University of Puerto Rico-Mayagüez

College of Arts and Sciences

Department of Geology

Shoreline Analysis in Villa Pesquera (Isabela) and Steps Beach (Rincón) during the last 90 years.

Manuel Iván Ramos Rodríguez

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GEOL 4049: Undergraduate Research I

Advisor: Prof. Fernando Gilbes, Ph. D.

Co-Advisors: Prof. Wilson Ramirez, Ph. D. and Gwendelyn Monge, Graduate Student

I. Abstract

This undergraduate research evaluated the shoreline erosion in Steps Beach in Rincón and Villa Pesquera in Isabela. Aerial Photographs and satellite images from 1930, 1975, 2010 and 2017 were used to analyze the shoreline changes. For quantitative results the DSAS software installed in ArcGIS 10.5 was used to create transects that analyzed the general shoreline and the areas were the beachrock was located. The general shoreline analysis showed that the area of Steps Beach is eroding at a rate of 0.06 m/yr. The analysis of the photos in which the beachrock was visible in Steps Beach showed a higher rate of erosion of 0.28 m/yr. The general shoreline analysis of Villa Pesquera showed a general trend of deposition of 0.02 m/yr but had areas were significant deposition and erosion were showed. One such area of deposition was where the beachrock was exposed and the analysis showed deposition of 0.152 m/yr. The DSAS software was able to analyze the simple horizontal shorelines but experienced problems when dealing with cliffs and complex landforms giving abnormal values and was very limited when analyzing the beachrock.

Keywords: Shoreline, Beachrock, DSAS, Erosion

II. Introduction:

Shorelines all over the world are retreating in a landward direction, a process called shoreline retreat or shoreline erosion (Pilkey et al., 2009). Coastal erosion is a widespread and ongoing process in Puerto Rico (Bush et al., 1995). Much of the sandy shoreline of Puerto Rico is in a state of change that includes erosion (Bush et al., 1995). Erosion is just a part of coastal evolution meaning that a beach is simply changing its location (Bush et al., 1995). There is no erosion ‘problem’ until a structure is built on a shoreline; beach erosion is a common and expected event, not a natural disaster (Bush et al., 1995). According to Pilkey et al. (2009) probably 80-85%

of the Earth's shorelines are retreating and the major causes of this are sea-level rise, reduction in sand supply to the shoreline by human intervention (damming of rivers, armoring of shorelines and dredging of navigation channels), shoreline engineering, wave energy and storm frequency. Construction on the shoreline can affect the very delicate balance between sand supply, beach shape, wave energy, and sea-level rise (Bush et al., 1995). Construction near or on the shoreline can 'reduce the natural flexibility of the beach' and result in increased erosion that threaten those constructions (Bush et al., 1995). Methods to "solve" shoreline erosion can cost a lot but include the construction of seawalls, beach nourishment, and relocation or abandonment of buildings (Pilkey et al., 2009). Rates of erosion vary along the coasts, for example on sandy (as opposed to rocky) shorelines common retreat rates are along 1 m, +/- 0.5 m per year (Pilkey et al., 2009).

Villa Pesquera is located at the northwest coast in Isabela while Steps beach is located in the western coast of Puerto Rico in Rincón (Figure 1). Villa Pesquera is a high energy beach and its beach deposits are composed of quartz sand, shell fragments, and grains from other minerals (Monroe, 1969). On the other hand Steps beach is underlain by the Rio Culebrinas Formation and consist of siliceous and calcareous mudstone and limestone (McIntyre, et al. 1970). The sand in Steps beach is mostly composed of shell fragments, quartz grains and other minerals (Monroe, 1969). These study areas have beachrock deposits and are currently being studied by Gwendelyn Monge in her graduate research (Figure 2). Pilkey et al., 2009, defines beachrock (Figure 3) as a "friable to well-cemented sedimentary rock in the intertidal zone, generally in tropical or subtropical regions" (occurring sometimes at mid latitudes) and is composed "of sand or gravel size particles (detrital and/or skeletal) cemented by calcium carbonate". Scoffin and Stoddart (1987) defines beachrock as "the consolidated deposit that results from lithification by calcium carbonate of sediment in the intertidal and spray zones of mainly tropical coasts". These units form

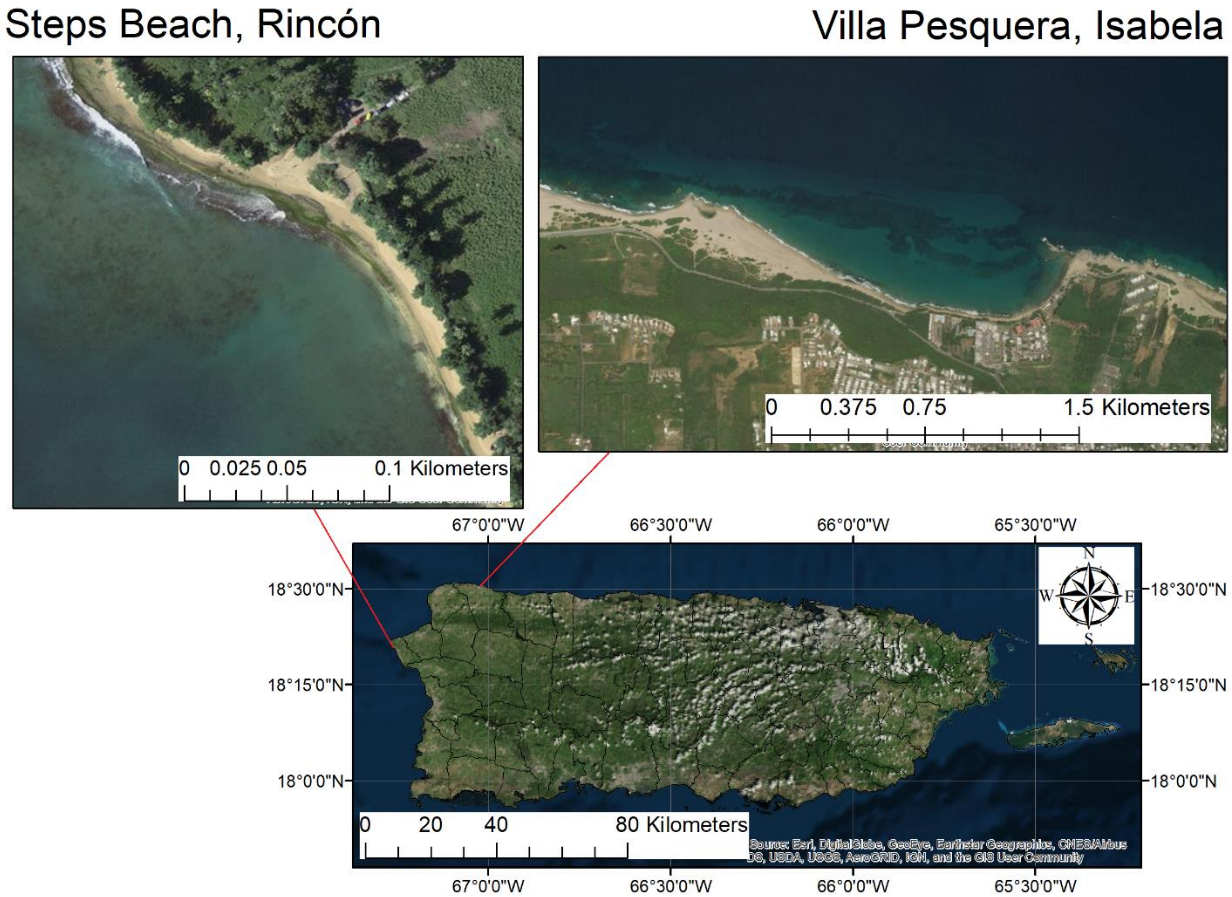


Figure 1. Study Areas of Villa Pesquera and Steps.

Figure 2. Beachrock exposure in Villa Pesquera Isabela (picture by Gwendelyn Monge).

under a thin cover of sediment and generally overlie unconsolidated sand, although they may rest on any type of foundation (Turner, 2005). Beachrock forms within the beach or beach ridges behind the present beach, and has been exposed in its present position on the beach by coastal retreat (Hopley, 1986). Sea level researchers have used them as guides to past sea levels (Hopley, 1986). They can also help as sea-level indicators and identifier of the coasts evolutionary history because of its wide distribution and extension on long stretches of coastlines (Kelletat, 2006). The great majority of beachrocks are found in tropical/subtropical and low temperate latitude, microtidal coasts (Vousdoukas et al., 2007). Modern outcrops may promote offshore loss of unconsolidated beach sediments and buried beachrock outcropping (Vousdoukas et al., 2007). Their presence have also significant ecological impacts, as the fauna and flora of the beach is replaced (Vousdoukas et al., 2007). According to Turner (2005) rates of beachrock formation are on a scale of month to years and most occurrences of intertidal beachrock is less than 2,000 years old. Erosion rates can be quantified by analyzing the shorelines where the present beachrock is and, if one were to study a larger interval of time, comparing the past outcrops of beachrock left offshore with the current shoreline.

Studies analyzing shoreline changes in Puerto Rico have been done by Robert Thieler, Rafael Rodriguez and Emily Himmelstoss (2007). They used the “Digital Shore-line Analysis System (DSAS)” to study the coastal changes in Rincón over the course of 70 years (1936-2006) and arrived to the conclusion that the erosion in the study area was most likely caused by not only natural but also human induced causes (Thieler et al., 2007). This study also recognized various factors that can affect shoreline evolution: underlying geology, interactions between the bathymetry and waves and/or currents, long-term rise in sea-level and hard stabilization (structures built to reduce waves) along the coast (Thieler et al., 2007). Beachrock in Puerto Rico occur mostly along the north coast and in some beaches of the west coast (Kaye, 1959). In some beaches of the island the cemented zones are widely exposed, due to the natural removal of the beach sands (Kaye, 1959).

The objectives of this research were:

a. Further help in the understanding of coastal erosion in Puerto Rico.
b. Use DSAS to quantify the coastal erosion or regression experienced in the study areas while confirming the use of the presence of beachrock as a viable method to track these coastal changes in Puerto Rico.
c. Compare the changes between the DSAS analysis of the shorelines and the DSAS analysis of the areas where beachrock is visible.

III. Methodology:

1. Aerial Photographs

This research utilized a total of 12 aerial photographs from 1930, 1975, 2010 and 2017. Photos from 2010 and 2017 were provided by the Geological and Enviroment Remote Sensing (GERS) laboratory, and photos from 1975 were found on the Earth Explorer Website. The datum for the 2010 photos is NAD 1983 State Plane Puerto Rico and Virgin Islands, their units are in meters and they have a total of 3 bands. The 2017 images from the study areas have the same datum, and units, but have a total of 4 bands. These 2017 images are after a post-storm event, as they were taken after hurricane Maria and in the case of the Villa Pesquera 2017 area a total of 4 images were provided with each one covering a part of the study area. On the other hand the 1975 aerial photographs from Earth Explorer are in Black and White, have 1 band, and were not georeferenced.

While initially the study aimed for study of the last 50 years the website "Porto Rico 1930 Georeferenced: A Mosaic of the Coast" provided an opportunity with its already georeferenced (NAD 1983 State Plane Puerto Rico and Virgin Islands) black and white mosaic of aerial 1930 photographs of the study area, these have a unit of 1 meter. In summary all images were previously georeferenced except the 1975 photographs, but using the ESRI ArcGIS 10.5 desktop software they were georeferenced (using particular locations, roads, buildings, and coastal rocks that were present in the 2010 images) so that they all follow the same coordinate system. The georeferencing was validated by comparing those particular locations close to the shore through the 1975 and 2010 photographs.

