

Broward County Office of Integrated Waste Management



Beach Renourishment Pre-Feasibility Study

January 8, 2003

An aerial photograph of a beach area. A long wooden pier extends from the shore into the ocean. The beach is sandy and populated with people. In the foreground, there are some buildings and palm trees.

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LIST OF ACRONYMS

BFI	Browning Ferris Industries
BIC	Broward Interim Contingency
EPA	United States Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
MRF	Material Recovery Facility
MSW	Municipal solid waste
NPV	Net present value
OIWM	Broward County Office of Integrated Waste Management
RRB	Resource Recovery Board
SMI	Strategic Materials Inc.
TAC	Technical Advisory Committee
USACOE	United States Army Corp of Engineering

1.0 INTRODUCTION

1.1 Background

Broward County (County), on the behalf of the Broward County Solid Waste District (District), currently processes approximately 13,100 tons of glass per year through a Material Recovery Facility (MRF) owned and operated by Browning Ferris Industries (BFI). The County/District pays BFI a processing fee to process and market the recovered glass. As part of the revenue provisions of the BFI contract, the net cost to the County/District is approximately \$145,000 to recycle glass, which includes a direct cost of approximately \$144,000 for mixed cullet.

Due to the limited market and ever increasing recycling costs for glass Malcolm Pirnie on the behalf of the Broward County Office of Integrated Waste Management (OIWM) conducted a Mixed Cullet Recycle and Reuse Study in October 2002. The purpose of the study was to identify economically and technically viable alternatives recycling and reuse options. This study identified four alternatives to the current program. Based on the analyses conducted as part of the Mixed Cullet Recycle and Reuse Study, the alternative to create a “New Intermediate Processor” was recommended as the most advantageous alternative for the following reasons:

- Keeps glass in the recycling program, which is economically and environmentally beneficial to the County/District and therefore does not reduce the County’s recycling rate and does not use valuable landfill space.
- Provides potential for further savings with more competitive unit recycling cost of mixed glass through a procurement process.
- Shifts some of the operational risk of processing the glass to the intermediate processor.
- Fosters the development of a new local intermediate processor in South Florida, which lowers the transportation costs and provides a more competitive glass recycling market. The current program is dependent on a single vendor to recycle/reuse the glass recovered at the MRF. In situations with a single vendor, the stability of the vendor must be considered as it can have significant impacts on a glass-recycling program.

This recommendation was presented to a subcommittee to the Technical Advisory Committee (TAC) to the Resource Recovery Board (RRB). This subcommittee subsequently requested further evaluation of the recommended alternative, specifically the investigation of a public intermediate processor to process glass for beach renourishment.

1.2 Purpose of Study

OIWM is conducting this beach renourishment pre-feasibility study to determine the technical and economical viability of processing glass through a public intermediate processor for beach renourishment. The objectives of this study are:

1. To collect and consolidate existing data on beach renourishment.
2. To identify and analyze the factors affecting producing glass sand, such as public perception, processing technologies, cost, regulatory requirements and environmental issues.
3. To identify alternative reuse options that utilize the same type of equipment used to produce glass sand for beach nourishment.
4. To estimate the economic impact of processing glass for beach renourishment.

1.3 Report Outline

This report provides a detailed summary of the findings of the beach renourishment pre-feasibility study and is divided into the following sections:

Section 2. Beach Renourishment

Section 3. Alternative Reuse Options

Section 4. Conclusions

2.0 BEACH RENOURISHMENT

2.1 County's Beach Management Program

The County has implemented several beach renourishment programs since the early 1960s. Broward County's beaches are currently in a chronic state of erosion and it is estimated that 21 miles of the 24 miles of Broward's beaches are critically eroded. The current beach management program is estimated to replace 2.5 million cubic yards of sand over approximately 12 miles of beach. The program is designed to achieve economies of scale by addressing the erosion problem at several municipal Beaches including parts of Pompano Beach, Lauderdale-By-The-Sea, Fort Lauderdale, John U. Lloyd Beach State Recreation Area, Dania, Hollywood, and Hallandale. This program was initially scheduled to commence construction in 2001 with an estimated cost of approximately \$35 million. However due to permitting and environmental issues, the project is now scheduled to commence construction in 2003 with an estimated cost of approximately \$52 million.

