APPENDIX J
Mitigation Plan

Miami Harbor GRR Study
Draft Environmental Impact Statement
Mitigation Plan

July 2002

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EXECUTIVE SUMMARY

This report outlines compensatory mitigation for unavoidable impacts to seagrass, unvegetated bottom, and offshore hardbottom/reef habitats impacted by implementation of the Recommended Plan (Alternative 2). Direct impacts include 6.3 acres of seagrass habitat, 49.4 acres (3.3 acres new impacts) of hardbottom/reef habitat outside or deeper than the present authorized channel width and depth, 123.5 acres of rock/rubble habitat previously impacted by channel dredging, and 236.4 acres of unvegetated sand/silt bottom located in the authorized channel. Of these impacts, mitigation is proposed for seagrass and hardbottom/reef habitats where new construction or dredging is proposed. All of these habitat types are considered Essential Fish Habitat (EFH) by the South Atlantic Fishery Management Council (SAFMC) and National Marine Fisheries Service (NMFS) (SAFMC 1998). For dredging the rock/rubble and unvegetated bottom within the channel, mitigation is not proposed since dredging was previously performed in the channel and temporal impacts are minimal.

Seagrass Impacts and Mitigation

Direct impacts to seagrass communities are restricted to the widening of the Fisherman's Channel cut and the Fisher Island Turning Basin. Impacts include the permanent loss (removal) of 0.2 acre of mixed seagrass beds. Indirect losses will occur from the natural equilibration of the side slopes and erosion of the area of seagrass located within 50 to 70 feet south of the proposed top of the new channel. The average equilibrium slope will be 1:7 for the south bank of the channel (see Appendix G in the EIS), resulting in the loss of 6.1 acres of seagrass. Based on the high probability for restoration success, and a high likelihood that the restored seagrass beds would be of much higher quality than those impacted, a compensation ratio of one-acre of seagrass as compensation for one-acre of impact is conceptually valid for all impacts due to dredging. Based upon the extent of impacts discussed above, creation/restoration of approximately 6.3 acres of seagrass beds is proposed as compensation for unavoidable impacts. Any excess areas restored as part of filling the dredged holes with suitable dredged material will be banked by the Port for future use.

In order to replace local seagrass functions and values, restoration will be implemented within Biscayne Bay, preferably in areas where seagrass once occurred and is now absent due to past anthropogenic activities such as dredging. Seagrass habitat will be restored by filling at least 6.3 acres of old borrow areas located north of the Julia Tuttle Causeway in North Biscayne Bay. Eight borrow areas were considered suitable for filling with dredged material, capping with sand and restoring seagrass habitat to an elevation consistent with the depths where adjacent seagrass beds are present (CTC 1989). Potential borrow areas are presently being further evaluated with the final selection to be coordinated with resource agencies prior to preparation of the Final EIS. Additional data recently collected included seagrass diversity and density, bathymetric profiles within and adjacent to the area, and diver observations within the borrow areas (DC&A, in preparation).

Dredged material will either be hauled or pumped to the selected borrow area(s) based on engineering analysis, cost, and recipient site conditions. Dredged material will be placed into the borrow areas. It is assumed that this can be accomplished without a coffer dam and will require a variance from water quality standards within a defined mixing zone. It is anticipated that ambient depths will range from -2 feet to -6 feet MSL in the restored areas following restoration and that seagrass recruitment will occur rapidly by *H. wrightii* and *H. decipiens,* all of which likely occur within the shallow flats adjacent to these sites (CTC 1989). Other species including *T. testudinum* and *S. filiforme* will also colonize the sites, but generally only after occupation by the early colonizing species previously cited. Site monitoring will be conducted for three years to document the characteristics and extent of recruitment. If established success criteria are not met within three years, supplemental planting may be performed to speed recovery. Detailed plans and specifications for the seagrass restoration will be prepared and provided for agency concurrence prior to construction.

Hardbottom Impacts and Mitigation

New impacts to low relief hardbottom and high relief hardbottom total 0.6 acre and 2.7 acres, respectively. Based on the Habitat Equivalency Analyses calculations (Appendix A), direct impacts to reef and hardbottom habitats would require the creation of artificial reef habitat at an effective mitigation ratio of 2.0 for high relief hardbottom/reef habitat and an effective mitigation ratio of 1.3 for low relief hardbottom/reef habitat. Mitigation reefs will be constructed in two different designs, to reflect the differences in the habitat structure of the two types of reef/hardbottom habitat to be impacted. The proposed mitigation will be type-for-type, to reflect the ecological differences between the different reef types impacted. A total of 0.8 acre of low relief-low complexity (LRLC) reef will be required to mitigate for the new low relief hardbottom/reef and previously impacted hardbottom habitat. A total of 5.4 acres of high relief-high complexity (HRHC) reef would be required to mitigate for the high relief impact. Reefs will be constructed at approved artificial reef sites managed by DERM.

Native rock excavated from the Entrance Channel will be used in reef construction. The dredged rock material will be deployed to mimic the orientation of typical natural reefs. This reef design will have an approximate vertical relief of 3 to 5 feet to provide the maximum structural complexity and to provide refugia for cryptic and reclusive species. As interstitial sand patches associated with reef habitat are thought to be important in the ecological function of the reef habitat, the reef footprint will contain approximately 20 percent open sand surface. Temporary buoys delineating the deployment strip will mark areas for deployment. Corner buoys for the sites shall be placed using DGPS with sub-meter accuracy. Natural excavated rock from the dredged channel will provide an ideal substrate for the establishment of a fouling community and colonization by the common reef community species. HRHC reefs are intended to provide persistent habitat with higher complexity and habitat diversity than LRLC hardbottom or reefs.

LRLC reefs will have a vertical relief of 1 to 2 feet and will be placed inshore of, and shallower than, HRHC reefs. It is recognized that the LRLC reefs may be periodically buried by shifting sands, like the low relief natural reefs they are intended to mimic. This does limit their habitat value to some extent, but it has been suggested (albeit without much empirical evidence) that this sort of ephemeral, low relief habitat may be particularly important in supporting the recruitment and post settlement survival of juvenile fishes. Natural rock excavated from the channel as described above and placed in sites where they may be expected to partially settle in the substrate, should provide LRLC habitat. Deployment sites will be delineated as outlined above for HRHC reefs.

The monitoring program for the mitigation reefs will consist of both physical and biological components. Physical monitoring one year after placement will assess the degree of settling of the reef materials, and biological monitoring will assess populations of algae, invertebrates, and fishes, as compared with concurrent control sampling of natural reefs. Biological monitoring will be conducted annually in the summer months for three years. Each monitoring effort will include video transects of the mitigation reefs to document Snapper Grouper Complex utilization.

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1.0 INTRODUCTION

This report outlines compensatory mitigation for unavoidable impacts to seagrass and offshore hardbottom/reef habitats impacted by implementation of the Recommended Plan considered in the Draft Environmental Impact Statement (DEIS). Direct impacts to the total project include 6.3 acres of seagrass habitat, 49.4 acres of reef habitat outside or deeper than the present authorized channel width and depth, 123.5 acres of rock/rubble habitat previously impacted by channel dredging, and 236.4 acres of unvegetated sand/silt bottom located in the authorized channel. Of these impacts, mitigation will be required for seagrass and hardbottom/reef habitats where new construction or dredging is proposed. All of these habitat types are considered Essential Fish Habitat (EFH) by the South Atlantic Fishery Management Council (SAFMC) and National Marine Fisheries Service (NMFS) (SAFMC 1998). For dredging the rock/rubble and silt/sand/rubble bottom within the channel, mitigation is not proposed since dredging was previously performed in the channel and temporal impacts are minimal.

1.1 Mitigation Policies

A summary of mitigation programs and policies in effect by federal reviewing agencies, including the Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (FWS), and NMFS, are provided below.

U.S. Environmental Protection Agency Mitigation Policy

Policy regarding mitigation under the Clean Water Act (CWA) Section 404(b)(1) guidelines were expressed within a Memorandum of Agreement (MOA) between EPA and the U.S. Army Corps of Engineers (USACE) and became effective February 7, 1990. The purpose of the MOA is to provide guidance to determine appropriate and practicable mitigation under the Section 404 Regulatory Program. Practicable is defined as "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of the overall project purposes."

