ESTIMATING THE ENVIRONMENTAL BENEFITS OF RECYCLING CONCRETE WASHOUT

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EXECUTIVE SUMMARY

The Department of Environmental Engineering Sciences through the Sustainable Materials Management Research Laboratory at the University of Florida (UF) assisted Diligent Services, Inc. (Diligent) by providing useful information on the benefits associated with their recycling concrete washout process. When materials are recovered and recycled in place of virgin resources this typically results in large environmental offsets, such as a reduction in greenhouse gas (GHG) emissions or energy use. The UF team used life cycle assessment (LCA) tools and mass data to estimate the environmental benefits of recycling the concrete washout processed by Diligent since 2017 to March 2021.

This report outlines the methods and results associated with the LCA environmental benefits of recycling concrete washout, along with an overview of how concrete washout it generated, the related rules and regulations, current practices of managing concrete washout, the recycling process of concrete washout, and a review of concrete washout best management practices. This report is valuable to not only Diligent, but also decision makers faced with determining how to more sustainability manage their concrete washout.

Since 2017 to 2020, Diligent has collected 63,823 tons of concrete washout from eight south Florida counties; and monthly they collect an average of approximately 2,000 tons. The two recycling approaches followed by Diligent is to collect and haul the concrete washout to: 1) an aggregate crushing facility, where concrete washout is mostly used to produce new concrete; and 2) a lake, where it is used as a structure fill material. Diligent has recycled 100% of their collected concrete washout through the crushing facility 22,063 tons and 41,760 tons as lake fill material. The recycling approach varies among projects and mostly depends on geographic proximity to closest recycling outlet.

The environmental benefit of recycling concrete washout resulted in a GHG emissions savings (or offset) of -5,649 tCO_2eq. and energy savings of -55,023, 364 MJ (results correspond to the 63,823 tons recycled). The analysis was conducted where concrete washout recycled by crushing was assumed to offset concrete production and when recycled as lake fill it offset virgin aggregate mining and processing. The environmental results revealed that although there was more concrete washout recycled as lake fill, the recycling crushing resulted in a greater environmental savings because concrete production has a greater environmental burden than aggregate mining/production. The environmental benefit in alternative metrics was also assessed. The GHG emissions savings was equivalent to the GHG emissions from 1,228 passenger vehicles driven for one year; 634,658 gallons of gasoline consumed; 240,362 trash bags of waste recycled instead of landfilled; 680 homes of energy use for one year; and the GHG emissions saved when 6,922 acres of US forests sequester carbon for one year.

Another environmental benefit of recycling concrete washout is its impact on increasing the local recycling rate. Florida currently has a 75% recycling rate goal, and each Florida county is required to report the various materials recycled in their county. After reviewing those reports, we found rarely any counties include the mass of concrete washout. Since concrete washout has a high density, reporting the recycled mass is advantageous in helping meet the goal.

Various reports and discussions with Diligent were used in compiling a list of potential management approaches for collecting and recycling concrete washout. The approaches included varying levels of management ranging from worst to best. The worst management approach would be to directly washout concrete from trucks and equipment onto the ground where it is left as is or later landfilled. The best management approach, which is what is done by Diligent, is to collect concrete washout in a water-tight sealed container lined with a corrosive layer and recycle 100% into concrete. Figure ES-1 displays an example worst and best management collection approach.

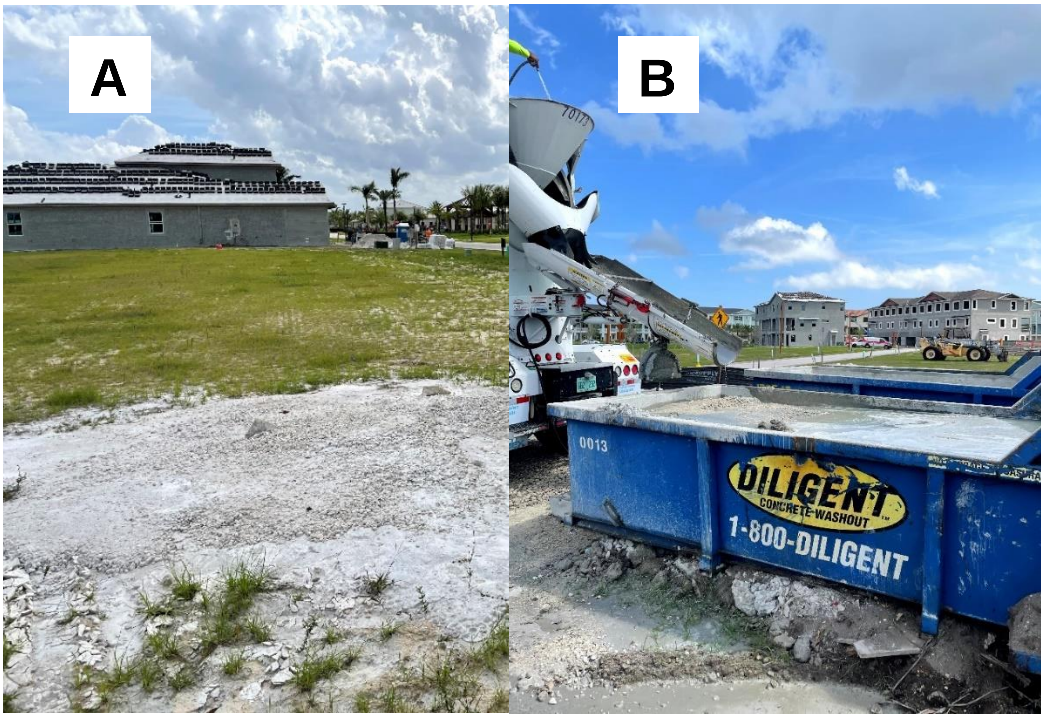

Figure ES-1. Concrete being washout out: A) directly on the ground which is the worst management collection approach and; B) into a best management collection container which will be transported with about 100% clean concrete washout that will be recycled/reused by crushing or as a lake fill material.

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1.1 Scope of Work

The University of Florida (UF), through a contract by Diligent Services, Inc. (Diligent), conducted this study in order to map the flow of concrete washout managed by Diligent and to estimate the benefits of recycling concrete washout. Motivation for this work was to provide Diligent a useful document that summarizes the environmental, economic, and policy impact of recycling concrete washout.