Previously beach renourishment was a one-stage process involving the dredging of sand and spreading over the impacted beach area. However, the current program is designed as a three-stage process consisting of the following:

- Offshore dredging from "borrow sites" and pumping to eroded segments of the beach making the nourished areas 75 to 150 feet wider.
- Strategic placement of erosion control structures, such as highly-engineered T-head groins, to stabilize acutely erosive stretches of the County's beaches.
- Inlet sand bypassing to "feed" beaches eroding as a consequence of the inlet stabilization.

It is estimated that under the current beach nourishment program, the renourishment of the identified beaches could last approximately 10 to 15 years. However, beach renourishment continues to encounter several challenges, such as:

- High implementation costs ranging from \$10 per cubic yard to \$20 per cubic yard of sand.
- Environmental resistance due to the potential effects of beach renourishment on the reefs and the sea turtle nesting.
- Access to sufficient quantities of sand.

2.2 Use of Glass for Beach Renourishment

Over the last 10 years, extensive studies have been conducted on the use of glass for beach renourishment. Both the manufacturing and scientific communities have invested extensive time and money to research the viability of using glass to produce a sand-like material. However to date, there are no known applications of glass for beach renourishment in the United States.

2.2.1 Scientific Studies

Due to the similarities in their characteristics, several studies have been conducted by various parties to determine the effectiveness of implementing the beach renourishment program using alternate material such as glass. Some of the scientific studies include:

1. ***Emergency Beach Fill from Glass Cullet: An Environmentally Green Management Technique for Mitigating Erosional “Hot Spots” in Florida by Charles Finkl and Loisa Kerwin, Department of Geology, Florida Atlantic University, 1997.*** This study, which was conducted based on information from beaches in Palm, Broward and Dade counties, identified the existence of erosional hot spots where beach fill degrades from a renourished area 15 to 20 times faster than the natural shoreline retreat. Therefore the control of hot spots would be critical to the success of a beach renourishment program. Due to high costs, limited availability of sand, and issues associated with dredging, the study recommended the use of glass to fill hot spots in emergency situations. The cost analysis from this study indicated that upland sand for Broward County costs \$3.90 per cubic yard in comparison to processed glass sand at \$2.70 per cubic yard.
2. ***Feasibility Study: Recycled Ground Glass Beach Sand, Encinitas California by Woodward-Clyde, May 1993.*** This study identifies the key issues associated with using glass for beach renourishment, which are:
 - Cost
 - Quality control
 - Material supply
 - Physical consideration such as natural versus artificial and physical size and shape
 - Environmental considerations
 - Assessment of feasibility

Overall these studies indicate that the use of glass for beach renourishment is a potentially viable option provided certain key elements are addressed. In addition to the two studies described above, Dade County is currently conducting a study on beach renourishment using non-native sand.

2.2.2 Glass and Sand Characteristics

Glass is made from silica sand, limestone and soda ash. Quartz sand and glass are both comprised primarily of silicon dioxide and thus share many basic physical characteristics. Table 2-1 summarizes the physical properties of glass cullet and compatibility with native beach sand.

Table 2-1: Summary of physical properties tests on glass cullet and compatibility with native beach sand beach fill materials dredged from offshore¹

Test	Compatible	Comments
Specific Gravity	Yes	Cullet = 2.5 to 2.65; natural aggregate = 2.68; silica-silicon dioxide = 2.21 to 2.32
Gradation	Yes	Shows little or no gradation
Particle Shape	Yes	Suitable for mechanical handling, low potential for punctures and cuts
Durability	Yes	Less than crushed rock but close to normal limits for roadway aggregate.
Compaction	Yes	Little or no gradation change, compaction curves are relatively flat, material insensitive to moisture content.
Permeability	Yes	Medium to high permeability corresponding to medium sand and gravel aggregate
Thermal Conductance	Yes	Slightly lower than natural aggregates, cullet conducts heat somewhat more slowly
Shear Strength	Yes	Cullet exhibits good to excellent CBR values, cullet has resilience moduli > 29 ksi at a bulk stress to 25 psi.

2.2.3 Equipment

Several types of pulverizing equipment have been developed to produce non-abrasive ground glass. The basic pulverizing system consists of a metering surge hopper, in-feed conveyor, glass pulverizer, conveyor to the trommel, trommel separator, and a control panel. Central to the system is the pulverizer, which has the capability of producing fine to coarse ground glass. These machines are capable of handling all types of glass, including glass containers, plate glass and ceramics of varying sizes. In addition, these systems can include components to remove metal, plastic, and lids from the final aggregate.