According to the MOA, on-site mitigation is preferable to off-site mitigation. Similarly, in-kind mitigation is preferable to out-of-kind mitigation. However, EPA may prefer off-site or out-of-kind mitigation if it is the most practicable solution. EPA expressed a preference of restoration of wetlands over creation of wetlands from upland habitat for two reasons. First, EPA considers the likelihood of success higher for restored wetlands than for created wetlands. Second, EPA is concerned about the reduction of potentially valuable uplands resulting from the mitigation.

The MOA states that the objective of mitigation for unavoidable impacts is to offset environmental losses. Mitigation should provide, at a minimum, one for one functional replacement (i.e., no net loss of wetland value), with an adequate margin of safety to reflect the expected degree of success, but this requirement may not be appropriate and practicable in all cases. A minimum of 1:1 acreage replacement may be used as a reasonable surrogate for no net loss of functions and values where definitive information is lacking. However, this ratio may be greater where the wetland being impacted is high and the replacement wetlands are of lower functional value or the likelihood of success is low. Conversely, the ratio may be less than 1:1 for areas where the wetland being impacted is low and the likelihood of success associated with the mitigation proposed is high.

U.S. Fish and Wildlife Service Mitigation Policy

The U.S. Fish and Wildlife Service Mitigation Policy (January 23, 1981) established policy for mitigating the adverse impacts of land and water developments on fish, wildlife, and their habitats. According to the policy, compensation may be accepted for wetland impacts in a variety of ways. Mitigation activities may include: wildlife management activities, habitat construction activities, fishery propagation, protective designations on public lands, buffer zones, property leases, wildlife easements, water right acquisition, and fee title acquisition. Compensatory mitigation actions should only occur after all efforts to avoid and minimize impacts have been utilized. FWS policy states that appropriate mitigation for unavoidable wetland impacts are based on the resource value of the potential impacted wetland. Four categories of resource value have been defined by the FWS for which different levels of mitigation may be determined.

A wetland classified as Resource Category 1 consists of high value wetland that is unique and irreplaceable on a national basis or in the eco-region. For this category, no loss of existing habitat value is the goal, and the FWS will recommend that all losses of existing habitat be prevented.

A Resource Category 2 wetland is of high value and relatively scarce on a national basis or within the eco-region. For this category, the FWS maintains a goal of no net loss of in-kind value. If unavoidable loss is likely to occur, in-kind replacement will be the recommendation. An exception to this rule may occur where the out-of-kind replacement is of greater value than the habitat to be impacted, or in-kind replacement is not physically or biologically obtainable in the region.

A Resource Category 3 wetland is of high to medium value and is relatively abundant on a national basis. The FWS mitigation goal is no net loss of habitat value while minimizing loss of in-kind habitat value. For impacts to Resource Category 3 wetlands, in-kind replacement is preferred. If in-kind replacement is not practicable, out-of-kind creation or restoration, or increased management of replacement habitat that increases the value of the existing habitat can achieve mitigation goals.

A Resource Category 4 wetland is of medium to low value, with a goal of minimum loss of habitat value. Compensatory mitigation for unavoidable losses to Resource Category 4 wetlands may be required.

National Marine Fisheries Service

As described in the Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), the EFH provisions of the act support one of the nation's overall marine resource management goals – maintaining sustainable fisheries.

The focus of the mitigation policy is to conserve and enhance EFH and to avoid, minimize, or compensate for impacts to EFH due to development activities. As with the other federal agency policies, the primary goal of any action is to avoid impacts to natural resources. However, if impacts to these resources are unavoidable, compensatory mitigation may be required. When unavoidable impacts to EFH occur, the NMFS will recommend mitigation measures to compensate for any loss of resource value. Recommendations may include: restoration of riparian and shallow coastal areas (i.e., re-establishment of vegetation, restoration of hardbottom characteristics, removal of unsuitable material, and replacement of suitable substrate), upland habitat restoration, water quality improvement or protection, watershed planning, and habitat creation. The preferred type of mitigation is enhancement of existing habitat, followed by restoration, and finally creation of new habitat.

Mitigation should focus on the replacement of lost habitat and associated values attributed to the habitat and toward maintaining sustainable fisheries. In particular, mitigation should be targeted toward impacts as a result of the proposed action to the listed managed species discussed in the Environmental Impact Statement (EIS).

Mitigation for EFH should focus on the replacement of lost habitat and associated values attributed to the habitat and towards maintaining sustainable fisheries. Since no definitive policy is currently available on mitigating EFH impacts, development of mitigation strategies is subjective and somewhat difficult to address. Therefore, mitigation for EFH impacts must focus on strategies that enhance fisheries production and help ensure the sustainability of fisheries. Creation of mangrove habitat and mud flats, enhancement of fisheries resources by creating shallow water habitat or artificial structures, restoration of seagrass habitat where feasible, and preservation of environmentally sensitive waterfront land threatened by development are all viable options that can compensate for impacts to EFH, and have been used and accepted elsewhere.

Mitigation requirements for EFH impacts, associated with proposed dredging of channels and basins, are difficult to define. While these areas will see a temporary loss of benthic production, all the affected areas will see recruitment of the benthic community, followed by fish utilization of the habitat. All of these dredged areas will continue to provide food chain support and act as functional EFH habitat, including the turning basins, terminals and inner and outer Entrance Channels. Since the existing harbor basin provides seasonal fishery habitat, we would expect the proposed basin to likewise provide comparable habitat.

2.0 MITIGATION OPTIONS

A total of 25 mitigation options have been identified that could serve as full or partial mitigation for impacts to seagrasses in Biscayne Bay. The amount of site specific information known at this time varies among projects listed below. Table 1 summarizes the mitigation potential of each site identified to date. Options explored vary from significant restoration of mangrove communities in Biscayne Bay, restoring prop scars adjacent to Virginia Key and restoring seagrass habitat in North Biscayne Bay through filling of old borrow areas with dredged material. More detailed information on most of the sites are provided in Appendix B (Mitigation Options Fact Sheets) of this plan, including location, current owner, project description, target habitat, estimated acreage benefited, credit type, likelihood of success, restoration procedure and schedule.

Based on significant coordination with Federal, state, and local resource agencies in-kind restoration of seagrass habitat is the agency preferred option for mitigating seagrass impacts. In the event that restoration of seagrass habitat is not feasible or no sites acceptable to the resource agencies are available, other options will be explored. Restoration of seagrass habitat through filling of old borrow areas in North Biscayne Bay is the preferred choice and is further discussed and analyzed in Sections 3 and 4 of this plan.

Table 1 Summary of Mitigation Project Sites

PROJECT NAME	OWNER	PROJECT DESCRIPTION			BENEFITS			
		Habitat	Credit Type	Acres	Wild-life	T/E Species	Water Quality	Public Park
Chapman/Matheson	Dade County							
Old King's Bay Landfill		Tidal mangroves	Restoration	10.23	X	X	X	
Small Fill Pad		Tidal mangroves	Restoration	1.63	X	X	X	
Old Plant Nursery		Brackish marsh	Creation	8.55	X	X	X	X
		Tidal mangroves, brackish marsh	Enhancement					
			Total:	13.04				
East Culvert		Tidal mangroves and lagoon	Enhancement	48	X	X	X	
Middle Culvert		Tidal mangroves and lagoon	Enhancement	48	X	X	X	
West Culvert and Spoil		Tidal mangroves, brackish marsh	Enhancement	55	X	X	X	
Exotics Eradication		Tidal mangroves, brackish marsh	Enhancement	40.83	X	X	X	X
Main Fill Pad		Tidal mangroves	Restoration	unk	X	X	X	X
			Enhancement	unk				
			Total:	19.4				
Old South Dade Landfill	Dade County	Brackish marsh	Restoration	20	X		X	
Virginia Key								
Marine Stadium	Dade County, City of Miami	Seagrass	Restoration	4.62	X	X	X	
		Tidal mangroves	Creation	9.47				
		Tidal mangroves	Restoration	1.32				
		Brackish marsh	Creation	4.14				
			Total:	19.55				

Table 1. (continued).

