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Net Zero Waste

Waste Minimization Plan for Concrete Masonry Maintenance Facilities at Fort Leonard Wood, MO

Fort Leonard Wood Installation Strategic Sustainability Plan

Jorge O. Flores-Dávila, Thomas R. Napier, Annette L. Stumpf,
and Susan J. Bevelheimer

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Abstract

Construction and Demolition (C&D) debris disposal has become problematic at Army installations in both economic and environmental terms. Some installations report that C&D debris constitutes about 80% of their solid waste stream. However, alternatives to conventional demolition and landfilling can divert more than 75% of debris from the landfill at considerable cost savings. Fort Leonard Wood, MO plans to remove 16 1960s-era Motor Pool buildings and eight accompanying storage and guard buildings. Demolishing these buildings will result in a significant amount of debris. As part of the Installation Strategic Sustainability Plan (ISSP), Fort Leonard Wood must reduce the amount of solid waste deposited in its waste stream, of which C&D waste is a major part. A sustainable way to reduce C&D waste is to reuse and recycle building components and materials. To facilitate that effort, this work: (1) characterized the target construction materials as reusable, recyclable, and potential debris; (2) identified beneficial use opportunities for salvaged and recycled materials; (3) developed a “waste minimization plan”; (4) identified apparent or suspected hazards their impacts on reuse and recycling building materials; and (5) ensured that this characterization is inclusive of all buildings of the type.

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Preface

This study was conducted for the Plans, Analysis, and Integration Office (PAIO) at U.S. Army Garrison Fort Leonard Wood under Military Interdepartmental Purchase Request (MIPR) 10598941 “Net Zero Waste.” The technical monitor was Mr. Mark Premont, Chief of PAIO.

The work was performed by the Engineering Process Branch (CFN) of the Facilities Division (CF), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, the ERDC-CERL Principal Investigator was Jorge Flores-Dávila, CFN. Project managers Ms. Annette Stumpf and Ms. Susan Bevelheimer, CEERD-CFN, assisted in the development of this project and coordinated the project specifics with Fort Leonard Wood. Mr. Donald Hicks was Chief, CEERD-CF and Mr. Charles Schroeder was Chief, CEERD-CFN; The Assistant Director of the Center for the Advancement of Sustainability Innovations (CASI) is Mr. Franklin H. Holcomb. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

COL Bryan S. Green was Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

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1 Introduction

1.1 Background

Construction and Demolition (C&D) debris disposal has become problematic at Army installations in both economic and environmental terms. Installations with U.S. Army Facility Reduction Program (FRP) requirements, active Military Construction (MILCON) programs, and Residential Communities Initiatives (RCI) face a significant C&D debris burden. Some installations report that C&D debris constitutes about 80% of their solid waste stream. The major cost components of demolition are loading and hauling of debris, and the payment of “tipping” fees at landfills. The diminishing numbers of C&D landfills across the United States, and regulatory constraints being placed on C&D debris disposal indicate that off-post landfilling will only become more expensive in the future. However, alternatives to conventional demolition and landfilling can divert more than 75% of this debris from the landfill at considerable cost savings.

In the near future, Fort Leonard Wood, MO plans to remove 16 1960s-era Motor Pool buildings and eight accompanying storage and guard buildings. These buildings were all constructed from U.S. Army Corps of Engineers Standard Designs and site adaptation to the 600-, 700-, 800-, and 900-areas. Four such buildings are located in each area, and two small storage and guard buildings are collocated with each four-building compound. Demolishing these buildings will result in a significant amount of debris.

As part of the Installation Strategic Sustainability Plan (ISSP), Fort Leonard Wood must reduce the amount of solid waste deposited in the waste stream. Since C&D waste constitutes a major part of the total Fort Leonard Wood solid waste stream, there is a critical need to reduce C&D waste at the installation. Moreover, reducing C&D waste is an integral part of reducing solid waste in general, which in turn is an integral part of sustainability.

The ISSP mandate is to reduce installations’ solid waste stream in total. This includes both municipal solid waste (MSW) and C&D waste together. While these streams are administered separately, there are not completely unique. One stream should not be considered in isolation of the other. To a large degree, they overlap; many materials are found in both streams. Common solutions can be more effective than two independent solutions combined. In

this case, one such common solution to reduce C&D waste is to reuse and recycle building components and materials.

1.1 Objectives

The objectives of this project were to:

1. Characterize the construction materials and identify what is reusable and recyclable, and what material will become debris.
2. Identify beneficial use opportunities for salvaged and recycled materials both on and off post.
3. Develop a “waste minimization plan” for the buildings’ demolition.
4. Identify apparent or suspected hazards and what impact they may have on reuse and recycling building materials.
5. Ensure that the characterization is inclusive of all buildings of the type.

1.2 Approach

The objectives of this project were accomplished in the following steps:

1. A detailed quantity “take-off” (i.e., all building materials by type and quantity) was performed based on the U.S. Army Corps of Engineers standard design for a Battalion Motor Repair Shop for all buildings of the type.
2. Construction materials were identified as reusable, recyclable, and debris.
3. Beneficial use opportunities for salvaged and recycled materials both on and off post were sought and identified.
4. A “waste minimization plan” was devised for the buildings’ demolition.
5. Apparent or suspected hazards and their potential impact on reuse and recycling building materials were identified.

1.3 Scope

Although this work characterized construction materials at specific buildings scheduled for removal at Fort Leonard Wood, MO, it is anticipated that the processes outlined in this report will be applicable to many U.S. Department of Defense (DoD) facilities throughout the United States.

1.4 Mode of technology transfer

The results of this work will be transferred to the Fort Leonard Wood Garrison for implementation.

2 Building Material Analysis

2.1 Characterization of construction materials

A detailed quantity take-off was performed based on the U.S. Army Corps of Engineers standard design for a Battalion Motor Repair Shop (a.k.a. Tactical Equipment Maintenance Facility [TEMF], or Motor Pool building). Taking off quantities consists of identifying all building materials by type and quantity. The Construction Specifications Institute's Master Format classification was used to categorize materials. While some small quantities have undoubtedly been missed, these omissions are not significant. It is recommended that the information presented in this report be shared with the agent contracted to perform the deconstruction work to help maximize waste diversion.

As requested by the Directorate of Public Works (DPW) Master Planner, only the buildings themselves were examined. The surrounding hardstand and ancillary features, such as grease racks, were not included. Bldgs. 672, 673, 680, and 681 were used as models. Record documents (i.e., "as-built drawings") show these buildings are identical from the foundation upward. However, since the same design was site adapted for each specific building, foundation configurations differ. Throughout the life of the buildings, tenants have modified the buildings to meet their specific needs. Quantities of the foundation concrete and interior construction materials were averaged to represent a "typical" condition. These variations were not discovered to be significant among the buildings. However, it was discovered that the roof systems differed between the different building groups. The 600 group buildings were constructed with gypsum decking; all other buildings were found to have metal decking supported with beams. One building, Bldg. 882, showed metal decking supported by metal joists. These differences were considered in the quantity take-off estimates.

