An Aerial Analysis of Shoreline Variability along the Western Shore of Guam

for

Shore-line Development Recommendations

Prepared for:

Government of Guam
Bureau of Statistic and Plans (BSP)

Prepared by:

OYO Corporation, Pacific
919 Pale San Vitores Road #103
Tumon, Guam 96913

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Final

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1.0 INTRODUCTION AND STUDY PURPOSE

The United States Territory of Guam is located in the western Pacific Ocean, at approximately 13° north latitude and 145° east longitude. It's location near the western Pacific typhoon breeding grounds results in it being regularly threatened by nearby and on top of full strength typhoons. Thus its shorelines are frequently buffeted by high storm water levels and waves.

Much of the islands interior consists of mountainous terrain, while the shoreline varies between sandy gravelly beaches and up to 400 foot high limestone facies cliffs. The majority of the villages are located on the west and southwest shores, where there is relatively flat low-lying coastal land. These villages are accessed by a perimeter highway, of which a significant portion is located near or immediately adjacent to the shoreline.

This project will assess the impacts of such natural hazards to Guam’s western shoreline subject to erosion potential with its present setback regulations and provide recommendations on changes to the Bureau and Administration that takes into consideration potential sea level rise and the increase in incidents of storms and flooding. However, the primary objective of this study is to provide information and recommendations concerning the negative impacts to building in areas inundated with storm waves, surges and the loss of natural barriers due to development that puts itself in harm’s way. Furthermore, the information can assist in strengthening the Guam Seashore Reserve Plan rules and regulations regarding development adjacent to the seashore reserve and provide policy to limit development in this area. The project finds l provide technical findings and regulatory recommendations for modifications to existing land use processes and codes pursuant to potential negative impacts to the coastal areas mentioned below. Furthermore, the information generated herein can assist in modifying Draft Guam Seashore Reserve Plan regarding future development and redevelopment processes adjacent to the seashore reserve in order to reflect a balance between competing community values.

2.0. CONTRACTUAL SERVICES

Task 1: Compile data and inventory GIS and other related information such as reports or previous studies to be utilized in the analysis. The data will include imagery and other GIS layers that show the shoreline of study areas over time. BSP provided data including:

- Imagery of Study areas
- Land Parcels – along shoreline area
- Mean High Water Mark
- Inventory of land uses
- Available infrastructure data

These datasets will form the foundation for producing quality flood and inundation maps and aid the consultants in developing risk assessment data, setback analysis, and regulation modification recommendations.

Task 2: Evaluation Probable Conditions

The consultant will develop quantifiable results to various questions that can then be extrapolated into qualified statements of value.

<u>Typhoon / Storm waves / Flooding (Per Watershed)</u>

Possible questions that focus on significant weather events that seek to quantify the island's vulnerability and the resulting impacts on erosion and to some extent flooding impacts will be explored. Using the data developed, the following queries may be developed as follows:

Environmental Characteristics / Legal (Lot Lines) Characteristics / Social Characteristics

Extrapolate / Qualitative

From questions such as these above, the consultant will identify trends in various 'financial groupings' such as the hotel industry's vulnerability and public infrastructure vulnerability and perhaps provide commentary on qualitative aspects of land use decisions such a loss of beach sands. The consultant shall also look at public infrastructure (power, water, roadways, etc.) and determine its vulnerability with respect to storm surge given that it influences the island as a whole.

Task 3 – Stakeholders Meetings
The consultant will be responsible for providing all presentation material. The following meetings have been preliminarily discussed with staff as follows.

- GovGuam Coordinating Agencies – meeting between various GovGuam agencies of BSP choosing and OYO to present a summary of our findings for the three conditions mention above in a written report in the context of a face to face question and answer situation.

- One (1) I general public meeting presentation – A present a summary of findings.

Task 4 – Recommendations Revisions to Current Land Use Laws regarding 'Shoreline Setbacks'

The consultant will develop a recommendations to the shoreline setback based on previous planning efforts and existing land use processing. The primary focus of legislative, regulatory and policy changes necessary would be consistent with n the Guam Zoning regulations, Guam Land Use Plans, Seashore Protection Act and Seashore Reserve Commission permitting process The consultant will develop recommendations to changes to the existing zoning designations include the possible creation of new zoning designations.

Task 5 – Recommendations Shoreline Setback Approval Process

Currently the SPC issues shoreline reserve permits pursuant to the SPA and Rules and Regulations promulgated under 18 GAR § 7101 et seq. The current Rules and Regulations are quite limited in scope and detail. Comprehensive rules and procedures should be promulgated by the SPC, encompassing the following:

- Determination of areas subject to shoreline setback area. This would include a certification of the shoreline by the SPC, including exception and waiver situations involving special or unusual physical circumstances or conditions of the land or where a structure or activity is proposed at a considerable distance inland.
- Establishment of shoreline setback lines.
- Determination of prohibited activities in the shoreline setback area.
- Determination permitted structures and activities within the shoreline setback area, including any "grandfathered" structures.
- Creation of variance procedures, including hardship bases and conditions for same and public hearings requirements.
- Determination of enforcement mechanisms and provide for appeals.

Task 6 – Develop "Draft" Legislation Based on Task 4 and 5 above

Proposed SPC comprehensive rules and procedures governing shoreline setback determinations, activities, permit procedures, variances, and enforcement mechanisms, would be prepared. Existing shoreline setback rules and regulations from other jurisdictions would be reviewed. Recommended changes to zoning designations would be prepared.

Potential "takings" issues resulting from recommended rules and regulations must be addressed, presumably within the variances options. Any new rules and procedures would be done in consultation with the Guam Attorney General's Office, GLUC, related governmental authorities, and made consistent the development plans discussed above.

Funding
Project funding through the Guam Coastal Management Program Section 309 Grant from National Oceanic and Atmospheric Administration (NOAA), Office of Coastal Resources Management,
Grant # NA 09 NOS 4190175.

3.0. AREAS OF ANALYSIS (Locations / Physical Characteristics)

The areas of analysis, excluding Apra Harbor are defined as follows:

1. Trinchera Beach
2. Anigua
3. Adelup
4. Asan
5. Piti (Fish Eye)
6. Apaca Point
7. Gaan Point
8. Taelayag Beach
9. Sagua Beach

By Watersheds as follows:

