CEER-M37: Prediction of the Effects of Resuspension of Sediment During the Construction Phase of a Hypothetical Offshore Power Plant, West of Mayaguez, Puerto Rico (May 1977) by A.W. Goldman, J.M. Lopez, and Roberto Castro. Center for Energy and Environment Research.

Prediction of the Effects of Resuspension of Sediment During the Construction Phase of a Hypothetical Offshore Power Plant, West of Mayaguez, Puerto Rico by Gary C. Goldman, José M. Lopez and Roberto Castro. Center for Energy and Environment Research, College Station, Mayaguez, Puerto Rico 00708.

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Foreword: The marine environment is flexible and capable of withstanding many natural stresses. Man-made stresses are usually destructive, and ultimately return to affect man. The nearshore marine environment constantly exists on a fragile balance between a healthy state and an unhealthy state. This is the area of the marine environment most strongly and frequently affected by man. The Marine Ecology Division of the Puerto Rico Center for Energy and Environment Research has as its dedicated goal the observation, prediction, and management alternatives of man-made stresses on the nearshore marine environment. This report serves to supply the observations and predictions of the effects of the construction phase of a power plant that would be constructed in the nearshore marine environment. Marine/Ecology Division.

Abstract: The purpose of this study was to evaluate those potential effects that would result from resuspended sediment during the construction phase, if an offshore nuclear power plant were to be built west of Mayaguez, Puerto Rico, in the Cabo Rojo Platform. During the study, we developed water current predictions and also evaluated.

Tables (cont.)

LIST OF FIGURES

SECTION 1 INTRODUCTION

In recent times, we, the world scientific and environmental community, have become aware of the importance and practicability of studying an environmental situation before a possible environmental insult could occur. Therefore, should the results of the analysis deem it necessary, the community could be prepared to take the necessary preventative or corrective action, take moderate precautions, or just be more aware of the potential problems if the symptoms were to develop. The subject of this report is a pre-environmental-insult study. There have been discussions as to the possibility of constructing, and subsequently operating, a nuclear power plant off the western coast of Puerto Rico. The area under discussion is called the Cabo Rojo Platform. Many questions arose during the Offshore Nuclear Power Siting Workshop (U.S. AEC, 1973) regarding just such a potential situation. This report has, as its primary purpose, the assessment of possible environmental effects that would result from the re-

The sediment in the area will be suspended during the construction phase of such a power plant, if it is built. The report describes the physical area, with special emphasis given to those features used during the subsequent analysis. The study is divided into ten sections, each with a subject matter contributing to the overall analysis.

The sediment is studied in detail, particularly with respect to grain size and possible contaminants. Furthermore, the sediment settling properties in salt water are evaluated. The study also considers the water, with emphasis placed on its physio-chemical properties and current patterns in the area. Using these results, it is possible to predict potential particle trajectories, indicating where the material may resettle. Lastly, the biota is considered, and some conclusions are reached regarding the potential effects of this environmental disruption on the biota.

SECTION 2 CONCLUSIONS

The major conclusions of this study are that if a nuclear power plant's construction were to occur offshore, west of Mayaguez, Puerto Rico, in the northern basin of the Cabo Rojo Platform, the following would occur:

1. The bio-available trace heavy metals would show little change throughout the basin in the sediment or in the water. This is primarily due to the present low contamination levels in the area.

2. There would be minimal effect due to the sediment relocating in areas far from the basin. This is because only a small amount of the material is projected to have a reasonable probability of leaving the basin. Of the material that may leave, most, if not all, is less contaminated than the areas it might move into.

There might be a significant build-up of fine sediment over the northern and southern boundaries of the basin. Some fine material would stay suspended long enough to deposit onto the reefs, rocks, and seagrass beds forming these boundaries. These major conclusions suggest...

There are two environmental problems that must be taken into account. The first problem pertains to the biota of the rocks, reefs, and seagrass beds, as well as the habitats themselves. These areas, positioned across the northern and southern boundaries of the basin, could be covered with a significant amount of sediment. It is noteworthy that these boundaries are the routes over which all the water must pass. The second problem involves the direct impact on any stationary benthic organisms that may be buried by large amounts of material that could rapidly settle to the sea bottom, particularly near the construction area.

SECTION 3: RECOMMENDATIONS

Based on the work completed in this study, three recommendations are proposed. Firstly, a specific location for a power plant is necessary to determine the effects sought in this study. The focus of this work was more on methodology than on a specific site. Therefore, the recommendation is to choose an exact location to determine potential effects.

Secondly, little research has been conducted to identify the effects of excessive sedimentation on specific benthic habitats. As increased resuspension of bottom material is becoming a larger by-product of humanity's exploitation of the sea, more research must be conducted to study this effect. The recommendation is to examine the direct effect of different size sediment loads on varied benthic habitats.

Lastly, this study did not investigate the effects of increased suspended load on primary productivity. This is a vast and complex subject. The recommendation is to investigate the direct relationship between suspended inorganic solids and primary productivity. This should be site-specific and consider both the specific sediment grain size and the particular biota involved.

SECTION 4: DISCUSSION

To study the potential environmental effects of resuspending sediment in the Cabo Rojo Platform, numerous factors must be independently investigated and then integrated. This will determine how the potential environmental insult might affect the ecosystem.

Area. The subjects studied were:

1. Physical description of the area.
2. Water masses.
3. Water currents.
4. Sediment origin and grain-size distribution.
5. Sediment variation below the sediment/water interface.
6. Particle settling velocity in seawater.
7. Sediment grain particle trajectory.
8. Analysis for trace heavy metals.
9. Foraminifera.
10. Benthos.

Physical Description of the Area: The Commonwealth of Puerto Rico, associated with the United States by bilateral agreement, consists of a main island and several smaller islands. These islands are all located along the Antilles Chain of islands, extending almost from Florida, U.S.A. to Venezuela, South America (see Fig. 1). Puerto Rico is approximately halfway along the chain, about 1700 km from Miami, Florida. The nearest large landmass to Puerto Rico is the island of Hispaniola, about 120 km to the west.

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Caribbean Sea. As Puerto Rico is situated along an east-west axis, the Atlantic washes its north coast, and the Caribbean, its south coast. At the latitude of about 18°N, Puerto Rico is in the trade wind belt, with both the winds and oceanic currents generally moving east to west past the island. The main island of Puerto Rico is roughly rectangular in shape, about 180 km east to west, and about 60 km north to south. The island is a mixture of mountains, rolling hills, and broad flat plains. Where the plains meet the sea, the climate is typically tropical marine (except along the desert-like south-western coast). The sea surface temperature changes little from day to day, night to night, and even throughout the year. Each morning the sun rises over a warm sea and a cooler land mass. The land quickly heats up causing a convection cell to form, bringing humid sea air inland. By late afternoon, the land is cooling rapidly, causing the reversal of the cell, with the wind now moving seaward. Frequently during these inland excursions, the moisture-rich sea air becomes saturated, and rain is the result. The area of concern in this report - the Cabo Rojo Platform - lies off the western coast of the main island of Puerto Rico (Fig. 2). The Cabo Rojo Platform has a somewhat right-triangular shape (U.S. NOS, 1975). The "base of the triangle” extends almost due west from about the midpoint of the western coast. (This is the location of the coastal city of Mayaguez - the island's third-largest population center.) This westward trend continues for about 25 km, and to a depth of about 35m. During the next 1 km, the depth drops quickly to 150 m, and the Mona Channel has been entered. The Mona Channel lies between Puerto Rico and the island of Hispaniola. The "hypotenuse of the triangle” travels from this furthest west point in a southeasterly direction to the southern shelf of the island. This occurs near Cabo Rojo, a point extending southward from the southwestern corner of the island. The third side of the

"The Triangle" refers to the western coastline of the island. The eastern part of the platform hosts numerous seagrass beds and runoff deposits of terrestrial origin, extending from Mayaguez (the Yaguez and Guanajibo Rivers) to about half the distance to the aforementioned drop-off. These shallows then transition in nature, primarily becoming coral reefs, and extend more towards the west and south.