2. Shoreline Change

The shoreline changes in this study were analyzed with the ESRI ArcMap 10.5.1 software and its tool called Digital Shoreline Analysis System (DSAS). DSAS is an application developed by the US Geological Survey (Thieler et al., 2007). It is a free ArcGIS software with focus on the calculation of rate- of- change statistical analyses (Thieler et al., 2007).

The different shorelines (of the whole area and of where the beachrock was visible) was delineated using linear shapefiles. In the case of the 2017 Villa Pesquera photos, the shoreline was delineated while overlapping the different images. These shapefiles were digitalized between the visible divide between the sand and the water. For reference the beachrock exposure or beachrock very close to the shore was also digitalized using a polygon shapefile. The shoreline along these areas were digitalized separately to view the shoreline change in the areas that have beachrock. Using the ArcMap Editor the value of "DATE_" was added to the shapefiles, this is necessary for the calculations done by DSAS. All of the different shapefiles of the two study areas were later stacked in order to provide a visual representation of their change through the years.

DSAS provides a mean for quantifying the shoreline changes once all shoreline shapefiles are completed. The ones that were used for this study were Net Shoreline Movement, End Point Rate and Simple Linear Regression. The Net Shoreline Movement (NSM) is associated with the date of only two shoreline as it calculates the distance in meters between the oldest and youngest shorelines (Thieler et al., 2009). The End Point Rate (EPR) reported as meters/years calculates the distance between the oldest and youngest shorelines and divides it by the time passed between them in each transect (Thieler et al., 2009). According to Thieler et al. (2009) the Simple Linear Regression (LRR) is determined by "fitting a least-squares regression line to all shoreline points for a particular transect." The linear regression rate is given in meters per year and is also the slope (m) of the regression line ($y = mx + b$) (Thieler, et. al., 2009). What is looked for primarily in this last analysis is an alternative to the EPR in analyzing the change in shorelines. The three statistical parameters were calculated for four groups of stacked shorelines. These are:

a. The 1930, 1975, 2010 and 2017 shorelines shape files of Steps Beach.
b. The shapefiles of Steps Beach where the beachrock was visible (1975, 2010, 2017).
c. The 1930, 1975, 2010 and 2017 shoreline shapefiles of Villa Pesquera.
d. Shoreline Shapefiles (1930, 1975, 2010, 2017) in an area in the eastern side of Villa Pesquera where beachrock was visible.

For these four groups of shorelines a baseline was created. This baseline was created as a polyline in ArcMap. For this the buffer method was used, placing the baseline completely offshore while following the movement of the shapefiles (mainly the 2010 shapefile). The values of "OFFshore" and "CastDir" were added to the baseline using the Editor. These values determine where is the baseline and where the transects will be generated. The OFFshore field was added with a value of 0 meaning that the segment of the baseline or the complete baseline is onshore (if the baseline or baseline segment were offshore by any case the value imputed would be 1). The CastDir field was placed with a value of 0 resulting in the transects being cast to the left of the baseline (a value of 1 would result in the transects being cast to the right). The transects were generated by DSAS with a transect spacing of 25m and a transect length of 80m. The stacked shorelines, baseline, and transects were all contained in Personal Geodatabase Files, one for each group analyzed. Once DSAS had generated the transects, quantitative results were provided.

IV. Results and Discussion:

The shoreline analysis of Steps beach from 1930 to 2017 was done with 13 transects. Figures 3-6 represent the individual shorelines while Figure 7 and 8 represent the transects and their calculations. These gave an average End Point Rate of -0.06 m/yr with standard deviation of 0.07 m/yr. The Net Shoreline Movement was -4.94 m with a standard deviation of 6.03 m. The Simple Linear Regression was -0.05 m/yr with a standard deviation of 0.07 m/yr. These negative values represent an erosion in the shoreline of the study area. A constant regression can be seen from 1975 to 2017 with the exception of transects 12 and 13 in which the 2017 shoreline seemed to overlap the 2010 shoreline. On the other hand the 1930 shoreline seemed to break the norm, in the 1930 aerial photograph the steps shoreline was visibly more inland. This difference had an effect on transects 4, 5 and 6 which had positive showed a positive endpoint rate of 0.03, 0.07 and 0.04 m/yr respectively. These three transects also had a positive net shoreline movement (2.61, 6.23 and 3.64 m) and a positive simple linear regression (0.01, 0.09 and 0.05 m/yr). Apart from these three transects the rest showed negative values. The lowest End Point Rates identified were

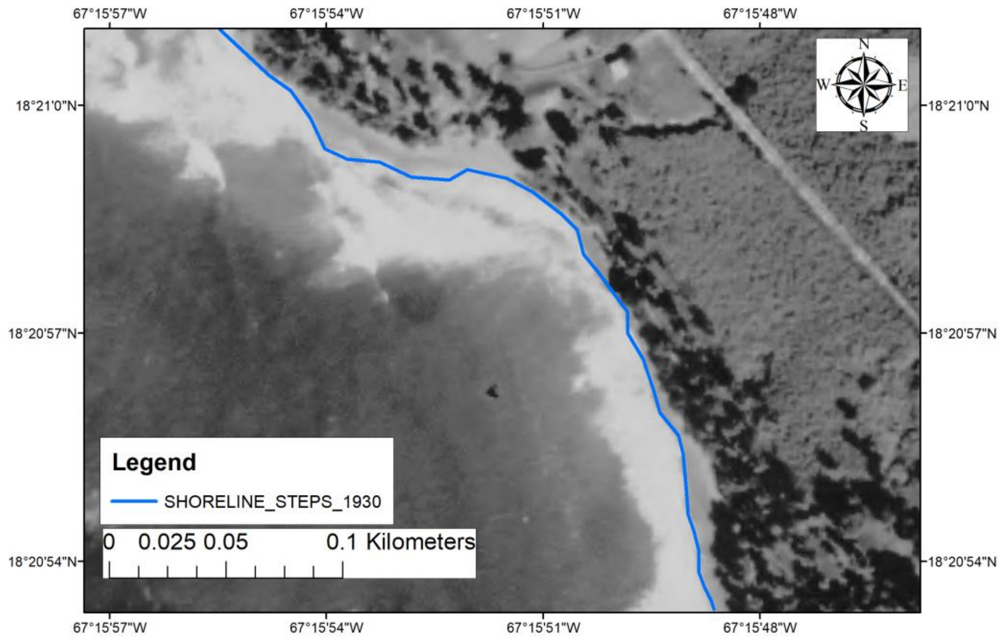


Figure 3. Shoreline of Steps Beach in 1930. Image was taken from the website "Porto Rico 1930 Georeferenced: A Mosaic of the Coast" (Lopez et al. 2017).

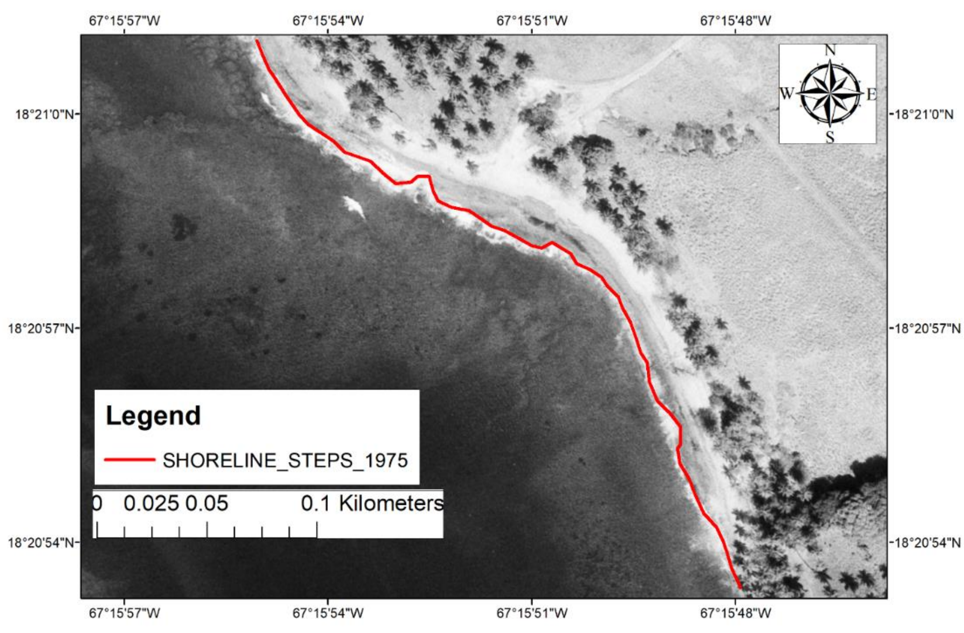


Figure 4. Shoreline of Steps Beach in 1975. Image was taken from EarthExplorer.

Figure 5. Shoreline of Steps Beach in 2010. Image provided by GERS.

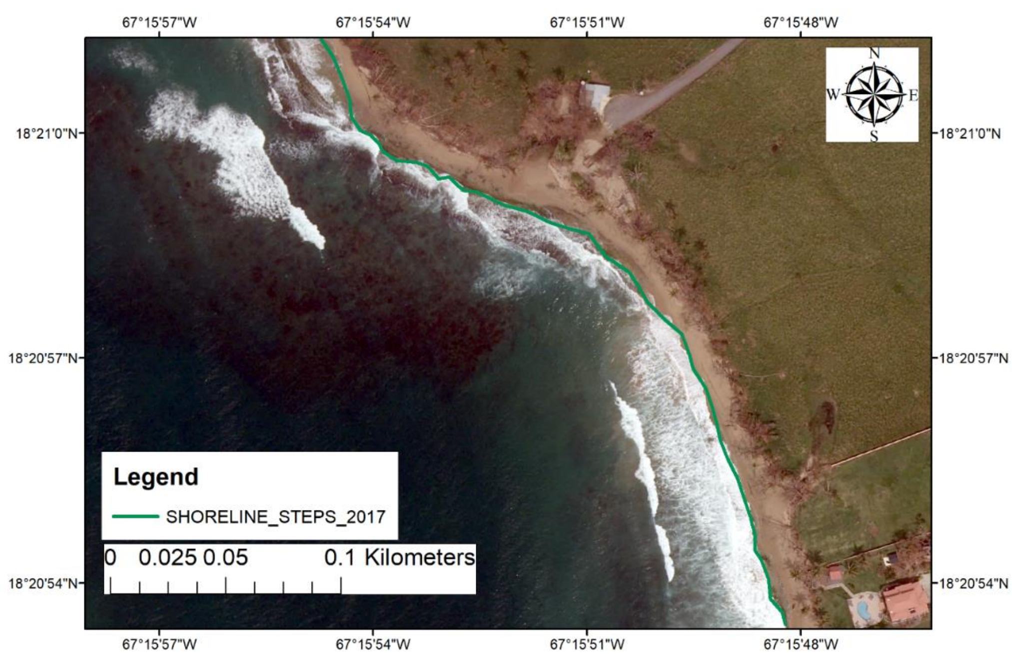


Figure 6. Shoreline of Steps Beach in 2017. Image provided by GERS Lab.