The Motor Pool buildings are simple, one-story rectangular buildings, 119 ft, 6 in. long by 40 ft wide. The construction type is structural steel frame and concrete masonry unit (CMU) exterior walls. The structural layout is similar to a pre-engineered metal building system, although it is designed with conventional steel shapes. There are seven steel coil overhead doors, two personnel doors, and a variety of windows. There was very little interior partitioning, although offices have been constructed with wood framing and gypsum wallboard (GWB) surfaces. The roof deck of these four buildings is

constructed out of poured-in-place gypsum with a reinforcing mesh. (Note that subsequent visits revealed that the remaining 12 buildings had steel joist and metal deck roofs.) The current roofing is an ethylene propylene diene terpolymer (EPDM) M-class (rubber) membrane roof.

The primary construction materials are structural steel, CMU, and reinforced concrete, of which concrete comprises the vast majority of the building's mass. Other materials, such as ducts, pipes, concrete reinforcing, window frames, electrical distribution, wood, etc., are also present. A few pieces of relatively new mechanical equipment are also present.

Figure 1 shows an example of the quantity take-off of the concrete masonry materials. This simple example consists of only three material line items: 8-in. CMU, 6-in. CMU, and #4 reinforcing bars. In contrast, the structural steel take-off includes 25 line items.

A summary of these buildings' contents is:

- concrete and steel reinforcing bars
- poured gypsum
- CMUs
- structural steel members
- dimensional lumber
- plywood
- fiberglass batt insulation
- board roof insulation
- EPDM roof membrane
- metal personnel doors
- wood personnel doors
- metal overhead coil doors
- aluminum window frames
- window glass
- gypsum wall board
- vinyl composition tile
- air compressor
- steel pipe
- cast iron pipe
- toilets
- lavatories
- hand-washing station, industrial type
- shower station, emergency type
- furnace, gas type
- exhaust fans
- ductwork
- electrical distribution components
- light fixtures, fluorescent.

Figure 1. Example quantity take-off.

04 MASONRY						
Perimeter =	119.67LF X	40.00LF W X =	319.34LF			
8" CMU	119.67LF long	40.00LF wide	12.67 LF H =	4,046 SF		
Back out	7 OH doors @		144 SF =	-1,008 SF		
Back out windows				-385 SF		
Back out sills				-43 SF		
Total 8" CMU =						2,610 SF
6" CMU	51.5 LF X	12 FT high =		618 SF		
Back out	2 doors @	19.74SF =		-39 SF		
Total 6" CMU =						579 SF
#4 rebar	Lower bond beam	319.34LF @	2bars =	639 LF		
	Upper bond beam	319.34LF @	4bars =	1,277 LF		
	Lintles			602 LF		
	Sills			330 LF		
				2,848 LF @		
Total #4 rebar				0.668 LB/LF =	1,902 LBS =	0.95 TONS
TOTAL MASONRY WEIGHT			2,610 SF 8"@	38LBS/BF =	99,181 LBS	
			579 SF 6"@	34LBS/BF =	19,670 LBS	
					118,851 LBS =	59.43 TONS
TOTAL REBAR WEIGHT						0.95 TONS

Once all materials were identified and their quantities calculated, each material was evaluated for its potential for reuse or recycling, or debris. This evaluation was based on common industry practice, previous experience, and a cursory survey of sources in the Fort Leonard Wood region. A more comprehensive survey of reuse and recycling resources in the region is continuing.

An optimistic approach was taken for evaluating some materials. For example, fiberglass batt insulation was placed in the ceilings of the offices added during the buildings' occupancy. Fiberglass insulation is rarely recycled, although it is possible. Fiberglass insulation can be reused, although it is still uncommon for demolition contractors to remove it and find reuse outlets. However, reuse outlets do exist in the region. Therefore, it is assumed this material has the potential to be recovered and reused.

A more pessimistic approach was taken for other materials. For example, the gypsum roof deck could possibly be recovered and recycled as a soil amendment on post. However, it is improbable that this material would be recoverable in a demolition scenario intact and without contamination, so it is assumed this material will become debris.

It is impractical to expect that 100% of some materials can be recovered for reuse or recycling. A loss factor was incorporated into the quantities.

Assumptions and loss factors are noted in the summary. Figure 2 shows an example of the Motor Pool buildings' materials quantities (rolled-up, or summarized) and potential disposition as reusable, recyclable, or debris. Appendix A to this report includes the full rollup.

In total, roughly 90% of the Motor Pool buildings' mass should be reusable or recyclable. Relatively little should end up in a landfill if the demolition contractor takes advantage of available resources. One variable is the disposition of the CMU walls, which are painted. It is believed the paint does not contain lead. A discussion of potential environmental issues follows in this interim report. Figure 2 shows a summary of the total materials, reusable materials, recyclable materials, and debris for each building and for all 16 buildings.

2.2 Beneficial use opportunities

Alternatives to landfill disposal are being sought. Both on-post and off-post uses are being considered. On-post materials will be preferable to create a "closed-loop" system; i.e., materials generated on Fort Leonard Wood property will be used on Fort Leonard Wood property. The following sources have been and/or will be consulted:

- DPW
- Tsay, Ferguson-Williams (Fort Leonard Wood maintenance contractor)
- Range Control
- Others.

Off-post source that have been and/or will be consulted. It is anticipated that a "market" radius of roughly 100 miles will be feasible. However it may be feasible to find outlets in St. Louis (roughly 120 miles) and possibly Kansas City (over 200 miles) depending on the material, volume, and transportation arrangements. These sources include:

- State of Missouri Recycling Programs
- Ozark Rivers Solid Waste Management Program
- Missouri Institute of Science and Technology
- Sustainable Ozarks Partnership
- Material Brokers
- Commercial reuse and recycling businesses
- Non-profit reuse organizations
- Others.

Figure 2. Example quantity take-off role-up.

03 CONCRETE			
		Gypsum Roof Deck	Metal Roof deck with beam support
Number of Buildings		4	12
Concrete		2,292.2 Tons	6,876.6 Tons
Gypsum		18.9 Tons	0.0 Tons
	TOTAL	2,311.1 TONS	6,876.6 TONS
	Reusable:	0.0 Tons	0.0 Tons
	Recyclable:	2,177.6 Tons (1)	6,532.7 Tons (1)
	Debris:	133.5 Tons (2)	343.8 Tons (2)
(1) Assume 95% recovery for recycling			
(2) Gypsum & 5% concrete rubble			
04 MASONRY			
		Gypsum Roof Deck	Metal Roof deck with beam support
Number of Buildings		4	12
CMU:	TOTAL	4,502.0 TONS	13,506.1 TONS
Reusable:		0.0 Tons	0.0 Tons
Recyclable:		4,276.9 Tons (3)	12,830.8 Tons (3)
Debris:		225.1 Tons	675.3 Tons
(3) Assume 95% recovered for recycling			
05 METALS			
		Gypsum Roof Deck	Metal Roof deck with beam support
Number of Buildings		4	12
Structural steel		72.1 Tons	216.2 Tons
Rebar		3.0 Tons	8.9 Tons
Ferrous, light		2.8 Tons	8.4 Tons
Ferrous, sheet metal		0.8 Tons	2.4 Tons
Ferrous, rebar		3.6 Tons	10.8 Tons
Aluminum		1.2 Tons	3.6 Tons
Copper		2.0 Tons	6.1 Tons
Miscellaneous metals		4.8 Tons	14.4 Tons
	TOTAL	90.3 TONS	270.8 TONS

Figure 3. Material totals summary.