There are two other east-west shallow areas on the platform, located south of this large northern rise. One almost completely encloses a northern basin, which occurs west of Punta Ostiones. There is a small channel through the reef and rock, marked by a buoy. Tidal currents information for this channel is provided by the U.S. National Ocean Service (1976a).

The more southern east-west shallow area is not as intense or noticeable. It has many channels and large openings, but it does serve to define a southern basin. The western part of the platform has a gentle seaward slope with few shallows and obstructions. Near the southern edge of the platform, the drop is from 25 m to 350 m in less than 1 km distance.

Both the north and south basins were considered as potential study areas, either separately or together. However, we chose to study the northern basin due to the following reasons: (a) the time and effort required limited the scope and area of the study, (b) this basin seems to us to be a more probable site for a power plant, (c) this basin is virtually enclosed, allowing for a clearer evaluation of potential problems.

The northern basin, seen in detail in Figure 3, is approximately square, with a portion of its northwestern corner removed. The basin measures about 7 km north to south, and about 6 km east to west. It is bordered on the north by seagrass beds, and across the northwest corner lies Escollo Negro, a reef with a depth of only 1-3 m. The western boundary consists of a reef and rocky outcroppings with depths of 1-3 m. The southern boundary is the aforementioned reef and rocky area west of Punta Ostiones, with a depth varying from 1-4 m. The eastern boundary is composed of muck.

The text is less defined, as there is a gradual slope from the land. However, an arbitrary line can be drawn at the 10 m contour that runs almost exactly north-south. This material is primarily land runoff. To better understand the oceanography of the platform, the water masses of the northern basin must be studied. The description of these waters, with their normal ranges of physicochemical parameters, is always useful to describe the overall situation.

A cruise was conducted on April 20, 1976, aboard the University of Puerto Rico's R/V MEDUSSA. The purpose of the cruise was to collect hydrographic data in the northern basin of the Cabo Rojo Platform. Bottom grabs were also taken on this cruise, and they will be discussed later. The stations visited are those shown in Figure 3. Note that the station's name serves as both the abstract reference name (E for example) and the location within the basin (Fast for example).

Water samples were taken from the surface (actually 1 meter below the surface), mid-depth, and bottom (actually 1 meter above the sediment/water interface). Two reversing thermometers (Watanabe Keiki protected type) measured temperature at each depth. These were attached to the Niskin type water sampling bottles. The accuracy of the thermometers is + .02°C, after calibration. In some cases, only one thermometer was readable, due to malfunction.

The salinity was measured using a Plessy Portable Laboratory Salinometer, Model 6220. The accuracy of this instrument is quoted at ¢ .002°/**. The water samples were brought back to the laboratory to measure the salinity.

The results of this hydrographic cruise are presented in Table 1. The hour on-station is also shown in the table. The tidal current tables (U.S. NOS. 1976a) indicate that the tidal currents in the basin are moving to the north in the early morning (when the ship was in the northern sector), slack during mid-day (the ship was in the middle of the basin during this time), and moving southward during the afternoon (ship in 10).

"Break - in the southern sector. Therefore, there is a good chance that the same water was being measured throughout the day. Some observations from the cruise indicate that on this day there was but one total water mass moving in and through the basin. The range of temperature at the surface was 25.88 - 26.16°C or 0.38 C. The range for the mid-depth was 26.81 - 26.16°C or 0.35 C. The range for the bottom water temperature was 25.40 - 26.12°C or 0.72 C. The total range throughout the water in the basin that day was 25.40 - 26.26°C or 0.86 C. The salinity range for the surface water was 36.010 - 36.092°, or .082°. The range for the mid-depth water was 36.036 - 36.127° or .091°. The range for the bottom water was 36.032 - 36.093° or .061°. The salinity range throughout the basin on that day was 36.010 - 36.127°, or .117°. The density of the water can be described by values of sig t (q) units. This measure takes into account the temperature and the salinity. The average sig t value for the cruise was 23.88. The values of the sig t varied by no more than 0.2 for any depth, and only 0.3 throughout the entire basin. The minimum salinity and minimum density occurred in the surface waters at station NE. This is the water most influenced by the outfall of the Guanajibo River. With all this evidence, it appears that during this time of the year, the water is moving in the basin as a single water mass, with the only possible exception being that water from the Guanajibo River.

Page Break - Table 2 contains data taken from past cruises into the area. This information was reported previously (Wood, et al., 1975). These data span an entire year (September 1973 - November, 1974). During any one cruise, sometimes lasting up to two days, the magnitude of variation was similar to that of our April, 1976 cruise. This is an indication that there is always a single water mass moving through the basins regardless of the time of the year. There is some indication of a slightly greater stratification during the fall cruises."

Than the others, this slight stratification is not substantial enough to consider a two-layer situation. To evaluate the trajectory of potentially resuspended sediment, understanding the current patterns in the area is necessary. Factors such as wind, tides, and other non-local effects like steady currents in the area must be taken into account. We must also inquire about the magnitude of the influence of nearby global-ranging currents, whether the currents are seasonal, and if these currents vary with depth. Answers to these questions are necessary to properly evaluate a study of this nature.

After evaluating numerous current measurement methods, the current drogues seemed to be the most optimal choice, especially when used in conjunction with the tide tables (U.S. NOS., 1976b) and the tidal current tables (U.S. NOS., 1976a). The primary hypothesis for this combination is that the water in the basin moves as a single mass, with the bottom layer moving in sync with the top layer.

The evaluation of the single-layer model involved examining the hydrographic data and using current drogues at varying depths. If the water indeed moved as a single mass, then the drogue measurements could be compared with the tidal and wind-driven currents. A positive confirmation from these two data sources would suggest that the tidal current predictions, along with the superposition of wind drift, could be used to predict the water movement in the basin. It was hoped that this method would provide enough accuracy to apply to the particle trajectory concept for the resuspended sediment.

Drogue measurements of the currents in the northern basin of the Cabo Rojo Platform were conducted on 14 and 16 July 1976. A schematic drawing of our drogue design can be seen in

Figure 4. The water sensitive surfaces are ballasted wooden panels set at right angles to each other. Each panel measures .91 m by .91 m, providing a water-sensitive area ranging from .83 nm to .64 m^2, depending on the panel's orientation to the actual current. These panels can be set to any.

Reasonable depth, depending on the length of the connecting line. In our case, the depths used were near surface, 5m and 10m. A float and flag assembly sit at the water surface. In this case, the float was a standard inflated automobile tire inner tube. The total cross-sectional area, exposed to either wind or water at the surface, is about 0.8 m^2. This type of surface float is designed so that the wind-sensitive area can be minimized by adjusting the inflation pressure of the inner tube. The single major disadvantage with the tube is its susceptibility to puncture. This never occurred. The flag is connected by a netting arrangement to the tube, as is also the connecting line.

During the first of the measurement periods, we used three drogues. One drogue was set at (or nearly at) surface, one at 5m and one at 10m. Figure 5 shows the trajectories for the three drogues. As these trajectories indicate, the surface drogue did not behave as did the others. The water-sensitive panel broke loose from this float, and the float was influenced primarily by the wind. The 5m and 10m drogues did follow the water pattern, to the best of our knowledge.

