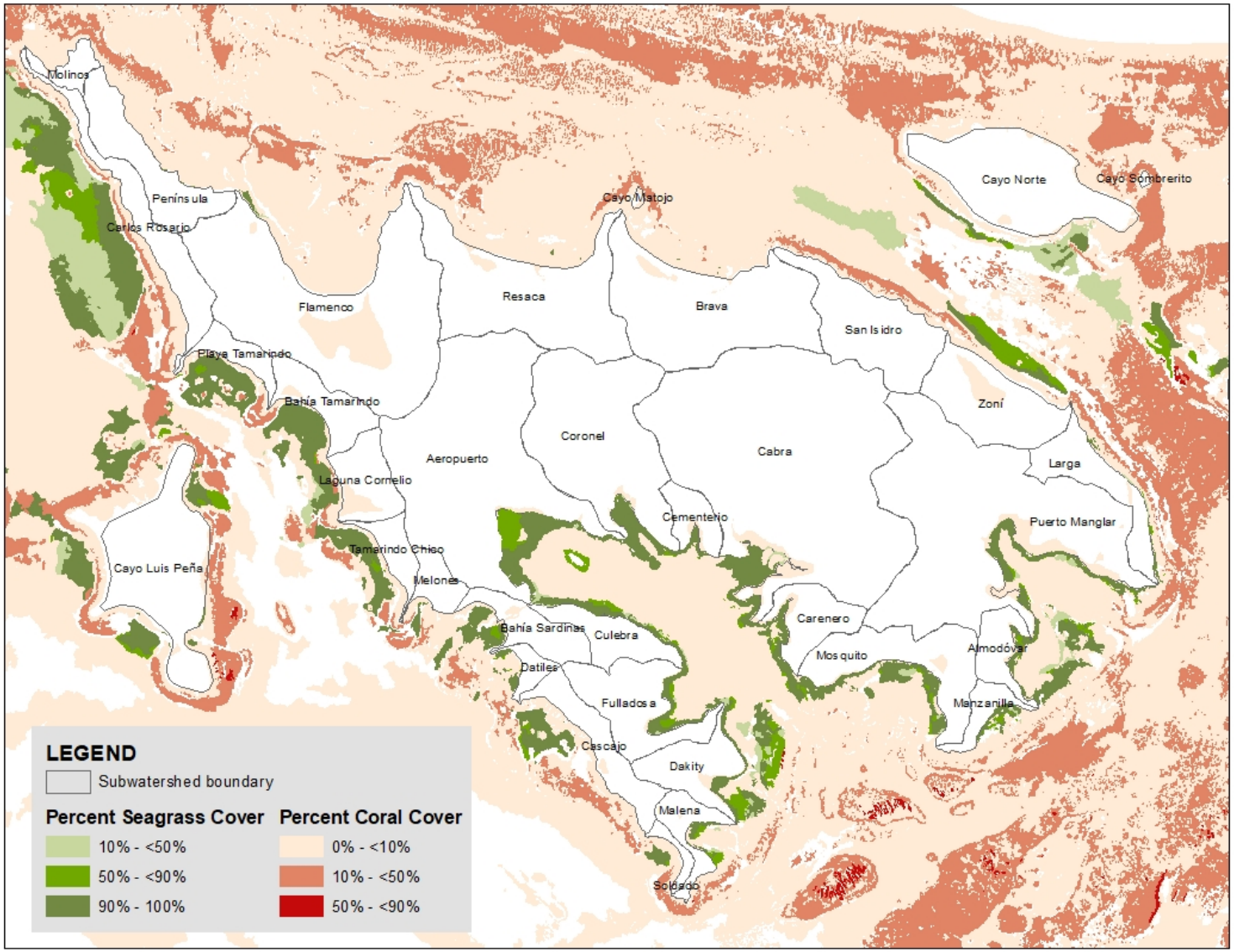

Figure 3. NOAA benthic habitat maps were used to characterize subwatersheds by 'Proximity of Corals' and 'Quality/Density of Corals' within each subwatershed's drainage area. Subwatershed 'Proximity to Corals' was characterized as 'Near' or 'Far'. All subwatersheds along the perimeter of the island were qualified as 'Near' and the subwatersheds that drained primarily into Ensenada Honda were characterized as 'Far'. The 'Quality/Density of Corals' that each subwatershed drained to was characterized as 'Good' or 'Fair'. Those subwatersheds that drained into a relatively large aerial extent of corals or corals with greater percent coverage (>50%) were qualified as 'Good'. On the other hand, those subwatersheds that drained to a relatively small aerial extent of corals with lower percent coverage (<50%) were qualified as 'Fair'.

