

# Appendix F

## Alternative Uses of Recovered Glass

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### 1. Existing Management of Recovered Glass

Currently, glass is collected as part of residential single stream recyclables, collected from some commercial businesses that contract for recycling, or delivered by some businesses and individuals that self-haul recyclables to the City's Transfer Station. At the Transfer Station, all glass, whether collected separately or with other recyclables, is loaded into a transfer trailer with all types of recyclable fiber and containers for transport to WM's Reuters MRF in Broward County. The City does not pay for transport and processing, nor does it receive any revenue for recyclables. According to WM staff, most of the glass processed at the Reuters MRF is used as road base at a WM landfill.

Glass is a comparatively dense material and, therefore, typically comprises about 20-25 percent by weight of residential recyclables. The value of recovered glass as a commodity tends to rank lower than that of other materials. Finding an end-use for recovered glass in the Keys could potentially put it to better use than landfill cover, and would also reduce WM's transport and processing costs. The primary benefit to the City would be the ability to encourage increased glass recovery from local businesses and the resulting reduction in waste transport and disposal costs (currently at \$71.55 per ton).

To take advantage of a local end-use market, glass would need to be separated from other recyclables. Because residential recyclables are collected in a single stream, the commercial sector, especially bars and restaurants, offers the most likely source of segregated glass.

### 2. Potential Recovery of Source-Separated Glass

Based on the recent waste composition study, glass comprises approximately 9.3 percent of commercial waste delivered to the City's Transfer Station. Based on FY 2011 tonnage, this equates to approximately 2,300 tons per year or about 200 tons per month (see Table 1). Achieving a 25 percent recovery rate would equate to about 50 tons per month, and a 50 percent recovery rate would amount to nearly 100 tons per month.

**Table 1: Estimated Disposal of Glass by Businesses**

Commercial Glass FY 2011	
Total garbage (tons/year)	42,697
Commercial garbage, 58% of total (tons/year)	24,764
Glass, 9.3% of commercial (tons/year)	2,303
Glass (tons/month)	192

### 3. Potential End-Uses for Recovered Glass in the Keys

Numerous uses for recovered glass exist other than bottle to bottle recycling; however, due to the limited number of manufacturers in the Keys, the most viable options for local utilization are (1) for beach renourishment, (2) for construction uses, and (2) as recycled glass mulch.

Through discussion with Florida Department of Transportation (FDOT) staff, KCI has confirmed that the use of recycled crushed glass in aggregate materials and construction activities is an acceptable practice.<sup>1</sup> Toppino & Sons, Inc., a local contractor specializing in the production, use and sale of construction materials including concrete aggregates, was initially contacted to gauge the company's interest in utilizing recovered glass. Toppino & Sons is located adjacent to the City's Transfer Station, making it a prime candidate for such a partnership.

#### Beach Renourishment

Recycled pulverized glass (cullet) has considerable advantages as potential beach fill material in that it provides a use for a material that is difficult to market as a recyclable commodity, and may provide a benefit in addressing the critical issue of beach erosion. Additional advantages to the use of cullet include: (1) the ability to select for color, size, and shape characteristics similar to those of natural sands,<sup>2</sup> (2) similar chemical, mechanical, and geologic properties as natural sands,<sup>3</sup> and (3) readily available supply. As such, recycled glass has been used in beach renourishment projects across the globe, including in Curacao; Lake Hood, New Zealand; Fort Bragg, California; and Kauai, Hawaii.<sup>4</sup>

Despite the use of recycled glass as renourishment material elsewhere, use in Florida has been limited, primarily due to permitting concerns. The Florida Department of Environmental Protection (FDEP) is the primary state regulatory agency that oversees beach management in Florida. Requirements for beach nourishment permits are listed in FDEP Chapter 62B - Section 41.007, Rules and Procedures for Application for Coastal Construction Permits, and stipulate material grain size, composition, and color. Prior to a FDEP-funded project in Broward County from 2004 to 2007, the use of glass cullet for beach reconstruction had not been permitted. To date, no other permits have been issued. However, the use of other alternative materials similar to glass, namely aragonitic oolite, have been approved.<sup>5</sup>

Regardless of the material used, if placed seaward of the mean high water line, a permit issued by the U.S. Army Corps of Engineers (USACE) is required per Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. Use of material landward of the mean high water line may require approval by the U.S. Fish and Wildlife Service, as provided by the Endangered Species Act, due to the perception of potential effects on marine turtles nests.<sup>6</sup> However, multiple studies indicate that different types of sands have little to no impact on turtle nesting success. In a multi-year study conducted on Miami Beach, Florida, no significant difference was found in hatching and emergence success between nests composed of carbonate, aragonitic, or

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<sup>1</sup> John Shoucair, P.E., FDOT, State Materials Office, personal communication, August, 2011.