1.2 Task Overview

The following tasks methodologies and results will be discussed in this report:

A. Conduct on-site visits at the Diligent Services, Inc. concrete washout facilities and processes to learn the approaches used to measure the mass of the recycled concrete washout. Compile mass estimates since the operation began, on the mass of concrete washout produced and the mass recycled. Use the data from the on-site visits and tracked masses to produce a schematic or illustrative flow-chart of the mass flows managed by Diligent Services, Inc.
B. Collect data from existing LCA tools or literature on the environmental impacts of recycling concrete or concrete washout. Use the collected data to estimate the benefit to reducing greenhouse gas emissions, energy use, landfill space use, and other similar environmental metrics.
C. Conduct an audit of all available management approaches for managing concrete washout, including evaluating potential reuse or recycling such as beneficial reuse for road fill material. Produce a simplified schematic that summarizes the potential best management practices and discusses each of their advantages and disadvantages either related to economical or environmental impacts.
D. Create a short user-friendly document that is stylized using creative designs and contains content on the previous tasks, including the descriptive schematic of the concrete washout management and recycling system, a discussion of current and potential best management practices, and the historic environmental benefits of Diligent Services, Inc. recycling concrete washout.

1.3 Report Outline

In this report, Section 2 provides an overview of how and where concrete washout is typically generated. Section 3 discusses any related rules or regulations pertaining to concrete washout. Section 4 reviews the Diligent process of collecting and recycling concrete washout. Section 5 includes quantifiable mass flows of the concrete washout collected and recycled by Diligent. Section 6 includes the estimates for the environmental benefits of recycling concrete washout. Section 7 describes several best management approaches of concrete washout collection and recycling.

2 OVERVIEW OF CONCRETE WASHOUT

Concrete contains Portland cement, water, and aggregate materials. Portland cement concrete is often produced in large amounts and used for building foundations, structural components, roads, and bridges. The ingredients of Portland cement include mixtures of limestone and clay which are used as sources of calcium, aluminum, silicon, iron. The cement is hydrated with water to serve as an adhesive for the other components of concrete. The Portland cement concrete is manufactured at concrete batch plants, where the aggregates, cement and water are mixed together to meet an engineered product design. The concrete is then distributed to construction sites or concrete product manufacturing plants via ready-mix concrete trucks.

At the conduction site, the concrete is poured using chutes or hoppers. Figure 2-1 shows a concrete hopper used at a construction site in south Florida. After concrete pours are completed any remaining concrete in the chutes, hoppers, and similar equipment must be washout out to ensure the concrete does not harden and damage the equipment. Figure 2-2 pictures a concrete ready-mix truck operator washing out the chute into a collection container. The concrete that is washed out is referred to as concrete washout or concrete washwater. Figure 2-3 provides a visual for typical concrete washout from a construction site. The concrete washout contains coarse aggregate fractions mixed with water to form a slurry, as seen in Figure 2-3. The slurry contains toxic metals, and is caustic/corrosive since it has a high pH (12).

Figure 2-1. Concrete hopper pictured at a construction site.

Figure 2-2. Concrete ready-mix truck operator washing out chute and truck.

Figure 2-3. Concrete washout collected.

3 RELATED RULES AND REGULATIONS

The US Environmental Protection Agency (EPA) provides guidelines on recommended best management practices of collecting and recycling concrete washout (US EPA, 2012). The guidelines are specific to different fractions of concrete washout materials (i.e., washwater, cement fines, fine aggregate, coarse aggregate, hardened concrete, and unused wet concrete). Example suggested uses of recycled materials includes reused as a ready mixed concrete ingredient or reuses ad an ingredient of precast concrete products like highway barriers or riprap.

The EPA does not provide specific concrete washout rules and regulations on its collection or management. However, if concrete washout were to be discharged to the environment it must comply with the National Pretreatment Standards of Prohibited Dischargers (40CFR 403.5) (US EPA, 2012).

The slurry to be discharged must comply with 40CFR 403.5 because it has adverse environmental and human health if discharged directly into the environment. The high pH is beyond the safe range of pH for aquatic life (pH 6.5-9), which can be toxic to fish gills and eyes and can interfere with reproduction. Likewise, the environmental impact to the local soil chemistry can cause inhibited plant growth and contaminate groundwater.

The EPA recommends treating the liquid portion by either filtering it to remove the grit/sand and reduce the pH, or to treat offsite at a wastewater treatment plant, or to retain the concrete washout until the water evaporates. For concrete washout collection, the EPA recommends siting the metal and vinyl containers/washout pit in locations nearby the concrete pour site but they should be at least 50 feet away from storm drains, open ditches, or waterbodies. They also recommend using gravel or rock to cover the ground where the containers are placed and to have signage for the concrete washout areas. These areas should be inspected daily and after rain events to ensure there are no leaks. In cases where the containers are at 75% capacity they recommend vacuuming the liquid fraction or retaining the slurry until it evaporates.

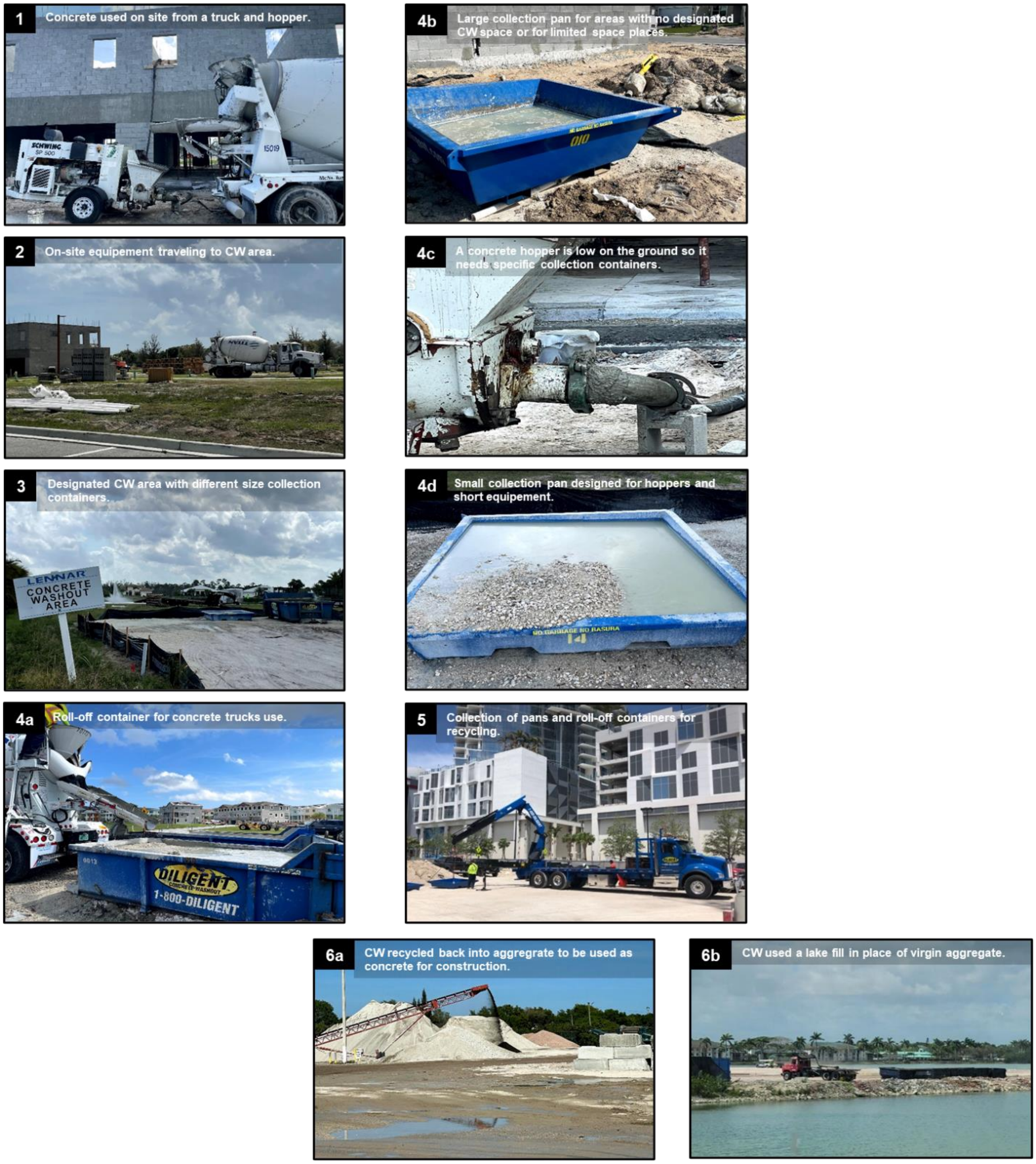
Local government county, city, and state regulations on concrete washout vary nationwide, however, most do not have any concrete washout specific rules and regulations and refer to the EPA recommendations for best management practices. Concrete washout is indirectly regulated through stormwater discharge rules. In Florida, concrete washout must comply with Florida Department of Environmental Protection (FDEP) Directive 923 and Section 403.121, Florida Statue (FDEP, 2013). In a complementary document, the guidelines for NPDES stormwater violations are described (FDEP, 2013).