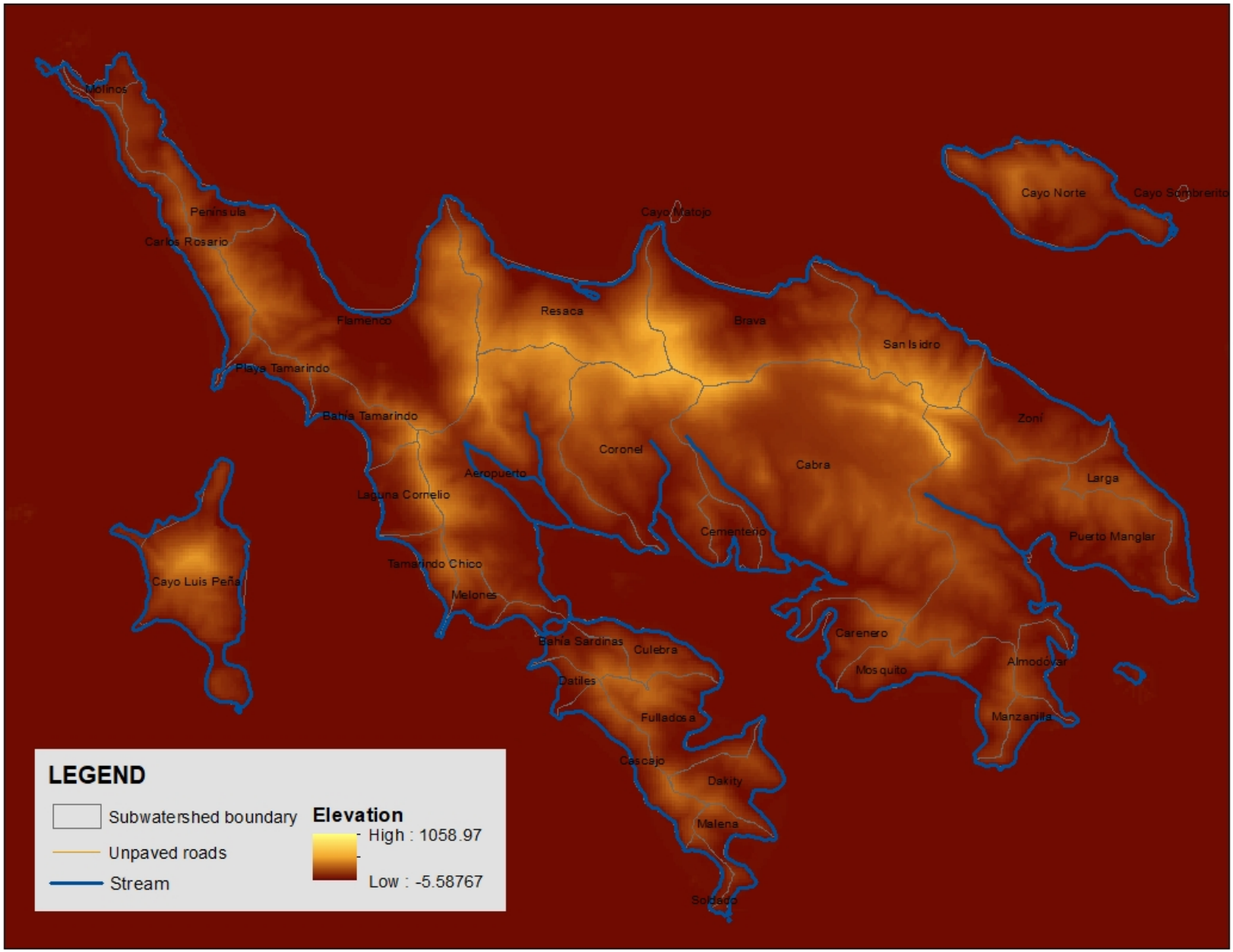

Figure 4. USGS stream data was combined with in-field knowledge of existing drainage systems to characterize the hydrologic connectivity of each subwatershed. Subwatersheds were qualified as 'High' if there were known natural or artificial drainage systems that discharged directly to the coast. Subwatersheds were qualified as 'Low' if there were no known natural or artificial drainage systems that discharged directly to the coast.

