APPENDIX D – CUMULATIVE EFFECTS ASSESSMENT

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The following describes the methods, rationale, and results of the Cumulative Effects Assessment for the proposed action in terms of the eleven steps identified by the Council on Environmental Quality (CEQ) (1997).

1. Significant Cumulative Effects Issues and the Assessment Goals.

   The goal of the NEPA process is to reduce adverse environmental effects, including cumulative effects. Cumulative effects analysis is an iterative process in which consequences are assessed repeatedly following incorporation of avoidance, minimization, and mitigation measures into the alternatives. Monitoring is the last step in determining the cumulative effects that ultimately results from the action. The significance of cumulative effects depends upon the ecosystem, resource baseline conditions, and relevant resource stress thresholds (CEQ, 1997).

   Cumulative impacts result from spatial and temporal crowding of environmental perturbations. Some authorities contend that most environmental effects can be seen as cumulative because almost all systems have already been modified, even degraded, by humans (CEQ, 1997). Priority habitats within the Broward County Shore Protection project area subjected to potential cumulative effects include offshore hardbottom reefs within the pipeline corridors, hardbottom reefs adjacent to the offshore sand borrow areas, and nearshore hardbottom habitat within and adjacent to the beach fill areas. These habitats are generally considered by the U.S. Fish and Wildlife Service as Resource Category 2, and no net loss of in-kind habitat value is recommended. The dense staghorn coral (*Acropora cervicornis*) cover on the seaward edge of the first reef in Fort Lauderdale, approximately 1,500 feet from shore, is considered Resource Category 1. No loss of habitat value is recommended for Resource Category 1 habitats as these unique areas cannot be replaced. Executive Order 13089 of June 11, 1998, Coral Reef Protection, requires "all Federal agencies to identify their actions that may affect U.S. coral reef ecosystems; utilize their programs and authorities to protect and enhance the conditions of such ecosystems; and to the extent permitted by law, ensure that any actions they authorize, fund, or carry out will not degrade the conditions of such ecosystems."

   The proposed action, in addition to past projects and any future actions, primarily impacts the beach, nearshore hardbottom epibenthic and fish communities, and the offshore sand borrow areas and adjacent reef epibenthic communities. The beach will continue to be maintained as an area suitable for shoreline protection, recreation, and wildlife habitat. The current offshore borrow areas will likely be depleted over the life of the authorized project, and alternative sand sources will have to be explored. Utilization of upland sources for future renourishment use may involve natural resource impacts to habitats adjacent to the sand mines, such as xeric sand pine and scrub oak habitats adjacent to the Lake Wales Ridge. Repeated placement of pipeline with periodic renourishment would have a direct negative impact on nearshore hardbottom communities. The establishment of permanent pipeline corridors for future renourishment use will minimize impacts and avoid foreseeable future impacts. Future nourishment actions will be evaluated separately with respect to the present impact analyses and monitoring of the initial nourishment project.

Local, short-term impacts of turbidity and sedimentation will occur adjacent to the beach fill sites and offshore borrow areas during project construction. Potential long-term effects of sedimentation and turbidity are unknown. Therefore, avoidance and minimization measures have been incorporated into the project to reduce this uncertainty. The added effect of localized, short-term turbidity and sedimentation upon stony corals adjacent to the borrow sites may cumulatively impact a low number of stony coral colonies which already exhibit signs of disease or bioerosion, possibly resulting in low levels of mortality.

Approximately 13.6 acres of nearshore hardbottom habitat will be impacted from project construction. Natural physical stresses in conjunction with anthropogenic influences limit the biodiversity and survivability of epibenthos in this environment, and the habitat is dominated by macroalgae and blue-green algae. Nearshore epibenthic communities do not appear to represent irreplaceable resources. Nearshore hardbottom in Broward County serves as valuable habitat for juvenile fish, particularly juvenile grunts (family Haemulidae) which make up more than 80% of the total fish assemblage. There will be significant short-term effects of nearshore habitat burial on associated fish assemblages. Significant reductions in feeding success are not expected. It also appears that the proposed project will have minimal qualitative impacts on nearshore fish assemblages; and from the perspectives of either richness, abundance, or predominant species commonality, nearshore hardbottom loss can be mitigated with artificial refuge.

Broward County beaches serve as nesting habitat for threatened and endangered sea turtle species. Overall, approximately 4% of the sea turtle nests laid annually in Florida are on Broward County beaches. The proposed project has the potential to adversely affect nesting females, nests, and hatchlings within the proposed project area. Most of the Broward County shoreline has been renourished several times since 1970. Appropriate remediative and protective measures and the use of compatible sand sources have maintained the beaches as suitable nesting habitat for sea turtles without jeopardizing the existence of these species.

2. Geographic Scope

Broward County is located on the southeast coast of Florida and includes approximately 24 miles of coastline. The coastal cities from north to south are Deerfield Beach, Hillsboro Beach, Pompano Beach, Lauderdale-By-The-Sea, Fort Lauderdale, Dania Beach, Hollywood, and Hallandale. The coastline includes two coastal inlets. Hillsboro Inlet is located approximately 4 miles south of the north county line, and is an improved inlet designed for recreational and commercial navigation. Port Everglades channel is located approximately 10 miles south of Hillsboro Inlet, providing entrance to Port Everglades, the second largest commercial port in the state of Florida.