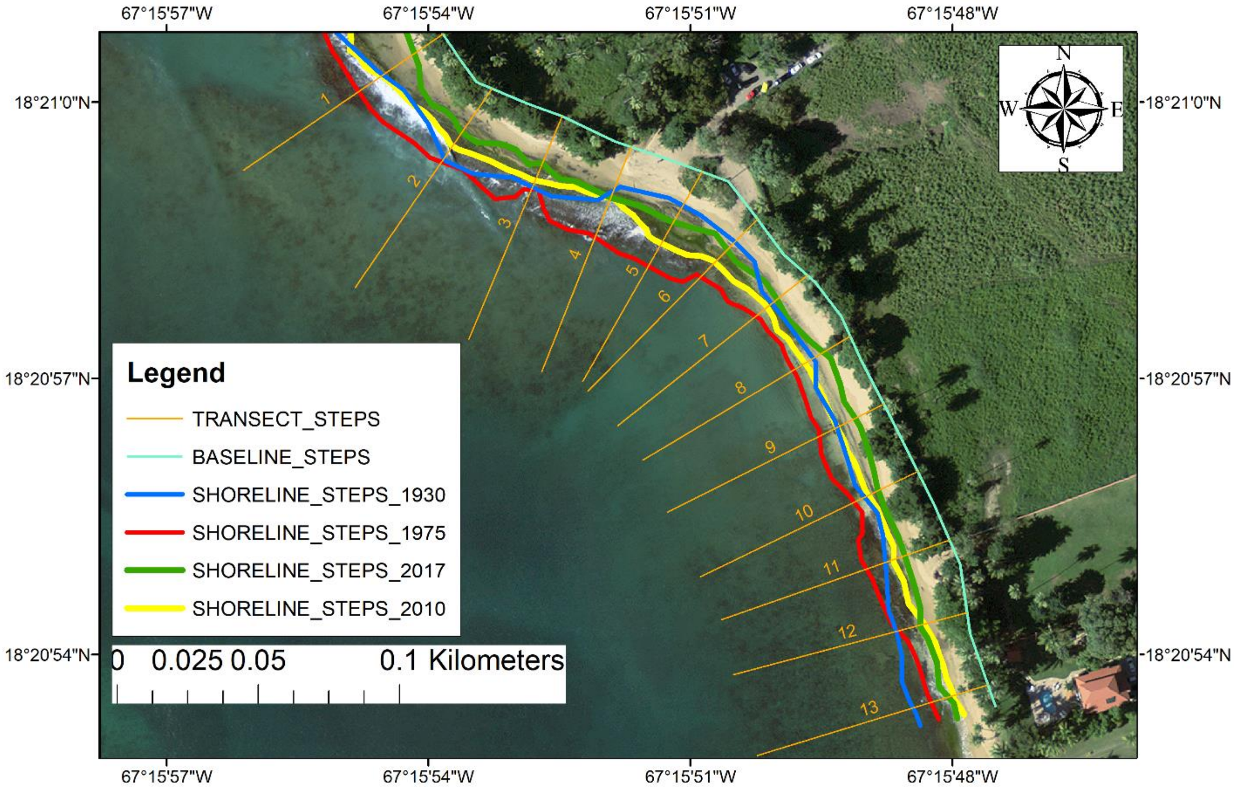
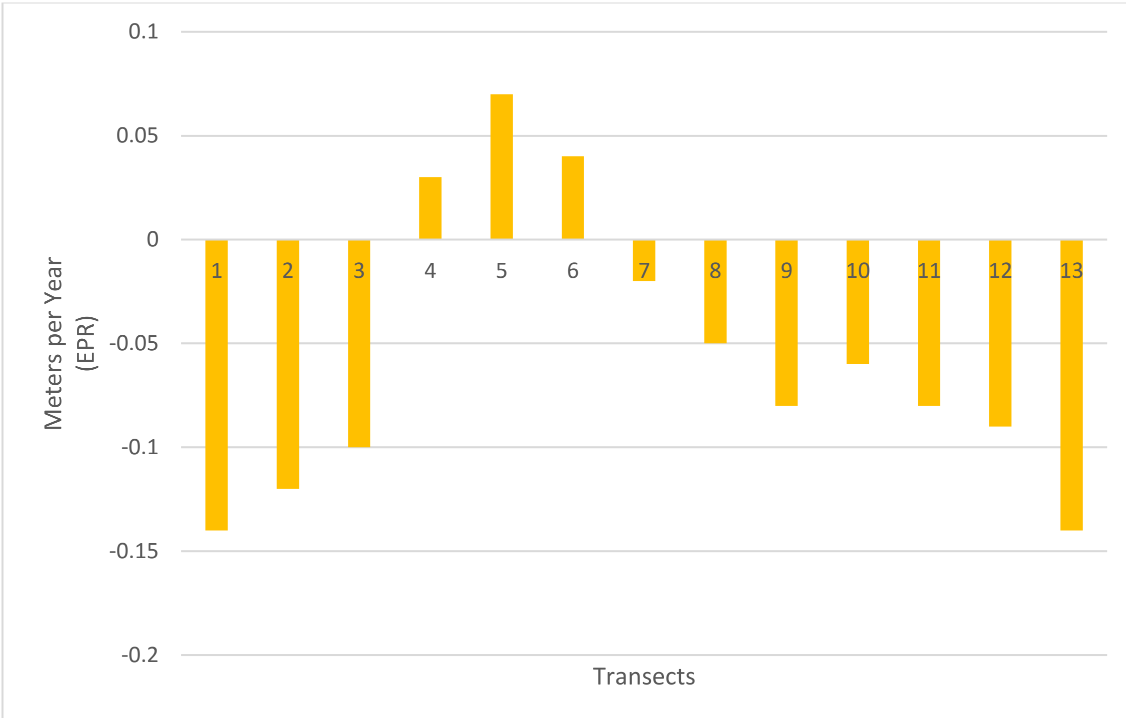


Figure 7. Transects on Steps Beach created with all of the shorelines.



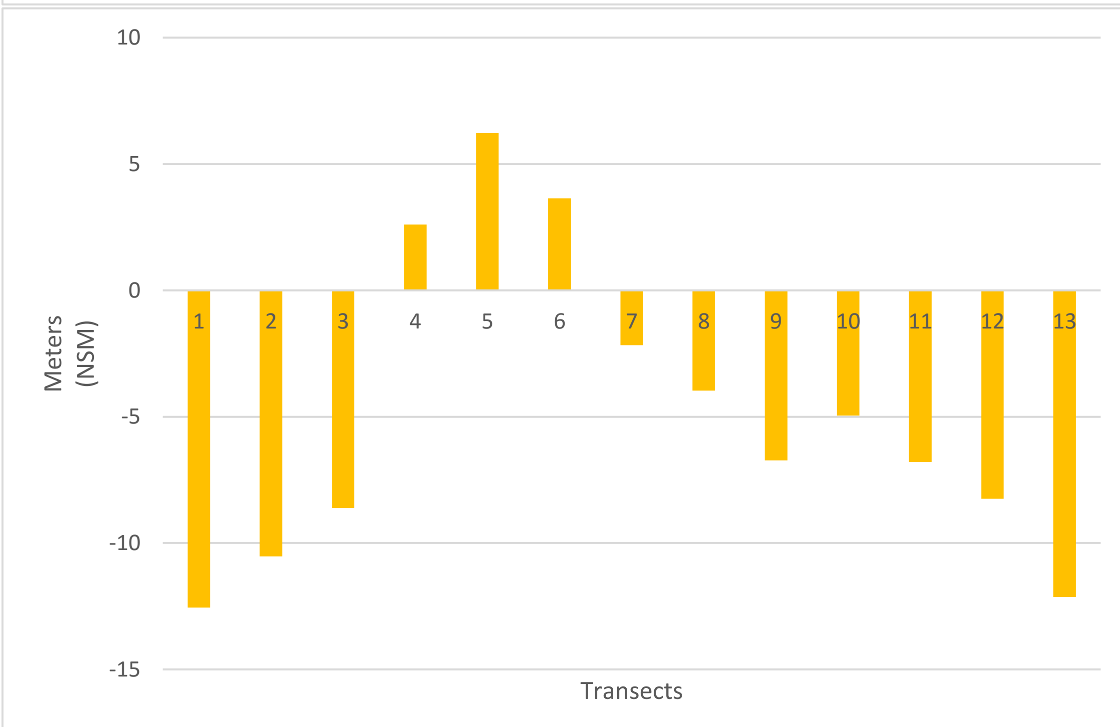


Figure 8. Graphs of the End Point Rate and Net Shoreline Movements for the Transects calculated using all the images in Steps Beach. Negative values indicate erosion and positive values deposition.

located in transects 1 and 13 as with -0.14 m/yr each. Thieler, et al. (2007), analyzed the region from Punta Higüero to the Balneario, this area included Steps Beach and had an average erosion rate of -0.2 m/yr with a standard deviation of 0.1 m/yr. Considering the standard deviation even though the value calculated was higher it is still within the possible range.

The beachrock was visible alongside the shoreline of Steps Beach in the 1975, 2010 and 2017 shoreline. Figure 9-11 show the beachrock (exposed or close to shoreline) of all the images where it was visible while Figure 12 and 13 represent the transects taken and their analysis. With the analysis of these shorelines a pattern of regression was visually notable and further confirmed by the values given: an average End Point rate of -0.28 m/yr with a standard deviation of 0.1 m/yr. The average Net Shoreline Movement was -12.04 meters with a standard deviation of 4.28 meters. The average Simple Linear Regression was -0.26 m/yr with a standard deviation of 0.08 m/yr. The lowest value of End Point Rate was of -0.52 m/yr in transect 1. This transect also had the lowest value of Simple Linear Regression was -0.44 m/year. While still in the range (considering the standard deviation) of Thieler's overall calculation of the area the average End Point Rate of this group is significantly higher than the overall Steps shoreline.

The shoreline analysis for Villa Pesquera resulted in an average End Point Rate of 0.02 m/yr with a Standard Deviation of 0.19 m/yr. The average Net Shoreline Movement was 1.75 m with a Standard Deviation of 16.76 m. The average Simple Linear Regression was 0.04 m/yr with a standard deviation of 0.19 m/yr. Generally these positive values mean deposition but with a high standard deviation it is not certain. The high standard deviation could be due to the variation of areas with accretion and areas with regression and due to the fact that transects 87 and 88 could not follow well the formation near Playa Jobos and gave seemingly abnormal values of EPR, NSM and LRR. The eastern most area contains transects 2-11 showed variability in erosion and accretion

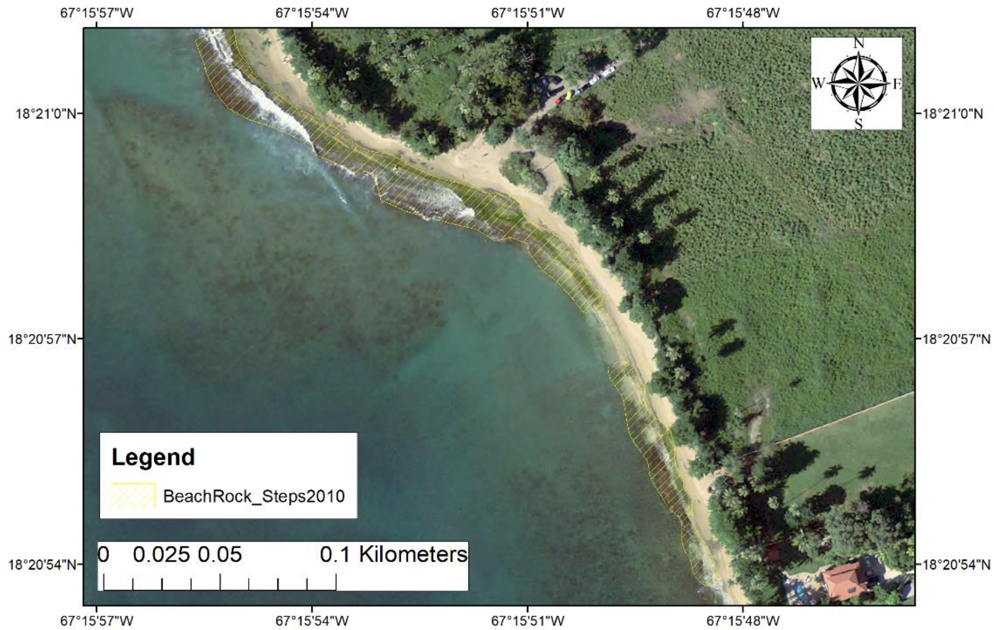


Figure 9. Beachrock (exposed or close to shoreline) of Steps Beach in 2010. Image provided by GERS Lab.