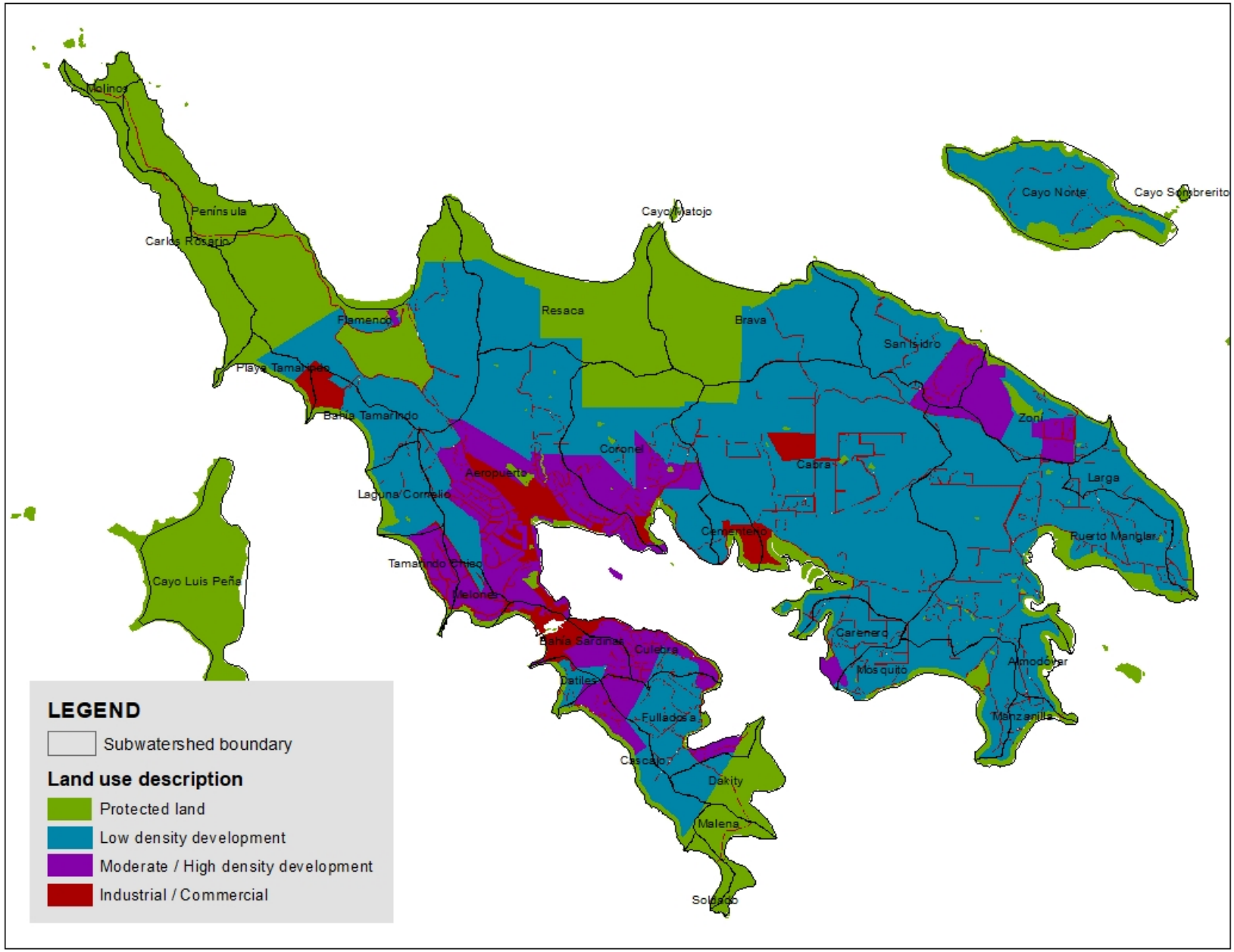

Figure 6. Data used to characterize 'Land Protection' within each subwatershed. Each subwatersheds was characterized as having 'Low' or 'High' land protection value based on land use zoning. Those subwatersheds that had more than 50% of their land protected were qualified as 'High' land protection value, while those that had less than 50% of land protected were qualified as having 'Low' land protection value.

Table 2. Summary of unpaved road stabilization projects, subwatershed location, funding, and contributing partners. Note this table does not include funding from CRCP FY17 and FY18 since the funding was used for hurricane repairs and floating treatment wetlands in the Culebra WWTP. Similarly, it does not include funding from OHC 2018 since the funding is going toward mangrove restoration projects.

Project Title	NOAA Funding Source	Fiscal Year	Subwatershed	NOAA Funds	Leveraged Funds	Miles Stabilized	Partners
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-2013	CRCP	2011	Puerto Manglar	$62,000	n/a	n/a	NOAA, DRNA, GME, RTR, HOAs
	CRCP	2012	Bahia Tamarindo	$43,976	$46,750	n/a	NOAA, DRNA, USFWS, Culebra Municipality, Abbie's School, Escuela Ecologica, RTR
	CRCP	2013	Zoní, Bahía Sardinas	$28,000	$26,200	0.6	NOAA, DRNA, USFWS, Culebra Municipality, Abbie's School, RTR
	CRCP	2014	Fulladosa, Bahia Tamarindo	$81,925	$64,100	0.5	NOAA, DRNA, USFWS, Culebra Municipality, HWG
	CRCP	2015	Puerto Manglar, Fulladosa, Culebra	$106,640	$113,900	0.7	NOAA, DRNA, USFWS, Culebra Municipality, HWG, HOAs
