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“Market-Smart” Deconstruction and Material Recovery at Brownfield Sites

How To Identify and Reuse Existing Materials Found at Brownfield Sites

Annette L. Stumpf, Samuel L. Hunter, Susan J. Bevelheimer,
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Abstract

As a member of the Federal Brownfields Partnership, the US Army Corps of Engineers supports the US Environmental Protection Agency and its brownfields grantees in their efforts to assess, remediate, and sustainably reuse brownfields. This project is based on the premise that communities have finite resources and that the sustainable practices of deconstruction and recycling/reuse can provide them with much needed economic and environmental benefits. The objective of this work is to develop tools and guidance for brownfields partners to assess the potential of extracting construction material assets from buildings, structures, and infrastructure on brownfield sites, and to reuse or recycle this material. This assessment will address the physical characteristics of the structures and materials present; the potential for extracting materials for recycling and reuse; economic considerations of extracting, processing, and reusing materials compared to landfill disposal; limitations due to contamination; industry resources; regulatory requirements and other practical considerations associated with construction material recovery. This report does not specifically address the (already well-documented) brownfield characterization and remediation process. Instead, it focuses on helping the project team assess a brownfield site to determine what buildings, materials, and resources on the site may be saved, reused, recycled, or deconstructed and sold.

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Preface

This study was conducted at the request of Headquarters, US Army Corps of Engineers (HQUSACE) under the Project called “Market-Smart Deconstruction and Materials Recovery at Brownfield Sites,” via EPA funding. The HQUSACE technical monitor was Jane Mergler.

The Engineering Processes Branch (CF-N) of the Facility Systems Division (CF), Construction Engineering Research Laboratory (CERL) managed and executed the work. The CERL principal investigators were Thomas R. Napier and Annette L. Stumpf. Appreciation is owed to William Turley, Director, Construction Materials Recycling Association. Donald Hicks is Chief, CF-N, and Michael Golish is Chief, CF. The Technical Director for the Installations business area is Martin J. Savoie, CV-T. The Deputy Director of CERL is Dr. Kirankumar V. Topudurti, and the Director is Dr. Ilker R. Adiguzel.

CERL is an element of the US Army Engineer Research and Development Center (ERDC), US Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (US liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
miles (US statute)	1,609.347	meters
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
tons (2000 pounds, mass)	907.1847	kilograms

1 Introduction

Background

A *brownfield* is an abandoned or underutilized piece of property burdened by real or perceived contamination, which normal market action has not redeveloped. Brownfields can pose a threat to the environment because contamination on the site can pollute soil, groundwater, and air. Because of the liabilities involved with cleaning up a brownfield, private developers tend to avoid brownfield sites. Instead, they develop land on the outskirts of a town (i.e., a “greenfield”), taking over untainted rural land while brownfields continue to deteriorate. This practice results in urban sprawl.

As a member of the Federal Brownfields Partnership, the US Army Corps of Engineers (USACE) supports the US Environmental Protection Agency (USEPA) and its brownfields grantees in their efforts to assess, remediate, and sustainably reuse brownfields.

This study effort, which looks at both brownfield assessment and redevelopment, builds upon the Corps’ technical assistance support role by developing guidance for identifying and reusing existing infrastructure and site materials (i.e., buildings and other structures) instead of demolishing and landfilling these resources. The premise of this project is that communities have finite resources, and deconstruction and recycling/reuse are sustainable practices that can provide them with much needed economic and environmental benefits. Existing structures and materials found on a brownfield site should be considered assets that can be of value to developers who salvage or recycle the materials, and/or to the municipalities that promote resource recovery.

Objectives

The primary objective of this report is to develop guidance for brownfields partners (e.g., agencies such as the USEPA and the Corps of Engineers, state and local regulators and planners, community development banks, and local development partners) to assess the potential of extracting construction material assets from buildings, structures, and infrastructure

present on brownfield sites and reusing or recycling this material. This assessment will address:

- physical characteristics of the structures and materials present
- potential for extracting materials for recycling and reuse
- economic considerations of extracting, processing, and reusing materials compared to landfill disposal
- limitations due to contamination
- industry resources
- regulatory requirements
- other practical considerations associated with construction material recovery.

Approach

The US Army Engineer Research and Development Center's Construction Engineering Research Laboratory (ERDC/CERL) surveyed current practices with respect to the disposition of construction material resulting from brownfield cleanup and redevelopment. They also investigated construction material reuse and recycling practices at brownfields in countries such as England and Germany, which have advanced brownfield practices.

ERDC/CERL identified buildings, structures, and other infrastructure elements that are present under common brownfield conditions. They documented material types and their typical condition, along with common contamination and the limitations contaminants place on possible recycling and reuse. They also developed the types of structures and materials likely to be found under various sets of common conditions.

ERDC/CERL also identified and described the benefits and value to brownfield grantees resulting from salvaging, recycling, and incorporating existing materials into redevelopment. These benefits are economic (costs and values), practical, and social (workforce development and employment opportunities).

Next ERDC/CERL identified the types of *services* required to extract and process materials for salvage, reuse, or sale on the commodities market. They also investigated the *technologies, equipment, and processes* applied to recovering and salvaging/recycling the subject materials. The project team assessed the availability of these services and how to apply them in a

demolition or clean-up scenario. Finally, the project delivery methods that can access and make best use of these services are described.

This report paints a scenario of material recovery at a brownfield site to include:

- who would likely be involved (e.g., city agencies, redeveloper, construction company, local recycler, nonprofit organization)
- what the reasons for their involvement would likely be
- where they would go for technical, financial, and regulatory support
- why they would likely need to work in partnership
- how they might jointly proceed with a material recovery endeavor.

The scenario then describes opportunities for uses as construction materials onsite or commodities for sale.

The report then synthesizes “best practices” for the most efficient and effective materials recovery process. These practices include project delivery methods, project economies, contracting approaches, project specifications, and interface with the demolition and the secondary commodity processing and recycling industries.

Scope

This technical report does not specifically address the already well-documented brownfield hazardous substances characterization and remediation process. Instead, it focuses on helping the project team assess a brownfield site to determine what buildings, materials, and resources are available on the site, and what may be saved, reused, recycled, or deconstructed and sold as assets to the redevelopment, instead of demolishing them and hauling them to a landfill.

Mode of technology transfer

This report provided in print and electronic forms to the USEPA Office of Brownfields Cleanup and Redevelopment, and will be made accessible through the World Wide Web (WWW) at URLs:

<http://www.cecer.army.mil>

<http://libweb.erdg.usace.army.mil>

2 Brownfields Redevelopment

Problems with brownfields

The reuse or redevelopment of abandoned or underutilized buildings, structures, and their infrastructure – commonly known as brownfields – is complicated not only by the presence or potential presence of contamination or hazardous substances, but also by the perception that brownfields are obsolete, physically unsuitable, and have no further value. Most brownfields are abandoned commercial and industrial properties that were originally developed because of real business advantages to the sites. Brownfields inhibit development because local governments and developers consider cleanup and disposal of construction and demolition (C&D) debris a financial liability, not to mention the possible exposure to liability associated with the initial contamination. Removal of buildings and structures is an expense that must be incurred before they can initiate any redevelopment and generate any income from the property.

Yet brownfields are not necessarily without any value. Various materials can often be recovered and recycled for use within the site itself. Other materials may have monetary value as commodities, the sale of which can offset expenses, or possibly even generate income. The bottom line is that demolishing buildings, structures, paving, and other constructed features and landfilling the debris creates an expense, which is a further burden on redevelopment. Cost avoidance opportunities are lost when hauling and landfilling debris, and purchasing new materials for subsequent development. Furthermore, landfill disposal of brownfield debris diminishes landfill capacity. When local landfills close, everyone has to haul their debris farther at a greater expense.

No guidance tailored to brownfields is available to help those involved with brownfield projects to assess what materials present on brownfield sites could be useful to further development. Given the appropriate information and tools, brownfield partners can use existing materials as assets, rather than disposing of them as liabilities.

Brownfields and sustainable redevelopment

Many opportunities are possible during the restoration of brownfield properties, but the most exciting is the chance to redevelop the site in a way that enhances the community, creates a viable financial opportunity for the development team, and restores the environment. The commonly used term for this type of development is “sustainable development.”

What is sustainable development? It is development that:

- meets present needs without compromising the quality of life for future generations
- maintains economic growth while producing an absolute minimum of pollution, repairing environmental damages of the past, producing less waste, and extending opportunities to life in a pleasant and healthy environment
- meets human needs by maintaining a balance between development, social equality, ecology, and economics
- demands systematic considerations of environmental impact, energy use, natural resources, economy, and quality of life
- has optimal benefit only when addressed at the inception of a project, and throughout the entire life cycle of a project — from concept to planning, programming, design, construction, and ownership.

Sustainable development is well-described in the literature, and projects can be measured using rating tools such as the US Green Building Council’s Leadership in Energy and Environmental Design (LEED) green building rating tools. LEED rating tools address a variety of building types and phases of a building/project life cycle. For more information see:

<http://www.usgbc.org/>

LEED-NC (New Construction) can be used to assess the project site and all infrastructure being removed or constructed on it. LEED-SS (Sustainable Sites) under Credit 3 “Brownfield Redevelopment,” intends to encourage rehabilitation of damaged sites where development is complicated by environmental contamination, thereby reducing pressure on undeveloped land (sometimes called “greenfields”). Each project sited on a redeveloped brownfield site is eligible to earn one LEED credit.

Community support is essential to the successful redevelopment of brown-field sites and can be earned if the project team highlights the environmental, economic, and community-related benefits of brownfield redevelopment. From the start of the project, the project team must actively consider ways to not only engage community members, but to discover partnership opportunities and mutual benefits that can be engineered into the brownfield redevelopment process. For instance, it might be possible to hire local unskilled labor and train those individuals while conducting recycling and recovery operations during demolition of obsolete facilities or infrastructure. Redevelopment of an abandoned brownfield property can benefit the community by creating local jobs, supporting local businesses, increasing the local tax base, and improving environmental conditions. To summarize, recycling C&D debris during brownfield redevelopment has the following benefits. C&D recycling:

- is a ranking criterion for many brownfield grants
- saves money
- conserves resources and energy
- extends the life of landfills
- creates jobs and supports local businesses
- provides job training through deconstruction
- can earn LEED credits
- is the right thing to do!

3 Best Practices in Europe and Asia

The world is looking at brownfields and what to do with them. This chapter gives a worldwide holistic view on brownfields, focusing on Europe and China. The following chapters focus on ongoing efforts in the United States.

Europe

The differences are obvious between brownfield regeneration in the United States and in Europe. The two foremost differences are the relative age of structures and the relative value of space. The culture of permanent cities and structures has been around much longer in Europe; therefore, they have many older structures with little complexity. Sustainable use of space is a long-term goal with limited short-term incentives for most of the United States. In Europe, the sustainable use of space has been born out of necessity. The demolition of structures in the United States must appear to Europe as an extension of our “throw away” society. The United States demolishes functional structures, seemingly for the sole purpose of replacing them with new structures, which serve essentially the same function. The United States currently uses the term ‘deconstruction’ to differentiate demolition with recycling/reuse of waste material from demolition without recycling/reuse. Europe seldom uses this term in printed materials dealing with brownfields. They do not need the term where they take recycle/reuse with demolition for granted.

As an example, the United Kingdom set a goal in February 1998 that they would build 60% of all new housing on brownfield land by the year 2008. In the United States this goal might seem unachievable, but the United Kingdom is already building about 75% of new housing on regenerated brownfields.

The United Kingdom and Germany are the two European countries with the most brownfield space. A significant volume of guidance prepared in the United Kingdom deals with the management of brownfields for reuse. Little guidance specific to Germany is available through normal English language searches (perhaps understandably), while the amount of guidance prepared by various organizations in the European Union (EU) is significant. The following European organizations address brownfield reuse.

NICOLE – Network for Contaminated Land in Europe (EU). NICOLE is a leading forum on contaminated land management in Europe. It promotes co-operation between industry, academia, and service providers on the development and application of sustainable technologies. NICOLE's objectives are to:

- provide a European forum for the dissemination and exchange of knowledge and ideas about contaminated land arising from industrial and commercial activities
- identify research needs and promote collaborative research that will enable European industry to identify, assess, and manage contaminated sites more efficiently and cost-effectively
- collaborate with other international networks inside and outside Europe and encompass the views of a wide a range of interest groups and stakeholders (for example, land developers, local/regional regulators, and the insurance/financial investment community).

CLARINET – Contaminated Land Rehabilitation Network for Environmental Technologies in Europe (EU). CLARINET is a Concerted Action of the European Commission's (EC's) Environment and Climate Research and Development Program. Its primary objectives are to develop technical recommendations for sound decision making on the rehabilitation of contaminated sites in Europe and to identify research and development needs, in particular in relation to the EC's Fifth Framework Program (FW5).

CLARINET also worked closely with its “sister” network NICOLE (<http://www.nicole.org>) in stimulating international collaborative projects for the contaminated-land-related areas of the FW5.

WRAP – Waste and Resources Action Program (UK). WRAP's initial mission was to create new markets for the additional materials, which contractors would collect and recycle as part of the drive to reduce the volume of waste that they send to the landfill. Then their mission and focus changed to encompass some work on waste minimization, to provide advisory services on best recycling practices for local authorities and, most importantly, to help to influence public behavior by programs of communication at local and national level. WRAP's focus is now to contribute to the United Kingdom's environmental targets through three key objectives to be delivered by March 2008:

- to cause the recycling or removal from the waste stream of at least three million additional tones [tons] of materials
- to increase the level of public participation in recycling by adding at least four million additional “committed recyclers,” an increase equivalent to 10% of the adult population in England
- to reduce the amount of food thrown away by consumers and ensure more of it is collected for composting and recycling.

BRE – Building Research Establishment (UK). BRE is a UK center of expertise on buildings, construction, energy, environment, fire, and risk. They provide research-based consultancy, testing, and certification services to customers worldwide. Their services are founded on but not restricted to the built environment.

ICE – Institution of Civil Engineers (UK). ICE is a charitable organization that exists to promote and progress civil engineering. They are a center for the exchange of specialist knowledge, and a provider of resources to encourage innovation and excellence in the profession, worldwide.

ANCORE – Academic Network on Contamination Land Research within Europe (EU). The Center for Applied Geosciences at the University of Tübingen, Germany initiated ANCORE as a platform for the exchange of ideas and the dissemination of results (new technologies, methods, etc.). They are becoming an important source of know-how for the problem owners and regulators working in the field of contaminated land.

NICOLE and ANCORE seem to focus primarily on contaminated soil and associated groundwater contamination at brownfield sites, while CLARINET has a less narrow focus and addresses all aspects of brownfields. WRAP, BRE, and ICE are construction-oriented organizations in the United Kingdom, with focus groups that deal specifically with brownfield structures.

European brownfield reuse guidance

Many documents are available that contain guidance regarding the reuse of brownfields. One comprehensive document that describes the planning processes involved is the “Best Practice Guidance for Sustainable Brownfield Regeneration,” prepared by RESCUE in May 2005. RESCUE (Regeneration of European Sites in Cities and Urban Environments) is a consor-

tium of 14 organizations that came together for the specific purpose of preparing the Best Practice manual. Figure 1 shows the general approach discussed in this manual.

The manual,* while thorough regarding the various planning aspects of brownfield reuse, is lacking in technical substance regarding an approach for managing contaminated deconstruction material. Another comprehensive document that provides guidance for managing contaminated deconstruction material is the “Demolition Protocol,” prepared by EnviroCentre Ltd., circa 2002-2003. The Protocol links the generation of demolition material to its ultimate specification as a high value material (comparable to new material) in new building construction. It shows how the planning process can drive improvements in resource efficiency. The intent of the Protocol is best reflected by quoting from a paragraph on page 5-5 of that document.

A building which has completed its useful life is now as valuable a resource as a mineral deposit ...

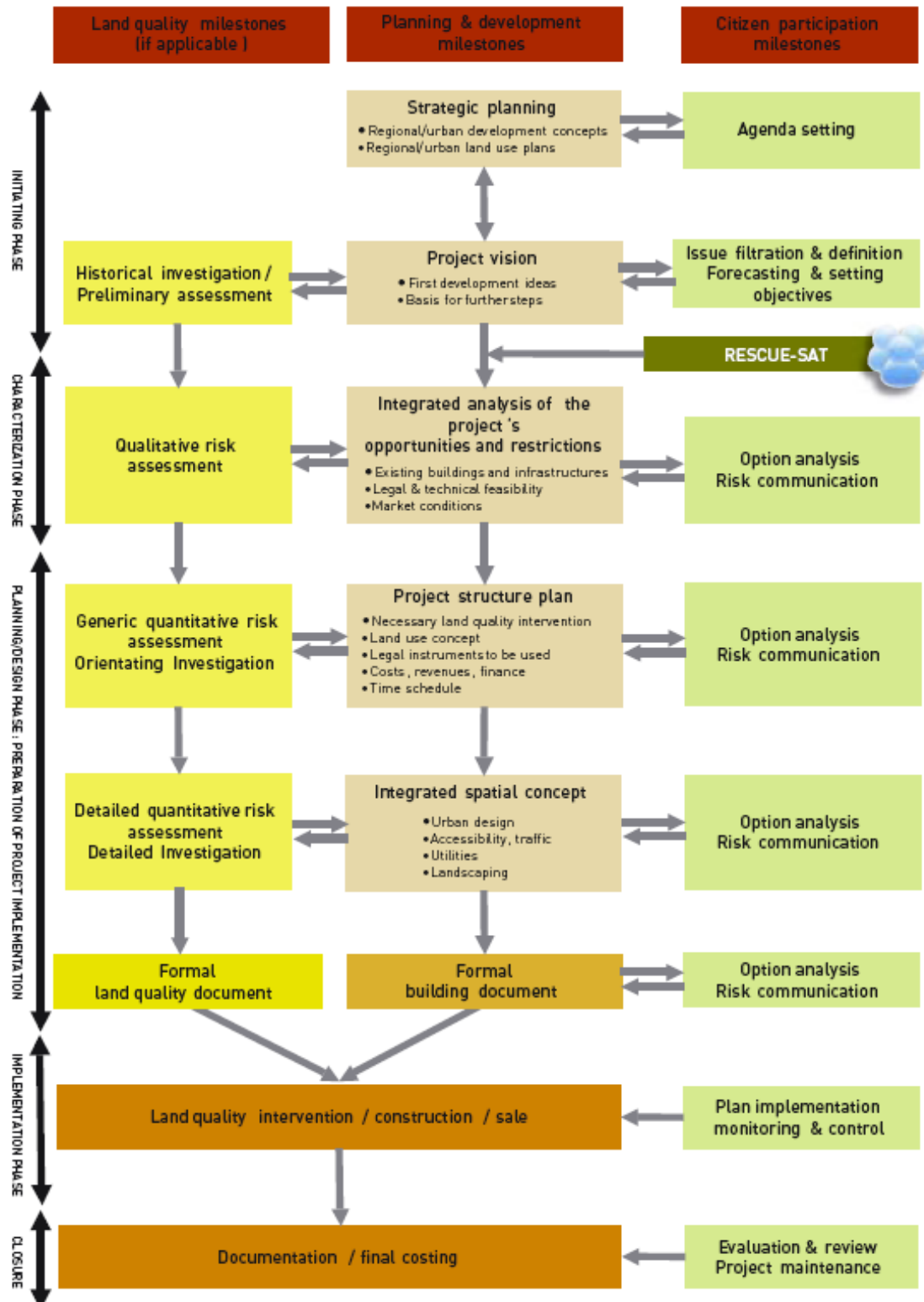
The common conception is that demolition is the end of a building project. However, it could often be the case that it is the start of a new building project ...

The following paragraphs contain observations derived from the Demolition Protocol, much of which is quoted directly from the document.

General observations: There are certain, perhaps obvious, conditions that promote recycling of demolition material. These are:

1. Those areas with the highest population densities and therefore more construction and demolition activity have the highest recycling rates and the lowest rates of landfill disposal (page 2-4 of the Protocol).
2. Traffic congestion, obviously related to population/infrastructure density, influences the cost of both transferring demolition waste to a landfill and the cost of obtaining new construction materials. High-density areas are most conducive to cost-effective recycling onsite.
3. Processing aggregate to meet the specifications for reuse onsite can serve two purposes. It will eliminate the cost to haul and landfill the aggregate as a waste. In addition, it can be counted in a recycled material inventory, even if it is used only as fill material, which may help meet reuse goals.

* downloaded from <http://www.rescue-europe.com/download/reports/RESCUE%20Manual.pdf>



(Used with permission.)

Figure 1. Roadmap of a holistic regeneration project illustrating stakeholder involvement.

Lessons learned: The following lessons learned are from demolition projects completed before the Protocol:

1. The planners for a construction project in a remote area (outside of Oban, Scotland) were unwilling to bring in specialized recycling equipment when local quarries were nearby. This was because they assumed recycling would not be economically feasible. A similar rural scenario might be that planners are concerned about local economics (i.e., they would prefer to have project funds go to a local industry [quarry in this case] as opposed to an outside contractor who is providing a service). See page 3-3 of the Protocol.
2. At a demolition project at a university in Glasgow, Scotland, contractors used traditional demolition in lieu of recycling because the project team was concerned about “putting in place a process which, it considered, would complicate the project management.” (See page 3-3 of the Protocol.)
3. A project team discussed the reuse of material from the demolition of two towers for redevelopment construction in the same area. “BS8500, the British Standard for concrete, was discussed with respect to using recycled aggregate in a number of concrete applications. The designers believed that time was insufficient to understand the full implications of meeting the Standard, having experienced difficulties with recycled demolition material in the past.” (See page 3-4 of the Protocol.)
4. Large clay brick buildings were being demolished to make way for the Glasgow, Scotland harbor development project. One phase of the harbor project required 150,000 m³ of material to fill in a quay. Originally, the 75,000 m³ of waste was designated as fill material for the quay. However, project planners asked the engineers for the development infrastructure to investigate a higher use for the recycled material. A new and significant project objective was to save costs by keeping and using demolition material onsite. The main use of the material would be for capping material in road construction around the new development. (See page 3-4 of the Protocol.)
5. The Channel Tunnel Rail Link project involves the construction of new track, bridges, stations, etc. to connect various parts of the United Kingdom rail infrastructure. The project incorporated recycling where possible. A significant amount of demolition was necessary to make way for the railway infrastructure. Most of the demolition material became fill material, as that was the greatest need for that type of project. One innovative aspect of the demolition included a contractual requirement to salvage bricks. Due to limited demand, however, this salvage met with limited success. Had the demolition project team prepared a detailed plan, the mild

embarrassment of the weak reuse attempt would have been prevented.
(See pages 3-4 and 3-5 of the Protocol.)

Demolition inventory

Demolition material segregation. One of the keys to the preparation of any demolition plan is the demolition inventory. It is critical to inventory the materials that will be generated during the demolition and segregation processes. Segregation is obviously an important first step to reuse. As page 5-2 of the Protocol states:

The maximum benefit from material will be obtained if a building is taken apart methodically, with processes geared to create waste streams of the following:

- Concrete – therefore producing Recycled Concrete Aggregate (RCA)
- Masonry (e.g., clay brick) – therefore producing Recycled Aggregate (RA)
- Steel – high reclaim value
- Non-ferrous metals such as copper, aluminum, etc. – high reclaim value
- Wood – structural timber has high reclaim value
- Plastic, such as polyvinyl chloride (PVC) – a potential reclaimable material of the future (from a 2003 perspective)
- Glass – high recycling value
- Mixed streams of “difficult” items such as plaster board which reduce the value of the other waste streams.

Hazardous materials, such as asbestos, are not discussed in the inventory with regard to recycling. Management of these materials is governed by specific environmental regulations. Certainly hazardous materials must be isolated as much as possible to prevent contamination of the recyclable components of the demolition wastes and to protect the demolition workers (see page 5-3 of the Protocol).