SUMMARY:				
SCENARIO A: DISPOSE OF CMU EXTERIOR WALLS AS DEBRIS				
	Gypsum Roof Deck	Potential Diversion	Metal Roof deck with beam support	Potential Diversion
Number of Buildings	4		12	
TOTAL:	7,003.2 Tons		21,822.7 Tons =	
REUSABLE:	96.3 Tons	1%	304.2 Tons =	1%
RECYCLABLE:	2,203.8 Tons	31%	6,616.5 Tons =	30%
DEBRIS:	4,703.2 Tons	67%	14,902.0 Tons =	68%
SCENARIO B: RECYCLE CMU EXTERIOR WALLS				
	Gypsum Roof Deck	Potential Diversion	Metal Roof deck with beam support	Potential Diversion
Number of Buildings	4		12	
TOTAL:	7,003.2 Tons		21,822.7 Tons =	
REUSABLE:	96.3 Tons	1%	304.2 Tons =	1%
RECYCLABLE:	6,480.7 Tons	93%	19,447.3 Tons =	89%
DEBRIS:	426.2 Tons	6%	2,071.2 Tons =	9%

Concrete can be recycled for aggregate on post or hauled off post for recycling (Figure 4). Common uses of recycled concrete aggregate (RCA) are for compacted base or engineered fill. Aggregate can also be used on trails and for erosion control. Opportunities for use on Fort Leonard Wood ranges are being discussed with Range Control, who said that they could use anything from the size of a golf ball to the size of a basketball.

The gypsum roof deck can possibly be recycled into a soil amendment, which could then be applied at Fort Leonard Wood. However, the condition of the gypsum in a demolition scenario and the dust generated during recycling will likely render this option infeasible.

CMU can be crushed and used for fill. However, the strength properties of crushed CMU are quite poor, so it would be unsuitable for any engineering application. CMU can be broken, but not crushed, creating angular shapes that would be useful for rip-rap or other erosion control applications.

Figure 4. Concrete recycling at Fort Campbell.

Metals are universally recyclable. However, the structural steel frame has the potential to be disassembled and used elsewhere on Fort Leonard Wood. Relocating pre-engineered metal building system is common practice. Figures 5 and 6 show pre-engineered buildings being disassembled for reuse off post at Fort Campbell, KY. Although the Motor Pool buildings are not pre-engineered metal building systems, their layout and detailing are similar. Discussions have taken place between Range Control and DPW Master Planning regarding new range buildings. It may be possible to reuse the recovered Motor Pool Structural frames in this new construction. To take advantage of this option, the exterior walls, roof system, interior construction, and mechanical and electrical systems of the new range buildings would need to be designed to meet the new requirements.

Figure 5. Metal building disassembly at Fort Campbell-perspective.

Figure 6. Metal building disassembly.

However, there are caveats to reusing these structural members. Each structural member must be inspected for damage. Also, building codes have changed since the Motor Pool buildings were designed; the structural sufficiency for the new use must be verified. Furthermore, the ability to fabricate new steel components from lead-based paint (LBP) coated steel is in question. As the LBP surfaces would be cut, torched, ground, and welded, occupational protection (at least) for fabrication personnel should be required.

Other metals will include reinforcing bar, light metals such as window frames, sheet metal such as ductwork, architectural aluminum, and copper from plumbing and electrical systems. No metals should end up in the landfill, with the exception of small scrap pieces that are difficult to separate from debris. Metals should be taken offsite and sold to a local metal recycler. Dimensional lumber and plywood found in the added offices are reusable. Figure 7 shows disassembly of wood-framed partitions in a warehouse at Fort Carson, CO. The lumber is not old growth, so use as millwork or other appearance purposes is unlikely. However, the office ceilings are framed with 2x12 framing timbers, which should be attractive in the reuse market. The $\frac{3}{4}$ -in. plywood used in this construction should also be attractive for reuse. These materials may not have a great resale value, but should be welcomed at non-profit reuse outlets such as Habitat for Humanity Restores. Contacts with the local Amish community are also being pursued. Balfour Beatty Communities will also be contacted regarding possible reuse of these materials in their residential Communities Initiative construction and operation.

The less-preferred option is to recycle the dimensional lumber. It can be recycled on post for mulch or erosion control. This could be accomplished by the demolition contractor or through an independent contract. It can also be hauled off post to a mixed C&D recycling facility, where it will likely be processed for bio-fuel.

There is some fiberglass batt insulation in the added offices. While this material does not constitute a great quantity by weight, it is useful and should be reused if possible. If the DPW has no use for it, outlets are available off post.

Figure 7. Recovering partition framing at Fort Carson, CO.

It is common to install additional board insulation when reroofing buildings, especially those with low-slope roofs. Whether additional insulation was added to the Motor Pool buildings during its last roof replacement is not known. Insulation board can be removed and reused unless it is glued to the deck surface, or the roof membrane above is glued to the insulation. Otherwise it will be destroyed on demolition and will become debris. If board insulation has been added and is accessible for recovery, it would be available for reuse on post. Alternatively, it can be offered to reuse outlets. There is little potential to reuse or recycle the roof membrane itself. This will become debris.

The windows and personnel doors will have little reuse potential as installed. The window system is a curtain-wall type system that was installed in pieces on site. (It was not delivered as complete window units.) The doors are in poor condition. Recycling the steel from doors and frames and the aluminum frames and glass from the windows is likely the best disposition of these materials. The demolition contractor will doubtlessly sell the steel and aluminum to a local metals recycler.

It is frequently problematic to recycle window glass. Not every recycling facility takes window glass. However, there are glass outlets in St. Louis and Kansas City, although delivery or pickup on a project-by project basis will generally not be economically feasible. If a sufficient quantity of window glass can be collected from multiple projects, delivery or pickup from these cities may be more feasible. For the Fort Leonard Wood Recycling Center to accept certain glass for recycling, very specific requirements must be met. Per information provided by the installation's Recycling and MS4 Program Manager, the Recycling Center does not accept windshield glass, safety glass, or glass with coatings. All glass would have to be removed from the frames (metal or wood). Materials such as caulk and window seals must also be removed. In short, the Recycling Center accepts the glass only; anything other than glass must be removed.

The overhead doors appear to be in good condition and can be removed for reuse. Discussions with DPW will confirm the usefulness of the overhead doors at Fort Leonard Wood. Otherwise, they can be sold or donated to reuse outlets. They are larger than residential garage doors, but not so large that they would not be useful for small shops or outbuildings. If nothing else, they will be recycled as scrap although this would be a serious underuse of this resource.