The best possible time for analyzing the speed of the drogues is between 1230-1400. The drogues were moving in a southerly direction, and using the distances and times shown in the figure, the speed was 50 cm/sec at the 5m depth and 59 cm/sec at the 10m depth. According to the tidal current tables, the tidal-driven currents past Punta Ostiones should be as shown in Table 3. The days of concern are 14 and 15 July 1976. The table shows the speed, direction, and time of the currents past the Punta Ostiones buoy. Except for a brief wind-driven westward excursion during the time of slack tide, the two remaining drogues did follow a parallel path. Recalling that the two were set at 5 meters and 10 meters in depth, this does supply evidence that at least the water from 5-10m moved as a single entity through the basin that day.

The next

The experimental period, 16 July 1976, had both of the two remaining drogues set at 5 m depth. The distance between the two drogues was 30 m upon starting. This distance varied from 15 m to 40 m throughout the day. Therefore, the two are shown as a single trajectory line in Figure 6. In this case, from 1001-1086 the water was moving at 13 cm/sec, northerly. To determine if the tidal current tables can adequately describe the water motion in the northern basin, cross-sections were taken at Buoy, Southern, and Central in Figure 7. The average depth and cross-sectional area at each line is shown on the figure. The tidal current tables give the current past the buoy on line Buoy. The total volume flow past this cross-section can be calculated. A factor of 0.87 converts the current past the buoy as listed in the tables, to that of the average current past the Buoy cross-section. To compare the tables with the drogues, the volume flow rate is calculated past Buoy line at any time. This volume flow is corrected for the Southern line or the Central line by using the cross-sectional area ratio. Then the new velocity at the Southern or Central Lines can be calculated, based on the tables for Punta Ostiones. These results are then compared to the calculated drogue speeds past that line at that time. For the case of the 14 July measurements, the drogues' trajectories passed the Southern cross-section. The estimated average speed of the water (average of the two drogues) while passing this line is 54 cm/sec, at 1315. According to the tidal current tables, the water velocity past the buoy at Punta Ostiones at that time was 60 cm/sec, southward. The average speed across the Buoy cross-section is 52 cm/sec (0.87 x 60 cm/sec). The average speed past the Southern cross-section is 36 cm/sec (63,000 m^2/90,000 m^2 x 52 cm/sec). The percent difference between these two determinations is 40%. In the case of the 16 July data, the drogues passed the Central cross-section at 1045. According to the tidal current

According to the tables, the speed past the buoy at Punta Ostiones at that time was 22 m/sec (0 cm/sec x 0.45 time correction). The speed past the Buoy cross-section was 20 cm/sec (22 cm/sec x 0.87). Additionally, the speed past the Central cross-section was calculated to be 15 cm/sec (65,000 n7/84,000 mn? x 20 cm/sec). The rogues were moving past this line at 13 cm/sec, which yields a percent difference of 14%. The average percent difference for these two cases of comparisons is 27%. If this error is acceptable, a north-south component of the water current can be predicted in the northern basin. The prediction will include direction, speed, and time. This can all be done without the use of long-term expensive measurements. This procedure is highly recommended wherever conditions such as these prevail.

It is very difficult to predict the effects of the predominant westerly currents moving past the island, both in the Atlantic and the Caribbean. On occasion, these currents do affect our study area, but these situations are not too frequent, and are relatively unpredictable. This information will not be used for the particle trajectory prediction.

In describing the potential effects of possible resuspension distribution in this area, a thorough study of the sediment origin and grain size was necessary.

Sediment information is used to understand the source material, as well as its potential and redistribution effects. During the aforementioned cruise of 20 April 1976, sediment grab samples were also collected at each station (Fig. 3). The samples were obtained using a Shipek Grab sampler. The sampler has an opening of 20 cm by 20 cm, and a total collection volume of about 3000 cm^3. One grab sample supplied many samples. Each station supplied at least one subsample (100 ml or 200-300 gm) for grain-size analyses.

Also, during a cruise of 25 March 1976, aboard the R/V PALUMBO (PRNC/CEER), core samples were taken at the approximate location of our station C. The piston coring device contained a 6.3 m inside diameter tube. The maximum length core that we collected with this corer was about 1.5 m long. From one of the successful cores, subsamples were taken at 0.0, 0.3, 0.6, and 0.9 m below the sediment/water interface for analysis of grain-size distribution and many other measurements.

The grain-size analysis involved using the wet sieve technique first to separate the coarse fraction from the finer material. Pipetting further separated the finer fractions. The wet sieve method (Griffiths, 1967; Folk, 1968) consists of washing a small sample of material with fresh water while sieving the material through screens of mesh size phi = -1, 3, and 4. The wet sieving technique serves to wash the salt from the sample, to separate the small particles that have been consolidated into larger lumps, and to lubricate the grains during the sieving to prevent their being abraded against the mesh and each other. (The size unit, phi (ϕ) = -log, (diam. in mm). Table 4 contains the conversions from the phi size used in this study to millimeters and inches.) The material remaining in each of the sieves is carefully removed and dried at about 80°C. The material that remains in the final pan, after passing through the phi = 4 sieve, is allowed to sit for an extended time while the sediment settles. The excess

Water is carefully decanted, and this very fine material is air-dried, with a subsample of about 20 gm being set aside for further analysis.

This fine material was separated into fine fractions using the pipette method (Griffiths, 1967; Folk, 1968; Carver, 1971; Shepard, 1963). The material used for this report was divided into sizes of phi = 4, 5, 6, 7, 8 and greater than 8. The results of the sediment grain-size analysis can be seen in Table 5. The table has listings for all eight stations, their average, and the four core subsamples. The stations are broken down by phi-size (columns) from ϕ = -1 to ϕ = 8. The finest material is shown as 6>8. The information on the table is given in percent by weight of the total sample.

The upper-level number for each entry is the percent by weight for the given phi-value for that station. The lower-level number for the entry is the accumulated percent, from ϕ = -1 toward the finer material (from left to right on the table). The final cumulative value is shown at the right. The value for the phi-arithmetic-mean (M-ϕ) for each station is shown in the extreme right column.

Figure 8 depicts a graphical representation of the grain-size distribution for each of the eight stations in the northern basin. The graphs of phi-size versus percent within the given phi range are displayed on the figure. The relative location of the graphs in the figure is similar to the layout of the stations within the basin. Figure 8 is useful in helping to interpret possible drift, movement, and sources of sediment in the northern basin. Moving southward along the eastern line (NE to E to SE) shifts the material from the mid-size grains toward finer material. The fine material is much more abundant at stations E and SE than any of the others.

This can be seen in Table 5 where the M-ϕ (phi-arithmetic-mean) shifts from 4.5 at station NE to 7.2 and 7.0 at stations E and SE, respectively. The material at station W is definitely of a different composition (M-ϕ).

2.3) This station is situated adjacent to an area of reef and rock, where the sediment is composed of larger shell fragments, which are not found in the same abundance at other stations. Station SW has more coarse material than the eastern stations, but not nearly as much as station W. Conversely, station W possesses more fine material than the western stations, but has more coarse material than the eastern stations. Station C appears to be a mix of material sourced from N and K. The material at station S seems to be very poorly sorted and evenly distributed with respect to grain size, with probable contributions from the north, east, and west. This station is near the southern entrance to the basin, with only a small opening in the reef, and the water moves at a higher speed here than elsewhere in the basin. This is likely the cause of the excellent mixing of sediment material.

In summary, it appears that the finer material may be entering the basin from the eastern side, possibly from land run-off, small creeks in the area, or from the Guanajibo River. From this eastern edge, the material tends to move southward, and then is swept along the southern boundary of the basin. From here, it is either evenly distributed on a northward tide or carried out of the northern basin to the south. The coarse material probably enters the basin from the western edge and moves north and east into the central area. The central area seems to be a mixing zone for the two main sources. There appears to be no difference in the vertical distribution of material.

