

ASSESSMENT OF ALTERNATIVE CONSTRUCTION TEMPLATE FOR BEACH NOURISHMENT PROJECTS

Phase I

FINAL REPORT

Prepared for:

Florida Department of Environmental Protection
Bureau of Beaches and Coastal Systems
3900 Commonwealth Boulevard M.S. 300
Tallahassee, FL 32399



Contract No. BS013
Task Assignment No. 34

Prepared by:

PBS&J
5300 West Cypress Street, Suite 200
Tampa, Florida 33607
&
Ecological Associates, Inc.
P.O. Box 405
Jensen Beach, Florida 34958

January 2007

EXECUTIVE SUMMARY

Florida's beaches support the highest density of loggerhead turtle nests in the western hemisphere, regionally significant numbers of green turtle nests, and regular nesting by leatherbacks. Beach restoration and nourishment have been used increasingly in Florida as a method for combating the erosive impact of inlets and storms and maintaining the social and economic values of sandy beaches. Beach nourishment has also been suggested as a means of increasing the quantity of sea turtle nesting habitat. Although national recovery plans for sea turtles acknowledge that "beach nourishment can improve nesting habitat in areas of severe erosion and is a preferred alternative to beach armoring," the simple creation of potential nesting habitat through the mechanical placement of sand on the beach does not necessarily confer an increase in nesting.

In November 2003 Post, Buckley, Schuh and Jernigan, Inc. (PBS&J) was contracted by the Florida Department of Environmental Protection (FDEP) to identify aspects of traditional beach nourishment projects that negatively or positively impact sea turtles and provide recommendations for alternative design criteria that may improve the quality of nesting habitat.

The initial phase of this work involved the compilation and review of physical and biological monitoring data from available reports of past beach nourishment projects throughout Florida. Although the analyses of these historical data were qualitative in nature, some generalizations could be drawn. Most, but not all, of the projects experienced a decline in nesting success and/or relative nest densities during the first year or two after project construction. Those effects often remained even when compaction and escarpments were absent or factored out of the analysis. A shift in the relative placement of nests on the beach was typical with proportionately more nests being deposited along seaward portions of the berm. That resulted in an increased incidence of nest loss to erosion as the beach equilibrated.

In an effort to identify which physical aspects of the traditionally built beach were responsible for observed nesting patterns, measurements for selected physical variables were sorted from highest to lowest and compared with corresponding biological effects during the first nesting season following project construction. This analysis proved difficult, as there was little consistency in monitored variables among projects. Due in large part to the limited scope and inconsistency of available data, no clear patterns were apparent.

The analysis then focused on a few key projects where physical and biological variables could be more closely related. Data for these projects were evaluated over several years before and after construction to compare changes in biological response to the beach as the profile underwent changes. From these comparisons, there were indications that berm width was negatively related, and a more gradual seaward slope positively related, to nest numbers and nesting success. In other words, the biological performance of the beach improved as the profile moved toward equilibrium.

Collectively, these findings suggest that beach profile may play an important role in the biological performance of beach nourishment projects. Although changes in sediment characteristics, compaction, and scarping can certainly affect nest densities, the most conspicuous feature of a nourished beach is its wide, flat profile. This differs markedly from the preferred Atlantic barrier island nesting beaches of loggerheads, which tend to be relatively narrow and steeply sloped.

Recommendations for altering traditional design criteria to improve the biological performance of nourished beaches were developed. In order to assess the efficacy of the proposed changes, an experimentally designed monitoring program must be established and implemented at an appropriate test site. The monitoring program presented herein will enable a statistical assessment of the extent to which measured physical beach variables influence sea turtle nesting behavior on nourished beaches. The design requires collection of baseline and control data using replicated treatments along the length of the nourished test beach.

Criteria were established for selecting an appropriate test location. Those included, high density nesting (ideally nesting by all 3 species), adequate project length to allow for multiple treatments, good historical nesting data, a construction timeline to allow for necessary permitting and collection of contemporary baseline data, availability of suitable reference beaches (controls), and absence of permitting constraints that would preclude construction of the alternative design. FDEP provided six sites for consideration. None were ideal, and it was suggested that additional sites be evaluated.

This report completes the first phase (Phase I) of this work assignment. Phase II represents the implementation portion of the work assignment and approval will be taken into consideration by FDEP following final acceptance of this report.

A Technical Advisory Group (TAG) was convened to review the work products and findings produced by the study team during Phase I. The principal responsibilities of the TAG were to provide technical and regulatory guidance to the design team and review and comment on work products.

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ASSESSMENT OF ALTERNATIVE CONSTRUCTION TEMPLATE FOR BEACH NOURISHMENT PROJECTS

1.0 INTRODUCTION

1.1 Background

Florida's beaches support the highest density of loggerhead turtle nests in the western hemisphere, regionally significant numbers of green turtle nests, and regular nesting by leatherbacks. Consequently, maintaining the quality of Florida's beaches as nesting habitat is critical to the national recovery plans for all three species of marine turtles (NMFS and USFWS, 1991a, 1991b, 1992).

Beach restoration and nourishment has been used increasingly in Florida as a method for combating the erosive impact of inlets and storms and maintaining the social and economic values of sandy beaches. This approach has also been suggested as a means of increasing the quantity of sea turtle nesting habitat. Although national recovery plans for sea turtles acknowledge that "beach nourishment can improve nesting habitat in areas of severe erosion and is a preferred alternative to beach armoring," the simple creation of potential nesting habitat through the mechanical placement of sand on the beach does not necessarily confer an increase in nesting. In fact, nest densities have often exhibited an inverse relationship with beach width on both natural (Provancha and Ehrhart, 1987) and nourished beaches (Ernest and Martin, 1999).

Beach nourishment can affect the sea turtle reproductive process in a variety of ways, as summarized by Crain et al. (1995). The principal documented impacts of beach nourishment projects in Florida can be summarized as follows:

1. The extent and persistence of scarping typically increases on nourished beaches. Increased scarping can prevent turtles from accessing upper areas of the beach, and nests placed at the seaward edge of the constructed berm are at increased risk of being washed out during profile equilibration.
2. Sediments of nourished beaches are typically more compact than those of natural beaches. Increased sediment compaction can increase the time and energy turtles spend constructing a nest or prevent nest chamber construction altogether. Compaction may also increase the prevalence of scarping.
3. Often, sediment characteristics of nourished beaches differ from the native sands they replace. Alteration of sediment characteristics may affect the physical environment of incubating nests and thereby influence the number of hatchlings produced. Changes in sediment composition and grain-size distribution can also affect the potential for scarping.
4. Traditionally built nourished beaches tend to be wide and flat, whereas heavily nested natural beaches are often relatively narrow and steeply sloped. Alteration of beach profile (width, slope, and elevation) presents nesting turtles with different tactile and visual cues that may affect pre-emergent assessments of beach suitability (i.e., affect the number of emergences onto the beach), nesting success (percentage of emergences resulting in nests), and nest site selection. Reductions in nesting success and/or relative nest densities are typically observed on most traditionally nourished beaches.
5. Changes in beach elevation and slope following nourishment may also alter incubation environments relative to natural beaches and can affect the prevalence of scarping.
6. Patterns of nest placement are altered on nourished beaches relative to natural beaches. A disproportionate number of nests are placed along the seaward edge of the beach berm. These nests are more susceptible to erosion during periods of profile equilibration.
7. Reduced nesting and increased nest loss to erosion typically reduce hatchling production on nourished beaches relative to natural beaches.

In addition to the documented impacts listed above, the increased width of nourished beaches may increase energy expenditures of nesting females utilizing upper areas of the beach (greater crawl distances) thereby reducing annual reproductive output. Similarly, increased energy expenditures of hatchlings migrating to the ocean from nests high on the beach may reduce their survivorship. However, to date, neither of these potential impacts has been empirically evaluated.

Since their inception, beach nourishment projects in Florida have drawn sharp criticism from the conservation community because of reported negative effects on the sea turtle reproductive process, as described above. Federal, state and local agencies have endeavored to improve the quality of habitat for sea turtles by restricting construction on the beach during the nesting season, requiring tilling to reduce sediment compaction, tightening standards for the quality of sand placed on the beach, and encouraging restoration of vegetated dunes. Today, sea turtle protection is one of the principle environmental constraints in the permitting of beach nourishment projects and a major focus of post-construction compliance monitoring. It is not surprising that the Florida Department of Environmental Protection (FDEP) has had a long-term interest in identifying those aspects of beach nourishment projects that impact sea turtles with possible consideration toward altering future design and construction criteria to minimize negative impacts.

Historically, environmental monitoring of beach nourishment projects took a piecemeal approach to identifying impacts. Studies typically focused on the issues of escarpments, compaction, and nest numbers and often inferred cause and effect without appropriate comparisons with baseline and control data. Rarely were studies experimentally designed to isolate particular variables or allow for reliable statistical testing. Monitoring of physical beach variables was typically done independently of biological monitoring and precluded correlations between physical and biological variables. Additionally, attention was given to engineering aspects of the project, such as beach profile, solely in consideration of longevity of the project, and not its effect on habitat quality.

Recognizing the need for a comprehensive assessment of the effects of beach nourishment on sea turtle nesting and reproductive success, the FDEP in 1994 funded a multi-faceted monitoring program. A large-scale beach nourishment project (4 miles, 1.2 million cubic yards) on Hutchinson Island in Martin County provided an excellent opportunity for a case study. The results of that study, concluded in 1997, indicated that compaction might not be as important as previously thought in accounting for reduced nesting success on nourished beaches. Beach profile, and possibly the relative proximity and shape of the dune horizon, was implicated as a more important contributor to reduced nesting success (Ernest and Martin, 1999). Of equal importance was the empirical data gathered on nest placement. Following construction of the project, a disproportionate number of nests (relative to control and pre-nourished beaches) were placed along the seaward edge of the beach berm. This portion of the berm experiences periodic and dramatic loss of sand following periods of high tides and heavy waves, as the beach equilibrates from a wide, flat profile to a more natural, gradually-sloped profile. Nests deposited in the equilibrium zone often experience relatively high rates of loss to erosion.