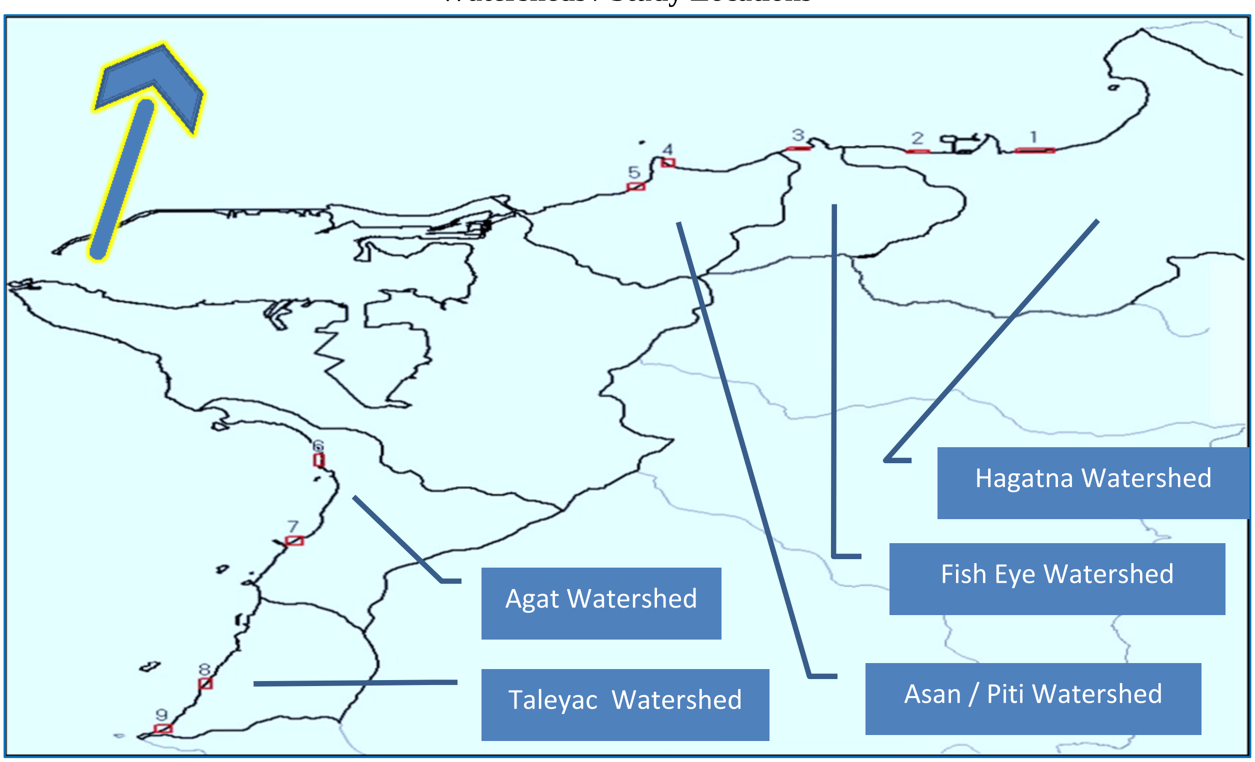
Hagatna Bay Watershed
- Aputgan Outfall - Tamuning
- Hagatna River - Hagatna

Apra Watershed - Asan / Piti Bay
- Fonte River - Haganta
- Asan River - Asan
- Malguey River - Anigua
- Taguag River - Piti
- Masso River - Piti

Agat Watershed
- Narro River – Agat

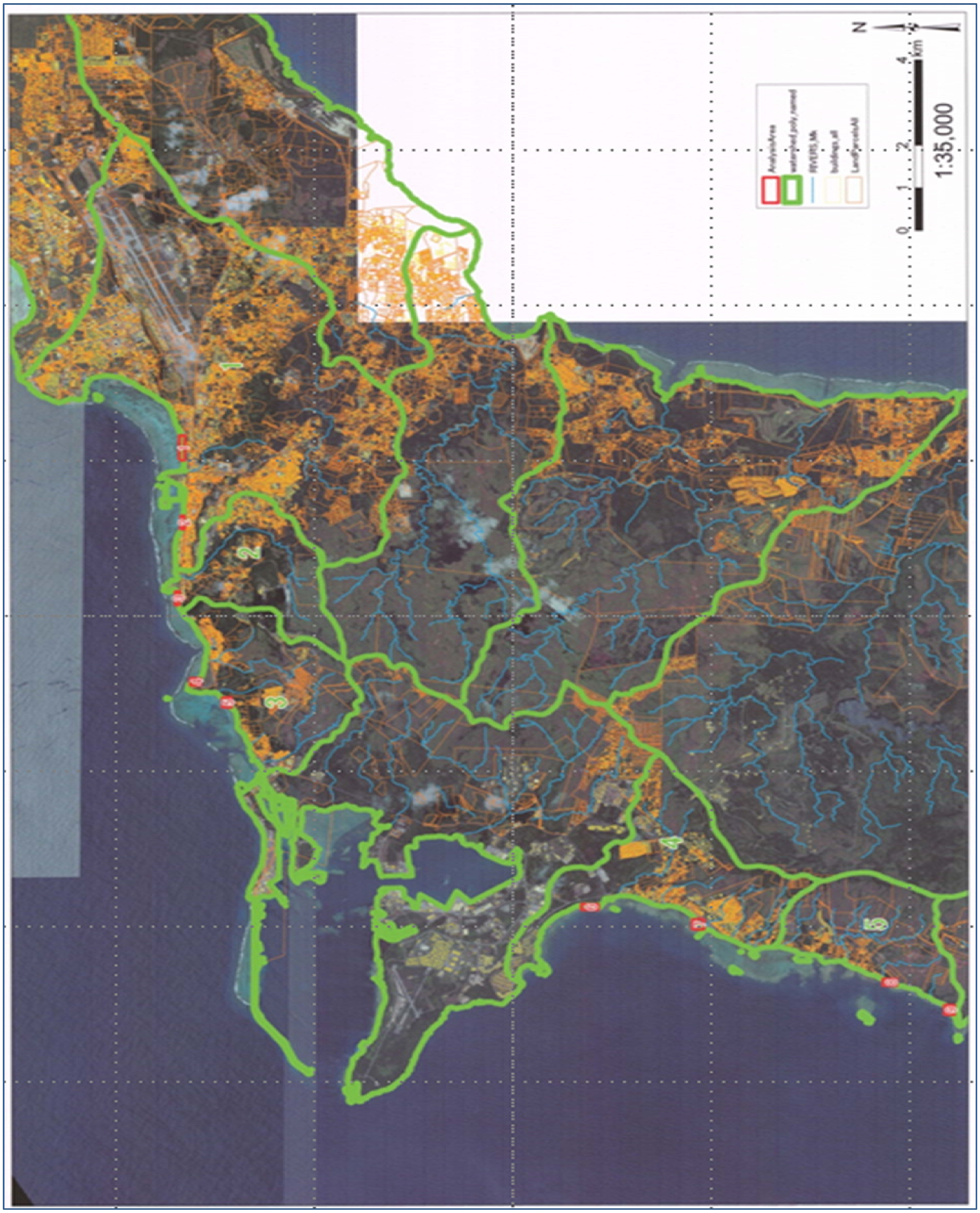
Taleyac Watershed
- Togcha River – Agat
- Salinas River – Agat
- Einile Creek – Agat
- Gaan River – Agat
- Auau Creek – Agat
- Chaligan Creek – Agat
- Taleyac River – Agat
- Taelayag River - Agat