The authorized project includes two segments. In Segment II (Hillsboro Inlet to Port Everglades), fill will be placed along 4.9 miles of beach in southern Pompano Beach, Lauderdale-By-The-Sea, and northern Fort Lauderdale (between FDEP monuments R-36 and R-43 in Pompano Beach; and between R-51 and R-72 in Lauderdale-By-The-Sea and northern Fort Lauderdale). In Segment III (Port Everglades to the south County line), fill will be placed along 6.9 miles of beach in John U. Lloyd State Park, Hollywood, and Hallandale (between FDEP monuments R-86 and R-92 in John U. Lloyd Beach State Recreation Area and R-99 and R-128 in Hollywood/Hallandale). The project will impact approximately 13.6 acres of nearshore hardbottom: 6.0 acres in Segment II, and 7.6 acres in Segment III.

The five borrow areas are located from ¾ to 1 ½ miles offshore of the central and northern portions of Broward County, and within the second and third intrareefal sand flats. Borrow Area I is the northernmost borrow area situated directly off the Deerfield Pier. Borrow Area II is located immediately north of Hillsboro Inlet between the first and second reef tracts, and Borrow Area III is located seaward of BA II between the second and third reef tracts. Borrow Area IV is located south of Hillsboro Inlet and north of the Pompano Pier, in the second intrareefal flat. Borrow Area VI is the southernmost borrow area situated between the Pompano Beach and Commercial Piers and between the first and second reef tracts. Rocks contained in the borrow material will be segregated on the hopper dredge and deposited in two offshore rock disposal areas. The northern rock disposal area is located approximately 2 miles offshore of Hillsboro Beach in approximately 380 feet of water. The southern rock disposal area is located approximately 2 miles offshore of Hollywood in approximately 200 to 350 feet of water.

3. Time Frame

The anticipated project construction start date is November 2003. Fill placement will begin in Segment III in Hallandale and continue north to Port Everglades. Construction in Segment II will begin after completion of eighteen months of post-construction environmental monitoring of the Segment III project area, and determination by the FDEP that project effects are within acceptable limits. If required, construction of Segment II will be conducted outside the main nesting season for sea turtles. The renourishment interval for both segments is six years. Project authorization expires in 2020 in Segment II, and 2026 in Segment III. Therefore, two future periodic renourishments are authorized in Segment II, and three are authorized in Segment III.

The proposed time frame for mitigation construction is separated into two phases. During Phase I, the Segment III mitigative boulder reefs will be placed prior to beach fill project commencement in November 2003. During Phase II, pending FDEP Notice of Intent to Issue Segment II beach fill construction permits and approvals, Broward County will construct the required mitigative artificial reefs mandated by State and Federal resource protection agencies prior to beach fill commencement.

4. Other Actions Affecting the Resources, Ecosystems, and Human Communities

The goal of characterizing stresses is to determine whether the resources, ecosystems, and human communities of concern are approaching conditions where additional stresses will have an important cumulative effect (CEQ, 1997).

Installation of subaqueous fiberoptic cables offshore of southeast Florida has caused irreversible damage to reef structure and stony coral colonies directly impacted by installation activities. Two fiberoptic cables were installed offshore of Hollywood in early 1999, resulting in direct impacts to 264 stony coral colonies on the second and third reef tracts. An unanticipated outcome of installation was the displacement of coral heads and surficial impact to the reef where the cable was presumably pulled laterally along the hardbottom during installation. Habitat Equivalency Analysis was used to determine the level of compensation for damage to stony corals, and artificial reef modules were used to create replacement habitat for mitigation (Deis, unpublished). Best Management Practices (BMPs) have successfully minimized adverse impacts to reef communities during subsequent fiberoptic cable installations in Boca Raton, Florida, and appropriate assessment and mitigative measurements have been applied during these projects.

Concurrent construction of beach renourishment projects along the coast of southeast Florida could generate several localized, short-term turbidity plumes. These projects include Delray Beach (Winter 2002) and South Boca Raton

(Winter 2002) and the proposed Town of Palm Beach Mid-Town renourishment (Winter 2003). The cumulative impacts of localized, turbidity plumes generated from these projects should minimally impact the sustainability of adjacent reef epibenthic communities, provided appropriate protective and mitigative measures and monitoring are applied during these unrelated projects. Future authorized renourishments (twice more in Segment II and three more times in Segment III) would generate local, short-term impacts of turbidity and sedimentation.