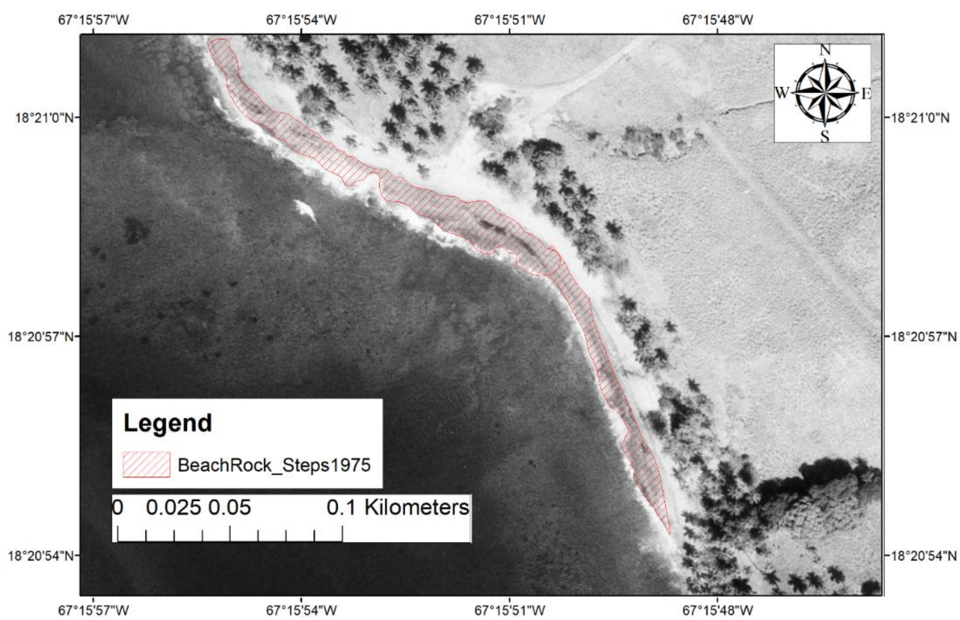


Figure 10. Visible Beachrock (exposed or close to shoreline) of Steps Beach in 1975. Image taken from Earth Explorer.

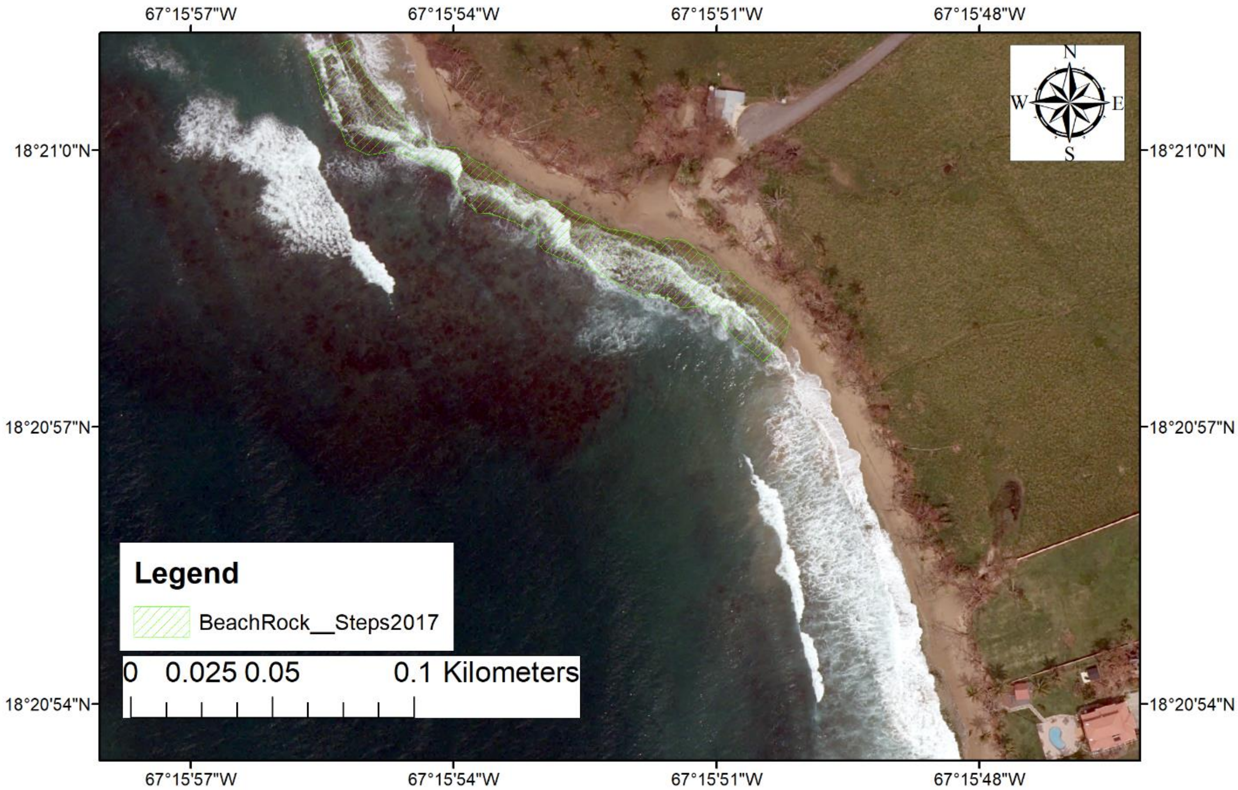


Figure 11. Visible Beachrock (exposed or close to shoreline) of Steps Beach in 2017. Image taken provided by GERS Lab.

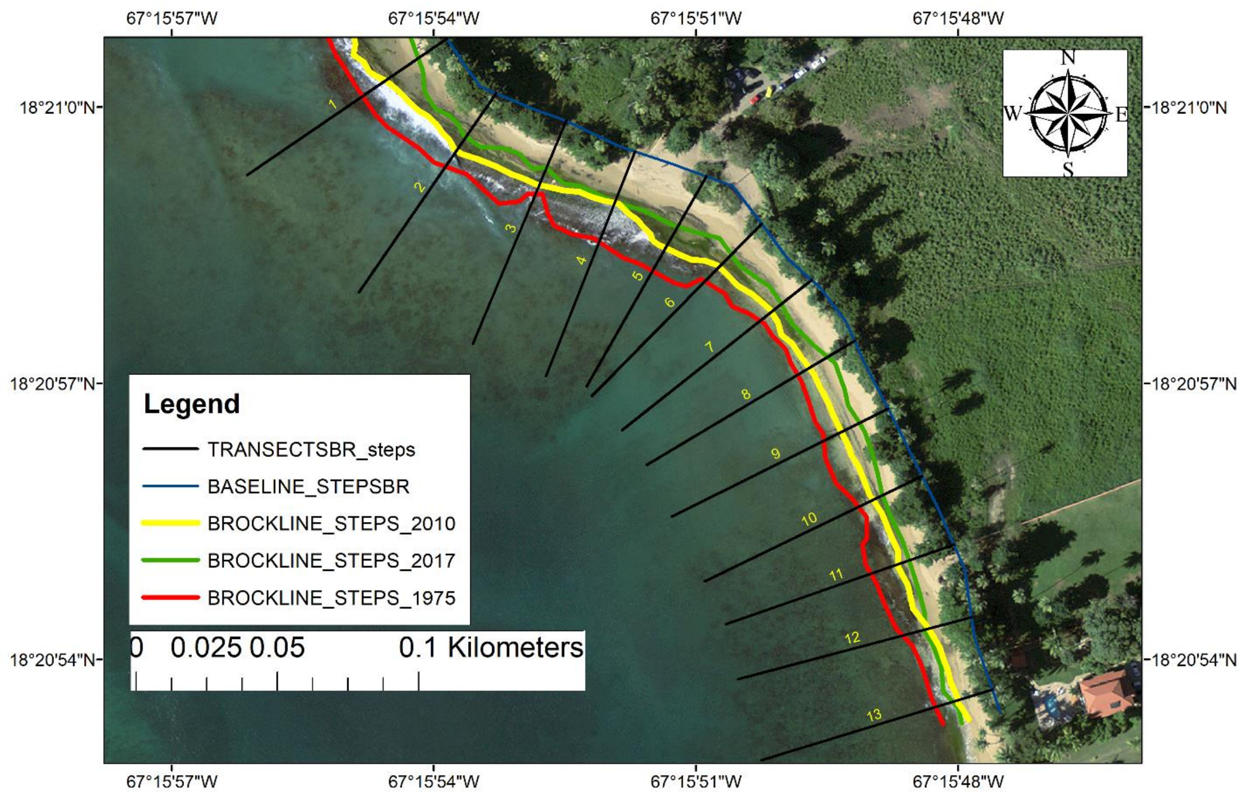


Figure 12. Transects of shorelines were Beachrock was visible.

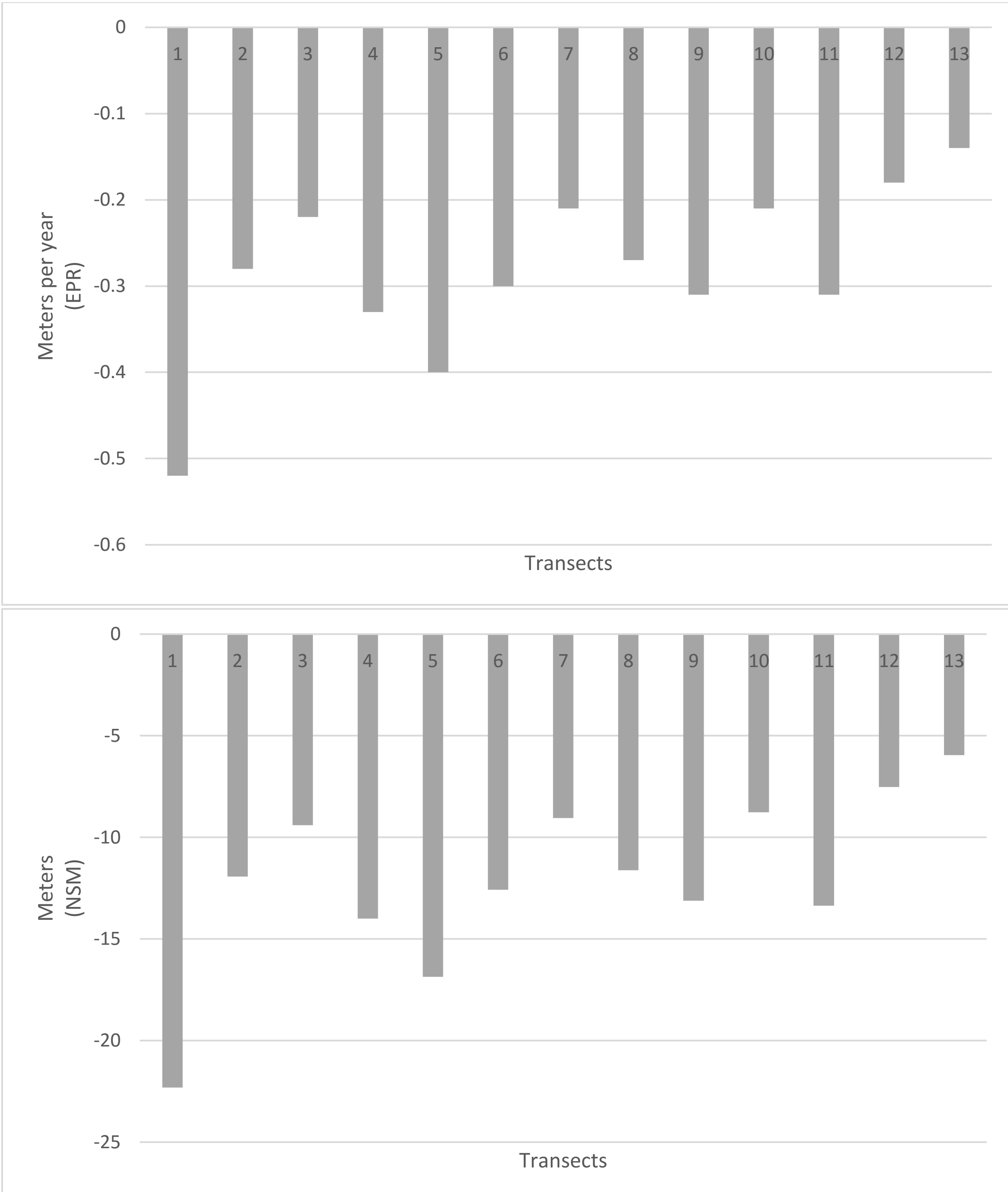


Figure 13. Graphs of the End Point Rate and Net Shoreline Movements for the Transects calculated using the images were Beachrock was visible in Steps Beach. Negative values indicate erosion.