The vinyl composition flooring tile and GWB wall and ceiling finishes in the office areas are not recyclable or reusable, and will become debris. A new air compressor remains in the building, which should be removed and reused. If no on-post use can be identified, it will certainly be attractive in the used equipment marketplace.

The plumbing fixtures are old and probably have little reuse potential. They can be broken or crushed to add to another fill material. Plumbing piping should be recycled. A gang-type hand-washing station remains in the building. While still, operable, it is well worn and may or may not be attractive for reuse.

There may be a potential to reuse ceiling hung gas heaters, gas fired furnaces, exhaust fans, and air-conditioning compressors/condenser units. The furnaces and heaters were recently installed, and are still serviceable. The air-conditioning unit was installed in 2002, but is still serviceable. If no further uses for this equipment can be identified on post, they can be

offered to reuse outlets. Otherwise, they can be recycled. Ductwork and piping should be recycled.

Electrical distribution components appear to have been modified over the years. It is probable that panel boxes, motor switches, and other electrical equipment are obsolete. These items should be recycled. Recycling conductor, conduit, and similar materials is probably the best disposition of these materials. The lighting fixtures in the shop areas appear to be contemporary, energy efficient fluorescent lights. These are reusable, either on post or through a reuse outlet.

2.3 Develop a C&D waste minimization plan

A construction and waste management plan is a critical tool for reducing C&D waste. The plan is a pre-construction submittal (or demolition in this case) developed by the contractor before being authorized to commence work. The plan verifies that the contractor is knowledgeable of and intends to comply with applicable laws, and with DoD and Army mandates and regulations. It also confirms the contractor's capability to efficiently recover or recycle materials. It verifies to the Government that the contractor has a high probability of performing the project successfully and satisfying the Government's waste reduction mandates. The Government can approve the plan if it represents a legitimate good faith effort that uses the resources available in the region. If the plan does not show that the contractor is putting forward a good faith effort, or is neglecting to apply the required resources, the Government should decline acceptance of the plan and return the plan to the contractor for revision. Once the plan is approved, it must be enforced through the project. The contractor must justify any deviation from the plan (i.e., lower diversion performance).

Although it is normally the contractor's responsibility to provide the C&D waste management plan, ERDC-CERL can compile critical information about reuse and recycling of materials taken from the Motor Pool buildings as a "quality control" measure. This information can provide Fort Leonard Wood with leverage to ensure that contract administrators and contractors provide (and follow) an appropriate construction and waste management plan.

Unified Facilities Guide Specifications (UFGS) 01 74 19 C&D *Waste Management** serves as a model for ERDC-CERL's waste minimization plan. The emphasis goes beyond the management of waste to the minimization of waste. UFGS 01 74 19 requires the following in the waste management plan:

- *Identify responsible individuals and provide qualifications.*
The Government should look for individual's familiarity with solid waste regulations, waste hauling and disposal practices, reporting and recording requirements, and the reuse/ recycling infrastructure in the Fort Leonard Wood region.
- *Consider actions taken to reduce solid waste generation.*
When reviewing tasks and processes, the Government should look for on-post and off-post opportunities for the following:
 - Reuse and recycling plans for the steel frames
 - Recycling plans for the concrete foundations and rebar
 - Reuse plans for the identified mechanical and electrical components
 - Reuse and recycling plans for lumber and plywood
 - Recycling plans for metal from unusable mechanical, electrical, miscellaneous items, flashing and sheet metal, doors and windows, piping and other metal items.
- *Review construction management and quality control process that the contractor will apply to demolish the subject buildings.*
The Government should look for the following:
 - Workforce training or briefings for removing, handling, segregating, and policing reusable and recyclable materials
 - Inclusion of recovery and recycling activities in the inspection schedule, daily (at a minimum)
 - Processes for identifying and correcting deficiencies
 - Disposal and diversion recording methods
 - Transmittal of debris and diversion data to the USACE agent, in the form required by the DPW solid waste manager.
- *Plan for meetings to address waste management.*
The Government should look for the following when reviewing contractor's meeting, monitoring, and reporting plan:

* Headquarters, U.S. Army Corps of Engineers (HQUSACE). 2007. *Construction and Demolition Waste Management*. Unified Facilities Guide Specifications (UFGS) 01 74 19. Washington, DC: HQUSACE, Naval Facilities Engineering Command (NAVFAC), U.S. Air Force Civil Engineer Center (AFCEC), National Aeronautics and Space Administration (NASA),
<https://www.wbdg.org/ccb/DOD/UFGS/UFGS%2001%2074%2019.pdf>

- Inclusion of waste reduction measures in quality control documentation (daily reports recommended) and progress reports (weekly recommended)
- Collection of all tickets and receipts for disposal, recycling, reuse, donation, and all transactions of material transfer transaction in an orderly fashion, easily retrieved and reviewed
- Compilation of disposal and diversion data in a format and contents useful to the DPW solid waste manager and to Solid Waste Annual Reporting (SWAR) reporting requirements.
- *Consider specific approaches to reuse/recycle materials.*

While the Government is not to direct the contractor as to means, methods, techniques, sequences, or processes, the Government should review the contractor's demolition plan and consider the following:

 - How serviceable equipment and materials will be removed and protected prior to demolition
 - If the steel frame is to be relocated, reused, or repurposed, how collateral materials are to be removed from the frame and how the frame will be disassembled to minimize damage and to preserve its usefulness
 - If the steel frame is to be recycled, how the framing members will be removed, segregated, and protected from contamination by debris material
 - How metals, ferrous and non-ferrous, will be removed, segregated, and protected from contamination by comingling with debris materials
 - If wood materials are to be reused or repurposed, how they will be removed and protected to preserve usefulness
 - If wood materials are to be recycled, how they will be removed, segregated, and protected from contamination by debris materials
 - If concrete will be recycled offsite, how rubble will be handled to prevent the excess oil and collateral materials from contaminating the rubble
 - If concrete will be recycled onsite, that the crushing equipment selected by the contractor is of sufficient capacity to meet the requirement
 - If concrete will be recycled onsite how rebar will be separated and how rubble will be crushed to the required or requested aggregate product
 - How recyclable window glazing will be removed, segregated, and kept clean from contamination and debris materials

- How other recyclable and reusable items will be removed and protected from damage and contamination by debris materials (list items)
- How recyclable materials' receptacles and collection points will be posted, policed, and protected from contamination and comingling with other materials.
- *Consider the characterization of materials by type and quantity.*
- *List the names of landfills and incinerators, and their costs for disposal.*

The Government must ensure that all disposal and recycling facilities are licensed for the purposes by the prevailing authorities, i.e., MO DNR in the state of Missouri. It is recommended that any recycling facilities, especially mixed C&D recycling facilities, report the portion of materials sent to secondary processors and materials sent for landfill disposal.
- *Consider local and regional reuse programs.*

Identify outlets for material reuse and recycling that are available in the Fort Leonard Wood region and could potentially participate in the Motor Pool buildings' demolition.
- *Consider materials to be salvaged for resale and recycling.*

The Government should look for:

 - A definitive list of materials and components that are to be sent to reuse outlets and that are to be recycled (list items)
 - Justification to dispose of materials or equipment that could possibly be reused or recycled, for which there are no lack of outlets or markets within a reasonable proximity to Fort Leonard Wood (list these potential items).
- *For materials that cannot be recycled, with justification to be approved by the Commanding Officer, the Government should consider:*
 - Location of materials to minimize risk of physical damage
 - Protection of materials to prevent environmental damage
 - Training, signage, and other means to educate the workforce in material recycling and reuse.
- *Consider methods to protect reusable, recyclable materials from contamination.*
- *Consider transportation means and material handling.*

The Government should look for the following:

 - Debris hauling that conforms to Fort Leonard Wood's guidance on haul routes and times for which hauling is permissible
 - Times, locations, and routes for which deliver of material to on-post locations is permissible.