	CRCP	2016	Puerto Manglar, Almodovar, Manzanilla	$91,475	$110,000	1.1	NOAA, DRNA, USFWS, Culebra Municipality, HWG, HOAs
Addressing Land Based Sources of Pollution and Restoring Reefs Through Coral Farming at Punta Soldado, Culebra Puerto Rico	CRCP	2016	Malena, Soldado	$26,000	$28,000	0.4	NOAA, DRNA, USFWS, Culebra Municipality, Abbie's School, RTR
Building Resiliency in the Puerto Rico Northeast Reserves by reducing Recreational Impacts, addressing Land-based Sources of Pollution (LBSPs), and Restoring Coral Reef Habitat.	OHC	2015	Aeropuerto Manzanilla	$79,759	$75,441	0.4	NOAA, DRNA, USFWS, Culebra Municipality, HWG, HOAs
	OHC	2016	Puerto Manglar, Mosquito, Manzanilla	$62,026	$61,166	1.2	NOAA, DRNA, USFWS, Culebra Municipality, HWG, HOAs
Expanding Efforts on Building Resiliency in the Puerto Rico Northeast Reserves by Addressing Land-based Sources of Pollution (LBSPs) and Restoring Coral Reef Habitat	OHC	2017	Cabra, San Isidro, Puerto Manglar, Zoní	$113,100	$150,208	4.3	NOAA, DRNA, USFWS, Culebra Municipality, HWG, Para la Naturaleza
Implementation of NOAA's Habitat Blueprint Focus Area Priority Actions in Culebra Island, Puerto Rico to restore Coral Reef Critical Habitat	RC	2016	Fulladoza	$83,385	$109,854	1.4	NOAA, DRNA, USFWS, Culebra Municipality, HWG, HOAs
	RC	2017	Coronel, Aeropuerto	$68,035	$67,585	2.3	NOAA, DRNA, USFWS, Culebra Municipality, HWG
	RC	2018	Puerto Manglar, Larga	$89,832	$96,970	2.2	NOAA, DRNA, USFWS, Culebra Municipality, HWG, HOAs