4 DILIGENT CURRENT PRACTICE OF MANAGING CONCRETE WASHOUT

Diligent complies with the EPA recommendations for best management practices of concrete washout collection and recycling and the FDEP rules related to NPDES stormwater management. In addition, recycling concrete washout through Diligent provides LEED certified points to construction operations. Diligent provides water-tight sealed containers for concrete used in road building, construction, and manufacturing. The containers also accommodate various types of concrete products including cementitious material, plaster, grout, concrete stone veneer, brick, CMU block, block pavers/concrete walling, stucco, pump and read-mix washout, shotcrete, pool plaster, rubble, and mortar. The two collection containers types provided by Diligent are roll-off bins and pans. The size of a roll-off bin is 7 yd^3, which allow for approximately 50 ready-mix concrete trucks to safely dispose of concrete washout. In space-limited construction sites Diligent provides two sizes of pans that allow for builders to comply with local and federal required stormwater pollution prevention plans (SWPPP) and to manage their concrete washout more sustainably. The smallest size pan was designed for smaller equipment (e.g., hoppers and hoses) concrete washing.

At a construction site, once the container is filled to its maximum capacity it is hauled to a nearby recycling facility or to the lake. Figure 4-1 shows a ready-mix concrete truck washing out the concrete into a roll-off container at a residential construction site. The containers are maintained and inspected daily to ensure any non-concrete materials are removed, no leaks or maintenance is required on the container, and the container is not over-filled. A container may reach its capacity from anywhere from several times a day/week to once every week or so, or once every month, and once every six months. The concrete washout is retained in the container for several days until the water has evaporated. At the lake the concrete washout is crushed and used as fill material, replacing virgin aggregate fill material. The overall process of Diligent’s concrete washout collection and recycling are detailed in a step-by-step schematic in Figure 4-2.

Figure 4-1. Concrete washout placed in specific fabricated container which will be collected and recycled.



1 Concrete used on site from a truck and hopper.

2 On-site equipement traveling to CW area.

3 Designated CW area with different size collection containers.

4a Roll-off container for concrete trucks use.

4b Large collection pan for areas with no designated CW space or for limited space places.

4c A concrete hopper is low on the ground so it needs specific collection containers.

4d Small collection pan designed for hoppers and short equipement.

5 Collection of pans and roll-off containers for recycling.

6a CW recycled back into aggregrate to be used as concrete for construction.

6b CW used a lake fill in place of virgin aggregate.

Figure 4-2. The collection and recycling process of concrete washout using a specifically fabricated collection container. The collection to recycling process is shown starting with photo 1 to photos 6a/6b.

5 MASS FLOW OF RECYCLED CONCRETE WASHOUT

The mass flow of collected and recycled concrete washout by Diligent from March 2017 to December 2020 were mapped on a county basis. The mass data were retrieved from Diligent on a per project site basis which were then summed based on the county the project site originated from. The mass flows of collected and recycled concrete washout are mapped in Figure 5-1. A total of 63,823 tons of concrete washout were collected by Diligent from eight south Florida counties (Indian River, Okeechobee, St. Lucie, Martin, Palm Beach, Broward, Miami-Dade, and Monroe). The monthly and annual collected mass of concrete washout are shown in Figures 5-2 and 5-3, respectively. The majority of the concrete washout was collected from construction projects in Miami-Dade county, followed by Broward and Palm Beach counties. Of the collected concrete washout, most was recycled as lake fill material in Broward and Miami-Dade counties. Out of the eight counties Palm Beach and Miami-Dade county projects had more concrete washout recycled at a recycling crushing facility, primarily because of the proximity of the facilities to the project sites.

Greater details on the recycling management of the concrete washout collected from each county are shown in Figure 5-2. Based on Figure 5-2, concrete washout collected from Palm Beach, Martin, Indian River, and Okeechobee county projects were recycled through recycling crushing, while Monroe and Broward were recycled through lake fill. The city the recycling management is located and the corresponding percent that recycling crushing or lake fill recycling is shown in Figure 5-3. The three major cities where recycling crushing and lake fill is managed is at Miami, Davie, and West Palm Beach (Figure 5-3), where recycling crushing is the major recycling management at West Palm Beach, and lake fill is the major recycling management at Davie.