and therefore negative and positive EPR, NSM and LRR. Transects 12-30 cover a large part of the sandy areas where accretion was determined by DSAS with End Point Rates ranging from 0.03 m/yr to 0.41 m/yr in specific transects. The Net Shoreline Movement and the Simple Linear Regression values followed this same trend. This was followed with a trend of apparent regression that covered transects 31 to 66 with the lowest End Point Rate being in transect 50 with -0.4 m/yr. This one along with transect 23 (0.41 m/yr) represent the highest and lowest values of End Point Rate besides the two abnormal values. Transects 67 up to 86 mainly followed another accretion trend, in this area was the shorelines with beachrock analyzed. Even though the main trend was accretion, transects 70 showed an EPR of 0 m/yr (with a NSM of -0.15 m and a Simple Linear Regression of -0.05 m/yr). Transects 89 to 120 were quite variable in their values but followed mostly a pattern of accretion. Even though the general calculations gave an overall pattern of accretion this, at plain sight can hide the fact of these visible trends of erosion and deposition during the time span studied. Figures 14-17 shows each individual shoreline while feature 18-19 show the transects and their analysis.

The beachrock area that was analyzed in Villa Pesquera is located in the eastern part of Villa Pesquera. This was the beachrock near the coast. Figure 20-23 show the Beachrock (exposed or close to shoreline) of all the area where it was visible while Figure 24 and 25 represent the transects taken and their analysis. The shoreline analysis for this area did not show a long term erosion from 1930 to 2010. The average End Point Rate was 0.15 m/yr with a Standard Deviation of 0.05 m/yr, the Net Shoreline Movement was 13.36 m with a standard deviation of 4.58 m. The average Simple Linear Regression was 0.01 m/yr with a standard deviation of 0.05 m/yr. The highest value of End Point Rate was of 0.22 m/yr in transect 4. The highest value of Simple Linear Regression was 0.15 m/yr in both transects 12 and 13. The highest value for Net Shoreline

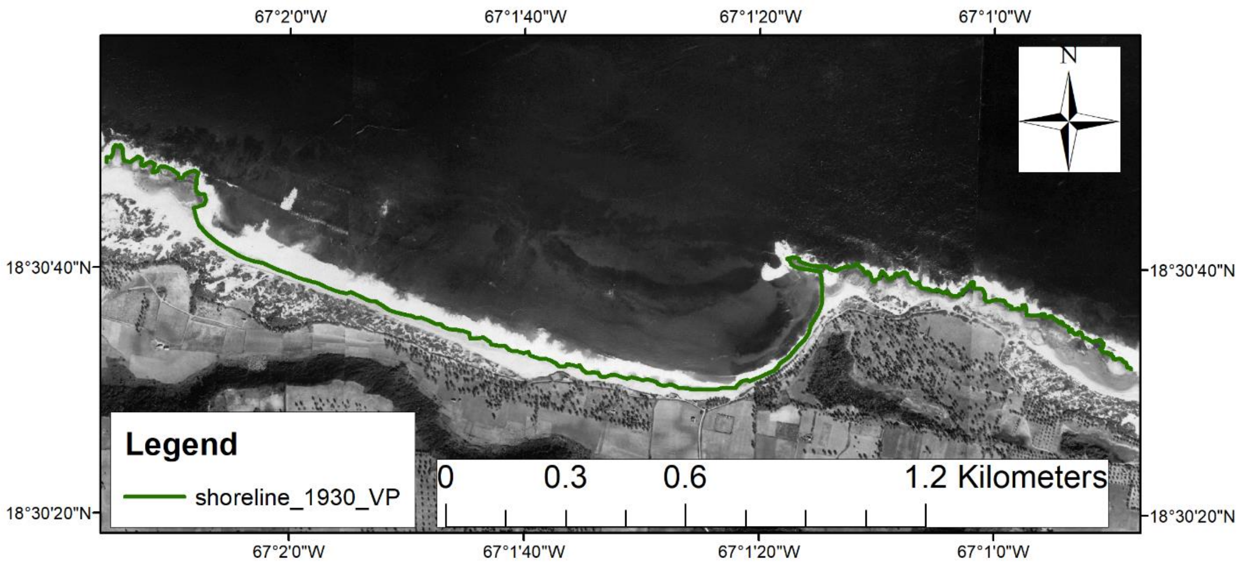


Figure 14. Shoreline of Villa Pesquera in 1930. Image was taken from the website "Porto Rico 1930 Georeferenced: A Mosaic of the Coast" (Lopez, et. al. 2017).

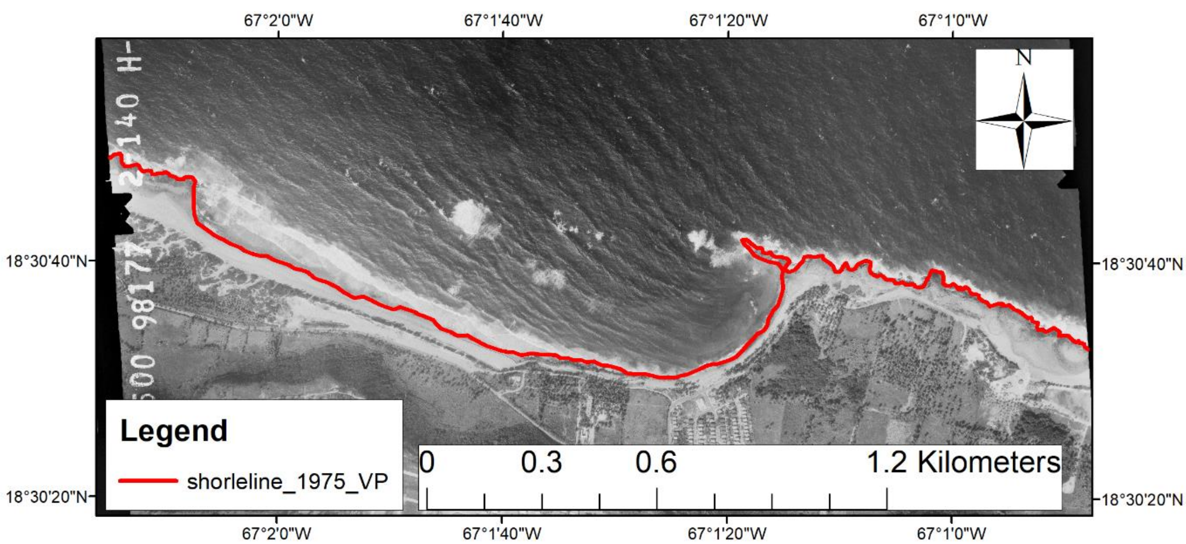


Figure 15. Shoreline of Villa Pesquera in 1975. Image was taken from EarthExplorer.

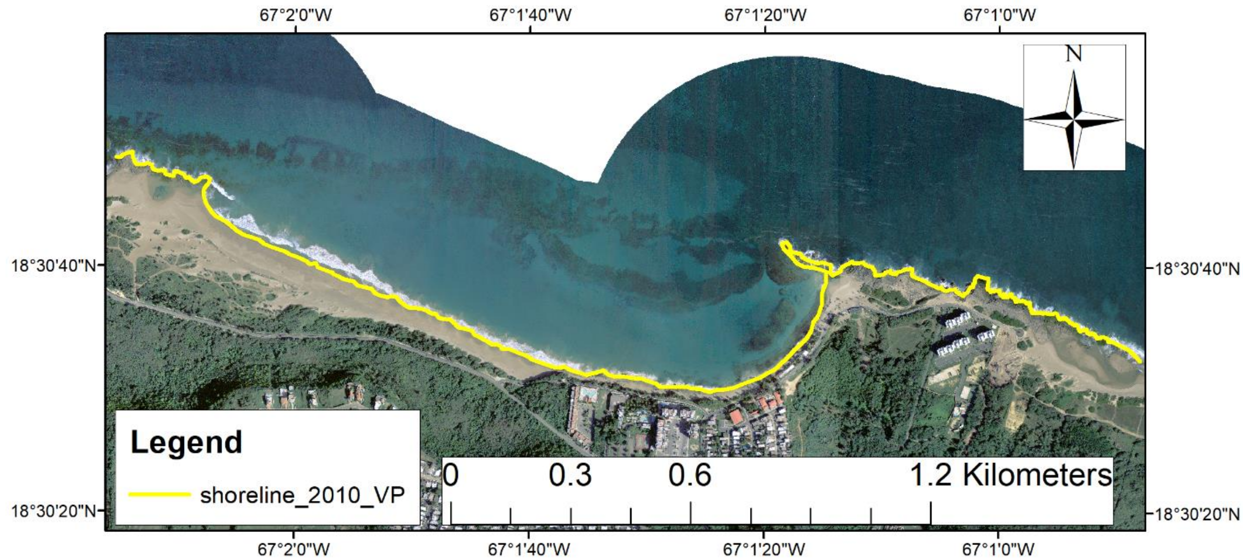


Figure 16. Shoreline of Villa Pesquera in 2010. Image was provided by GERS Lab.

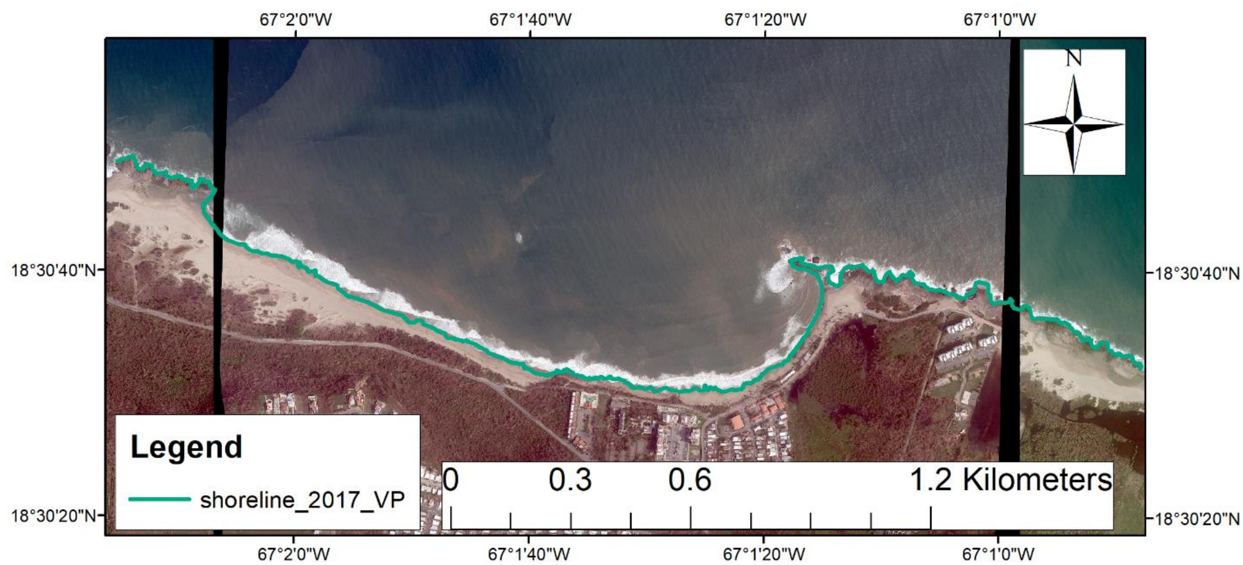


Figure 17. Shoreline of Villa Pesquera in 2010. Images were provided by GERS Lab.