PROJECT NAME	OWNER	PROJECT DESCRIPTION			BENEFITS			
		Habitat	Credit Type	Acres	Wild-Life	T/E Species	Water Quality	Public Park
Virginia Key								
Virginia Key Impounded	Dade County	Forested freshwater wetlands	Enhancement and Creation	48.13	X		X	
Sewage Treatment East		Tidal mangroves	Restoration	0.77	X		X	
		Tidal mangroves	Enhancement	4.4				
		Coastal upland buffer	Creation	1.74				
			Total:	6.91				
Sewage Treatment West	Dade County	Tidal mangroves	Restoration	7	X		X	
Spoil Islands	Dade County	Coastal hammock, Tidal mangroves	Creation	unk	X		X	
Virginia Beach Hammock	City of Miami	Coastal hammock	Restoration	unk	X		X	X
CWA/BAP Seagrass	State of Fla.	Seagrass	Restoration	unk	X	X	X	
BNP Seagrass	USA	Seagrass	Restoration	unk	X	X	X	X
EEL Program	Private		Preservation					
Biscayne Wetlands		Coastal wetlands		445	X	X	X	
Black Point Wetlands		Coastal wetlands		192	X	X	X	
Cutler Wetlands		Coastal wetlands		1,194	X	X	X	
Hardy Matheson Addition		Coastal wetlands		42	X	X	X	
Deering Estate N. Addition		Coastal wetlands		5	X	X	X	
Vizcaya Hammock Addition		Coastal uplands		2	X			
Oleta River State Park	State of Fla.	Mangrove wetlands	Restoration	7	X		X	X
North Biscayne Bay Borrow Areas	State of Fla.	Seagrass	Restoration	±40 *	X	X	X	

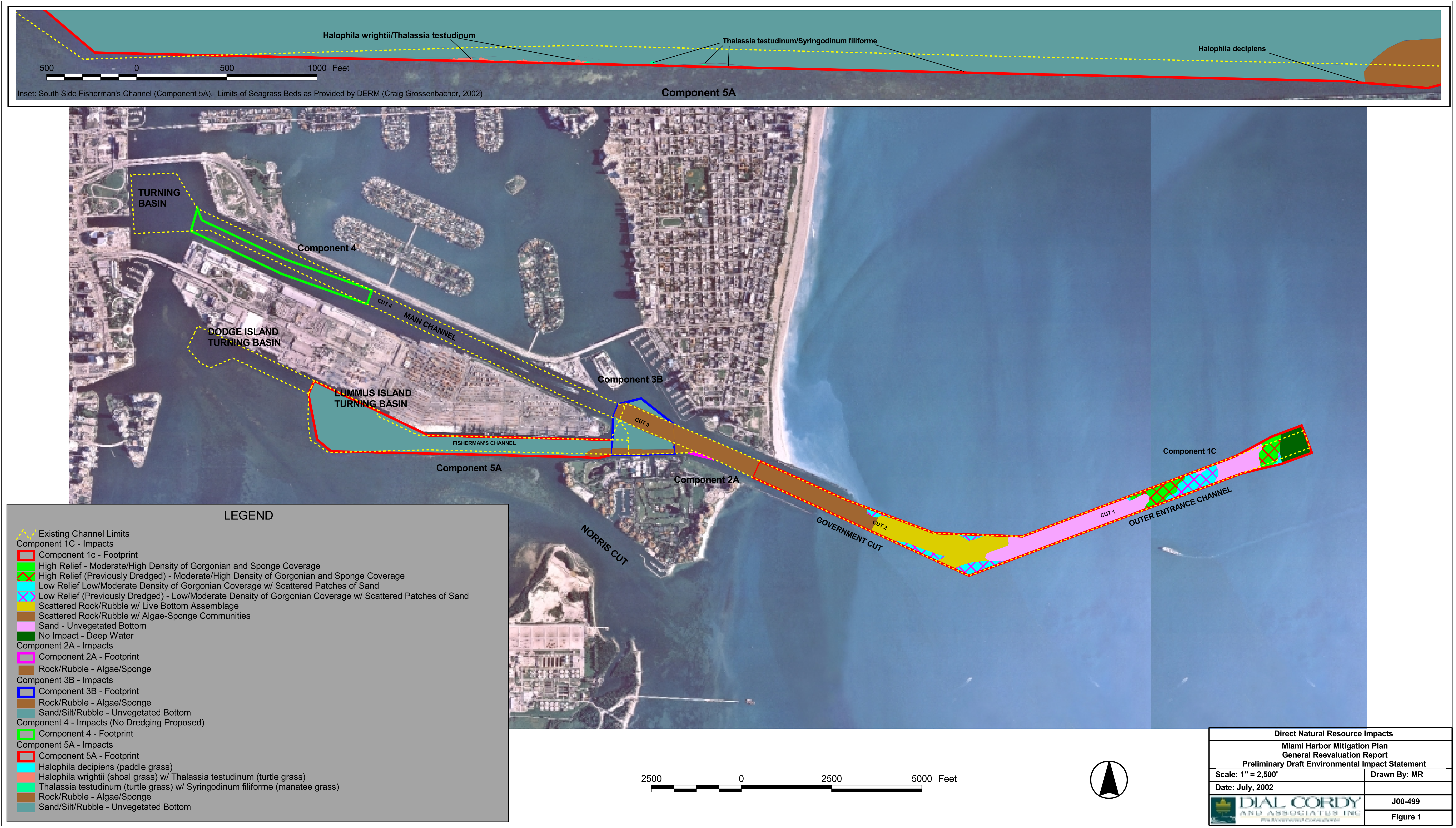
* Potentially available for restoration

3.0 MITIGATION REQUIREMENTS

3.1 Seagrass

Direct impacts to seagrass communities are restricted to the widening of the Fisherman's Channel cut and the Fisher Island Turning Basin. Impacts include the permanent loss (removal) of 0.2 acre of mixed seagrass beds. Indirect losses will occur from the natural equilibration of the side slopes and erosion of the area of seagrass located within 50 to 70 feet south of the proposed top of the new channel. The average equilibrium slope will be 1:7 for the south bank of the channel (see Appendix G in the EIS), resulting in the loss of 6.1 acres of seagrass. Based on the high probability for restoration success, and a high likelihood that the restored seagrass beds would be of much higher quality than those impacted, a compensation ratio of one acre of seagrass as compensation for one acre of impact is conceptually valid for all impacts due to dredging. Based upon the extent of impacts discussed above, creation/restoration of approximately 6.3 acres of seagrass beds is proposed as compensation for unavoidable impacts. Any excess areas restored as part of filling the dredged holes with suitable dredged material will be banked by the Port for future use.

Restoration of seagrass communities, while still considered experimental by some resource agencies, can enhance habitat heterogeneity and the diversity of invertebrate and fish communities, if carefully implemented. The recent treatise on seagrass restoration entitled "Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters" by Fonseca et al. (1998) discusses the benefits, risks, and successful approaches associated with seagrass restoration. Given the documented success of more recent efforts to restore seagrass communities including those in South Florida, restoration is quickly becoming a proven resource management tool in some areas where conditions are appropriate.



Halophila wrightii/Thalassia testudinum
Thalassia testudinum/Syringodinum filiforme
Halophila decipiens
500 0 500 1000 Feet
Inset: South Side Fisherman's Channel (Component 5A). Limits of Seagrass Beds as Provided by DERM (Craig Grossenbacher, 2002)
Component 5A
TURNING BASIN
Component 4
CUT 4
MAIN CHANNEL
DODGE ISLAND TURNING BASIN
Component 3B
LUMMUS ISLAND TURNING BASIN
CUT 3
FISHERMAN'S CHANNEL
Component 5A
Component 2A
NORRIS CUT
GOVERNMENT CUT
CUT 2
CUT 1
OUTER ENTRANCE CHANNEL
Component 1C
LEGEND
Existing Channel Limits
Component 1C - Impacts
Component 1c - Footprint
High Relief - Moderate/High Density of Gorgonian and Sponge Coverage
High Relief (Previously Dredged) - Moderate/High Density of Gorgonian and Sponge Coverage
Low Relief Low/Moderate Density of Gorgonian Coverage w/ Scattered Patches of Sand
Low Relief (Previously Dredged) - Low/Moderate Density of Gorgonian Coverage w/ Scattered Patches of Sand
Scattered Rock/Rubble w/ Live Bottom Assemblage
Scattered Rock/Rubble w/ Algae-Sponge Communities
Sand - Unvegetated Bottom
No Impact - Deep Water
Component 2A - Impacts
Component 2A - Footprint
Rock/Rubble - Algae/Sponge
Component 3B - Impacts
Component 3B - Footprint
Rock/Rubble - Algae/Sponge
Sand/Silt/Rubble - Unvegetated Bottom
Component 4 - Impacts (No Dredging Proposed)
Component 4 - Footprint
Component 5A - Impacts
Component 5A - Footprint
Halophila decipiens (paddle grass)
Halophila wrightii (shoal grass) w/ Thalassia testudinum (turtle grass)
Thalassia testudinum (turtle grass) w/ Syringodinum filiforme (manatee grass)
Rock/Rubble - Algae/Sponge
Sand/Silt/Rubble - Unvegetated Bottom
2500 0 2500 5000 Feet
Direct Natural Resource Impacts
Miami Harbor Mitigation Plan
General Reevaluation Report
Preliminary Draft Environmental Impact Statement
Scale: 1" = 2,500'
Drawn By: MR
Date: July, 2002
DIAL CORDY AND ASSOCIATES INC
J00-499
Figure 1