The findings of the Martin County study have been duplicated elsewhere. In fact some of the effects noted above have been accentuated in other projects. In Palm Beach County, for example, nearly 80% of all nesting by loggerheads at the Juno Beach Shoreline Protection Project occurred within 50 feet of the most recent high tide line, despite an equilibrium beach width of 177 feet (Palm Beach County DERM, 2002). Clearly, loggerheads exhibit a disposition for placing nests along the seaward portion of the nourished beach berm and are generally disinterested in exploring and/or utilizing upper areas of the beach.

Since the Martin County study was completed, both the state and federal governments have convened working groups to try to identify methods for improving the biological performance of beach nourishment projects. The U.S. Fish and Wildlife Service (USFWS) held an inter-agency meeting in December 2000 for the purpose of standardizing permitting conditions for sea turtle protection during beach nourishment projects. The meeting was attended by the U.S. Army Corps of Engineers (USACE), the

USFWS, and state conservation agencies. One issue that received special attention was the evaluation of alternative construction templates for nourished beaches to reduce the incidence of scarping and improve nesting success.

In November 2001, the FDEP convened a workshop of the Coastal Engineering Technical Advisory Committee (CETAC). Entitled Environmental Design of Beach Nourishment Projects in Florida, the workshop brought together a mix of professionals from federal, state, and county government agencies, engineering firms, environmental consultants, non-governmental agencies, and universities to assess methods for improving the overall design, permitting, and construction of beach nourishment projects in Florida (Montague and Chesnes, 2003). Similar to the federally sponsored meeting, attendees of the CETAC workshop also addressed the issue of an alternate construction template that would more closely mimic an equilibrium profile. Central to this discussion was acknowledgement that certain engineering and environmental constraints might make placement of large quantities of fill material seaward of the mean high water line problematic. Additionally, it was recognized that dramatic changes to the traditional construction template would be constrained by state and federal cost/benefit ratios that require beach nourishment projects to provide an acceptable level of shoreline protection in relation to their construction costs. Thus, the goal of this project was to design an alternative construction template that more closely mimics a natural beach profile, improves the quality of the built beach as sea turtle nesting habitat, and provides an acceptable level of shoreline protection.

1.2 Project Goals and Objectives

The Florida Department of Environmental Protection (FDEP) contracted with Post, Buckley, Schuh and Jernigan, Inc. (PBS&J) in November 2003 to identify aspects of traditional beach nourishment projects that negatively or positively impact sea turtles and provide recommendations for alternative design criteria that may improve the quality of nesting habitat. Of those physical changes resulting from a traditional beach nourishment project, the most apparent is the alteration of beach profile. Thus, the goal of this project

was to determine if statistically significant improvements in nest densities and hatchling production can be achieved through modifications to the traditional construction template. While it is recognized that changes in sediment characteristics, compaction, and scarping can affect the biological performance of a newly built beach, those features are currently being addressed through improved regulation and quality control.

This task assignment involved the compilation and qualitative review of monitoring data from beach nourishment projects throughout Florida from both a physical and biological standpoint. The coupling of these monitoring data was intended to identify apparent relationships between physical design features and observed nesting activity. From these patterns, recommendations for altering traditional design criteria could then be developed and presented to the FDEP for consideration. An experimentally designed monitoring program would then be established to assess the efficacy of the design changes. This monitoring program would enable a statistical assessment of the extent to which physical beach variables influence sea turtle nesting behavior on nourished beaches. The overall work assignment has been broken into two phases.

- 1) Phase I – evaluate past project performance, develop screening criteria for potential test sites, provide recommendations for altering traditional construction templates and develop a monitoring program.
- 2) Phase II – select a test project site, design/permit the project and implement the project.

This report completes the Phase I portion of the work assignment. Phase II will be taken into consideration by FDEP following final acceptance of this report.

Study Team (Phase I):

Client Project Managers: Roxane Dow and Rebecca Roland (FDEP)

Project Manager: Jeff Tabar (PBS&J)

Coastal Engineer: Kathy Ketteridge (PBS&J)

Chief Biologist: Bob Ernest (EAI)

Senior Biologist: Erik Marin (EAI)

QA/QC Biology: Don Dies (PBS&J)

QA//QC Engineering: Ken Jones/Wayne Lasch (PBS&J)

A Technical Advisory Group (TAG) was convened to review the work products of the study team. The principal tasks of the TAG were to provide technical and regulatory guidance to the design team and review and comment on work products.

Four meetings were held with the TAG during this task assignment. The meeting minutes can be found in Appendix A. The selection process of the TAG members had several criteria and included state and federal regulatory agencies and sea turtle conservation groups. Members were required to be knowledgeable of beach nourishment projects and related impacts to sea turtles and be able to contribute technical and/or regulatory guidance to the study team. The following individuals participated.

Technical Advisory Group (TAG):

Robbin Trindell, Florida Fish & Wildlife Conservation Commission (FWC)

Sandy MacPherson and Nicole Adimey, United States Fish & Wildlife Service (USFWS)

Paden Woodruff, Florida Department of Environmental Protection, Bureau of Beaches & Coastal Systems (FDEP, BBCS)

Ken Dugger and Bill Fonferek, US Army Corp of Engineers (ACOE)

Llewellyn Ehrhart, University of Central Florida (UCF)

Gary Appelson, Caribbean Conservation Corporation (CCC)

2.0 ASSESSMENT OF PHYSICAL AND BIOLOGICAL DATA

Past beach nourishment projects have often resulted in reported impacts to sea turtle nesting. However, few studies have been conducted in such a manner as to establish cause and effect between different physical aspects of the built beach and monitored biological variables. That is because detailed physical monitoring of the beach is

typically conducted independently of biological monitoring with no overarching plan to relate the data in a manner that would permit meaningful comparisons. Furthermore, attention is rarely given to the effects of beach profile on nesting patterns, other than to manage scarping. Obviously, it is difficult to develop an alternative construction template if those elements of the traditional template which are responsible for documented impacts cannot be identified.

2.1 Objective

As part of PBS&J's contractual agreement with FDEP, a search was undertaken of past nourishment projects in Florida in an attempt to correlate physical aspects of the built beach with observed nesting activity. Timing and budget constraints precluded an exhaustive evaluation of this information. The qualitative assessment only utilized information presented in available monitoring reports, and no raw data were analyzed. The goal was simply to identify obvious recurrent patterns between the physical character of the built beach and the resultant effects on sea turtle nesting activity.

Sea turtle monitoring reports were solicited for all known beach nourishment projects in Florida. In some cases written reports were either non-existent or unavailable. A review of reports from forty projects was undertaken. In all, historical biological data were obtained from reports for 29 nourishment projects on both the east and west coasts of Florida (Appendix B). The reports were reviewed to document reported or inferred effects from the projects on selected sea turtle nesting variables, including:

- Numbers of emergences by nesting females onto the beach,
- Numbers of nests,
- Nesting success,
- Percentage of false crawls (non-nesting emergences) caused by beach escarpments,
- Nest placement relative to the tide line and dune,
- Incubation period,
- Percentage of nests washed out,
- Reproductive success (hatching and emerging success), and

- Number of disorientation events.

2.2 Results

In many cases, project effects on one or more biological variables could not be determined because: 1) the variable was not monitored, 2) the sample size was too small to determine whether or not an effect occurred, 3) there was no control, and/or 4) there was no baseline data.

Of the biological variables monitored, nesting success provided the most extensive data set for evaluation of project effects. Of the 29 projects reviewed, 23 had sufficient data to determine if there was an effect. Of these, 16 exhibited a negative effect during the year of construction. Two additional projects (for which the first year's data were not available) exhibited a negative effect on nesting success during the first full nesting season following construction. All together, nesting success was reduced in 18 of the 23 projects (78 percent). The other five projects (22 percent) showed no effect on nesting success during the year of construction.

Although the annual number of nests occurring in a project area was typically reported for the 29 projects reviewed, a determination as to whether or not the project affected nest densities often could not be made due to the lack of sufficient baseline and/or control data. In 12 of the 16 projects (75 percent) for which a determination could be made, nesting was reduced during the year of construction. For the other four projects (25 percent) there was no apparent effect on nest numbers during the year of construction.

Only 11 of the 29 projects provided information that allowed determination of project effects on numbers of emergences by females, incidence of false crawls at scarps, and nest location relative to the tide line and/or dune. Effects on numbers of emergences were mixed (post-project decreases at four projects, no post-project effects at four projects, and post-project increases at three projects). The post-construction incidence of false crawls at scarps increased at five of the 11 project sites (45 percent), while there

was no effect at the other six. All 11 of the projects exhibited post-construction changes in the relative location of nests on the beach.

Project effects on reproductive success were mixed with no apparent effects at most projects. However, there was an increase in the percentage of nests washed out, with six of ten projects exhibiting an increase in washouts after project construction.

Using data for the first nesting season after project completion (i.e., year of construction), measurements for each of several physical variables (e.g., beach width, median grain size, slope of seaward face of berm, etc.) were sorted from highest to lowest and compared with corresponding effects on biological variables. No clear patterns were apparent. For example, decreases in nesting success occurred at projects with both the widest as well as the narrowest beach widths. Results can be found in Appendix C.

Based on the previous results, it was decided that a better approach to investigating template effects on sea turtles would be to focus on several key projects beginning the year prior to construction (baseline) and continuing for several years after construction. This allowed comparison of biological variables as the template underwent changes over time.

In order to compare several different sets of profile lines with the biological data, distinct areas of the beach profile were defined based on traditional definitions found in the Shore Protection Manual (USACE, 1984). For the purposes of this study, four distinct areas of the beach profile were identified: dune, berm, foreshore, and inshore. In order to keep nomenclature consistent within this report, as well as with current literature, the beach areas will be referenced as follows:

- Dune
- Berm
- Upper Slope (instead of *Foreshore*)
- Lower Slope (instead of *Inshore*)

For the berm, upper slope, and lower slope, characteristic widths and slopes were calculated in order to make comparisons between physical and biological data sets (Appendix D). The dune width and slope were not consistently calculated or considered in the analyses due to lack of profile data for the landward portions of the dune in many cases.