- *Consider (document) anticipated net costs and savings.*

This waste minimization plan will include:

- It will be the contractor's responsibility to assign a waste management (or minimization) manager. Recommendations will be made for the qualifications this individual should possess, as well as for the tasks the manager should perform.
- It will be the contractor's responsibility to determine specific tasks and processes that they will apply to minimize demolition waste. Options will be described that should result in maximizing material reuse and recycling and minimizing waste, such as reusing the structural steel frame and lumber materials. Recommendations will also be developed for project management practices such as inclusion of C&D waste management activities in Quality Control/Quality Assurance (QC/QA) processes, diversion performance monitoring, and reporting and other similar tasks.
- Recommendations will be made for meeting, monitoring, and reporting waste and diversion progress. Discussions will also include compiling data that are compatible with the Army's SWAR field structure.
- While the means, methods, techniques, sequences and procedures for removing the Motor Pool buildings will be the responsibility of the contractor, opportunities and potential approaches to recovering and recycling materials will be described, similar to the discussion given above. Potential reuse and recycling opportunities, both on post and off post, will be confirmed in the plan.
- The complete material take-off and characterization of materials will be included in the plan.
- The St. Robert transfer station is essentially the default depository for C&D. The Fort Leonard Wood SWAR cites a tipping fee of \$50/ton. This value will be used in the plan unless future information indicates otherwise. If any other landfill facilities are identified that may provide further sorting or recycling services, these will be included as alternatives to be considered.
- Local and regional reuse outlets will be identified by consulting with the information sources cited above and by canvassing the industry in the Fort Leonard Wood region. Resources in St. Louis and Kansas City, and logistics considerations for locations at these distances will also be identified. On-post resources such as Range Control, DPW, and TWF will be identified.

- Materials to be salvaged for resale and recycling have been identified above. Materials that cannot be reused or recycled are also described above.
- The contractor will be responsible for handling and protecting their materials to preserve their value. In the case of Motor Pool buildings, most materials (by weight) will be recycled. Handling and protection from damage will be less critical. Comingling and loss will be more critical. Practices must be established to ensure that recyclable items are deposited in the appropriate locations or containers, and to prevent comingling. These will include signage, workforce training, and placement of recycling receptacles for optimum convenience. Protection of the steel structure for reuse will be critical. Recommendations will be made for the Government to ensure that the steel structure and other reusable items are handled so as to retain their suitability for reuse.
- Transportation of material will be the contractor's responsibility. In the case of the Motor Pool buildings, standard Fort Leonard Wood guidance for hauling materials to their destinations on post or off post should suffice. This may include routes, schedules, vehicle dimensions and load limits.
- UFGS requires an estimate of potential net costs and savings. This should include the cost of debris disposal assuming all materials are landfilled, the value of reused and recycled materials, cost avoidance by reducing tipping fees, the cost invested in recovering and recycling materials, and overall net value to the Government. This should be valuable information to the Government to assess the economic viability of the required deconstruction or demolition approach. The contractor does submit some cost data to the Government, such as payroll data. The Government may also estimate the value of work performed under a payment request to judge the reasonableness of the request. However, the contractor is not obligated to reveal their actual costs, at least in a fixed price contract. Therefore, careful monitoring of tasks performed by the contractor, of personnel and equipment applied, of task durations, and of estimated recycled and reused material values through independent market research may provide the contractor with a reasonable estimate of net costs. Recommendations for obtaining cost data and estimating costs will be provided.

2.4 Develop value proposition

Demolition contractors are knowledgeable about conventional demolition tasks and the value of common recyclable materials. In a competitive bidding situation, they will incorporate recycling value into their bids. They will not pass this value to the Government in total, but the Government should see some value represented in bids. Demolition contractors may not be knowledgeable about the value of reuse, especially if the reuser will be the Government. Since concrete, structural steel, and concrete masonry constitute the vast majority of the buildings' mass, a value proposition will be developed for each. In this way, Fort Leonard Wood can assess either the value it will gain by paying a demolition contractor to recover these materials for use at Fort Leonard Wood, or the potential value to the contractor if the contractor is allowed to recover and recycle the material. The value proposition calculations should include the following:

- Cost of disposal if landfilled
- Cost of reduction or avoidance if taken to an offsite recycling facility or reuse outlet in lieu of a landfill facility
- Cost avoidance, removal or disassembly costs and value if recovered for reuse.

While the Government can take no role in ensuring that a contractor actually achieves an economic value, it can use this information to encourage a higher and better use of materials than they would ordinarily consider in a conventional demolition scenario. While the value of recovered wood is rarely recognized in the demolition industry, the wood materials present in the Motor Pool buildings should be included in the assessment.

Figure 8 shows an example of a value proposition calculation for reusing the structural steel frame. Three scenarios are described: (1) disposing of the all steel (which will be unlikely), (2) recycling steel (which will be the common approach given no other intervention), and (3) reusing the steel frames. The value of recycled steel was given by the Fort Leonard Wood Solid Waste Manager. The value of fabricated steel delivered on site was taken from the 2014 RS Means Building Construction Cost Data. An assumption was made that disassembling a structural steel frame will require roughly the same resources as steel erection, although this may be a

slightly conservative assumption. This cost was also taken from the 2014 *RSMeans Building Construction Cost Data*.*

Figure 8. Example value proposition.