The results of the analysis for the four core samples are shown in Table S. The surface core sample (C-0) does have a tendency to peak more towards the mid-sizes than towards the coarse or fine material, but not to a significant degree. During this analysis, there were many possible sources of error. We were on alert for the obvious ones, but the not-so-obvious ones could have caused some problems. Some possible sources of error in this... [text cut off]

Grain-size analysis issues include: 1. Non-representative sample. 2. Failure to eliminate clumps of small grains. 3. Loss of material while removing from sieves. 4. Loss of material while decanting off the water. 5. Insufficient removal of salt (poor washing). 6. Errors in mass measurements. 7. Incorrect penetration distance for the pipette. 8. Incorrect timing for the pipette action. 9. Unequal weight gain during temperature equilibration after drying.

Analysis for calcium carbonate helps show the origin of the sediment. It may also help predict the influence the material might have when it is redeposited in a new area. We analyzed samples from each of the eight stations and the four core sub-samples (Fig. 3). We followed the procedure described by Carver (1971), and each sample had a comparison replicate.

We measured the weight loss after washing, dissolving with hot acid, heating, decanting, and drying the material. Our hypothesis was that this weight loss was due entirely to the calcium carbonate dissolving in the acid (Carver, 1971). Figure 9 shows the results of this work, as does Table 6. The table contains the values for the percent by weight of calcium carbonate in each of the replicate pairs.

These average values appear in Figure 9, showing the calcium carbonate tending toward a minimum along the eastern and southeastern sectors of the basin. The values rise to the west, reaching maximums at stations W and C. Within this basin, it can probably be assumed that the source of the calcium carbonate in the sediment is biologically and marine-formed.

This material was probably produced by mollusks, algae, corals, Foraminifera, silica spicules, etc., (Shepard, 1963; Twenhofel, 1932). The material is likely being formed along the western edge in the reefs and rocks and is then deposited. The larger materials are found at station W, and the smaller are found at station C. This is due to the drift of the water when reaching the cut-off northwestern corner. The water at this corner is probably diverted.

The text is somewhat directed towards the east, towards stations C and N. Moreover, the heavier and larger material descends through the water column faster than the smaller material, hence it is found at station W and the smaller material at station C, "downstream" from station W. The terrestrial material, containing little calcium carbonate, is probably entering from the eastern edge and then moving primarily south and west. There is some mixing with the calcium carbonate material in the central areas.

The lower portion of Table 6 shows the calcium carbonate content of the sediment below the sediment/water interface. These values are from the four core samples. The average value for the surface sample, Core-0, is 77.64. The average value then decreases to Core-90, where it is only 60.2%.

At first glance, it appears that there is a real decrease in the calcium carbonate deposition over time. Bathurst (1971) found similar results occurring off Florida and the Grand Bahama Banks. A possible explanation is that the sediment settles and then covers the already existing sediment. This new material now removes the old material from direct contact with its major source of oxygen, the water. As the benthic organisms respire and oxidation of organic matter continues, the available oxygen is slowly consumed. Therefore, an excess of carbon dioxide remains. The environment becomes more acidic, and the calcium carbonate appears as a constituent of the buried sediment.

Using this model, the evidence does not indicate that the rate of calcium carbonate deposited in previous times is any different from now. The actual amount may have been somewhat less, but the evidence is inconclusive. As can be seen in Table 6, some of the replicates at a particular station show considerable differences. For instance, at station SW, one replicate has 52.5% calcium carbonate, the other has 64.4%. The most accepted reason for such a large variation from the same sample is the occurrence of one or two large shell fragments in the sample.

Replicate which registered the higher value. This would certainly produce such a result. Other possible sources of error in this procedure are: 1. Sediment loss during decanting. 2. Insufficient salt removal from sediment. 3. Insufficient dissolution of calcium carbonate. 4. Unequal shell fragments in the replicates. 5. Errors in mass measurements. Particle Settling Velocity in Sea Water. In order to determine the trajectory of any resuspended material in the northern basin of the Cabo Rojo Platform, the settling velocity for the resuspended sediment in sea water must be known. A literature search failed to provide data for material as is in this basin, so the settling velocity had to be determined experimentally. We proceeded in the direction of first assuming that in distilled or fresh water, the settling velocity of the sediment particles follows Stokes' Law (Carver, 1971). However, in sea water, there is a tendency to build up ionic charges on the individual particles. Rather than settle as individuals, the particles tend to clump together and react as a larger single particle. This clump falls at a much different rate in sea water than the individual particles in fresh water--usually much faster. We thought that if a representative sample of the sediment material from the Cabo Rojo Platform could be analyzed in both distilled/fresh and ambient sea water, much information could be obtained comparing the fresh water settling rates (Stokes' Law) with the settling rates in sea water--or those settling rates that would actually occur in nature. A sample of the fine fraction (> 4) of sediment from station C was carefully washed, mixed, and divided into two portions, each containing about 20 gm. The first portion was re-washed in distilled water, mixed, and allowed to set for a few days in the distilled water. The second portion was given the same treatment in Cabo Rojo sea water. This setting allowed the sediment and water to come to chemical equilibrium. Some of the water was decanted, and

The individual portions were then poured into their respective settling tubes of fresh or sea water. The pipette technique was used again to fractionate the samples by size. Seven pipette draws were made from each of the two tubes. Table 7 provides the cumulative percent by weight in each of the seven draws for both the sea and fresh water. In the case of fresh water, the cumulative percent of material versus sediment particle size is shown in Figure 10. Because each pipette sample was drawn at the same time from tubes, the same settling characteristics (velocity) can be said to exist for the matching pipette draws, although each may be associated with a different grain-size. The velocity characteristics of the first pipette draw in the fresh water corresponds to that of the first pipette draw in sea water, etc. However, the cumulative percent of material in the sea water tube did not follow that of the material in the fresh water tube, but increased faster. Therefore, a given percent of the same material in sea water was settling faster than the same percent of material in fresh water. (Recall that the actual material in each tube is assumed to be of the same size distribution.) On the curve seen in Figure 10, the circled numbers indicate the pipette draws from the fresh water tube, and the squares indicate the sea water tube. Each circle (fresh water draw) provides three bits of information. Its value along the abscissa corresponds to the grain-size. This is determined by using Stokes' Law (Carver, 1971) and using a preset formula for deciding when and how deep to draw into the testing tube. The ordinate value is the cumulative percent of the sediment by weight, starting from the coarse material. This is determined mathematically from the actual amount remaining after the material drawn is dried and weighed. Of course, the last bit of information is the number of the pipette draw. This number is found inside the circle. For the salt water case, there is also multi-information. The number

The text within the square indicates the pipette draw number. The location along the ordinate indicates the cumulative percent, as in the freshwater case, and the grain-size value corresponding to the square indicates the same as for freshwater. A careful look at the figure reveals that the first three pipette draws for both conditions are similar. The fourth and fifth draws are quite different. The fourth draw for seawater has the same cumulative percent as the sixth draw for freshwater. This means that the fourth draw involves material 26.

This is settling at a rate calculated in the freshwater (4th draw). But the material involved in seawater is of a much finer size, +7. The particles are settling at a rate of .05 cm/sec, and in freshwater this corresponds to a size of ¢ = 5.5. Similarly for the fifth pipette draw from seawater, and the seventh draw from freshwater. Following this reasoning, the estimated settling velocity of the sediment is shown in Table 8. This table shows the settling velocity in both the freshwater and seawater versus the grain-size.