As part of this study nine equipment manufacturers were contacted. Two of the manufacturers contacted, Glass Aggregate Manufacturing Equipment (GAME) and Andela were willing to provide information on their pulverizing systems. The appropriate equipment needed to process approximately 13,100 tons of glass annually with an operation schedule of 52 weeks per year, 5 days per week and 7 hours per day for

¹ Source: Emergency Beach Fill from Glass Cullet: An Environmentally Green Management Technique for Mitigating Erosional "Hot Spots" in Florida by Charles Finkl and Loisa Kerwin, Dept. of Geology, Florida Atlantic University, 1997

the GAME and Andela systems are summarized in Table 2-2. More detail information is provided on these systems in Appendix C.

Table 2-2: Comparison Of Pulverizing Systems and Equipment

Manufacturer	GAME	Andela
Model	GM-1 System	GP-1 System
Capacity (Tons/Hr)	10-12	10
System Size (L x W x H)	40' x 28' x 11.5'	55.8' x 9.9' x 10'
Mechanism	Shearing & Sanding Units	Flail Mill w/ Flexible Impactors
Weight (lbs)	10,000	15,000
Motor(s) Size	(3) 7.5hp, (2) 2hp, (2) 1hp	(2) 10hp
Electrical Requirements	3-phase	3-phase
Aggregate Size	Any Size	Any Size
# Passes To Create Sand	One Pass	Two Passes
Dust Remover	Optional Dust Bag	Optional Misting
Labels & Lids	Screened Out	Screened Out
Comments	Hopper, Conveyor (2), Trommel, Pulverizer Unit	Hopper, Conveyor (2), Trommel, Pulverizer Unit

Pulverizers are currently used successfully for grinding glass for several different applications. Different types of pulverizing technologies are successfully used in Sumter County and are planned for use in Duval County. A report prepared by Sumter County indicates that the pulverizer is effective in pulverizing glass for various end-market uses. However moisture was identified as one of the issues and hence the report recommended covering the equipment and glass prior to processing in order to obtain consistent quality end-product. Duval County, through a contractor, is in the process of implementing a pulverizing system that will process approximately 50,000 tons of glass annually to be used for asphalt shingles.

2.2.4 Regulatory Requirements

Beach renourishment is regulated on a local, state and federal level. At the local level the Department of Planning and Environmental Protection under the Broward County Commission is responsible for the beach renourishment program. While on the state level, beach renourishment is regulated by the Beach and Coastal Systems Department of the Florida Department of Environmental Protection and other state agencies, and by the United States Army Corp of Engineers (USACOE) at the Federal level.

In addition to the various regulatory agencies, the beach renourishment process is also impacted by the following legislation and programs:

- Fish and Wildlife Coordination Act
- Endangered Species Act
- Coastal Barrier Resources Act
- Florida Coastal Zone Management Program
- Coastal Zone Management Program
- Fishery Conservation and Management Act

As part of this study, representatives from local, state and federal agencies were contacted. All representatives contacted expressed interest in the using glass for beach renourishment. However, the following concerns were identified:

- Geotechnical conditions
- Endangered species
- Quality control and aesthetics
- Permitting

2.2.4.1 Geotechnical Conditions

Some of the key characteristics that must be assessed for the beach renourishment process with any non-native type of sands are:

- Grain Size
- Color

Grain Size

Grain size is important to the success of a beach renourishment process. Smaller particles wash away easier, hence resulting in a faster rate of erosion. The USACOE Jacksonville District has determined a set of generic sand specifications for Dade County, which can

be applied to renourishment programs in Broward County. These specifications were outlined in the Request for Information (RFI) issued by the USACOE April 2002, titled "Dade County Beach Erosion Control and Hurricane Protection Project, North Miami Beach Renourishment". As described in the RFI, sand suitable for beach renourishment must have an average mean grain size equal to or greater than 0.30 mm and less than 0.55mm, where the fines are limited to less than 5 percent. Ninety-nine percent of the material must pass the three-eighths-inch sieve with no particles larger than three-fourths inch diameter.