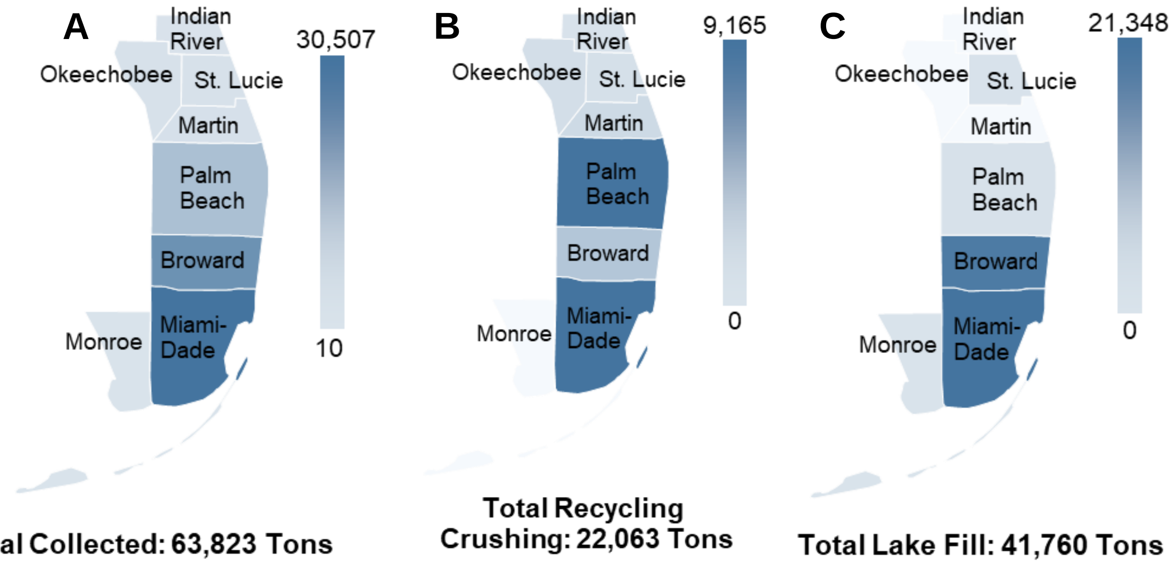


Figure 5-1. Geographic distribution of A) the mass of concrete washout collected from the various construction project sites in south Florida by Diligent from March 2017-December 2020; B) the mass of concrete washout recycled through crushing to produce aggregate; and C) the mass of concrete washout recycled as lake fill material.

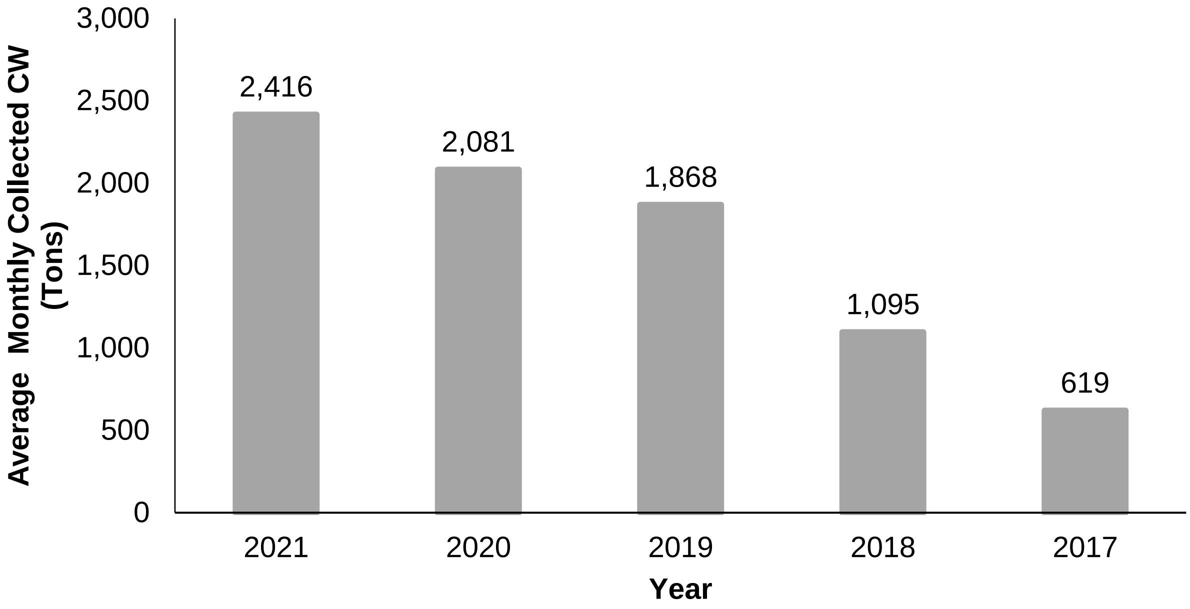


Figure 5-2. The average monthly collected mass of concrete washout from 2017 to 2021 for Diligent. Results are using data in Table A-4.

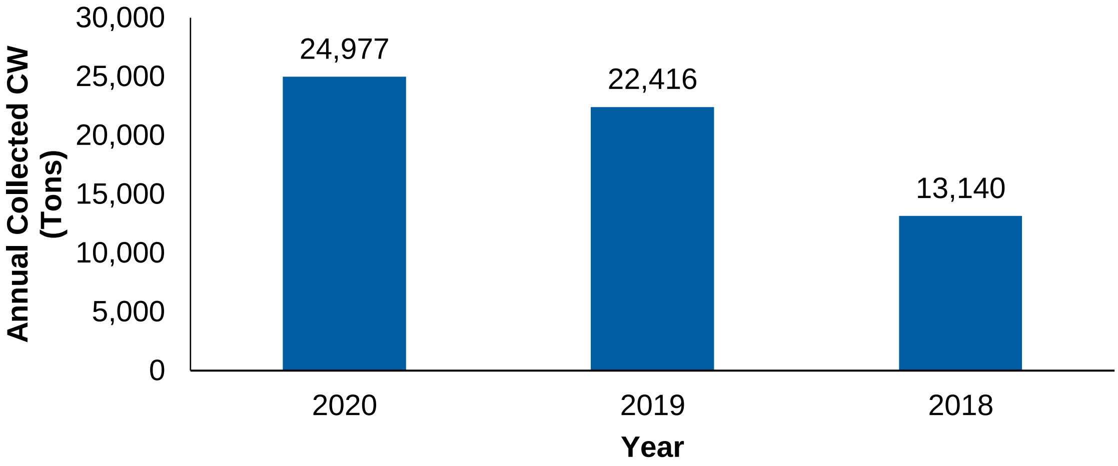


Figure 5-3. The annual collected mass of concrete washout from 2018 to 2020 for Diligent. Results are using data in Table A-4.