Figure 3-1
Watersheds / Study Locations



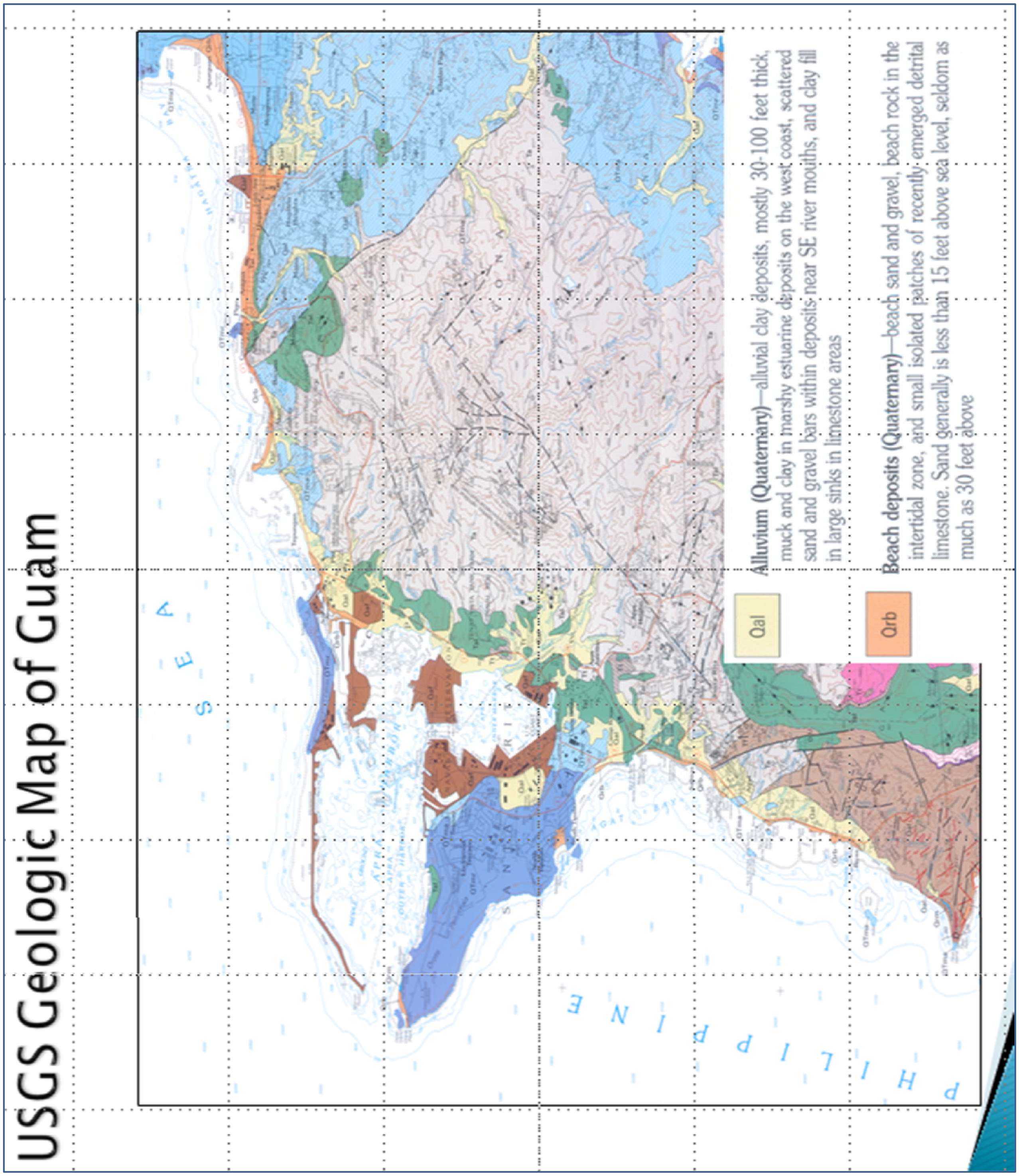
The areas of analysis" (red rectangles) shown with red (blue lines), watershed outlines (green lines), and lot lines (gold lines). Rotated

Figure 3-2
Guam Aerial GIS Overlay



The "areas of analysis" consist of the two geologic formations shown in the legend. The alluvium is highly erodible due to the high content of fine material. (Less than #200 sieve).

Figure 3-3
Guam Geological Map



4.0 ANALYSIS PROCEDURES

The following step by step approach to aerial analysis was used for all nine areas. Aerial photos from 1953, 1975, 1993, 2006 and 2009 were provided by BSP. It should be noted that cost effective PC based Geographic Information Systems really didn't really begin in earnest until 1991 when ESRI released ArcView in response to the popularity of a GUI desktop environment.

1) Manually-Digitizing 1953 and 1975 Aerial Photo

- ✓ 1953 and 1975 Aerial Photo have no geographic information therefore cannot ortho-rectify.
- ✓ Aerial Photo of 1993, 2006, and 2009 has geographic information. Used them without amendment.

2) Digitizing shore line and reference line

- ✓ Digitizing shoreline and reference line.
- ✓ Reference line: relatively permanently affixed mark that establishes exact position of a place. (Roads and buildings).

3) Adjusting shore line and reference line

- ✓ Aerial Photo of the year 1953, 2006, 2009 have position gap to a greater or lesser extent.
- ✓ Gap level differs each year and varies from region to region.
- ✓ Adjusted position differences using reference line of 2009 Aerial Photo.

4) Calculating area of the sea

- ✓ Selected 9 defined areas and created GIS polygon data of the sea area.
- ✓ Used these polygons for calculation.