Color

One of the specifications of beach renourishment is attaining sand of similar color to the native sand. To attain a similar color of natural sand from glass would be dependent on the distribution of flint, amber and green glass. In the USACOE RFI, it specified that the sand must have a color similar to the existing beach, based on the Munsell Soil Color Chart. The desired color of the glass product could potentially be attained by mixing glass with natural sand.

Color is not only important aesthetically, but it also affects the rate of heat retention by glass. Since changes in temperature can affect the sea turtle hatching, this would also be an important factor for the beach renourishment process using glass.

2.2.4.2 Endangered Species

Compliance with the Endangered Species Act may prove to be one of the most important environmental considerations in the use of glass sand for beach renourishment in the County. The County's beaches are inhabited by marine turtles and hardbottom/reef habitat, which are of particular concern during the beach renourishment process. As part of the standard beach renourishment process, the County is required to study the effect of the new sand on the hatching of sea turtles, where the particular concern is the effect of a temperature change on the hatching process. Since ground glass may have a tendency to absorb and dissipate heat differently than normal beach sand, this may be of particular concern.

2.2.4.3 Quality Control

For beach renourishment using natural sand, quality control is important to the success of the program. Hence quality control would also be a critical issue when using glass for beach renourishment. Mixed cullet contains small amounts of non-glass materials, such as ceramic, rock, and metal fragments, which for the County corresponds to 4.5 percent of the cullet. In addition, even after washing, bottles may contain some residue primarily consisting of paint and paper.

The pulverizing equipment also tends to create glass dust, which adheres to the glass fragments. Dust and fine particles may leach out and add to water turbidity with potential effects on coastal reefs and marine life. The paper prepared from the study conducted by Charles Finkl and Loisa Kerwin stated that in previous studies tests indicated low levels of base metals in the leachate from ground glass.

Quality control standards will have to be developed in order to establish limits for non-glass material residue and glass dust on aggregate to be used for beach sand. As stated in Section 2.2.3, some of the equipment includes components for removing metal and other residue. A sampling and testing would be recommended to determine the efficiency of these components in removing metals and other residues.

2.2.4.4 Permitting

Permitting will be one of the most challenging aspects of this proposed approach and will be governed by the previously discussed issues. Beach renourishment projects are currently permitted under the Beaches and Wetlands Department of the FDEP. However due to the potential environmental effects associated with beach renourishment, other state agencies such as the Fish and Wildlife Commission, are also be involved in the permitting process.

Based on discussions with FDEP representatives, the use of glass for beach renourishment would be considered to be an innovative technology. Under Title XI, Chapter 161 Section 161.082 of the 2002 Florida States, “the department is directed to periodically review innovative technologies for beach renourishment and, on a limited basis, authorize, through the permitting process, experimental projects that are alternatives to traditional dredging and fill projects to determine the most effective and economic techniques for beach nourishment.”. The Beach Management Rules under Chapter 62B-41 cover the rules and procedures for application for coastal construction permits. Section 62B-41.0075 of this chapter specifies the conditions for experimental coastal construction, under which the use of glass for beach renourishment would be covered. This section, as included in Appendix D, specifies the conditions and specifications to receive such approval.

2.2.4.5 Public Relations

Another concern of the regulatory agencies is the public perception and aesthetics of placing glass on the beach. A public outreach program could be implemented to educate the public on the safety, economic and environmental benefits of glass sand. Significant tests have shown that the end-product is non-abrasive. In addition, since the quantity of glass is not large enough in comparison to quantities, the county may opt to mix the glass with natural sand prior to spreading on the beach, which could help to avert aesthetic concerns.

2.2.5 Economic Analysis

An economic analysis was conducted to determine the net present value of implementing a public intermediate processor to produce glass sand for beach renourishment. The current glass recycling program was used as the base line condition to conduct an evaluation of the alternatives. It should be noted that the economic analyses conducted as part of this evaluation are provided for comparison purposes only and therefore reflect the scenarios created by the assumptions used. For the purpose of this analysis, the current glass recycling program was assumed to be the following:

- BFI continues to operate the MRF in accordance with the current contract.
- Glass recovered at the MRF sold to Strategic Materials Inc. (SMI).
- Annual growth rates for the flint glass, green glass, amber glass, and mixed cullet were based on the annual historical quantities recovered at the MRF.
- Annual change in the unit recycling costs rates for glass based on the historical changes in price from 1995.
- Annual change in the hauling cost is 1 percent.
- Discount rate of 3 percent.