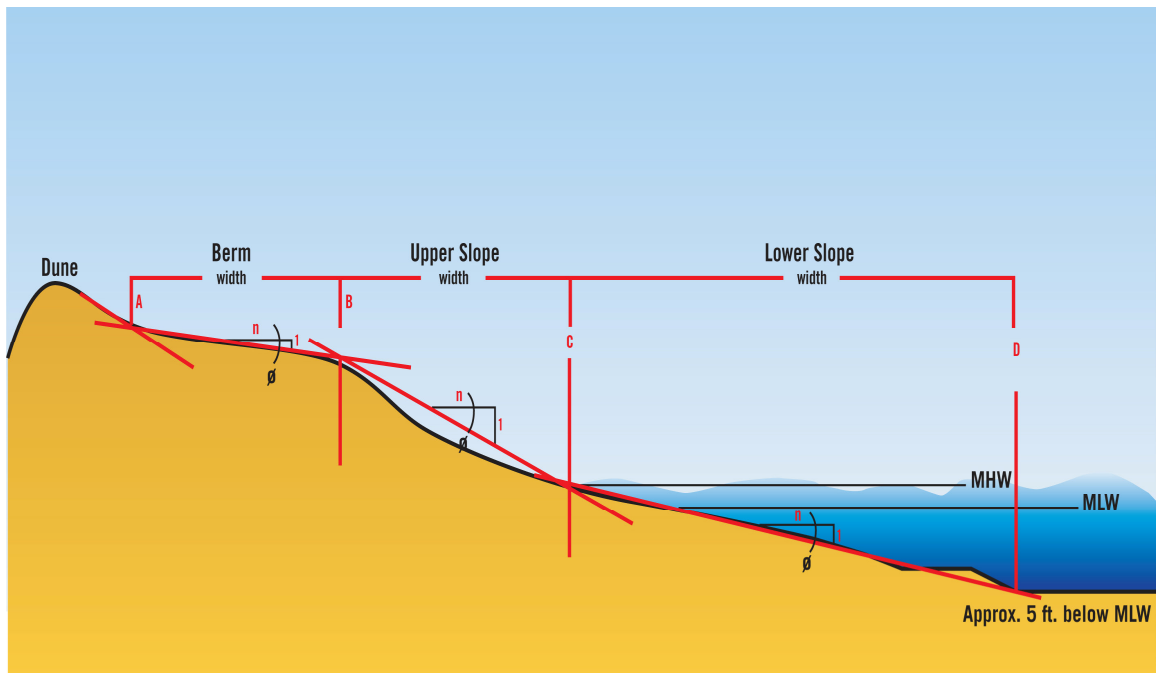


Figure 1 – Definitions of beach sections and parameters.

These characteristic widths/slopes are shown graphically in Figure 1 and the methodology for calculating these values is described below:

- Berm
 - Width is measured as the horizontal distance from the slope break at seaward foot of dune (Point A in Figure 1) to the next seaward slope break (Point B in Figure 1). This point is typically above the water line.
 - The slope is taken as the composite slope over the above width, from Point A to Point B in Figure 1.
- Upper slope

- Width is measured as the horizontal distance from the from the slope break at the end of the berm section (Point B in Figure 1) to the Mean High Water (MHW) Line (Point C in Figure 1)
- The slope is taken as the composite slope over that width, from Point B to Point C in Figure 1.
- Lower slope
 - Width is measured as the horizontal distance from the MHW Line (Point C in Figure 1) seaward to where the elevation of the profile is approximately -5 feet MWL (Point D in Figure 1).
 - The slope is taken as the composite slope over that width, from Point C to Point D.

Measurements for each of these profile variables were compared to nesting success values at the following five projects: Patrick Air Force Base (AFB) -2001, Brevard South Reach-2003, Martin County North Treatment-1996, Martin County South Treatment-1996, and Ocean Ridge-1998 (Appendix D). These were the only projects for which reliable multi-year physical and biological data could be paired. One additional project, Brevard North Reach (Southern Component)-2001 was also evaluated. However, annual nest numbers were used for comparison with beach profile variables for this project, because no baseline nesting success data were available.

Several examples of apparent relationships between nesting success/nest numbers and beach profile were evident:

- 1) Brevard North Reach (Southern Component) – The number of nests deposited each year showed an inverse relationship with berm width (Figure 2).
- 2) Brevard North Reach (Southern Component) – Annual nest numbers were positively related to lower slope width (Figure 3). It was noted that the slope and width of the beach seaward of the Mean High Water Line are inversely related; as the beach equilibrates the submerged profile widens and the slope decreases.

- Researchers monitoring sea turtle nesting at Cape Canaveral noted a similar relationship; nesting was highest in areas with a gradual underwater slope.
- 3) Martin County North Treatment – Nesting success was inversely related to upper slope (Figure 4). An anomaly in this study was a decrease in nesting success two full years after project construction, which was attributed to extreme weather conditions (i.e., historically hot and dry conditions). This anomaly illustrates the importance of documenting weather conditions during the period of monitoring when evaluating project effects on sea turtles.
 - 4) Patrick AFB – Nesting success was positively related to berm width (Figure 5). This provides some indication that a nourishment event can increase nesting success along shorelines that have little to no berm width prior to construction. Also, there may be a critical threshold for nesting in terms of berm width or suitable habitat (i.e., nesting success may increase as beach width increases on previously eroded beaches, but at some point additional width may provide little additional benefit and may actually result in a decline in nesting success.

Based on these results, it appears that an immediate major effect of beach nourishment is a reduction in nesting success/nest numbers. However, there are a few cases, such as Patrick AFB-2001, where nesting success actually increased following project construction. Apparently, beaches at these project sites were severely eroded and had little or no suitable nesting habitat (sometimes exacerbated when previously buried shoreline armoring is exposed). Once additional nesting habitat was provided through nourishment, nesting success increased.

Members of the TAG noted that nesting success should be considered a conservative measure of project effects. Often, turtles abandon the nesting beach while still in the surf zone, and this is not measured. Also, the numbers of false crawls below the previous high tide line can be quite high at some project locations, particularly where escarpments are present. These false crawls are not typically included in calculations of nesting success, as per FWC protocol.

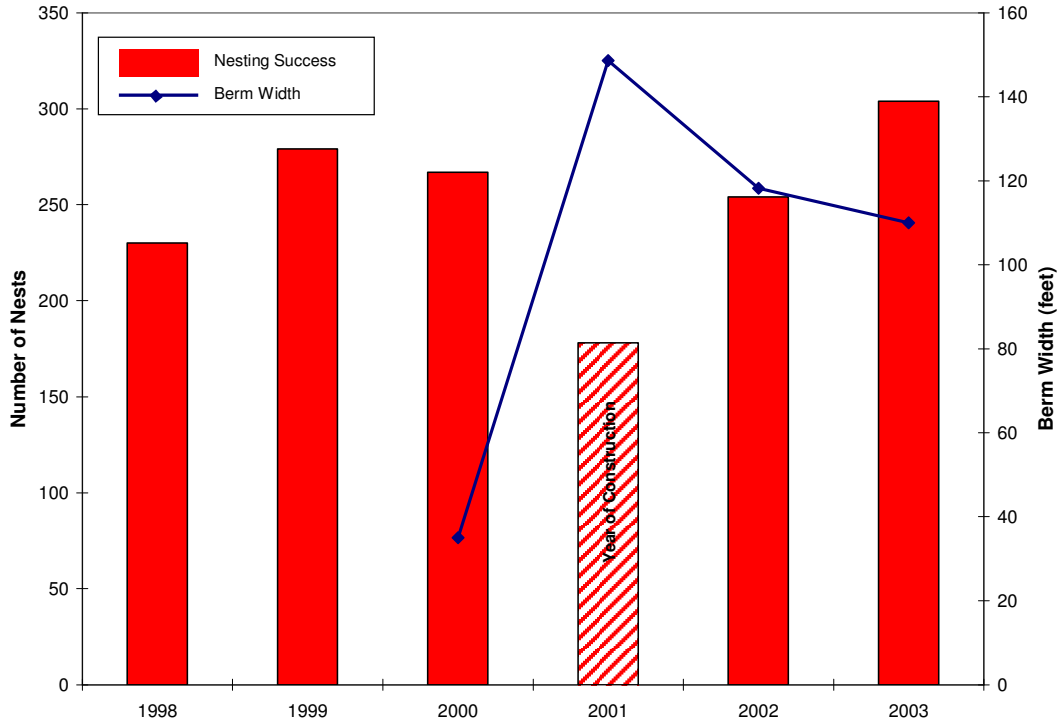


Figure 2 – Brevard County North (Southern Component), nests vs. berm width.