Sediment Particle Trajectory

One of the most important subjects of this report is the determination of the expected particle trajectory for the re-suspended sediment. In this section, an attempt will be made to make a reasonable estimate of this trajectory, as well as predict the new location of the re-suspended material, after it has again settled to the bottom. In making this estimate, the following assumptions were made for the northern basin of the Cabo Rojo Platform, based on information learned during this study:

The water moves as a single mass throughout the basin. The currents are similar from top to bottom in the water column. The water current studies seem to confirm this. The east/west cross-sectional area across the basin is always the same, regardless of latitude. A given north-south current near the southern

section will result in essentially the same current in the central or northern section of

The basin. This may introduce a possible error of up to 25-50% in velocity for the worst cases, but it simplifies the calculations considerably. The times for the maximum and slack tidal currents in the basin are those shown in the tidal current tables for the Vieques Passage, Puerto Rico, with the appropriate correction for Punta Ostiones, Puerto Rico. The maximum current speeds are assumed to be always the same, the listed average is 0.5 m/sec, and this will be used. This is for both ebb (southward) and flow (northward) tidal periods. This is accurate for an average, but the actual values may range from 0.2-0.9 m/sec. The tidal period is semi-diurnal. This is based on the tide tables. The tidal current follows a sine curve, having a maximum speed of 0.5 m/sec, and a period of 12 hours. The exact 12 hours is to again simplify the calculations. The wind-driven currents have a magnitude of 1% that of the wind velocity. The wind is steady out of the east at 5 m/sec (10 knots) producing a continuous 0.05 m/sec westward water current in the basin.

Page Break

8. There are no currents in the basin other than the observed north-south and wind-driven westerly currents. This is not always the case, but other currents in the area are very unpredictable as to frequency and magnitude.

9. During the proposed construction, a mass of unconsolidated, but contiguous sediment would be raised as a single entity to the surface, then allowed to fall as individual particles.

10. The boundaries to the north, south, and west of the basin have depths of 3 meters. Some results of the predictions are seen in Table 9. The table shows the estimated percent of the material from each of the stations that may be carried out of the basin. Also, the direction of departure and percent of time each day that such a redistribution could occur is also seen. Of all the material in the basin, only that material of a size 7 or finer would remain in the water column long enough to be carried out past the basin boundaries. Also, in all cases...

Except for station W, the northern stations appear to lose material only to the north, and the southern stations appear to lose material only to the south. By the time the water would move from the southern stations to the northern boundary, it would have lost its sediment load. The case of station W is an anomaly. This station is located directly south of a diagonal boundary cut-off. For this reason, the material from this station is lost over the northwestern corner.

It is also noteworthy to mention that, except for the material of size @ = 4 and larger, much of the finer material will be re-deposited within the basin, but not onto the boundary areas, such as the reefs, rocks, and Thalassia beds. The larger material will be more randomly distributed throughout the basin, with much falling back to the bottom near its original resting place. The last column in Table 9 contains the percent of time of each day, or actually a probability time-function, that the indicated activity could exist. These values verify that the rest of the prediction is an upper limit, occurring only part of the time. For example, if the currents are moving northward, and the material is resuspended from station X, some may be carried out of the basin. However, if the currents are slack or moving southward, no material will leave the basin. The last column shows the maximum percent of the time that the material could be swept out of the basin. It is also important to see that based on these assumptions, no material would be lost out of the basin if the construction took place near either stations C or E, or actually almost anywhere along this line, except south of the northwestern corner.

Analysis for Trace Heavy Metals

During the hypothetical construction and resuspension, the sediment will be lifted and moved from its original position. The sediment may be associated with various contaminants, specifically heavy metals. Some of these metals occur in trace amounts in nature and are necessary for the survival of

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Heavy metals can disrupt aquatic organisms. However, if the amount of heavy metals exceeds certain limits (different for each organism), adverse effects can result. To assess their potential environmental significance arising from resuspension and resiltation, an analysis was conducted of the trace metals in the sediments and water of the northern basin of the Cabo Rojo Platform. The resiltation of the sediment and/or the mixing of the sediment with the water column could cause changes in the amounts of these trace heavy metals throughout the water column and sediment layer.

In this regard, the amounts of various heavy metals were determined for samples of surface sediment (see Fig. 3 for stations), for sediment as a function of depth below the sediment/water interface (from a core at station C), and from the water column (water sample from mid-depth at station C). The surface sediment was part of the material collected during the cruise of 20 April 1976, as was the water. The core material was abstracted from a one-meter-long core collected on 25 March 1976.

The original surface and core sediment samples were oven-dried (95°C) and triplicate subsamples of 3 grams each were acid-digested to obtain total metals. The samples were subjected to a successive treatment with inverse aqua regia (3 HNO, THCl), hydrogen peroxide, and 2N HCl to accomplish total dissolution of the material. Finally, they were centrifuged and the supernatant was saved for analysis.

Determinations were performed on a Perkin-Elmer Atomic Absorption Spectrophotometer, Model 303 on an air-acetylene flame. The instrument featured deuterium background correction. Blank samples were carried through the procedure for systematic corrections.

Chromium, zinc, nickel, copper, lead, and cadmium were the unknown metals sought in the sediment. The water analysis determined the concentration for zinc, copper, lead, nickel, cadmium, iron, manganese, and cobalt. These metals were chelated with ammonium pyrrolidine dithiocarbamate.

(APDC) and concentrated by extraction into a small volume of methyl isobutyl ketone (MIBK) using a method adapted by Lopez (1973) from that suggested by Standard Methods (APHA et al., 1971). We placed triplicate 150 ml sample portions in 250 ml volumetric flasks and adjusted the pH to 2.5 ± .01 using a 0.2% bromophenol blue indicator in an alcoholic solution. The color was adjusted to blue by dropwise addition of NaOH (308). The samples were back-titrated with HCl (2.8), until the blue color just disappeared. At this point, addition of 1.01 ml of 2.58 HCl brought the pH to the desired value. A freshly prepared solution of APDC (21) was twice extracted with appropriate portions of MIBK, and the organic phase discarded. A 5.0 ml portion of the APDC solution was added to each flask and mixed. This was followed by 10.0 ml of MIBK and vigorous shaking on a wrist-action shaker for 5 minutes. The phases were allowed to separate. We then added deionized water to bring the organic phase up to the neck of the flask for direct aspiration into the atomic absorption flame. A blank and standard addition made on water of the appropriate matrix were carried through the procedure.

Table 10 shows the results of the analysis for trace heavy metals in sediment. The mean concentration (N=3) for the selected metals is given in mg/kg. The standard deviations show the precision of the analysis. The table also shows the measurement detection limits for each of the metals. In addition, the U.S. EPA Region VI (Dallas, Texas) proposed guidelines for determining the acceptability of dredged sediment (cited in Lopez, 1976) is given in the table for comparison. These criteria, although not directly applicable, provide a useful guideline as to the expected potential significance of sediment resuspension in a water column. The values presented represent total metals present in the sediment. These values do not necessarily bear any simple relationship to the potential contamination of the water by the sediment, should

Resuspension occurs. Generally, the results indicate that the sediment is relatively uncontaminated with heavy metals, as similar levels of these same metals are found in areas known to have little or no pollution influence (López, 1976). The quantities of lead and cadmium are close to naturally occurring levels and are distributed uniformly throughout the basin and with depth. This implies there is little, if any, foreign or unnatural inputs of Ce into the area in the near or distant past. Other metals such as chromium, zinc, nickel, and copper indicate significant enrichment along the eastern edge of the basin and to the south (Stations NE, E, SE and S). This seems to align closely with the probable path of water from land-based sources (Guanajibo River and rain runoff). Kattman (1972) and Guillou and Jewell (1957) confirm that there is a high concentration of these heavy metals in the watershed of the Guanajibo River and near shore in the hills where direct runoff is possible.