Under the beach renourishment alternative, the County or their contractor would operate a public intermediate processing facility to process glass for use in beach renourishment. The County/District would be responsible for providing glass to the local beach renourishment program. The County/District would be responsible for all capital investment and operating expenses associated with the intermediate processing facility. Under this alternative, flint, amber and green glass would not be manually sorted; therefore a single stream of glass would be recovered at the MRF. BFI would continue to operate all other aspects of the MRF under the current BFI contract.

The assumptions used to develop the model for the beach renourishment alternative are:

- Creation of a new local public intermediate processor in South Florida during fiscal year 2004 to pulverize glass for beach renourishment.
- Prior to the creation of a new local intermediate processor, glass would continue to be recycled under the current program.
- Mixed glass recovered at the MRF would be given to the new local public intermediate processor at zero cost.
- The County would be responsible for the cost of transporting the glass from the MRF to the proposed pulverizing facility. The County department or city accepting the ground glass would be responsible for the transportation costs from the facility.
- Ground glass produced at the public intermediate processing facility would be given to the appropriate County department or city.
- Annual growth rates for flint glass, amber glass, and mixed cullet were based on the annual historical quantities recovered at the MRF.
- The cost estimate includes the full capital cost of the project, which includes the following:
 - A building will be provided to protect the equipment and to store 1-week supply of mixed glass. The estimated cost of the building is approximately

\$177,000 based on an approximate cost of \$35 per square foot for 5,000 square feet.

Estimated engineering and design costs for the facility

Equipment and utilities costs

20 percent contingency

- Operation and maintenance cost, excluding labor but including electricity of \$3.00 per ton.
- Replacement costs for equipment included at approximately \$12,600 per year based on an estimate of \$6,300 per 1,000 hours of operation.
- Labor costs for facility based on four employees at an average of \$10 per hour for 40 hours per week and 52 weeks per year plus benefits at 35 percent of the labor costs.
- Reduced BFI's process fee due to a reduction in the MRF labor by 4 personnel. The reduced fee of \$70,614 is assumed to be the labor cost for the 4 personnel.
- Annual change in the unit recycling costs rates for glass based on the historical changes in price from 1995.
- Annual change in the hauling cost is 1 percent, where the initial hauling cost to the local intermediate processor facility is assumed to be \$3.50/ton.
- Discount rate of 3 percent.
- CPI of 3 percent.

An economic analysis was conducted to determine 5-year, 7-year and 10-year net present value ("NPV") of the alternative in comparison with the current glass recycling program. The 7-year period was used in order to ensure that the model covered the period through the scheduled termination of the BFI contract on September 30, 2009.

Table 2-3: Comparative Summary of the Costs to Implement the Current Glass Recycling Program and Beach Renourishment Alternative

NPV	Current Program	Beach Renourishment Alternative
5-year period	\$1,053,000	\$1,332,000
7-year period	\$1,502,000	\$1,613,000
10-year period	\$2,187,000	\$2,236,000

The results of this economic analysis, as summarized in Table 2-3, indicate that the beach renourishment alternative would operate at similar costs to the current program for the 10-year NPV with slightly higher costs for the 5-year and 7-year NPVs. The complete models for the current glass recycling program and this alternative are included in Appendix E. It should be noted that this model does not include the associated permitting costs for the project and any potential grants or subsidies that may be available.

3.0 ALTERNATIVE REUSE OPTIONS

3.1 Overview

In addition to use for beach renourishment, there are several other alternative reuse options for glass, as shown in Table 3-1.

Table 3-1: Market and End Uses of Mixed Cullet ²

Market Type	Uses
Building Materials	Foam Glass Glass Tiles Glass Brick Masonry supplies Architectural panels Ceramic tiles Roof tiles Roof shingles Silica filler roof coating Precast concrete bridge drainage wall units
Construction Applications	Drainage aggregate Fill for sewer connections, electrical conduits, backfill areas, frost heave-sensitive areas Road sub-base Landfill cover Lightweight aggregate concrete additive
Paving Applications	Glasphalt (Glass in asphalt) Hot-mix asphalt component Paving bricks
Insulation	Composite fiberglass component Fiberglass insulation component Foamglass insulation
Filter Media	Filter media component
Industrial Mineral Use	Abrasive component Sandblasting media Deburring media
Miscellaneous	Beach Sand Floor grit Jewelry Tableware Desktop accessories Reflective beads in reflective paint Silica substitute in steel production