Constraints to segregation and recycling. Certain site-specific conditions can limit the extent to which demolition materials may be segregated and/or recycled. These are:

- Space constraints within and around the site. Available room may not be sufficient to segregate all of the eight waste streams listed above.
- Time constraints. The need to fast-track demolition may prohibit some recycling options or innovative approaches.

- Financial incentives and markets. If no viable market exists for any of the recyclable components of the demolition waste, there is little incentive to segregate those components. It may be possible that the components could be stored onsite until market options improve, but that is unlikely when demolition precedes new construction.
- Proximity to other properties. The close proximity of residential or commercial areas may cause a fast-track situation, due to agreements made to acquire permission for the project (see page 5-2 of the Protocol).

Demolition recovery index

The building inventory allows the recycling potential of a building being demolished to be properly assessed through the creation of a Bill of Quantities (BOQ). Recyclable building material/components are inventoried regarding tonnages, and then further evaluated regarding potential options for reuse/recycling; and percentages of the material suitable for reuse/recycling. In some cases, the BOQ information is then used to calculate the Demolition Recovery Index (DRI). The DRI basically represents the percentage of all potentially recyclable building components that can actually be recycled. The DRI has various planning and regulatory purposes in the United Kingdom. It:

- Demonstrates that the project team's demolition methodology has identified the resource potential of the building.
- Allows a negotiated quantity/percentage of demolition material to be recovered based on the DRI. With respect to negotiations with planning authorities, this can then be enforced by a Section 106 Agreement (England and Wales) or Section 75 Agreement (Scotland).
- Provides a monitoring system for planning authorities, which then allows an assessment to be made on the way that material has actually been managed. The project team may be required to issue copies of material recovery notes for the demolition, which demonstrate the quantity of material actually recovered.
- Drives resource efficiency by linking the material resource potential of old buildings (for demolition) to the design and procurement of material for the new builds.
- Provides planning authorities with a tool for specifying the percentage of reused/remanufactured/recycled material in the new builds. If the new build is managed by the project team responsible for demolition,

then the DRI for the old building is linked to the materials procured for the new build (Demolition Protocol, page 5-4).

They have divided the BOQ spreadsheet into seven sections for the different building components: (1) Concrete, (2) Non-concrete masonry, (3) Metals, (4) Wood, (5) Composites, (6) Glass, and (7) Hazardous. Each of those sections is then divided into more specific components. For example, items under the Concrete listing include blocks, floor slabs, foundations, curbing, stair units, etc. The hazardous section generally does not have recoverable components, though the example in the Protocol document shows fuels in storage tanks and mercury in fluorescent lights as being 98% recoverable.

The European culture is replete with permanent cities and structures that have existed much longer than any in the United States. They also place a higher value on the space in which to construct facilities because, relatively speaking, only a small amount of space is available. Therefore, they have implemented regulations and protocols, such as those mentioned in the preceding sections, to assist the construction industry in recovering, recycling, and reusing materials. The European people as a whole have captured the recover/recycle/reuse “vision” and seem to lead the world in brownfield development efforts.

China

Countries such as China are undergoing an unprecedented boom in construction and are consuming international resources. According to a report entitled “China's Impact on Military Construction” (Bobotas 2006), China has an unprecedented appetite for common construction materials. Their demand for these materials affects both their cost and availability. It currently consumes one-half of the world's cement, one-third of the world's steel, one-quarter of the world's copper, and one-fifth of the world's aluminum (Janacek 2006). China has become the world's largest consumer of steel, which drives up prices for the rest of the world. From mid-2004 to mid-2005, the cost of steel in the United States rose 27%, and concrete products increased 12% (Simonson 2005).

Concrete prices have increased in the United States because our cement industry is constrained by environmental regulations, while the same controls

do not exist in China. Copper prices have risen 75% in the past year. The prices of petroleum-based products and by-products continue to increase with the cost of oil. For example, the price of asphalt increased 46% in 2005 and 77% in 2006 (Bureau of Labor Statistics 2006). Increases in gasoline prices also mean that costs to transport construction products continue to rise. As the price of construction materials increases, reclaiming/recycling C&D materials becomes much more cost effective and attractive.

Many countries throughout Asia have large construction efforts under way to develop their infrastructure. These efforts are consuming huge amounts of international resources. Their demand for construction materials impacts both the cost and availability of traditional construction materials. Apparently, however, very few regulations or protocols in these countries exist to recover, recycle, or reuse construction waste. They are perhaps still trying to capture the recover/recycle/reuse vision.

Summary

The world is looking at brownfields redevelopment. Some countries are actively engaged with brownfields and some have yet to capture the vision. Some countries have limited construction space and must be actively engaged in the brownfield process. Other countries have so much construction space that brownfields may mean little to them. Yet countries will continue to construct infrastructure to support their economies, which will eventually make brownfields redevelopment important to the world.

4 Introduction to Construction and Demolition Materials Recycling

Current trends

Responsibly managing waste on a construction jobsite is a vital component of sustainable building. In this context, managing waste means minimizing the construction waste or demolition debris that leaves the jobsite for landfill disposal (Napier 2006).

In 1998 the USEPA estimated that the United States generates 136 million tons of building-related waste, which is 25 to 40% of the national solid waste stream. A 2003 update shows an increase to 164 million tons annually, of which 9% is construction waste, 38% is renovation waste, and 53% is demolition debris.

C&D waste disposal (Figures 2 and 3) triggers a sequence of adverse effects that are not always apparent to building professionals. These include the loss of useful property, wasted materials and embodied energy,* greenhouse gas generation (Figure 4), and environmental stressors associated with producing new materials instead of using existing materials. The number of C&D landfills is declining, which means fewer disposal options, greater hauling distances, and increased fuel consumption and vehicle emissions. Capping, closing, and monitoring landfills, and cleaning up leaking or contaminated landfill sites drain public funds.

The USEPA also estimates that only 20% of C&D waste is currently being recycled. This low percentage suggests an enormous potential for improvement. It also suggests that a significant resource is available for future use. In the book *Cradle to Cradle*, William McDonough draws the analogy to natural systems where waste is food. “Technical waste” should become “industrial food” (McDonough 2002).

* Embodied energy is the energy consumed by all the processes associated with the production of a building, from the acquisition of natural resources to product delivery. This includes the mining and manufacturing of materials and equipment, transport of the materials, and administrative functions. Embodied energy is a significant component of the life-cycle impact of a home.



Source: Army Environmental Command, Ed Engbert

Figure 2. C&D landfill.



Source: ERDC/CERL, Steve Cosper

Figure 3. Commingled C&D waste in roll-off container.



Figure 4. Methane vents at Fort Lewis, WA.

Source: Fort Lewis, Ken Smith

Waste reduction practices are applicable to virtually any construction and demolition project scenario. The goal is to divert materials from landfill disposal to the greatest extent practical under the circumstances.

Two opinions are held about whether this expectation is realistic under real-world project conditions. One view is that waste reduction costs money, and the other is that waste reduction saves money. As with any construction project, planning and project management will ultimately dictate whether waste reduction is accomplished within the established cost, schedule, and quality parameters.

The greatest uncertainty is usually the availability of salvage and recycling services and outlets, and any costs associated with handling these materials. Resources are available to help owners, architectural/engineering (A/E) and Construction Management professionals, and contractors familiarize themselves with the salvage, reuse, and recycling industries and infrastructure.

Few regions are experiencing a shortage of C&D landfill space. However, the increase in tipping fees (especially in the Northeast and the Northwest); regulations excluding C&D materials from landfills; the decline of the numbers of C&D landfills in the United States (26% fewer between 1990 and 2002); and more rigorous standards for new landfill design all suggest landfill disposal of C&D waste will be significantly more expensive in the future.

The architectural, engineering, construction, and waste management industries are becoming more sensitive to C&D waste reduction. Public awareness of waste reduction and recycling has elevated to a point where public policy is also directing C&D waste diversion. Public agencies are encouraging through policy, or requiring by ordinance or regulation, waste diversion in both public and private construction. Many agencies have developed resources such as best practice guides and market directories to facilitate waste diversion at the project level. Furthermore, the US Green Building Council's LEED rating system's MR-2.1 and MR-2.2 credits provide incentive to reduce waste in “green building” design and construction.

The growth in numbers of architectural salvage and used building materials retail businesses and of C&D recyclers is further evidence that building material salvage and recycling is becoming an important segment of the construction industry. Momentum is building in the United States toward salvaging, reusing, and recycling C&D materials. Nationally, estimates of C&D materials recycled are over 325 million tons annually, which exceeds the 215 million tons of municipal solid waste generated in the United States annually (Turley 2006a). Three primary factors motivate diversion of C&D materials from landfill disposal:

1. The environmental benefits of landfill diversion are almost universally recognized. Not landfilling otherwise useful materials reduces waste, conserves landfill capacity, avoids the adverse affects of landfill disposal such as greenhouse gas emissions and hazardous leachate, and avoids the adverse affects of manufacturing new construction materials.
2. Salvaging, reselling, reusing, and recycling materials often costs less than landfill disposal. While the economic benefits are dependent on individual project conditions, it is increasingly apparent that salvaging and recycling C&D materials is less expensive than landfill disposal in many cases.
3. Governmental jurisdictions and private facility owners, through various means, need to promote the diversion of C&D materials from landfill disposal. Examples include:
 - a. Legislation excluding C&D materials from landfill disposal (Commonwealth of Massachusetts (MDEP 2006; Turley 2006a)
 - b. Legislation or regulation to divert C&D waste materials from landfills (State of California, City of Chicago, US Army; Turley 2006b)
 - c. Adoption of LEED and other Green Building standards in facilities development programs (local governments, institutional and commercial property owners)

- d. Programs to support recycling and waste reduction established by the USEPA, EPA Regions, and most states' solid waste management authorities
- e. Industry promotion of a national C&D recycling policy (National Demolition Association).

It would be an overstatement to say aggressive salvage, reuse, and recycling are standard practice within the construction industry. Unfortunately, the path of least resistance is still conventional demolition and landfill disposal in many cases. It is increasingly apparent, however, that waste diversion practices are becoming more common in the C&D industries. This becomes easier when the environmental and economic benefits are both present within a given project.

This report describes the conditions where both the economic and environmental benefits can coexist, and where materials present in a brownfield's buildings and infrastructure can be recognized as assets to the property's redevelopment, or an opportunity to reduce redevelopment cost, instead of a further obstacle and expense.

Materials and resources available on brownfield sites

The hierarchy of responsible resource use (Figure 5) dictates reuse of buildings and structures in preference to recycling. Analysis by the redevelopment team would be required to determine whether existing facilities can be adapted to the appropriate occupancies and incorporated into redevelopment plans, or whether to remove them to enable redevelopment to begin or continue. The feasibility of reusing buildings is a complex issue depending on buildings' physical conditions, intended occupancy, engineering requirements, costs, and other factors specific to the site and redevelopment plans. However, adaptive reuse of existing features should not be summarily dismissed as an option for redevelopment without due consideration.

While buildings' adaptive reuse can be a signature feature of a development, it is not always feasible in either physical or economic terms. Demolition may be the only reasonable recourse to enable redevelopment. When this is the case, the first considerations and discussions for a brownfield site's redevelopment should be the potential benefits of salvaging and recycling construction materials.

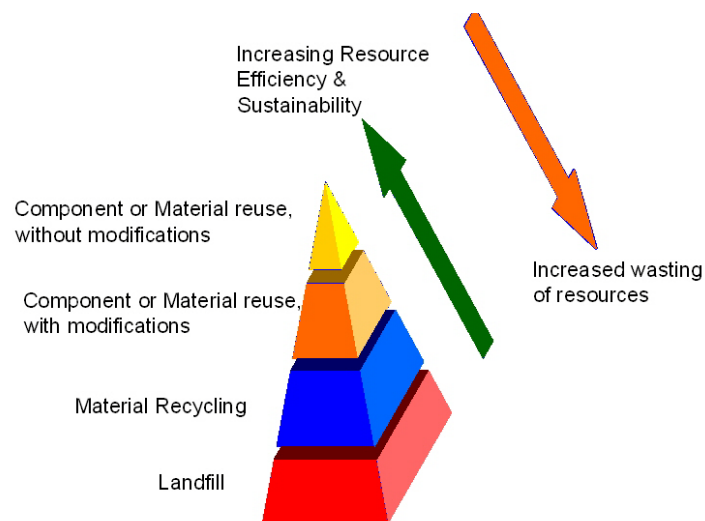


Figure 5. Resource efficiency hierarchy.

As the redevelopment process progresses, decisions become fixed and opportunities close. Salvage and recycling are less likely to achieve positive results when inserted as an afterthought into a demolition or construction contract. When strategic planning incorporates salvaging and recycling practices into project-specific scheduling and budgeting development, making them integral with demolition and construction activities, then are the potential benefits more likely to be realized.

The material types available on brownfield sites depend on the specific site, previous occupancies, facilities, and extant infrastructure. Aggregate materials and asphalt are commonly recycled from paving. Concrete from buildings, structures, and paving is commonly recycled into aggregate products. Commonly salvaged for reuse are brick and architectural stone. Brick and stone can also be recycled into landscape material or fill. Frequently, timbers from floor and roof assemblies are salvaged for reuse, especially if they are old growth hardwoods, Douglas fir, Longleaf Pine, and other desirable appearance-grade materials.

Other clean wood materials (i.e., not painted or otherwise contaminated) not appropriate for salvage and reuse are frequently recycled into garden mulch or for hog fuel for power generation plants. Structural steel is almost universally recycled from steel buildings, structures, tanks, piping, and industrial equipment. Reinforcing from concrete and metals from obsolete heating and cooling equipment are recyclable, and contemporary equipment may have a resale value. Valves, pumps, and other industrial

equipment may be reusable or at least recyclable. Sheet metals and metal fabrications are recyclable. Aluminum, brass, and copper components may be worth more as commodities than reusable products. Plain glass is recyclable. Other items such as doors, windows, and furnishings may be salvageable for resale and reuse if they are in serviceable condition. Otherwise, most of these materials can be recycled. Chapters 6 through 9 and Appendix A provides further information on reusable and recyclable construction materials.

A Road Map for brownfields investigation and cleanup

The USEPA (2005) has developed a document entitled *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup*. This document provides a general outline of the steps in investigating and cleaning up a site intended for redevelopment (Figure 6). It introduces brownfields stakeholders to the range of innovative technology options and resources available to them. The *Road Map* portrays five major steps in the cleanup process:

1. site assessment
2. site investigation
3. assessment of cleanup options
4. cleanup design and implementation
5. redevelopment.

In addition to a process-flow type of approach, the *Road Map* also provides resources to assist stakeholders in identifying and selecting innovative site characterization and cleanup technologies for brownfields redevelopment. The emphasis of this USEPA document is the characterization of brownfields sites, identification of hazardous and toxic contamination, identification of cleanup technologies, development of a cleanup design, and implementation of cleanup operations. These activities are necessary to prepare the site for redevelopment, which is the ultimate goal of the brownfields program.

The *Road Map* does not explicitly address the issue of salvaging and recycling existing construction materials as resources for redevelopment construction activities. Furthermore, the *Road Map* is useful to describe the sequence of activities and decision points involved in the analysis of conditions and development of cleanup strategies.

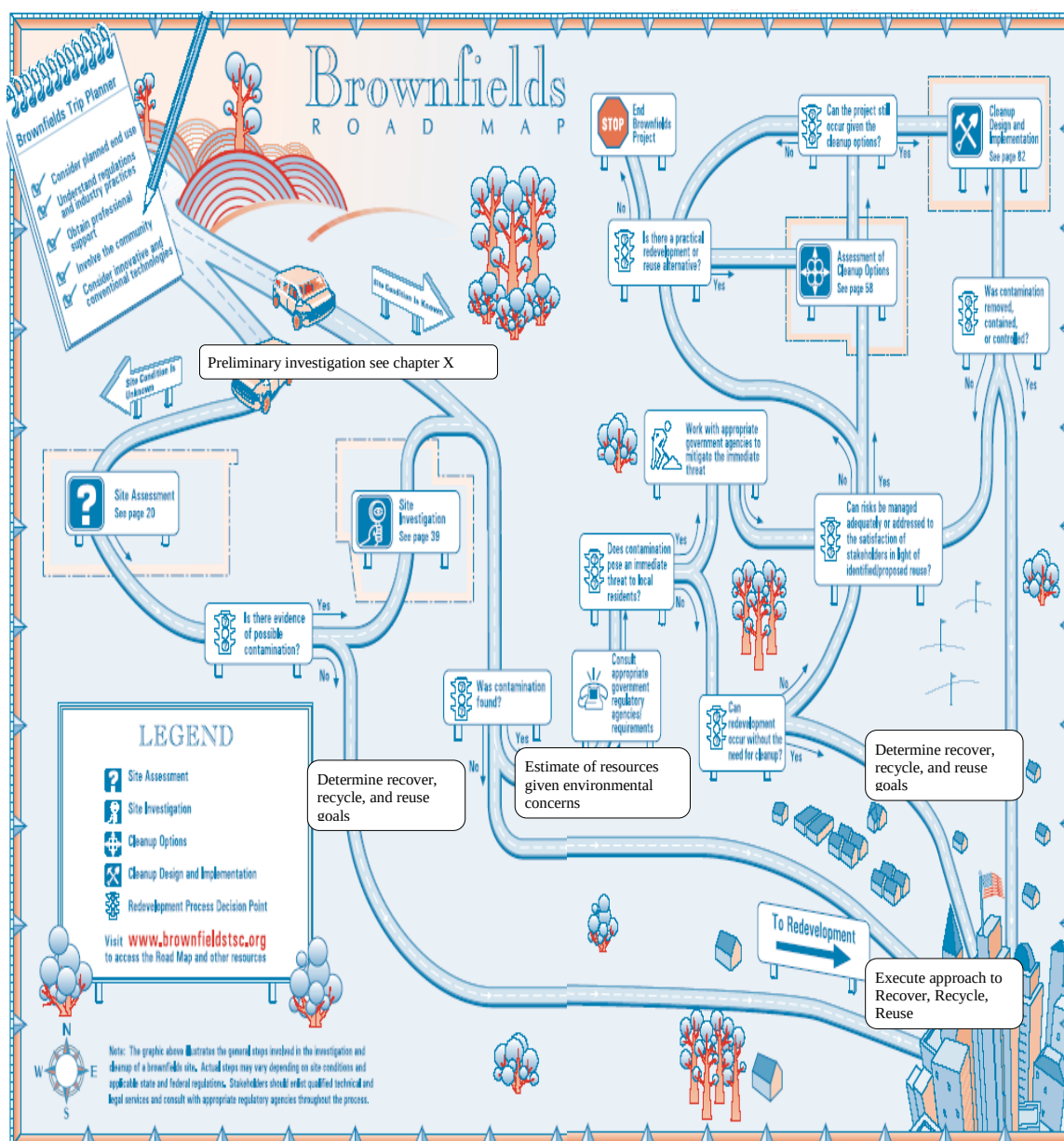


Figure 6. Road Map to brownfield site investigations/clean up.

The very first discussions of brownfield redevelopment must consider the potential for using resources that are already onsite. As the process progresses, considerations must also be given to:

- types and quantities of equipment, materials, or other items present in buildings, structures, and infrastructure that may have some salvage, reuse, or recycle potential
- the suspected presence or absence of contamination in these materials

- the presence and characterization of contamination that is actually detected on equipment or materials
- the extent of the contamination (i.e., how much is contaminated and how much is not)
- the impact contamination may have on the viability of the affected equipment and materials if salvaged or recycled
- the impact cleanup operations may have on salvage or recycling operations.

As the *Road Map* follows a sequential process through the cleanup process, a similar process should be followed when considering, then evaluating, then specifying provisions for salvaging, reusing, and recycling equipment and material resources. The *Road Map* does not explicitly describe the redevelopment activities themselves, and it is during redevelopment (demolition and construction) or preparation for redevelopment (demolition) that resource recovery will actually take place. However, without the appropriate evaluation and planning for resource recovery prior to demolition and construction, the effectiveness and benefits to the redevelopment team may be less than effective. This report will refer to the *Road Map* to indicate consideration of resource recovery throughout the cleanup and redevelopment process.

The *Road Map to Understanding Innovative Technology Options for brownfields Investigation and Cleanup* is comprehensive and covers all phases of the cleanup process. Appendix A of the *Road Map* document lists typical brownfield sites and potential contamination found due to site activities.

Construction and demolition materials recovery

Prior to demolition, remove any hazardous materials including asbestos, asbestos-containing materials, mercury (Hg), and polychlorinated biphenyls (PCBs) from the buildings and structures. Hazardous materials abatement is required prior to demolition, and the demolition industry is familiar and capable of handling these materials. In a brownfields scenario, additional hazardous and toxic materials may be present. Therefore, the developer must perform the site assessment, site investigations, evaluation of cleanup options, cleanup design, and implementation of cleanup activities independent of demolition activities.

Conventional demolition, or “wrecking” as it is often called, is essentially the removal of a building or structure by mechanically collapsing it, crushing or cutting the debris into manageable sizes, loading the debris into a truck or receptacle, and hauling it off the site. Demolition typically removes the building in sections or areas, beginning at the top of a building and moving downward, and possibly from one end to another depending on the shape and volume of the buildings. The sequence progresses as debris is cleared and the equipment is able to reach new areas of the building. While swinging a wrecking ball is still a useful method for demolishing concrete and masonry structures, contractors also apply more sophisticated demolition equipment such as hydraulic hammers, pinchers, shears, grapples, and claws. The industry has adopted these methods and they are better suited for more specialized demolition tasks. Whole buildings may also be imploded, especially when they are too tall for conventional excavators or boom-mounted equipment to reach.

Precautions are usually not taken to preserve the integrity or usefulness of construction materials as a whole during the demolition process. As demolition is a destructive process, personnel are not present in the building itself while it is being demolished. Contractors frequently extract major components, such as structural steel framing members or boilers, from the facility during demolition and set them aside as scrap for recycling. Further separation is accomplished by sorting through the debris pile for metal scrap that can be picked up with a hydraulic excavator’s bucket. Materials that cannot be picked up with the hydraulic excavator bucket are generally left in the debris pile. Manual sorting is not common at the building site. Many people frequently perceive these tasks as requiring additional effort and time on the demolition site, however, which increases the demolition cost. It has become more common recently to extract metals from the debris and to recycle concrete rubble into aggregate products. However, the state of practice is still such that other materials typically end up as debris because these tasks are frequently perceived as requiring additional effort and time on the demolition site, which increases demolition cost.

Some approaches can be applied to increase materials salvage and recycling, which will be to the advantage of the redevelopment team. The relationships among the community, development team, engineering consultants, demolition services, and construction services will help determine

which approach is most practical for any given situation.* Chapters 9 and 10 detail these approaches, which are summarized as:

- Remove (salvage) equipment, materials, and other items of value from buildings and structures prior to demolition.
- During the demolition of buildings, structures, and infrastructure, extract and separate recyclable materials. However, any useable equipment or items will be damaged during the demolition process.
- Demolish buildings, structures, and infrastructure with conventional demolition practices. Any useable equipment or items will be damaged during the demolition process. The demolition contractor can dispose of the debris at a C&D recycling facility, where they will crush and separate it into recyclable materials.
- The demolition contractor deconstructs (disassembles) the building to preserve its components and materials for resale and reuse. Deconstruction is applicable mostly to construction types that lend themselves to disassembly, such as wood structures, or pre-engineered structures that can be disassembled and reassembled.

The redevelopment team can realize value from existing equipment and construction materials as follows:

- By retaining salvaged materials and selling directly to the specific markets, the redevelopment team can achieve the highest revenue. However, the team must assume the risk of market fluctuations and sales. The team must also possess the capabilities to conduct direct sales, such as knowledge of the markets, facilities to store and handle the materials, and staff to conduct sales.
- By retaining equipment and materials that will be used in subsequent construction and offering them to construction contractors, the redevelopment team can reduce the cost of construction. These materials may include recycled concrete aggregate, asphalt paving, fill materials, landscape materials, timber members, and other components that may be used in buildings. Bidding or negotiating for construction services should reflect the value of these materials and cost avoidance to the contractors. The value to the redevelopment team will be in reduced contract prices for construction services.