POTENTIAL VALUE: 19 TONS STRUCTURAL STEEL		
SCENARIO A: DISPOSAL		
	Per Ton	Per Bldg
Tipping fee	\$ 50 /Ton =	\$ (950) /Building
		\$ (15,200) 16 Buildings
SCENARIO B: RECYCLING		
Tipping cost avoidance	\$ 50 /Ton =	\$ 950 /Building
Recycle value	\$ 105 /Ton =	\$ 1,995 /Building
Net value	\$ 155 /Ton =	\$ 2,945 /Building
		\$ 47,120 16 Buildings
SCENARIO C: REUSE		
Tipping cost avoidance	\$ 50 /Ton =	\$ 950 /Building
Fabricated steel value	\$ 2,600 /Ton =	\$ 49,400 /Building
Selective demolition/salvage (estimated)		\$ (34,000) /Building
		\$ 16,350 /Building
		\$ 261,600 16 Buildings

2.5 Potential hazardous materials

Fort Leonard Wood will perform a hazardous material survey on the Motor Pool buildings regardless of how they are to be removed or where the materials are deposited. Therefore, ERDC-CERL will not perform complete hazardous material surveys per se. However, observations of potential hazardous materials have been made. Impacts on the ability to reuse or recycle materials will be described. While not all materials are “hazardous” by definition, the following should be considered in a reuse and recycling scenario:

- There are opaque panels in the windows (Figure 9). These consist of a brittle fibrous material. While they could possibly be wood fiber or some other inert fiber, it is more likely they would be cement-asbestos

*RSMeans. 2014. *RSMeans Building Construction Cost Data*: 2014. Rockland, MA: The Gordian Group.

fiber board; i.e., transite. If tests indicate it is transite, these panels would have to be removed and disposed of by a certified asbestos abatement contractor. This would be necessary regardless of whether materials are recycled. Once removed, however, there should be no impact on the ability to recycle the window materials.

Figure 9. Opaque panels in Motor Pool buildings.

- The original lift equipment remains in the lift pits. This presents the likelihood of hydraulic fluids, or fluid residue, remaining in the pits. Petroleum, Oil, and Lubricants (POLs) may have also accumulated in the pits and in the floor drains under overhead doors (Figures 10 and 11). The presence of these materials should not inhibit recycling the concrete floor slabs. However, before demolition, this material should be identified and it should be determined whether it is hazardous material (or not). If necessary, the concrete from the pit and around the floor drains can be separated out as the floor slab is being removed.

Figure 10. Floor drains in Motor Pool buildings.

Figure 11. Lift pits in Motor Pool buildings.

Mercury (Hg) was found in thermostats and is present in fluorescent lamps (Figure 12). The light fixtures in the maintenance bays and office are contemporary so it is unlikely that the ballasts contain Polychlorinated Biphenyls (PCBs). However, the older fluorescent light fixtures in the office areas must be checked for PCB-containing ballasts. Mercury and PCB disposal should be performed according to standard Fort Leonard Wood procedures.

The refrigerant from the air-conditioning compressor (Figure 13) and drinking fountain is a potential greenhouse gas, and must be captured before these items can be reused or recycled.

Figure 12. Mercury and potential PCB-containing materials.

Figure 13. Air-conditioning compressor containing refrigerant.

It was suspected that the exterior walls were painted with LBP. Lead-check swabs confirmed this. Personnel in the Environmental Division at Fort Leonard Wood indicated that it may be possible to remove the LBP by sandblasting or other mechanical means, but that the resulting sand/LBP mixture would be a hazardous material, which would require disposal according to standard requirements. Although there may potentially be markets for used CMU for building construction, the buyer would have to be informed that the blocks contain LBP and that the buyer would assume the liability for any issues related to or resulting from the LBP content. If the CMU cannot be treated or recycled, the CMU blocks may (as a last resort) have to be considered debris and sent to the landfill. This would have a negative effect on the overall diversion potential for the buildings since a large portion of the quantity was derived from the wall material being recycled. These numbers are reflected in the quantity take-off sheet in Appendix A.

Lead-check swabs indicate the structural steel paint is LBP as well. The contractor should have test done to positively determine whether there is LBP present on both the walls and structural steel members to determine the best course of action.

3 Conclusion

3.1 Lessons learned

Fort Leonard Wood personnel requested ERDC-CERL share any lessons learned encountered during project execution. Since the Motor Pool buildings have not yet been demolished, ERDC-CERL estimated the potential for reuse and recycling of demolition materials from those buildings. Many of the same lessons learned from the FRP “deconstruction” of WWII-era buildings apply to the Motor Pool demolition, especially if this will be administered by the FRP. These lessons learned can be developed as guidance that highlights specific elements that the installation should watch out for, ensure, or avoid. As with information relevant to a C&D Waste Management Plan, anticipating problems can help Fort Leonard Wood personnel and USACE QA representatives on site to preempt or correct such problems before they jeopardize the project’s waste reduction objectives.

Issues to be addressed will include:

- *Project Development.* This includes awareness of and adherence to Fort Leonard Wood project goals and objectives, Army mandates, performance criteria, and project administration issues such as communications and cooperation among all stakeholders.
- *Industry Engagement.* This involves outreach to resources and services to ensure that the necessary capabilities are applied, and that equipment reuse outlets, both on- and off-post, are identified.
- *Contract Requirements and Technical Criteria.* These must represent Fort Leonard Wood’s requirements.
- *Monitoring and Recording Waste and Diversion Performance.* Monitoring and recordkeeping must ensure that project execution is consistent with the contract and Fort Leonard Wood’s expectations.
- *Documentation and Reporting of Project Data.* This must be done to facilitate Fort Leonard Wood’s upward reporting requirements.

3.2 Recommendations

ERDC-CERL recommends that Fort Leonard Wood require its construction agent to pursue an aggressive waste diversion approach when removing the subject Motor Pool buildings. Fort Leonard Wood can accomplish

this by reusing and recycling the greatest quantity of materials, as practical. Many materials found in the buildings, such as the concrete and structural steel, could provide economic value to the contractor as seller and resource value to a potential buyer.

Efforts were made to identify constructive uses for concrete and steel recovered from these buildings on post. However, it was difficult to find uses on post for the salvaged steel. Some interest was expressed in using the structural steel members to build a permanent building for recreation and other public activities conducted on post; however, these interests were not fully confirmed. It is recommended that outlets off the installation should be considered before the steel is treated as debris. LBP was found to be on the steel members, which makes them hard to reuse or recycle. However, companies were contacting in or near the Missouri area to find out if there was interest in structural steel even though with LBP might be found to be on them. Two metal recycling companies, USA Metal Recycling and Advantage Metals Recycling LLC, expressed interest in the structural steel even with LBP on the members. This interest indicates that there might be a market to recycle the structural steel in spite of the LBP. Fort Leonard Wood should explore these and other outlets to recycle this material.

In addition, although the various Motor Pool buildings visited by the researchers were not exactly the same with respect to the interior divisions and usages, all the buildings had the same dimensions and relative layout. Depending on the building occupants, for example, divisions, rooms and stairs had been added accordingly and some buildings also had metal cranes. A major difference seen among the buildings was the roof construction. The 600 area Motor Pool buildings seemed to have a gypsum roof construction while the other motor buildings in the 700, 800, and 900 buildings appeared to have a steel deck design with beam supports. This has been taken into account in the quantity take-offs. Of the 16 buildings studied, four were in the 600 area and the remaining 12 were in the other areas. One building in particular, Bldg. 822, has bar joists along the administrative side of the building. While this was not common across the other Motor Pool buildings, it could occur in other buildings and could affect the amount of steel estimated. This was also taken into consideration in the quantity take-offs found in Appendix A.

Figure 14. Quantity take-off rollup summary.