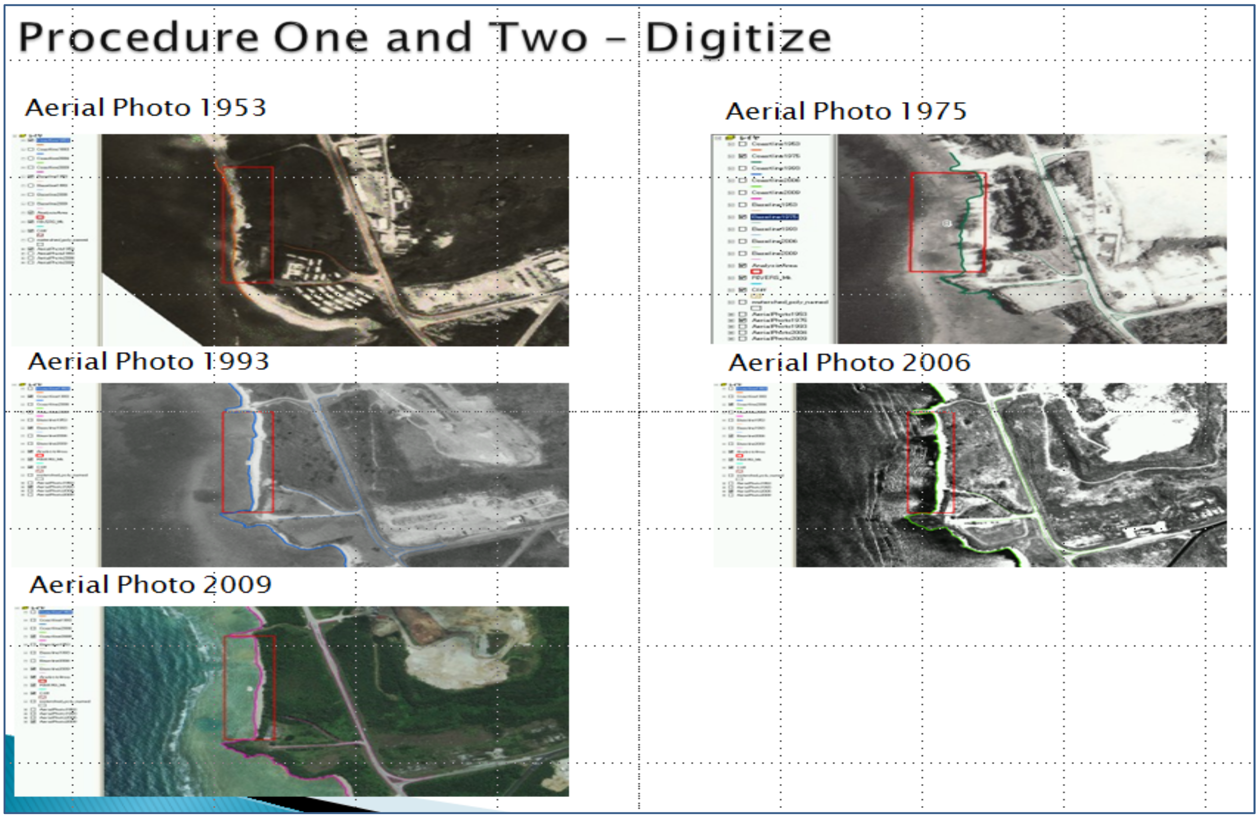
5) Analyzing shoreline secular change

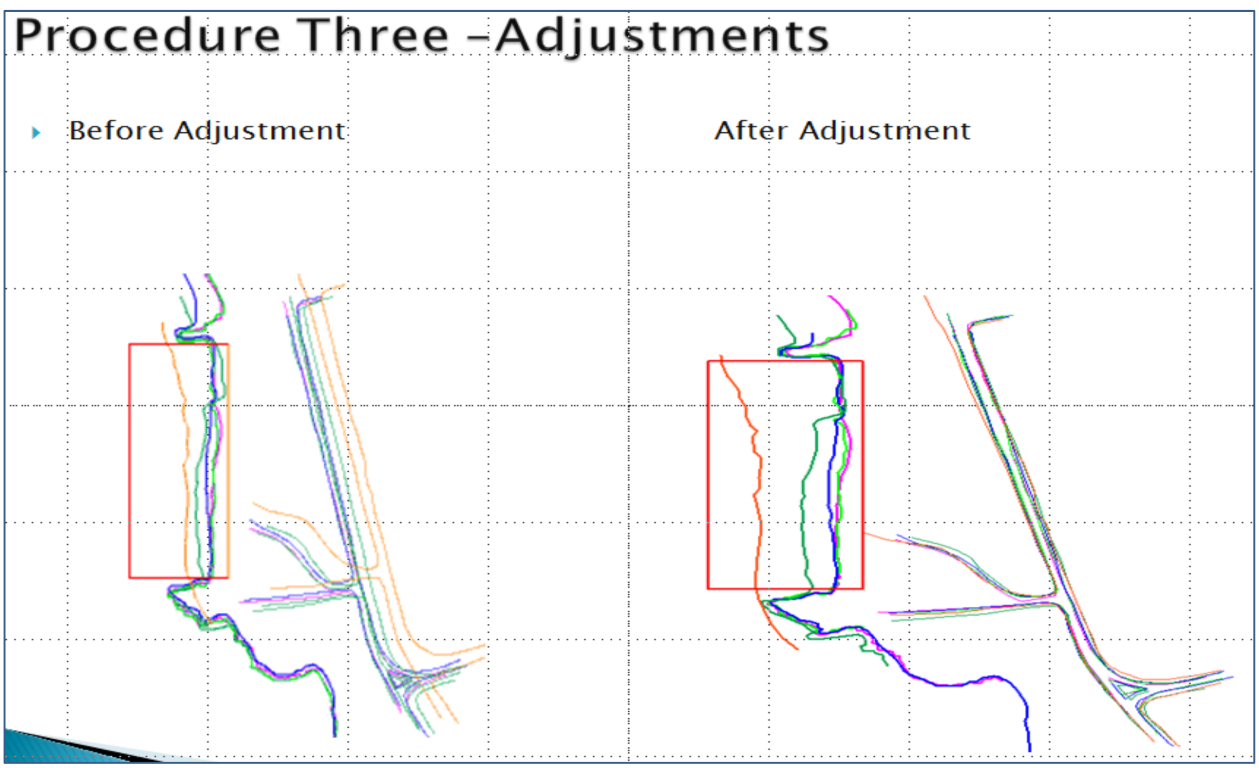
- ✓ Produced graphs showing shoreline secular change based on the sea area polygon calculation.

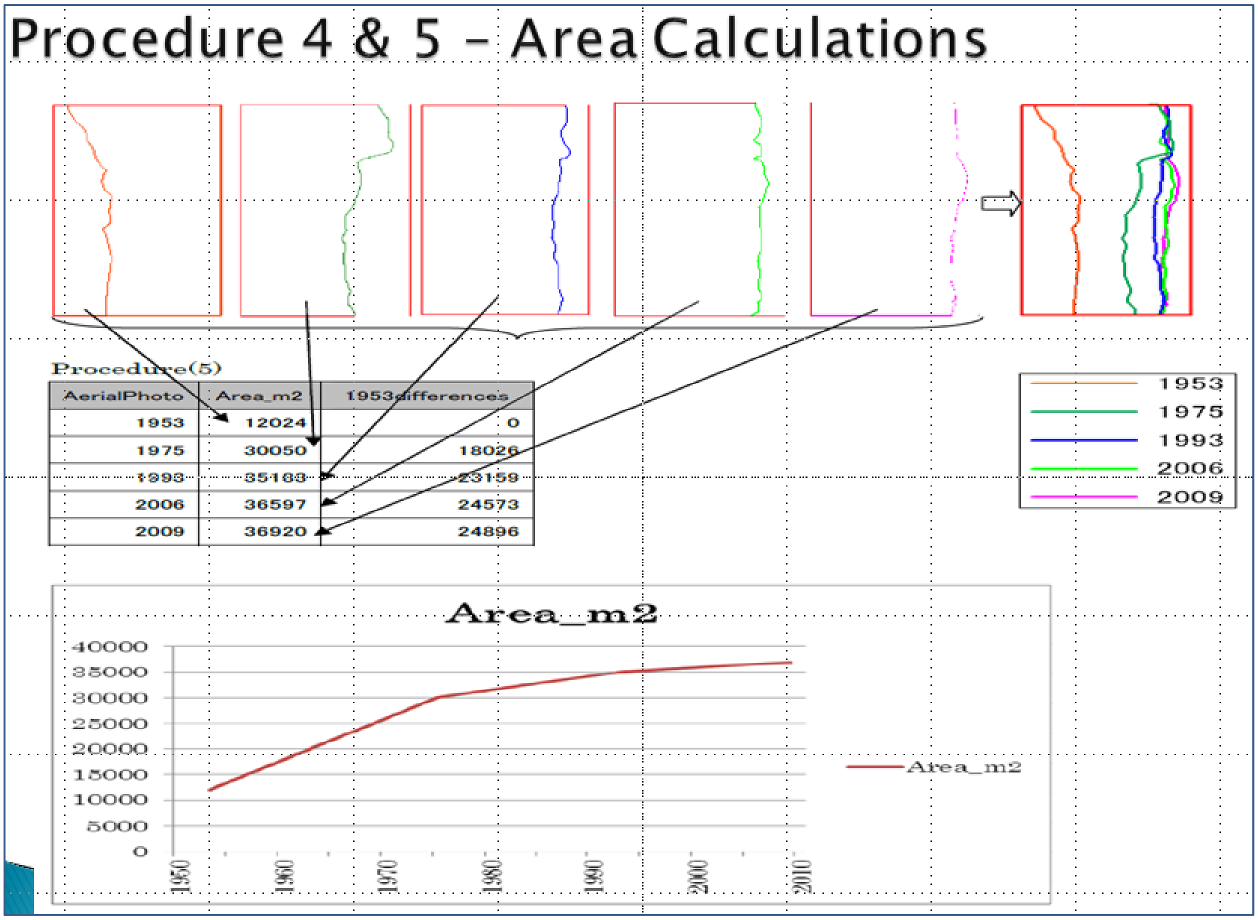
Definitions:
Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographically referenced data. In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology

Ortho-rectification of an aerial removes the geometrical errors or displacement caused by the terrain relief. Without ortho-rectification, scale is not constant in the image and accurate measurements of distance and direction cannot be made.