Continued urbanization and population growth in South Florida places burden upon wastewater and stormwater management. In 1990, the total population of Miami-Dade, Broward, and Palm Beach counties combined was approximately 4.06 million (1.26 million in Broward County). By 2010, the population in Broward County is projected to increase by 46% to approximately 1.77 million, and the overall tri-county population is expected to reach 5.93 million (South Florida Water Management District, 1995). Recreational usage is intense with evidence of fishing gear impact and anchor damages observed on south Florida reefs. In 1997, the total number of registered vessels Miami-Dade, Broward, and Palm Beach Counties was 124,189. In 2000, this number had increased to 137,880, of which 41,900 was in Broward County (FWCC, 2001), increasing the potential for cumulative impacts to these habitats. Broward County has established mooring buoys in areas on heavy recreational usage to alleviate the potential for anchor damage. Shipping from large ports (Port Everglades, Miami, and Palm Beach) also increases the potential for ships to run aground or anchor on reefs (Causey et al., 2000). For example, the nuclear submarine, the *USS Memphis*, grounded on the second reef off Dania Beach in 1993, resulting in physical damage to reef substrate and destruction of the epibenthic community. The submarine was immobile for approximately 90 minutes. When the *Memphis* finally freed herself, an estimated 2,310 square meters of reef was left damaged. The grounding of the submarine resulted in the loss of 2,324 stony corals, 10,277 octocorals, and 13,034 sponges (Broward County DNRP, 1994). To replace substrate lost or damaged by the grounding, artificial reef structures have been deployed in the sand flats adjacent to the second reef where the *Memphis* grounding occurred.

5. Response of Resources to Change and Stress

Disease, temperature extremes, hurricanes, and other natural events periodically destroy corals and may result in ecosystem wide repercussions. Healthy reefs are resilient and will recover with time (Bryant et al., 1998). The impact of multiple stressors, both natural and anthropogenic, can have a multiplication effect on reef ecosystems. There is evidence to suggest that reefs damaged from human activity may be more vulnerable and require more time to recover from natural disturbances (Bryant et al., 1998).

Turbidity impacts are chronic perturbations that cause long-term reductions in primary and secondary productivity of reef epibenthic communities by reducing the amount of light available for photosynthesis and increasing respiration rates of stony corals. Healthy corals are relatively resilient and able to withstand acute pulses of turbidity, sedimentation, and recover from bleaching events. The added effect of localized, short-term turbidity and sedimentation upon stony corals adjacent to the borrow sites may cumulatively impact a low number of stony coral colonies which already exhibit signs of disease or bioerosion, possibly resulting in low levels of mortality. Heavy sedimentation is associated with reduced coral species richness and live coral cover, lower coral growth rates, greater abundance of branching forms, reduced coral recruitment, decreased calcification, decreased net productivity of corals, and slower rates of reef accretion (Rogers, 1990). This study also acknowledged the species-specific ability of corals to clear themselves of sediment or survive in lower light, and that larger (i.e. adult) corals are more tolerant to sedimentation than newly settled coral colonies. In Broward County, the stony corals are dominated by species known as competent sediment removers such as *Montastrea cavernosa* (Dodge et al. 1991, 1995).

Past monitoring reports of Broward County nourishment projects (1991 John U. Lloyd and 1995 Hollywood/Hallandale) did not document turbidity and sedimentation rates on adjacent reef system that produced any statistically significant long-term resource affects directly attributable to the nourishment actions (Dodge et al. 1991, 1995). However, the reports documented a general degradation in the quality of the benthic resources on the offshore reefs throughout the County. Corals that exhibited declines during the post-construction surveys showed signs of decline prior to project construction, and corals that appeared healthy during the pre-construction period remained healthy during the study (Dodge et al. 1991). No specific anthropogenic or natural phenomena were identified that would suggest a particular action or event was the primary contributing factor. However, references were made to nutrient enrichment, sedimentation and turbidity, temperature fluctuations, freshwater inflows, and other regional and global climatic changes as possible contributing factors.

In a study done in 1984, Goldberg found that 14 months after a beach nourishment project in northern Broward County, a decline to the coral population was noted although the locations of the affected stations did not correspond to any of the dredging locations. Therefore, stresses other than dredging may have occurred causing tissue reduction and scleractinian losses (Goldberg, 1984).

The reef damage survey of John U. Lloyd State Recreation Area waters following the 1976-1977 beach renourishment project showed that weather was the most important factor in coral survival under heavy sedimentation stress. High sedimentation rates may result in coral mortality when the seas are relatively calm. Waves can assist corals in removing excess sediment even at depths in 20 meters of water (D.E. Britt Associates, Inc., 1979). The average turbidity values in this study were 50% less than sediment levels. The reason for this difference may have been the result of sediment grains in the water samples. Sand grains add weight to the sample, but reflect a small amount of light when compared to silt sample of equal weight.

A study done by Courtenay et al. (1972) comparing ecological aspects of two beach nourishment projects in Broward County found that sedimentation damage can reduce species diversity, degrading the health of a reef habitat. Results showed that many aquatic organisms could quickly repopulate an area after a dredge event. This was not the case for large reef building corals. These larger corals are slow-growing and small stresses can inhibit growth and reestablishment.