Table 2 Dredging Impacts by Habitat Type

Habitat Type and Current Dredge Status	Component					
	1C	2A	3B	4	5A	Total
Seagrass- new impacts, side slope equilibration to areas not previously dredged that exist *outside proposed channel boundaries* (ac)	0.0	0.0	**0.1**	0.0	**6.0**	**6.1**
Seagrass- new impacts, not previously dredged, inside proposed channel boundaries (ac)	0.0	0.0	0.0	0.0	**0.2**	**0.2**
Low relief hardbottom/reef- new impacts, not previously dredged (ac)	**0.6**	0.0	0.0	0.0	0.0	**0.6**
Low relief hardbottom/reef, previously dredged and recolonized (ac)	**28.1**	0.0	0.0	0.0	0.0	**28.1**
High relief hardbottom/reef- new impacts, not previously dredged (ac)	**2.7**	0.0	0.0	0.0	0.0	**2.7**
High relief hardbottom/reef, previously dredged and recolonized (ac)	**18.0**	0.0	0.0	0.0	0.0	**18.0**
Rock/rubble w/ live bottom- new impacts, not previously dredged (ac)	0.00	0.0	0.0	0.0	0.0	0.0
Rock/rubble w/ live bottom, previously dredged and recolonized (ac)	**51.7**	0.0	0.0	0.0	0.0	**51.7**
Rock/rubble w/ algae/sponges- new impacts, not previously dredged (ac)	0.0	**0.6**	**0.9**	0.0	**1.5**	**3.0**
Rock/rubble w/ algae/sponges, previously dredged and recolonized (ac)	**41.3**	0.0	**25.2**	0.0	**2.3**	**68.8**
Unvegetated (i.e., sand/silt/rubble, sand habitats without seagrasses)- new impacts, not previously dredged (ac)	**1.3**	0.0	**5.3**	0.0	**16.7**	**23.3**
Unvegetated (i.e., sand/silt/rubble, sand habitats without seagrasses), previously dredged (ac)	**66.9**	0.0	**19.1**	0.0	**127.1**	**213.1**
Project Footprint, excludes seagrass impacts that are outside proposed channel boundaries and "deepwater non-impacts" (ac)	**210.6**	**0.6**	**50.6**	**0.0**	**153.8**	**441.5**

*Channel Wall Impacts are not included in the table.

Based upon the extent of impacts and ratios discussed above, restoration of approximately 6.3 acres of seagrass beds would be required as compensation for unavoidable impacts (Table 3).

Table 3 Seagrass Impacts and Proposed Mitigation Ratios and Areas

Habitat Type	Impact Area	Ratio	Type of Mitigation	Mitigation Required
Dredged Seagrass	0.2 Ac	1:1	Restoration	0.2 Ac
Seagrass Impacted by Sloughing	6.1 Ac	1:1	Restoration	6.1 Ac
Total	6.3 Ac			6.3 Ac

3.2 Hardbottom/Reef

Mitigation Requirements

To calculate the acreage of creation of artificial reef required for compensation, Dial Cordy and Associates Inc. performed Habitat Equivalency Analyses (HEA) (see NOAA 2000). The method used was designed to take into account both projected impact acreages for various habitats and recovery times to calculate the overall loss of habitat function that occurs from the time a new impact occurs to the time of full functional recovery. HEA is usually applied to situations where previously non-impacted habitats are damaged and was used, in this case, to calculate compensatory mitigation acreages for removal of habitat in previously undredged areas. Projected impact acreages were not only classified according to the method that would be applied to calculate functional loss, but were further classified according to relief/profile. This was necessary because the proposed mitigation will be type-for-type, to reflect the ecological differences between the hardbottom/reef types impacted.

Several assumptions are involved in the HEA method. These assumptions include (1) the relative functionality (usually expressed as a percentage) of both impact and mitigation areas at “time-0” (time zero) (i.e., at the initiation of mitigation operations or at the time the impact occurs to the habitat), (2) the relative functionality of both the impact and mitigation area at the completion of recovery of each area, (2) the form of the recovery function (e.g., linear, exponential, hyperbolic, etc.), and (3) the recovery/completion time for the impact area and mitigation area to reach full functionality (i.e., the level that existed prior to impacts/mitigation activities. For low relief hardbottom/reefs assessed with HEA, the following assumptions were used: (1) dredging would leave habitat 10 percent function, (2) habitat value in both the impact and mitigation areas would increase in a linear fashion, (3) both the impact and mitigation areas will reach full (i.e., 100%) functionality in 12 years, and (2) placement of substrate in the mitigation will immediately result in 20 percent of full habitat function. For high-relief hardbottoms assessed with HEA, the same assumptions were used, except recovery to full functionality was based on a 30-year period.

Based on the HEA calculations, direct impacts to reef and hardbottom habitats would require the creation of artificial reef habitat at an effective mitigation ratio of 2.0 for high relief hardbottom/reef habitat and an effective mitigation ratio of 1.3 for low relief hardbottom/reef habitat (Appendix A). Mitigation reefs will be constructed in two different designs, to reflect the differences in the habitat structure of the two types of reef/hardbottom habitat to be impacted. The proposed mitigation will be type-for-type, to reflect the ecological differences between the different reef types impacted. The tables and calculations of the HEA are included in Appendix A.

Mitigation reefs will be required in two different designs, to reflect the differences in the habitat structure of the two types of hardbottom/reef habitat to be impacted. A total of 0.8 acre of low relief-low complexity reef will be required to mitigate for the new low relief reef and previously impacted hardbottom habitat (Table 4). A total of 5.4 acres of high relief-high complexity reef would be required to mitigate for the high relief impact (see Section 3.2.2 for reef design). Reefs will be constructed at approved artificial reef sites managed by DERM.

Table 4 Reef and Hardbottom Impacts and Proposed Artificial Reef Ratios and Areas

Habitat Type	Impact Area (ac)	Ratio	Type of Mitigation	Mitigation Required
Low Relief Reef/Hardbottom	0.6 Ac	1.3:1	Creation of LRLC	0.8 Ac
High Relief Reef/Hardbottom	2.7 Ac	2:1	Creation of HRHC	5.4 Ac
Total	3.3 Ac			6.2 Ac