Sample Process – Graphical Presentation







AerialPhoto	Area_m2	1953differences
1953	12024	0
1975	30050	18026
1993	35183	23159
2006	36597	24573
2009	36920	24896

The above area calculation was developed as follows:

1. A rectangle of known dimensions is place over (layered) over an area of analysis for each year.
2. Within the rectangle, both the land area and sea area in square meters is determined.
3. The sea area is place in the column labeled Area_m2 for each year
4. The change, or delta, in the area is placed in the column to the right.
5. An increasing delta or area indicates the sea area increased and the land is eroding.
6. In turn the area divided by the length of the rectangle over time provides an estimation or mean rate of erosion on an annual basis.

5.0 ANALYSIS RESULTS

The following estimates of *annual rate of erosion* in inches in shown in tabular format below based on the areal analysis apporach presented in section 4.0.

Location	Description	Shoreline Facing	Aerial Photo	Reef to Shoreline_m	Sea Area _m2	Measured Shoreline Length_m +/-	Sea Area Delta_m2	Delta_year	Estimate Annual Rate of Erosion_inches
1	Trinchera Beach	N	1953	570	34,648	580	-		
1	Trinchera Beach	N	1975	570	27,638	580	(7,010)	22	
1	Trinchera Beach	N	1993	570	30,217	580	(4,431)	40	
1	Trinchera Beach	N	2006	570	27,272	580	(7,376)	53	
1	Trinchera Beach	N	2009	570	30,594	580	(4,054)	56	1/
2	Anigua	N	1953	620	13,062	340	-		
2	Anigua	N	1975	620	15,652	340	2,590	22	
2	Anigua	N	1993	620	16,274	340	3,212	40	
2	Anigua	N	2006	620	15,450	340	2,388	53	
2	Anigua	N	2009	620	16,278	340	3,216	56	6
3	Adelup	NW	1953	240	16,075	330	-		
3	Adelup	NW	1975	240	15,477	330	(598)	22	
3	Adelup	NW	1993	240	15,091	330	(984)	40	
3	Adelup	NW	2006	240	15,382	330	(693)	53	
3	Adelup	NW	2009	240	16,834	330	759	56	1.5
4	Asan	NE	1953	250	21,084	260	-		
4	Asan	NE	1975	250	21,712	260	628	22	
4	Asan	NE	1993	250	21,370	260	286	40	
4	Asan	NE	2006	250	21,143	260	59	53	
4	Asan	NE	2009	250	21,854	260	770	56	1.5
5	Piti (Fish Eye)	NW	1953	850	23,450	240	-		
5	Piti (Fish Eye)	NW	1975	850	21,215	240	(2,235)	22	
5	Piti (Fish Eye)	NW	1993	850	20,292	240	(3,158)	40	
5	Piti (Fish Eye)	NW	2006	850	20,261	240	(3,189)	53	
5	Piti (Fish Eye)	NW	2009	850	20,362	240	(3,088)	56	2/
Location	Description	Shoreline Facing	Aerial Photo	Reef to Shoreline_m	Sea Area _m2	Measured Shoreline Length_m +/-	Sea Area Delta_m2	Delta_year	Estimate Annual Rate of Erosion_inches
6	Apaca Point	W	1953	100	12,024	340	-		
6	Apaca Point	W	1975	100	30,050	340	18,026	22	
6	Apaca Point	W	1993	100	35,183	340	23,159	40	
6	Apaca Point	W	2006	100	36,597	340	24,573	53	
6	Apaca Point	W	2009	100	36,920	340	24,896	56	50
7	Gaan Point	NW	1953	260	22,612	350	-		
7	Gaan Point	NW	1975	260	24,070	350	1,458	22	
7	Gaan Point	NW	1993	260	24,830	350	2,218	40	
7	Gaan Point	NW	2006	260	25,400	350	2,788	53	
7	Gaan Point	NW	2009	260	26,161	350	3,549	56	7
8	Taelayag Beach	W	1953	120	20,779	290	-		
8	Taelayag Beach	W	1975	120	15,922	290	(4,857)	22	
8	Taelayag Beach	W	1993	120	20,833	290	54	40	
8	Taelayag Beach	W	2006	120	21,449	290	670	53	
8	Taelayag Beach	W 3/	2009	120	20,842	290	63	56	0.1
9	Sagua Beach	NW	1953	120	16,231	300	-		
9	Sagua Beach	NW	1975	120	22,085	300	5,854	22	
9	Sagua Beach	NW	1993	120	25,890	300	9,659	40	
9	Sagua Beach	NW	2006	120	26,026	300	9,795	53	
9	Sagua Beach	NW	2009	120	26,353	300	10,122	56	23

1/ Man-made hardening (i.e. small seawalls) exteneded shoreline outward to sea.

2/ 2007 Sea Engineering Inc. report indicated signs of erosion in this area.

3/ Taelayag Beach is protected by Anea Islet

As should be expected there is no uniform rate amongst each area of analysis as it has its own unique physical characteristics in the water and on land. The following statements present the physical parameters and our understanding of the results.

Trinchera Beach
This section of shoreline in East Agana is a north facing shoreline with 580 meters of shallow reef acting as an energy dissipater from high wave and wind action. Small retaining walls were erected perhaps in the early 1970s so as to create a level parking areas for the business establishments.

Anigua
This section of shoreline in Agana is a north facing shoreline with 340 meters of shallow reef acting as an energy dissipater from high wave and wind action. The area in question does not appear to have erected any wall thus the erosion rate is erosion rate estimated at 6-inches a year.

Adelup Point
This section of shoreline in Adelup is a north-west facing shoreline with 340 meters of shallow reef acting as an energy dissipater from high wave and wind action.

Asan Point
This section of shoreline in Asan is a north-east facing shoreline with 260 meters of shallow reef acting as an energy dissipater from high wave and wind action. The area in question is surrounded by a park and appears to have numerous lava outcroppings with an erosion rate estimated at 1.5 inches a year.

Fish Eye
This section of shoreline in Piti is a north-west facing shoreline with 240 meters of shallow reef acting as an energy dissipater from high wave and wind action. The area in question is near the public highway Route 1. We calculated a negative area while past visual observations show a vertical scarp area which has undermined coconut tree. We believe there may be negligible amount of erosion in this area due in part to the topography being about a meter higher than much of Route 1.

Apaca Point
This section of shoreline in Agat is a west facing shoreline with 100 meters of shallow reef acting as an energy dissipater from high wave and wind action. The area in question is adjacent to an undeveloped portion of the Naval Base. The shore line creped inward at a rate of 50 inches a year perhaps in part due to the short and shallow reef which offers little protection from wave action.

Gaan Point
This section of shoreline in Agat is a north-west facing shoreline with 260 meters of shallow reef acting as an energy dissipater from high wave and wind action. The low lying shoreline which has land development has crept inward at a rate of 7 inches a year.

Taelayag Beach
This section of shoreline south of Agat is a north-west facing shoreline with 120 meters of shallow reef acting as an energy dissipater from high wave and wind action. The shoreline, which is surrounded by very little development land appears to be fed by badlands (erodible silt areas) via an unnamed creek and is also protected by Anae Islet. Erosion in this area is negligible

Sagua Beach
This section of shoreline is a north west facing shoreline with 120 meters of shallow reef acting as an energy dissipater from high wave and wind action. The area in question is adjacent to an undeveloped

land that is covered in vegetation and not fed by any discernible waterways. The shore line creped inward at an erosion rate estimated at 23-inches a year.