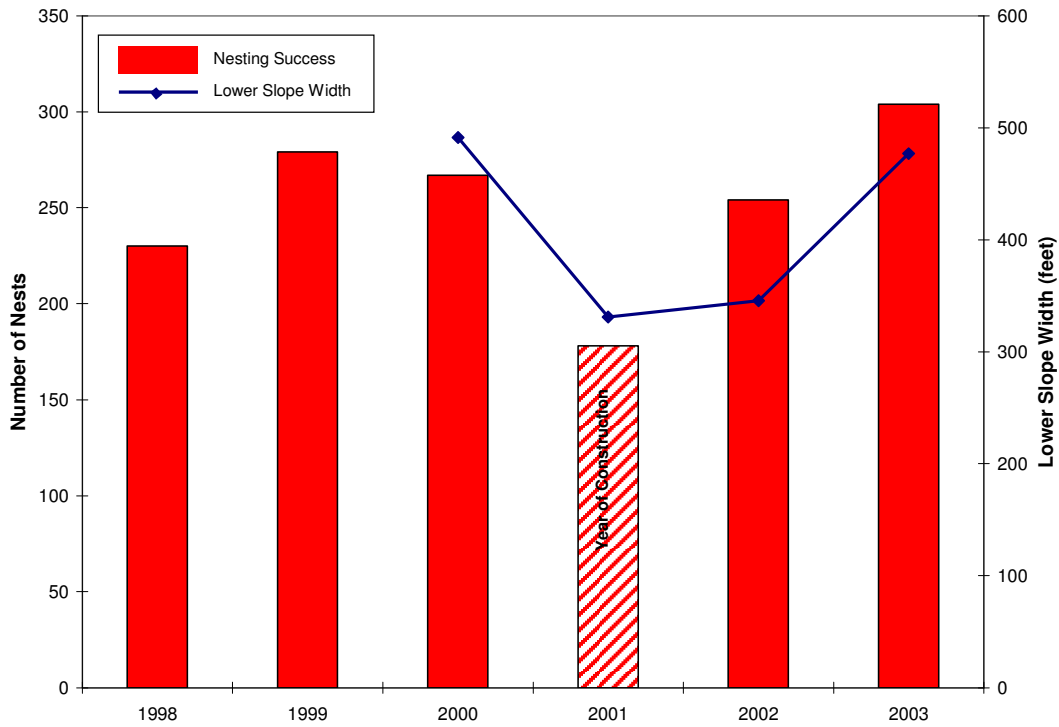


Figure 3 – Brevard County North (Southern Component), nests vs. submerged width.

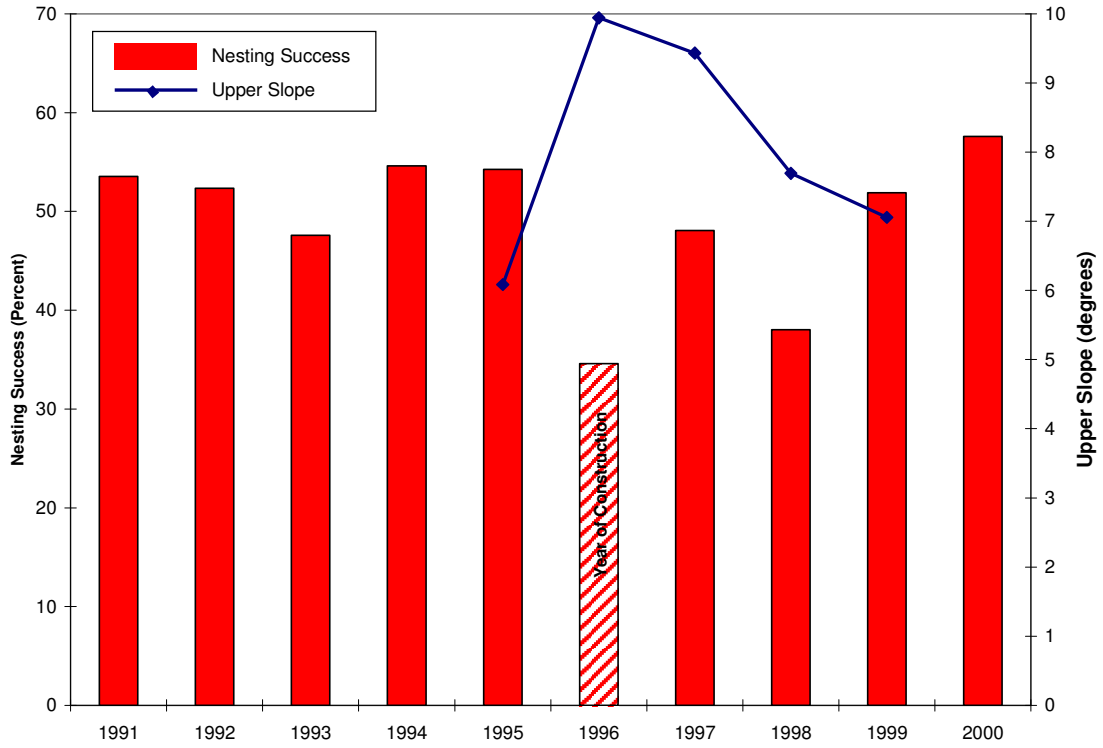


Figure 4 – Martin County North Treatment, nests vs. upper slope.

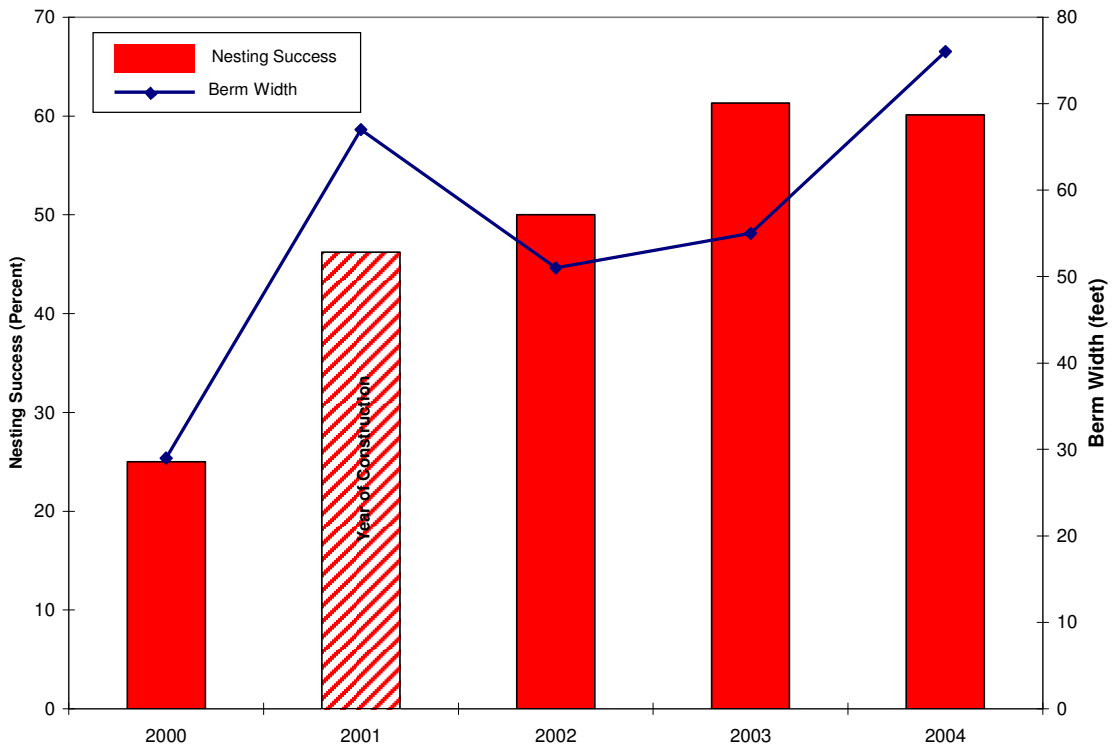


Figure 5 – Brevard County Patrick AFB, nests vs. berm width.

Scarps, particularly those that are relatively high and/or persistent, can contribute to both reduced nest densities and nesting success (Bagley et al., 1994; Davis et al., 1994; Herren, 1999). However, scarps alone cannot explain the effects documented at several project sites. For example, in Juno Beach, where a post-construction reduction in nests was documented, scarps were generally lacking. Similarly, when scarp encounters were factored out of analyses for the Martin County Project, nesting success on nourished beaches remained significantly lower than values reported for control and pre-nourished beaches.

All other factors being equal, reduced nesting densities equate to proportionately fewer hatchlings leaving nourished beaches. However, other factors are not equal. Reduced hatchling productivity on nourished beaches is exacerbated by increased nest loss resulting from the disproportionate placement of nests in the equilibrium zone. Of the 29 projects reviewed, 10 had sufficient data to infer whether the project had an effect on the percentage of nests washed out during the year of construction; nest loss to erosion increased at six of the projects, while no effects were evident at the other four. Thus, proportionately fewer nests are being deposited on many nourished beaches relative to control and pre-nourished beaches and proportionately more of those nests are being washed out.

The foregoing discussion has, thus far, ignored the importance of sediment characteristics in improving the quality of nourished beaches as nesting habitat. Sediment characteristics can affect the propensity for scarping and compaction and can alter the nest incubation environment. Consequently, national recovery plans for sea turtles stress that the quality of fill material used for beach nourishment should be similar to that found on local natural beaches (NMFS and USFWS, 1991a, 1991b, 1992). Recent revisions to FDEP criteria for characterizing borrow sediments are intended to improve the quality of materials placed on the beach by specifying criteria for sediment compatibility and by requiring improved quality control procedures. Projects that have carefully selected and utilized beach-compatible sediments have shown a reduction in both scarping and compaction (Palm Beach County DERM, 2002).

With respect to reproductive success (percentage of eggs hatching and number of hatchlings leaving the nest), as reported in the literature, beach nourishment projects have yielded mixed results. Some projects have improved (Broadwell, 1992), while others have reduced (Trindell et al., 1998; Herren, 1999), reproductive success. In some cases, there have been no detectable changes (Raymond, 1984; Ryder, 1993). This is also reflected in the data for the nourishment projects reviewed under this contract. Data from 13 of the 29 projects allowed a determination of project effects on hatching success. A negative effect was documented for one, no effects were shown for nine, and positive effects were demonstrated for three. Similar results were obtained for the 11 projects where determination of project effects on emerging success could be inferred. A negative effect was documented for one, positive effects were shown for three, and no effects were indicated for seven.

Sediment characteristics (e.g., color, grain-size, chemical composition, organic content, and sorting) undoubtedly play an integral role in affecting this outcome, as they influence temperature, moisture content, permeability, and the other physical variables, which collectively constitute the incubation environment within and around the egg chamber (Ackerman, 1997). Each element of the incubation environment may act independently and synergistically to affect the vitality of developing embryos, and the extent of their influence may vary in relation to prevailing weather conditions (e.g., air temperature, rainfall, etc.). Consequently, it is generally very difficult to conduct controlled field experiments to assess the extent to which any particular sediment characteristic influences reproductive success. What is certain is that reproductive success is not diminished if sediments similar to local native sands are used for beach nourishment, and in some cases reproductive success may actually increase relative to control and baseline conditions (Broadwell, 1992). This is particularly true where beach compatible sands replace inferior sediments used in prior nourishment projects.