* Note that none of these approaches are mutually exclusive; combinations can be adapted for any given demolition requirement.

- By allowing salvage or demolition contractors to retain the materials themselves and dispose of them in the most economical fashion, the redevelopment team will reduce the cost of demolition. Bidding or negotiating for salvage or demolition services should reflect the value of these materials and potential receipts for the contractors. If the content of the buildings or structures is valuable enough, salvage or demolition contractors may even pay for salvage rights.

5 Sustainable Brownfield's Redevelopment

Brownfield redevelopment

The whole idea of a brownfield site is to redevelop the site by removing a liability and developing an asset for the community that hopefully will encourage economic growth and employment. The potential usefulness of existing facilities or construction materials may or may not influence the redevelopment of the site at the strategic level. However, it should not be ignored. The potential utility of the resources onsite may be enough to keep some options viable. An owner/developer will have many considerations to look into before they can redevelop the brownfield site. The intent of this chapter is to summarize all the considerations into some simple steps and allow the reader to consult the references if additional information is needed.

Many scenarios will have to be considered by the various participants in the process of brownfield redevelopment (property owners, community organizations, property developers, designers and engineers, construction contractors, and others). One common scenario is that a community, redevelopment commission, or property owner will hire a developer to generate redevelopment strategies, from which they will select one they feel will best meet the community's redevelopment objectives. Then the developer's team will include the planning, architectural, and engineering disciplines that will eventually create all the design and construction documents (drawings and specifications) for construction contractors to execute (see example, next page). Another common scenario is for the community or the property owner to develop their own redevelopment strategies and produce designs and construction documents themselves for construction contractors. Some projects are large and complex involving acres of land, a large number of buildings, a large single facility, or complicated infrastructure. Other projects may be small involving a single facility or a parcel of land. All site clearing and new construction may be initiated as a continuous process or in stages. The scope and complexity of the site, staffing capabilities, local resources, and interests, and the preferred role of the prevailing authority are factors contributing to how a brownfield site will ultimately be redeveloped.

Much planning will occur before the community can decide on a brownfield site's appropriate reuse. They may call in a number of other organizations to assist in this process. These organizations will include regulatory agencies such as the Federal and state environmental protection agencies, organizations that have performed previous projects (such as the Corps of Engineers), and subject material experts. The Corps of Engineers is probably one of few organizations that have been involved in a variety of projects throughout the United States. They not only can be a springboard of redevelopment ideas, they can assess the existing facilities, building components, and materials for potential contribution to the redevelopment process.

Once all the players have formulated a picture of the ultimate final product, they will lay out the path to achieve that goal. This plan will require the removal and/or reuse of the existing facilities in many cases. Even though for most cases the removal of existing facilities or demolition is a small portion of the overall development contract, removal of the existing facilities through recovery and reuse can substantially lower the development costs. Generally, the keys to successful C&D waste management are effective project planning, economic analysis, and program integration. The waste management objectives and process must be planned well in advance of the actual development activities and coordinated with key steps in the building construction process.

Brownfield redevelopment example

The following example of the redevelopment process in Madison, WI, incorporates salvage and recycling of existing materials. Even though not officially designated a brownfield site by the USEPA, it follows a brownfield-type development scenario, being "... an abandoned or ***under-used*** piece of property that is burdened by real or perceived contamination." In 1998 a local businessman, W. Jerome Frautschi, donated \$50 million to the city to develop a cultural arts district in downtown Madison. The city looked at several sites and selected the underutilized Madison Civic Center to redevelop. This site consisted of several old retail stores; a bank, offices, restaurant, and a grocery store. They then engaged the internationally famous architect Cesar Pelli to design the Overture Center of the Arts. This center would include an Overture Hall, a Playhouse, the Madison Museum of Contemporary Art, meeting rooms, four art galleries, a glass lobby, and the Capital Theater.

To assist in this project, the state gave a grant to J.H. Findorff & Sons to look at ways to reduce C&D debris. J.H. Findorff (the project's general contractor) hired WasteCap of Wisconsin (a nonprofit waste reduction consulting organization), which developed the procedures to reuse, recover, and recycle the materials, reducing the amount going to the landfill by 55% (Findorff 2004). See Figures 7–9. Appendix B contains other examples of salvaging and recycling projects.



(Used with permission of the Overture Center.)

Figure 7. Bank One and other existing structures.



Source: <http://epdweb.engr.wisc.edu/aecarticles/rsr19.lasso>

Figure 8. Artist's conceptual view of new Civic Center.



Source: <http://www.overturecenter.com/history.htm>

Figure 9. Constructed Civic Center.

Generic steps of redevelopment

All brownfield redevelopment projects have five generic steps that have to be accomplished before the project is complete. Figure 10 shows the generic steps of reuse, recovery, and recycling on a project. A more detailed explanation of each of the steps follows in Chapters 6–10.

1. Determine disposition of any existing facilities. Theoretically, the recovery or reuse of any building is possible. However, the practicality of reuse and recovery will limit the options. The community and the developer need to consider the reuse and recovery of all facilities in redeveloping the brownfield site until the reuse option proves unfeasible. Furthermore, the contractor will recover/reuse only where it will be possible to obtain a profit or benefit. Therefore, some facilities have a higher reuse and recovery potential than others. For example, a clear span open bay warehouse has more options for redevelopment than does a multi-story cast-in-place concrete hospital.

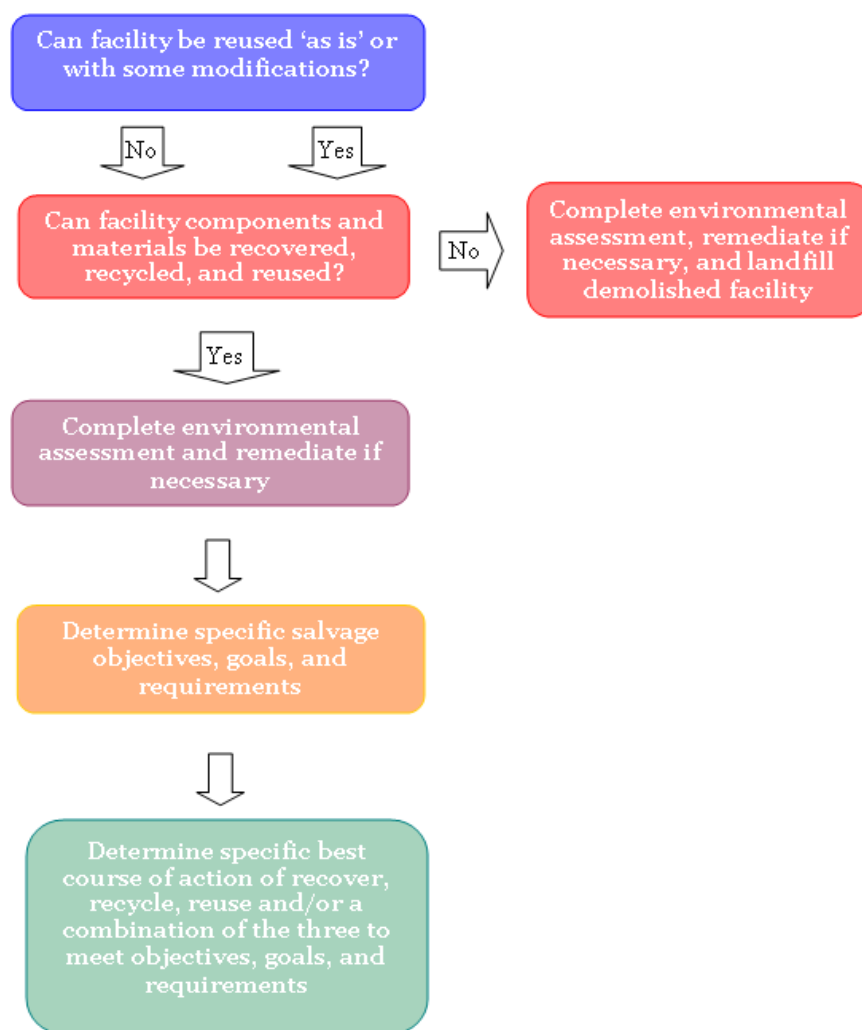


Figure 10. Flowchart of reuse, recovery, and recycle process.

2. Preliminary inventory of facility components and materials. During this planning stage of the reuse and recovery process, the land developer should inspect and assess the facilities to have a basic idea of what components and materials are available for reuse and recovery and the potential market for those items. The developer does not need to know exactly how much of an item can be reused (e.g., 6.65 tons), only that available quantity is sufficient to make recovery and reuse an economic possibility. Also during this phase, the land developer will need to determine whether any of the components or materials is environmentally hazardous. He/she will also have to determine if these materials will hinder or even prevent the reuse or recycling of other components and materials. The Corps of Engineers should inspect and assess facility components and materials for any military property.

3. Survey, access, and abate environmentally hazardous materials. Generally, brownfield sites do have some level of contamination. During the inspection and assessment process of step 1, the developer should become aware of these potential contaminations to be able to alert the contractor. In turn, the contractor must deal with these contaminations before any reuse and recovery operations begin. This mitigation makes it safe for the contractor to work in the facility and allows access to salvage materials that may not have been previously possible. In some cases, removing the hazardous material may prevent the reuse, recovery, or recycling process.
4. Develop specific salvage objectives, goals, and requirements. The redevelopment contract is probably most important for requiring the contractor to reuse, recycle, and recover. The developer should make it very clear in the contract that the contractor will perform these actions and could even offer additional incentives for the more material reused, recycled, or recovered. This report will present more information on this topic later.
5. Determine approaches to salvaging facility components. The five generic ways to reuse or salvage items at a site are to reuse the facility component with minor modifications, demolish and remove it, recycle the item, recover the item for a later same-use scenario, and deconstruct the facility. While these approaches all sound very logical and simple, no solution is “one size fits all.” Some options that will work for certain situations will not be feasible in others. These categories are not intended to be all-encompassing. Each brownfield remediation site will be different and may require a combination of all five categories.

USACE role in brownfields construction and demolition

USACE is the construction agent for the Army. The Corps performs planning, design and engineering, construction, construction management, facility management, operations, and environmental management for the Army’s Military and Civil Works missions. These capabilities can be applied to brownfields redevelopment in a variety of ways. For the purposes of this report, however, the term “the Corps” or “USACE” will be used to represent any office within the Corps of Engineers that participates in brownfields projects to any degree.

The Corps cannot participate directly in brownfields projects, as they have no direct authority, which means they have no direct funding support. The Corps partners with other agencies to execute the Federal brownfields program and has signed memoranda of understanding (MOUs) with

USEPA and the Department of Housing and Urban Development (HUD). The MOUs recognize USACE expertise and authority in water resource development, and how that expertise can aid in redevelopment of adjacent properties. USACE may provide technical assistance for brownfields projects funded by either agency. The USEPA is generally the Federal lead in the overall brownfields program. Their program is chiefly executed through four types of grants:

- assessment grants support environmental investigation and planning
- revolving loan funds provide low interest loans for communities for any phase of brownfield clean up
- cleanup grants
- job training grants foster workforce development relevant in communities impacted by brownfield sites.

The Brownfields and Land Revitalization Technology Support Center is a joint program from USEPA, USACE, and Argonne National Laboratory. USEPA grant recipients can request technical assistance, such as document review, or information on innovative cleanup technologies.

Corps participation in a brownfields redevelopment project would be through reimbursement under related authorities for Civil Works, Water Resources, Support to Others, and Planning Assistance to States programs. These programs would not necessarily consist of brownfields redevelopment, but brownfields may be one element within the subject site and project. These programs frequently require cost sharing between the Corps and local authorities. Interagency Agreements or Memoranda of Agreement with the Redevelopment Authority are the instruments that enable Corps participation. This report focuses on the responsible use of existing construction materials in brownfields redevelopment (i.e., salvage, reuse, and recycling). Further discussion of the various avenues to engage the Corps in brownfields work is beyond the scope of this report. Regarding material salvage, reuse, and recycling, suffice it to say the Corps may be involved in some fashion.

The Corps participates in partnership with some other Redevelopment Authority or authorities. These may include state agencies (economic, environmental, others), the USEPA region, local agencies (municipal and/or county), commercial developers, engineers and consultants retained by partners, community leaders, local nongovernmental organizations, and

others. Typically, a single authority will be responsible to lead and manage the redevelopment. This authority may be one of the agencies involved, or may be a separate group chartered specifically to manage the redevelopment. For the purposes of this report, the term “Redevelopment Authority” will be used to represent any agency or organization that leads and manages redevelopment efforts, to which the Corps would be responsible. It is important to note that, while the Redevelopment Authority may be a single organizational entity, it should represent all stakeholders in the redevelopment. In all probability, stakeholders will promote many diverse interests, not all of which will be consistent. The Redevelopment Authority must represent the community’s stakeholders and resolve the collective input when developing a cohesive redevelopment strategy, and definitive redevelopment plans.

The organizational element within the Corps that most commonly participates in brownfields projects is the District, which is a geographic region defined by either political boundaries (Military Districts) or watershed boundaries (Civil Works Districts). Virtually all planning, engineering, cost engineering and analyses, materials technologies, construction, operational, environmental, ecosystems, hydrology, real property, technology transfer, and related disciplines are present within a District’s workforce. Expertise in research and development (R&D) and technology specialties (such as hazardous, toxic, and radiological waste) are available through Corps laboratories and centers.

A chain of responsibilities and actions also involves other interim-level offices and the Corps’ Headquarters. With respect to site clearing, demolition, and construction issues — specifically debris management — a Corps District will be involved at the working level in most cases.

The Corps does not initiate brownfields redevelopment, or lead redevelopment policy and processes. Rather, the Corps provides services to the Redevelopment Authority, per Agreement and their direction. Hazardous materials’ surveying and analyses, clean up, site preparation, renovation, and new construction will be activities relevant to the salvage, reuse, recycling, or disposal of existing construction materials. Corps tasking may include hazardous materials surveying, cleanup design and specifications, cleanup contract management, site clearing design and specifications, and C&D contract management for site preparation activities. While commer-

cial developers, construction contractors, subcontractors, and trades typically execute the new construction activities, the Corps may be tasked with some type of engineering support or construction management activities.

The specifics of these tasks and activities may be outside the strategic-level attention of the Redevelopment Authority, and may ultimately become the responsibility of their C&D services, property developer, or general contractor. The Redevelopment Authority may not provide specific direction in this regard. Therefore, the Corps' role in maximizing the benefit of existing construction materials may be to:

- evaluate the potential for their beneficial use in redevelopment.
- assess local interests in salvage and recycling, and identify industry capabilities, labor, and services' availability.
- communicate these benefits and promote salvage, reuse, and recycling in the appropriate policy-level decisions.
- represent materials salvage, reuse, and recycling in planning, development, and design decision-making processes.
- preserve useful materials' integrity in the cleanup design and cleanup activities.
- upon clean up, develop quantity take-offs or estimates of materials suitable for salvage and reuse and recycling, and describe potential outlets and uses onsite for these materials in subsequent site development and construction activities.
- with the Redevelopment Authority partners and other stakeholders, assist in exploring opportunities for job training and business development, which can support materials' salvage, reuse, and recycling objectives.
- incorporate salvage, reuse, and recycling provisions into cost analyses, contract provisions, technical (design and specification) documents, per tasking from the Redevelopment Authority.
- incorporate salvage, reuse, and recycling provisions into construction management and quality control/quality assurance activities, per tasking from the Redevelopment Authority.

The following references may be useful in understanding the Corps' role in brownfields redevelopment:

- The Brownfields and Land Revitalization Technology Support Center, <http://www.brownfieldstsc.org/>

- MOU between Office of Community Planning and Development, HUD, and USACE, 21 June 1999
- MOU between USEPA and USACE, 24 October 2003
- USACE Environmental Community of Practice,
<http://hq.environmental.usace.army.mil/programs/brownfields/brownfields.html>
- USEPA Brownfields Cleanup and Redevelopment,
<http://www.epa.gov/brownfields/pilot.htm>

6 Determine Disposition of Existing Facilities

The type of facility and its component parts are critical to material salvage economy. Some facilities, such as a warehouse or office building, might lend themselves to reuse, while others, such as a specialized industrial facility, might be better suited for material recycling. Additionally, construction material will play an important part in the reuse, recycle, and recover process. Wood is a material typically sought after, especially from older facilities. Dimensional lumber and timbers are common wood products that are recovered and reused. In some cases, the larger the timber dimensions, the higher the potential reuse. Different wood species have different potential values, with hardwoods and firs being the most desirable. Older seasoned wood products also have a high reuse and recycle potential.

An individual with lots of ingenuity can reuse any building type. However, some types tend to have a higher potential as reusable facilities than others. One of the most desirable facilities is a large clean span warehouse because it offers a number of reuse choices that might range from a strip mall to an apartment complex. On the other hand, a vehicle repair facility tends to be reused as the same facility type or something very similar. Other common facility types that offer a number of reuse possibilities are administrative/office, commercial, and light industrial buildings.

7 Preliminary Inventory of Facility Components and Materials

During the planning phase, it is not the intent to do a detailed analysis of all the potential facility components available for reuse, recycle, or recovery. However, the community and land developer need to have a very good general idea of what can fit into these categories and the available market. With this knowledge, they will be able to encourage the contractor to reuse, recycle, and recover based on the condition of the facility component.

During the execution phase, the contractor will have to accomplish a detailed inspection and assess the facilities to determine components and materials are available for reuse and recovery. Also during this phase, the contractor will need to determine whether any of the components or materials is environmentally hazardous. He will also have to determine if these materials will hinder or even prevent the reuse or recycling of other components and materials.

Over time many facilities will have been remodeled more than once, and these recently installed building components and equipment are valuable on the used building material market. Some of the building systems that fit into this category are interior partitioning and finishes. Affecting the reuse, recycle, and recovery process are accessibility to materials and the effort needed to salvage them (i.e., the harder it is to get to the item and remove it, the lower the potential for reuse, recycle, and recovery). If the facility is still in good shape, materials and building components may be recoverable/desirable. However, if the facility has been abandoned for 40 years and is in poor condition, there is probably very little salvage material on the inside.

Facility components

A large number of facility components have some potential recycle or reuse depending on their existing condition. The following are typical components and materials recovered for reuse. Appendix A gives a detailed list of building components and materials.

- acoustical ceiling tiles
- architectural features – historically sensitive building components

- asphalt / bituminous roofing
- asphalt pavement
- cabinets and casework
- cardboard packing and packaging
- carpet and carpet pad
- ceramic tiling (wall and floor)
- concrete
- dimensional lumber (e.g., 2x10, 2x8, 2x6)
- electric equipment and light fixtures
- glass (untempered)
- gravel and aggregate products
- gypsum board
- hardwood flooring
- heating ducts, sheet metal
- landscape and land clearing debris (green wood materials)
- large, heavy timbers
- lighting fixtures and electrical components
- masonry products (bricks, blocks, tiles)
- mechanical equipment
- metals, structural steel, ferrous and nonferrous
- piping (metal/ PVC)
- plastics (films, containers, PVC products, polyethylene products)
- plumbing fixtures and equipment
- siding
- timbers
- windows, doors, and frames
- wood (dimensional lumber, sheet goods, millwork, scrap, pallets)
- wood paneling, molding, and trim.

Composition

The *Whitestone Building Maintenance and Repair Cost Reference 2006-2007* (Lufkin and Pepitone 2006) is an excellent source for a global picture of the amount and types of building components in certain types of facilities. Even though the focus of the manual is when to do repair and how much per square foot it will cost, it also highlights some of the building components that might be encountered in these facilities.

The composition of debris will vary significantly. For example, debris from older buildings is likely to contain plaster and lead piping, while new construction debris may contain significant amounts of drywall, laminates, and plastics. For building debris, USEPA estimates the overall percentage and weight-volume of materials in C&D debris fall within the ranges listed in Tables 1 and 2 (Sandler 2003). See Appendix C for a detailed breakout of the weight-volume of the materials in building components.

Table 1. Overall percentage of materials in C&D debris.

Material	C&D Debris (%)
Concrete and mixed rubble	40-50
Wood	20-30
Drywall	5-15
Asphalt roofing	1-10
Metals	1-5
Masonry	1-5
Plastics	1-5

Table 2. Weight-volume conversions for common remodeling waste materials.

Material	Pounds per cubic yard	Cubic yards per ton
Wood	300	6.7
Cardboard	30-100	20-50
Drywall	400	5
Rubble	1400	1.4
Mixed waste	350	5.7

Uses for C&D recycled materials

The following list contains some common reuses of building materials:

- *Asphalt* (including roofing) – asphalt patch for roads (cold-mix) pavement, onsite processing into hot-mix for roads, road base, or fill.
- *Bricks and other masonry items* – fill material, aggregate, road base
- *Cardboard* – paper products, feedstock for more cardboard
- *Concrete* – lime for a neutralizing agent, rip-rap for harbors (large pieces)
- *Drywall* – soil amendment (gypsum), cement additive (gypsum), new drywall (gypsum), animal bedding (paper)

- *Glass* – reuse of windows and mirrors, inert granular material additive, fiberglass, reflective beads, glasphalt
- *Metals* – reuse by salvagers, various metal feedstocks
- *Paper* – paper fiber, feedstock (paper), and animal bedding (paper)
- *Rubble* – aggregate for fill or road base, construction entrance roads, drainage bed material, landfill cover material
- *Stone* – road base, fill material, aggregate for new ready-mix
- *Synthetic materials from carpets* – feedstocks
- *Wood* – wood fuel, mulch, bulking agents for composting, manufactured wood products, alternative wood fiber-based materials (e.g., particle board, door panels for cars, cement additives).

Salvage value

Table 3 (USACE 2001) lists estimated salvage values for some commonly recovered materials is from. Even though the costs are outdated, one can see the concept of salvage value for commonly recovered materials.

Preliminary salvage market

Recyclable material has potential for returning a value to the contractor only if it has a market demand. The value of the recycled materials may recoup the handling and hauling costs. The contractor may create a cost avoidance if he/she will not have to purchase the building materials or pay to dispose of them. Therefore, the community and the developer need to have a basic idea of the market and the cost savings to the contractor. With this information, they can entice, encourage, and/or require the contractor to perform reuse, recycle, and recovery operations. Appendix B includes information that can help assess market demand and infrastructure.

Table 3. Estimated salvage values for some commonly recovered materials.

Item	Description	Unit	Retail Unit Value	Estimated Salvage Value
Metals	Aluminum Scrap	Ton		\$480.00
	Brass Scrap	Ton		\$560.00
	Copper Scrap	Ton		\$980.00
	Lead Scrap	Ton		\$380.00
	Steel Scrap	Ton		\$35.00
Oak Flooring	2-1/4-in. wide	SF	\$2-\$2.50	\$0.65-\$1.00
	3-1/4-in. wide	SF	\$2-\$2.50	\$0.65-\$1.00
Framing Lumber "higher" quality (#2 grade)	2 x 4 (8-10 ft)	EA	\$ $\approx$ 3.00	\$0.90-\$1.10
	2 x 4 (12-14 ft)	EA	\$ $\approx$ 4.50	\$2.00-\$2.40
	2 x 8 (12 ft)	EA	\$ $\approx$ 8.75	\$3.90-\$4.80
	2 x 8 (14-15 ft)	EA	\$ $\approx$ 10.00	\$4.50-\$5.50
Framing Lumber "lower" quality (construction grade)	2 x 4 (8-10 ft)	EA	\$ $\approx$ 3.00	\$0.30-\$0.75
	2 x 4 (12 x 14 ft)	EA	\$ $\approx$ 4.50	\$0.45-\$1.10
	2 x 8 (12 ft)	EA	\$ $\approx$ 8.75	\$0.90-\$2.20
	2 x 8 (14-15 ft)	EA	\$ $\approx$ 10.00	\$1.00-\$2.50
	2 x 12 (10 ft)	EA	\$ $\approx$ 10.00	\$1.00-2.50
Brick	Flush	EA	\$0.30-\$0.35	\$0.10-\$0.20
Windows (double-glazed, aluminum replacements)	31 x 54-in.	EA	\$90-150	\$15-\$30
	34 x 45-in.	EA	\$90-150	\$15-\$30
	20 x 36-in.	EA	\$90-150	\$10-\$15
Doors	36-in. ext. panel	EA		\$0-\$15
	18-in. paneled	EA		\$5-\$10
	24-in. paneled	EA		\$5-\$10
	30-in. paneled	EA		\$5-\$10
Tubs/toilets/sinks	Cast iron tub/ stainless steel	EA		\$5-\$10
Stair units, treads	Oak treads/ units include stringers	EA		\$25-\$50

8 Survey, Access, and Abate Environmentally Hazardous Materials

The contractor will have to address all environmental concerns before any items can be reused, recycled, or recovered. Sometimes hazardous toxic substances in or on some building materials will render that material unsuitable for reuse or recycling. The contractor will have to remove these items in accordance with all regulatory requirements. The following list of hazardous materials and equipment components is not intended to be all-inclusive; it is meant to give only an idea of what can be found in building materials.