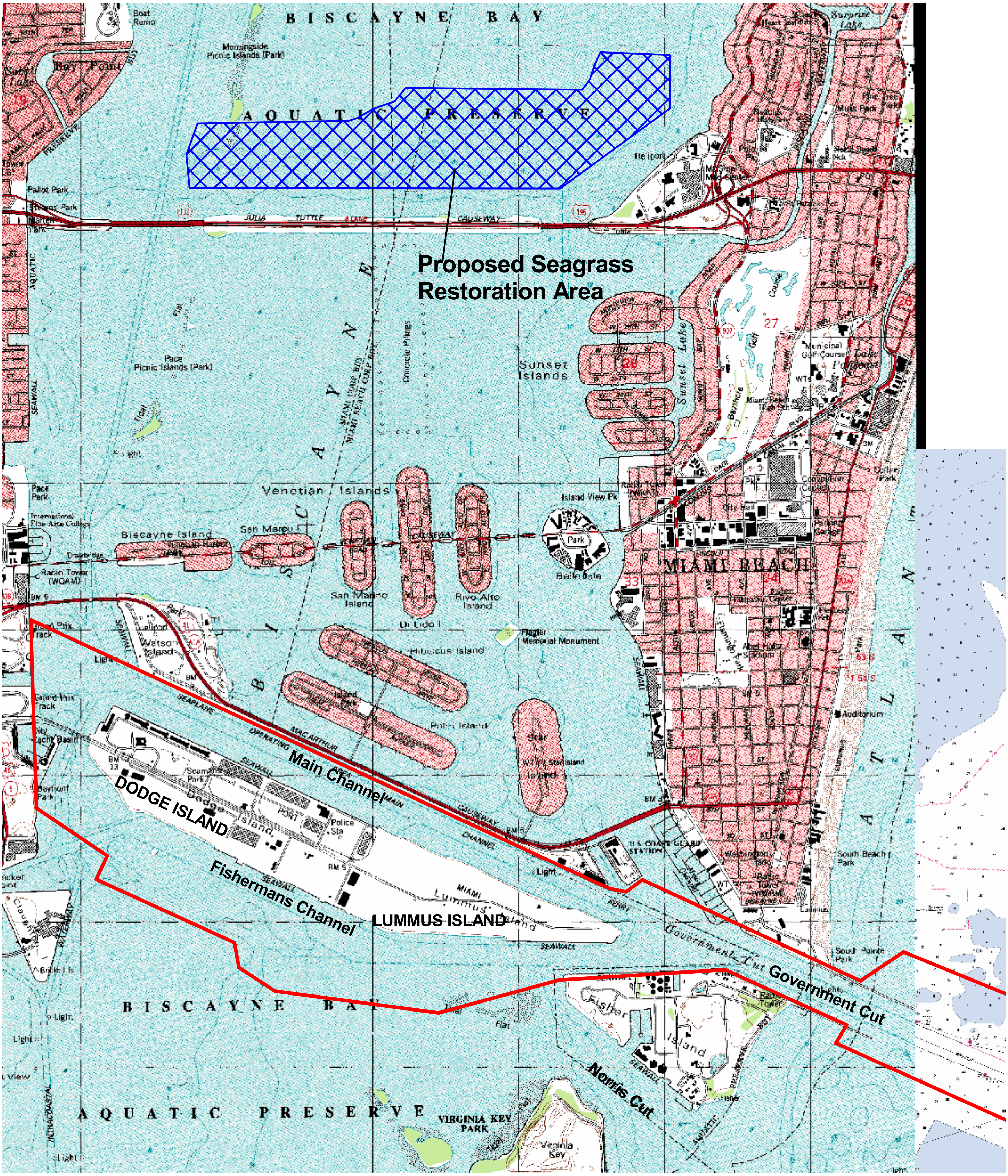
4.0 PROPOSED PLAN

This mitigation plan focuses on compensation options available for unavoidable impacts associated with implementation of Alternative 2 (Recommended Plan) to seagrass and hardbottom/reef habitats located within the tidal influence of the Port Entrance Channel, including Biscayne Bay and adjacent offshore waters. Other options evaluated did not provide in-kind type-for-type replacement of habitat lost and may not be acceptable to the resource agencies unless opportunities to provide like replacement were not available or did not have a likely probability of success.

4.1 Seagrass Restoration

In order to replace local seagrass functions and values, restoration will be implemented within Biscayne Bay, preferably in areas where seagrass once occurred and is now absent due to past anthropogenic activities such as dredging. Seagrass habitat will be restored by filling at least 6.3 acres of old borrow areas located in North Biscayne Bay (Figure 2). As shown in Table 5, there are eight borrow areas which were considered suitable for filling with dredged material, capping with sand, and restoring seagrass habitat to an elevation consistent with the depths where adjacent seagrass beds are present (CTC 1989). Based on the need to restore 6.3 acres of seagrass habitat, only one site may be required. Of the eight sites identified in 1989, those within Areas III and IV would be most practicable to restore due to the five-mile hauling or pumping distance for sites in extreme North Biscayne Bay (Areas II -A and II-B). All of the sites in III and IV appear feasible for restoration except III-A, due to its location immediately adjacent to a deeper channel where fill containment would be difficult and cost-prohibitive. To be cost-effective for hauling fill or pumping directly from the dredge site to the selective borrow areas, sites in Areas III or IV would be most acceptable subject to a cost feasibility analysis. Within Area III-B, 17.0 acres of potential restoration area was identified (CTC 1989). Further site evaluations of the area are underway and will be completed during the public review process. Field data collected included seagrass distribution, bathymetric profiles within and adjacent to the area, collection of sediment samples, and diver observations of the borrow areas.

Dredged material will either be hauled or pumped to the selected borrow area(s) based on engineering analysis, cost, and recipient site conditions. It is anticipated that ambient depths will range from -2 feet to -6 feet MSL in the restored areas following restoration and that seagrass recruitment will occur rapidly by *H. wrightii* and *H. decipiens,* both of which likely occur within the shallow flats adjacent to these sites (CTC 1989). Other species including *T. testudinum* and *S. filiforme* will also colonize the sites, but generally only after occupation by the early colonizing species previously cited. In the event that natural recruitment has not started within three years following excavation based on site monitoring, supplemental planting may be performed to speed recovery. Planting methods will be developed following guidance by Fonseca et al. (1998) and peer review by NMFS. Detailed plans and specifications for the seagrass creation will be prepared and provided for agency concurrence prior to construction.



LEGEND

- Approximate Extent of Study Area
- Proposed Seagrass Restoration Area

3000 0 3000 6000 Feet

Location of Potential Borrow Area for Seagrass Restoration	
Miami Harbor Mitigation Plan General Reevaluation Report Preliminary Draft Environmental Impact Statement	
Scale: 1" = 3,000'	Drawn By: MR
Date: July, 2002	
DIAL CORDY AND ASSOCIATES INC	J00-499
	Figure 2

Table 5 Potential Borrow Areas Suitable for Seagrass Restoration in Biscayne Bay, FL

Location	Surface Area (ac)	Water Depth (ft)	Ambient Depth (ft)	Borrow Area Substrate Type	Max. Current Velocity (ft/sec)	Suspended Solids (mg/l)	Estimated Fill Required (cy)	Adjacent Habitat Type	Distance from Port of Miami
II-A	10	7	2-5	Sand	0.2	10	46,000	Seagrass/Algae	5 mi
II-B	46	7-8	3-5	Sand	0.2	10	3000,000	Seagrass/Algae	5 mi
II-C	3	8	6	Silt /Mud	0.2	8	3,000	Seagrass/Algae	5 mi
III-A	18	13-17	3-6	Silt /Mud	0.3	5	290,000	Seagrass/Algae	2 mi
III-B*	17	16-24	5-6	Silt /Mud	0.3	6	360,000	Seagrass/Algae	2 mi
III-C	4	4-7	2-3	Silt /Mud	0.3	7	19,000	Seagrass/Algae	2 mi
IV-A	4	7-8	1-3	Silt /Mud	1.0	13	31,000	unk	1 mi
IV-B	31	7-8	4-6	Silt /Mud	1.0	6	150,000	unk	1 mi