Examination of heavy metals concentration in the core samples (C-0 to C-80) shows little or no change with depth for most of the metals. These data (Table 10) show no change in chromium, copper, lead, or cadmium. There is an apparent increase in zinc and nickel concentration as a function of depth from the surface of the sediment. This may be attributable to the increased land usage for agriculture or housing, causing an increase in the metal content of the runoff due to lack of normal vegetation. Another likely source is the increased use of tin roofing material in the area over the past century. Generally, it can be said that the sediment in the area is not contaminated with excessive amounts of heavy metals.

Comparing the results from this study with the proposed guidelines for determining the acceptability of dredged sediment for disposal into the ocean (EPA-cited in López, 1976), it shows that only copper and nickel exceed the suggested EPA limit (Table 10). It must be noted that these

Criteria represent limits for sediment concentration, beyond which the resuspension of sediments may be expected to result in a water quality problem from the viewpoint of aquatic life. However, this type of criteria is also questionable, due to the implication that a greater metal concentration will result in a greater metal release to the water column. This may be a geochemical oversimplification. Based on the above information, it can be said that little or no direct effect can be expected in the water column due to the resuspension of these sediments, as far as the trace heavy metals are concerned. The results of the analysis for trace heavy metals in the water are shown in Table 11. This table shows the total metal concentration for the selected metals as the water was not filtered to exclude the non-dissolved fraction. The second column of the table shows the average value of the metal concentration considering the three replicates. The third column is the standard deviation of the three replicates. The fourth column is the value of the concentration for these metals for typical sea water (Horne, 1969). The fifth column is the proposed maximum acceptable limits of the concentration of each of the metals (U.S. EPA, 1975). This last column has units of either ug/t or fractions of the concentration. In some cases, the criterion is a fraction of the 96 hr LC50, Standard Methods for the most sensitive important animal of the locality. The trace heavy metal concentration found in the northern basin of the Cabo Rojo Platform is higher than typical sea water values. However, the proximity of the metal-rich coast greatly influences this enrichment. Also, in all cases (using similar water and temperature), the concentrations we found were lower than the EPA proposed limits, and in many cases as much as ten times lower. The true environmental significance of the trace heavy metals is their bio-availability to aquatic life. Once the material becomes available within the water.

Column, the next significant feature is the relative toxicity of each existing chemical species. For instance, it is generally felt that the particulate forms of the elements are less available for uptake by floating and swimming organisms. These particulate forms are often strongly bound to materials like clay-minerals and other inorganic precipitates that are not assimilable by these organisms. Likewise, by being bound in this fashion, the potential toxicity of these elements is effectively reduced as they are removed from the water column by sedimentation and their chemistry also changes. Jenne (1968) and Lee (1975) have treated this subject in detail with particular reference to the role of ubiquitous hydrous oxides of iron, manganese, and aluminum in controlling the concentration of trace heavy metals in natural water systems. In general, the free ionic form of a metal is usually its most toxic form. This is followed in toxicity by other dissolved forms, which may be variously complexed by either organic or inorganic ligands. These chemical forms are usually readily bio-available. Conclusions regarding the trace heavy metal results are that if the construction of an offshore power plant would occur in this area, there is little or no significant addition of bio-available trace heavy metals. The sediment is below the "proposed" limits of heavy metal concentration (except for copper 36).

Of the eight stations observed, only three showed any living foraminifers. They were stations W, E, and SE. Normally, this kind of result would give rise to the suggestion of severe pollution at the other stations. However, the most probable cause of this lack of live fauna was that the grab sampler may have penetrated too deeply into the sediment, thereby passing the upper few centimeters of sediment where the living foraminifers are found. A second strong possibility as to the lack of the living animals is that the sediment/water interface may have been washed out of the sampler while

The text has been corrected as follows:

If there is any influence at all, it is only slightly indicated at the end, again at station SE. From Table 14, the number of nematodes can be compared to the number of foraminifers. In all given cases, the nematodes far outnumber the foraminifers. This is usually a strong indicator that the area is virtually free from any significant man-made pollution, or its influence.

The examination of the 90 cm of the core failed to reveal any difference between the origins and mechanisms of sedimentation from the time necessary to deposit 90 cm of sediment and now. The animals found in the core appeared to be uniformly distributed throughout its length.

Sediment Variation Below the Sediment/Water Interface

Studying the properties of the sediment and the variation of these properties with depth below the sediment/water interface involves studying samples from the grab and core data, as well as looking far beneath the sediment surface. Coring attempts yielded only a maximum of 1-1.5 m cores. Four subsamples from a 1 meter core have been analyzed for grain-size, calcium carbonate, foraminifers, and trace heavy metals. The results of each of these analyses are discussed in their respective sections of this report. Only a summary of each will be given in this section.

The sediment grain-size analysis (Table 5) shows no variation with depth that cannot be explained by sampling technique. Calcium carbonate content in the sediment appears invariant with depth (Table 6), if the pH and available oxygen are taken into account. The variation in trace heavy metals with depth (Table 10) appears negligible, with the exception of the zinc and nickel concentration. This was discussed in the trace metal section. The Foraminifera analysis showed no change in neither fauna nor number of fauna with depth along the core.

Therefore, from this evidence - although it is only from about one meter depth - there is no reason to believe that there has been any change in the sources, mechanisms, or rates of deposition in the recent history.

Of the northern basin of the Cabo Rojo Platform, the second method to evaluate the sediment's characteristics with depth considered the basin's history. Historical dating, as well as sub-bottom profiling, were combined to provide a first approximation as to the estimated "life" of the basin. Carbon-14 dating on a sediment sample taken from one meter depth indicates that the sediment at that depth is 2110 +/- 80 years old. From this information, it is estimated that the deposition rate in recent history has been 0.047 cm/yr, or about 0.5 m/1000 yr. Communication with Mr. James V.B. Trumbull of the San Juan Puerto Rico Office of the U.S. Hydrographic Survey resulted in a sub-bottom profile along the line indicated by dots in Figure 2. No attempt will be made to reproduce the profile in this report, as the loss in quality and readability would be too significant. The depth of the bottom of the unconsolidated sediment can be calculated from these seismic profiles. The velocity of the sound in seawater is taken to be 1700 m/sec (Shepard, 1963). The depths of unconsolidated sediment are shown in Table 15 for values every 350 m along a north-south line through our study area. The depth of this sediment ranged from 13-424 meters with an average depth of 274 meters. Using the information obtained by the carbon-14 dating, and the estimated settling rates, the age of the sediment sitting directly on the bedrock in the northern basin of the Cabo Rojo Basin is estimated to be about half a million years old, assuming the same mechanisms, sources, and rates apply from the 1-meter depth down to the sediment/bedrock interface. Possible sources of error in this analysis are: 1. Speed of sound in seawater. 2. Readability of thickness of sediment in the seismic profile. 3. Location of distance and position in the seismic profile. 4. Measurement of the length of the core sample. 5. Carbon-14 counting. 6. Assumption of "no variation in sediment" between 1 m and bedrock. Benthos The

The resuspension and recirculation of marine sediment that could and likely would occur during offshore construction jobs could adversely affect slow-moving or stationary organisms living at the ocean floor. These benthic organisms, or benthos, could be impacted by siltation, which could cause smothering and/or reduced light penetration.

Siltation could potentially smother sessile organisms such as corals, gorgonians, sponges, and algae. The reduced light penetration could affect the photosynthetic abilities of algae associated with coral and gorgonians. Furthermore, the resuspended sediment could completely cover substrates that are otherwise available and usable, which are needed for the settling of larvae of sessile organisms. Additionally, the removal or destruction of food sources could then affect the plant and invertebrate population, and ultimately higher food chain organisms such as fish or even humans. These reasons necessitate at least a preliminary examination of the benthos in the northern basin of the Cabo Rojo Platform.