Disclaimer

There is a direct correlation between the data received and the extent and quality of the analysis to be performed. In relating information from different sources, geographic information accuracy depends much upon source data.

1953 Aerial Photo is not ortho-rectified. For more precise result, we need additional digital topographic data. As it stands now, shoreline and reference line in 1953 are not accurate. Unfortunately, most of Aerial Photos have ill-defined borders. It is difficult to discriminate the border between the sea and the land from black-and- white photo and even in color photos. The most significant one is grainy 1953 photo.

Coastal lines are generally swayed by phases of the moon. (Thus photo shooting date and time influences coastal line positions. (In Japan for example, height fluctuation between low tide and high tide Japan is 2m.) Since there is no information about date and time, this should be taken into consideration.

6.0 GENERAL OCEANOGRAPHIC CONDITIONS

The geographic location of Guam in the western tropical Pacific Ocean generally means mild wind and sea conditions most of the time. And, like many tropical areas, the weather consists of a dry season and a rainy season. The dry season runs from December to May, and the rainy season runs from June through November. This region is known to spawn tropical storms, typhoons and super-typhoons, some of the strongest storms on Earth. Tropical storm and typhoon occurrences can punctuate the normally mild conditions with periods of extreme weather with intense winds and high waves. The project sites are all exposed to prevailing and storm winds, waves, and water levels.

The dominant winds on Guam are the easterly trade winds. There is a distinct seasonality to the wind conditions in Guam with the trades stronger and steadier in the winter (January to April), and light and variable winds prevail in the summer typhoon season (July to November). Winds from east-northeast through southeast occur about 70 percent of the time. Wind speeds greater than 21 knots occur only 0.4 percent of the time.

We believe the ubiquitous, dominant climate events in terms of dominant shoreline erosion are prevailing winds and storm winds, waves, and water levels as opposed to land-side development. The following information was developed by *Sea Engineering Inc. in 2007 for the Government of Guam* and is summarized herein as it's germane to the making informed recommendations regarding shoreline land use decisions.

Figure 6-1
Guam Winds / Tides Information

Winds

- Dominant winds are easterly trade winds;
- Winds from east-northeast through southeast occur about 70 percent of the time;
- Wind speeds greater than 21 knots occur only 0.4 percent of the time;

Table 3-2
Predicted Wind Speed at Guam as a Function of Return Period

Return Period (year)	Sustained Wind Speed (mph)
5	56
10	71
25	90
50	104
100	118

Tides

The tides in Guam are semi-diurnal with pronounced diurnal inequalities. The mean tide range is 1.6 feet and the diurnal range is 2.4 feet. The extreme tides observed in Apra Harbor are a high tide of 2.95 feet and a low tide of 3.74 feet. Tidal data for Apra Harbor are as follows:

Table 3-3
Tide Elevations at Apra Harbor (MSL – feet)

Description	MSL (feet)
Highest Tide Observed	2.95 (8/28/1992)
Mean higher high water	1.0
Mean high water	0.8
Mean tide level (MSL)	0.0
Mean low water	-0.8
Mean lower low water	-1.4
Lowest tide observed	-3.74 -10/24/72

Figure 6-2
Guam Waves / Typhoons Information

Waves	**Storms and Typhoons**
Western Guam is exposed to deep-water waves generated south, west and north of Guam.	Nineteen typhoons typically occur annually across western North Pacific and South China Sea. Over a 44-year period, 1946-1989, 126 tropical cyclones were tracked within 180 nautical miles of Guam with at least tropical storm strength.
On a yearly average, about 3 percent of the waves affecting the west coast are greater than 6.5 feet, and about 1 percent is greater than 10 feet	
	Of these storms, 49 were of typhoon intensity, yielding an average of 1.1 typhoons per year (EKNA,1990).
	Nine storms between 1946 and 2002 virtually passed over the island. **These data indicate a great likelihood of a typhoon threatening Guam each year.**

Figure 6-3
Guam Water Rise during Typhoons

Water Rise – Typhoon Scenario

The total combined still water level rise, including the effects of astronomical tide, pressure setup, wind setup, and wave setup are listed below:

Table 3-14
Scenario Typhoon – Total Still Water Level Rise

	10-year	25-year	50-year
Astronomical Tide (msl) ft.	1.0	1.0	1.0
Pressure setup (ft.)	0.9	1.0	1.2
Wind Setup	0.16	0.2	0.2
Wave Setup	5.3	5.4	7.2
Total still Water Level Rise (ft)	7.4	7.6	9.6

The reef elevation is typically -1 to -2 feet msl. Using this, plus total still-water level rise from Table 3-14 and a breaker height to water depth ration of 0.5, the design breaker height at the shoreline is shown below.

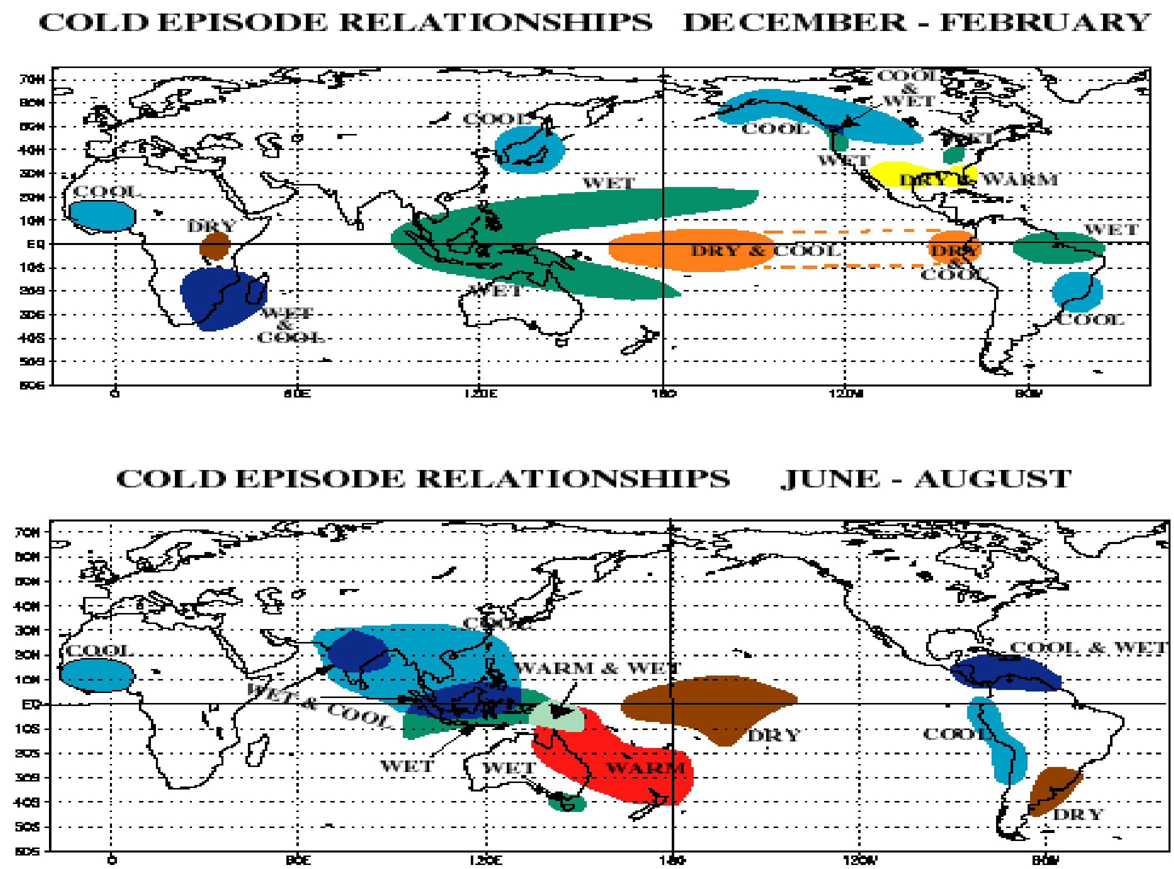
Table 3-15
Scenario Typhoon – Total Still Water Level Rise