<sup>2</sup> L. Kerwin, *Potential Applications for Recycled Glass in Beach Management: Emergency Stabilization of "Hot Spots" in Broward County Florida*, (M.S. thesis, Florida Atlantic University, 1997).

<sup>3</sup> G.G. Thompson et. al. for the Broward County Office of Integrated Waste Management, Broward County Department of Planning & Environmental Protection, *Broward County Beach Demonstration Project Literature Review*, January 2005, page 1.

<sup>4,5,6</sup> G.G. Thompson, et al., pages 6-10.

silicate sands<sup>7</sup> (silicate sands being native material, and the most chemically similar to manufactured glass sands). Additionally, no significant difference in sex ratio between nests of different sand types was found, though variability of the sex ratio within each nest was high.<sup>8</sup> A more recent study published in 2008 found that recycled glass cullet maintains the oxygen saturation and temperature levels required in nesting chambers for successful sea turtle embryo development. No significant differences were found among nests composed of native sands and those composed with significant portions of glass cullet.<sup>9</sup>

As noted above, FDEP did approve the use of recycled glass for use in the Broward County Beach Demonstration Project, which commenced in 2004. The intent of this project was to demonstrate the feasibility of using recycled glass cullet as emergency beach renourishment material for erosion “hot spots.” Phase I of the study included geotechnical comparisons of beach sand and processed glass cullet in which samples were analyzed to compare grain size distribution and color, carbonate content, and grain angularity. For all tests, recycled glass cullet was found to be geologically compatible. Additionally, the recycled glass cullet samples were analyzed for bio-contaminants including fecal coliform and other bacteria, lead, mercury, semi-volatile organics (VOCs), petroleum hydrocarbons, and salt. All contaminants were found to be within acceptable regulatory limits specified for beach renourishment materials.<sup>10</sup> To address sea turtle nesting concerns, test plots of glass-sand blends were constructed in upland beach areas of Hollywood Beach, and monitored through spring and summer of 2006. Monitoring results were compared with natural sand plots, and demonstrated little to no abiotic differences between plots of glass-sand blends and natural sands. As in other studies, these results provide further evidence the glass and sand mixtures offer nesting environments equal to those of native sands.

Phase II of the Broward demonstration project included the placement of 3,000 tons of recycled glass cullet directly onto the shoreline. Construction was slated for 2010; however the project faced a series of challenges. Initial material requirements for Phase II represented nearly a month’s supply of glass collected within Broward County and processed by the County’s recyclable materials processor, Waste Management. No storage facility for this amount of material was identified prior to the study. In addition, once glass was delivered to the MRF, ownership transferred from the County to Waste Management.<sup>11</sup> Obtaining glass from other sources increased total projects costs to approximately \$1.5M, nearly double the amount of funding available through grants from the FDEP, the Resource Recovery Board (RRB) and Broward County. After two years of failed discussions with glass processors to secure local or regional processing and supply, the Broward County Board of Commissioners approved reversion of remaining project funds.<sup>12</sup> Together, these challenges put a halt to the Broward

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<sup>7</sup> S.M. Blair, et al., “Evaluation of quartz, aragonite, and carbonate beach compatible sand on nest temperature and success parameters of *Caretta caretta* nests in southeastern Florida, USA,” *Proceedings of the 18<sup>th</sup> International Sea Turtle Symposium* (US Dept. of Commerce, NOAA Technical Memo NMFS-SEFSC-436), 2000, pages 170-180.

<sup>8</sup> D.A. Nelson, et al., “Preliminary Assessment of loggerhead turtle (*Caretta caretta*) nest sex ratios of nests incubated in aragonite sands,” *Proceedings of the 16<sup>th</sup> Annual Symposium on Sea Turtle Biology and Conservation* (US Dept. of Commerce, NOAA Technical Memorandum NMFS-SEFSC-412), 1998, pages 110-112.

<sup>9</sup> Christopher Makowski, et al., “Abiotic suitability of recycled glass cullet as an alternative sea turtle nesting substrate,” *Journal of Coastal Research*, June, 2008, pages 771-779.

<sup>10</sup> Peter Foye, “Beach in a Bottle,” *Waste Age*, July, 2005, pages 20-22.