In 1979 and 1980, Goldberg characterized reef areas one and two years after a beach restoration project (1978) to assess any impacts to the community and its associated marine life. Of the ten stations monitored in the 1980 survey, three showed a decrease in diversity since the 1979 survey. Two of the three stations (1 and 10) were in close proximity to the shore and were described as having extremely poor visibility from increased turbidity resulting from suspended sediment. The scleractinians and sponges were adversely affected at these stations post-construction. The stations located offshore were not as negatively impacted as the previous two and recovery was predicted to occur rapidly. Changes in coral composition at one of the stations (8) were attributed to taxonomic differences rather than evironmental stress. In 1981 the same reef areas were characterized for a second re-survey to note additional changes which may have occurred between February 1980 and June 1981 from the 1978 restoration. The 1981 characterization indicates that coral communities close to shore will suffer immediate damage due to the presence of suspended sediments. The damage did not persist. Sixteen months after the restoration project, recolonization and regrowth were evident. Damage was also noted at the offshore stations that were near borrow areas. The damage to the station (7) that was in close proximity to the borrow area (<50 m) did not recover at the time of this survey. The offshore stations at least 136 m from the borrow site showed much less damage to the reef habitat.

A 1987 study by Richard E. Dodge showed potential effects from past beach renourishment projects on stony coral growth rates. The growth of hermatypic corals has been used as an indicator of environmental conditions in previous studies. Stressful conditions, such as excessive sedimentation and turbidity, are environmental factors associated with beach renourishment projects that have negative impacts on coral growth. Over a 16-year period, growth rates of stony corals, located in areas that had a close proximity to increase sedimentation and turbidity from renourishment projects, were examined. Results showed that stony corals living both near and offshore (9 m and 18 m water depth) had negligible impacts from renourishment projects.

In 1998 sand was placed along Hillsboro and Deerfield Beach, which were two chronically eroding locations in Broward County. One year following project construction, no significant sedimentation or burial had occurred on the nearshore hardbottom bordering the renourished beaches. A decrease in the density of sponges did occur but it may have been the result of large scale natural occurrences such as the 1998 El Nino Southern Oscillation (ENSO).

6. Stresses Affecting the Resources and Thresholds

The physical stresses of the nearshore habitat limit the biodiversity and survivability of epibenthic species. The natural stresses of this environment include wave energy, turbidity, and temperature extremes. Coral recruitment is limited by competition with algae for space and high suspended sediment levels. Evidence to suggest eutrophication along the coastal waters of Broward County has been documented during the past several decades. Recurrent blooms of the green macroalgae, *Codium isthmocladum*, occurred on Broward County and Palm Beach County reefs in depths from 20 to 60 meters in 1989/90 and 1996/97 (Lapointe and Hanisak, 1997). The excessive biomass of these blooms causes hypoxia/anoxia on the reef surface, leading to relocation of motile fish and suffocation of epibenthic organisms. Rapid population growth rates and corresponding urbanization of south Florida has increased the potential for coastal water quality degradation.

In addition to the natural physical habitat stresses, anthropogenic influences of eutrophication and pollution affect the quality of nearshore hardbottom habitat. These human-induced pressures are particularly evident in areas south of Port Everglades, in areas in close proximity to the fishing piers, and adjacent to beaches of intense recreational usage. The cumulative impacts of these pressures have resulted in a possible degradation of nearshore hardbottom habitat quality and overall dominance by macroalgae and blue-green algae. The blue-green algae, *Lyngbya* sp. covered up to 90% of the benthic community immediately south of Port Everglades in the summer of 2001, and the highest coverages corresponded to the areas of lowest biodiversity. The proliferance of *Lyngbya* sp. may be suggestive of eutrophication (Richardson, 1996), and its growth pattern densities generally parallel the flow of nutrient rich water from Port Everglades. Evidence of fishing gear impacts (balls of line, fishing reels and rods, and hooks) was observed in the nearshore characterization stations adjacent to the Pompano Beach and Commercial Piers, as well as during the towed-diver video transects during the summer of 2001. Trash (beer cans, sneakers, clothing, beach chairs) was commonly observed along the hardbottom edge adjacent to beaches of intense recreational usage, particularly Fort Lauderdale and Pompano Beach.

Coral diseases are becoming an increasing threat to the overall health of the south Florida reef system with over 10 coral diseases observed in the Florida Keys (Causey et al., 2000). An increase in frequency and duration of coral bleaching events has also occurred during the past 20 years (Causey et al., 2000). Corals which are subjected to increased levels of stress from chronic sedimentation, eutrophication, and higher temperatures and salinities are more susceptible to disease. Due to their lowered stress thresholds, diseased corals are less able to resist the usually sublethal effects of sedimentation and eutrophication, and exhibit increased susceptibility to damage from bioeroders and storm activity.

It has been suggested that mean sediment rates for reefs not subject to anthropogenic stresses are <1 to approximately 10 $mg/cm^2/day$ (Rogers, 1990). This study, conducted in the U.S. Virgin Islands, suggested that chronic rates above these values are 'high." However, it is important to note that this standard might not universally apply to reef communities due to geographical differences in natural sedimentation rates. Sedimentation analysis of the twenty-three reef monitoring sites in Broward County from October 1997 to December 2000 indicates that the first reef typically has the highest sedimentation, followed by the second reef, and then the third reef sites (Gilliam et al. 2001). Overall average sedimentation rates were: 252.2 $mg/cm^2/day$, 23.3 $mg/cm^2/day$, and 4.6 $mg/cm^2/day$ for the first, second, and third reef sites respectively. Average grain size was significantly highest on the first reef sites. Both sedimentation rate and average grain size from the sampling interval were apparently consistent with data collected from previous years during the same sampling interval (late fall/winter) (Gilliam et al., 2001). Comparison of these values to the 10 $mg/cm^2/day$ standard proposed by Rogers (1990) suggests that the natural sedimentation rates observed in Broward County are naturally, chronically high, which may contribute to the low stony coral abundance and epifaunal species richness observed on Broward County reefs as compared to reef communities located further south (Dodge et al., 1991).