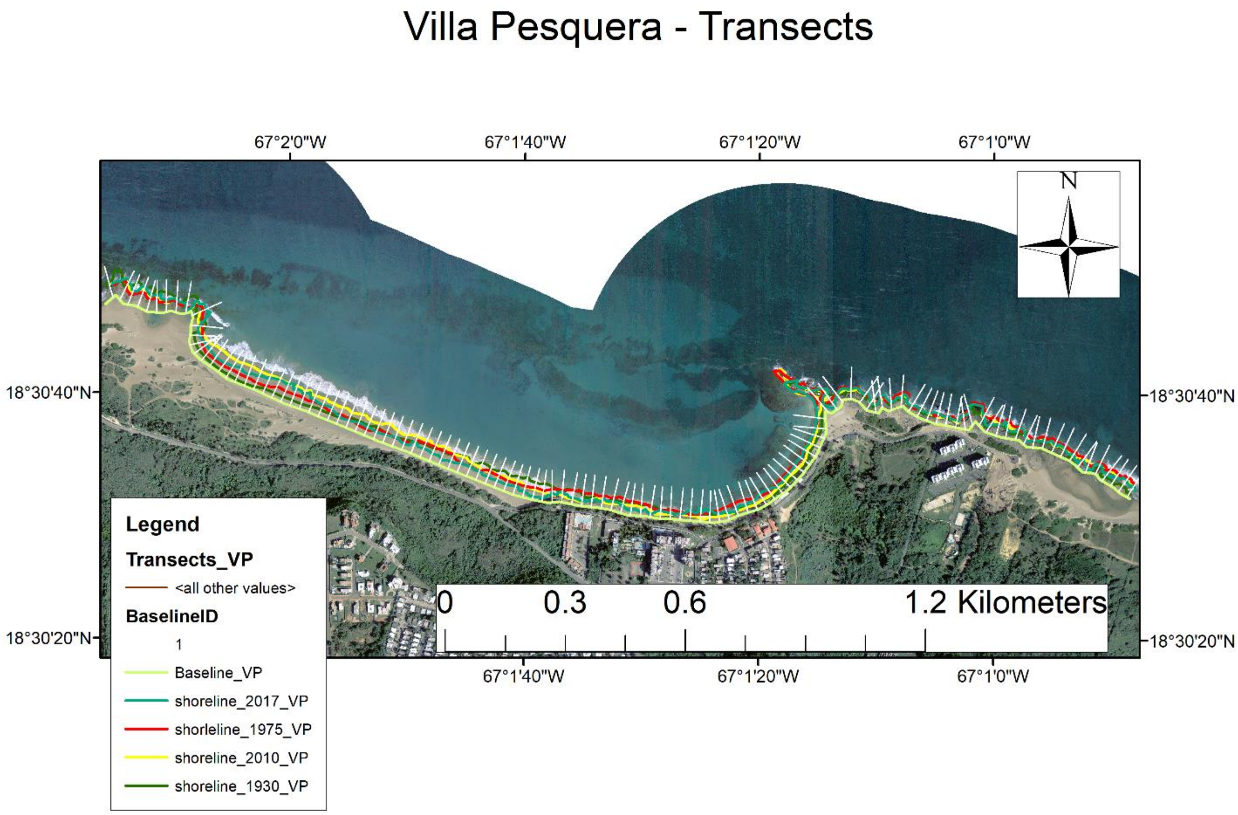
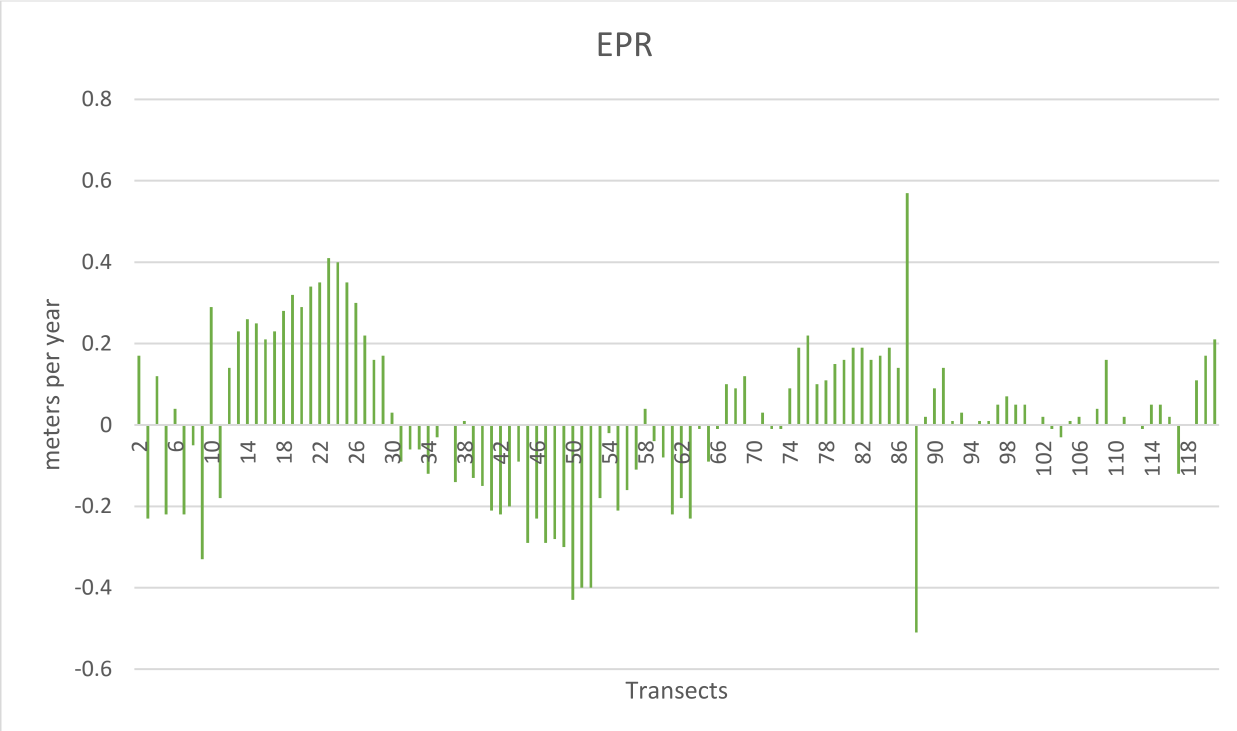


Figure 18. Transects on Villa Pesquera created with all of the shorelines.



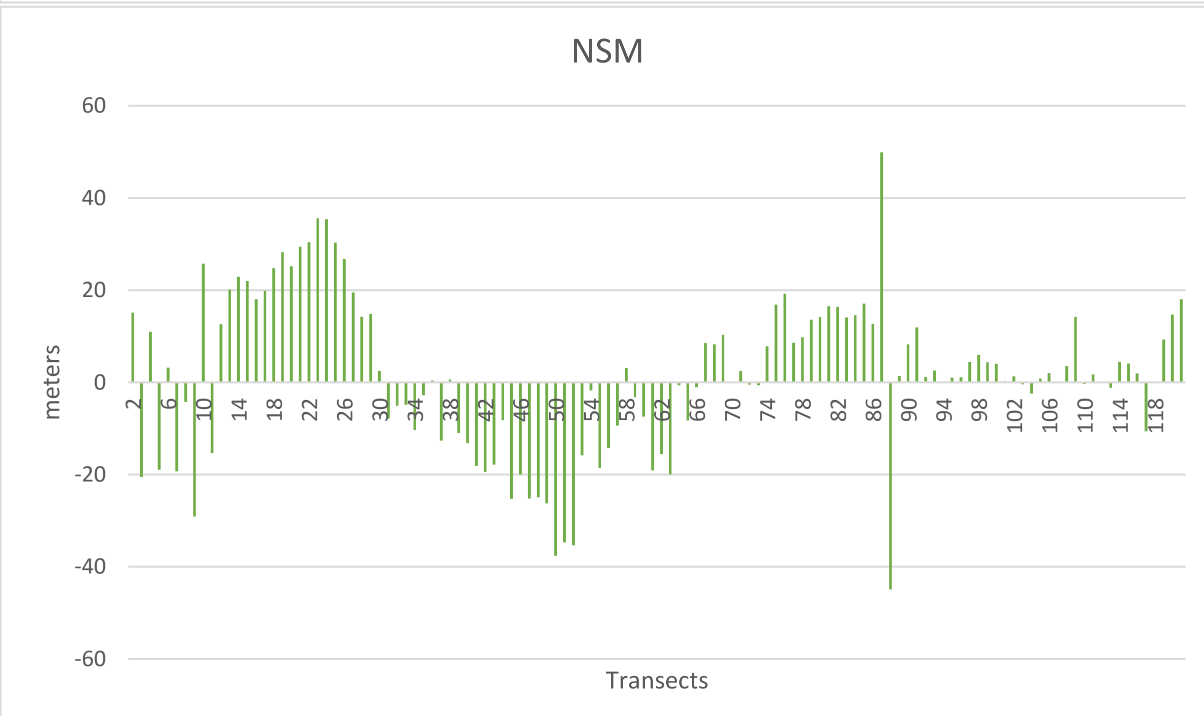


Figure 19. Graphs of the End Point Rate and Net Shoreline Movements for the Transects calculated using the images in Villa Pesquera. Negative values indicate erosion and positive values deposition.

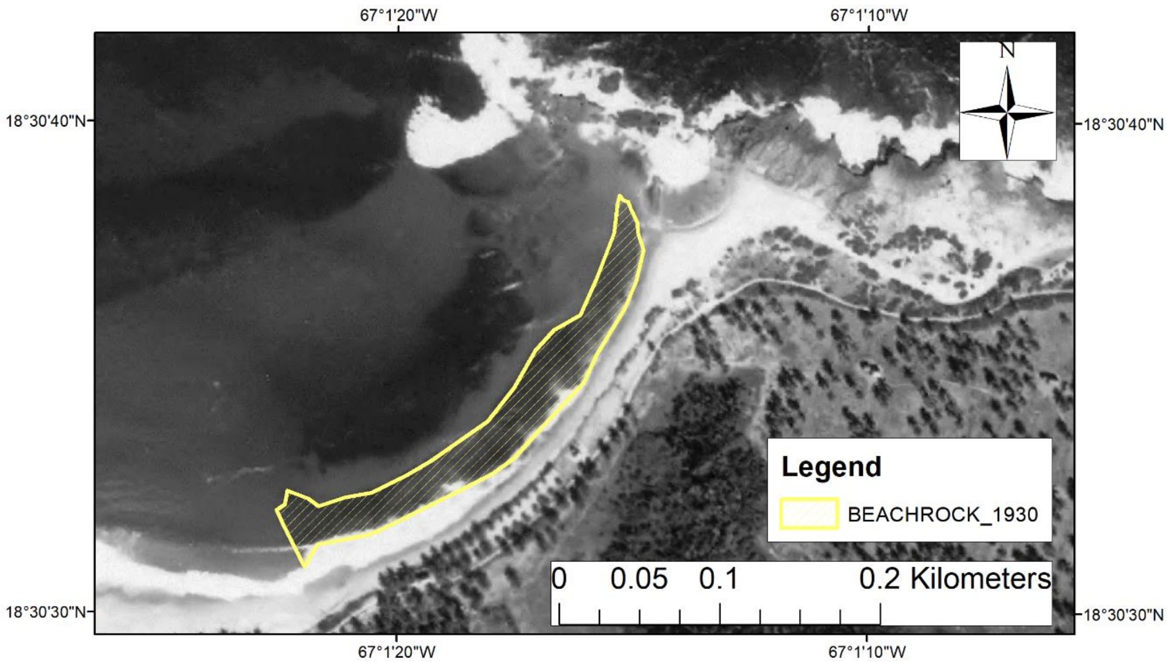


Figure 20. Visible Beachrock (exposed or close to shoreline) of Villa Pesquera in 1930. Image was taken from the website "Porto Rico 1930 Georeferenced: A Mosaic of the Coast" (Lopez, et al. 2017).