<sup>11</sup> Phil Bresee, “Beached Glass,” *Resource Recycling*, February 2007, pages 1-3.

<sup>12</sup> Broward County Commission Regular Meeting (September 14, 2010)1-2.

County Demonstration Project. However, the project did succeed in proving the environmental feasibility of recycled glass use as beach renourishment material. Despite the recent lapse of the project permit provided by FDEP, local interest in the project has picked up. Broward County is currently in the process of procuring recyclables processing with a new service provider, and as such may find a solution to the processing and supply issues that ultimately doomed the Broward County Demonstration Project.

Currently, beach renourishment in Key West is performed by private contractors permitted by the FDEP. Recent renourishment projects in Key West utilized sands from the Ortona sand mine located in Moore Haven, Florida and owned by E.R Jahna. The material is transported and applied by American Earth Movers.<sup>13</sup> The use of recycled glass as beach renourishment material in Key West offers the potential for increased waste diversion for the City, and savings in transport costs for the County's contractor. Because the City does not own processing equipment or have readily available storage space, a public-private partnership would likely be required. An agreement with Waste Management or Toppino & Sons could provide a local solution to processing and storage problems, while the sale of recycled materials for renourishment materials could provide incentive for the private sector in the form of revenue. Using glass cullet produced locally as beach renourishment material would also serve to increase local "green" branding efforts.

## Construction Uses

Glass is a product of the supercooling of a melted liquid mixture consisting primarily of sand (silicon dioxide) and soda ash (sodium carbonate) to a rigid condition, in which the supercooled material does not crystallize and retains the organization and internal structure of the melted liquid. When waste glass is crushed to sand-like particle sizes, similar to those of natural sand, it exhibits properties of an aggregate material.<sup>14</sup>

Type S Asphalt Concrete is a specific aggregate concrete in which a bituminous mixture replaces cement as a binding agent. Per FDOT specifications, recycled crushed glass may be used as a component of the bituminous mixture if it meets certain criteria. However, based on discussions with City staff, asphalt is not manufactured in the Keys.

Embankment fill comprises the lowest zone of construction material in roadway projects and is generally made of sandy soils with some silt or clay. While crushed glass would not be suitable for use in the sub grade or base layers, FDOT has confirmed that waste glass is a viable material for embankment fill.<sup>15</sup> Supporting research conducted by the Florida Institute of Technology (FIT) demonstrates that crushed waste glass is an acceptable highway fill material as it can be cleaned at a reasonable cost with negligible environmental impact, and has excellent highway engineering properties. In this study, crushed waste glass was successfully mixed with limerock, cemented coquina and reclaimed subgrade, all of which exhibited adequate highway engineering characteristics.<sup>16</sup> FDOT concurs with this conclusion per results from repeat load

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<sup>13</sup> Jay Gewin, Utilities Manager City of Key West, communication via email, May 2012.

<sup>14</sup> U.S. Department of Transportation Federal Highway Administration, *User Guidelines for Waste and Byproduct Materials in Pavement Construction, Waste Glass* (FHWA-RD-97-148), 2011, page 1.

<sup>15</sup> John Shoucair, P.E., FDOT State Materials Office, personal communication August, 2011.

<sup>16</sup> P.J. Cosentino et. al., "Developing Specifications for Waste Glass, Municipal Waste Combustor Ash & Waste Tires as Highway Fill Materials Final Report Volume 2," *National Technical Information Service*, April 1998, pages 29-37.

testing via Resilient Modulus testing (AASHTO T 307). It should be noted that FIT's research cautioned against the inhalation of glass dust during roadway construction.

Glass cullet can be used for utility trench bedding and backfill, as well as for construction of drainage facilities such as drainage blankets, french drains, foundation drains, and behind retaining walls. Cullet content up to 100 percent can be used for backfill up to the last two feet below the final grade. Depending on the loading conditions on the backfill area, the last two feet of the backfill may have cullet contents varying from 15 to 100 percent. Conventional materials include granular soils and geosynthetics (geotextiles and geonets). Design considerations for these conventional materials and glass cullet include compaction, permeability, thermal conductivity, filtration, and puncture resistance. In drainage applications, a geotextile filter should be used to separate glass cullet from the surrounding soil and to prevent clogging of the drain, similar to conventional aggregate filtration requirements. The 1991 National Standard Plumbing Code allows the use of glass crushed to 3/4-inch as aggregate in storm drains, which are used to drain water away from the parts of the buildings that are below ground.<sup>17</sup>