2.3 Deficiencies Identified During the Evaluation of Past Projects

In the course of reviewing past studies, numerous deficiencies were identified. First and foremost, considering the extensive nature of permit-compliance monitoring that has occurred in support of Florida's shoreline protection programs, it is surprising that the resulting data are not more readily accessible to potential users. Most reports, which vary widely in both scope and style, are in hard copy form only. Many had to be obtained directly from the researchers/groups that performed the monitoring.

One of the principal deficiencies in past studies is that appropriate physical data were not collected or were collected in such a manner that did not readily allow their coupling with biological data. This made it difficult to correlate observed nesting patterns with specific aspects of the built beach and precluded statistical inferences regarding cause and effect.

In many cases, project effects could not be determined because of the following.

1. The biological variable of interest was not monitored. The variables monitored varied widely among projects, particularly for some of the early projects. Recent FDEP/FWC guidelines have made monitoring requirements for beach nourishment projects more consistent.
2. There was insufficient background information to allow independent interpretation of results. The following provide examples of insufficient background information.
 - a. There was no indication whether or not relocated nests were included with *in situ* nests for the purposes of determining hatching/emerging success.
 - b. There was no indication whether or not washed out nests were included in calculations of reproductive success.
 - c. There was no indication of what characteristics were evaluated when determining the suitability of a control site.
 - d. There was no indication of beach conditions during baseline years (i.e., did other projects occur at that location during previous years, did the

extent of development, beach usage, and/or beachfront lighting change between baseline and project years, what was the general character of the beach prior to nourishment, etc.).

3. The results were not interpreted or even summarized. Often the results were poorly presented, and in some cases there were inconsistencies in reporting at a project site between years.
4. Sample sizes were frequently inadequate to determine if the project had an effect.
5. Different projects in the study area overlapped (i.e., some areas of the project may have been previously nourished while others had not), making comparisons of historical (background) data with contemporary data difficult.
6. Most projects lacked an appropriate experimental design. Requisite baseline and control data were typically lacking. Project effects cannot be inferred without at least one of these components.

2.4 Recommendations

The following recommendations are provided to improve information and data required to analyze project effects on turtle nesting.

1. Describe standardized data collection techniques (i.e. develop protocols so data from all projects are collected in a consistent manner).
2. Where possible, establish minimum sample sizes for various biological variables (e.g., minimum number of nests for determining reproductive success).
3. Provide a standard for data reporting by:
 - a. Requiring that data be summarized in tables that include the sample size, mean, range, and standard deviation for all monitored biological and physical variables;
 - b. Presenting reproductive success data including and excluding washed out nests (the former provides a gauge of overall hatchling production; the latter reflects the quality of the incubation environment);
 - c. Reporting reproductive success data separately for relocated and *in situ* nests;

- d. Establishing minimum analysis standards for assessing project effects; and
- e. Standardizing the format for reporting monitoring data.

FWC could develop an electronic report form similar to the spreadsheets used for reporting Index Nesting Beach Survey data that would ensure consistency in reporting among different projects.

4. Provide criteria for establishing control area(s).
5. Establish minimum standards for collecting baseline data. These data are needed for both the construction area and control(s).
6. Document any changes in physical conditions within the study area over the period of monitoring, including
 - a. Type and extent of shoreline development;
 - b. Nighttime lighting environment;
 - c. Human beach usage at night (e.g., low, moderate, high);
 - d. Dune type and condition (e.g., natural well-vegetated dune, revetment, seawall, etc.);
 - e. Prevailing weather patterns; and
 - f. Erosion patterns.

This information could be presented in tabular form as part of the project final report showing conditions for each of the different elements by year (pre and post construction).

7. Ensure that physical data are collected over the same temporal (both pre and post construction) and spatial scales (project area and controls) as biological data.
8. Identify additional physical variables that should be routinely monitored to permit inferences regarding project effects.
9. Integrate the physical and biological data in a manner that permits statistical testing of project effects.

Again, considering the enormous amount of effort and expense that goes into monitoring of nourishment projects, resultant data should be readily available to a broad audience of potential users, including local governments, coastal engineers, regulatory agencies, sea turtle biologists, conservation groups, and researchers. At present there does not appear

to be a single repository for all project information and the information that is available must be manually retrieved. Consequently, a statewide database would be extremely valuable for archiving project data. The database could include permit information (location, date of project, design profile, borrow source, length of beach constructed, etc.), engineering data (beach profiles before and after construction), physical monitoring data (sediment compaction, sediment grain size, results of scarp surveys, etc.) and biological monitoring data. Raw data could be submitted electronically and posted to project-specific folders. Monitoring reports could be converted to PDF files and stored in the appropriate electronic project folder. All of this information would then be available for downloading upon demand.

3.0 EXPERIMENTAL DESIGN CONCEPT

It should be emphasized that the analysis of historical project data were qualitative in nature and no universal effects were identified; every project was unique. Nevertheless, some generalizations can be drawn. Most, but not all, of the projects experienced a decline in nesting success and/or relative nest densities during the first year or two after project construction. Those effects often remained even when compaction and escarpments were absent or factored out of the analysis. A shift in the relative placement of nests on the beach was typical with proportionately more nests being deposited along seaward portions of the berm. That resulted in an increased incidence of nest loss to erosion as the beach equilibrated.

These findings, along with the apparent relationships identified between physical and biological data, suggest that beach profile may play an important role in the biological performance of beach nourishment projects. The most conspicuous feature of a nourished beach is its wide, flat profile. This differs markedly from the preferred Atlantic barrier island nesting beaches of loggerheads, which tend to be relatively narrow and steeply sloped.

Provancha and Ehrhart (1987) compared physical beach characteristics between areas of relatively high and low nesting densities at Cape Canaveral Air Force Station. They found that the total number of crawls was positively correlated with the beach slope ($r = 0.86$) and negatively correlated with beach width ($r = -0.79$). Steeply sloped beach sections had higher nest densities and higher total emergences than more gradually sloped beaches. However, they found that nesting success was not correlated with beach slope and therefore concluded that females appeared to be selecting nesting locations prior to emergence from the ocean. They speculated that nearshore bottom contours might have influenced nest site selection. Similar conclusions were drawn from studies conducted on a nourished beach in Palm Beach County (Palm Beach County DERM, 2002).

Others have also concluded that slope and offshore configuration of the beach affect nesting beach preferences of sea turtles (Caldwell, 1959, Mortimer 1982). However, these conclusions have often been more speculative than empirical. In perhaps the best assessment, to date, of the physical variables influencing loggerhead nest site selection on a natural beach, Wood and Bjorndal (2000) concluded, "Of the four environmental factors evaluated, slope appears to have the greatest influence on nest site selection, perhaps because it is associated with nest elevation." Higher elevations reduce the potential for nest loss to tidal inundation, and thus increase the probability of survival.

As part of PBS&J's contract with FDEP, variations in beach profile were examined at five project sites to determine if there was a possible relationship between several beach width/slope variables and sea turtle nesting success (see Section 2, Assessment of Physical and Biological Data). At two of the projects, where only three years of comparable physical and biological data were available, no relationship was indicated, possibly due to the limited data. At the three projects with four years of comparable physical and biological data, there were indications of relationships between nesting success and beach width/slope (either above or below the water line, depending on the project).

From the above review, it would seem that a beach with a sloped berm would improve the response of turtles to a newly built beach. However, there is little empirical information to support any particular configuration. The consensus of the TAG was to push the alternative template design as close to equilibrium as practical in consultation with FDEP, coastal engineers, and dredging contractors. Issues that were considered in the alternative design included: shoreline protection function of the built beach, construction costs, physical constraints related to constructing the new design, effects on nourishment intervals, and effects on nearshore resources (e.g., hardbottom).

In considering the many aspects that influence the construction of a beach nourishment project, constructability and functionality present the most significant challenges in terms of designing an alternative template. It is important that the alternative template is cost effective (built at a competitive cost as compared to a traditional template) while maintaining the shore protection value. Several dredge contractors and project managers were contacted during this study in order to gather feedback regarding potential cost impacts resulting from modifying a traditional template. Consensus of those interviewed was that the template modifications presented herein will have little to no influence to the overall cost of the project. Minor cost impacts may be realized from added final grading, additional equipment requirements and increased survey time; however no major cost impacts are expected from the alternative template.

In considering an alternative template design, the beach width/slope is believed to provide the most meaningful relationship between physical parameters and biological performance (specifically nesting success). Recently, FDEP has required terraced or otherwise altered templates on a project-specific basis. However, minimal design guidance exists regarding specifications of appropriate slopes for these projects (Creed, et. al., 2000). Traditional beach nourishment projects are designed to extend the natural berm horizontally with a fairly steep slope at the seaward limit of placement (Dean, 2002, USACE, 2002). This shape makes it convenient for all parties to agree on the amount of sand that has been placed on the beach and thus the amount the contractor is paid. The resulting traditional construction template or profile is steeper along the seaward limit

than the equilibrium profile. The equilibrium profile is the natural form or shape the beach fill would take due to its sediment characteristics and response to the wave environment.

In attempting to design a “more equilibrium” construction template, to improve turtle response, several modifications to a traditional design were considered. The design is conceptual at this point and cannot be finalized until a project test site is selected. Once a site is chosen, it will be necessary to work with the local sponsor and their consulting engineer to ensure the final template is appropriate for the specific site conditions. Information presented herein should be considered preliminary and is intended only to provide guidance in specifying beach profile construction templates. In addition, necessary adjustments to the conceptual design will need to be made ensuring the final design can be permitted. Largely, the final design will be highly dependent on site specific conditions and the geometry of the existing beach.