Asbestos

A building probably has asbestos if it:

- was built between 1955-1978 and has ceilings that are bumpy, as if coated with cottage cheese or popcorn
- was built between 1940-1955 and has hard, rock-like shingles or siding
- was built between 1940-1983 and has vinyl flooring
- was built between 1955-1978 and has gypsum drywall in the walls
- has ductwork sealed with white duct tape
- has steam lines
- has pipe insulation that looks like corrugated cardboard
- was built between 1920-1978 and has pipe insulation wrapped in canvas.

Asbestos containing building materials can be found in heating, ventilating, and air-conditioning (HVAC) systems, some electrical items (such as transit panels in transformer boxes), interior walls (such as plaster and wall board), exterior walls (such as siding, putty, and fire doors), insulation (rock wool insulation), flooring (such as floor tiles), roofing felts, acoustical ceiling tiles, and plumbing (pipe insulation).

CFCs, halons, and other refrigerants

Chlorofluorocarbons (CFCs) and other chlorine- and bromine-containing compounds have been implicated in the accelerated depletion of ozone in

the Earth's stratosphere. CFCs are manufactured under the trade name Freon. CFCs were developed in the early 1930s and are used in a variety of industrial, commercial, and household applications. These substances are nontoxic, nonflammable, and nonreactive with other chemical compounds. These desirable safety characteristics, along with their stable thermodynamic properties, make them ideal for many applications — as coolants for commercial and home refrigeration units, aerosol propellants, electronic cleaning solvents, and blowing agents. Not until 1973 was chlorine found to be a catalytic agent in ozone destruction.

Halons, or brominated CFCs, are unfortunately very effective at destroying stratospheric ozone. Halons are used in fire protection because they are effective fire extinguishing agents, are electrically nonconductive, leave no solid or liquid residue, are noncorrosive, and are not considered toxic at recommended concentrations for occupied areas.

In 1987 most of the developed nations of the world signed the landmark international treaty (sometimes abbreviated as “Montreal Protocol”) that prescribes actions, including cessation of production, to move the world community away from the use of severe ozone depleting substances, including CFCs and halons. In developed countries, the production of halons 1211 and 1301 stopped 1 January 1994.

CFCs, halons, and other refrigerants can be found in refrigeration and air conditioning equipment, vending machines/food display cases, dehumidifiers, refrigerators/freezers/chillers, heat pumps, water fountains/coolers, walk-in coolers, and fire extinguishers.

Lead

Generally, the older a house is the greater the chance it contains lead-based paint (LBP), although any house built prior to 1978 has the potential to contain it. A house built prior to 1940 is almost guaranteed to have LBP somewhere in it.

Lead oxide is a white pigment used since ancient times; it was used rather than any of the many other white mineral pigments because of its greater ability to hide what it covers. Prior to 1940, lead was in almost every paint. As titanium dioxide (a white pigment with hiding power superior that of to

lead oxide) became economical, the use of lead oxide diminished. Lead chromate pigments in colors of yellow, orange, or green (when mixed with a blue pigment) were also quite prevalent during the same period of use as lead oxide. Lead was burned in leaded gasoline from the 1930s to 1970s, and much of this lead still lies in the soil adjacent to major roads.

Lead is a poisonous heavy metal that can be absorbed into the body through breathing fumes or particles, eating or drinking contaminated food, or through the skin (for organic lead compounds, such as leaded gasoline). The major hazards to the general public today are existing LBP materials and soil contaminated by a combination of deteriorating paint and automobile emissions. Children, with their still developing neurological systems and poorer hygienic practices, are at greater risk than are adults. It is thought that an important pathway of lead into a child is by hand, as the child crawls along a contaminated floor, then puts a hand into his/her mouth. LBP was primarily applied in kitchens, baths, and on wood trim and siding. Lead can also be found in lead pipes and solder, flashing, roof vents, and lead-acid batteries.

Mercury

Because mercury is very dense, expands and contracts evenly with temperature changes, and has high electrical conductivity, it has been used in thousands of industrial, agricultural, medical, and household applications (Huber 1997). Mercury is a common material used in the control systems of HVAC systems and appliances such as:

- float or lever controls
- fluorescent lights
- high intensity discharge lights
- load meters
- manometers
- mercuric-oxide batteries
- space heater controls
- switches, relays, and sensors
- thermometers and gauges
- thermostats
- boilers, furnaces, heaters, and tanks
- electrical systems.

When a mercury-containing product such as a thermometer is broken over a sink or improperly cleaned up after a spill, the mercury could be flushed down the drain. Mercury may also be present in a facility's sewer pipes and traps from historical use of mercury. Therefore, specialty buildings and locations (such as dairy barns, hospitals, clinics, laboratories, dental offices, and schools) can be a source of mercury.

For fetuses, infants, and children, the primary health effect of mercury is impaired neurological development. For adults, high exposures to mercury may result in damage to the gastrointestinal tract, the nervous system, and the kidneys.

Polychlorinated biphenyls

PCBs are mixtures of up to 209 individual chlorinated compounds (known as congeners). PCBs have no known natural sources. They are either oily liquids or solids that are colorless to light yellow. Some PCBs can exist in the air as a vapor. PCBs have no known smell or taste. Many commercial PCB mixtures are known in the United States by the trade name Aroclor.

PCBs have been used as coolants and lubricants in transformers, capacitors, and other electrical equipment because they do not burn easily and are good insulators. The manufacture of PCBs was stopped in the United States in 1977 because of evidence that they build up in the environment and can cause harmful health effects. Products made before 1977 that may contain PCBs include old fluorescent lighting fixtures, electrical transformers, heat transfer equipment, capacitors, specialty paints (e.g., for swimming pools or other industrial applications), sumps or oil traps in maintenance and industrial facilities, and old microscope and hydraulic oils.

Creosote wood

Creosote is the name used for a variety of products: wood creosote, coal tar creosote, coal tar, coal tar pitch, and coal tar pitch volatiles. These products are mixtures of many chemicals created by high-temperature treatment of beech and other woods, coal, or from the resin of the creosote bush.

Chemicals of concern in creosote are polycyclic aromatic hydrocarbons. The International Agency for Research on Cancer has determined that coal tar is carcinogenic to humans and that creosote is probably carcinogenic to

humans. USEPA has also determined that coal tar creosote is a probable human carcinogen.

Coal tar creosote is the most widely used wood preservative in the United States. Virtually all wooden railroad ties and telephone poles in use are treated with creosote to retard rotting. It is used in log homes, bridges, fence posts, etc. Coal tar, coal tar pitch, and coal tar pitch volatiles are used for roofing, road paving, aluminum smelting, and coking.

Miscellaneous environmental issues

The following items will need to be considered and addressed to ensure that there are no environmental concerns:

- appliances
- batteries (nonlead containing)
- computers
- demolition waste
- exit signs (may contain radioactive tritium)
- hazardous waste
- oil
- open burning
- petroleum, storage or spills
- solid waste
- smoke detectors (labeled ones may contain radioactive material and should be returned to the manufacturer)
- soil contamination
- storage tanks
- well abandonment
- wood waste.

The data in Table 4 is intended to help brownfields stakeholders better understand the types of contaminants typically found at brownfields sites and the range of technologies that may be appropriate for assessing and remediating those contaminants during the various phases of a site clean-up (USEPA 2005).

Table 4. Typical contaminants found at brownfields sites.

Brownfield Site Type	Building Type	Potential Site Contamination (See Detailed List in Appendix A of USEPA Roadmap Report)	Construction Type	Potential Contamination of Building Materials*	Building Reuse Potential	Resource Recovery Method
Dry Cleaning	Commercial Dry Cleaning Building	- perchlorethylene - other VOCs	Typically masonry load bearing struc- ture or perhaps metal frame	Solvents could have spilled on floor	Most likely same reuse, or commercial	Clean VOCs up, Recycle equipment, metals, and reuse concrete/ masonry
Gasoline Stations Marine Maintenance Vehicle Maintenance Painting & Automomobile body repair	Vehicle Maintenance Facility	-POL - solvents - paints - antifreeze - batteries, acids - refrigerants - compressed gas used for welding - USTs	Typically masonry load bearing structure, could be steel frame for hoists and lifts	Solvents, fuels, paints, & chemicals could have spilled on floor or on the ground	Most likely, same reuse, com- mercial or light Industrial	Clean up site, remediate building contami- nation, recycle metals, reuse or recycle equipment, demolish & recycle concrete, masonry, etc
Agricultural	Feed Supply & Agricultural Chemical Distribution Points, (Food Processing Plant, Grain Silos, Slaughterhouses, Fresh Pack, Confined Animal Feed Opera- tions [CAFO])	Oils, fertilizers, pesticides, herbi- cides, fuels, grease, solvents, animal wastes	Most common are heavy timber or metal frame buildings	Chemicals, oils, fertilizers, pesticides, herbicides, fuels, grease, & solvents could have spilled on the ground or floor of the structure	Adaptive industrial reuse Grain silos – Indoor climbing wall	Clean up contamination Reclaim timbers and wood recycle metals, concrete /masonry, and old equipment
Manufacturing Plants chlor-alkalai cosmetics glass leather photo supplies plastic printing and ink mfg. semiconductor	Manufacturing Plants & Related Storage Tanks	- VOC's - metals & metalloids - mercury - corrosives	Could be concrete or masonry load bearing structure, steel frame or heavy timber, depending on age and size of struc- tures	Chemicals used in the manufacturing process could have spilled in building or on ground. Could have storage tanks.	Long-span buildings have many reuse possibilities if they are structurally sound, well- built structures that can be cleaned up properly and reno- vated for new occupants. Numerous reuse examples are documented.	If reusing structure, decontaminate and remove / recycle any equipment and metals/ material not saved, then renovate. If clearing structure, salvage metals, nice timbers, fixtures, then demolish and recycle concrete masonry.

Brownfield Site Type	Building Type	Potential Site Contamination (See Detailed List in Appendix A of USEPA Roadmap Report)	Construction Type	Potential Contamination of Building Materials*	Building Reuse Potential	Resource Recovery Method
Manufacturing Plants chemical and dye pharmaceutical pesticide mfg. and use	Manufacturing Plants & Related Storage Tanks	- VOC's - metals - corrosives	Could be concrete or masonry load bearing structure, steel frame, or heavy timber, depending on age and size of structures	Chemicals used in the manufacturing process could have spilled in building or on ground. Process chemicals may remain in equipment or piping.	Chemicals residues and unique construction layout might make reuse of the building difficult. Buildings with large clear span may be adaptable.	Decontaminate as necessary, recycle metal equipment, and building materials, recycle concrete.
Recycling Plants Battery recycling and disposal Drum recycling auto salvage metal salvage	Manufacturing plants, scrap yards, large crushing, baling machines	- Acids - POL - metals - contaminated "fluff" from auto recycling	Could be concrete or masonry load bearing structure, steel frame, or heavy timber, depending on age and size of structures	Chemical spills, storage tanks	Most buildings in this category would be very specialized and utilitarian. Reuse likely limited to similar operations.	Decontaminate as necessary, recycle metal equipment and building materials, recycle concrete.
Hospitals Research and Educational institutions	Office, laboratory, classrooms	Any number of chemicals used in a research or medical context, generally small quantities	Multiple – larger complexes will be reinforced concrete and steel	Minimal	Office space, commercial, or light industrial	High reuse potential. Very good "cherry picking" salvage potential
Incinerators	Incineration equipment, material handling systems, receiving area / tipping floor, associated office and storage buildings	- fuels - ash (containing heavy metals or other toxics) - any unburned waste materials, depending on type of waste treated	Specialized steel	Ash, heavy metals	Due to the specialized nature of these facilities, direct reuse unlikely. Building shell could be used for other industrial purpose	Recycle steel equipment and structure. Recycle concrete
Landfills	Landfill earthworks Storage, maintenance, office buildings Truck scales	Many possibilities, including corrosive leachate, methane generation, solvents, metals	Earthworks Utilitarian steel frame buildings	Small quantities of many possible contaminants	Direct reuse of closed landfill limited to recreational uses (parks, golf). No substantial construction should occur due to landfill cover requirements, and settling potential. Associated buildings could be reused for similar purposes	Buildings could be reused. Steel frame buildings could be disassembled and moved.
Machine shops and metal fabrication Metal plating and finishing	Industrial buildings with specialized equipment. Metal plating bath systems	Cutting fluids, solvents, corrosives, paints, chromium, acids	Heavy industrial construction, any material type depending on age	Contamination in process equipment, from spills, in storage tanks	Reuse for similar heavy industry. Potential conversion to other industrial uses, warehouse, office.	Heavy construction types offer good deconstruction and recycling opportunities

Brownfield Site Type	Building Type	Potential Site Contamination (See Detailed List in Appendix A of USEPA Roadmap Report)	Construction Type	Potential Contamination of Building Materials*	Building Reuse Potential	Resource Recovery Method
Munitions manufacturing and ordnance sites	Industrial buildings for production of explosives and ordnance. Multiple building or bays incorporating heavy blast protection Associated office, and warehouses Ammunition storage bunkers	Any of the explosives produced or handled. Chemical precursors, (e.g., acids, toluene) Solvents Groundwater contamination	Varied – wood frame, steel frame with masonry in-fill, heavy reinforced concrete	Main concern is explosive residues collecting in and on building components, process equipment, cracks, etc	Reuse limited due to safety concerns. Possible industrial uses if explosive safety concerns addressed. Most warehouse or office space could be reused directly. Bunkers could be reused for misc. storage	Process equipment removed; buildings decontaminated by explosive safety experts. Once explosive safety addressed, good potential for timber recovery, metal and concrete recycling
Railroad yards	Train sheds, maintenance buildings	POL, creosote, PCP, arsenic herbicide				
Wood preservation		CCA, creosote, PCP		Persistent chemical contamination on ground; potential for overall site contamination		
Wood Pulp and Paper manufacturing		Corrosives, chlorine bleaches				
* Note that lead-based paint and asbestos can be found in almost all building types. CCA = chromated copper arsenate PCP = pentachlorophenol POL = petroleum, oils, and lubricants UST = underground storage tank VOC = volatile organic compounds						

9 Develop Specific Salvage Objectives, Goals, and Requirements

Salvage objectives

Waste management should be an integral part of a project's development. Each of the principal project participants—the owner, their A/E services (or construction management consultant), the contractor, and subcontractors—will engage in waste management to some degree throughout the project. Initially, project stakeholders and Redevelopment Authority must establish waste reduction goals, define what levels of diversion are achievable and reasonable under the project's conditions, and what associated practices or policies should be included in demolition activities. Objectives can include the following:

- cost targets or budgets for demolition activities
- schedule parameters for demolition activities
- types of materials to be salvaged, reused, and recycled
- quantities of materials to be salvaged, reused, and recycled
- total debris diversion quantities or rates
- intended disposition of materials (sale, use in redevelopment, other).

Other objectives may be defined to achieve goals, which are not necessarily related to the physical demolition activities but will have some affect on the execution of demolition, salvage, and recycling work. These goals may include:

- affirmative action goals
- set-asides for local businesses
- preferences for minority, disadvantaged, veteran-owned, woman-owned, local, or other similar classifications of contractors, subcontractors, or vendors
- goals for minority or local hiring, or labor composition
- job training opportunities
- business development opportunities in the demolition, salvage, recycling industries.

Depending on their involvement in any specific brownfield redevelopment, USACE and USEPA partners providing technical support should assist in identifying opportunities for materials reuse and recycling, economical analyses and cost engineering, valuation for materials, and defining the

most practical set of reuse and recycling goals for the redevelopment. As specific project conditions will dictate these definitive values, it would be misleading to suggest numerical values in this document. See Appendix B for a list of commonly reusable and recyclable construction materials and components as a point of departure for establishing project-specific diversion goals.

As requirements for Affirmative Action, set-asides, and other similar provisions are common in public construction (including USACE contracts), no further discussion of these topics will be covered in this report. The Redevelopment Authority (and USEPA and USACE partners) should, however, be aware that material salvage and recycling activities may provide another enterprise to support these objectives.

Objectives for materials' salvage, reuse, and recycling should be established in a preliminary fashion as soon as general characterization of the site and its potential resources is made. Objectives can be refined and redefined as the redevelopment planning progresses, and as specific site use, planning, and facilities design tasks are accomplished. Neglecting to consider materials' salvage, reuse, and recycling at the strategic development stages will only make it more difficult to incorporate these practices as specific redevelopment decisions, designs, budgets, and schedules are developed.

Once the specific redevelopment plans have been established and the necessary clean up has been performed, site clearing and demolition activities will proceed. The Redevelopment Authority must then communicate the established objectives to those responsible for the site clearing and demolition tasks. How this takes place depends on the preferences and capabilities of the community and Redevelopment Authority, the size of the property and project, the complexity of the redevelopment, and other factors. Although many variations exist The most common scenarios are:

- The Redevelopment Authority may assume responsibility for clearing the site as an independent action, in order to expedite the redevelopment process, or make it more attractive to potential developers. In this case, the Redevelopment Authority will issue a contract for site clearing (i.e., excavation and demolition) services. Materials salvage, reuse, and recycling objectives can be incorporated directly into these contract requirements.
- The Redevelopment Authority may engage A/E services to develop master plans and specific facility designs for the site. The Redevelopment Authority may then engage a general construction contractor to

- execute the designs. Site clearing and demolition services may be included within in the General Contractor's responsibilities (i.e., Scope of Work). The General Contractor may then subcontract site clearing and demolition, and other specific tasks and trades. The Redevelopment Authority will have to either incorporate materials salvage, reuse, and recycling objectives into contract requirements they will provide to the A/E, or direct the A/E services to incorporate the appropriate materials salvage, reuse, and recycling requirements into their design and the contract requirements that will govern construction (i.e., site clearing and demolition tasks).
- The Redevelopment Authority may engage a property developer to assume all redevelopment responsibilities. In this case, the Redevelopment Authority should incorporate salvage, reuse, and recycling objectives into the proposal, negotiation, and selection criteria by which the developer is selected, and then oversee that the developer respects these objectives as the site clearing and demolition work is performed.

Contracting process

To achieve higher rates of recovery, building material reuse and recovery must be part of the project planning and contracting process. (Detailed information on the contract options is included in Appendix C). A typical demolition contract will not work well to ensure maximum waste reduction, reuse, and recycling, and its use is *highly discouraged*.

Solicitations for reuse, recycle, and recovery have the highest potential for success if a “Best Qualified Bidder” approach is used. This approach explicitly outlines the reuse, recovery, and recycling goals so that the bidder understands what is to be accomplished. This approach will require contractors to submit such boilerplate information as a list of completed projects and references that will show their qualifications to perform the reuse, recycle, and recovery operations. The submission will also include a list of subcontractors, a project schedule, and the plan to meet or exceed the expressed goals.

If Federal lands are involved, consideration must be given to whether the governing entity abided by Federal Acquisition Regulations or another set of governing procurement regulations. These regulations are very restrictive and will require additional work to be “creative.” In any case, USACE must be a constructive partner with the local contracting authority.

The scope of the building removal project will be constant. What the contractor does with the materials will vary. The community and land developer will prepare the contract requirements differently for a small project than for a larger project. For a small project, the community and land developer will most likely spell out the recover, recycle, and reuse process in the contract. With a smaller quantity of material, more information will have to be given to entice the contractor to perform these operations.

For a large project, the process would be to have potential contractors submit proposals and have the developers evaluate those proposals based on merit. This source selection approach will require an investment by the contractor who will have to bring demolition, salvage, recycling services, and used-materials outlets to the project. Furthermore, they will have to coordinate among the various parties for proposal development. The request for proposals, therefore, must soundly show a high potential for recovering materials for resale and reuse in order to justify this investment. The attractiveness of the project also depends on the buildings' construction types, types of materials available in the buildings, and market demand for the salvaged or recycled materials. No specific minimums exist for square footage or for building, inventory, or dollar value of the contract that would justify proposal development. Evaluation of the materials available in the buildings and availability of local service will help determine the feasibility of initiating a source selection approach to removing buildings.

The owners and their developer must determine how their waste management requirements will be represented in the contract documents and incorporated into the project. Several provisions are relevant to the project's overall waste reduction performance.

1. Waste reduction requirements can be represented in the contract documents in essentially three ways.
 - a. Describe the waste reduction goals and rely on the contractor's own initiative to achieve them. This strategy may be effective if the owner and contractor share a good working relationship and encouraging the contractor is sufficient for them to "do the right thing."
 - b. Specify definitive minimum waste and debris diversion criteria. This information is commonly incorporated into the demolition specification as a numerical criterion, such as "divert from landfill disposal a minimum of 75% of the nonhazardous construction waste generated at the jobsite."
 - c. Develop incentives to reward the contractor. This may be implemented as an award-type incentive based on the diversion rate, or by including

options in the bid schedule for each of several ranges of diversion rates.

Note: Simply requiring a specific LEED rating does not guarantee credit MR 2.1 or 2.2 (50%, and an additional 25% C&D waste diversion, respectively) will be attained. If the owners and their developer desire to rely only on LEED as their requirement for environmental performance, they can still specify that MR-2.1 or MR-2.2 are mandatory for the project.

2. Solicitations for these reuse, recycle, and recovery have the highest potential for success if a “Best Qualified Bidder” approach is used. This approach explicitly outlines the reuse, recovery, and recycling goals so that the contractor understands what is to be accomplished. Contractors will be required to submit such boilerplate information as a list of completed projects and references that will show that they are qualified to perform the reuse, recycle, and recovery operations. The submission will also list the subcontractors, have a project schedule, and describe how they plan to meet or exceed the goals.
3. Require the contractor to submit a C&D Waste Management Plan. Typically, the Plan includes the following:
 - a. Name of individual(s) responsible for waste prevention and management
 - b. Actions that will be taken to reduce solid waste generation
 - c. Description of the regular meetings to address waste management
 - d. Description of the specific approaches to be used in recycling/reuse
 - e. Waste characterization; estimated material types and quantities
 - f. Name of landfill and the estimated costs, assuming no salvage or recycling
 - g. Identification of local and regional reuse programs
 - h. List of specific waste materials to be salvaged and recycled
 - i. Estimated percentage of waste diverted by this Plan
 - j. Recycling facilities to be used
 - k. Identification of materials that cannot be recycled or reused
 - l. Description of the means by which any materials to be recycled or salvaged will be protected from contamination
 - m. Description of the means of collection and transportation of the recycled and salvaged materials
 - n. Anticipated net cost or savings.
6. Require the contractor to document their actual waste diversion performance throughout the project. The Waste Management Plan, therefore, should also include progress reporting procedures to record actual diversion and cost corresponding to each diversion and cost estimate.

7. As the accepted Plan is a part of the contract document, it should be incorporated into the Contractor's Quality Control and Owner's Quality Assurance processes. Some public owners go so far as to specify that progress payments will not be approved until updated actual diversion performance reports are submitted.
8. Vest title to debris and waste materials to the contractor, and allow the contractor to accrue the economic benefits. These include cost avoidance through reduced debris tipping expenses, revenues from salvaged and recycled materials, and cost avoidance by using materials taken from the jobsite back into the project.