Source: CTC 1989
* Preferred site

4.2 Artificial Reef Creation

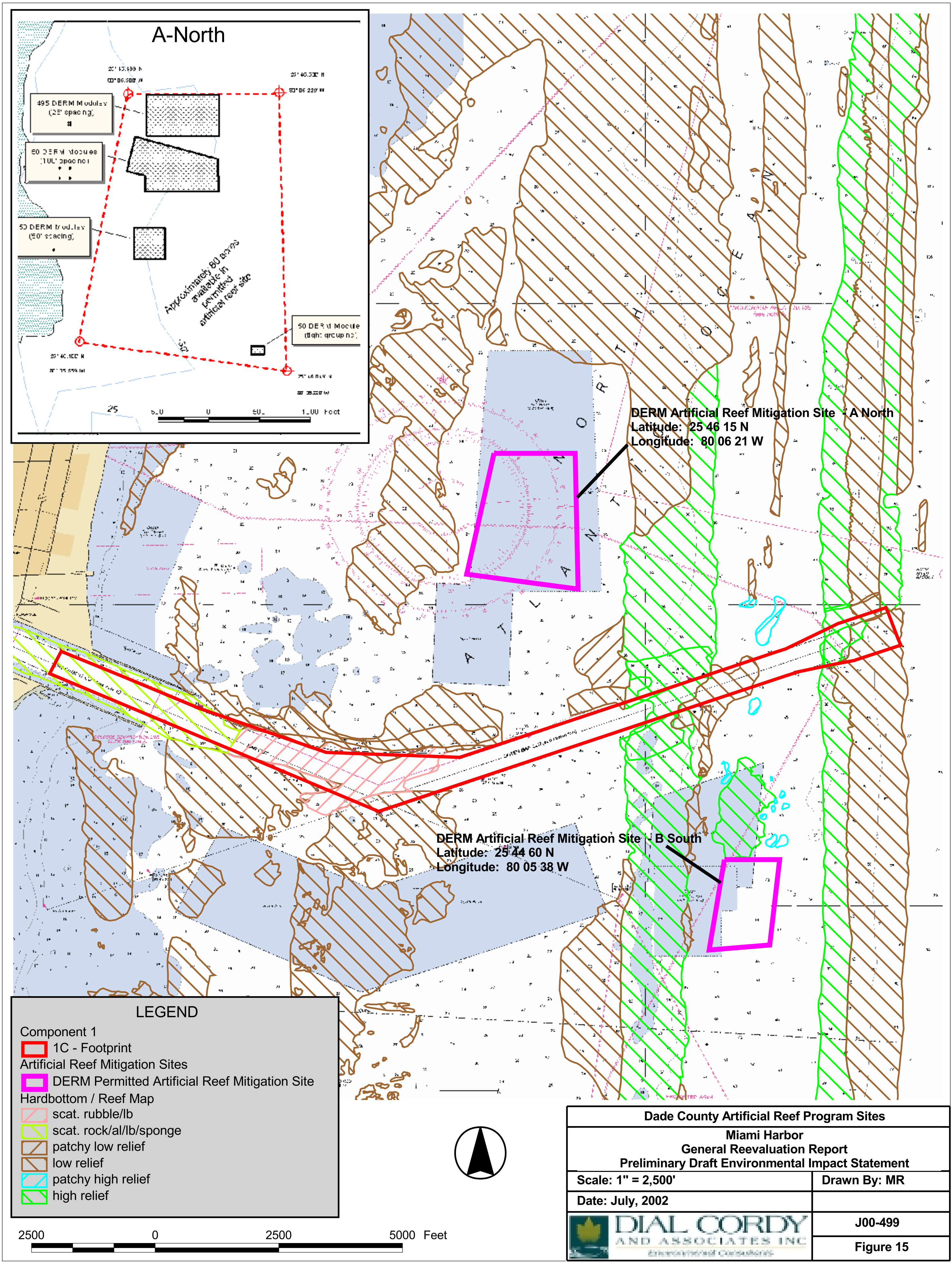
The proposed mitigation for reef and hardbottom impacts will be type-for-type, to reflect the ecological differences between the different reef types impacted. A total of 0.8 acre of low relief-low complexity (LRLC) reef will be created to mitigate for the new low relief reef and previously impacted hardbottom habitat. A total of 5.4 acres of high relief-high complexity (HRHC) reef will be created to mitigate for the high relief impact. The proposed location for mitigation reefs is found in Figure 3 and design drawings for LRLC and HRHC types are found in Figure 4. Specific design requirements and the reef design are described in this section.

4.2.1 General Design Requirements

Artificial reefs are often proposed for mitigating impacts to natural hardbottom habitats as a result of beach restoration (Lutz 1998). Mitigation reefs differ in several ways from traditional artificial reefs for fishing enhancement. Traditional artificial reefs are usually constructed offshore, are generally of high relief, are promoted as fishing destinations, and often utilize vessels or other non-natural substrate to offer divers an interesting alternative to natural reefs. In contrast, mitigation reefs should be designed to mimic the lost habitat as closely as possible in terms of relief and structural complexity. They should be placed in the same habitat depth zones as the impacted natural hardbottom/reef, and consumptive use of the reefs should be discouraged.

Artificial reefs have been used successfully for many years to mitigate impacts in sheltered waters (Duffy 1985) (Davis 1985) or in relatively deep water offshore (Mostkoff 1993). Reef deployments in shallow, open coastal areas present special challenges in the wave stability of materials and burial by sand movements in this very dynamic habitat. Palm Beach County has had considerable success with deploying shallow water artificial reefs as mitigation measures. The proposed design reflects the limitations on design and placement imposed by navigation regulations, liability issues, construction limitations, and stability concerns.

Mitigation reefs have often been required to be built in the immediate vicinity of the natural reefs impacted by construction activities. In areas where the habitat that was impacted was the only habitat in the area, this approach has merit. A guiding principle of artificial reef development has always been that reefs should not be deployed adjacent to productive reef habitats. From a fisheries standpoint, reefs placed in non-reef habitats are biologically more productive as they are trophically coupled with foraging habitats that are unexploited by other reef fishes (Bortone 1998). More importantly, the shifting of reef materials in storms may severely damage adjacent natural habitats. For this reason, the Florida Artificial Reef Development Plan prohibits material from being placed within 100 yards of "live bottom" areas (Myatt and Myatt 1992). Following Hurricanes Andrew, Opal, and Erin, it was found



A-North
495 DERM Modules
(25' spacing)
Approximately 60 acres available in permitted artificial reef site
50 DERM Module (tight group no)
500 0 500 1,000 Feet
DERM Artificial Reef Mitigation Site - A North
Latitude: 25 46 15 N
Longitude: 80 06 21 W
DERM Artificial Reef Mitigation Site - B South
Latitude: 25 44 60 N
Longitude: 80 05 38 W
ATLANTIC OCEAN
LEGEND
Component 1
1C - Footprint
Artificial Reef Mitigation Sites
DERM Permitted Artificial Reef Mitigation Site
Hardbottom / Reef Map
scat. rubble/lb
scat. rock/al/lb/sponge
patchy low relief
low relief
patchy high relief
high relief
2500 0 2500 5000 Feet
Dade County Artificial Reef Program Sites
Miami Harbor
General Reevaluation Report
Preliminary Draft Environmental Impact Statement
Scale: 1" = 2,500'
Drawn By: MR
Date: July, 2002
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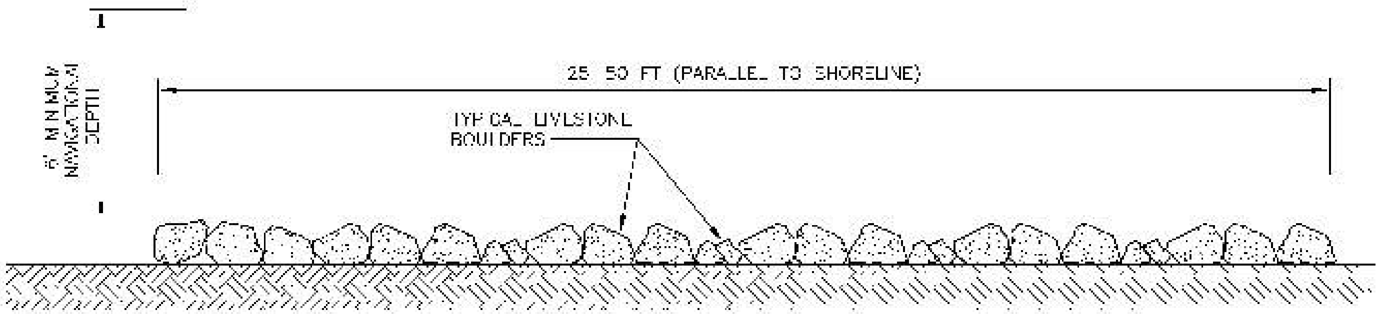
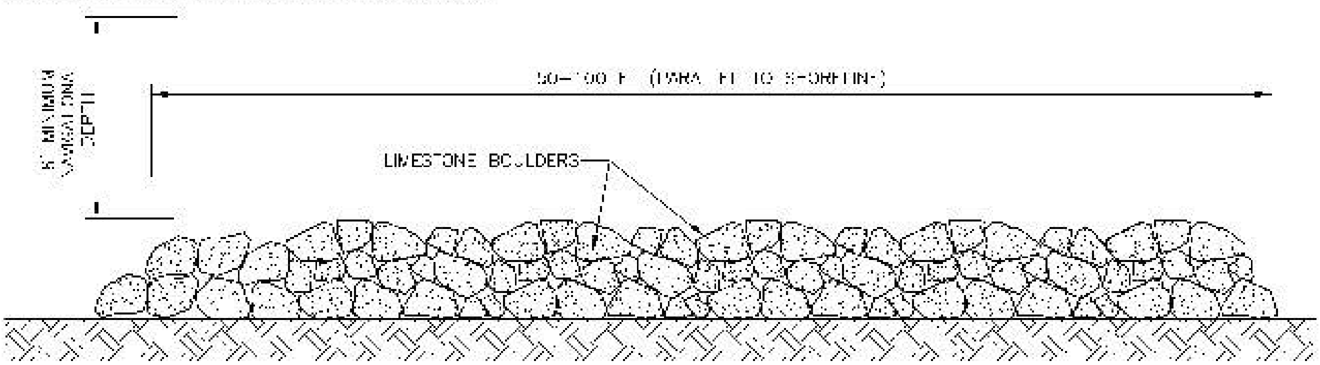
J00-499
Figure 15

Low-Relief, Low Complexity Artificial Reef Design



High-Relief, High Complexity Artificial Reef Design



Conceptual Design for Artificial Reefs Miami Harbor Preliminary Draft Fish & Wildlife Coordination Act Report	
Scale: NTS	Drawn By: MR
Date: May, 2002	
DIAL, CORDY AND ASSOCIATES INC Environmental Consultants	J00-499
	Figure 10

that even massive materials in relatively deep water were moved or broken up by tremendous wave forces (Lin 1998, Turpin 1998). For the above reasons, sites selected for mitigation reef construction should have no significant areas of natural reef within 100 yards and no reefs should be placed directly seaward of any significant area of natural reef.