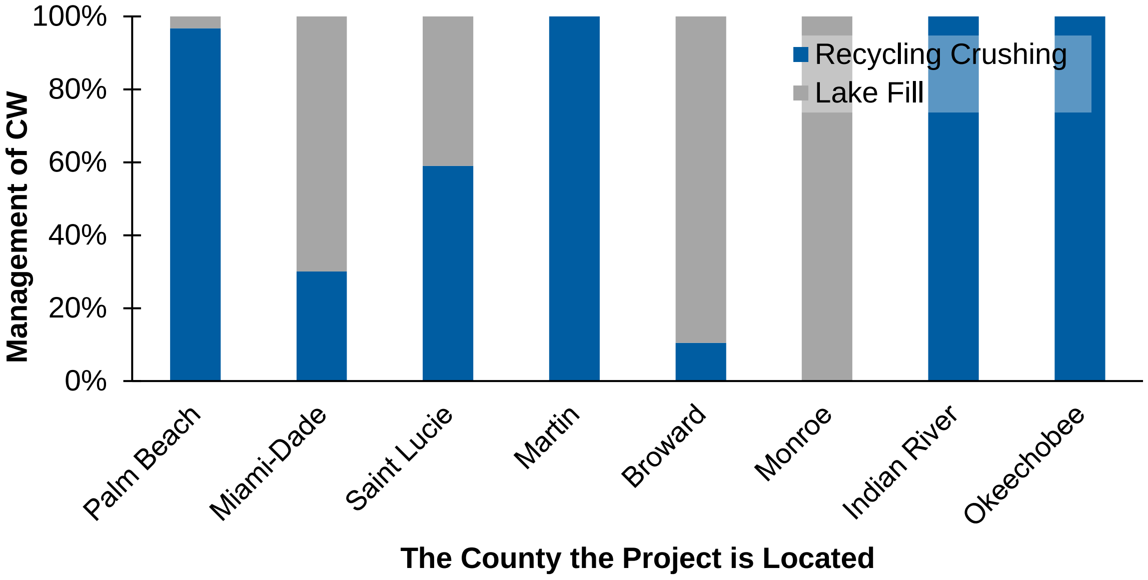


Figure 5-4. The corresponding recycling management of concrete washout by either recycling crushing to produce aggregate or lake fill for each county. Results are using data in Table A-2.

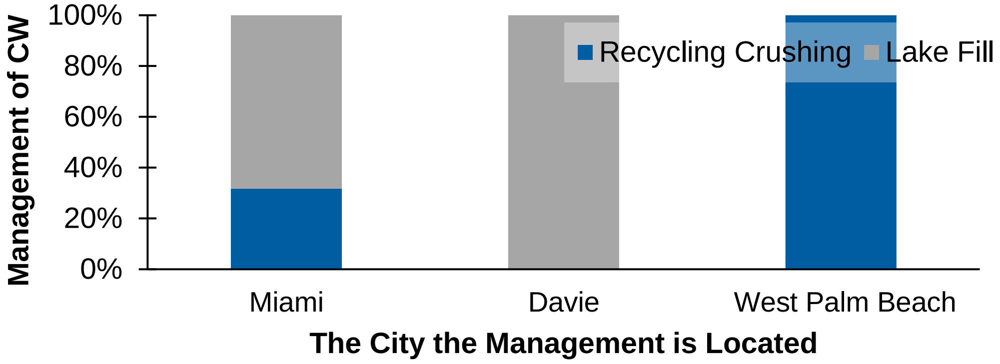


Figure 5-5. The location of where concrete washout management is recycled as either recycling crushing to produce aggregate or lake fill material. Results are using data in Table A-3.

6 BENEFITS OF RECYCLING CONCRETE WASHOUT

6.1 Environmental Benefits

Recycling provides a source of materials that would otherwise have to be mined from the earth. Aggregate produced from crushing concrete washout provide a substitute for virgin rock sources and they offset some of the resources demand needed to extract the virgin materials from the earth. One commonly used method to understand and quantify the environmental benefit of recycling materials, is through an LCA study. In an LCA all the flows of energy, materials, and waste are mapped for each life cycle stage of material, including mining, processing, manufacturing, and end-of-life management. Replacing virgin materials with recycled materials has a results in decreasing greenhouse gas (GHG) emissions and saving energy. We provide here the environmental benefits of recycling concrete washout instead of landfilling it as measured in GHG emissions, energy savings, and realistic GHG emissions equivalent metrics.

The environmental benefit was calculated using reported literature and the mass flow data in Section 5. Many previous literature and reports have conducted an LCA to estimate the environmental footprint of producing aggregate and concrete. Six studies were collected, evaluated, and data on the GHG emissions/energy use footprint were extracted. The results are summarized in Table 6-1 on a per ton of either concrete or aggregate basis. The landfilling data is limited and therefore the US EPA WARM (Waste Reduction Model) v15 was used to retrieve the environmental impact of landfilling concrete.

The environmental benefit of recycling concrete washout resulted in a GHG emissions savings (or offset) of -5,649 tCO_2eq. and energy savings of -55,023, 364 MJ (results correspond to the 63,823 tons recycled). The analysis was conducted where concrete washout recycled by crushing was assumed to offset concrete production and when recycled as lake fill it offset virgin aggregate mining and processing. The environmental results revealed that although there was more concrete washout recycled as lake fill, the recycling crushing resulted in a greater environmental savings because concrete production has a greater environmental burden than aggregate mining/production. Figure 6-1 and 6-2 show the GHG emissions and energy use benefits of recycling concrete washout instead of landfilling it.

The environmental benefit in alternative metrics was also assessed. The GHG emissions savings was equivalent to the GHG emissions from 1,228 passenger vehicles driven for one year; 634,658 gallons of gasoline consumed; 240,362 trash bags of waste recycled instead of landfilled; 680 homes of energy use for one year; and the GHG emissions saved when 6,922 acres of US forests sequester carbon for one year. The results for the alternative environmental metrics are shown in Figures 6-3 to 6-7.

Another environmental impact, not measured through LCA, is that every ton of concrete washout recycled results in that quantity of material not buried in the ground through landfilling. Over time, landfills have to expand their capacity, in segments called cells. Diverting concrete washout to recycling facilities instead of to landfills slows down landfill expansion.

Table 6-1. Collected GHG emission and energy factors in metric tons CO_2 equivalents and mega joules per ton of material from published peer-reviewed literature. Studies that did not have available data are shown as blank cells. Detailed data extracted from each study to get these values are shown in Table A-5.

	Aggregate production		Concrete production		Landfilling concrete/ aggregate	
Study	$tCO_2eq./t$	MJ/t	$tCO_2eq./t$	MJ/t	$tCO_2eq./t$	MJ/t
Estanqueiro et al. (2018)	0.02	246				
Korre and Durucan (2009)	0.01					
US EPA (2020)	0.01	116			0.02	285
Martinez-Arguelles et al. (2019)	0.04	530				
Colangelo et al. (2018)		347	0.13			
Yazdanbakhsh et al. (2018)			0.13			
Pradhan et al. (2019)			0.24	1,083		
Average	**0.02**	**310**	**0.17**	**1,083**	**0.02**	**285**

Table 6-2. Recycling concrete washout environmental benefit factors. The average values for aggregate and concrete production were subtracted from landfilling concrete/aggregate in Table 7-1.