During the sediment/hydrographic cruise of April 20, 1976, bottom grabs were also taken to analyze the benthos in the area. The sampler was the same Shipek grab, with an area of 0.0 sq n. Three replicate grab samples were taken at each of the eight stations indicated in Figure 3. Each of the grab samples was washed through a 1.5 mm mesh screen and the residue was preserved in a 70% ethanol solution. Laboratory analysis separated the living organisms and classified them to the lowest reasonable taxon.

The results of the analysis and identification are shown in Tables 16 and 17. Table 16 has the identification for each of the three replicate samples at the eight stations. Table 17 intercompares the occurrence of the different species with the stations.

Thirty-six different species representing seven animal phyla and one plant phylum were collected in the sampling area. The most common species were represented by the Pelecypods (9 species), polychaetes (8 species), and ascidians.

Seven species were identified. The polychaetes were present at all stations, with a total of 19 specimens collected. Station W had the highest diversity with 10 species, whereas the lowest diversity was at Station S, with only three species. Out of the 36 species collected, 10 were sessile organisms, which can be directly affected by siltation. In the specific case of Halophila baillonis, a seagrass and the only representative of the plant kingdom collected, reduced light penetration can also be detrimental. Since H. baillonis, coral reefs, and Thalassia testudinum beds are found on the bottom, their photosynthesis (in the case of corals, the zooxanthellae associated with it) and growth could be limited by the available light, all other things being equal. Turbidity and siltation reduce light penetration to the bottom, which could reduce the primary productivity of the seagrass beds and reefs. Furthermore, corals can survive for short periods when covered with sand and sediment (Edmondson, 1921; Vaughan, 1916; Marshall and Orr, 1931). This survival is accomplished by removing the sediment from their surfaces. However, data is not available regarding how much sediment an organic reef can remove when experiencing high rates of siltation. It has also been shown that sponges and ascidians could be adversely affected by sedimentation, particularly due to the clogging of their canals and chambers, along with their total burial (Bakus, 1968). The most obvious sources of error in this benthos study are the sampling methods. Using a grab sampler of only 20 cm by 20 cm will cause the data to be highly insensitive to naturally occurring patchiness, as well as to more mobile species.

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CRP-8B/o © 29.43, 38.442, 23.38, 10, 25243, 35.134, 23133,
CRP-73/S ° 25.47, 35.173, 23.25, 10, 25.82, 35.160, 23.38,
April 197,
CRP-98/8 ° 26.58, 20, 26.26,
CRP-aB/C ° 25.88, 10, 16137,
CRP-78/8 0 26.08, 10, 25132,
CRP-98/N1 ° £7.08, 34.033, 22.00, 10, 26.95, 342023, 22103,
CRP-sB/c ° 27.47, 33.784, 21.74, 10, 26.89, 341072, 22:05,

CRP-78/S ° 27.12, 33.810, 23.81, 20, 25192, 331885, 23.93, 50

TABLE: Tidal currents past Punta Ostiones during the period of our current measurements (from Tidal Current Tables, U.S. NOS, 19762). Velocity Slack Time Maximum Current Time Speed-Direction (on/sec~deg)

44 July 1976-. 0616 60-000 1245 50-189 auu 30-000

36 July 1976- — 0738 50-000 1127 1407 60-180 3623 ~ 31

TABLE 4. Conversion of phi (6) units to metric and English units.

Metric English . (nm) : inches)

“1 2 07874 - o 1 03937 a 8 -01968 2 +28 00988

3 +128 00492 - 4 -0625 00246

s +0212 00123 6 +0156 +0007

7 0078 +0031 7 =003¢ 00035

Se G2 | Si4s 62 xg 8 9 Seal? {ss 4 g | Blo 2 2 a 8 o 2 ie 53

TABLE 6. Results of the analysis for calcium carbonate in the sediment and core of the northern basin of the Cebo Rojo Platform. (Two replicates at each station.)

Station Calcium Carbonate Average CaCO3

c 79.6 14.7 59.8

N ua 62.3 60.8 NE 55.8 61.6 67.3

E 40.8 39.5 38.2 SE 40.8 40.6 40.2

s sue 56.2 sw uae 58.3 52.2

w 70.1 74.8 72.8

core-0 83.3 17.6 . 7204 78.0 75.4 75.3

core-60 67.4 70.4 - 72.8

Core-90 60.2 60.2 60.2

TABLE 7. Cumulative percent of the extracted sediment material with successive pipette draws during the determination of the sea water settling rate for the sediment of the Cabo Rojo Platform.

Pipette Draw @ for Fresh Cumulative Percent Cumulative $ w@ water for Fresh Water(s) for Sea Water

1 4 18.5 16.3

2 4S 39.4 22.8

3 s 80.2 ue. 5 5.8 se. 72.7

5 6 79.8 302.3

6 7 80.0 a

7 8 300.2 -

TABLE 8. «Settling velocity for sediment grains of a given phi size in fresh water (Carver, 1971) and Cabo Rojo Platform sea water-determined

Experiment was conducted at 28°C. Settling Velocity for Sediment in Phi Size for Fresh Water and Sea Water is presented in the following format: (cm/sec) (cm/sec).

Calculations were made for the 9 Platform. Results of particle trajectory are as follows:

Description and location of material leaving basin:

Material Leaving	Direction Leaving	Time
5	0	13
180	21	26
180	28	

Results of the analysis for total trace heavy metals in the water of the northern basin of the Cabo Rojo Platform are as follows:

Metal	Cabo Rojo	"Normal" Sea Water	EPA Proposed Detection Limits(U.S. Limits - ug/L)
Copper	38.2	8.9	20
Iron	90.0	39.0	30
Lead	<2.0	+0.3	1
Manganese	<10	2	200

Nickel	10.8	0.8	2
Cadmium	2.8	0.2	0.2

% is the average of three replicates.
© is the standard deviation of the three replicates.

Table 12: Living foraminifers at three stations in the northern basin of the Cabo Rojo Platform, April 1976.

Foraminifers	Station 1	Station 2	Station 3
Ammonia catesbyana	2		3
Angulogerina angulosa	1		
Articulina mayori	2		
Bageina philippinensis	1		
Bigenerina textularioidea	1	1	3
Brizalina cf, variabilis	2	1	
Bulininella elegantissima	2		
Cancris			

The text provided is quite chaotic and contains many unrecognizable components. I have tried to format and correct as much as possible based on the context provided. However, without more context, it's difficult to fully correct some parts of the text.

"Sagre, 1 1 Cribroelphidium poeyanum 56 ‘ Cymbaloporetta squamose 1 Discorbinella floridensis 2 Discorbis bulbosa 3 Elphidium grateloup 5 2 1 Fursenkoina punctata 1 1 1 Miliolinella subrotunda 2 Neoconorbina terquemi 1 Nonionella cf. turgida 1 Noura polymorphinoides 2 Planorbulina larvata a Protelphidium sp. a Quinqueloculina bosciana: 1 2 Q- candeiana 1 1 Q. cf. seminulum 1 1 Q sp. 2 1 Sagrina pulchella 1

TABLE 32 (continued) TO STATION Foraminifers SE E W Siphogenerina duartei 2 Spirillina densepunctata 2 Triloculina trigonula 2 Textularia conica a Trochanmina cf. challenger 3 Unidentified forams. 1 TOTAL = 21 73 32 61

Analysis: Leaving Foraminifers at CW stations. An examination of the basin of the Cabo Rojo Platform (Seiglie, 1270). Station CR-13 corresponds to our station E, station CRT-18 corresponds to our station W. The values assigned to each species are the percent of the total number at that station.