SUMMARY:				
SCENARIO A: DISPOSE OF CMU EXTERIOR WALLS AS DEBRIS				
	Gypsum Roof Deck	Potential Diversion	Metal Roof deck with beam support	Potential Diversion
Number of Buildings	4		12	
TOTAL:	7,652.9 Tons		23,990.9 Tons =	
REUSABLE:	96.8 Tons	1%	305.0 Tons =	1%
RECYCLABLE:	2,525.2 Tons	33%	7,641.8 Tons =	32%
DEBRIS:	5,031.0 Tons	66%	16,044.1 Tons =	67%
SCENARIO B: RECYCLE CMU EXTERIOR WALLS				
	Gypsum Roof Deck	Potential Diversion	Metal Roof deck with beam support	Potential Diversion
Number of Buildings	4		12	
TOTAL:	7,652.9 Tons		23,990.9 Tons =	
REUSABLE:	96.8 Tons	1%	305.0 Tons =	1%
RECYCLABLE:	7,097.1 Tons	93%	21,483.0 Tons =	90%
DEBRIS:	459.0 Tons	6%	2,202.9 Tons =	9%

Therefore, ERDC-CERL also recommends that Fort Leonard Wood consider the quantity take-off made for the 16 Motor Pool buildings investigated here as typical for the Motor Pool buildings in Fort Leonard Wood. Also, note that the lead-check swabs indicated that the steel members and the CMUs have LBP on them. Special attention must be given to the summary section at the end of the quantity take-offs in Appendix A. Figure 14 illustrates the summary.

When a building is under contract for demolition, the contract includes a requirement to perform a Toxicity Characteristic Leaching Procedure (TCLP). This scientific test, which is done in a laboratory, will verify the presence of lead, and if present, whether the concentration of lead is at a negligible level. In either case, it is recommended that this test be performed to determine the best course of action to follow.

3.3 Sustainability, solid waste, and C&D waste materials

It is important to recognize that reducing C&D waste is an integral part of reducing solid waste in general and is an integral part of an installation's sustainability objectives. C&D waste constitutes roughly 60% of the total Fort Leonard Wood solid waste stream. Although MSW and C&D waste streams are administered separately, many materials are common to both streams. ERDC-CERL proposes exploring common solutions for both waste streams, which can be more effective than two independent solutions combined.

Fort Leonard Wood's recent SWAR data reveals that C&D diversion rates ranged between 64 and 90%, with an average of almost 80% of C&D materials over the past 3 years (Figure 15). This exceeds the current Office of the Assistant Secretary of Defense for Installations, Energy, and Environment (OASD-IE&E) Sustainable Design and Development (SDD) policy. However, the remaining 20% are still landfilled. That is, an average of over 4,700 tons of materials is still wasted. While completely eliminating waste is an unrealistic expectation, an improvement to current performance is possible.

Figure 15. Fort Leonard Wood's FY12-14 SWAR data.

Average Waste & Diversion Average, FY12-14 (from SWAR)				
	Generation, Tons	Disposal, Tons	Diversion, Tons	Diversion, %
Total	39,075	13,216	25,859	66.2%
C&D	23,357	4,704	18,653	79.9%
Non C&D	15,718	8,512	7,206	45.8%

Conventional wrecking practices typically include recycling asphalt, brick, and concrete (ABC) materials and metals. The reasons why other materials are not recycled or reused are because there is not sufficient quantity to justify separating and hauling, because finding outlets for these "other" materials is an inconvenience, or simply because hauling materials to an off-post recycler is "more trouble than it's worth."

Therefore, the central question is— whether there is a way to use the Fort Leonard Wood Recycling Center as a more convenient outlet for C&D materials, which in turn will improve Fort Leonard Woods overall solid waste diversion performance. It is understood that solid waste management resources at Fort Leonard Wood are extremely limited. Therefore, any such discussion must address the following:

- Materials should be common to both MSW and C&D waste streams (metals, certain plastics, glass, clean wood, packing and packaging materials, others).
- Recycling services and infrastructure must be currently available to Fort Leonard Wood.
- Little or no additional administrative effort should be required.

If half of the C&D materials currently landfilled can be diverted through the Recycling Center (i.e., roughly 2,300 tons/year), Fort Leonard Wood's overall solid waste diversion rate would increase to 72%.

Appendix A: Summary of Fort Leonard Wood Motor Pool Quantity Take-Off

ROLLUP:		FORT LEONARD WOOD MOTOR POOL QUANTITY TAKE-OFF				
03 CONCRETE						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Concrete			2,600.2	Tons	7,848.2	Tons
Gypsum			18.9	Tons	0.0	Tons
		TOTAL	2,619.0	TONS	7,848.2	TONS
	Reusable:		0.0	Tons	0.0	Tons
	Recyclable:		2,470.2	Tons (1)	7,455.8	Tons (1)
	Debris:		148.9	Tons (2)	392.4	Tons (2)
(1) Assume 95% recovery for recycling						
(2) Gypsum & 5% concrete rubble						
04 MASONRY						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
CMU:		TOTAL	4,812.6	TONS	14,569.7	TONS
Reusable:			0.0	Tons	0.0	Tons
Recyclable:			4,571.9	Tons (3)	13,841.2	Tons (3)
Debris:			240.6	Tons	728.5	Tons
(3) Assume 95% recovered for recycling						
05 METALS						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Structural steel			72.6	Tons	216.7	Tons
Rebar			3.0	Tons	8.9	Tons
Ferrous, light			2.8	Tons	8.4	Tons
Ferrous, sheet metal			0.8	Tons	2.4	Tons
Ferrous, rebar			3.6	Tons	10.8	Tons
Metal Roof Deck, 18 ga.			23.8	Tons	71.4	Tons
Floor Grates			3.1	Tons	9.2	Tons
Bollards			0.3	Tons	0.8	Tons
Aluminum			1.2	Tons	3.6	Tons
Copper			2.0	Tons	6.1	Tons
Outbuildings			0.0	Tons	14.8	Tons
Miscellaneous metals			4.8	Tons	14.4	Tons
		TOTAL	117.9	TONS	367.6	TONS
	Reusable:		75.5	Tons (4)	225.6	Tons (4)
	Recyclable:		42.4	Tons (5)	142.0	Tons (5)
	Debris:		0.0	Tons	0.0	Tons
(4) Assume 100% structural steel reusable						
(5) Assume 100% other metals recyclable						