As part of this study to determine the feasibility of using glass for beach renourishment, an investigation was conducted to identify the flexibility of the equipment to producing

² Source: Westchester County Mixed Cullet Market Development Study, October 1999

alternate end-use products. As specified in Section 2.2.3, the equipment that would be used to produce glass sand has the capability to produce a wide cross section of material from fine to coarse particles. Therefore given this production flexibility, the following alternate end-uses could be used for the public intermediate processor:

- Landscaping
- Fill

Due to the difference in specifications for these products and glass sand, they may also be produced as end products while preparing glass to meet the specifications for beach renourishment. It is not expected that there would be a difference in cost associated with these different alternatives. In addition, the pulverizing system could be used to produce these products in the interim after the facility is built and prior to full permitting for glass sand. It should be noted that the use of glass for these alternatives may require regulatory approval and in other cases marketing to establish a local market. The establishment of local markets for any of these alternatives is imperative as the alternatives are only economically viable for a local market due to transportation costs.

3.2 Landscaping

Glass can be used for landscaping in parks, playground areas and golf courses. Several communities use glass for landscaping by pulverizing the glass in to various sizes. Sumter County is currently pulverizing all glass generated in the community for landscaping. With the abundance of golf courses in Broward County, the sand-like material could be used to replenish sand traps and other landscaping elements. Best practices for landscaping applications are included in Appendix F.

3.3 Fill Material

Glass can also be used as a fill material in the following situations:

- Lake Fill - As part of the development of Broward County, material is needed to fill areas to create artificial lakes. Fine to coarse glass can be used for lake fill. There are several regulatory issues associated with this option which includes residue and contamination of the water body.
- Roadbase - Due to the strength of glass and its density and compaction achiever, glass is ideal for use as a road base. Fine to coarse glass could be used for roads in Broward County and at the landfill. In addition to road base, fine to coarse glass can be used for drainage.

Glass is currently used as fill in several applications. The best practices for compaction of glass fill and the behavior of glass aggregate under structural loads are included in Appendix F.

4.0 CONCLUSIONS

The use of glass for beach renourishment appears to be a viable alternative due to similar characteristics of glass and sand. This alternative appears to be technically viable based on the studies conducted to date and would likely have a large consistent demand, while addressing some of the recycling problems currently being experienced with glass. Based on the analysis conducted the beach renourishment alternatives is more advantageous than the current program for the following reasons:

1. ***Self-Reliant County Operation*** - Under the proposed structure for the beach renourishment alternative, this project would operate as a self-reliant county operation independent of the South Florida glass market. Within the self-reliant County operation, the County would provide the glass from its glass recycling program, own the pulverizing facility and use the ground glass for various uses, such as beach renourishment, within the County's various departments. Some of the benefits of this proposed structure are:
 - Not affected by the variations in the cost to recycle glass on the glass recycling market.
 - The cost for operation of the facility would be an internal cost within the County structure; therefore this would provide the County with greater control of the cost to recycle the recovered glass.
 - Flexibility to cater to more than one end-use market, such as beach renourishment, lakefill and landscaping, within the County based on supply and demand.
2. ***"Green" Project*** - In addition this project would be considered a "green" project providing a technically viable alternative for recycling and reuse of the glass recovered at the MRF. Even though there will be challenges marketing the beach renourishment approach to the public, it is believed that this project can be marketed to the public in a positive manner highlighting the environmental benefits.
3. ***Economic Feasibility*** – Even though economics would not be the driving factor for this project, it should be noted that the preliminary results of the economic analysis indicate that the cost for the beach renourishment alternative is comparable to the current glass recycling program over a 10-year period. However the beach renourishment alternative, unlike the current program, is not vulnerable to market failures and therefore may have a higher long-term potential. One additional economic benefit of this project is the deferred cost of the County not having to buy sand.