The most desirable areas for deployment of reefs are areas that have a thin veneer of sand over bedrock, which limits the extent that deployed materials will settle. The specific areas that appear to meet the site selection criteria have been identified and include those managed by Miami-Dade County. These areas are without extensive reef present, and a fairly steep profile that allows for reefs to be deployed in suitably deep water while still being close to shore. A potential ecological benefit of deploying reefs in this area is that mitigation reefs, deployed in a shore parallel strip, would serve as a habitat corridor. Such habitat corridors are a cornerstone of terrestrial conservation biology, and have begun to attract some attention in the marine environment as well.

4.2.2 Reef Design

Two types of mitigation reefs will be constructed; HRHC reefs and LRLC reefs. The HRHC reefs are intended to mitigate for impacts to high relief habitat and the LRLC reefs are intended to mitigate for impacts to lower relief reef and for temporal impacts to hardbottom habitat previously impacted by channel dredging. The two reef types will be deployed in acreages proportional to direct impacts expected on each type of natural reef habitat in the final project design.

Limestone rock excavated from the Entrance Channel will be used in reef construction. The material will be deployed to mimic the orientation of typical natural reefs. This reef design will have a vertical relief of 3 to 5 feet and rocks will be deployed to provide the maximum structural complexity and to provide refugia for cryptic and reclusive species. As interstitial sand patches associated with reef habitat are thought to be important in the ecological function of the reef habitat, the reef footprint will contain approximately 20 percent open sand surface. Temporary buoys delineating the deployment strip will mark areas for deployment. Corner buoys for the sites shall be placed using Differential Global Positioning System (DGPS) with sub-meter accuracy. Natural limestone provides an ideal substrate for the establishment of a fouling community and colonization by the common reef community species. HRHC reefs are intended to provide persistent habitat with higher complexity and habitat diversity than LRLC hardbottom or reefs.

LRLC reefs will have a vertical relief of 1 to 2 feet and will be placed inshore of, and shallower than, HRHC reefs. It is recognized that the LRLC reefs may be periodically buried by shifting sands, like the low relief natural reefs they are intended to mimic. This does limit their habitat value to some extent, but it has been suggested (albeit without much empirical evidence) that this sort of ephemeral, low relief habitat may be particularly important in supporting the recruitment and post settlement survival of juvenile fishes. Dredged limestone rock will be placed in sites where they may be expected to partially settle in the substrate, should provide LRLC habitat. To provide interstitial sand habitat, approximately 20 percent of the LRLC reef footprint shall be open sand. Deployment sites will be delineated as outlined above for HRHC reefs.

Construction of mitigation reefs will take place during dredging of the Entrance Channel, such that suitable rock material excavated from the channel may be used for reef building.

4.2.3 Reef Monitoring

The monitoring program for the mitigation reefs will consist of both physical and biological components. Physical monitoring will assess the degree of settling of the reef materials after the first year, and biological monitoring will assess populations of algae, invertebrates, and fishes, as compared with concurrent control sampling of natural reefs for three years. Monitoring will be conducted annually in the summer months. In order to provide a permanent record of reef conditions and biota, each sampling effort will include video transects covering representative areas of the mitigation reefs.

Fish population evaluations will be based on visual censuses conducted separately on HRHC and LRLC mitigation reefs and high and low relief control reefs. The point-count method (Bohnsack and Bannerot 1986) will be used for fish assessment. This method has the advantage of gathering quantitative data in a relatively short time in a very repeatable pattern that is relatively insensitive to differences in habitat structure. Each census will have a duration of 5 minutes and a radius (the distance from the stationary observer) of 10 feet. Ten censuses will be collected on each of the four reef types. Data from these types of censuses are rarely distributed, so the Wilcoxon Rank-Sum or a similar nonparametric test will be used for significance testing. The criteria for mitigation reef success will be a finding of no significant difference at p=0.05 between reef type pairs (HRHC vs. high relief control and LRLC vs. low relief control).

Results of all mitigation reef monitoring efforts will be summarized in an annual report to be completed by December 31 of each year the monitoring program is in place. Copies of the report will be distributed to all agencies and interested parties.

5.0 EFFECTIVENESS OF PROPOSED MITIGATION

A review of the effectiveness of each proposed mitigation treatment is summarized below.

5.1 Seagrass Restoration

Restoring seagrass beds, if successful, can be an appropriate mitigation strategy due to its high ecological value and declining abundance. Seagrass restoration adds habitat value to unvegetated sand or mud substrates. The addition of seagrass beds increases the productivity and diversity of the unvegetated bottom, which can directly compensate for the historic loss in productivity and diversity.

Fonseca et al. (1996a, 1996b) found that within three years, restored seagrass beds (*H. wrightii*) planted on 0.5-m centers reach the same areal density and support animal densities, number of taxa, and species composition equivalent to natural beds. Some restored seagrass beds support invertebrate populations that are as or more abundant than those in natural grassbeds (Bell et al. 1993). Restored seagrass beds appear to be as suitable as natural seagrass beds for juvenile and small adult fish (Brown-Peterson et al. 1993).

Restored seagrass beds support animal densities similar to natural seagrass beds when shoot density is only one-third that of a natural seagrass bed (Fonseca et al. 1996). Thus, the habitat value of a restored seagrass bed is maximized relatively quickly, prior to the restored bed reaching the same vegetative density as a natural seagrass bed. In addition to providing habitat itself, seagrass beds increase the productivity of adjacent habitats. Irandi and Crawford (1997) found that the presence of seagrass beds adjacent to tidal marshes increased the abundance and growth rates of fish in the tidal marsh.

Research has identified that seagrass beds are more diverse and productive than unvegetated substrate. Average fish densities in natural seagrass beds were ten times greater than those on unvegetated areas (~20 individuals/m^2 versus 1.74 individuals/m^2). Shrimp densities in natural shoal grass beds averaged 151 individuals/m^2 compared to 3.02 individuals/m^2 in unvegetated areas. Crab densities in natural seagrass beds were 20 to 50 individuals/m^2 compared to an average of 1.91 individuals/m^2 on unvegetated areas (Fonseca et al. 1996). Within 1.5 years of planting, restored seagrass beds support shrimp, fish, and crab densities similar to natural seagrass beds (Fonseca et al. 1996). Thus, restored seagrass beds can increase the density of shrimp, fish, and crabs by 10 to 50 times compared to unvegetated substrates.

Although research has identified that seagrass beds are more diverse and productive than unvegetated substrates, relatively few studies compare secondary productivity between seagrass beds and other habitats. Heck et al. (1995) determined that eelgrass beds in the northeastern United States had macroinvertebrate production 5 to 15 times higher than adjacent unvegetated habitats. At least a similar increase in productivity is expected for *H. wrightii* and *T. testudium*, which have a higher primary productivity than eelgrass. Also, a similar increase in abundance, diversity, and productivity of fish species may also be expected.

Restoration of seagrass communities, while still considered experimental and not highly successful by resource agencies, can enhance habitat heterogeneity and the diversity of invertebrate and fish communities, if carefully implemented. The recent treatise on seagrass restoration entitled "Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters" by Fonseca et al. (1998) discusses the benefits and risks associated with seagrass restoration. Given the documented success of more recent efforts to restore seagrass communities, including those in South Florida, restoration is quickly becoming a proven resource management tool in some areas where conditions are appropriate.

Restoration of a three-acre borrow area in North Biscayne Bay was completed in the late 1990's by Miami-Dade Environmental Resources Management (DERM) and recently inspected by NMFS, FWS, and DERM staff during an agency site visit with the USACE's contractor in March of 2002. Although no monitoring has been done by DERM since planting of the site, a visual inspection by the agency team revealed that seagrass occurs throughout the site and was dominated by *H. wrightii* and *T. testudinum*. Discussions with DERM staff indicate the old borrow area was filled with rubble and sand and planting units of both *H. wrightii* and *T. testudinum* installed. Based on this evidence of general success, all in attendance agreed that seagrass restoration was a viable option for mitigating seagrass loss.