Contractor's point of view

Even though the community and developer have provided information to the contractor to perform salvage activities, when it finally comes down to the contractor to perform the work, additional constraints may appear. The following are some generic issues for contractors.

Time and money constraints

For the contractor, time is money. The faster that the project can be completed, the more profit will be made. Therefore, the time available to enact a salvage type of contract must be sufficient to allow for the advertisement, proposal, evaluation, and salvage execution process. These operations will not occur if sufficient time is not allowed in the contract for this process. For example, under a demolition type of scenario, the time to remove the existing facilities will not be significant when compared to other tasks in project. The actual construction of the new facilities and the potential long material lead-time tend to consume the most time in the overall project. Under a reuse, recycle, and recovery scenario, salvage operations can take significantly longer than conventional demolition depending on the scope and complexity of the project.

Even though a World War II (WWII) barracks is not a typical brownfield site, the comparison between the deconstruction and demolition process can show a drastic time and cost differential. The Fort Ord Redevelopment Agency (FORA) did a pilot project where 12 workers took a week to disassemble a typical 2-story WWII wood barracks. Additional time was then required to remove nails and process the salvaged materials. On the other hand, using heavy machinery, the same facility can be knocked down with a Trachoe and hauled off to the landfill with two dump trucks in less than a day. The difference is at least 6 days of savings to the contractor. If he is on

a tight schedule, deconstruction is not an option. Therefore, time constraints frequently discourage salvage. If developers allow sufficient time in the early project planning stages, however, reuse, recovery, and recycling options can be accommodated.

Demolition will not allow or provide the incentive for extensive salvage, and is usually a small portion of the overall project cost. Without an incentive, a profit, or a benefit for the contractor, the path of least resistance will be followed by demolishing and landfilling the debris. Conversely, deconstruction can be specified as the required method. Without a high level of certainty that the value of salvaged materials can offset cost, the contractor will pass the increased costs onto the project.

Project execution issues

Project execution issues, also called logistical issues or construction tasks, most likely will appear in large and complex brownfield redevelopment projects. These issues include:

- construction task sequencing
- the need for additional staging areas
- hauling distance to deposit recycled building components
- availability of additional manpower and other resources to salvage materials
- market availability.

The more issues a project has, the more it tends to discourage salvage. Usually for a small project such as a brownfield environmental restoration project, specifying reuse, recovery, and recycle options may not achieve the best economic or environmental results for the site.

Detailed structures and materials take off

The community/land developer needs to provide to the contractor a generic list of facilities, building components, and materials that potentially have a recovery, reuse, or recycle value. The contractor will then have to do an in-depth analysis of the facilities, building components, and materials with their respective quantities to obtain a good planning number. The more that is known going into the project, the higher the potential that more of the building components and materials can be salvaged.

Benefits available

The contractor may also have to consider nonmonetary benefits in performing salvage activities, which might mean, for example, that the contractor could be asked to use a nonprofit organization to deconstruct and salvage the facility. These nonprofit organizations should not be counted on to absorb large quantities, however. Another benefit would be for the contractor to perform the salvage operations and donate the materials to a nonprofit organization, creating a tax deduction.

10 Determine Approaches to Salvaging Existing Components and Materials

The community, developer, and contractor can contribute in several ways to waste reduction. It starts with the A/E firm during the design process, followed by deconstructing, recycling, reusing, or recovering the existing facility and its components, and finally constructing the new facility. The following are ways in which each of these groups can reduce waste.

Engineering and design

The contractor is responsible for the means, methods, techniques, sequences, and procedures of construction, which include waste disposal. However, the A/E design team can contribute to waste reduction in several ways, to include:

1. Observe Value Engineering principals. Perform multiple functions with one material rather than requiring multiple materials to perform one function. Design to optimize systems' and components' use. Avoid extraneous materials that do not contribute to function.
2. Be efficient in area and volume. If less material is required by the design, less waste is generated at the jobsite.
3. Observe standard material and product dimensions. Locate features "on module" to the extent possible to reduce cutting and special fitting, which creates scrap.
4. Where possible, select construction systems that do not require temporary support, shoring, construction aids, or other materials that will be disposed of as debris during the project.
5. Where possible, select materials that do not rely on adhesives, which require containers and create residue and packaging waste. Furthermore, adhesives inhibit salvage and recycling at the end of the component's or building's life.
6. Where possible, reduce requirements for applied finishes, laminates, coatings, adhesives, and the associated scrap, packaging, and waste. Select materials with integral finishes.
7. Where possible, avoid materials that are sensitive to damage, contamination, environmental exposure, or spoilage onsite, which increase the potential for jobsite waste.

Select the appropriate contractor

The community and land developer should be aware of the most frequently used design, build, and demolition contractors within their area. This knowledge will assist them in obtaining a qualified individual who can obtain the most potential out of reusing, recovering, and recycling the building components. This information can be gathered by polling a number of the contractors and asking whether they are experienced in sustainable building design, job-site waste diversion, and deconstruction techniques. Responses will give an idea of the qualified contractors.

The community developer could also contact professional societies such as the local chapters of the Associated General Contractors, National Society of Professional Engineers, and American Institute of Architects. These organizations can be a good source in identifying design firms and building/demolition contractors with experience and interest in construction and demolition waste management.

An often overlooked way to find this information is to search the local yellow pages (to include the on-line yellow pages) for the same information under “recycling,” “demolition,” “waste,” “salvage,” and “contractors.” A search in a local metropolitan area yellow pages identified advertisements for 30 salvage and demolition contractors and 21 recycling centers.

Be aware of the market

The community and developer should be aware of the potential local and regional salvage, reuse, and recycling markets and facilities (see Appendix D). The identification of markets and facilities is critical to successfully manage reuse, recycle, and recovery operations. Without this information, the community and the developer may cause the contractor a great deal of unproductive time for something of no value. For example, it would make no sense to require a contractor to separate and recycle gypsum wallboard if there is no supporting market or handling facility.

Communities and developers must have a basic understanding of the conditions under which contractors and facilities will accept or reject materials for reuse or recycling. For example, dimensional lumber is definitely a reusable resource. Contractors can easily separate and store it at the job-site. However, a material handling facility may not accept it if the contractor has not removed the nails or it is wet because it was not protected during storage.

Another type of market is the material exchange. Material exchange facilities take reused and recovered building components. If required, they will refurbish the component and then resell it for construction. A contractor can theoretically take the items that recovered from a demolition site to the facility and exchange them for newer materials. Some of the more common material exchange facilities are:

- Habitat for Humanity (HfH) operates more than 250 “Restores” across North America. Restores focus on selling used building and household materials to serve a residential market for use in home maintenance and remodeling. Institutional or industrial material types are generally not of interest to the Restores. Furthermore, Restores have a limited capability to handle material quantities and to absorb additional materials.
- The Recycler’s Exchange is a worldwide trading site for used building materials that also provides global access to recycling markets (see Appendix D).
- The Salvaged Building Materials Exchange is another international trading site for diverted building materials.
- The Reusable Building Materials Exchange is a State of Washington exchange for buying or listing small and large quantities of used or surplus building materials.

Material disposition

The initial cost to the contractor may be higher to recover and recycle building components. The costs can be offset by the value of the salvaged materials, but this is not always guaranteed. To make salvaging work, the contractor needs to have ownership rights to the any materials that can be reused, recovered, or recycled. Otherwise, reuse, recycle, and recovery operations are an expense without compensation. If site clearing (demolition) and construction take place as one action, then the General Contractor may be in a position to claim the material. However, clearing the site so that redevelopment can occur later will detach the material ownership. If the scope of the project is large enough, redevelopment may occur throughout several phases and ownership will need to be clarified.

Demolition waste

The waste diversion potential in a demolition scenario is considerable. The building’s construction type and project schedule are the two primary factors in determining what and how to accomplish salvage, reuse, and/or recycling. Consider the following:

- Develop the project schedule to accommodate salvage, reuse, or recycling. The quality and quantity of materials salvaged is a direct function of the time available for salvage.
- Prior to demolition, salvage as much useable material and components as the schedule will allow. Windows and doors, wood flooring, cabinetry, architectural millwork, electrical fixtures, plumbing fixtures, mechanical equipment — anything that can be detached and removed — can usually be salvaged and reused. When developing the C&D Waste Management Plan, identify the most accessible and valuable materials, thereby optimizing the application of resources to this task.
- Concrete and masonry materials can be recycled to produce aggregate. This recycling may be accomplished onsite with mobile equipment or by hauling rubble to a permanent recycling facility. Preferences vary among demolition contractors and recyclers about whether to gut the building prior to demolition, leaving only the crushing of concrete and reinforcement, or demolishing the facility intact and sorting the debris as part of the concrete crushing process. Consider how the recycled concrete aggregate (RCA) will be used, what RCA products are most useable, and how the rubble should be processed to produce these products. If aggregate materials are required for the project, onsite recycling can provide these materials at a reduced net cost. The Construction Materials Recycling Association can supply information on methods and service providers.
- Landscape materials and wood that is not painted with LBP, treated with an arsenic-based preservative, or otherwise contaminated with a hazardous or toxic material can be shredded into mulch, composted, or chipped for boiler fuel. This shredding can be accomplished onsite or offsite. If mulch or compost is required for the project, shredding onsite can provide these materials at a reduced net cost.
- Structural steel and metals are almost universally recycled and should be standard practice with any demolition contractor.
- Old growth timber is a valuable material and will usually justify the time required for a more delicate removal process. Timbers are generally sold through timber brokers to be cleaned and resold for timber framing, or as feedstock for high quality architectural millwork.
- Some species of dimensional lumber can also be quite valuable. Wood framed buildings can be partially or totally deconstructed. While this is often a more labor-intensive approach, cost avoidance and the value of the materials can offset initial cost. The Building Materials Reuse Association can provide information on deconstruction contractors and used building materials retail businesses.

- If none of the alternative salvage, reuse, or recycling options is possible, mixed demolition debris can be hauled to a C&D debris recycling facility.

Deconstruction

Table 5 lists labor hours recorded for the disassembly and salvage of components from a 2000 sq ft building comprising the deconstruction of four residential units (see PWTB 420-49-32 for more information). The intent of these data is to show what it takes to deconstruct a facility. They are not to be taken as strict measures. Each deconstruction project will be different and will have a variety of factors that will change the rates listed. These labor hours can be used as a baseline and in combination with more comprehensive references, such as R.S. Means *Building Construction Cost Data*, Micro Computer-Aided Cost Engineering Systems (MCACES), and Marshall & Swift *Dodge Unit Cost Book*. While the R.S. Means and Marshall & Swift approaches do not address deconstruction specifically, they do provide labor costs associated with selective demolition tasks (Means 2006; Marshall & Swift 2006).

Construction debris

From 10 to 12% of a project's construction waste stream can be cardboard alone. While protecting new materials is necessary, the contractor can direct their subcontractors and suppliers to reduce extraneous packing and packing. Instruction can include:

- Purchase materials in bulk where possible. Avoid individual packaging for volume purchases.
- Use returnable containers and packing materials.
- Reuse nonreturnable containers on the jobsite to the maximum extent possible. Develop 101 uses for plastic barrels, buckets, and tubs.
- Give away nonreturnable containers. Contact local and community organizations (schools, youth groups, community service groups, Habitat for Humanity).
- Use scrap in lieu of cutting full new materials. Direct subcontractors and trades to collect and keep scrap at cutting and fabricating locations. Collect paints and liquids from almost-empty containers; avoid disposing of useable materials simply because there is not enough in one container to finish a job.

Table 5. Labor hours for disassembly and salvage of a 2000 SF building.

Component	Tasks (hours)			Component Total	Labor Hours	Unit
	Disassembly	Processing	Support			
Plaster - 1st level	34.25	10.0	5.50	49.75	0.012	SF (plaster area)
Plaster - 2nd level	23.75	10.75	2.0	36.50	0.009	SF (plaster area)
Piping and wiring	6.75	3.25	0.50	10.50	0.0072	LBS
Partition walls	6.25	24.75	3.0	34.0	0.18	LF
Windows and trim	10.0	2.5	0.50	13.0	0.54	EA
Ceiling joists	1.0	4.75	0.5	6.25	0.0075	LF
Load-bearing walls	2.75	15.5	1.75	20.0	0.027	LF
Sub-floor - 2nd	16.0	6.0	1.25	23.25	0.023	SF
Joists - 2nd level	7.25	16.25	1.5	25.0	0.027	LF
Sub-floor - 1st	7.75	8.0		15.75	0.016	SF
Joists - 1st level	7.0	10.0		17.0	0.020	LF
Stairs	2.5	0.75	0.75	4.0	0.3	Riser
Exterior						
Gutters, fascias	2.25	1.0		3.25	0.014	LF
Chimney	33.25	40.5	4.75	78.5	0.16	CU FT
Gable Ends	8.0	3.0	0.75	11.75	0.053	SF
Masonry walls - upper	14.75	104.5	20.5	139.75	0.25	SF (brick area)
Masonry walls - lower	15.75	84.0	5.25	105.0	0.078	SF (brick area)
Roof						
Roofing material	17.75	18.25	1.75	37.75	2.68	SF
Sheathing boards	21.25	14.5	1.5	37.25	0.028	100 SF
Framing	7.25	9.75	7.0	24.0	0.021	LF
Shed roof framing	1.25	2.25		3.5	0.036	LF

(Source: PWTB 420-49-32.)

- For materials that are heated, mixed, exposed to environmental conditions, or otherwise subject to spoilage, limit preparation of these materials to quantities that can be installed within their expiration times. Working in smaller batches will reduce the necessity to throw out expired or spoiled materials. Ensure volatile materials, and materials that degrade when exposed to heat, cold, or moisture, are protected from spoilage and not wasted.
- Recycle damaged components, products, and materials, or disassemble them into their constituent materials for recycling.
- Establish a return or buy-back arrangement with suppliers. Alternatively, unused or used but serviceable materials and products can be

sold to architectural salvage or used materials retail outlets. Donations to a nonprofit outlet, such as an HfH ReStore, are usually tax-deductible.

- Contract with a C&D recycling firm that accepts commingled debris. At the recycling site, concrete and masonry rubble are separated out of the debris for crushing into aggregate products. The remaining debris is typically crushed or shredded, then conveyed along a pick line for sorting and recycling. Recycling commingled debris and waste offsite requires virtually no adjustment in practice on the contractor's part. C&D waste recyclers generally describe their fees as “competitive” with landfill disposal, which means a modest savings over prevailing landfill tipping fees. This method typically achieves a very high diversion rate. However, clean wood is frequently sold for boiler fuel, and some agencies do not count incineration as diversion.
- Contract with individual recycling firms who deal in specific materials, in addition to a general waste hauler. This requires the contractor, subcontractors, and tradespersons to segregate waste, deposit it in the appropriate receptacles, and guard against contamination by other materials. The key to effective jobsite segregation is to place receptacles in the path of least resistance to the workforce, training the workforce to observe segregation practices, and policing the jobsite to prevent contamination. The construction process lends itself to onsite segregation. As trades enter and leave the jobsite, each generates a relatively homogeneous waste stream, given the specific tasks and the materials with which they work. As the recyclable materials are segregated, the recycling firms generally offer a higher price for the material (if the contractor hauls), or a lower hauling rate (if the recycler hauls). Alternatively, the contractor can contract with a waste hauler who provides receptacles for recyclable materials and debris (Figures 11 and 12), and hauls all materials as a one-stop service. While some contend site separation increases the cost of construction, efficient materials movement and site layout should minimize any increased effort.



Figure 11. Construction debris for “wood only” receptacle.



Source: Wilmot Associates, Nashville, TN

Figure 12. Construction debris “metals only” receptacle with steel siding and steel deck trimmings.

11 Conclusion

The objective of brownfield redevelopment is to convert a site from an abandoned or underutilized property into a benefit for the community. In addition to cleaning up hazardous and deteriorated materials, the redevelopment must also address social and economic objectives, rendering the redevelopment a holistic improvement and overall asset.

The community and their Redevelopment Authority will have decided on an appropriate land use and occupancy for the site. Existing construction materials can often be useful to the redevelopment. Concrete, stone, and masonry materials can be recycled into aggregate products. Asphalt can be recycled into new paving. Structural and light metals can be sold to recyclers for income. Wood structural members can be salvaged for reuse or remanufactured into other wood products. Clean wood that is unsuitable for reuse can be sold for hog fuel or shredded into landscape mulch. In addition to displacing the cost of purchasing new materials, salvaging and recycling materials help contractors avoid other environmental burdens.

Public health and safety are paramount in the brownfield redevelopment process. Existing materials that: (1) contain hazardous or toxic substances, (2) are removed during clean-up operations because of contamination, or (3) may remain contaminated after clean-up operations should be disposed of according to prevailing regulations and not be considered for salvage, reuse, or recycling. The Redevelopment Authority may need to communicate to environmental justice advocates and the public at large that the materials considered for salvage, reuse, and recycling are, indeed, free from hazard.

While salvaging and recycling construction materials can reduce the cost of removing buildings, structures, and infrastructure, and avoid cost in purchasing new materials in most cases, the costs and benefits must still be determined on a site- and project-specific basis. Generalities and rules-of-thumb will not be sufficient to ensure economic feasibility. Local markets, hauling distances and expenses, debris tipping fees, and other factors will contribute to overall economic feasibility. Furthermore, inefficiencies in salvaging and recycling processes may negate any economic benefits and project schedules. Therefore, selecting demolition services with a

proven expertise and experience in materials' salvage, reuse, and recycling will help ensure that potential benefits are realized.

Construction materials salvage and recycling processes may provide an opportunity for job training and employment, either on the development site, or at an offsite recycling facility. The Redevelopment Authority should utilize construction contract provisions, which are common to public entities (including the Corps of Engineers), to ensure Affirmative Action, business preferences or set-asides, wage rates, and similar provisions incorporate other social and economic objectives into redevelopment work.

The Redevelopment Authority should consider reuse, recycle, and recovery scenarios as viable options throughout the redevelopment phases beginning with earliest project feasibility and planning activities. Ignoring this potential at the early stages will only make it more difficult to incorporate salvage, reuse, and recycling into definitive planning, design, and contracting activities as they are implemented. Only when a conclusive finding is made that existing materials will be of little value when recycled, or cannot contribute to new construction, should salvage, reuse, and recycling no longer be considered.

The Redevelopment Authority should establish objectives for salvage, reuse, and recycling existing construction materials. These objectives may be general at early strategic stages, but should be refined to definitive objectives for specific material types, quantities, and applications to new construction as planning progresses.

The Corps of Engineers, in support of the Redevelopment Authority, can first help assess the usefulness and value of existing structures and construction materials; promote salvage, reuse, and recycling throughout the Redevelopment Authority's decision-making processes; and then incorporate the appropriate salvage, reuse, and recycling provisions into their analyses, design and engineering support, contract development, and demolition and construction oversight, as tasked by the Redevelopment Authority.

The Redevelopment Authority's intentions and objectives for materials salvage, reuse, and recycling must eventually be communicated through the contracts and specifications issued for site clearing and demolition services. A variety of mechanisms are available to achieve the maximum practical utility from salvaged and recycled materials, such as contractor

selection criteria, incentive provisions, bid options, or definitive minimum quantities. The Corps of Engineers would be capable of supporting the Redevelopment Authority in determining the project delivery strategy best suited to achieving the Redevelopment Authority's goals and objectives for the project.

Glossary

Commingled: Materials of varied types deposited into the same receptacle or pile, or mixed together during demolition.

Construction waste: Waste materials generated by construction activities, such as scrap, damaged, or spoiled materials, temporary and expendable construction materials, and aids that are not included in the finished project, packaging materials, and waste generated by the workforce.

Deconstruction: The systematic disassembly of a building, generally in the reverse order of construction, in an economical and safe fashion, for the purposes of preserving materials for their reuse. It is most often associated with wood buildings (Figures 13 and 14). A good example of a deconstruction would be again a pre-engineered metal building. A contractor deconstructs the facility piece by piece and then reconstructs it at another location. Appendix B provides other deconstruction project examples. In general, buildings exhibiting one or more of the following characteristics are likely to be good deconstruction candidates:

- wood-framed with heavy-timbers and beams, or with unique woods such as Douglas fir, American chestnut, and old growth southern yellow pine
- constructed with high-value specialty materials such as hardwood flooring, multi-paned windows, architectural molding, and unique doors or plumbing/electrical fixtures
- constructed of high-quality brick laid with lime-based rather than cement-based mortar (to allow relatively easy break-up and cleaning); or
- structurally sound (i.e., generally weather-tight) to minimize rotted and decayed materials.

Demolition debris: Waste resulting from removing a building from the site by wrecking.

Disposal (or Landfilling, or Landfill disposal): Depositing materials in a solid waste disposal facility licensed for the subject materials (in this case, C&D materials). Traditionally, contractors remove buildings by means of conventional mechanical demolition techniques.



Figure 13. Wood building deconstruction.



Figure 14. Salvaged wood at job site.

The “Demolition” process refers to the razing of a building with heavy equipment that results in rendering building components into rubble which are then fit for nothing more than landfill. This process occurs when time is a top priority and mechanical wrecking is the quickest way to save time. As a result, there is no consideration for recovery, recycling, or reusing of any materials. Demolition provides very limited opportunities for cost offsets or to generate income. These opportunities mostly lie with sending the crushed mixed material to a C&D recycler who will then extract the value out of the materials. This method is not the preferred method and developers should consider it only when no other salvage or recycling options exist.

Land clearing debris: Vegetative waste materials removed from a site.

Offsite separation: Sorting and separating commingled waste at a location other than the construction jobsite, at a location specifically established for recycling.

Recovery: Recovery includes the removal of materials or components from the solid waste stream in a manner that the item retains its original form and identity, for the purpose of its reuse in the same or similar form as when produced. A good example would be a recently constructed facility on the site. The owner/contractor would go into the facility and extract such things as interior doors and frames, piping, cabinetry, etc. Each of these items would then save the contractor from purchasing new for the redevelopment and, of course, saving on the project cost. Once all the available items are “cherry-picked” and removed from the facility, it is then razed, rendered into rubble, and hauled to the landfill. Another ex-

ample could be stripping out old pieces of equipment and fixtures from a factory and using them in an “industrial chic” motif for a bar or restaurant.

Recycling: Introducing a material into some process for remanufacture into a new product, which may be the same or similar product or a completely different type of product. Recycling includes diverting materials that are not reusable from the solid waste stream and using these extracted materials as feedstock for reprocessing into other useful products. A good example of recycling would be a pre-engineered metal building, more commonly referred to as a “Butler Building.” Recycling in this case would mean that everything from the structural steel beams to the “skin” or exterior cladding would become feedstock to make more steel products.

Reuse: The subsequent use of a material, product, or component upon salvage. Reuse signifies that the existing facilities will be remodeled and reused as a similar type of building. For example, remodeling an old office building to become a “new” office building; turning an old Taco Bell fast food restaurant into a McDonald’s restaurant, etc. There is some degree of remodeling in this category, but less than 50 percent of the existing structure has to be changed.

Salvage: Recovery of components, products, or materials to reuse them for the same or similar purposes as their original use.

Source separation (or Segregation): Keeping materials separated by type from the time they become scrap or waste until the time they are salvaged or recycled.