	10-year	25-year	50-year
Water Depth Below MSL (ft)	1.5	1.5	1.5
Total Stillwater Level Rise (ft)	7.4	7.6	9.6
Total Water Depth (ft)	8.9	9.1	11.1
Design Breaker Height (ft)	4.5	4.6	5.6

Miscellaneous

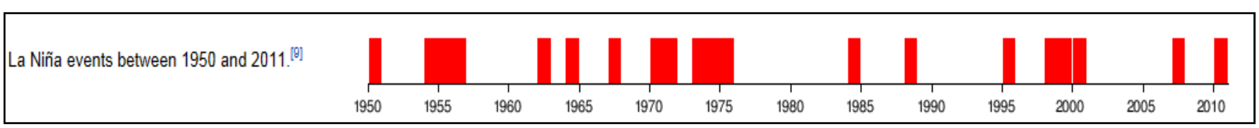
We are of the opinion that sea-level rise is unlikely to have a significant impact on secular change. Japan has seen an 8cm rise in the last 100 years with repeating ups and downs cycles. Other non-uniform cyclical events such as El Nino, which is a tropical pattern that occurs about every five years across that Pacific Ocean also has had little impact on Guam as indicated below.

Figure 6-4
El Nino Pattern



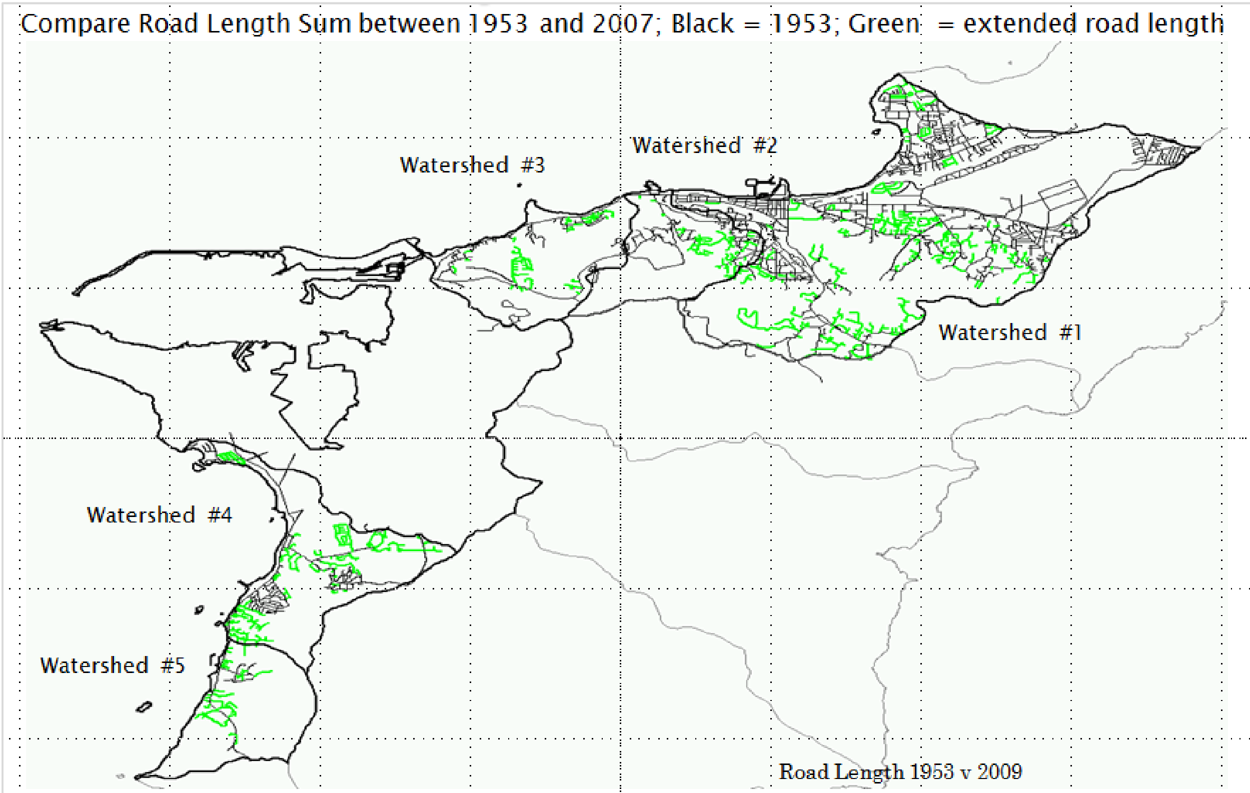
No higher resolution available.

La_Nina_regional_impacts.gif (486 × 539 pixels, file size: 22 KB, MIME type: image/gif)



We also looked briefly at land use changes over a 56 year period in a very cursory approach. From 1953 to 2007 period, the length of roadway (impervious surface has increased by about 110 %.) That is to say the amount of paved road has more than doubled. To what degree did this increase in impervious surface increase storm water runoff which in turn could make its way down to the shoreline and perhaps feed sediment into the reef system? Another question is has parcel development along the shoreline created focused runoff that erodes the top layers of beach deposits? A more detailed analysis of land use changes might reveal changes in sediment flows over time that historically have fed the beach deposits. The following figure shows new paved roadway in the watersheds in question in green while the existing roadways are shown in black.