7. Baseline Condition

The 2001 Laser Airborne Depth Soundings (LADS) survey represents the first comprehensive remote sensing survey of the reef tracts offshore of Broward County. Several studies have shown that the nearshore hardbottom areas along Florida's southeast coast are ephemeral in nature, being alternately covered and uncovered by shifting beach sand (Ginsburg 1953, Gore et al. 1978, Goldberg 1982, Arthur V. Strock and Associates, Inc. 1983, and Continental Shelf Associates, Inc., 1984, 1985, 1987). Nearshore hardbottom burial events have been documented by Broward County both seasonally and over an extended period of time. More recently, the ephemeral nature of the nearshore hardbottom edge was documented during mapping performed in July/August of 2001 by CPE/Olsen (J-V). Since no comprehensive nearshore reef baseline survey exists for comparative purposes, the 2001 nearshore data set represents the baseline condition. The GIS database will be used as the primary tool to analyze cumulative impacts based upon the 2001 baseline conditions, allowing for analysis of the effects of future projects by overlaying data layers from post-construction monitoring events.

The overall community structure of the nearshore impact areas indicates that the physical stresses of the habitat limit the biodiversity and survivability of epibenthic species. The 2001 nearshore biological investigations suggest that suitable replacement habitat can be created for impacted epibenthic species. Average epibenthic species density at the impacted, inshore equilibrium toe of fill sites was 2.7 organisms/square meter, and average algal coverage was 24.1%. Classification of the impact areas inshore of the equilibrium toe of fill revealed that 88% of the cumulative community composition consisted of macroalgae and blue-green algae. Very few stony corals of significant size were observed within the nearshore impact areas. Just over one-third of the 55 nearshore sites exhibited stony coral coverage greater than 1%; and only two of the sites were located inshore of the proposed equilibrium toe of fill.

In 2000, an encouraging report was released that indicated that some Florida southeast reef fish populations are in relatively good condition (*2000 Status of Coral Reefs of the U.S. Caribbean and Gulf of* Mexico, Causey et al., 2000). Broward County has established 23 permanent monitoring sites along the first, second, and third reef tracts along the 24 miles of coastline. These stations will be monitored through the four year post-construction period to assess any potential long-term effects from the proposed Broward County Shore Protection Project. In response to numerous concerns by resource protection agencies and non-governmental organizations for secondary impacts of turbidity and sedimentation to areas of high stony coral coverage located on the first reef tract offshore of Fort Lauderdale (approximately FDEP monuments R-65 to R-67), Broward County has added two additional reef community and sedimentation monitoring sites (FTL5 and FTL6). These two sites were added in 2002 and will be monitored during the annual site visit conducted in September/October 2002.

Eighteen of the twenty-three sites were previously monitored from 1997 through 1999 and five additional sites were established in December 2000. Comparison of 1997 to 1998 data revealed similar average stony coral coverage at the 18 original stations: 1.43% and 1.46% respectively (Broward DPEP, 1999). Comparison of offshore reef data from 1997 to 2000 also revealed minor differences in stony coral, soft coral (gorgonian), and sponge populations. In 2000, mean stony coral density for the 23 sites was 2.30±0.95 colonies/m^2(± 1 S.D.), and mean stony coral coverage was 2.25±3.41%. These values were comparable to the 1997, 1998, and 1999 values for the original eighteen stations. A slight increase in percent cover was observed, but no trends in density or evenness were suggested. Mean gorgonian density was 9.27±11.75 colonies/m^2 and mean sponge density was 19.81±10.44 colonies/m^2.

Overall coral density increased from 2000 to 2001 but the increase was not statistically significant. A total of 1,800 colonies and 31 species were observed at the 23 sites during the September/October 2001 monitoring event. Overall mean stony coral density in 2001 was 2.62 ±1.85 colonies/m^2. Overall mean coral cover was 2.39 ±3.96%. Mean density was highest on the first reef tract, and one site in Fort Lauderdale (FTL 4) had the highest stony coral coverage of 19.95% in comparison to a mean cover of 1.45% for the remaining first reef sites. The first reef showed the greatest increase in coral density between 2000 and 2001. The large increase and high variability of coral density observed at the first reef sites can be attributed to an increase in small *Siderastrea* spp. recruits at site DB1 in 2001. Stony coral percent species composition was similar in 2000 and 2001 with the exception of *S. radians* which showed an increase from 5% to 21%. Overall soft coral density decreased to 7.91± 8.01colonies/m^2 in 2001 which was not statistically different from 2000. Mean sponge density decreased significantly between 2000 and 2001 with an overall mean density of 14.09 ±6.93 colonies/m^2 observed during the September/October 2001 monitoring (Gilliam et al. 2001b).