Acronyms and Abbreviations

Term	Definition
A/E	Architect/Engineer
AFCEE	Air Force Center for Engineering and the Environment
ANCORE	Academic Network on Contaminated Land Research in Europe
BEES	Building for Environmental and Economic Sustainability
BOQ	Bill of Quantities
BRE	Building Research Establishment
C&D	Construction and Demolition
CAFO	Confined Animal Feed Operations
CCA	Chromated Copper Arsenate
CERL	Construction Engineering Research Laboratory
CLARINET	(European Union) Contaminated Land Rehabilitation Network for Environmental Technologies
DNR	Department of Natural Resources
DOE	(Chicago) Department of Environment
DRI	Demolition Recovery Index
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
EU	European Union
FORA	Fort Ord Redevelopment Agency
GSA	General Services Administration
HQUSACE	Headquarters, US Army Corps of Engineers
HUD	Department of Housing and Urban Development
HVAC	Heating, Ventilating, And Air-Conditioning
ICE	Institution of Civil Engineers (UK)
LBP	Lead-Based Paint
LEED	Leadership in Energy and Environmental Design
LEED-NC	LEED-New Construction
LEED-SS	LEED-Sustainable Sites
MCACES	Micro Computer-Aided Cost Engineering Systems
MDEP	Massachusetts Department of Environmental Protection
MOU	Memorandum of Understanding
NAVFAC	Naval Facilities Engineering Command
NICOLE	Network for Contaminated Land in Europe
NIST	National Institute of Standards and Technology
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
PDF	Portable Document Format
POL	Petroleum, Oils, and Lubricants

Term	Definition
PVC	Polyvinyl Chloride
PWTB	Public Works Technical Bulletin
R&D	Research and Development
RA	Recycled Aggregate
RCA	Recycled Concrete Aggregate
RESCUE	Regeneration of European Sites in Cities and Urban Environments
SF	Standard Form
TR	Technical Report
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UK	United Kingdom
US	United States
USACE	US Army Corps of Engineers
USACERL	US Army Construction Engineering Research Laboratory
USEPA	US Environmental Protection Agency
UST	underground storage tank
VOC	Volatile Organic Compound
WARM	(EPA) WAsTe Reduction Model
WBDG	Whole Building Design Guide
WRAP	(United Kingdom) Waste and Resources Action Program
WWII	World War II
WWW	World Wide Web

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Additional reading

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Additional resources

The following references are intended to provide further information about the C&D Waste Management subject. This list is only a sampling of available information. There are numerous other publications and web-sites that also provide useful information. Unfortunately, there also resources that are of questionable credibility. The Authors have found each of the following to be reasonable and useful.

Whole Building Design Guide (WBDG)

- Construction Criteria Base: Unified Facilities Criteria (UFC),
http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4
 See: UFC 1-900-01 Selection of Methods for the Reduction, Reuse and Recycling of Demolition Waste (12-01-2002)
- Construction Criteria Base, Unified Facilities Guide Specifications (UFGSs),
http://www.wbdg.org/ccb/browse_org.php?o=70. See:
 UFGS 01 57 20.00 10 (01355A) Environmental Protection (04-2006)
 UFGS 01 74 19 (01572) Construction and Demolition Waste Management (07-2006)
 UFGS 02 41 00 (02220) [Demolition] [and] [Deconstruction] (07-2006)

Construction Criteria Base, Army Public Works Technical Bulletins (PWTB):

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215 See:

- PWTB 200-1-17 Recycling Interior Finish Materials - Carpet and Ceiling Tiles
- PWTB 200-1-23 Guidance for the Reduction of Demolition Waste Through Reuse and Recycling
- PWTB 200-1-24 Quantifying Waste Generated From Building Remodeling
- PWTB 200-1-26 Market Valuation of Demolition Salvage Materials
- PWTB 200-1-27 Reuse of Concrete Materials From Building Demolition
- PWTB 200-1-40 Characterizing Demolition Debris for Diversion Opportunities
- PWTB 420-49-30 Alternatives to Demolition for Facility Reduction
- PWTB 420-49-32 Selection of Methods for the Reduction, Reuse, and Recycling of Demolition Waste

Federal Leadership in High Performance and Sustainable Buildings Memorandum of

Understanding, Technical Guidance, http://www.wbdg.org/sustainablemou/mou_cw.php

WBDG C&D Waste Management Database, <http://www.wbdg.org/tools/cwm.php>

General C&D Waste Management Information

Construction & Demolition Recycling Magazine: <http://www.cdrecycler.com/>

King County WA Solid Waste Division, Construction Recycling,

<http://your.kingcounty.gov/solidwaste/greenbuilding/construction-demolition.asp>

National Demolition Association Position Paper promoting C&D waste material recycling:

http://www.demolitionassociation.com/Portals/0/pdfs/C-D_Recycling.pdf

North Carolina Division of Pollution Prevention & Environmental Assistance:

<http://www.p2pays.org/ref/01/00173.htm>

Resource Venture, Sustainable Building Publications,

<http://www.resourceventure.org/free-resources/get-started/green-building-publications>

US Department of Housing and Urban Development (HUD). *A Report on the Feasibility of*

Deconstruction: An Investigation of Deconstruction Activity in Four Cities,

<http://www.huduser.org/publications/destech/deconstruct.html>

US Environmental Protection Agency (USEPA). 1998. Characterization of Building-Related Construction and Demolition Debris in the United States. Report No. EPA530-R-98-010.

Washington, DC: USEPA Municipal and Industrial Solid Waste Division, Office of Solid Waste, <http://www.epa.gov/osw/hazard/generation/sqg/c%26d-rpt.pdf>

USEPA C&D Debris website: <http://www.epa.gov/epaoswer/non-hw/debris-new/index.htm>

USEPA C&D Debris, Resources by Debris Type: <http://www.epa.gov/epaoswer/non-hw/debris-new/bvtype.htm>

WasteCap Massachusetts, Information on Recycling Construction and Demolition Debris,

<http://www.wastecap.org/resources/construction-demolition/>

Environmental Life Cycle Information

Environmental Resources Guide, American Institute of Architects, Washington DC, published by John Wiley & Sons, Inc., New York NY

EPA Waste Reduction Model (WARM),

http://www.epa.gov/climatechange/wvcd/waste/calculators/Warm_home.html

National Institute of Standards and Technology (NIST). *Building for Environmental and Economic Sustainability (BEES)*, <http://www.bfrl.nist.gov/oae/software/bees.html>

Selected C&D Waste Management Guides

Air Force Center for Environmental Excellence, C&D Guide

<http://www.p2pays.org/ref/24/23088.pdf>

California Integrated Waste Management Board,

<http://www.calrecycle.ca.gov/>

Deconstruction Institute: "A Guide to Deconstruction,"

http://www.deconstructioninstitute.com/files/learn_center/45762865_guidebook.pdf

King County WA, Solid Waste Division,

<http://your.kingcounty.gov/solidwaste/index.asp>

Massachusetts Department of Environmental Protection / Boston Society of Architects,

<http://mass.gov/dep/recycle/reduce/cdrguide.pdf>

National Association of Home Builders Research Center, Deconstruction Guides:

<http://www.toolbase.org/index.aspx>

<http://www.nahbrc.com/bookstore/cw0403w.aspx>

National Association of Home Builders Research Center, Residential Construction Waste Management: A Builder's Field Guide.,

<http://www.nahbrc.com/bookstore/cw0503w.aspx>

Solid Waste Agency of Lake County, IL, <http://www.swalco.org/>

State of Hawaii, Department of Business & Economic Development

<http://www.hawaii.gov/dbedt/info/energy/publications/cwmg.pdf>

Triangle J Council of Governments, NC, "WasteSpec"

<http://www.tjcog.dst.nc.us/regplan/wastspec.shtml>

C&D Recycling Databases and Building Materials Exchanges

California Integrated Waste Management Board, C&D Debris Recyclers Database,

<http://www.ciwmb.ca.gov/ConDemo/Recyclers/>

Georgia Pollution Prevention Assistance Division, Recycling & Waste Exchange Resources:

<http://www.gasustainability.org/recycling>

King County WA Solid Waste Division C&D materials recycling database:

<http://your.kingcounty.gov/solidwaste/wdidw/category.asp?CatID=17>

King County WA Solid Waste Division Reusable Building Materials Exchange:

<http://your.kingcounty.gov/solidwaste/exchange/building.asp>

North Carolina Department of Natural Resources, Division of Pollution Prevention & Environmental Assistance,

<http://www.p2pays.org/DMRM/start.aspx>

Recycler's World: <http://www.recycle.net/>

Southern Waste Exchange Information: <http://www.wastexchange.org/>

US Department of Agriculture, Forest Products Laboratory Directory of Wood Framed Building Deconstruction and Reused Building Materials Companies,

http://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr150.pdf

USEPA national database of materials and waste exchanges:

<http://www.epa.gov/itr/comm/exchange.htm>

Selected State, County, or Local Agencies

Alameda County CA Waste Management Authority,
<http://www.stopwaste.org/docs/buildersguide-05.pdf>

California Integrated Waste Management Board: <http://www.ciwmb.ca.gov/ConDemo/>

City of Austin TX Greenbuilder Program:
<http://www.greenbuilder.com/sourcebook/ConstructionWaste.html>

Georgia Pollution Prevention Assistance Division: <http://www.p2ad.org/>.

King County WA Solid Waste Division, Construction Recycling,
<http://your.kingcounty.gov/solidwaste/facilities/cdl-stations.asp>

Minnesota Office of Environmental Assistance, C&D Recycling,
<http://www.pca.state.mn.us/index.php/topics/preventing-waste-and-pollution/green-building/construction-and-demolition-waste.html>

North Carolina Department of Natural Resources, Division of Pollution Prevention & Environmental Assistance: <http://www.p2pays.org/>

Recycling & Waste Management Councils.

Association of State and Territorial Solid Waste Management Officials: <http://www.astswmo.org/>.
See also links to State and other Federal solid waste management contacts,
<http://www.astswmo.org/index.htm>

Mid America Council of Recycling Officials: (<http://www.epa.gov/epaoswer/non-hw/recycle/jtr/state/macro.htm>)

Mid Atlantic Consortium of Recycling and Economic Development Officials: <http://macredo.org/>

National Recycling Coalition: <http://www.nrcrecycles.org/>

Northeast Recycling Council: <http://www.nerc.org/>

Waste Reduction Resource Center: <http://wrrc.p2pays.org/>

Associations

Building Materials Reuse Association: <http://www.buildingreuse.org/>

Construction Materials Recycling Association: <http://www.cdrecycling.org/>

National Demolition Association: <http://www.demolitionassociation.com/>

Organizations

Habitat for Humanity ReStore network: <http://www.habitat.org/env/restores.aspx>

GreenGoat <http://www.greengoat.org/>

Reuse Development Organization: <http://www.redo.org/>

The Deconstruction Institute: <http://www.deconstructioninstitute.com>

The Green Institute: <http://www.greeninstitute.org/>

The Loading Dock: <http://www.loadingdock.org/>

Miscellaneous references

Dolan, Patrick J., Richard G. Lampo, and Jacqueline C. Dearborn. 1999. Concepts for Reuse and Recycling of Construction and Demolition Waste. USACERL Technical Report 97/58/ADA368252,paa. Champaign, IL: US Army Construction Engineering Research Laboratory (USACERL),
http://www.deconstructioninstitute.com/files/learn_center/27449035_LAM_RERE_FLM_post.PDF

Appendix A: Reusable and Recyclable Building Materials

The following describes building materials that are commonly salvaged for resale and reuse, and/or are recyclable. Note that all materials may not be present in any one building or group of buildings. Note also that the salvage value of materials varies according to the quantity of materials present in the buildings, the materials' condition, the availability of used materials outlets or recycled materials processors, and the local market.

Table B1. Reusable and recyclable building materials.

Materials	Reuse / Recycle Potential	Comments
Division 02, Sitework		
Land Clearing Debris	Recyclable	Wood landscape materials can be shredded into landscape mulch.
Ductile Iron Distribution Systems	Recyclable	Ductile iron pipe & fittings may have a modest scrap value. Valves and controls may be reusable, depending on age and condition.
Elevated Steel Water Tanks	Recyclable	Structural steel is recyclable as scrap.
Wood Poles	Reusable	Poles are commonly reused if in a suitable condition. Some commercial utilities accept or purchase used poles in good condition.
	Recyclable	Preservative treated wood poles unsuitable for re-use can be ground into boiler fuel.
Corrugated Metal Pipe	Recyclable	Drainage piping may have a modest scrap value.
Catch Basins and Manholes, Concrete	Recyclable	Concrete drainage structures can be broken and crushed for concrete aggregate. Separating concrete from reinforcing bars is practical; separating from welded wire fabric (common with precast units) is problematic.
		Ferrous metal components (grates, ladders, manhole covers, etc) can be reused or recycled as scrap.
Asphalt Paving	Recyclable	It is common practice in many regions to stockpile and recycle asphalt removed from pavement. Equipment is also available to remove, grind, re-mix, and re-lay asphalt in a single operation.
Concrete Paving	Recyclable	Clean concrete can be crushed to meet jurisdictions' specifications for base aggregate, compacted fill, and other engineered applications. Reinforcing can be removed by magnetic separators.

Materials	Reuse / Recycle Potential	Comments
		Presence of dirt, fines, and other inert contaminants may still be tolerable in loose fill or erosion control applications.
Unit Paving	Reusable	Paving bricks are a marketable commodity in most regions, especially when the same style is available in large quantities.
Misc. Site Structures & Appurtenances	Recyclable	Concrete structures can be broken and crushed for aggregate. Separating concrete from reinforcing bars is practical; separating from welded wire fabric (common with precast units) is problematic.
		The quality and usefulness of recycled concrete depends largely on the presence of dirt, fines, and other contaminants.
Chain Link Fence	Reusable	Chain link, accessories, and hardware can be reused several times if appearance is not critical. Poles may be reused if not embedded in concrete, or where attached concrete can be broken off without bending the pole.
Wood Fence	Recyclable	Wood that is not preservative-treated, stained, or painted (most commonly cedar) can be ground into landscape mulch.
Concrete Retaining Walls	Recyclable	Clean concrete can be crushed to meet jurisdictions' specifications for base aggregate, compacted fill, and other engineered applications. Reinforcing can be removed by magnetic separators.
		Presence of dirt, fines, and other inert contaminants may still be tolerable in loose fill or erosion control applications.
Sheet Pile Retaining Walls	Reusable	Sheet piling is commonly reusable. Damaged piles unsuitable for reuse can be recycled as steel scrap.
Stone Retaining Walls	Reusable	
Division 03, Concrete		
Steel reinforcing	Recyclable	Reinforcing steel is separated during crushing operations and is recyclable as scrap.
Cast-in-Place Concrete	Recyclable	Clean concrete can be crushed to meet jurisdictions' specifications for base aggregate, compacted fill, and other engineered applications. Reinforcing can be removed by magnetic separators. Dirt, masonry rubble, fines, and other inert contaminants would have to be screened out of the aggregate.
		Presence of dirt, fines, masonry rubble, and other inert contaminants may render the aggregate unsuitable for specification grade applications, but may still be acceptable in loose fill, trails, or similar applications.

Materials	Reuse / Recycle Potential	Comments
		Wood, fibrous materials, adhered finished, and other non-inert debris should be separated from the concrete debris prior to crushing. Removing these materials prior to demolition may be more practical.
Precast Concrete	Recyclable	Precast concrete members have been removed from their original structures and reused intact. However, this would require analysis to verify their adequacy for a new application. This may be impractical in most cases. Recycling the concrete and reinforcing materials may be the practical recourse.
Division 04, Masonry		
Concrete Unit Masonry (CMU)	Recyclable	CMU can be crushed into a granular fill or trail topping. Reinforcing can be separated during crushing by magnetic conveyors.
Brick Unit Masonry	Reusable	Unbroken used bricks are a marketable commodity in most regions, especially when the same style is available in large quantities. Clean bricks and solid bricks command higher prices.
	Recyclable	Bricks can be ground into landscape materials or crushed for other granular fill applications.
Division 05, Metals		
Structural Steel	Recyclable	Structural steel shapes are routinely separated out of demolition debris and recycled as scrap. Larger members are frequently returned to the mill.
Structural Aluminum	Recyclable	Structural aluminum shapes are a high-value recycle commodity.
Metal Joists	Recyclable	Joists are routinely separated out of demolition debris and recycled as scrap.
Steel Deck	Recyclable	Steel deck is routinely separated out of demolition debris and recycled as scrap.
Cold Form Metal Framing	Reusable	Light gage steel studs and joists can be removed and reused if not damaged during removal. Light gage trusses can be reused if not damaged during removal. However, reuse would require a thorough analysis to verify adequacy for the intended application, which may be impractical in many cases.
	Recyclable	Metal framing systems (rafters, trusses, studs, channels, and joists) are routinely separated out of demolition debris and recycled as scrap.
Metal Fabrications	Recyclable	Ferrous metal grates, stairs, rails, and other fabrications are routinely separated out of demolition debris and recycled as scrap.
Ornamental Metals	Reusable	Steel and wrought iron components are routinely removed prior to demolition and reused. Architectural metals such as brass and stamped

Materials	Reuse / Recycle Potential	Comments
		copper are relatively high-value artifacts.
	Recyclable	Ferrous metal components with no other after-market value are routinely recycled as scrap. Aluminum and copper components are high-value recycle commodities.
Division 06, Wood and Plastics		
Wood Framing	Reusable	Wood framing can be reused if not damaged upon removal. 2X8s and larger are the more marketable commodities. 8 ft lengths are typically the preferred minimum, although shorter pieces can also be used as blocking and fillers.
		Remilling old growth lumber into architectural millwork is an emerging market.
	Recyclable	Clean wood members (not preservative-treated or painted) that are damaged or too short to be reused can be shredded for landscape mulch. Nails can be removed during shredding by magnetic conveyers.
Wood Decking	Reusable	Clean wood decking is commonly reused. Cedar species, tongue-and-groove shapes, and an antique "distressed" finish surface are desirable characteristics in the used building materials market.
	Recyclable	Clean wood decking (not preservative-treated or painted) that is damaged or too short to be reused can be shredded for landscape mulch. Nails can be removed during shredding by magnetic conveyers.
Sheathing	Reusable	Plywood sheathing can be reused if removed in whole- or half-sheets, and are not damaged upon removal.
		Board sheathing can be reused if it is not damaged or too brittle. Refinishing old growth 1-inch board for architectural millwork is an emerging market.
		Oriented Strand Board sheathing can be reused if removed in whole- or half-sheets, and are not damaged upon removal.
	Recyclable	Clean board sheathing (not preservative-treated or painted) that are damaged or too short to be reused can be shredded for landscape mulch. Nails can be removed during shredding by magnetic conveyers.
Engineered Wood Products	Reusable	Composite joists and trusses can be reused given their intended spans, support and panel points, and loading conditions are consistent with their original design.
Glue-Laminated Construction	Reusable	Glue-laminated columns, beams, and arches, are generally valuable in the used building materials

Materials	Reuse / Recycle Potential	Comments
		market. Reuse as structural members will require analysis to verify their adequacy for their new application.
		Micro-laminated and parallel strand members can be reused if not damaged during removal. Reuse as structural members will require analysis to verify their adequacy for their new application. Cutting to shorter spans is also possible.
Architectural Millwork	Reusable	Decorative millwork is routinely removed prior to demolition and can be a valuable commodity, especially if it is not excessively painted, not damaged, and in a relatively large quantity of the same style.
Casework	Reusable	Cabinetry and counter tops are routinely removed prior to demolition for reuse or resale. Residential cabinetry is generally more marketable than specialized commercial or institutional casework.
Division 07 Moisture & Thermal Protection		
Rigid Insulation Board	Reusable	Board insulation can be reused if not wet, damaged in-place, or damaged during removal. Loose-laid board should be recoverable. Mechanically fastened board insulation may be problematic. It may be impractical to attempt to remove fully adhered insulation board.
		Cellular plastic insulation diminishes in thermal resistance over time. Thermal resistance of used boards should be considered no greater than the aged R-value.
Fiberglass Batt or Blanket Insulation	Reusable	Fiberglass insulation can be reused if not wet, damaged in-place, or damaged during removal. Kraft or foil faced batts lend themselves to removal and handling better than unfaced batts. Compression-fitted batts and loose-laid blankets can be removed with less damage than stapled or nailed batts.
		Because of fiberglass insulation's bulk, handling and storage of used insulation may be problematic. The opportunity to reuse insulation in the same locale and shortly after removal suggest reuse may be feasible.
Asphalt Roofing	Recyclable on a limited basis	Bituminous roofing is accepted for recycling in some regions. Removing nails and other hardware is problematic.
Metal Roofing	Recyclable	Aluminum, terne, and steel shingles or panels are routinely removed from building debris and recycled as scrap.
		Standing seam roof panels can be recycled as scrap. Unseaming will damage the panels beyond

Materials	Reuse / Recycle Potential	Comments
		reuse.
Tile Roofing	Reusable	Clay tiles, ceramic tiles, concrete tiles, and slate shingles are routinely removed prior to demolition for resale or reuse.
Vinyl Siding	Reusable	Vinyl siding can be reused if not damaged during removal. Full-length panels are more desirable. A relatively large quantity of the same style and color is more desirable.
Metal Siding	Reusable	Steel and aluminum horizontal siding can be reused if not damaged during removal. Full-length panels are more desirable. A relatively large quantity of the same style and color is more desirable.
		Preformed steel siding panels can be reused if not damaged during removal.
	Recyclable	Aluminum and steel siding materials can be recycled as scrap.
Flashing & Sheet Metal	Recyclable	Galvanized and coated steel, stainless steel, and aluminum flashing can be recycled as scrap. Copper flashing is a valuable recycle commodity.
Division 08 Doors & Windows		
Metal Doors & Frames	Reusable	Metal doors can be removed and reused. Keeping the frame with the door is also preferred, if the frame can be removed without damage. Providing hardware, especially keys, will improve marketability.
		Residential doors, or doors of common residential dimensions, are generally more marketable than specialized commercial or institutional doors.
	Recyclable	Metal doors and frames can be recycled as scrap if damaged beyond reuse, and if vision panels, insulation, and other nonmetallic materials can be easily removed.
Wood Doors	Reusable	Wood doors can be removed and reused. Keeping the frame with the door is also preferred, if the frame can be removed without damage. Providing hardware, especially keys, will improve marketability.
		Residential doors, or doors of common residential dimensions, are generally more marketable than specialized commercial or institutional doors.
		Wood panel doors may have a higher value as an architectural artifact, especially if a relatively large quantity of the same style doors is available.
Specialty Doors	Reusable	Various types of overhead doors can be reused if tracks, springs, coil mechanisms, and other

Materials	Reuse / Recycle Potential	Comments
		hardware accompany the door. Dimensions suitable for residential or smaller sized commercial applications may be more marketable than large, specialty applications.
Metal Windows	Reusable	Steel and aluminum windows can be removed and reused if not damaged during use or by removal. Keeping screens and hardware is preferred.
	Recyclable	Steel and aluminum frames can be recycled as scrap if the glazing is removed.
Wood Windows	Reusable	Wood windows can be removed and reused if not damaged during use or by removal. Keeping screens and hardware is preferred.
		Single glazed, multi-lite double hung sashes are frequently sold as decorative or craft items and converted to other products.
Hardware	Reusable	Hardware not heavily coated with paint and in good working condition is reusable. Keys should accompany locksets.
	Recyclable	Metal building hardware that is no longer serviceable is recyclable as scrap. Brass is a valuable recycle commodity.
Division 09 Finishes		
Non-Load Bearing Wall Framing Systems	Reusable	Light gage metal studs and channels can be reused if not damaged during removal. Consideration must be given to the location and condition of holes for re-installation. Holes from drywall fasteners should not compromise re-use of framing members.
	Recyclable	Light gage metal studs and channels not suitable for reuse can be recycled as scrap.
Carpet	Reusable	Relatively clean and unworn carpet tiles can be removed for reuse.
		Carpeting can be cut down to utilize the non-worn areas.
	Recyclable on a limited basis	Selected carpet mills accept used carpet for recycling if the manufacturer and materials can be identified. See PWTB 200-1-17, Recycling Interior Finish Materials – Carpet and Ceiling Tiles.
Acoustical Ceilings	Reusable	Ceiling tiles can be removed and reused if they are reasonably clean and not damaged during use.
		Metal suspension systems are generally damaged beyond reuse when removed, but are recyclable as scrap.
	Recyclable on a limited	Select manufacturers accept used ceiling tiles for recycling if the manufacturer and material