## Processing Requirements

When used in construction or beach applications, glass must be crushed and screened to produce an appropriate design gradation. Glass crushing equipment normally used to produce a cullet is similar to rock crushing equipment including hammermills, rotating breaker bars, rotating drum and breaker plate, and impact crushers.<sup>18</sup> Because MRF glass crushing equipment has been primarily designed to reduce the size or density of cullet for transportation purposes and for use as a glass production feedstock material, the crushing equipment used in MRFs is typically smaller and uses less energy than conventional aggregate or rock crushing equipment. Successful production of glass aggregate using recycled asphalt pavement (RAP) processing equipment (crushers and screens) has been reported.<sup>19</sup> Magnetic separation and air classification may also be required to remove any residual ferrous materials or paper still mixed in with the cullet. Additionally, pulverized glass intended for beach application requires decontamination, usually via high temperature exposure in a burner or dryer, and subsequent screening.

Due to the relatively low glass-generation rates from small communities, stockpiles of sufficient size need to be accumulated to provide a consistent supply of material in order for glass use to be practical in large-scale construction applications.<sup>20</sup> However, the infrequent nature of beach renourishment activities may provide the necessary time to acquire sufficient stockpiles to mitigate erosion "hot spots."

## Recycled Glass Mulch

As public awareness concerning recycled consumer products increases, "Greenscaping" has become a popular trend. Greenscaping encompasses a set of landscaping practices that can improve the health and appearance of lawns and gardens while protecting and preserving

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<sup>17</sup> HDR Engineering, "Glass Cullet Utilization in Civil Engineering Application," *Civil Engineering Applications Nebraska State Recycling Association*, June, 1997, pages 12-13.

<sup>18,18,19</sup> FHWA-RD-97-148, 2011, page 1.

natural resources.<sup>21</sup> One Greenscaping method includes the use of glass mulch for landscaping purposes on a variety of scales.

The sharp edges of the glass are eliminated when producing glass mulch. The glass is processed with pulverizing equipment that produces cullet with rounded edges, or with crushing equipment and subsequent tumbling. Depending on the size of the cullet, it can be used as fill in golf sand traps or as decorative material in residential or public spaces. Currently, landscaping companies market glass mulch from \$0.80 - \$4.32 per pound, depending on color and quantity.<sup>22</sup> When used as a landscape cover, glass mulch touts some benefits over traditional materials including increased water permeability. As such, less water is required to maintain landscape plants. However, it should be noted that unlike traditional organic mulch, glass mulch provides no nutrient benefits to soils.

Municipal production of recycled glass mulch occurs in a number of regions throughout the United States. Two Florida programs and one North Carolina program are discussed below.

**Polk County:** Polk County previously processed glass to produce a glass mulch product. First, glass was sorted from other materials at the county's Recovered Materials Processing Facility (RMPF) using a trammel with 1-inch openings, after which the county used a G.A.M.E. Manufacturing glass crusher to reduce the cullet in size from 1-inch minus down to the size of beach sand with little or no sharp edges. The glass crusher was rated at 10 ton per hour, though with regular use this rate decreased to 6-8 tons per hour depending on the quality of the material input. The crusher required maintenance after every 8-10 hours of use, which involved cleaning, lubrication, and screen inspection. Screen replacement was needed after every 20-30 hours of use. Screens made out of high wear-resistant metal alloys for longer screen life are available, but the screen life to cost ratio for these was such that it was more cost-effective to utilize cheaper screens and change them more regularly. Polk County processed approximately 500 tons of glass per month, of which residents utilized 1 to 2.5 tons of glass mulch per month for landscaping purposes and the rest was used as landfill road base material.<sup>23</sup>

**Sumter County:** A project was developed by Sumter County to demonstrate the benefits of processing mixed color glass at the local level to help divert a recyclable material from disposal, and to eliminate the costs of transporting a low-value material to distant markets. Sumter County purchased a G.A.M.E. model GM-1 system, which produces a consistently sized aggregate product in a "one-pass" operation that promotes efficiency and lowers maintenance costs. The unit had interchangeable screens (3/8" and 3/16") to control product size, with RPM adjustments to the sander unit shaft allowing for additional size control. Some operational problems were encountered with the GM-1 glass processing system. These included material jams in the hopper, debris falling from the conveyor, the trommel causing a glass material diversion and loss of material, dust collection system malfunctions, and excessive wear on tines and screens. It was determined that moisture in the glass was a major problem and was causing some of the excessive wear on the equipment. Sumter County constructed a pole barn over the crushing unit and glass storage bunker to substantially reduce moisture problems. The manufacturer made several modifications and upgrades and also provided additional instruction in proper equipment maintenance. Specific modifications included installation of ball vibrators

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<sup>21</sup> EPA Greenscapes ([www.epa.gov](http://www.epa.gov)).