The alternative template was divided into three zones I) dune/berm, II) upper slope (seaward slope above the waterline) and III) lower slope (seaward slope under the waterline) (Figure 6). In designing an alternative template it would be advisable to include a dune feature. Dune features allow for placement of additional sediment within the template and provide a suitable location for planting vegetation. In addition, it has been suggested that emerging sea turtles take important cues from the silhouette of dunes and landward features as they select a suitable beach for nesting (Salmon et. al., 1995, Caldwell, 1959).

Traditional berms have been built flat with no slope. As shown in Figure 6, introducing gentle slope to the berm is recommended. Suggested slopes range from 1:40 to 1:100. This slope would be from the toe of the dune to the seaward edge of the berm. Additional sand placement may be necessary along the back-berm to maintain the design volume. By creating a gentle slope in the berm the project profile will more closely resemble equilibrium and may also prevent a negative slope from forming. Negative slopes on nourished berms may cause ponding or pockets to form along its length.

Anecdotal information suggests that negative sloped berms in a nourishment project may contribute to hatchling disorientation (EAI, personal observation).

It is recommended that the upper slope range from 1:10 to 1:25 to allow for a gradual transition from the seaward crest of the berm towards the waterline. It would seem by creating a more gradual slope than traditionally used in this zone, the potential for scarping would be reduced. From inspection of data presented herein, scarp formation generally occurred along the upper slope. Selecting an upper slope of the construction template similar to the design equilibrium profile will minimize the likelihood of severe scarping (USACE, 2002).

During the equilibrium process, slopes at or below the waterline were correlated to the sediment characteristics of the beach fill (Creed, et. al., 2000). Therefore the seaward slope under the waterline or the lower slope should be designed to closely represent the equilibrium profile. Figures 2 and 3 demonstrate that as the beach equilibrates the submerged profile widens and the slope decreases resulting in higher sea turtle nests. Of the data evaluated during this study, modifications to the lower slope were shown to have the greatest potential for improving the biological performance of beach nourishment projects. Recommendations for lower slope range from 1:30 to 1:50.

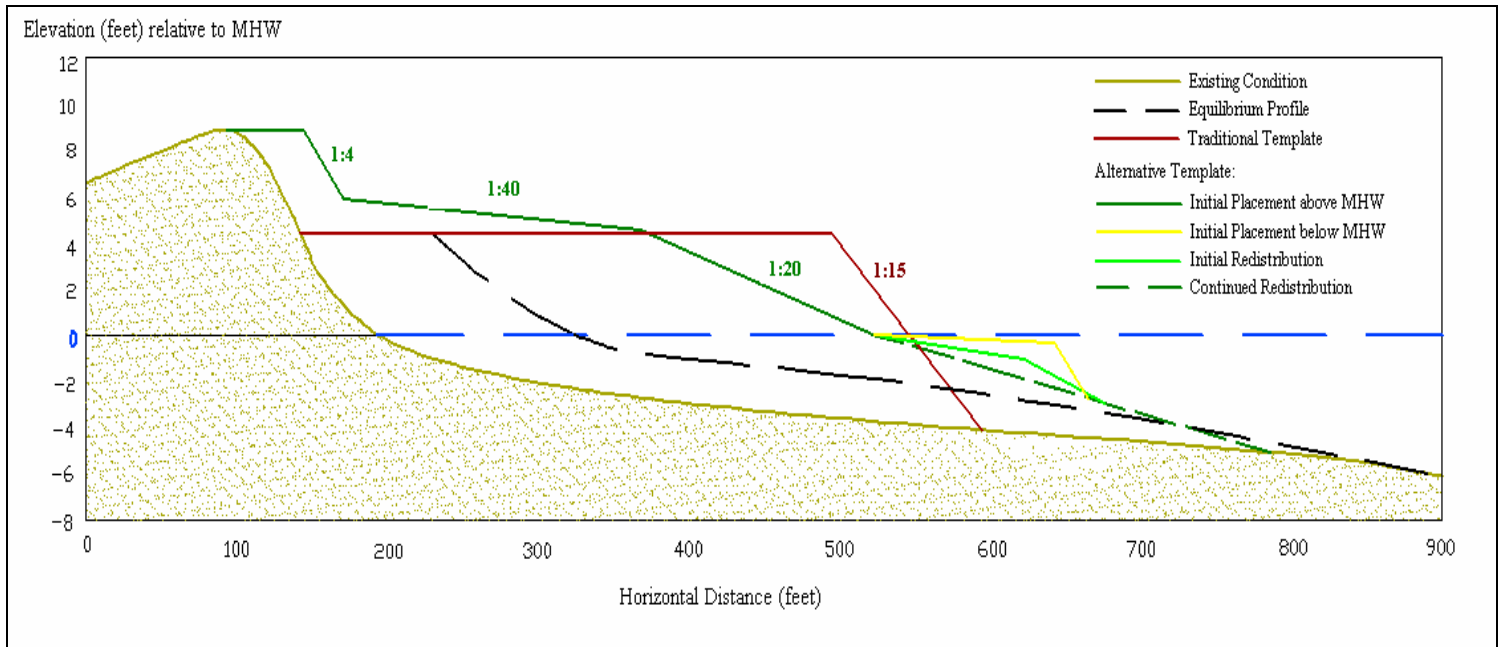


Figure 6 – Conceptual Alternative Template Design (actual slope dependent on site-specific considerations).

4.0 DEVELOPMENT OF MONITORING PLAN

As discussed in Section 2, Assessment of Physical and Biological Data, historical monitoring data do not permit a thorough analysis of the extent to which specific physical beach variables influence turtle nesting behavior on nourished beaches. An integrated and comprehensive contemporary monitoring program using an acceptable experimental design is essential for a reliable determination of the efficacy of an alternative construction template in improving the quality of the beach as sea turtle nesting habitat.

4.1 Proposed Experimental Design

The goal of this project is to determine if statistically significant improvements in nest densities and hatchling production can be achieved through modifications to the traditional construction template for beach nourishment projects. The design described herein was created in consultation with the TAG.

Ideally, the project site should be sufficiently large (e.g., 2 to 4 miles in length) to allow partitioning of the nourished beach into experimental and traditional template treatments of equal length. Half the treatments will be fashioned into the new template design and the other half constructed with the traditional design. The construction design used for any particular treatment will be randomly assigned. This experimental design will yield the replication needed to account for spatial variability in beach conditions throughout the project area and optimize statistical comparisons.

FDEP personnel have indicated that it is feasible to alternate design templates every 1,000 feet along a project area. This would yield a relatively large number of replicates for statistical testing. However, balance must be struck between the number of treatments utilized (the larger the sample size the greater the ability to detect statistically significant differences) and the increasing influence of edge effects as treatment size decreases (i.e. because physical beach conditions at the boundary between two different treatment designs will blend, corresponding biological data cannot be assigned reliably to either treatment). It was the consensus of the TAG members that the edge effects of treatments that are only 1,000 feet in length might be considerable and suggested that half-mile segments would be more practical. Monitoring will occur within the central portion of each treatment to eliminate edge effects. Six-hundred-foot (600-foot) buffers between adjacent treatments will yield individual treatment sizes of approximately 2,000 linear feet of shoreline. Adjustments to buffer sizes can be made in the field post-construction in response to specific conditions at the time of monitoring.

One of the criteria for selecting a test project site will be the availability of reliable historical biological and physical (e.g. beach profiles, sediment characteristics) monitoring data for that location. Additionally, one or more nearby and comparable reference (control) beaches (not previously or at least recently nourished) with similar historical data will be selected to provide a basis for examining natural temporal changes between historical and present conditions.

The TAG acknowledged that sediment characteristics are an important consideration in the experimental design. If the selected site has been previously nourished, the new project should use the same borrow source for sediments as the previous nourishment event at that site. Furthermore, sufficient testing of the borrow site is needed to ensure homogeneous sediment quality among the different treatments. If the site has not been previously nourished, the borrow sediments should have similar grain-size characteristics to the native sediments they replace. If possible, these sediments should conform to FDEP's new criteria for beach compatibility. If a prominent vegetated dune feature is incorporated into the project design (recommended if feasible for the selected test location), it will be constructed similarly throughout all treatments.

At least one year (preferably two) of pre-construction monitoring data and at least three years of post-construction monitoring data should be collected at both test and control sites. The incorporation of both control and baseline data in concert with the replication of alternative and traditional template treatments should provide sufficient statistical rigor to reliably assess the effectiveness of the new design. However, an additional analytical benefit would be realized if the test project site had been previously nourished using the traditional template with documented impacts to sea turtle nesting and/or reproductive success. Statistically significant differences in measured biological variables between the new and traditional templates on the newly constructed beach and between the new and traditional templates at the same location during different project timeframes would provide compelling evidence that the new template has been effective in reducing impacts.

4.2 *Species Monitored*

The hypothesis is that the alternative construction template will improve nesting and nesting success for the loggerhead turtle. However, to the extent practical, the selected test site should also support substantial nesting by leatherback and green turtles as project effects may differ among species. This would allow assessment of benefits on all three principal species nesting on Florida's beaches.

4.3 Monitored Variables

In developing a suite of variables to be monitored during the test project, it was recognized that the availability of both baseline and control data would greatly improve the interpretive capability for segregating natural patterns and trends from those related solely to the beach nourishment project. Background data for this project will come in two forms: contemporary baseline data (i.e., collected immediately prior to the new test project using the monitoring program set forth below) and historical baseline data (i.e., collected during the previous nourishment project or during recent years if the site has not been previously restored). However, even if some historical data are available, it is unlikely that all of the proposed monitored variables listed below will have been monitored previously. Consequently, two years of contemporary baseline data would be preferable to one. Ideally, historical baseline data will be available for both the project and control sites. This will improve the capacity to draw inferences regarding the effectiveness of the new construction template.

The following data will be collected during contemporary baseline and post-construction monitoring of all treatments and control sites.

1. Enumeration of crawls by species and treatment.
2. Photo documentation of dune horizon for each treatment.
3. Documentation of nighttime lighting conditions for each treatment.
4. Characterization of weather patterns affecting the project area during the period of monitoring, including air temperature, rainfall, and wind speed and direction. Any anomalous or dramatic weather events (e.g., drought, record temperatures, tropical storms) will be documented. Weather data may be obtained from the internet and/or portable weather stations deployed at the project site. Wave heights affecting the project area during the period of monitoring will be summarized using NOAA data, if available.