However considering the benefits of the beach renourishment alternative identified above, there are some components to the beach renourishment alternative that may provide challenges in its implementation. These challenges include:

1. **Regulatory Requirements** – The biggest challenges for this project will be attaining regulatory approval. At a minimum the primary concern will be obtaining permitting which will require studies to address the effect of the glass on the endangered species. In order to address these concerns, pilot testing would have to be conducted. Since this is a new technical approach with no standard specifications, the pilot testing would be used as the basis for developing specifications for beach renourishment using glass sand. The pilot study would address issues such as grain size, color and chemical composition of the glass.
2. **Typical Beach Renourishment Schedule** – The typical 10-year interval for beach renourishment is a considerable period of time. In order to meet this schedule, it would require the County to stockpile large quantities of ground glass over a ten year period. This may hinder the feasibility of using glass for beach renourishment as large spaces of land would be required for stockpiling the estimated 130,000 tons recovered over ten years.

In order to address the issues associated with the 10-year beach renourishment program, the County may consider the use of the glass for emergency beach renourishment to combat “hot spots”, as discussed in the Charles Finkl and Loisa Kerwin Study. Typically these hot spots are caused by storms which typically occur at least twice a year. The preliminary research conducted as part of this study indicates that the use of glass sand for emergency hotspots may potentially be the most beneficial application. Based on discussions with FDEP representatives, the treatment of hot spots is covered by the beach renourishment permit. Using glass to fill hot spots may present an issue since there are no formal standards.

3. **Quantity of Glass Available** – In both cases, under the typical 10-year schedule for beach renourishment and emergency renourishment for hot spots, the quantity of glass recovered at the MRF would not be sufficient to satisfy the required quantities of sand. For example the typical beach renourishment program uses over 2 million tons of sand, however over a 10-year period the County would only recover approximately 130,000 tons of glass. In order to address this issue, the County may consider using glass as filler with natural sand for beach renourishment. In this situation a ratio of sand to glass would be used to create a combined product for beach renourishment. The combination of sand and glass may potentially address the aesthetic issues related to the placement of glass on public beaches.

In addition, the County may consider attempting to gain control of the glass generated by commercial properties. This may potentially be a significant quantity of glass and could increase the viability of this project.

4. **Liability** – Even though it appears that the use of glass for beach renourishment is economically and technically viable there may be potential liability associated with the use of glass as beach sand. The County or another body may be held liable for any damaged caused by a non-natural material.

5. **Marketability** – In addition to attaining approval from the regulatory agencies, the County will also have to market the use of glass sand in beach renourishment to the public to ensure that it meets all aesthetic and other considerations.

This study has identified the benefits and challenges associated with this proposed alternative, which provide evidence that this project is viable. The County should pursue various avenues to identify the feasibility of addressing the challenges listed above. As stated previously, the primary challenges for this project will be satisfying the regulatory requirements. In addition, an updated economic analysis should be performed once a more definitive structure for the project has been developed, including the proposed project site.

APPENDIX A

LIST OF CONTACTS

- Steve Higgins, Broward County Commission, Department of Planning and Environmental Protection
- Ana Cook, Glass Aggregate Manufacturing Equipment Sales Representative,
- Cynthia Andela, Andela Products, Ltd. Sales Representative
- Francis, Michael, Glass Aggregate Manufacturing Equipment Representative/San Diego State University Professor
- Padon Woodruff, FDEP, Division of Water Facilities, Bureau of Beaches and Coastal Systems
- Jackie Thompson, FDEP, Division of Water Facilities, Bureau of Beaches and Coastal Systems
- Doug Rosen, USACOE, Jacksonville Section
- John Carter, MINPRO
- Cheryl Miller, Recycling Specialist, City of Deerfield Beach
- Casey Eckels, City of Fort Lauderdale
- Professor Charles Finkl, Department of Geology Florida Atlantic University

APPENDIX B

LIST OF EQUIPMENT MANUFACTURERS CONTACTED

- American Pulverizer Company
- Andela Tool & Machine Inc.
- Carpo, Inc
- Glass Aggregate Manufacturing & Engineering
- MINPRO
- Pennsylvania Crusher Corporation
- Prodeva, Inc.
- Recycling Equipment
- Resource Recovery Systems

APPENDIX C

EQUIPMENT DATA

ANDELA EQUIPMENT

GAME EQUIPMENT

APPENDIX D

PERMITTING REQUIREMENTS FOR AN INNOVATIVE TECHNOLOGY

APPENDIX E

ECONOMIC MODELS FOR THE CURRENT GLASS RECYCLING PROGRAM AND THE BEACH RENOURISHMENT ALTERNATIVE

APPENDIX F

BEST PRACTICES FOR GLASS USE