Parameter	$tCO_2eq./t$	MJ/t
Recycling - landfilling aggregate (A)	-0.19	-1,368
Recycling - landfilling concrete (B)	-0.04	-595

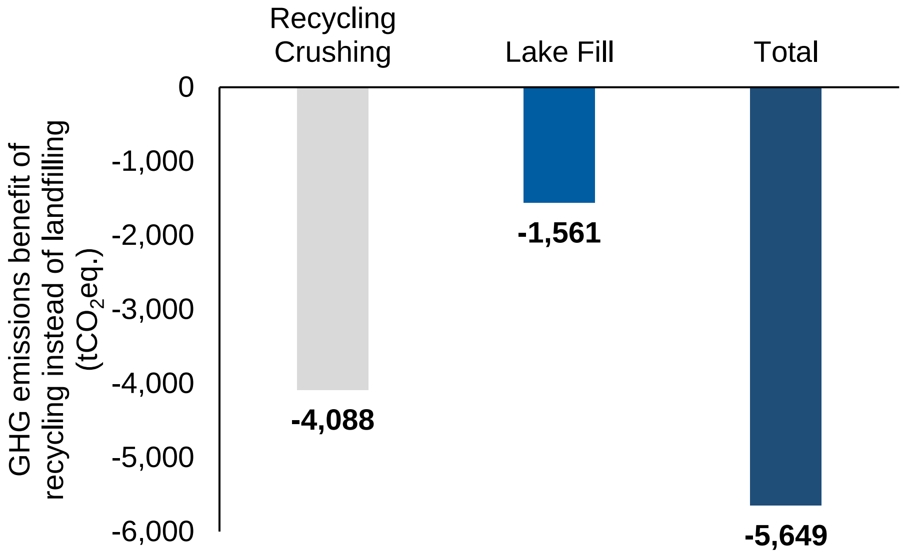


Figure 6-1. The GHG emissions benefit of recycling concrete washout by Diligent. Results for recycling crushing were found by multiplying B (for $tCO_2eq./t$) in Table 7-2 by the mass of total recycling crushing CW in Table A-2. Results for lake fill were found by multiplying A (for $tCO_2eq./t$) in Table 7-2 by the mass of total lake fill CW in Table A-2.

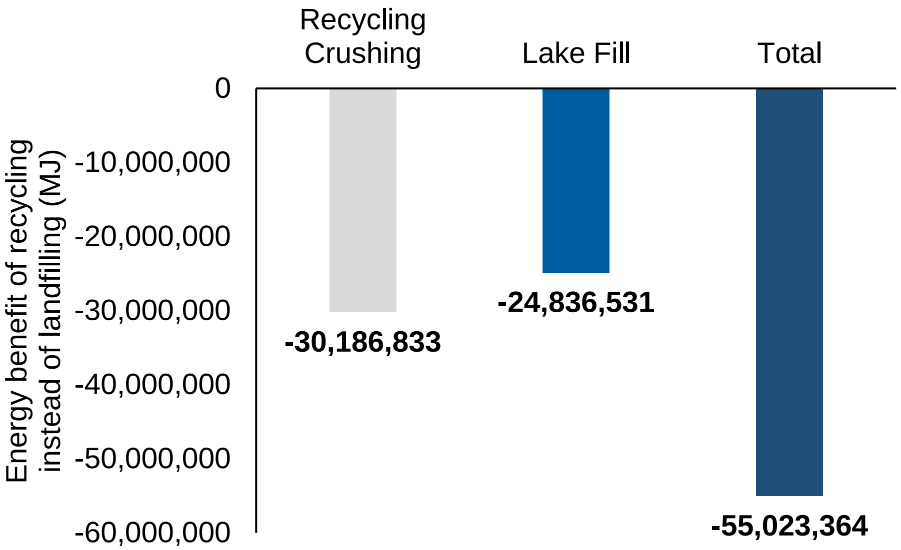


Figure 6-2. The energy benefit of recycling concrete washout by Diligent. Results for recycling crushing were found by multiplying B (for MJ/t) in Table 7-2 by the mass of total recycling crushing CW in Table A-2. Results for lake fill were found by multiplying A (for MJ/t) in Table 7-2 by the mass of total lake fill CW in Table A-2.

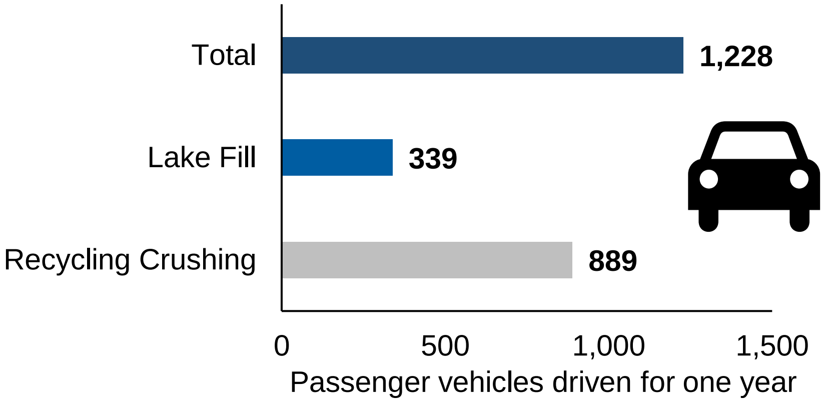


Figure 6-3. The GHG emissions benefit (from Figure 7-1) equivalent value for number of passenger vehicles driven for one year.

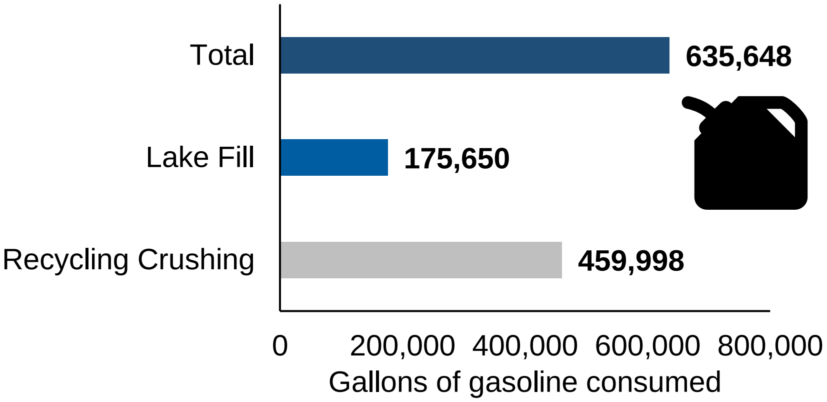


Figure 6-4. The GHG emissions benefit (from Figure 7-1) equivalent value for gallons of gasoline consumed.