8. Cause and Effect Relationships

Causal relationships are very difficult to determine when multiple actions and resources are involved (CEQ 1997). For example, most coral diseases are due to unknown pathogens. A human connection has been suggested for the fungal pathogen, *Aspergillus sydowii*, in sea fans. Harvell et al. (1999) proposed that this marine pathogen is a terrestrial fungus that has secondarily invaded the marine environment via sediment runoff from land. More recently, dust studies have established African dust storms as the source of *A. sydowii* on reefs (Shinn et al., 2000).

Corals which are subjected to increased levels of stress from chronic sedimentation, eutrophication, and higher temperatures and salinities are more susceptible to disease. Due to their lowered stress thresholds, diseased corals are less able to resist the usually sublethal effects of sedimentation and eutrophication, and exhibit increased susceptibility to damage from bioeroders and storm activity. Heavy sedimentation upon stony corals is associated with increased respiration rates, decreased calcification, and slower rates of reef accretion (Rogers, 1990). The added effect of localized, short-term turbidity and sedimentation upon stony corals adjacent to the borrow sites may cumulatively impact a low number of stony coral colonies which already exhibit signs of disease or bioerosion, possibly resulting in low levels of mortality.

Dredging of the offshore borrow will directly result in high mortality of benthic infaunal communities. Likewise, the beach infauna within the fill areas will be buried and subsequently lost during sand placement. Grazers and detrivores that feed upon macroinvertebrate communities within the proposed borrow areas will be temporarily displaced during dredging activities. Construction activity will cause most motile fish species to flee the disturbed areas and return when conditions approximate previous levels. Some less motile demersal and burrowing fish species may be lost during dredging, as their response may be to burrow deeper than to flee. Direct burial of nearshore hardbottom will result in mortality of macroalgae and faunal epibenthic species, as well direct burial of newly settled life stages of fishes. Suspension of sediment has been shown to cause mortality of eggs and larvae of marine and estuarine fish (Newcombe and Jensen, 1996), and a reduction in feeding in juvenile and adult fish. Settlement of juvenile fish may be reduced by the gradual burial of 11.6 acres of nearshore hardbottom habitat. Foraging sea turtles and fish will be displaced to adjacent areas of hardbottom. Reduced feeding success may influence survival, year-class strength, and recruitment of juvenile fish that inhabit nearshore hardbottom (Wilber and Clarke, draft manuscript). In turn, the feeding success of larger predatory game fishes could be affected by a decrease in their prey.

9. Magnitude and Significance of Cumulative Effects

The potential for a resource, ecosystem, and human community to sustain its structure and function depends on its resistance to stress and its resilience (CEQ, 1997). In order to assess the significance of impacts resulting from the Broward County Shore Protection project, cumulative impacts were examined from an overall resource sustainability perspective.

Results of Broward County's 2000/01 monitoring of the 23 permanent reef stations indicate that the reef communities in these locations have remained relatively stable during the past four years. Implementation of the proposed protective and preventative measures should provide the means necessary to minimize potential cumulative impacts upon these resources related to project construction. The long-term monitoring for the proposed project will provide the data to determine the cumulative impacts of turbidity and sedimentation upon adjacent hardbottom resources, and predict the future impacts of turbidity and sedimentation related to authorized renourishment projects.

Previous studies clearly have shown there will be significant short-term effects of beach renourishment and habitat burial on associated fish assemblages. The gradual burial of the remaining 11.6 acres of nearshore hardbottom habitat may negatively impact the settlement rates of juvenile fish, as well as eliminate foraging resources for juvenile fish and invertebrates. Reduced feeding success may influence survival, year-class strength, and recruitment of juvenile fish that inhabit nearshore hardbottom (Wilber and Clarke, draft manuscript). In turn, the feeding success of larger predatory game fishes could be affected by a decrease in their prey. The major component of the Broward County inshore fish assemblages is juvenile grunts, both in species numbers as well as individuals (Spieler, 2000b). Juvenile grunts serve as an important food source for many game fish (Spieler, 2000a), therefore reductions in their populations could reduce the feeding success of predatory reef fish that migrate inshore to feed upon them. However, given the extensive areas of nearshore hardbottom in Broward County, significant reductions in feeding success are not anticipated. Previous substrate/recruit availability and settlement studies of Broward County hardbottom have suggested that the marine environment is not substrate limited, but rather, that reef fish assemblages are recruitment limited and primarily structured by predation (Spieler, 2000). The results of this study also suggested that since the hardbottom in Broward County may be refuge limited, the placement of artificial reefs aimed at increasing juvenile refuge could increase the forage base for game fish, and depending upon site selection, may also increase the number of game fish (Spieler, 2000b).