<sup>22</sup> American Specialty Glass Pricelist ([www.americanspecialtyglass.com](http://www.americanspecialtyglass.com)).

<sup>23</sup> Ed Sparks, Polk County Waste Resource Management Division, personal communication, January 2012.

to shake loose and prevent buildup of clumps of moist crushed glass in the screens and tines. Additionally, a portable compressor unit was procured for pressure cleaning the equipment as needed. Because of the limited volume of glass collected, traditional construction material markets were not feasible due to the need for consistently large quantities. Therefore, Sumter County screened a portion of the material for in-house sandblasting operations and utilized the remainder for landscaping on county property.<sup>24</sup>

**Dare County, North Carolina:** A program provided by the Dare County Public Works Recycling Division of North Carolina, was initiated in response to state legislation that requires bars and restaurants which serve alcoholic beverages to prepare glass bottles for recycling. The county’s recycling center processes about 600 tons per year of glass, which is used by local residents and governments as supplementary material for parking areas, for use in flower beds, and as roadbed material. An economic motive for the program is the area’s disposal rate of about \$70 per ton.<sup>25</sup>

For such a program to be feasible for Key West, location, storage and equipment concerns must be addressed. One possible location for processing equipment and production is a small building located at the City’s Transfer Station, previously used for cardboard recycling. Further research is needed to evaluate whether this building contains adequate space for processing equipment and storage. Equipment necessary to produce glass mulch is available with a variety of processing capacities. Table 2 provides examples of single-step processing equipment model specifications and costs; however, used equipment is also generally available.

**Table 2: Examples of Glass Recycling Equipment Models**

Model:	Cost*	Capacity	Products	Operation Time**	Size:
Andela GP05	\$ 82,000	1-2 tons/hr	3/8" non-sharp gravel	4.5 hr, 5 days per week or 8 hrs, 3 days per week	7'5" x 5'8" Adjustable height
Andela GP05L	\$ 91,000	1-2 tons/hr	3/8" non-sharp gravel 1/8" sand	4.5 hr, 5 days per week or 8 hrs, 3 days per week	8'8" x 5'8" Adjustable height
Andela GPT-1	\$ 154,000	5 tons/hr	3/8 – 1/8" non-sharp gravel 1/8" sand	1 hr, 5 days per week or 5 hr, once weekly	14'x 5'4"x 9'

\* Cost includes installation supervision, startup and maintenance training.

\*\*Operation time is the time that would be required to process commercial glass if 50% of commercial glass generated in the City were recovered (1,200 tons per year).

## 4. Next Steps

As mentioned previously, glass would need to be separated from other recyclables to take advantage of a local end-use market. Because residential recyclables are collected in a single stream, the commercial sector, especially bars and restaurants, offers the most likely source of

<sup>24</sup> TIA Solid Waste Management Consultants, *Processing Mixed Cullet for Local Alternative Markets*, December 2000.

<sup>25</sup> Resource Recycling, *Glass Recycling Undergoes Change* (<http://resource-recycling.com/node/1100>), March 2011.

segregated glass. The City does not have direct control over this recycling stream because State law does not allow local governments to give any company the exclusive right to collect commercial recyclables. However, because of location, the City's collection service provider likely collects most, if not all, of the commercial glass currently recycled.

Glass is one of the lowest value recyclable commodities, but diverting it from disposal is beneficial to the City. It is one of the heaviest (i.e., densest) recyclable materials, and for every ton diverted from disposal, the City saves approximately \$70 in transport and disposal fees. Finding a local end-use for glass would benefit the City's collection contractor, which no longer would have to pay to transport glass collected for recycling out of the Keys to be processed. Therefore, it is mutually beneficial for the City and its collection contractor to further explore a local end-use for recovered glass.

Because of its proximity, a partnership with Toppino & Sons is worth exploring. Further communication is needed to determine if the company has the capacity to process recovered glass to specifications for use in local projects requiring FDOT or FDEP approval. In addition, further discussion is needed to determine if the amount of recovered glass that might be provided by the City is sufficient for Toppino & Sons to utilize this material in construction or beach renourishment applications.

Alternatively, a more detailed analysis could be conducted of the cost-effectiveness of investing in a glass crushing system to produce glass mulch, as well as to assess local demand for this product.