5. Determination of beach profile along randomly selected crawls using Real Time Kinematic (RTK) Global Positioning System (GPS) surveying. The surveyor will walk along the path of the crawl taking readings at:
 - a. the water's edge,
 - b. the seaward edge of the ascending path,
 - c. the previous high tide line,
 - d. every point where a distinct change in beach slope (grade break) is observed,
 - e. the base and top of any scarp encountered,
 - f. the location of each abandoned digging attempt,
 - g. the approximate clutch location (if a nest is present),
 - h. the apex (most landward advance) of the crawl, and
 - i. the most seaward edge of the descending path.

Additionally, a reading will be taken one meter landward and one meter seaward of the clutch or crawl apex (false crawl), as applicable, and at the toe of the dune or armoring structure immediately landward of those points. These data will be used to establish beach width, slope, and elevation at key points along and in the vicinity of the crawl in an effort to discern cues that may be used by the turtle in assessing nesting beach suitability and/or nest site selection.

6. Description of the tallest upland feature (trees, sea grapes, building, etc.) immediately landward of the clutch or crawl apex (false crawl) for each of the randomly selected crawls used to collect GPS data.
7. Collection of terrestrial Light Detection and Ranging (LiDAR) data once during each nesting season to establish beach elevations for relatively stable beach features such as dune crest, vegetation, and beachfront structures. The LiDAR data will be integrated with GPS data to establish the inclination and distance from the clutch or crawl apex (false crawl) to the highest adjacent upland horizon feature (dune vegetation or building).
8. Documentation of the spatial distribution of nests. GPS and LiDAR data will be used to determine the horizontal (shore-parallel) and vertical (shore-

- perpendicular) distribution of nests and false crawls relative to key beach features (e.g., tide line, dune, escarpments, beach elevation).
9. Compaction adjacent to the clutch or crawl apex (false crawl) and at all abandoned digging sites along the path of each randomly selected crawl.
 10. Scarp encounters. For all crawls, any encounter with a scarp will be recorded along with the height of the scarp and the turtle's response to the contact (e.g., returned to ocean without nesting, scaled scarp, nested at base of scarp).
 11. Weekly scarp monitoring. The, location, distance, average height, and maximum height of all scarps will be recorded with GPS.
 12. Grain-size analysis of representative samples across selected beach profiles at the beginning (April) and end of each nesting season (September). Samples will be collected from the surface and at mid-clutch depth (~ 45cm).
 13. Abandoned digging attempts. For all crawls, all abandoned digging attempts will be recorded. These digs will be characterized as either abandoned body pits or abandoned egg chambers, depending on the stage of digging when the site was abandoned.
 14. Nest fate of randomly selected nests. Nests along randomly selected crawls will be marked and monitored throughout their incubation period. The fate of each will be assigned to one of several pre-determined categories (e.g., hatched, depredated, washed out, etc.). At least 75 nests per treatment (dependent on the number and size of treatments), or as otherwise determined by appropriate power analysis), will be marked for this task.
 15. Reproductive success. All marked nests will be excavated after hatching in accordance with FWC guidelines to determine reproductive success. Nest contents will be assigned to one of several categories and measures of hatching success (i.e., percentage of eggs in clutch that hatch) and emerging success (i.e., percentage of eggs that produce hatchlings that successfully escape from the nest) calculated. A sufficient sample size is needed to allow for some nest loss to erosion, predation, and other factors while still retaining a sufficient sample of nests to produce a high degree of statistical certainty as to project effects. These

- data together with nests that are depredated and washed out will be used to extrapolate total hatchling production for each monitored treatment.
16. Assessment of hatchling orientation. If hatchling tracks are observed emerging from a marked nest, a qualitative assessment of orientation will be made by assigning the emergence to one of three categories: properly orientated, moderately disoriented or severely disoriented. The approximate number of disoriented hatchlings will be recorded.
 17. Monthly engineering profiles of the beach and nearshore bottom at each 0.5 FDEP monument within control and test parcels between April (early nesting season) and September (late nesting season). This will permit an evaluation of changes in beach profile that occur between and within nesting seasons using traditional profile methods.

4.4 *Spatial Data Collection*

Two methods will be used for collecting physical beach data. The RTK GPS system uses satellites and a correction factor from known control points to measure point elevations. This system consists of a base station receiver and a rover receiver. The base station is assembled on a fixed-height tripod over a control point (e.g., FDEP monument) with known horizontal location and vertical elevation. A data collector is used to start the base station and then the rover. The operator will then check-in to another known control point in the area with the rover on a fixed-height bipod to verify that the settings in the base station and the rover are working properly before beginning the survey.

After checking-in, the operator will drive the rover down the beach on an ATV to the first randomly selected crawl site. The operator will allow the rover system to initialize and then walk the path that the turtle crawled taking measurements with the data collector and rover at each location listed in Monitored Variable No. 5, above. The operator will continue down the beach collecting data at all of the randomly selected crawls for that day and then will check-in to another known control point which verifies that there were no interruptions to the base station during the survey. These data are used to create

Computer Aided Drafting (CAD) or Geographic Information Systems (GIS) drawings of the nesting features to compare to the initial topographic surface of the study area.

The LiDAR system uses lasers to take multiple returns of data to give a topographic surface of the project area. The last pulse return can be used to develop a bare-earth Digital Terrain Model (DTM), which depicts the topographic surface in the absence of all features (trees, buildings, etc.). This method will provide precise elevations of all dune horizon features and can be used to create a one-foot contour map of the beach.

4.5 *Other Considered Data*

The proposed approach does not provide for an evaluation of some of the factors likely to affect reproductive success (e.g., sediment moisture content, sediment temperature, sediment permeability) because of the added monitoring costs and the interpretive hurdles likely to be encountered. First, because of the high degree of natural variability in reproductive success, it is difficult to establish cause and effect relationships without monitoring a large number of variables. Second, the results may vary appreciably at a particular project site depending on the sediment material and construction methods (e.g., piping vs. trucking) used to build the beach. Thus, results from one project site may not be applicable to another. Third, external interactive variables, such as weather (e.g., temperatures and rainfall), cannot be controlled, and prevailing weather conditions at the time of study may have a significant influence on embryonic development. Therefore, it seems more appropriate to address factors affecting reproductive success, other than those associated with beach profile and direct physical disturbance (e.g., erosion, predation), through ancillary experimental tests where a particular variable(s) of interest can be isolated in a controlled manner to study its effect on embryonic development and hatching success.

4.6 *Monitoring Costs*

The exact cost for implementing the program described above will depend on the location of the test site, the size of the project, the year of construction, and the personnel used to conduct the monitoring. The cost estimate provided below highlights key elements of the monitoring program and assigns costs based on a hypothetical project on the east coast of Florida.

Although the monitoring program described below is relatively intensive, costs will be partially offset by the dollars typically appropriated for standard permit compliance monitoring. If valid conclusions are to be expected, it is imperative that the experimental design be sufficient enough to allow for valid statistical analysis. *An a priori* statistical analysis would require such considerations as a balanced design, sufficient replication, and hypothesis testing. *A posteriori* analysis would be performed on other data as appropriate.

4.7 *Transferring Results to Other Project Sites*

If the monitoring of the new construction template reveals statistically significant improvements in biological response, as collectively determined by the TAG and expert collaborators, the experimental design should be applied full-scale to other project sites and/or to the same site during subsequent nourishment events. Data from the full-scale projects should also be evaluated to ensure that the benefits identified during the experimental project persist at the larger scale. Any additional needed adjustments would then be incorporated into future projects. This approach would implement one of the principal recommendations stemming from the CETAC Workshop.

Table 1 – Cost Estimate for Monitoring Program.

TASK	SUB-TASK	ESTIMATED COST
Mobilization	Establish survey boundaries	\$4,170
	Assemble equipment & supplies	
	Develop site-specific SOP	
Daytime & Nighttime Characterization of Study Site	Review of aerial photos	\$6,120
	Photo documentation of dune horizons	
	Assessment of nighttime lighting conditions	
Daily Monitoring	Count of all crawls by type (nest or false crawl) and survey area	\$74,580
	GPS data collection for randomly selected crawls	
	Documentation of abandoned digs along randomly selected crawls	
Nest Marking & Monitoring	Marking of nests along randomly selected crawls	\$21,190
	Daily monitoring of marked nests	
	Assessment of hatchling orientation for all marked nests	
	Excavation of marked nests after hatching and evaluation of nest contents	
Biological Data Management	Entry of data into Access or other appropriate database	\$11,300
	Data verification	
	Generate data summaries	
GPS, LiDAR, and GIS Data Management	Import data into GIS	\$19,750
	Assemble data layers for different biological and physical data sets	
	Develop graphic data presentations	
Sediment Compaction Analyses	Measure compaction along randomly selected crawls	\$8,015
Scarp Monitoring	Measure scarps each week	\$1,400
Grain-size Analyses	Collect and analyze sediments at 32 locations twice a year	\$15,950
Characterization of Weather and Wave Conditions	Obtain and summarize weather and wave data from official websites	\$3,500
LiDAR Data Collection	Collect LiDAR data once each year	\$24,400

TASK	SUB-TASK	ESTIMATED COST
Engineering Profiles	Determine beach profiles (across dune and berm to approximately – 4 ft NGVD) at approximately 500 foot intervals six times a year	\$84,000
Data Analyses	Identify and/or develop appropriate analytical tools	\$36,100
	Conduct statistical analyses	
	Prepare tables and figures for presenting data	
Reporting	Monthly data summaries	\$14,080
	Year-end project report describing methods and results	
	Final Report with interpretation of results and statistical assessment of project performance (Final year only – not included in these costs)	
Project Management	Coordination w/ FDEP & local sponsor	\$10,880
	Personnel management (scheduling, training, QA, etc.)	
	Allocation & maintenance of equipment & supplies	
	Contract administration	
Equipment & Supplies	ATVs (purchase, operation, and maintenance)	\$4,500
	Cone penetrometer	\$2,100
	Trimble R8 System (2)	\$101,060
	Nest marking materials	\$750
	Miscellaneous	\$250
Other	GPS training	\$10,000
	Analytical peer-review (Final year only – not included in these costs)	\$0.00
TOTAL COST FOR YEAR 1 SERVICES (BASELINE)		\$454,095
RECURRENT ANNUAL COSTS (YEARS 1&2 POST-CONSTRUCTION)		\$314,065
FINAL YEAR COSTS (YEAR 3 POST-CONSTRUCTION)		\$413,065
TOTAL COST FOR 4 YEAR PROGRAM		\$1,495,290

In assessing the benefits of the test project, it must be realized that although beach nourishment projects share many general features, they are each unique. A variety of factors (e.g., borrow sediment characteristics, placement method, weather, etc.), some

within and some outside of the project planner's control, can independently and collectively influence how a project performs from an engineering standpoint. In turn, project performance will influence how sea turtles respond to both the quantity and quality of nesting habitat available to them. Consequently, results from the test project may vary to a certain degree depending upon the type of sediment used and prevailing weather conditions during the period of study. Nevertheless, if positive results are obtained, the integrity of the experimental design should permit a high degree of confidence in applying the new construction template to other sites.