06 WOOD AND PLASTICS						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Dimensional lumber			20.8	Tons	62.4	Tons
Plywood			1.6	Tons	25.3	Tons
Miscellaneous wood			0.4	Tons	1.2	Tons
		TOTAL	22.8	TONS	364.3	TONS
	Reusable:		16.8	Tons (6)	65.7	Tons (6)
	Recyclable:		6.0	Tons (7)	23.1	Tons (7)
	Debris:		0.0	Tons	0.0	Tons
(6) Assume 75% lumber & plywood reusable						
(7) Assume misc & 25% of lumber & plywood						
07 MOISTURE & THERMAL PROTECTION						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Board insulation			47.0	Tons (8)	92.2	Tons (8)
Fiberglas batt insulation			0.4	Tons (9)	0.0	Tons (9)
Roof membrane			3.2	Tons	9.5	Tons
Out Buildings			1.9	Tons	5.9	Tons
		TOTAL	52.5	TONS	107.6	TONS
	Reusable:		0.0	Tons	0.0	Tons
	Recyclable:		0.0	Tons	0.0	Tons
	Debris:		52.5	Tons	839.8	Tons
(8) Assume gyp deck formboard & 1 layer iso board added during reroofing						
(9) Possible to reuse but not common						
08 OPENINGS						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Window glazing			6.68	Tons	20.9	Tons
		TOTAL	6.7	TONS	20.9	TONS
	Reusable:		0.0	Tons	0.0	Tons
	Recyclable:		6.7	Tons	20.9	Tons
	Debris:		0.0	Tons	0.0	Tons
(1) Assume 100% recovery for recycling						
09 FINISHES						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
			Building 600s		Building 700s	
Gypsum wall board			12.6	Tons	37.9	Tons
VCT floor tile			2.1	Tons	6.2	Tons
		TOTAL	14.7	TONS	235.2	TONS
	Reusable:		0.0	Tons	0.0	Tons
	Recyclable:		0.0	Tons	0.0	Tons
	Debris:		14.7	Tons	235.2	Tons

11 EQUIPMENT						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Air compressor			1	Tons	3.0	Tons
		TOTAL	1.0	TONS	3.0	TONS
	Reusable:		1.0	Tons	3.0	Tons
	Recyclable:		0.0	Tons	0.0	Tons
	Debris:		0.0	Tons	0.0	Tons
22 PLUMBING (10)						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Fixtures			2.33	Tons	7.0	Tons
		TOTAL	2.3	TONS	7.0	TONS
	Reusable:		0.0	Tons	0.0	Tons
	Recyclable:		0.0	Tons	0.0	Tons
	Debris:		2.3	Tons (11)	7.0	Tons (11)
(10) Piping included in 05 METALS						
(11) May possibly reuse hand-washing station						
23 HVAC (12)						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Fans			0.5	Tons	1.6	Tons
Heaters/furnace			0.8	Tons	2.5	Tons
AC compressor			0.3	Tons	0.9	Tons
Outbuildings			0.1	Tons	0.4	Tons
		TOTAL	1.7	TONS	5.3	TONS
	Reusable:		1.7	Tons	5.3	Tons
	Recyclable:		0.0	Tons	0.0	Tons
	Debris:		0.0	Tons	0.0	Tons
(12) Ductwork , sheet metal, & HVAC piping included in 05 METALS						
24 ELECTRICAL (13)						
			Gypsum Roof Deck		Metal Roof deck with beam support	
Number of Buildings			4		12	
Light fixtures			1.4	Tons	4.2	Tons
Miscellaneous			0.4	Tons	1.2	Tons
		TOTAL	1.8	TONS	5.4	TONS
	Reusable:		1.8	Tons	5.4	Tons
	Recyclable:		0.0	Tons	0.0	Tons
	Debris:		0.0	Tons	0.0	Tons
(13) Conductor & conduit included in 05 METALS						

SUMMARY:						
SCENARIO A: DISPOSE OF CMU EXTERIOR WALLS AS DEBRIS						
	Gypsum Roof Deck		Potential Diversion	Metal Roof deck with beam support		Potential Diversion
Number of Buildings	4			12		
TOTAL:	7,652.9	Tons		23,990.9	Tons =	
REUSABLE:	96.8	Tons	1%	305.0	Tons =	1%
RECYCLABLE:	2,525.2	Tons	33%	7,641.8	Tons =	32%
DEBRIS:	5,031.0	Tons	66%	16,044.1	Tons =	67%
SCENARIO B: RECYCLE CMU EXTERIOR WALLS						
	Gypsum Roof Deck		Potential Diversion	Metal Roof deck with beam support		Potential Diversion
Number of Buildings	4			12		
TOTAL:	7,652.9	Tons		23,990.9	Tons =	
REUSABLE:	96.8	Tons	1%	305.0	Tons =	1%
RECYCLABLE:	7,097.1	Tons	93%	21,483.0	Tons =	90%
DEBRIS:	459.0	Tons	6%	2,202.9	Tons =	9%

Acronyms and Abbreviations

Term	Definition
ABC	Asphalt, Brick, and Concrete
AC	Alternating Current
ANSI	American National Standards Institute
C&D	Construction and Demolition
CASI	Center for the Advancement of Sustainability Innovations
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CMU	Concrete Masonry Unit
DNR	Department of Natural Resources
DoD	U.S. Department of Defense
DPW	Directorate of Public Works
EPDM	ethylene propylene diene M-class [rubber]
ERDC	U.S. Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
FRP	Facility Reduction Program
GWB	Gypsum Wallboard
HVAC	Heating, Ventilating, and Air-Conditioning
IPR	In Progress Review
ISSP	Integrated Strategic and Sustainability Plan
LBP	Lead-Based Paint
MILCON	Military Construction
MIPR	Military Interdepartmental Purchase Request
MSW	Municipal Solid Waste
NSN	National Supply Number
OASD-IE&E	Office of the Assistant Secretary of Defense for Installations, Energy, and Environment
OMB	Office of Management and Budget
PAIO	Plans, Analysis, and Integration Office
PCB	Polychlorinated Biphenyl
POL	Petroleum, Oil, and Lubricants
QA	Quality Assurance
QC	Quality Control
QC/QA	Quality Control/Quality Assurance
RCA	Recycled Concrete Aggregate
RCI	Residential Communities Initiative
SAR	Same As Report
SDD	Sustainable Design and Development
SF	Standard Form

Term	Definition
SF	Standard Form
SWAR	Solid Waste Assessment Report
TCLP	Toxicity Characteristic Leaching Procedure
TEMF	Tactical Equipment Maintenance Facilities
TR	Technical Report
TWF	Tsay, Ferguson-Williams
UFGS	Unified Facilities Guide Specification
URL	Universal Resource Locator
USACE	U.S. Army Corps of Engineers
VCT	Vinyl Composition Tile
WWII	World War II

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14. ABSTRACT Construction and Demolition (C&D) debris disposal has become problematic at Army installations in both economic and environmental terms. Some installations report that C&D debris constitutes about 80% of their solid waste stream. However, alternatives to conventional demolition and landfilling can divert more than 75% of debris from the landfill at considerable cost savings. Fort Leonard Wood, MO plans to remove 16 1960s-era Motor Pool buildings and eight accompanying storage and guard buildings. Demolishing these buildings will result in a significant amount of debris. As part of the Installation Strategic Sustainability Plan (ISSP), Fort Leonard Wood must reduce the amount of solid waste deposited in its waste stream, of which C&D waste is a major part. A sustainable way to reduce C&D waste is to reuse and recycle building components and materials. To facilitate that effort, this work: (1) characterized the target construction materials as reusable, recyclable, and potential debris; (2) identified beneficial use opportunities for salvaged and recycled materials; (3) developed a "waste minimization plan"; (4) identified apparent or suspected hazards their impacts on reuse and recycling building materials; and (5) ensured that this characterization is inclusive of all buildings of the type.					
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