STATIONS Foraminifers CR-13 CRT-15 Ammonia spp. 2.6 8.2 Amphistegina gibbosa is present. Angulogerina cf. bella Phi. and Park 1.0 Fabianites angulatus is present. Asterigerina carinata has 8 instances. Bigenerina textularoides 206 Comuspira involvens Reuss 3 Discorbis (7) bulbosa 10 Elphidium discoidale is present. E. poeyanum is present. E. sagra is present. E. spp is present. Florilus grateloupit 18 58 Fursenkoina pontoni 1.0 1 Heterohelix (thin-walled and small) 1904 30.8 Neoconorbina orbinculari is present. Pyrgo subsphaerica is present. Quinqueloculina agglutinens is present. Q. Biscostat spp. is present. Rosalina sp. A is present. Reussella atlantica is present. Spiroloculina arenata is present. Triloculina trigonula is present. Totals 100.0 100.0 62

TABLE 13. Meiofauna at three stations in the northern basin of the Cabo Rojo Platform, April, 1976.

STATIONS Meiofauna SE E W Foraminifers 2 73 32 Kenkotodes 310 320 are present. Polychaeta are present. Other worms 24 26 36 Bivalves are present. Ostracods, 2 20 Amphipods 2 122 2 Bivalves 5 Bryozoans (colonies) 2 Totals 158 378 206 63

TABLE 15. Calculated depth of the unconsolidated sediment in the northern basin of the Cabo Rojo Platform.

SSS Point Depth (m) 1 357 2 357 3 213 - 4"

The following is the corrected text:

Now 5 373 8 308, 1 285 8 186 s 136 10 340 - 14 306 22 237 23 220 4 153 - 45 169 18 306 7 306 - 18 306 19 208 Average 270.

Quantitative benthos results from the April 1976 cruise in the northern basin of the Cabo Rojo Platform:

SAL NET Number, STA. Net number, Yatoshiia basilionis tulina aurieincta 3 er eanteee 2 Ba Ree See Se eeteretus i inmciajeae 3 STA, Not sta. NE=21 fan. Maldani dae: Halophila baillonis fam. Aphroditidee a ae Unidene, Polychaete 1 SoA. NEI ce es Yalophite bainionis Uniden. Polychaete piece Teigoniovardin mec 2 stA._c-t poygadaium dendriticun 1 fan, Haldanidae 2, peeeseoean, eos 3 indents Sipmmeuties 4 er Grbiniicne (Polycn) 2 taiilansesidee sta. Unident. Sipuncusiee Unigens: Polycheese 3 aoe ecisne, Cnione se: ‘en. Aphroditicee Geiger. Polychaete piece Aphroditides, 2 madent. Sipuneuitda: 7 lent. Sipunculids 4 tnidens. Pebecypod oxen) 2 sta. to unigent. sipmnowtid soa, se Halophila bailionis iepos tiles fila i SoA, SE=21 Pitar aresta 1 fam, Didennidae Molgula occidentalis 1 small Nereis sp. sta,_eata Halogpite bafiionie Hactljoniae a: nant: Polycerpa spongiabilie 2 fon: Acooaldae i polveanpe spo 3 Vickersit Fam, Xenthicae 1 aliclona sp. 6s

Haliclona sp. Marphyse sp- 2 STA. W-TTT ~ Chasmocarcinus “gylindricus 2 Haliclona sp- Alpheus sp. Csrolana sp. Unident. Polychaete STA. SW-T Tellina sp. 1 fam. Anphiuridae STA. SW=TIT Unident. Sipunculid Unident. Polychaete Unident. Natantian (no key available)

Spatial distribution of benthos collected during the April 1976 cruise in the northern basin of the Cabo Rojo Platform:

STATIONS SPECIES NE_E se NC S$ Ww sw Spermatophyta Hydrocharitaceae Halophyla baillonis x x x x Porifera Haliclona sp. x Cyamon vickersi x punculida Unident. Sipunculias x x x

Annelide Polychaeta ereis sr. x mvsa sp. x > Foiyonicae x am. Acaetidae x Maléanicae fam. Aphroditidae Zam, Orbiniidae x Unident. Polychaetes XX x x x x x xx Arthropoda Crustacea. Isopoda Decapoda Alpheus sp. x Natantian x fam. Callianassidae xX x

(Note: The original text appears to have numerous misspellings and possibly scientific terms in a different language. The errors have been left as is due to lack of context to provide appropriate corrections.)

Chasmocarcinus cylindricus, Unident, Nanthid, Mullusea, Gastropoda Eulima, Pelecypoda Tellina sp., and Chana florida sp.

(continued) STATIONS. SPECIES NEE se N oc oS Ww SW 7 Pelecypods (cont.) ‘Teigonocardia, antillarun, Anypdalum dendriticun, Chtene, Gorbula caribaea, Phacoides muricatus, Fitar aresta, Unident. Felecypod, Echinodermata Ophiuroidea fam, Amphiuridae, Chordate - Ascidiaces, Polvearpa sp., Rgoidia syaneiensis, Yeerocosmus exasperatus, Molgula occidentalis.

vas NV¥aeat1uvO { 1 | | | OS * Mui La o 8 ooiy o1uand WF Kw Nva20 o1anviiy Ww 8 vou

Sub-bottom Profile line Northers, 10 20 Kilometers CONTOURS IN METERS West Coast of Puerto Rico.

FIG.5 Northern basin of the Cabo Rojo Platform. Stations and Depths (in meters) are also shown.

FIG.6 Stem

FIG.7 Surface Drogue, 10m Drogue SOUTHERN BASIN trajectories for the current drogues in the northern basin of the Cabo Rojo Platform during 14 July 1976.

FIG.8 SOUTHERN BASIN 1 Kilometers ‘Trajectory for the current drogues in the northern basin of the Cabo Rojo Platform during 16 July 1976.

FIG.9 PROFILE. Southern Basin Location of the cross-sectional profiles through the northern basin of the Cabo Rojo Platform.

PERCENTAGE Graphical representation of material sampled.

FIG.10 SOUTHERN BASIN Average value of the percent of calcium carbonate in the sediment of the northern basin of the Cabo Rojo Platform.

FIG.11 Xth. PIPETTE SAMPLE FROM FRESH WATER SUBSAMPLE . Yth. PIPETTE SAMPLE FROM SEA WATER SUBSAMPLE. Sediment particle grain size in phi units: particle size (in phi units) versus cumulative percent for fresh water and Cabo Rojo Platform sea water samples.

TECHNICAL REPORT DATA.

[CW: Aviation Science: PREDICTION OF THE EFFECTS OF RESUSPENSION OF SEDIMENT DURING THE CONSTRUCTION PHASE OF A HYPOTHETICAL OFFSHORE POWER PLANT WEST OF MAYAGUEZ, Gary C. Goldman, José M. López and Roberto Castro. Center for Energy and Environment Research. Mayaguez, Puerto Rico 00708. TAG-D-5-B581. Environmental Research Laboratory. Narragansett, R.I. 02882.

ABSTRACT: The purpose of this study was to evaluate potential effects that could result from resuspended sediment during the construction phase if an offshore nuclear power plant was built west of Mayaguez, Puerto Rico, on the Cabo Rojo Platform. During the study, we developed water current predictions and evaluated sediment for grain size, trace heavy metals, settling velocity, and sedimentation rate. The water was also analyzed for trace heavy metals. The results suggested a potential particle trajectory model, indicating potential redeposition locations. The conclusion reached from this study was that, except for sessile benthos near the actual construction site and the seagrass, rocks, and reef habitats to the north and south of the area, few negative effects would be felt during the construction of such a plant.

Keywords: Resuspension, Effects of offshore sedimentation, Construction of offshore power plant, Puerto Rico, Occurrence of trace heavy metals.