5.0 SELECTION OF TEST PROJECT SITE

Based in part on information presented in previous sections of this report, the following criteria were used to screen for potential test sites:

1. A high-density sea turtle nesting area;
2. A location with reliable, long-term, sea turtle monitoring data;
3. A location with long-term beach profile data;
4. A project of sufficient shoreline length to allow establishment of multiple treatments;
5. A site previously nourished using the traditional construction template with documented reductions in relative nest densities and/or nesting success and skewed placement of nests toward the seaward portion of the berm (this criterion is not essential but is desirable);
6. A project whose timing would allow collection of adequate (preferably two years) baseline data using the new monitoring protocols listed in Section 4, Development of Monitoring Plan;
7. A project in which the environmental setting would allow the construction of the alternative design template without undue permitting constraints; and
8. A project location that would permit the establishment of at least one control site (preferably two, one north and one south of the test parcels) similar in characteristics to the project site.

So as not to limit the number of potential project sites, it was suggested that the requirement for a site to have been previously nourished with documented negative impacts to turtles be eliminated. It was agreed that previously demonstrated impacts associated with the traditional template would help substantiate the benefits of an alternative template if significant differences were found between the two template designs. However, the use of a previously nourished site (with or without negative effects) is not crucial to the experimental design. The incorporation of control and baseline data in concert with the replication of alternative and traditional template treatments should provide sufficient rigor to assess the effectiveness of the new design.

FDEP representatives noted that considerable time (in an excess of one year) will be needed to modify permits to allow for the construction of an alternative template. Thus, projects were screened that were two or more years away from construction were considered to allow sufficient time for permit modifications and implementation of contemporary baseline monitoring.

On November 21, 2005 FDEP provided a list of five (5) potential test sites that met some of the physical criteria and timing constraints developed by the TAG. These then underwent subsequent screening with respect to biological data. Each is discussed below.

5.1 *Mid-Reach Restoration, Brevard County* (R99-R118.3 – only the southern portion is planned for nourishment)

Considerations Presented by FDEP: The area north of the project, Patrick AFB could be used as a control (although the shoreline is narrow ~ 50 yards). This area has never been nourished. They currently do not have a permit, so the experimental design could be considered during the initial permitting process (i.e., no permit modifications required). Hardbottom is present in the adjacent nearshore area and constraints have been placed on the design. Impacts are already expected at the southern portion, and it is possible the alternative template design could be used there. However, the alternative template is not constructible at the northern portion due to the presence of nearshore hardbottom in that area. A dune and berm system (mostly above MHW) is

currently proposed to avoid hardbottom impacts, which may not be ideal for comparison purposes.

Suitability Assessment:

- This beach satisfies the requirement for a high-density turtle nesting area.
- It appears that University of Central Florida (UCF) researchers have monitored this beach for a number of years, so there is reliable, long-term sea turtle monitoring data.
- Since this area has never been restored, there is no documentation of traditional template impacts.
- It appears that the timing is such that adequate baseline data could be collected.
- The presence of hardbottom along the shoreline may not allow for the construction of appropriate templates. This fact alone may be sufficient to eliminate this site from consideration.
- The total length of the project area is 3.6 miles, which is sufficiently long for the study, but only the southern portion is planned for nourishment. This portion may not be long enough to allow multiple treatment replicates.
- It is stated that Patrick AFB could be used as a control, but this area has been nourished in the past so would not be an appropriate control. It is possible that beaches south of the South Reach Project (far enough south not to be influenced by that project) may be used as a control.
- This is a federal project and changes to the traditional design template may be encumbered by federal funding criteria and approval procedures.
- The local sponsor is anxious about the possibility of a modified design and may not want to deal with any uncertainties associated with a prototype project.

5.2 *Jupiter Island, Martin County* (R76-R111 – placement area changes with each nourishment event)

Consideration Presented by FDEP: There are no hardbottom issues and few lighting issues. The next nourishment may not be for 5+ years (currently planned for nourishment).

Suitability Assessment:

- This beach satisfies the requirement for a high-density turtle nesting area.
- This beach has been monitored annually for a long period of time. However, numerous parties have been involved in the monitoring, and there is uncertainty about the scope, consistency, and reliability of the data.
- This area has been nourished on numerous occasions using a traditional template with a corresponding reduction in nesting success.
- It appears that the timing is such that adequate baseline data could be collected.
- There are no apparent environmental conditions that would result in undue permitting constraints related to construction of the alternative template.
- The total beach length is sufficient to allow multiple treatment replicates, but the lengths of past projects have varied. Past projects have often been too short to allow multiple treatment replicates.
- There are beaches within Hobe Sound National Wildlife Refuge that could be used as a control. There may also be suitable beaches to the south that could serve as a control.

5.3 Juno Beach, Palm Beach County (R26-R38)

Considerations Presented by FDEP: There are possible control sites to the north and south. The area has been previously nourished. A new permit is needed prior to the next nourishment event. There are outstanding mitigation requirements, which are currently in the feasibility stage. A borrow area has not been identified. A new permit will not be issued until the mitigation is constructed. This will leave enough time for obtaining baseline monitoring data, but the year of construction will depend on the County's scheduling and funding. Additionally a pier is located within the project limits, which has occasionally resulted in turtle fatalities.

Suitability Assessment:

- This beach satisfies the requirement for a high-density turtle nesting area.
- The applicant has expressed an interest in hosting the test project.
- Reliable, long-term, sea turtle monitoring data are available.

- There have been documented impacts on numbers of nests and nest location but not on nesting success after a prior nourishment project at this site.
- It appears that timing for this project would allow collection of adequate baseline data. The County has indicated a willingness to postpone project construction to ensure collection of adequate baseline data.
- There are no apparent environmental conditions that would result in undue permit constraints related to constructing the alternative template.
- Project length may not be sufficient to allow multiple treatment replicates.
- It appears that there are appropriate control sites to the north and south.
- The pier in the middle of the project may confound assessment of project performance.

5.4 North Boca, Palm Beach County (R-205-R212)

Considerations Presented by FDEP: There is a possible control site to the south between this site and the Central Boca project (R-216-R222). The area has been previously nourished. This is a federally funded project, which will determine the next nourishment event (should be coming up in November 2006 or 2007). A new permit is also needed, which will leave enough time for obtaining monitoring data and permitting a new template. Rock (Jap Rock) at the northern end of the project does influence a portion of the fill area, therefore the test area will have to be outside of this influence.

Suitability Assessment:

- Loggerhead nest densities are moderate on this beach.
- Reliable, long-term, sea turtle monitoring data are presumably available for this site.
- This area has previously been nourished, but the effects on sea turtle nesting, nesting success, and nest location were unavailable and have not been reviewed.
- If the project begins in November 2006 there would not be sufficient time to collect appropriate baseline data.

- The small size of this project area and the presence of rock at the north end may result in permitting constraints with respect to constructing an alternative template.
- Project length will not be sufficient to allow multiple treatment replicates.
- There is a potential control site south of the project.
- This is a federal project and changes to the traditional design template may be encumbered by federal funding criteria and approval procedures.

5.5 South Siesta Key, Sarasota County (R67-R79)

Considerations Presented by FDEP: There are possible control sites to the south at Midnight Pass Park. The south west coast has lower nesting densities than the East coast. This project has never been nourished. It will only be an option if they do not move forward with construction this winter (still finalizing the permit). Most upland development is in the form of single family homes, which will reduce the lighting issues.

Suitability Assessment:

- Loggerhead nest densities are low on this beach. This fact alone may be sufficient to eliminate this site from consideration.
- Reliable, long-term, sea turtle monitoring data are thought to be available for this beach.
- Since this area has never been nourished, there is no documentation of traditional template impacts at this site.
- There is probably not sufficient time to collect appropriate baseline data.
- There are no apparent environmental conditions that would result in undue permit constraints related to constructing the alternative template.
- Project length may not be sufficient to allow multiple treatment replicates.
- It is not know whether there is a suitable control site nearby.

5.6 Site Selection

Based on the selection criteria presented above and project timing, the Jupiter Island Project appears to be the most suitable of the five sites presented by FDEP. One potential drawback is that the Town has nourished the entire shoreline over the past several decades but at different intervals, such that historical beach conditions may not be consistent among treatment replicates. Past projects have been funded at the 65% local level, and it is not known whether the Town would be amenable to altering their design template to accommodate a future test project there. Furthermore, there is uncertainty regarding the Town's current monitoring program and their ability and willingness to accommodate the considerable additional monitoring required for a test project and provide the level of detail and accuracy needed to reliably assess project performance. All of these details must be explored before proceeding further with the project. In the interim, it is recommended that FDEP continue to screen additional project locations and identify sponsors willing to provide the local support needed for a successful test project.

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