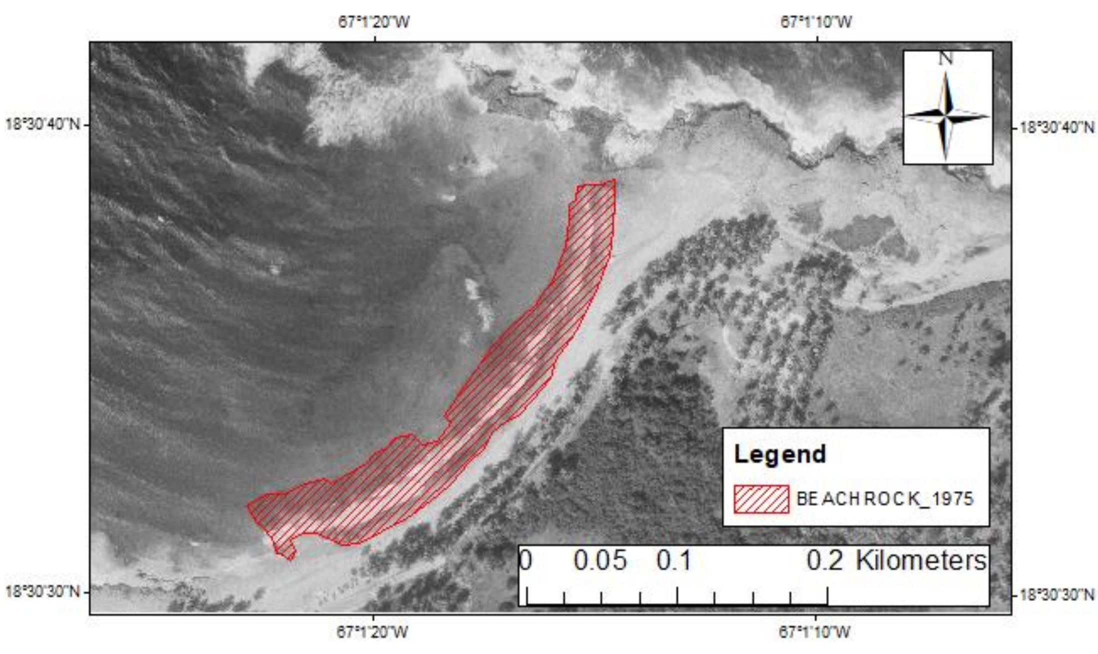


Figure 21. Visible Beachrock (exposed or close to shoreline) of Villa Pesquera in 1975. Image was taken from EarthExplorer.

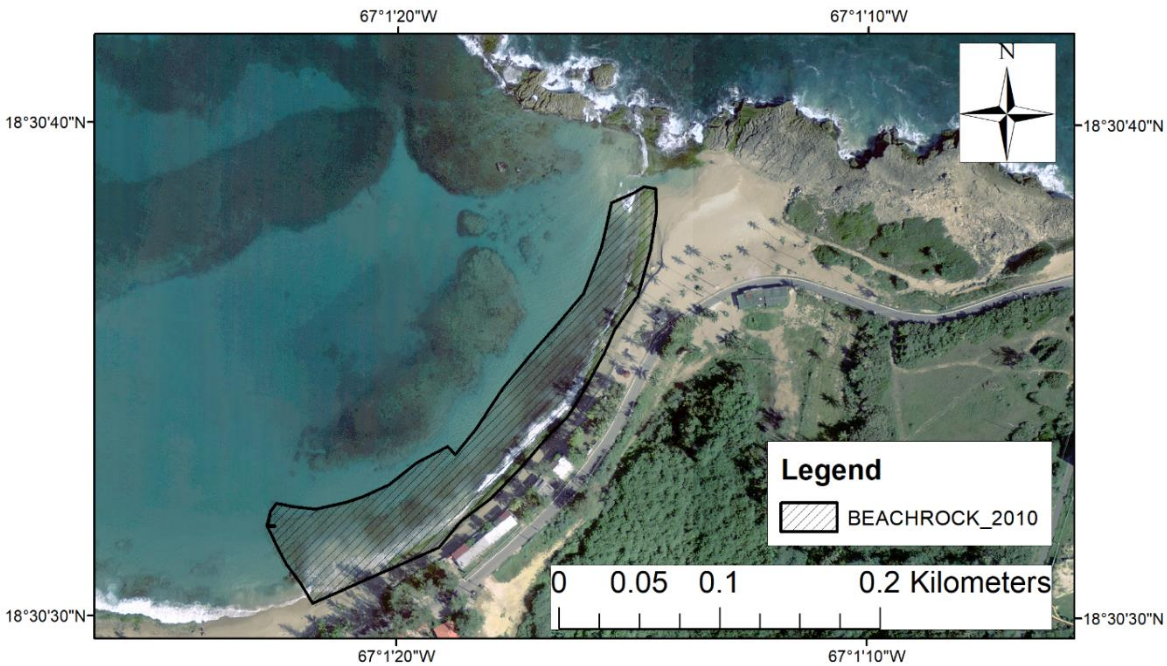


Figure 22. Visible Beachrock (exposed or close to shoreline) of Villa Pesquera in 2017. Image was provided by GERS Lab.

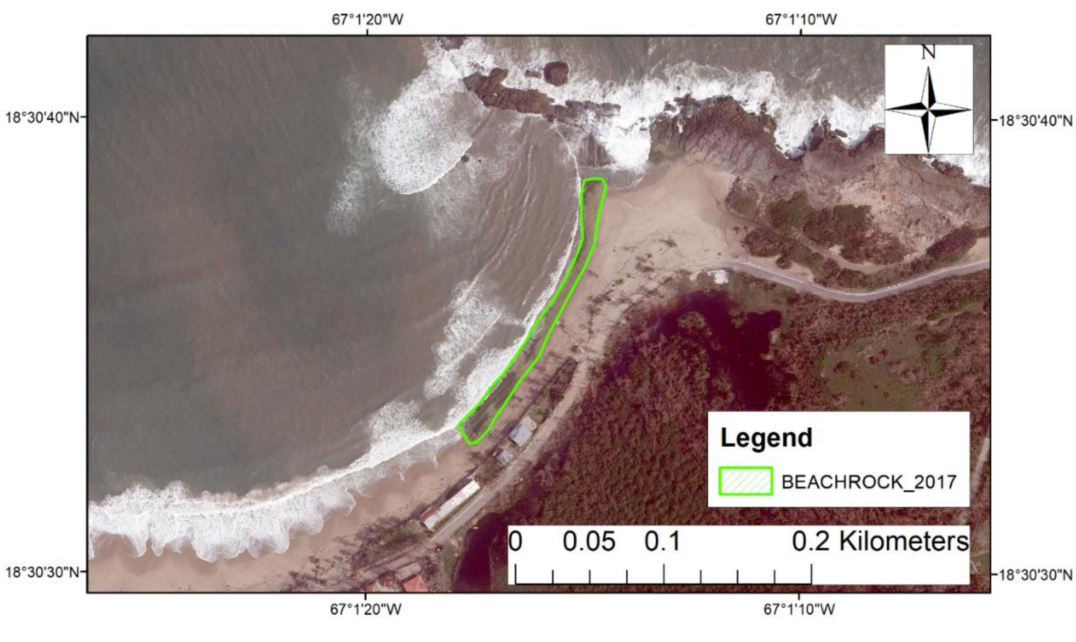


Figure 23. Visible Beachrock (exposed or close to shoreline) of Villa Pesquera in 2017. Image was provided by GERS Lab.

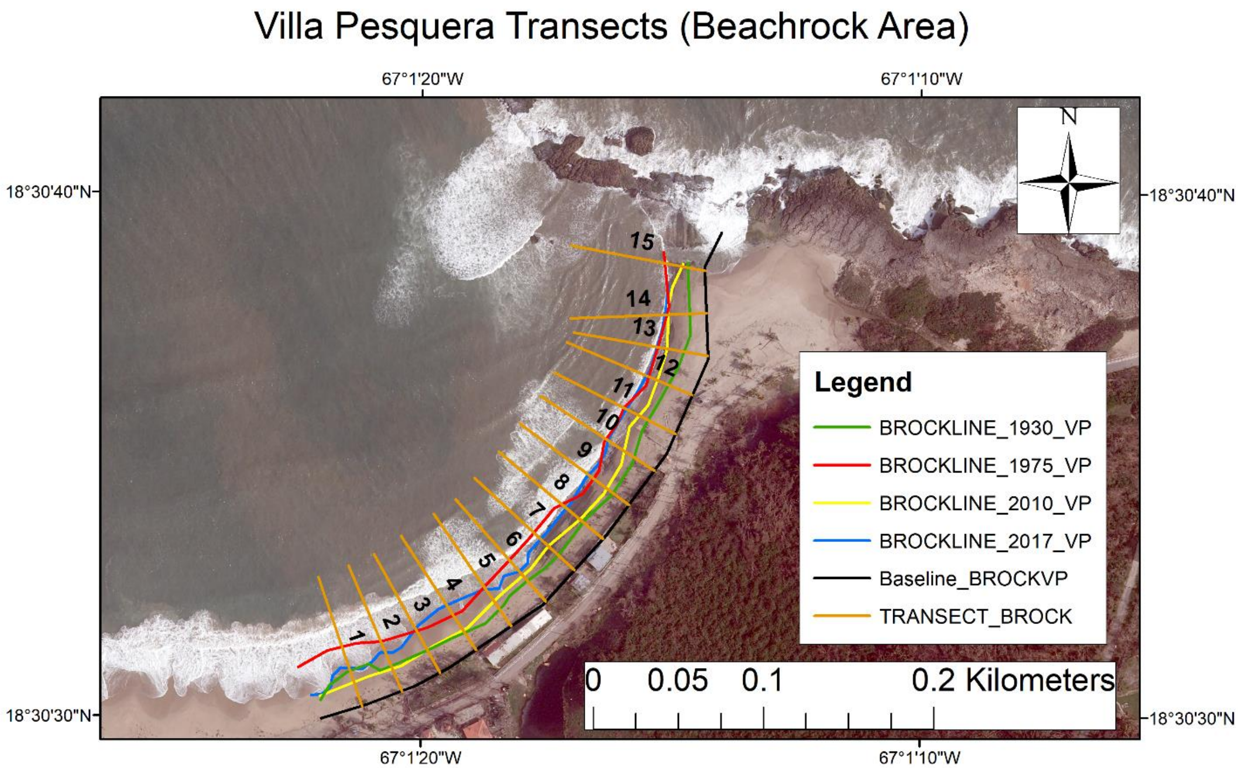


Figure 24. Transects created in the area of exposed Beachrock.