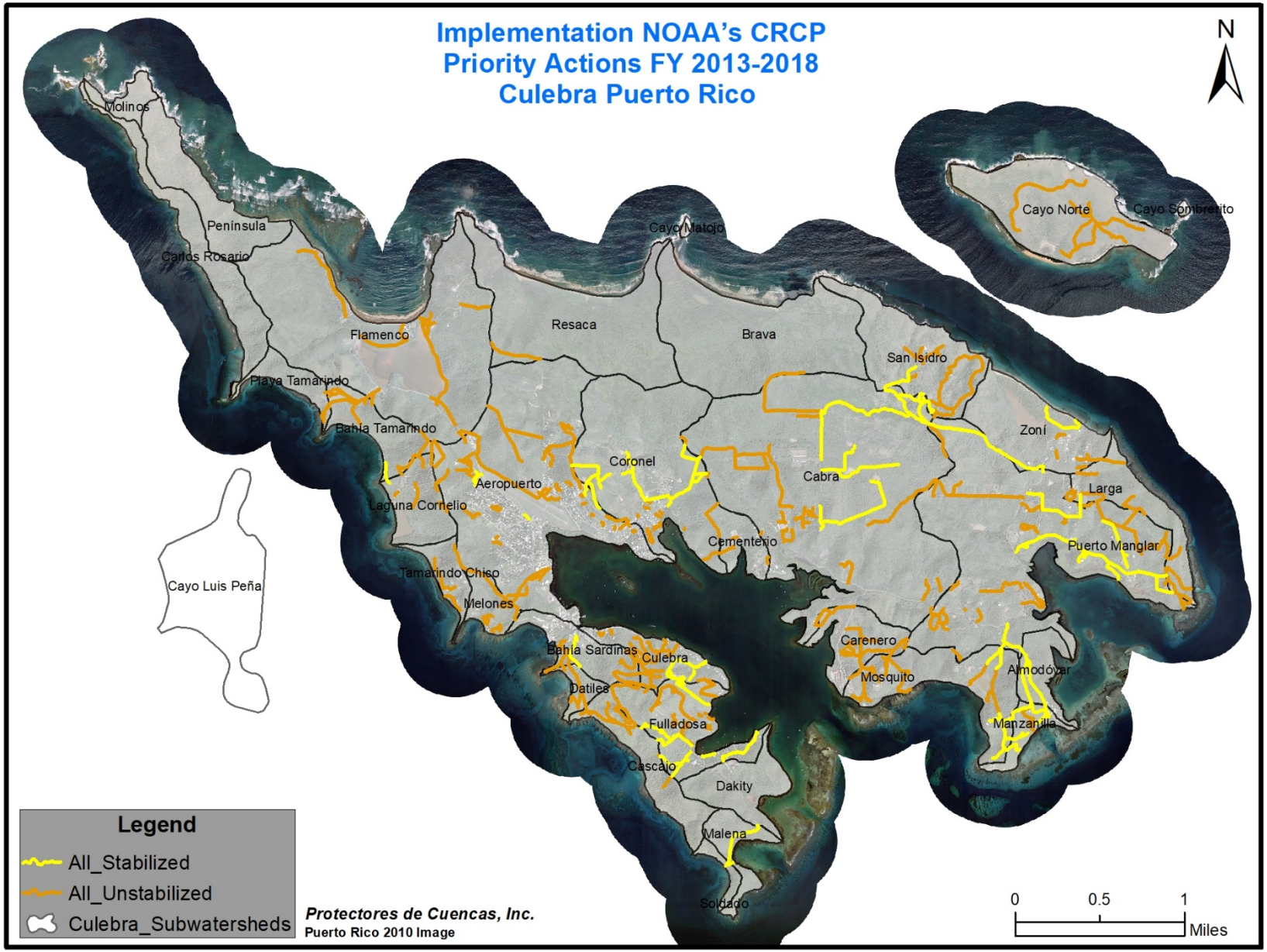

Figure 7. Map of the stabilized and unstabilized unpaved road system in Culebra.