Materials	Reuse / Recycle Potential	Comments
	basis	composition can be identified. See PWTB 200-1-17, Recycling Interior Finish Materials – Carpet and Ceiling Tiles.
Wood Flooring	Reusable	Wood strip flooring is commonly removed for resale and reuse. Oak, maple, and long-leaf pine species are valuable commodities in the used building materials marketplace in most regions. Parquet flooring is generally installed with adhesive and, therefore, difficult to remove without damage.
Brick Flooring	Reusable	Brick flooring can be removed and reused.
Division 10 Specialties		
Visual display, compartments and cubicles, access flooring, fire protection specialties, prefabricated or operable partition systems, lockers and wardrobes, other architectural specialties.	Reusable	Virtually any architectural specialty can be reused if it is in reasonably good condition upon removal. Value and marketability depend on the type of item, condition, and quantity available in the same model or style. Residential-style items may be more marketable than commercial or institutional types of specialties.
Division 11 Equipment		
Any	Reusable	Virtually any type of built-in equipment and appliances can be reused if they are serviceable and reasonably new (approximately 5 years). Residential appliances are marketable in most regions.
Division 12 Furnishings		
Any	Reusable	Any furniture not taken by the occupant can be excessed.
	Recyclable	Metal furniture that is no longer serviceable can be recycled as scrap.
Division 13 Special Construction		
Pre-engineered Metal Buildings	Reusable	Pre-engineered building systems are commonly sold, disassembled, and reassembled.
	Recyclable	Roof and wall panels damaged during removal can be recycled as scrap.
Division 15 Mechanical		
Piping systems	Reusable	Valves and controls can be removed and reused if still serviceable.
	Recyclable	Piping materials can be recycled as scrap. Copper and stainless steel piping are valuable recycle commodities.
Plumbing Fixtures and Equipment	Reusable	Plumbing fixtures can be removed and reused. Residential style fixtures may be more marketable than institutional or commercial styles.
		Water heaters, storage tanks, water fountains, and other plumbing equipment can be removed and reused if the items are reasonably new

Materials	Reuse / Recycle Potential	Comments
		(approximately 5 years), and if the local water conditions are such that capacity is not diminished by mineral deposits. Residential capacities may be more marketable than institutional or commercial, heavy-duty equipment.
Heating Equipment	Reusable	Boilers can be removed and reused if still serviceable, not damaged by removal, and of recent enough manufacture that they do not contain asbestos. Residential capacities may be more marketable than institutional or commercial, heavy-duty equipment.
		Furnaces can be removed and reused if still serviceable, reasonably new (approximately 5 years), and not damaged by removal. Residential capacities may be more marketable than institutional or commercial, heavy-duty equipment.
		Gas or oil-fired space heaters can be removed and reused if still serviceable, reasonably new (approximately 5 years), and not damaged by removal.
	Recyclable	Heating equipment that is no longer serviceable can be recycled as scrap. Asbestos, if present, must be removed prior to recycling.
Cooling Equipment	Reusable	Chillers, compressor/condenser units, evaporative coolers, and other cooling equipment can be removed and reused if still serviceable and not damaged by removal. Residential capacities may be more marketable than institutional or commercial, heavy-duty equipment.
	Recyclable	Cooling equipment that is no longer serviceable can be recycled as scrap. R33 refrigerant must be purged and captured prior to recycling.
Radiators	Reusable	Cast iron freestanding radiators can be removed and reused.
		Fin-tube baseboard radiators can be removed and reused if not damaged through use or by removal.
	Recyclable	Radiators unsuitable for reuse can be recycled as scrap. Aluminum and copper from fin-tube radiators should be separated.
Ductwork	Recyclable	Galvanized steel and stainless steel ductwork can be recycled as scrap. Remove insulation.
Fans	Reusable	Ventilation fans can be removed and reused if still serviceable. Residential styles and capacities may be more marketable than institutional or commercial, heavy-duty equipment.
Diffusers	Reusable	Grills and diffusers can be removed if not

Materials	Reuse / Recycle Potential	Comments
		damaged by use or removal.
	Recyclable	Grills and diffusers no longer suitable for reuse can be recycled as scrap. Aluminum is a more valuable recycle commodity.
Division 16 Electrical		
Conductors & Cables	Recyclable	Copper conductor is recyclable. The feasibility of recycling copper conductor depends on the availability of recyclers or processors capable of stripping insulation, and the quantity of copper available in any one project.
Conduit	Recyclable	Metal conduit is recyclable as scrap.
Raceways, Cable Trays, Auxiliary Gutters	Recyclable	Metal distribution components are recyclable as scrap.
Distribution Components	Reusable	Circuit breaker panels, switchboards, control centers, and other distribution components can be removed and reused if they remain in serviceable condition, conform to current electrical codes, and are not damaged upon removal. Residential-capacity equipment may be more marketable.
	Recyclable	Metal panel boxes, cabinets, and other distribution components that are not suitable for reuse can be recycled as scrap.
Luminaries	Reusable	Light fixtures can be removed and reused if they remain in serviceable condition, conform to current electrical codes, and are not damaged upon removal. Verify that ballasts in fluorescent fixtures are explicitly labeled as "contains no PCB" or similar wording.
		Fluorescent fixtures with PCB-containing ballast should not be reused. Dispose of ballasts according to the prevailing hazardous waste regulations.
	Recyclable	Metal fixtures that are not suitable for reuse can be recycled as scrap. Remove lamps, ballasts, and plastic lenses and covers.
Fluorescent Lamps	Recyclable	Fluorescent tubes that are not suitable for reuse can be recycled.
Exterior Light Poles	Reusable	Exterior poles can be removed and reused.
	Recyclable	Steel and aluminum poles and bracket arms can be recycled as scrap. Aluminum is a valuable recycle commodity.
Communications Cable	Reusable	Coaxial cable can be reused if it remains in serviceable condition.

Appendix B: Brownfield Redevelopment Projects Using Material Recovery and Reuse

The following examples are Brownfield Redevelopment Projects in which buildings, components, and materials were recovered, reused, and recycled.

Chicago Center for Green Technology

Previous use of site: 17-acre site that was formerly the Sacramento Crushing Corporation, a construction materials recycler. The company closed in 1996 after they discovered 600,000 cu yd of waste on the site. They then gave the land to the City of Chicago as part of a settlement.

New use of site: The building is a renovated 1952 building (40,000 SF – building type is Commercial Office/Industrial Assembly). It has seven zones: one zone is a large assembly area and the other six zones are each an office area. The Chicago Department of Environment (DOE) now owns the two-story building.

Environmental features of the building include solar panels, rainwater collection for irrigation, recycled building materials, smart lighting, a green roof, and a geothermal exchange system. The building's tenants also reflect an environmental ethic: Spire Corporation (a solar panel production company), GreenCorps Chicago (a community gardening and job-training program), and a Chicago DOE satellite office.

A \$100 million settlement to the DOE from Commonwealth Edison (ComEd) Company's violation of their franchise agreement rebuilt the Center as a model environmentally responsible and energy-efficient building.

Clean-up challenges: Getting homework done up-front is basic for any project, but critical in the green-building arena. A lesson learned was choosing the right contractor. The city fired the contracting firm on this project for a number of reasons that made it difficult to get a quality product of any kind, let alone an ambitious sustainable design. They used \$6 million to clean up the site and \$3 million to crush the remaining gravel

and take it to other city sites for use in construction. Construction and renovation costs were an additional \$5.4 million.

Working with the planning and budgeting departments, Chicago's DOE was able to identify funds to reprocess the materials and use the cleanup operation as a way to give back to the local community. In the beginning, they processed the housing teardown piles, recycling all materials they could and hauling out the rest. Leaders at the DOE encouraged other city departments to reuse the wealth of materials, such as gravel previously dumped at the site. They treated local businesses as a preserved resource as well. As the project progressed, the city was able to help local companies build capacity.

They removed all asbestos from the building. The contractor designed and implemented a construction indoor air quality management plan that involved protecting ducts from contamination and cleaning ducts prior to occupancy.

Reuse, recovery, salvage of materials: The majority of the material accumulated on the site was recycled or salvaged for reuse.

As a 1950s office building, the structure had been designed for natural cross ventilation as well as de-lighting using narrow wings extending out from a common circulation core. The renovation took advantage of this existing condition to retain operable windows while adding a mechanical cooling system. The primary strategy relies on cross ventilation rather than stack effect or other techniques to maintain natural ventilation. The City of Chicago code requirements do not allow the inclusion of natural ventilation in total air-conditioning ventilation requirements for commercial facilities. Engineers design mechanical ventilation systems as if no natural ventilation existed. During construction, city code inspectors required the installation of additional through-the-wall powered vents in those spaces identified for light manufacturing. While not necessary for the natural ventilation design, open windows and activated wall vents in effect provide for an additional economizer cycle. The contractor installed insulated, spectrally selective, low-E glazing on the windows throughout the facility.

- Rehabilitation retained 100% of the original building's structural shell.
- Diversion of all construction waste from the landfill was 84%.
- Approximately 36% of all building materials have recycled content, including: drywall, cellulose insulation, linoleum, ceiling tiles, rubber

- flooring, gravel, fill materials, steel, tile, medium density fiberboard, and fireproofing.
- More than 50% of the building materials (excluding mechanical and plumbing systems) were manufactured or assembled within 300 miles of the construction site.
 - The elevator runs on canola oil.
 - Light (highly reflective) parking lot surface glued together with resin byproducts of the paper industry, and tree islands to provide shade in the parking lot. A pond collects and cleans storm water runoff from building, parking lots, and sidewalks, leeching out toxins before water enters the sewer system.
 - Four water-storage cisterns (combined capacity of 12,000 gallons) catch rainwater for irrigation, reducing flow into sewers.
 - Native plants minimize maintenance and water needs.
 - Green roof on a portion of the project also reduces storm water runoff.

Source of information:

<http://www.eere.energy.gov/buildings/database/overview.cfm?ProjectID=97>

Nathaniel R. Jones Federal Building and US Courthouse, Youngstown, OH

Previous site use: This site was an urban 3-acre brownfield site that had a previously paved portion of the site converted to greenspace.

New site use: Construction was complete in September 2002 on a new four-story 52,200 SF public order and safety building type. The Nathaniel R. Jones Federal Building and US Courthouse in Youngstown, OH, houses the US Bankruptcy Court and various Federal offices (Figure B1).

The building was the first courthouse completed by the US General Services Administration (GSA) to receive Leadership LEED certification from the US Green Building Council.

The lot size is 3.09 acres and the building footprint is 13,700 SF. The building is primarily steel frame construction, with some masonry at the lower level. The exterior is clad with brick, cast stone, and a glass and aluminum curtain wall.



Figure B1. Nathaniel R. Jones Federal Building.
(Photo by Peter Aaron, ESTO)

Reuse, recovery, salvage of materials: Earth and foundation materials excavated from the site, including approximately 300 tons of crushed concrete, were used to regrade the site. The reuse of excavated earth and foundation materials, as well as reusing and recycling all concrete, steel, and metal debris, saved the project over \$100,000.

Diversion of C&D waste: The contractor separated concrete and over 12.5 tons of steel from the waste stream and recycled them. According to hauler receipts and other documentation, 72% of the total construction debris, by weight, was recycled.

More than 60% of the building materials used, by cost, were sourced or manufactured locally. The building uses recycled content materials including low-VOC (volatile organic carbons) recycled carpeting and structural steel with 90% post-consumer recycled content. Additionally, 75% of the indoor space is daylit, presenting a brighter, improved workspace with better outdoor views for employees.

A 1.8-acre previously paved portion of the site was converted to green space with climate-adapted, drought-tolerant plant species. The completed site has 58% less impervious surface than the original site. The planting of adapted, drought-tolerant plant species eliminated the need for irrigation and saved over 1 million gallons of water at an approximate cost of \$2000 each year.

Source of information:

<http://www.eere.energy.gov/buildings/database/overview.cfm?ProjectID=339>

Naval Facilities Engineering Command Building 33 (NAVFAC Bldg 33), Washington Navy Yard, DC

Previous site use: The four-story building is in the Washington (DC) Navy Yard, on an industrial brownfield site that was decontaminated prior to the start of the renovation. The renovation of Bldg 33 included updating all interior spaces and finishes in what was originally a weapons-manufacturing facility.

New site use: Bldg 33, the Sanger Quadrangle at the Washington Navy Yard, was a pilot project for the Navy's sustainable development program. The building cluster consists of an "L" shaped main building linked to three smaller courtyard buildings, providing approximately 156,000 gross SF of office and conference space (Figure B2).

Bldg 33's construction dates back to 1850. Originally a 45-foot-high, open-bay factory building, the facility, along with a linked building cluster, underwent a substantial renovation. The building's primary function is to house the general offices of the Naval Facilities Engineering Command.

Clean-up challenges: No additional funding was allocated for this project to pay for sustainable building strategies, so applying such strategies with no or minimal increase in initial costs became a top priority during the predesign phase. Making use of the "building within a building" concept was also an important priority for reasons of historical preservation and avoidance of the need to construct a new building.

The renovation of the building involved removing a large quantity of interior structural elements and hazardous materials, including asbestos. Due to the original open-bay configuration of the building, new floor structures had to be constructed to allow for the building's conversion to office space (Figure B3). The original outside structure of the building was retained, with the exception of a small lean-to addition, which was demolished.

Reuse, recovery, salvage of materials: Some bricks were recovered during demolition activities, cleaned up, and reused on the site. The sheets of drywall contain recycled gypsum, and the ceiling tiles contain recycled newsprint. Poured concrete and concrete masonry units (blocks) used in the building have fly ash content. Increased wall and roof insulation was accomplished by constructing new insulated wall and roof assemblies inside the existing historic shell.



Photo by Ewing Cole



Photo by Ewing Cole

Figure B2. Outside of Building 33.**Figure B3. Inside Building 33.**

Existing windows were retained and repaired when possible to operable condition. The retention of historic fixed windows was leveraged to create a “super window” effect. Double-glazed insulating glass was installed inside of the existing glazing creating a high thermal performance with over 12 in. of overall thickness.

Many of the furnishings, carpet, geotextile materials, and waterproofing materials used for the project have recycled plastic content. All toilets, urinals, showers, faucets, and drinking fountains were selected for their efficient use of water.

Sources of information:

<http://www.eere.energy.gov/buildings/database/overview.cfm?projectid=495>

http://www.wbdg.org/references/cs_bldg33.php

Stapleton International Airport, Denver, CO

Previous site use: In 1995 the 4700-acre Stapleton International Airport in Denver was closed (Figure B4).

New use of site: This is the largest urban infill and brownfield redevelopment project in the nation. The site is being transformed into a mixed-use master planned community with over 15 million sq ft of commercial, industrial, and institutional space, including a Wal-Mart SuperCenter and a Home Depot (Figure B5). The new development will include residential neighborhoods with a sustainable approach. The extensive park and trail system amounts to nearly 30% of Stapleton’s 4700 acres, increasing the size of Denver’s park system by 25%.



Source: http://www.parsons.com/about/press_rm/potm/08-2005/index.html

Figure B4. Original location of Stapleton International Airport.



Source: http://www.parsons.com/about/press_rm/potm/08-2005/index.html

Figure B5. Quebec Square, a new commercial business on the property.

Newly constructed commercial buildings have been erected at locations such as the former Consortium Fuel Farm, where large aboveground storage tanks of jet fuel once stood. Approximately 30% of the redevelopment work is complete.

Clean-up challenges: The prime remediation contractor for the city and county of Denver excavated approximately 30% of the nearly 5-square-mile site, almost 5 million cu yd. The contaminated soil was the result of 65 years of aviation activity at Stapleton. The contractor removed all the contaminated soil within 20 feet of the previously existing ground surface and conducted soil and groundwater sampling and analysis to verify that the property was suitable for residential development.

Reuse, recovery, salvage of materials: Recycled Materials Company, Inc. has completed the demolition and removal of approximately 6.5 million

tons of concrete and asphalt hardscape at the former airport (more than 975 acres of runways and taxiways). Under the largest agreement of its kind, the material is being removed for free in return for the right to sell the recycled material to others.

High-quality aggregate is a prized commodity in the Denver area. Strict zoning has restricted the development of new aggregate resources. RMCI thought that, given the high quality control programs the Federal Aviation Administration mandates, the aggregate in the runways had to be some of the best new resources Denver had seen in some time. These pavements were then mined and recycled into high-quality construction aggregates.

Removal began in early July 1999, taking fully 6 years to complete. Recycled concrete and asphalt from Stapleton have been reused in numerous Colorado state and municipal road projects, at the Rocky Mountain Arsenal, and in development and redevelopment projects throughout the northeast corridor. It has even been utilized by nonprofit groups to build handicapped accessible roads and wilderness trails. A large amount of the recycled specification aggregate generated by this project was reused at the Stapleton redevelopment site itself.

Many of the hangars on the property have been recycled for uses that include a movie studio, sports club, and shop and offices for a mechanical contractor.

Sources of information:

http://www.parsons.com/about/press_rm/potm/08-2005/index.html

<http://www.cdrecycling.org/press/stapleton.pdf>

<http://www.rmci-usa.com/redevelopment.html>

http://findarticles.com/p/articles/mi_m0NSY/is_9_22/ai_n6180997

Orlando Naval Training Center – Baldwin Park, Florida

Previous site use: The former Orlando Naval Training Center (ONTC), now called Baldwin Park, is a little over 2 miles from downtown Orlando, FL. From 1940 throughout WWII and until 1968, the 1100-acre site was an Army Air Corps and Air Force base. The Orlando Army Air base was decommissioned in 1946. The military retained the land, with the exception of the airfield, which was returned to the City of Orlando (today's Orlando Executive Airport). In 1968 the base became the Orlando Naval Training Center (ONTC). The Federal Base Realignment and Closure Commission identified ONTC for closure in July 1993.

New site use: Baldwin Park is one of the largest in-city redevelopment projects in the country. The old naval base became a mixed-use, large-scale master planned community by weaving the redeveloped portion with existing neighborhoods surrounding the old naval base. Baldwin Park is comprised of new home construction, retail and office spaces, and newly developed parks, lakes, and wetland areas. Baldwin Park contains about 400 acres of built/buildable real estate. The remainder of the 1100 acres consists of 250 acres of lakes, 200 acres of parks, and the streets, public spaces, civic sites, and existing buildings.

Clean-up challenges: This brownfield redevelopment reflected the complexities of redeveloping a former military base. Before rebuilding could begin, 256 buildings, 200 miles of underground utilities, and 25 miles of road had to be dismantled and recycled. Asbestos and lead paint in the buildings and arsenic and petroleum in the soil needed to be cleaned up. Four hundred and forty days after demolition began, one of the largest recycling projects in the nation's history was complete – at a cost of about \$40 million – and the work of building a new community began.

Reuse, recovery, salvage of materials: Five buildings from the ONTC remain, housing 700 workers who are part of the built-in market for town center businesses. The rest of the facility has been razed in an operation that removed 4.5 million sq ft of offices, dormitories, and classrooms, 200 miles of underground utilities, and 25 miles of roads.

Concrete and masonry materials from demolished buildings were crushed onsite and recycled in a massive underground storm water filtration system and in road base for new public streets. Reusing 750,000 tons of recycled concrete onsite eliminated the 40,000 truck trips it would have taken to transport waste materials to a landfill.

Baldwin Park redevelopment also took advantage of existing power plants and water and wastewater treatment facilities.

The Navy Hospital officially closed June 2, 1995, and was converted into a Veterans Administration Outpatient Clinic.

Baldwin Park partnered with The National Audubon Society of Florida with the planning of the parks and water edges, to create viable ecosystems where none existed. The developer also preserved and enhanced the existing mature tree canopy.

Sources of information:

USEPA's New Urban News, Volume 7, No. 2, March 2002

<http://www.newurbannews.com/Mar02.html>

<http://www.baldwinparkfl.com/web/history.asp>

<http://www.cityoforlando.net/planning/ntc/ntchome.htm>

<http://www.smartgrowth.org/library/articles.asp?art=2174&res=1280>

http://www.epa.gov/smartgrowth/awards/2005_base_redev_orlando.htm

<http://www.cfhf.net/orlando/military/ntc.htm>

Pepsin Syrup site (Pepsin Building), Monticello, IL

Previous site use: Starting from a local drug store, Harry Crea and Dr. W. B. Caldwell built the four-story structure to produce laxatives and various tonics in the small town of Monticello, IL (Figure B6). From there, the Pepsin Syrup Company reputedly became the largest single pharmaceutical manufacturing facility in the nation. The facility included employee cafeterias, gymnasiums, lounge, and club facilities. The factory closed in 1985.



Figure B6. Pepsin Syrup factory site (top left) historical print (top right) circa 1920 photograph, (bottom) circa 1990 photograph.

New site use: A number of potential developers have expressed preliminary interest in “Pepsin Hill” — now a greenfield site. They are continuing negotiations and hope to have redevelopment started soon.

Clean-up challenges: After closing in 1985, the historic site became increasingly derelict and a safety hazard. The facility contained asbestos, lead, and other hazardous materials, making it difficult for the small town to shoulder the remediation costs. Not until the USEPA provided funds in 2005 was the community able to complete environmental remediation, preserve unique historical architectural and decorative fixtures, and clean up for demolition of the decaying structure.

Sources of information:

Steve Colantino, Office of Brownfields Assistance, Bureau of Land, IL EPA, 3 November 2006 email.

http://cityofmonticello.net/cms/uploads/2005_fall.pdf

<http://web.extension.uiuc.edu/piatt/downloads/194.pdf>

Photo sources:

<http://www.epa.state.il.us/environmental-progress/v32/n1/environmental-progress.pdf>

<http://www.will.edu/news/archives/features2005d.htm>

International Harvester brownfields cleanup site

The 33-acre former International Harvester site in Canton, IL is ideally located in the center of the city. It was used for the manufacturing of farm implements and equipment between 1840 and 1984. The site was used for a variety of purposes after 1984 and is currently vacant. Contaminants present include nonaqueous-phase liquids, metals, cyanide, and friable asbestos. The redevelopment plan for the site includes retail, cultural, and light industrial areas, all of which would promote economic activity in the area.

Sources of information:

Steve Colantino, Office of Brownfields Assistance, Bureau of Land, IL EPA, 3 November 2006 email.

http://www.epa.gov/swerosps/bf/03grants/canton_il.htm

<http://www.epa.state.il.us/community-relations/fact-sheets/canton-industrial/canton-industrial-2.html>

Cinderella City Shopping Mall, Englewood, CO

In its day, the Cinderella City Shopping Mall in Englewood was the largest enclosed mall west of the Mississippi River. It closed in 1997. While investigating the site for redevelopment, the City of Englewood found PCBs, asbestos, gasoline, and dry cleaning chemicals. The project made use of environmental insurance products, state voluntary cleanup tools, and concrete recycling. Englewood remediated and rebuilt Cinderella City into a city center and light rail transportation hub. The site is now a thriving city center for Englewood, complete with a Wal-Mart and other shopping and dining opportunities, plus more the 200 rental properties.

Sources of information:

http://www.mayors.org/uscm/us_mayor_newspaper/documents/11_21_05/denver_englewood.asp

<http://www.burnsfigawill.com/Issue1.pdf>

Dry cleaning property, New Britain, CT

As part of a community-wide revitalization project, a former dry cleaning property is being redeveloped into a portion of an 8.5-acre urban park that will include a community center and residential units. The New Britain Brownfields Assessment Demonstration Pilot was used to conduct assessments that determined that no cleanup was necessary, which led to the City of New Britain accepting the transfer of ownership of the property from the State of Connecticut. Located in one of the city's most poverty-stricken and crime-ridden neighborhoods, the community center will include a Head Start Program for kids and a computer laboratory, while the residential area will include up to eight moderate-income homes. At the opposite end of the planned urban park, another Pilot-targeted site is being redeveloped into an urban organic farm in which greenhouses are being constructed on uncontaminated portions of the site, as well as on adjacent property. The Pilot has helped to leverage more than \$1.3 million in redevelopment funding for this project from various sources that include the city, the state, and private companies.