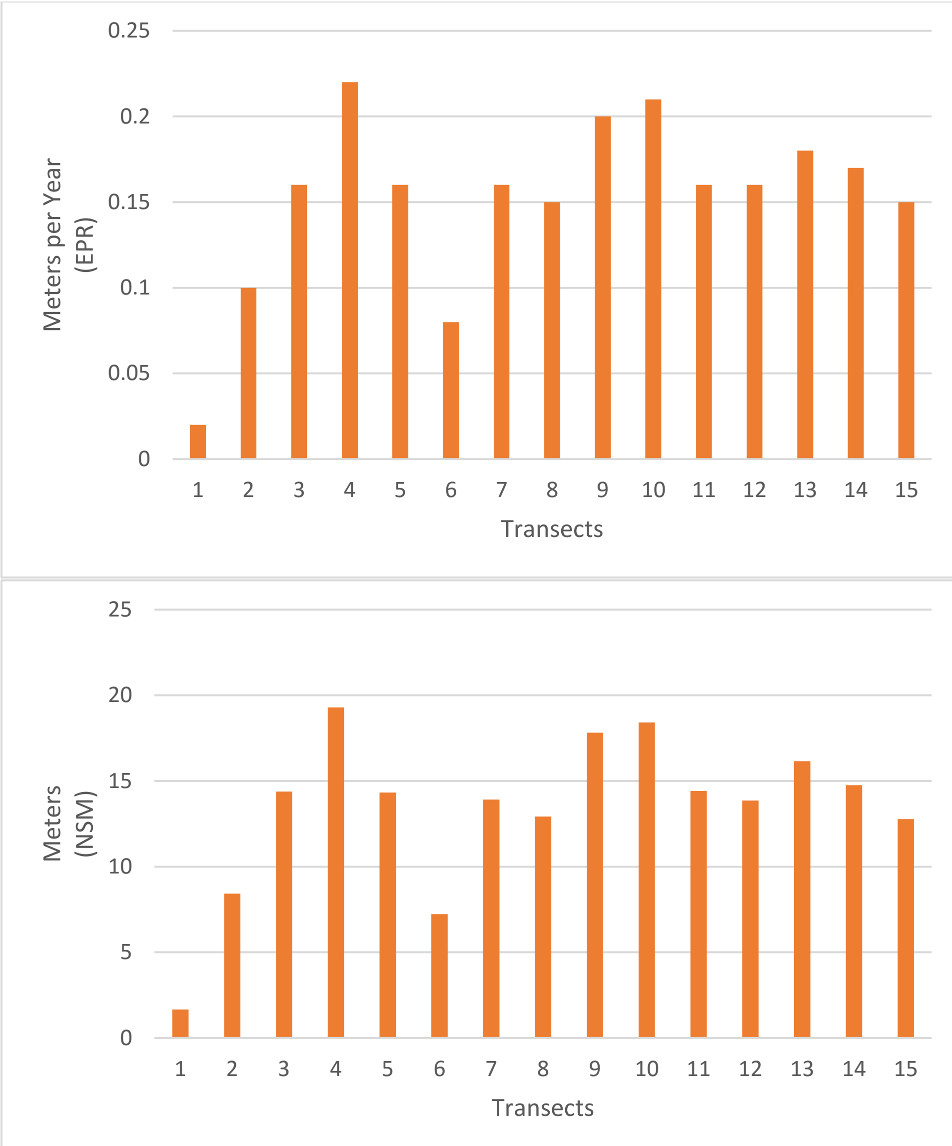


Figure 25. Graphs of the End Point Rate and Net Shoreline Movements for the Transects calculated using the area were Beachrock was visible in Villa Pesquera. Negative values indicate erosion and positive values deposition.

Movement was 19.3 meters in transect 4. This is consistent with the overall pattern showed by that area in the general analysis. Variations or errors in the methodology may be due to the variations in shoreline and visibility of the beachrock in the aerial images.

V. Conclusion:

The performed analyses show that the coast of Steps Beach is eroding at a rate of 0.06 m/yr. It should be noted that his analysis was done in a relatively long range and that shoreline changes and evolution may vary when analyzed in shorter time scales. The shoreline analysis using the photo where beachrock was visible provided a higher rate of erosion of 0.28 m/yr. This can be due to the effect of the inland sea level of the 1930 photograph but, accounting for standard deviation, these values are in range of the those given by Thieler, et. al. (2007). The Villa Pesquera shoreline is generally being deposited with 0.02 m/yr but has areas of specific erosion and deposition. One of such areas is the one where the beachrock was analyzed in which the analysis gave a deposition of 0.152 m/yr. The DSAS software proved successful in analyzing simple horizontal shorelines but experienced problems when dealing with cliffs and complex landforms giving abnormal values. DSAS also proved limited in the analysis of long-term beachrock deposits, only being able to analyze these areas within the timeframe of the aerial photos given and that the “DATE_” that each transect should have value can only be a 4 digit value. Future investigation can include the shoreline analysis in a much longer timeframe.

VI. Acknowledgements:

Special Thanks to Prof. Fernando Gilbes for his support as advisor for this project and clearing any doubts that I had with the photographs and with the Arc GIS software. Special thanks to Prof. Wilson Ramirez and Gwendelyn Monge, for her input on how to approach the Beachrock analysis and clearing any doubts that I had on that subject. I would also like to thank the Geology Department and the Undergraduate Research coordinators: Prof. Lizzette A. Rodriguez and Prof. Hernán Santos.

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VIII. Appendices

Table 1. Data given by DSAS for the analysis of all of the photos in Steps Beach.

TransectId	EPR	NSM	LRR
1	-0.14	-12.55	-0.1
2	-0.12	-10.53	-0.11
3	-0.1	-8.62	-0.08
4	0.03	2.61	0.01
5	0.07	6.23	0.09
6	0.04	3.64	0.05
7	-0.02	-2.17	-0.02
8	-0.05	-3.97	-0.02
9	-0.08	-6.73	-0.06
10	-0.06	-4.95	-0.05
11	-0.08	-6.79	-0.08
12	-0.09	-8.25	-0.11
13	-0.14	-12.14	-0.15

Table 2. Data given by DSAS for the analysis of the photos were Beachrock was visible in Steps Beach.

TransectId	EPR	NSM	LRR
1	-0.52	-22.32	-0.44
2	-0.28	-11.93	-0.25
3	-0.22	-9.4	-0.18
4	-0.33	-14	-0.35
5	-0.4	-16.86	-0.35
6	-0.3	-12.58	-0.26
7	-0.21	-9.05	-0.19
8	-0.27	-11.62	-0.23
9	-0.31	-13.12	-0.27
10	-0.21	-8.77	-0.19
11	-0.31	-13.37	-0.3
12	-0.18	-7.52	-0.2
13	-0.14	-5.95	-0.16

Table 3. Data given by DSAS for the analysis of all of the photos in Villa Pesquera.

TransectId	EPR	NSM	LRR
2	0.17	15.15	0.15
3	-0.23	-20.55	-0.22
4	0.12	10.96	0.09
5	-0.22	-18.98	-0.22
6	0.04	3.15	0.02
7	-0.22	-19.33	-0.25
8	-0.05	-4.28	-0.05
9	-0.33	-29.12	-0.3
10	0.29	25.73	0.26
11	-0.18	-15.37	-0.19
12	0.14	12.64	0.2
13	0.23	20.12	0.29
14	0.26	22.88	0.33
15	0.25	22	0.35
16	0.21	18.03	0.34
17	0.23	19.86	0.35
18	0.28	24.76	0.38
19	0.32	28.27	0.42
20	0.29	25.16	0.41
21	0.34	29.44	0.42
22	0.35	30.37	0.41
23	0.41	35.61	0.45
24	0.4	35.39	0.44
25	0.35	30.3	0.4
26	0.3	26.75	0.35
27	0.22	19.48	0.28
28	0.16	14.24	0.25
29	0.17	14.82	0.25
30	0.03	2.51	0.15
31	-0.09	-7.88	0.03
32	-0.06	-5.08	0.08
33	-0.06	-4.87	0.06
34	-0.12	-10.33	0
35	-0.03	-2.81	0.12
36	0	0.43	0.1
37	-0.14	-12.67	-0.01
38	0.01	0.6	0.09
39	-0.13	-10.99	-0.02
40	-0.15	-13.23	-0.05

41	-0.21	-18.16	-0.06
42	-0.22	-19.43	-0.13
43	-0.2	-17.83	-0.11
44	-0.09	-8.21	-0.03
45	-0.29	-25.28	-0.23
46	-0.23	-20.01	-0.17
47	-0.29	-25.24	-0.23
48	-0.28	-24.94	-0.2
49	-0.3	-26.25	-0.22
50	-0.43	-37.63	-0.36
51	-0.4	-34.69	-0.33
52	-0.4	-35.34	-0.35
53	-0.18	-15.81	-0.22
54	-0.02	-1.73	-0.08
55	-0.21	-18.64	-0.26
56	-0.16	-14.24	-0.21
57	-0.11	-9.41	-0.12
58	0.04	3.14	0.01
59	-0.04	-3.17	-0.09
60	-0.08	-7.42	-0.09
61	-0.22	-19.08	-0.18
62	-0.18	-15.54	-0.15
63	-0.23	-19.94	-0.21
64	-0.01	-0.63	-0.06
65	-0.09	-8.3	-0.12
66	-0.01	-1.02	-0.02
67	0.1	8.56	0.04
68	0.09	8.24	0.01
69	0.12	10.35	0.03
70	0	-0.15	-0.05
71	0.03	2.52	-0.04
72	-0.01	-0.51	-0.05
73	-0.01	-0.65	-0.07
74	0.09	7.8	0.02
75	0.19	16.89	0.11
76	0.22	19.19	0.14
77	0.1	8.61	0.06
78	0.11	9.8	0.07
79	0.15	13.57	0.1
80	0.16	14.14	0.09
81	0.19	16.52	0.12

82	0.19	16.4	0.13
83	0.16	14.11	0.1
84	0.17	14.55	0.13
85	0.19	17.06	0.17
86	0.14	12.7	0.13
87	0.57	49.89	0.35
88	-0.51	-44.89	-0.43
89	0.02	1.4	0.02
90	0.09	8.24	0.07
91	0.14	11.95	0.13
92	0.01	1.15	0.02
93	0.03	2.59	0.06
94	0	0.15	-0.03
95	0.01	1.01	0.03
96	0.01	1.09	0.01
97	0.05	4.41	0.06
98	0.07	5.97	0.07
99	0.05	4.38	0.03
100	0.05	4.02	0.01
101	0	0.28	0.01
102	0.02	1.32	-0.01
103	-0.01	-0.45	0
104	-0.03	-2.45	-0.01
105	0.01	0.79	0
106	0.02	2.03	0.07
107	0	0	0.02
108	0.04	3.53	0.06
109	0.16	14.24	0.15
110	0	-0.35	-0.03
111	0.02	1.69	0.02
112	0	-0.07	-0.02
113	-0.01	-1.16	-0.05
114	0.05	4.43	0.03
115	0.05	4.07	0.02
116	0.02	1.94	0.02
117	-0.12	-10.64	-0.04
118	0	-0.14	-0.01
119	0.11	9.28	0.15
120	0.17	14.73	0.19
121	0.21	18.03	0.19

Table 4. Data given by DSAS for the analysis of the area were Beachrock was visible in Villa Pesquera.

TransectId	EPR	NSM	LRR
1	0.02	1.66	-0.05
2	0.1	8.42	0.02
3	0.16	14.39	0.08
4	0.22	19.3	0.13
5	0.16	14.32	0.11
6	0.08	7.23	0.05
7	0.16	13.91	0.11
8	0.15	12.93	0.08
9	0.2	17.81	0.13
10	0.21	18.41	0.14
11	0.16	14.41	0.11
12	0.16	13.86	0.12
13	0.18	16.15	0.15
14	0.17	14.76	0.15
15	0.15	12.78	0.09