Overall, the data collected during the 2001 nearshore characterization study does not suggest that the nearshore hardbottom communities adjacent to never nourished beaches are higher in epibenthic species richness and stony coral coverage than communities adjacent to previously nourished areas in Broward County. However, the data does suggest a high degree of variability among and between the nourished/never-nourished sites at both the inshore and offshore equilibrium toe of fill locations. Comparison of the epibenthic data from previous nourished sites to never nourished sites did not show clear, site-dependent differences in species diversity and stony coral coverage. The highest faunal species richness at the inshore ETOF sites was at the Pompano Beach sites, adjacent to a renourished beach. The Pompano Beach sites also exhibited the lowest overall algal coverages for both the inshore and offshore ETOF sites. Although overall faunal species richness was highest at the offshore sites in Fort Lauderdale, adjacent to a never nourished beach, examination of species richness at the individual sites revealed similar values for Pompano Beach and Fort Lauderdale. However, faunal density (individuals/square meter) was slightly higher at the Fort Lauderdale sites than Pompano Beach and Lauderdale-By-The-Sea. The data from the John U. Lloyd stations is difficult to evaluate from a beach nourishment perspective due to apparent Port Everglades Inlet related influences upon the epibenthic habitat.

Comparison of previously renourished beaches within Broward County to never renourished sites or of sites proposed to be buried by the equilibrium toe of fill to those not to be affected did not show clear, site-dependant differences in fish assemblages. A comparison of the nearshore hardbottom assemblage with reports on the fishes of the middle and offshore reef indicated, for the most part, that the inshore reef had lower abundance and richness than the other reef tracts; and that the majority of the nearshore species are also found at deeper hardbottom sites. Although juvenile grunts are not unique to the nearshore reef, they are more abundant there than on the other reef tracts. With rare exception (a single count of 2000, 3-cm grunts), juvenile grunts are not found on the offshore reef tract or the eastern edge of the middle reef in Broward County. However, as noted above, in order to determine the cumulative impacts of beach renourishment upon the trophic dynamics, one would need to know the feeding habits of each predator species and the impact of each renourishment action upon each prey/food resource, a Herculean task requiring years (Spieler, 2001b). Therefore, when examining the cumulative impacts of the proposed project, it is necessary to examine them from an overall habitat sustainability perspective.

The Broward County nearshore hardbottom does not appear to provide a unique habitat for some fish species that is unavailable at other hardbottom sites. The major discernable impact of any hardbottom burial will be on the loss of juvenile grunt habitat, primarily refuge (Spieler, 2001). It appears that the proposed beach renourishment will have minimal qualitative impact on the nearshore fish assemblages; and from the perspectives of either richness, abundance, or predominant species commonality, nearshore hardbottom loss can be mitigated with artificial refuge (Spieler, 2001b). Comparison of the inshore assemblage with fishes found on local artificial reefs indicates that loss of the hardbottom refuge of the predominant fish assemblage can be mitigated with artificial structure (Spieler, 2001b).

10. Mitigation of Significant Cumulative Effects

Broward County, through coordination and discussion with the representatives of the Corps, National Marine Fisheries Service, U.S. Fish & Wildlife Service, Environmental Protection Agency, and Florida Department of Environmental Protection, has reduced the potential for significant cumulative effects from turbidity and sedimentation through the selection of the borrow areas, the maximization of buffer zones, and the mode of alternating dredging of the borrow sites. As mitigation for the 13.6 acres of unavoidable nearshore hardbottom impact, Broward County is creating 13.6 acres of nearshore mitigative reef using limestone boulders as required by the State and Federal resource protection agencies. Limestone boulders replicate the rough surface and calcareous nature of the natural nearshore hardbottom formations. Previous studies of limestone mitigative boulder reefs in southeast Florida have found that the reefs provide suitable mitigation for nearshore, low-relief habitat lost to beach renourishment (Cummings, 1994). Interim results of nearshore mitigative reef monitoring in Jupiter/Carlin demonstrate rapid colonization of the limestone boulders by benthic invertebrates and algae, and colonization by key nearshore reef indicator species such as wormrock and hairy blenny (Palm Beach County ERM, 2000).

The proposed time frame for construction of the boulder reefs is to begin deployments at Mitigation Area 8 offshore of a DEP monument R-103 beginning in spring, 2003. Segment III mitigative artificial reef deployment will be carried out from April 1 through September 30. Areas not completed in 2003 will be completed in 2004, but it is anticipated that all deployments will be completed in 2003. Segment II mitigative artificial reef deployment will occur prior to beach fill commencement as required by the State and Federal resource protection agencies. The 10.1 acres of net hardbottom impact were anticipated to require 12.4 acres of compensatory mitigative reef. To offset the temporal lag in habitat functionality, scleractinian corals greater than 15 cm in diameter will be transplanted to the mitigative reef. Project construction of the artificial reefs will also occur prior to project fill equilibration impacts. The reduction of the temporal lag by coral transplantation reduced the required 12.4 acres to 11.9 acres of compensatory mitigative reef for both Segments II and III combined.

The proposed mitigative artificial reef construction prior to the commencement of beach project construction will provide refuge for displaced fish species as well as structure for larval recruitment during project construction. Lindeman and Snyder (1999) advocated the up-front construction of nearshore artificial reefs as mitigation for beach renourishment impacts to fishes, stating that “If constructed before burial and at similar depths, mitigation reefs may have provided a refuge for a sizeable fraction of the thousands of displaced fishes during the burial of the hardbottom reef, as well as thousands of subsequent new recruits.” The results of the long-term mitigation reef monitoring will provide the information necessary to assess the overall cumulative impacts of nearshore hardbottom burial upon the nearshore fish assemblages in Broward County.