Figure 6-5
Long Term Land Use Development Indicator



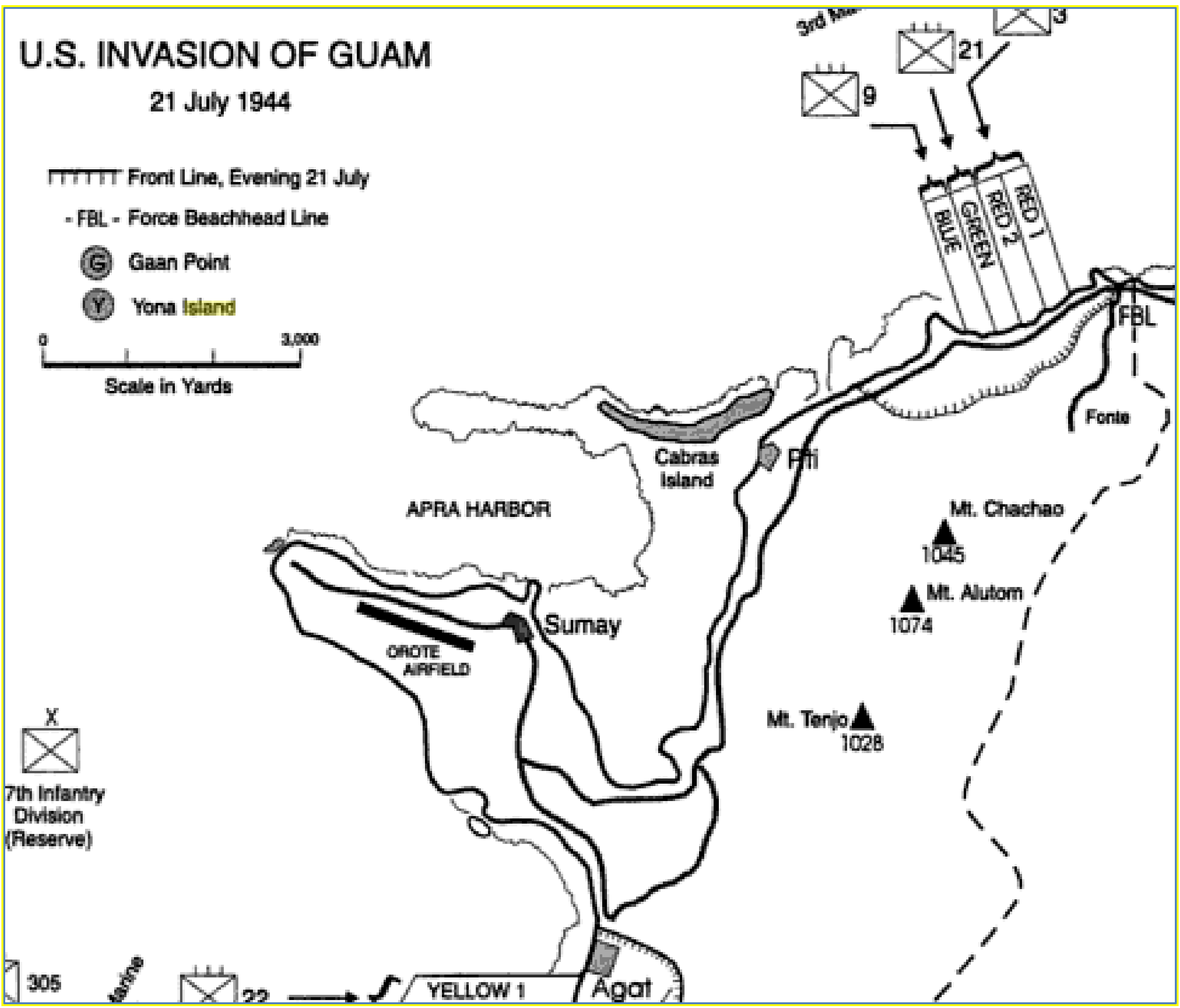
AreaNo	Road1953SumDistance m	Road2007SumDistance m	Difference m	UpRate
1	170920	220225	49305	128.8%
2	22636	31033	8397	137.1%
3	23885	32063	8178	134.2%
4	29928	50958	21030	170.3%
5	6438	13496	7058	209.6%

7.0 SPECIAL CASES

Piti / Cabras Island

The coast line perhaps known as the Tepungan Channel is a section of the shallow reef system that was altered to accommodate land side development, namely the construction and operation of the Piti Coal Fired power plant around 1933. Cabras Island was a completely separate island from Guam that arose out of the shallow coral reef. The US Navy made a decision to build a power plant, with coal being the most ubiquitous fuel during the era worldwide. In order to get coal barges to the power plant, a channel was cut through the shallow reef. While I don't believe anyone has ever measured flow, it would stand to reason that deep water currents and waves could send enough energy through the channel creating increased velocity on a more frequent along the shore line perhaps creating erodible velocities.

Invasion Map showing a portion of Guam's Western Shoreline



2009 Aerial – Former Piti Coaling Barge Channel, Guam (Google Earth)

Agat Harbor

Agat Harbor, Guam, is a small boat harbor excavated from a coral reef flat and protected by a detached breakwater. It has been studied by the Army Corp of Engineers prior and after its construction around 1984. The western side of Guam is in the lee of the predominant trade winds, and, since the reef dissipates much of the incoming wave energy, the reef flat and harbor are quiescent the majority of the time. Some lessons learned are presented herein as taken directly from reference four.

Lesson learned and results include:

a. Most hydrodynamic data obtained during the monitoring effort represented mild conditions. Therefore, some of the quantitative objectives of the study were not met because of the lack of data during the rare high-energy events.

b. Wind waves dissipate most of their energy in breaking at the reef face. Wave energy propagates across reef flats moving water shoreward, that returns seaward through breaks in the reef face. Agat Harbor and its entrance channel provided such a pathway.

c. Wave heights on the reef flat do not increase appreciably as wave height offshore increases, but the amplitude of seiche of the entire reef is affected by incident energy.

d. The combination of seiche, return flow from wave setup, and mass transport of bore-like waves can result in large currents running parallel to shore. For structures located on the reef flat, forces due to the resulting currents may be of larger magnitude than forces due to the wind waves themselves.

h. The detached breakwater design promotes flushing of the harbor, but can result in a significant influx of sediment during high-current events.

Figure 1 - 2009 Aerial – Agat Marina, Guam (Google Earth)
Excessive Shoreline Erosion

8.0 CONCLUSIONS

OYO's aerial analysis of nine portions of Guam's western shoreline reveals variations in the probable erosion amounts. These variations demonstrate that physical parameters such as vertical depth and distance from shore length of the facing reef, the type of alluvium clay or beach deposit as opposed to solid limestone formations and the type of adjacent land use play a significant role in determining how a shoreline area changes over a 56 year period. Some areas demonstrated very little in the way of erosion as to be negligible while others much more.

Erosion is a natural occurrence that happens through various weather phenomena beyond human control. It's generally known that Guam has a wet and dry season with very little variation in air temperature and humidity year round. Phenomenon such as wind tides and deep ocean waves along with typhoons present the largest probability that erosion will continue as it historically has along Guam's western shoreline.

It's been stated in various USACOE publications, the shallow depth reefs along the western shoreline dissipate up to 80 percent of the deep ocean wave energy. This means that only waves greater than 10 feet in height, which occur about 3% of the time annually in Guam, would have any chance of increasing the shoreline wave action and facilitating erosion. In addition when combined with Guam's diurnal tides, which produces two low tides a day, less than three percent of large wave action reaches the shoreline with any erodible velocity. Therefore, typhoon events, which occur on average about once a year on Guam, are the most likely events to cause erosion on the shoreline. This suggests that those erosion events occur perhaps one percent of the time each year with the remainder of the time the beach zone is at a standstill.

While Guam has certainly increased urbanization over the last 56 years, its effects on the shoreline are not fully understood. There are numerous outlet channels along the western shoreline. In addition, localized parcel development adjacent to the shoreline may also have some impact on how the beach erodes. The western shoreline of Guam does have its share of ephemeral creeks that drain the land yet appear to being bring only a small amount of sediment out to the reef area.

We conclude the dominant climate events in terms of shoreline erosion are prevailing winds and storm winds, waves, and water levels as opposed to land-side development. However localized parcel develop can also contribute to localized erosion. Both scenarios need to be understood prior to developing comprehensive recommendation for land use regulations that attempt to guide the use of land adjacent to the beach zone.

Special Cases

Tepungan Channel (Piti) was created in 1933 to allow coal barges through the reef to supply the first coal fired power plant on Guam. The relatively deep channel allows for increasing velocities in the shallow waters adjacent to the channel and may be increasing erosion along the nearby shoreline during tidal changes.

Agat Marina / Nimitz Park – it appears a short man-made channel was created at such an angle to the deeper main channel to allow wave action along with increasing velocities to occur along the shoreline during tidal changes. This diurnal occurrence most likely allows erodible velocities to occur frequently along the shoreline which is comprised of a reasonable amount of fine grained materials susceptible to erosion.

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