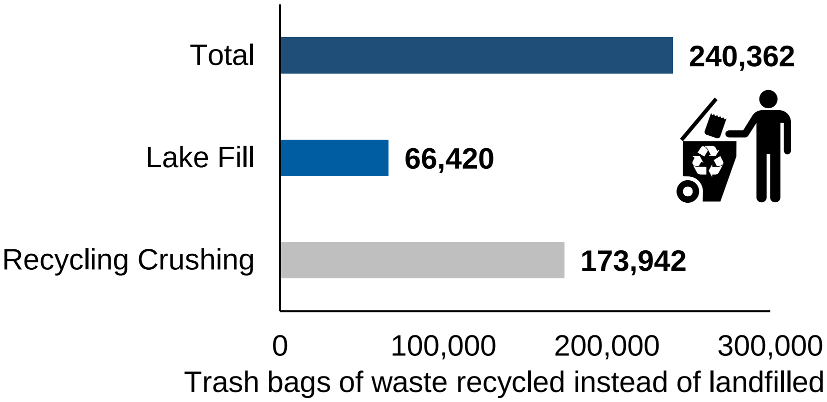


Figure 6-5. The GHG emissions benefit (from Figure 7-1) equivalent value for number of trash bags of waste recycled instead of landfilled.

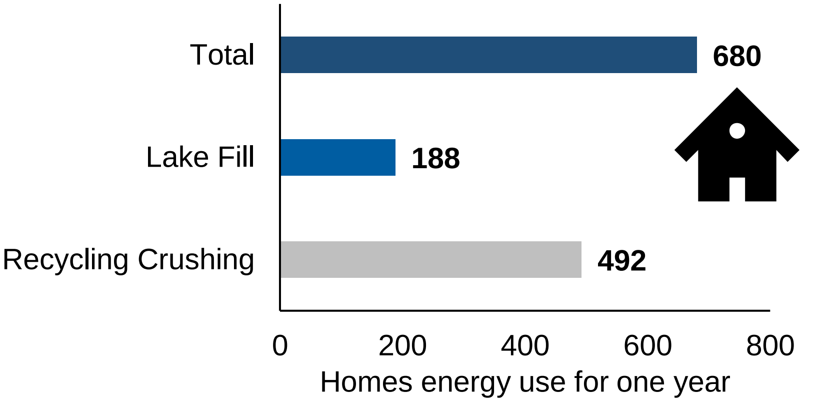


Figure 6-6. The GHG emissions benefit (from Figure 7-1) equivalent value for number of homes energy use for one year.

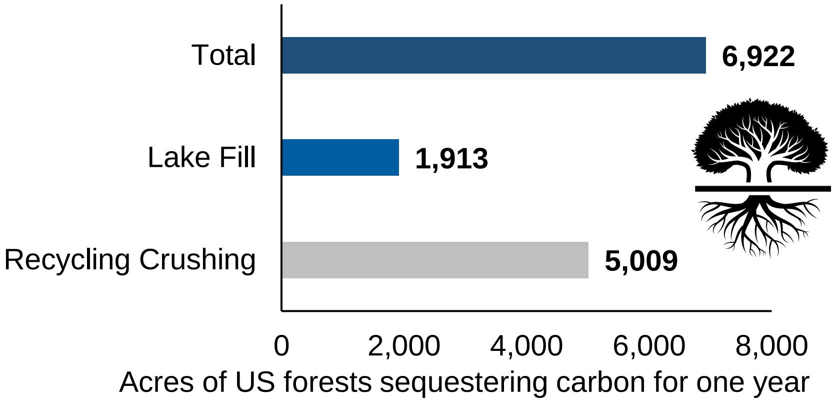


Figure 6-7. The GHG emissions benefit (from Figure 7-1) equivalent value for acres of US forests sequestrating carbon for one year.

6.2 Recycling Rate Benefits

Another environmental benefit of recycling concrete washout is its impact on increasing the local recycling rate. Florida currently has a 75% recycling rate goal, and each Florida county is required to report the various materials recycled in their county. After reviewing those reports, we found rarely any counties include the mass of concrete washout. Since concrete washout has a high density, reporting the recycled mass is advantageous in helping meet the goal. Florida recycling coordinators should contact Diligent annually so that Diligent can provide the total recycled mass of concrete washout per county (like the data shown in Figure 5-1) which can be used in the calculation of recycling rate and in the annual FDEP solid waste county reporting.

7 CONCRETE WASHOUT BEST MANAGEMENT PRACTICES

Various reports and discussions with Diligent were used in compiling a list of potential management approaches for collecting and recycling concrete washout. The approaches included varying levels of management ranging from worst to best. The worst management approach would be to directly washout concrete from trucks and equipment onto the ground where it is left as is or later landfilled. Figures 7-1 to 7-4 show an example of the worst management practice for concrete washout. The best management approach, which is what is done by Diligent, is to collect concrete washout in a water-tight sealed container lined with a corrosive layer and recycle 100% into concrete. Figures 7-5 to 7-7 show the best management practice enforced by Diligent, where minimal to no contaminates are found in the containers and they are sent to recycling facilities. Table 7-1 and 7-2 provide a summary of potential management approaches for collecting and recycling concrete washout along with the advantages and disadvantages of each.

Table 7-1. Summary of potential management approaches for collecting concrete washout.

Best management approach	Description	Advantages	Disadvantages
Collection and disposal approaches			
Collect in designated area	The concrete washout is placed directly on the ground without any lining materials in a designated area of the construction site. The concrete is collected for landfill disposal.	• Can potentially be not costly only for collection (not for disposal)	• Not cost efficient (due to extra labor and machinery used for disposal) • Illegal discharges into waterways can bring fines of $10,000 per day plus $10 per gallon and can reach $27,500 per day if US EPA becomes involved • Difficult to reuse/recycle concrete washout • Caustic and corrosive which can harm aquatic life in neighboring water bodies • Soil chemistry imbalances
Collect on a tarp	The concrete washout is placed on a HDPE liner or tarp on the ground and collected for landfill disposal.	• Can potentially be not costly only for collection (not for disposal)	• Difficult to reuse/recycle concrete washout • Typically tarp surface area capacity is not sufficient to ensure concrete washout is fully contained • Plastic can not be reused/recycled