11. Monitoring and Management

Proper controls and procedures will be used to avoid mechanical damage to offshore reef communities during dredging; and no significant impacts are expected to occur from the mechanical operation of the dredge. Construction specifications will include the use of recording and real-time precision electronic location equipment during dredging operations. The equipment will provide exact position of the dredge to the operator and allow continuous monitoring of the dredge location during operations. Avoidance of direct mechanical damage during dredging activities should prevent the devastating cumulative impacts of direct impact to these sensitive habitats. In the highly unlikely event of a misalignment, a reef damage assessment will be performed to determine the full areal extent of irreversible loss and/or amount of necessary remediation.

Direct impacts associated with pipeline placement will be minimized by determining the least impactive routes feasible and the use of pipeline support with either tires and/or H frames when needed. Direct impacts from pipeline placement have been estimated at 190 square feet per corridor. For seven corridors, hardbottom resource impacts are estimated to be 1,330 square feet (0.03 acres). If eight corridors are necessary for project construction, hardbottom impacts would increase by 190 square feet to 1,520 square feet. Immediately prior to construction, the preferred route will be marked with buoys to facilitate placement by the contractor. Pipelines will be visually surveyed weekly during operation to check for sand leakage. Accidental breakage is monitored continuously during operation through visual observation of flow from the discharge point and through electronic monitoring of the pipeline pressure at the pump station. No significant impacts are expected to occur from pipeline leakage or accidental breakage. In the unlikely event that leakage or a pipeline breaks occurs, a reef damage assessment will be performed to determine the extent of damage and/or amount of necessary remediation.

Careful placement of pipelines during the proposed project and adherence to the above protective measures will minimize direct impacts to hardbottom biological resources. The establishment of permanent pipeline corridors for future renourishment use will minimize the cumulative impacts of direct damage associated with repeated placement and avoid foreseeable future impacts from establishment of alternative pipeline corridors. Future nourishment actions will be evaluated separately with respect to the present impact analyses and monitoring of the initial nourishment project.

The sand source for the proposed Broward County Shore Protection Project is a silicate/carbonate mix with the carbonate content primarily derived from shell. It is anticipated that this sand source will generate less turbidity during washing on the hopper dredge than what was observed during previous Miami-Dade projects, thereby reducing the potential for extended turbidity plumes. On average, the diverse, mature benthic communities found of the reef crests adjacent to the proposed borrow areas are protected by buffer distances of 400 feet or greater, thereby decreasing the likelihood of significant turbidity and sedimentation impacts. Construction specifications shall require that the borrow areas are dredged in an alternating pattern, thereby reducing the volume and duration of sediment deposition on adjacent hardbottom communities. The proposed sedimentation monitoring program and alternating dredging pattern should minimize turbidity/sedimentation impacts upon adjacent, offshore reef communities. Although the potential exists for long-term chronic turbidity and sedimentation impacts adjacent to the borrow areas, monitoring and preventative measures should reduce the potential for significant long-term impacts. Observations of biological stress indicators will be used to evaluate the level of stress upon the epibenthic communities and to provide a check for the proposed sedimentation monitoring protocol. Histological tissue analysis will be used as a tool to judge the effectiveness of the sediment rate value and to provide a scientifically valid justification for changes in sedimentation rate monitoring (See Appendix E – Biological Monitoring Program).

A nearshore turbidity monitoring program with a plume mixing zone of 150 meters from the discharge site will be implemented to minimize turbidity impacts during project construction. In order to assess the potential for a gradual shift in community structure and corresponding reduction in biodiversity, a long-term, nearshore hardbottom monitoring program will be implemented. A network of beach fill stations and control stations will be established offshore of the expected equilibrium toe of fill to assess changes in epibenthic community structure and fish utilization. The results of the long-term mitigation reef monitoring will provide the information necessary to assess the overall cumulative impacts of nearshore hardbottom burial upon the nearshore fish assemblages in Broward County (See Appendix E – Biological Monitoring Program). Provided that the mitigative reefs function as designed, there should be limited cumulative impacts upon nearshore epibenthic communities from implementation of the proposed project and authorized renourishment projects. However, it must be noted that in order to truly determine cumulative impacts of beach renourishment upon the trophic dynamics of nearshore hardbottom habitat, one would need to know the feeding habits of each predator species and the impact of each renourishment action upon each prey/food resource, a Herculean task requiring years (Spieler, 2001b). Therefore, when examining the cumulative impacts of the proposed project, it is necessary to examine them from an overall habitat sustainability perspective.

The Broward County GIS database will be used as the primary tool to analyze cumulative impacts based upon the baseline conditions recorded during 2001. The creation of the GIS to document pre-project conditions significantly reduces the effort needed to analyze the effects of future projects by overlaying data layers from post-construction monitoring events for comparison to the baseline data set.