Another example of successful seagrass restoration is the Miami-Dade sewage cross-bay force main installed by the Miami-Dade Water and Sewer Authority Department in the mid-1990s. The project required trenching of over one mile of Miami Harbor baybottom for pipeline installation, including excavation of 1.80 acres of seagrass beds. Once the pipeline was installed the 22-foot wide trench path was refilled and allowed to recruit with seagrasses. Recruitment had begun within one-year and after two years seagrasses and macroalgaes covered the trench pathway so that it was no longer visible on aerial photography.

Recent success has also been achieved with restoration of propeller scars through various methods in the Florida Keys. Filling of scars, planting with seagrass and "spiking" scars with concentrated nutrient loads have all been use to encourage expansion and recruitment of seagrasses there (Kenworthy et al. 2000).

5.2 Artificial Reef Construction

Currently there are many options for the construction of artificial reefs. Methods used previously have included limestone boulders, concrete tetrahedrons, and Reef Balls™, among others. Miami-Dade County currently prefers the use of limestone boulders as the material for artificial reef construction. Currently there are two locations, one north and one south of the channel, that can be utilized for artificial reef creation. These areas occur in water depths of 30 to 60 feet below MSL. Placement of limestone material in any or all of these areas would provide suitable habitat replacement for the loss of reef associated with channel widening and deepening.

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APPENDIX A
Habitat Equivalency Analyses

Table A-1: HEA effective acreage gained from recovery of low-relief hardbottoms

Assumptions: dredging leaves 10% service, w/ linear increase

Year	% Service Level	% Service Loss	Effective Ac lost	Discount Factor	Discount Off ac lost
2003	10.00%	90.00%	0.60	0.97	0.58
2004	17.50%	82.50%	0.50	0.94	0.47
2005	25.00%	75.00%	0.45	0.91	0.41
2006	32.50%	67.50%	0.41	0.88	0.36
2007	40.00%	60.00%	0.36	0.85	0.30
2008	47.50%	52.50%	0.32	0.82	0.26
2009	55.00%	45.00%	0.27	0.79	0.21
2010	62.50%	37.50%	0.23	0.76	0.17
2011	70.00%	30.00%	0.18	0.73	0.13
2012	77.50%	22.50%	0.14	0.70	0.09
2013	85.00%	15.00%	0.09	0.67	0.06
2014	92.50%	7.50%	0.05	0.64	0.03
2015	100.00%	0.00%	0.00	0.61	0.00
			Total effective-acre years/ac:		3.07

Table A-2: HEA effective acreage gained from recovery of low-relief hardbottoms

Assumptions: 20% service immediate, w/ linear increase

Year	% Service Level	% Service Increase	Discount Factor	Discount Eff ac gain
2003	20.00%	0.00%	1.00	0.00
2004	26.67%	6.67%	0.97	0.06
2005	33.33%	13.33%	0.94	0.13
2006	40.00%	20.00%	0.91	0.18
2007	46.67%	26.67%	0.88	0.23
2008	53.33%	33.33%	0.85	0.28
2009	60.00%	40.00%	0.82	0.33
2010	66.67%	46.67%	0.79	0.37
2011	73.33%	53.33%	0.76	0.41
2012	80.00%	60.00%	0.73	0.44
2013	86.67%	66.67%	0.70	0.47
2014	93.33%	73.33%	0.67	0.49
2015	100.00%	80.00%	0.64	0.51
			Total effective-acre years/ac:	3.90

Table A-3: HEA acreage calculation for low-relief hardbottom compensation

Impact area		0.6
Present discounted interim losses		3.07
Present discounted lifetime gains per acre of replacement project		3.9
R= # acres required for compensation		
3.07=3.9*R		
R=	3.07/3.9	
R=	0.787179	
	Effective mitigation to compensation ratio:	1.316667

Table A-4: HEA effective acreage lost from impacts to high-relief reefs

Assumptions: dredging leaves 10% service, w/ linear increase

Year	% Service Level	% Service Loss	Effective Ac lost	Discount Factor	Discount Eff ac lost
2003	10.00%	90.00%	2.70	0.97	2.62
2004	13.00%	87.00%	2.35	0.94	2.21
2005	16.00%	84.00%	2.27	0.91	2.06
2006	19.00%	81.00%	2.19	0.88	1.92
2007	22.00%	78.00%	2.11	0.85	1.78
2008	25.00%	75.00%	2.03	0.82	1.65
2009	28.00%	72.00%	1.94	0.79	1.53
2010	31.00%	69.00%	1.86	0.76	1.41
2011	34.00%	66.00%	1.78	0.73	1.29
2012	37.00%	63.00%	1.70	0.70	1.19
2013	40.00%	60.00%	1.62	0.67	1.08
2014	43.00%	57.00%	1.54	0.64	0.98
2015	46.00%	54.00%	1.46	0.61	0.88
2016	49.00%	51.00%	1.38	0.58	0.79
2017	52.00%	48.00%	1.30	0.55	0.71
2018	55.00%	45.00%	1.22	0.52	0.63
2019	58.00%	42.00%	1.13	0.49	0.55
2020	61.00%	39.00%	1.05	0.46	0.48
2021	64.00%	36.00%	0.97	0.43	0.41
2022	67.00%	33.00%	0.89	0.40	0.35
2023	70.00%	30.00%	0.81	0.37	0.30
2024	73.00%	27.00%	0.73	0.34	0.25
2025	76.00%	24.00%	0.65	0.31	0.20
2026	79.00%	21.00%	0.57	0.28	0.16
2027	82.00%	18.00%	0.49	0.25	0.12
2028	85.00%	15.00%	0.40	0.22	0.09
2029	88.00%	12.00%	0.32	0.19	0.06
2030	91.00%	9.00%	0.24	0.16	0.04
2031	94.00%	6.00%	0.16	0.13	0.02
2032	97.00%	3.00%	0.08	0.10	0.01
2033	100.00%	0.00%	0.00	0.07	0.00

Total effective-acre years/ac: 25.76

Table A-5: HEA effective acreage gained from recovery of high-relief reefs

Assumptions: 20% service immediate, w/ linear increase

Year	% Service Level	% Service Increase	Discount Factor	Discount Eff ac gain
2003	20.00%	0.00%	1.00	0.00
2004	22.67%	2.67%	0.97	0.03
2005	25.33%	5.33%	0.94	0.05
2006	28.00%	8.00%	0.91	0.07
2007	30.67%	10.67%	0.88	0.09
2008	33.33%	13.33%	0.85	0.11
2009	36.00%	16.00%	0.82	0.13
2010	38.67%	18.67%	0.79	0.15
2011	41.33%	21.33%	0.76	0.16
2012	44.00%	24.00%	0.73	0.18
2013	46.67%	26.67%	0.70	0.19
2014	49.33%	29.33%	0.67	0.20
2015	52.00%	32.00%	0.64	0.20
2016	54.67%	34.67%	0.61	0.21
2017	57.33%	37.33%	0.58	0.22
2018	60.00%	40.00%	0.55	0.22
2019	62.67%	42.67%	0.52	0.22
2020	65.33%	45.33%	0.49	0.22
2021	68.00%	48.00%	0.46	0.22
2022	70.67%	50.67%	0.43	0.22
2023	73.33%	53.33%	0.40	0.21
2024	76.00%	56.00%	0.37	0.21
2025	78.67%	58.67%	0.34	0.20
2026	81.33%	61.33%	0.31	0.19
2027	84.00%	64.00%	0.28	0.18
2028	86.67%	66.67%	0.25	0.17
2029	89.33%	69.33%	0.22	0.15
2030	92.00%	72.00%	0.19	0.14
2031	94.67%	74.67%	0.16	0.12
2032	97.33%	77.33%	0.13	0.10
2033	100.00%	80.00%	0.10	0.08
			Total effective-acre years/ac:	4.84

Table A-6: HEA acreage calculation for high-relief compensation

Injured area	2.7
Present discounted interim losses	25.76
Present discounted lifetime gains per acre of replacement project	4.84
R= # acres required for compensation	
25.76=4.84*R	
R= 25.76/4.84	
R= 5.322314	
Effective mitigation to compensation ratio:	1.971227

APPENDIX B

Mitigation Options Fact Sheets