Collect in roll-off box	A traditional roll-off box is used for concrete washout collection.	• Roll-off containers can easily be hauled to disposal/recycling facility • Concrete washout is semi-contained from leaking which minimizes some adverse environmental impacts	• Roll-off boxes are not water-tight sealed which can result in the liquid portion of the concrete washout to leak into the environment
Collect on a temporary built structure	A section of the site is excavated to produce a graded containment area that is lined with vinyl or hay bales/sand bags are used to make a containment area or a flexible vinyl container is used. Collected concrete washout is either landfilled or recycled.	• Concrete washout is semi-contained from leaking which minimizes some of adverse environmental impacts • Can be inexpensive depending on the structure	• Difficult to collect and transport the concrete washout for disposal/recycling • Difficult to maintain structure • Depending on the structure leaks are common
Collect in specifically fabricated containers	The concrete washout that is collected is filtered to separate the liquid and the coarse aggregate fractions. Then, the concrete washout is placed in a container that is water-tight sealed with a non-corrosive lining layer. The filtered liquid is treated to remove metals and lower pH and discharged back into the environment.	• Cost efficient • Concrete washout is fully-contained from leaking which minimizes all adverse environmental impacts • Easy to transport for recycling/disposal • Nearly 100% of the collected concrete washout can be recycled which reduced disposal costs and increases environmental benefits	• Can be difficult to locate local companies with service • Must maintain that other non-concrete materials are not contaminated container

Table 7-2. Summary of potential management approaches for recycling concrete washout.

Best management approach	Description	Advantages	Disadvantages
Recycling approaches			
Produce aggregate/reuse for concrete production	Concrete washout is crushed to produce fine and coarse aggregate which can be used for new concrete production	• The greatest environmental benefit since it is recycled/reused directly into it's original material (concrete)	• May be costly to crush concrete washout to specific size fraction
Use as a fill material	Concrete washout is crushed to be used as bed foundation material, base or asphalt pavement, or fill material for lakes	• More easy to recycle/reuse since coarse size fraction crushing is easier processes than fine crushing	• Smaller environmental benefit than recycling directly into new concrete

Figure 7-1. Concrete washout directly placed on tarp on ground.

Figure 7-2. Concrete washout placed directly on ground; this is the worst management collection approach.

Figure 7-3. Concrete washout disposed directly on a tarp on the ground.

Figure 7-4. Concrete washout placed on ground and placed in best management container.

Figure 7-5. Concrete washout container filled with some contaminants.

Figure 7-6. Concrete washout collection container in a construction site with limited space.

Figure 7-7. Concrete washout recycling facility where it is crushed and used/reused as aggregate for new concrete.

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APPENDIX

Table A-1. The mass of collected concrete washout from 2017 to 2020 by geographic project location.

Project County	Collected Concrete Washout (Tons)
Palm Beach	9,476
Miami-Dade	30,507
Saint Lucie	398
Martin	712
Broward	22,263
Monroe	10
Indian River	88
Okeechobee	368
Total	**63,823**

Table A-2. The mass of concrete washout recycled by either recycling crushing or lake fill from 2017 to 2020 by geographic project location.

	Collected Concrete Washout (Tons)	
Project County	Recycling Crushing	Lake Fill
Palm Beach	9,165	311
Miami-Dade	9,160	21,348
Saint Lucie	235	163
Martin	712	
Broward	2,336	19,928
Monroe		10
Indian River	88	
Okeechobee	368	
Total	**22,063**	**41,760**

Table A-3. The mass of concrete washout recycled by either recycling crushing or lake fill from 2017 to 2020 by geographic location where the recycling was conducted.

	Collected Concrete Washout (Tons)		
Destination Type	Miami	Davie	West Palm Beach
Recycling Crushing	9,086		12,978
Lake Fill	19,509	22,252	
Total	**28,594**	**22,252**	**12,978**

Table A-4. The mass of concrete washout collected annually and monthly from 2017 to 2021 (to date March 2021).

Date	Collected Concrete Washout Annually	Collected Concrete Washout Monthly
2021	7,247	2,416
2020	24,977	2,081
2019	22,416	1,868
2018	13,140	1,095
2017	5,569	619

Table A-5. Detailed collected GHG emission and energy factors in metric tons CO_2 equivalents and mega joules per ton of material from published peer-reviewed literature. The functional unit refers to the mass modeled, the resulting emission and energy factors were calculated by dividing the study energy and GHG emissions footprints by the functional unit. In some cases, several conversion factors were used to produce the $tCO_2eq./t$ and MJ/t.

Paper	Functional Unit	Material	Value	Unit	Data for:
Colangelo et al. (2018)	2,400 kg	Electric energy consumption	1.85	kWh/t	Extraction of natural raw material and to the production of **natural aggregates.**
		Diesel consumption	0.9	L/t	
		Water consumption	0.45	L/t	
			347	MJ/t	
		CO_2 bio	286	kg	Extraction of natural raw material and to the production of **concrete**.
		CO_2 fossil	24	kg	
		CH_4	0.003	kg	
		kgCO_2eq.	310	kgCO_2eq.	
			0.13	tCO_2eq./t	
Estanqueiro et al. (2018)	1 t	Global warming potential	15.4	kgCO_2eq.	**Coarse aggregates** used in concrete production.
		Cumulative energy demand	246	MJ	
			0.02	tCO_2eq./t	
			246	MJ/t	
Korre and Durucan (2009)	1 t	CO_2	8.58	kg/t	**Land won sand and gravel** extraction and production.
		CH_4	4.93E-04	kg/t	
		kgCO_2eq.	8.58	kgCO_2eq./t	
			0.01	tCO_2eq./t	
US EPA (2020)	1 t	tCO_2eq.	0.01	tCO_2eq./t	Recycling of **aggregate**.
		mmBTU	0.11	mmBTU/t	
		mmBTU	116	MJ/t	
		tCO_2eq.	0.02	tCO_2eq./t	Landfilling of **concrete**.
		mmBTU	0.27	mmBTU/t	
		mmBTU	285	MJ/t	
Martinez-Arguelles et al. (2019)	1 t	kgCO_2eq.	35.6		Extraction of natural raw material and to the production of **natural aggregates.**
		MJ	530	MJ/t	
			0.04	tCO_2eq./t	
Yazdanbakhsh et al. (2018)	2.4 t	kgCO_2eq.	300	kgCO_2eq./ t t	Extraction of natural raw material and to the production of **concrete**.
			0.13	tCO_2eq./t	
Pradhan et al. (2019)	2.4 t	kgCO_2eq	580	kgCO_2eq./ t t	Extraction of natural raw material and to the production of **concrete**.
		MJ	2,600	MJ/ t t	
			0.24	tCO_2eq./t	
			1,083	MJ/t	