Source of information:

<http://www.epa.gov/swerosps/bf/success/nocleanup.pdf>

GAF plant in South Bound Brook, NJ

In December 2004 the Dallas Contracting Co., Inc., a contractor specializing in demolition, equipment salvage, wrecking, dismantlement, onsite

concrete crushing, and scrap metal recycling, completed the demolition of the former GAF plant in South Bound Brook, NJ (Figure B7). The approximate 11-acre industrial site, which was formerly used to produce roofing and siding shingles, was composed of 10 buildings and various other structures including a water tower and several vertical above ground storage tanks. The footprint of the buildings to be demolished was more than 170,000 SF. From a redevelopment standpoint, this designated brownfield site will eventually be turned into a residential development. Several of the older buildings had a substantial amount of salvageable wood, which was predominantly yellow pine. The contractor dismantled the wooden sections of these buildings to salvage the Yellow Pine timbers, beams, and posts. The salvaged wood was then stacked, banded, and sent to a wood salvage company where they were remilled into wood flooring. In total, the contractor salvaged approximately 40,000 board feet of wood. Following demolition of the buildings, which included the slabs and foundations, the concrete, block, and brick materials were crushed to 2-inch minus for use as onsite backfill. Approximately 30,000 tons of concrete, block, and brick were crushed (Figure B8) and used onsite for backfill, which was a dual benefit for the company. They did not have to pay to send the materials offsite for recycling and did not have to pay for imported backfill material.



Source: Dallas Contracting Co., <http://www.dallascontracting.com/Sections-read-43.html>

Figure B7. Aerial view of GAF Plant.



Source: Dallas Contracting Co., <http://www.dallascontracting.com/Sections-read-43.html>

Figure B8. Crushing material at former GAF site.

Sources of information:

http://www.deconstructioninstitute.com/casestudy.php?cas_ID=48

http://www.deconstructioninstitute.com/article.php?art_ID=79

Fort McCoy, WI

Fort McCoy has adopted a standard practice of selling surplus WWII-era buildings through competitive bidding. To summarize, the Fort McCoy Directorate of Public Works (DPW) and Corps of Engineers' Omaha District developed a process to advertise buildings for salvage. Local interests consisting mainly of individuals, families, and small building contractors bid competitively for the buildings. The successful bidder signs a contract and makes payment to the Treasurer of the United States. Fort McCoy removes all asbestos and hazardous materials prior to the purchaser beginning work. The purchaser then dismantles the building to the foundations and removes the salvaged materials for their own use. Lumber is typically the most valuable and most sought after material. Debris is deposited in receptacles provided by Fort McCoy. The DPW then disposes of the debris in the Fort McCoy landfill. Omaha District administers real property and contract transactions. The contract includes requirements for safety training, period of performance, deposit requirement, disclaimers and hold harmless provisions, provisions for disposing of debris. The purchaser is responsible for removing the building materials with the exception of foundations and floor slabs. Foundations are removed and provided to

Engineering Battalions to crush onsite and use in their exercises and around the Fort McCoy property. The Fort McCoy DPW reports that since 1992 more than 140 buildings have been deconstructed, for an estimated savings of \$3.5 million. PWTB 420-49-30 describes the Fort McCoy procedures in detail.

Fort Knox, KY

The Fort Knox Recycling Program has established a similar program for recycling surplus buildings. This program differs from the Fort McCoy program in that Fort Knox sells recycle rights to the parties performing deconstruction, as opposed to selling the building. In this way, revenues return to the Fort Knox Recycle Program instead of the Treasurer of the United States. The Recycle Program administers the process and conducts public auctions instead of sealed bidding. This process takes place during a 6-week window inserted into an otherwise conventional demolition schedule. When abatement activities and McKinney Act screening are completed, the property is transferred to the Recycle Program, whereupon it advertises, conducts the auction, sells recycle rights to the building, and completes the contract. The purchaser then salvages materials and removes debris from the site. The Recycle Program requires the contractor to remove a minimum of 50% of the building's weight (excluding foundations). When salvage is completed, the Recycle Program transfers the property back to the DPW, which then contracts for demolition services to remove the remainder of the debris. The demolition contractor separates concrete and masonry rubble and any leftover metal materials for recycling.

The contract includes criteria to extract a minimum volume of salvaged materials, safety requirements, period of performance, disclosure statements for LBP materials, identification, site security, and times of the day at which salvage activities may take place.

The purchaser must report to the installation the types and quantities of materials they are recovering so the installation can take credit in their Solid Waste Annual Report, as well as to verify salvage of the minimum amount of materials.

The Fort Knox Recycle Program reports the following results in roughly 3 years of operation:

- 258 buildings recycled
- 451 family housing apartments recycled
- 153,468 tons of debris diverted from the Fort Knox landfill
- Life of the landfill extended by 20 years
- \$1,534,680 landfill savings
- \$1,253,893 potential demolition savings
- \$256,085 new income generated for the Recycle Program.

Appendix C: Extensive List of Weights of Building Components

This list of material weights has been compiled from many different sources, including American Society of Civil Engineers (ASCE), Associated General Contractors (AGC), US Army Corps of Engineers (USACE) databases, and manufacturers. CERL staff had to develop a few of the values internally.

Table C1. Door-related weight conversions.

Door Type	Weight
Windows, glass, frame, and sash	8 lb per sq ft
Wood trim 4-in. wide	0.25 lb per ft
Door (2-1/4-in. thick white pine)	4.5 lb per sq ft
Door (1-3/4-in. thick solid core)	5 lb per sq ft
Door (2-1/4-in. thick oak)	9 lb per sq ft
Door (1-3/4-in. thick hollow core)	2.5 lb per sq ft
Exterior door (same as window)	8 lb per sq ft
Hollow metal	6.5 lb per sq ft
Hollow metal door frame	1.4 lb per ft
Screen door (1/4 door)	2 lb per sq ft

Table C2. Concrete weight conversions.

Form of Concrete	Weight
Reinforced concrete (stone)	4,050 lb per cu yd
Reinforced concrete (stone)	150 lb per cu ft
Concrete fill per inch thickness	12 lb per sq ft
Concrete floor, plain per 1-in. thickness	12 lb per sq ft
Concrete floor, reinforced 1-in.	12.5 lb per sq ft
Concrete curb, 4-in. high x 8-in. thick (0.008 cu yd/ft)	29 lb per ft
6-in. concrete slab (unreinforced)	72 lb per sq ft
10-in. thick foundation wall	125 lb per sq ft
12-in. thick foundation wall	150 lb per sq ft
Footings 1 x 1 ft including reinforcing	151 lb per sq ft
Footings 1 x 2 ft including reinforcing	303 lb per ft
Footings 2 x 2 ft including reinforcing	605 lb per ft
Concrete joist 20-in. wide form, 6-in. depth of slab	111 lb per sq ft

Table C3. Wall surface weight conversions.

Siding/Wall Covering	Weight
Vinyl siding	46 lb per square
Plywood (1/2-in.)	1.5 lb per sq ft
Plywood (3/4-in.)	2.4 lb per sq ft
Gypsum (1/2-in.)	2 lb per sq ft
Plywood (1/8-in. thick), e.g., paneling	0.4 lb per sq ft

Table C4. Flooring weight conversions.

Floor covering	Weight
Vinyl flooring/trim, 1/8-in.	1.33 lb per sq ft
Ceramic tile, glazed wall 3/8-in.	3 lb per sq ft
Ceramic tile floor, 1-in. mortar bed	23 lb per sq ft
Ceramic tile floor, 1/2-in. mortar bed	16 lb per sq ft
Ceramic tile floor, 3/4-in.	10 lb per sq ft

Table C5. Miscellaneous sheet metal weight conversions.

Metals	Weight
Gutters (0.032-in. thick)	0.471 lb per ft
Louvers 16 ga. Galvanized or cold rolled steel	2.042 lb per sq ft
Louvers 14 ga. Extruded aluminum alloy	0.913 lb per sq ft
Louvers 12 ga. Extruded aluminum alloy	1.16 lb per sq ft

Table C6. Miscellaneous metal fence and pipe weight conversions.

Metal piping and fencing	Weight
Gas Pipe (2-in. galvanized steel)	3.66 lb per ft
Waste & Vent Pipe (2-in. copper)	1.164 lb per ft
Steel stair nosings	1 lb per ft
Chain-link fence fabric	0.696 lb per sq ft
Chain-link fence corner/end posts (2-1/2-in. O.D.)	2.315 lb per ft
Chain-link fence support/middle posts (1-5/8-in. O.D.)	1.431 lb per ft
Galvanized steel H posts	3.26 lb per ft
Aluminum H posts	1.25 lb per ft
Roll formed steel line posts 1.625 x 1.875-in.	2.34 lb per ft
Roll formed steel brace rails and top rails 1.25 x 1.625-in.	1.35 lb per ft

Table C7. Wall structure weight conversions.

Walls	Weight (lb/unit)
2 x 4-in. studs, 8 ft high, = 5.33 bf/stud	0.75 lb per ft +1
2 x 4-in. studs, 10 ft high, = 6.667 bf/stud	0.75 lb per ft +1
2 x 4-in. studs, 1/2-in. gypsum wall board on both sides	8 lb per sq ft
6-in. Drywall on wood studs	10 lb per sq ft
2 x 4-in. wood stud, plywood on both sides	7 lb per sq ft
Plywood (1/8-in. thick), e.g., paneling	0.4 lb per sq ft
6-in. CMU wall, lightweight, with gypsum wall board	35 lb per sq ft
8-in. CMU wall, lightweight, with gypsum wall board	47 lb per sq ft
8-in. CMU wall, lightweight, no gypsum wall board	35 lb per sq ft
8-in. CMU wall, stone or gravel, no gypsum wall board	55 lb per sq ft
8-in. hollow CMU wythes 24-in. o.c. grout spacing	46 – 54 lb per sq ft
8-in. solid concrete block	67 lb per sq ft
8-in. solid concrete block, (stone aggregate light-weight)	48 lb per sq ft
8-in. hollow concrete block	55 lb per sq ft
8-in. hollow concrete block (stone aggregate)	38 lb per sq ft
4-in. Brick, low absorption	46 lb per sq ft
Furring 1 x 3-in. wood strips	0.25 lb per ft
Gypsum furring, 0.75 linear ft of 1 x 3-in. wood strips per square foot of wall	0.25 lb per ft
Gypsum furring, 0.75 linear ft of 1 x 3-in. wood strips per square foot of wall	0.1875 lb per sq ft

Table C8. Partition weight conversions.

Misc. Partitions	Weight
Removable steel partitions	4 lb per ft
Toilet partitions (1/2 of hollow metal door)	3.25 lb per ft

Table C9. Ceiling and roof weight conversions.

Ceilings/Roof	Weight (lb/ft)
Acoustical tile unsupported per 1/2-in.	0.8 lb per sq ft
Acoustical Fiber Board	1 lb per sq ft
Suspended Steel Channel System	2 lb per ft
Batt Insulation (per 1-in. thickness)	0.1 - 0.4 lb per sq ft
Built-up Roof tar & gravel	5.5 lb per sq ft
Built-up Roof	6.5 lb per sq ft
Cement tile roof	15 lb per sq ft

Table C10. Piping weight conversions.

Piping	Weight
3/4-in. steel pressure tubing	1.13 lb per ft
4-in. steel pipe	10.79 lb per ft
6-in. steel pipe	18.97 lb per ft
10-in. steel pipe	40.48 lb per ft
14-in. steel pipe	54.75 lb per ft
16-in. steel pipe	62.58 lb per ft
18-in. steel pipe	70.59 lb per ft
1-in. copper tubing (type L and ACR)	0.655 lb per ft
1-1/2-in. copper tubing (type L and ACR)	1.14 lb per ft
2-in. copper tubing (type L and ACR)	1.75 lb per ft
2-1/2-in. copper tubing (type L and ACR)	2.48 lb per ft
3-in. copper tubing (type L and ACR)	3.33 lb per ft
4-in. copper tubing (type L and ACR)	5.38 lb per ft
3-in. PVC (schedule 80)	1.903 lb per ft
4-in. PVC (schedule 80)	2.782 lb per ft
Electrical conduit (1/2-in. steel)	0.82 lb per ft
Electrical conduit (1-in. steel)	1.6 lb per ft

Table C11. Cabinet weight conversions.

Cabinets	Weight
wood upper wall cabinets	20 lb per ft
wood lower base cabinets	40 lb per ft

Appendix D: State Recycling Resources

Nationwide

Alter Trading Corporation: Metal Recycling Facilities in the Midwest
<http://www.altertrading.com/index.html>

EPA: Construction and Demolition Debris
<http://www.epa.gov/epaoswer/non-hw/debris-new/index.htm>

EPA: Resource Conservation – Reduce, Reuse, Recycle: Business Directories and Market Studies
<http://www.epa.gov/osw/conserve/rrr/rmd/bizasst/bizdir.htm>

Institute of Scrap Recycling Industries, Inc,
http://www.isri.org/iMIS15_prod/ISRI/default.aspx

National Demolition Association
<http://www.demolitionassociation.com/>

Policy Link: Brownfields
<http://www.policylink.org/EDTK/brownfields/default.html>

Recyclers World
<http://www.recycle.net/>

Steel Recycling Institute
<http://www.recycle-steel.org/>

Timber Framers Guild
<http://www.tfguild.org/>

Waste Material Exchanges
<http://peakstoprairies.org/p2bande/Construction/C&DWaste/exchange.cfm>

Whole Building Design Guide: Construction Waste Management Database
<http://www.wbdg.org/tools/cwm.php>

States

Alabama

EPA
<http://www.epa.gov/jtr/state/al.htm>

Regional Recycling
<http://regionalrecycling.com/>

Alaska

Alaska Reuse & Recycling Services
<http://alaska.earth911.org>

Green Star Alaska Materials Exchange
<http://www.greenstarinc.org/ame/index.php>

Arizona

Arizona Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=recycling&bkid=21&cache=%5E>

EPA

<http://www.epa.gov/itr/state/az.htm>

Arkansas

Arkansas Recycling Marketing Directory

http://www.adeg.state.ar.us/solwaste/branch_market_dev/mkt_dev.asp

EPA

<http://www.epa.gov/itr/state/ar.htm>

California

Integrated Waste Management Board: C&D Recyclers Database

<http://www.ciwmb.ca.gov/ConDemo/Recyclers/>

Oakland Public Works Agency: C&D Recycling

<http://www.oaklandpw.com/PageFactory.aspx?PageID=39>

SF Environment: Salvage Yards Directory

http://www.salvageyards.ws/salvage_yards_in_ca.shtml

The Reuse People

<http://thereusepeople.org/>

<http://thereusepeople.org/Deconstruction>

Colorado

Boulder County: Resource Conservation Division

http://www.co.boulder.co.us/recycling/fag/fag_c&d.pdf

The Colorado Materials Exchange

<http://ecenter.colorado.edu/recycling>

Connecticut

Connecticut Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/wsna.dll/WService=wsbrk1/viewpg.htm?docsstart=1&ncls=3455&bkid=17&cache=^>

Connecticut Department of Environmental Protection: Construction and Demolition Aggregate Recycling Facilities

<http://dep.state.ct.us/wst/recycle/constrct.htm>

Recyclopedia: Reuse and Recycling Resources

<http://www.town.simsbury.ct.us>

Delaware

Delaware Department of Natural Resources and Environmental Control: Recycling Companies and Organizations

<http://www.dnrec.state.de.us/DNREC2000/Divisions/AWM/hw/wrrr/Recycle%20Directory%20Part%202-%20Recycling%20Companies.xls>

Delaware Solid Waste Authority: Bulky Waste Programs

http://www.dswa.com/programs_bulky.html

Florida

Florida Department of Environmental Protection Recycling Facilities List

<http://www.dep.state.fl.us/waste/categories/recycling/default.htm>

Florida Department of Environmental Protection Recycling Program Contact List

<http://www.dep.state.fl.us/waste/categories/recycling/pages/recyclingstaff.htm>

Georgia

C&D Landfill and Transfer Station
<http://www.co.walker.ga.us/C&D%20Landfill.htm>

Georgia Construction and Demolition Waste Recyclers
<http://www.usg.edu/ref/compliance/sustainable/index.phtml>
cepm.louisville.edu/Pubs_WPapers/practiceguides/PG7.pdf

Georgia Department of Natural Resources – Land Protection Branch
http://www.gaepd.org/Documents/regcomm_lpb.html

Georgia Recycling Market Directory
<http://www.dca.state.ga.us/development/EnvironmentalManagement/programs/recycling/default.asp>

Regional Recycling
<http://www.regionalrecycling.com/geoframe.html>

Reuse and Salvage Centers
<http://swix.ws/Resources/Building-Material-Reuse-Centers/>

Hawaii

Aloha Shares
<http://www.alohashares.org/>

Idaho

Idaho Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&bkid=5&cache=%5E&keyword=construction+and+demolition+debris+recycling>

Idaho Department of Environmental Quality Online Recycling Directory
http://www.deq.state.id.us/waste/recycling/Recycle_category.cfm?county=&recycle_category_id=116

Illinois

Construction and Demolition Debris Recyclers in the Chicago Area
http://www.cityofchicago.org/dam/city/depts/doe/general/RecyclingAndWasteMgmt_PDFs/CandDrecycling/CDRecyclerList.pdf

Illinois Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&bkid=8&cache=%5E&keyword=construction+demolition+debris+recycling+>

Solid Waste Agency of Lake County
<http://www.swalco.org>

The City of Champaign: Public Works Recycling Household Products
<http://ci.champaign.il.us/departments/public-works/residents/recycling/recycling-household-products/>

Indiana

Indiana Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=construction&bkid=31&cache=%5E>

Indiana Department of Environmental Management: Indiana Recycling Locations
http://www.in.gov/idem/recycle/files/ewaste_collectors_by_county.pdf

Indiana Material Exchange

http://www.in.gov/cgi-bin/idem/imx/list_materials.cgi

Iowa

Iowa Construction and Demolition Management Resources

<http://www.iowadnr.com/waste/recycling/files/cndcontact.pdf>

Kansas

Kansas Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=recycling&bkid=28&cache=%5E>

Kentucky

EPA: Materials Exchange and Reuse Programs

<http://www.epa.gov/itr/state/kv.htm>

Kentucky Division of Waste Management

<http://waste.ky.gov/RLA/recycling/Pages/recycling.aspx>

Louisiana

EPA: Materials Exchange and Reuse Programs

<http://www.epa.gov/itr/state/la.htm>

Louisiana Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=recycling&bkid=32&cache=%5E>

Maine

Maine State Planning Office: Waste Management Services Directory

http://portalx.bisoex.state.me.us/pls/spo_wm/spwmdev.directoryv.main_page

Maryland

Maryland Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=&bkid=2&cache=3455>

MD Recycles: Recycling Directory

http://www.mde.state.md.us/programs/Land/RecyclingandOperationsprogram/RecyclinginMaryland/Pages/Programs/LandPrograms/Recycling/md_recycling/index.aspx

Massachusetts

Massachusetts Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&bkid=6&cache=%5E&keyword=construction+demolition+debris+recycling+>

Recycling Services Directory for Massachusetts

<http://www.wastecap.org>

Michigan

Michigan Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/mi/htm/0228113100008.shtml>

The University of Michigan: Waste Management Services Reuse Resources

<http://www.recycle.umich.edu/grounds/recycle/>

Minnesota

Eureka Recycling: Recycling and Save Disposal Guide
<http://www.eurekarecycling.org/page.cfm?ContentID=95>

Green Guardian: A to Z Material Management Directory
http://greenguardian.com/business/rwmg_AtoZ_C.asp

Minnesota Office of Environmental Assistance: Recycling Markets Directory
<http://www.pca.state.mn.us/index.php/topics/preventing-waste-and-pollution/recycling/minnesota-recycling-markets-directory/minnesota-recycling-markets-directory-home.html?menuid=&missing=0&redirect=1>

Mississippi

Mississippi Recycling Directory
[http://deg.state.ms.us/Mdeg.nsf/pdf/Recycling_StatewideRecyclingDirectory/\\$File/Mississippi%20Recycling%20Directory.pdf?OpenElement](http://deg.state.ms.us/Mdeg.nsf/pdf/Recycling_StatewideRecyclingDirectory/$File/Mississippi%20Recycling%20Directory.pdf?OpenElement)

Missouri

EPA: Materials Exchange and Reuse Programs
<http://www.epa.gov/itr/state/mo.htm>

Missouri Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/cl/all3455.htm>

Missouri Recycling Association
<http://mora.org/>

Montana

Montana Material Exchange
<http://www.montana.edu/mme/search.php>

Montana Recycling Locator
http://deg.mt.gov/Recycle/Where-to-Recycle_New.mcp

Nebraska

Nebraska Department of Environmental Quality: Nebraska Recycling Resource Directory
<http://www.deg.state.ne.us/recdir.nsf/recdirlist?openpage>

WasteCap Nebraska
<http://www.wastecapne.org/>

Nevada

Nevada Division of Environmental Protection: Places to Recycle in Nevada
<http://ndep.nv.gov/>

Nevada Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&bkid=34&cache=%5E&keyword=construction+demolition+debris+recycling>

New Hampshire

New Hampshire Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=construction&bkid=6&cache=%5E>

New Hampshire Department of Environmental Services: Companies that Resell or Reuse Construction and Demolition Materials
<http://des.nh.gov/organization/divisions/waste/swrtas/cdlist.htm>

New Jersey

New Jersey Approved Class B Recycling Facilities
<http://www.state.nj.us/dep/dshw/lrm/classbsch.htm>

New Jersey Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=construction&bkid=10&cache=%5E>

Passaic County Office of Natural Resource Program: Construction and Demolition Debris
http://www.passaiccountynj.org/Departments/naturalresources/mar_CD.htm

New Mexico

New Mexico Recycling Coalition: Recycling Directory
<http://www.recyclenewmexico.com/search/>

New York

New York Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=&bkid=1&cache=3455>

Sources or Nerc State Recycling Information
https://www.nerc.org/documents/recycling_economic_information_project.html

North Carolina

North Carolina Construction and Demolition Debris Recycling Centers
<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&keyword=&bkid=29&cache=3455>

Recycling and Salvage Directory
<http://www.fac.unc.edu/OWRRGuidelines/?Topic=CDResourcesLinks>

Recycling Markets Directory
<http://www.p2pays.org/DMRM/start.aspx>

North Dakota

North Dakota Department of Health: Concrete/Asphalt Recycling Facilities List
<http://www.ndhealth.gov/wm/Publications/ConcreteAsphaltRecyclingFacilities.pdf>

North Dakota Reuse and Recycling Centers
<http://northdakota.earth911.org/master.asp?s=ls&a=Recycle&cat=1#20>

Ohio

Ohio Office of Compliance Assistance and Pollution Prevention: Recycling Directory and Resource Guide
http://www.epa.ohio.gov/ocapp/p2/recvc/debris_add.aspx

Oklahoma

Oklahoma Department of Environmental Quality: Recyclers (A-L)
http://www.deq.state.ok.us/LPDnew/recyclers/recyclers_a-l.html

Oklahoma Department of Environmental Quality: Recyclers (M-Z)
http://www.deq.state.ok.us/LPDnew/recyclers/recyclers_m-z.html

Oregon

Metro Recycling and Waste Prevention: Construction Debris Recycling Facilities

<http://www.oregonmetro.gov/index.cfm/go/by.web/id/732>

Pennsylvania

North East Recycling Council,

http://www.nerc.org/state_information/pennsylvania.html

Pennsylvania Department of Environmental Protection: Recycling Markets Search

http://www.ahs2.dep.state.pa.us/recycle_markets/search.aspx

Rhode Island

Rhode Island Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/2011/index.php?id=30&tab=mybb&request=listing&srch=keyword&view=bpm&cls=3455&bkid=6>

Rhode Island Resource Recovery: Resource Exchange

<http://www.resourceexchange.org/>

Rhode Island Reuse and Recycling Centers

http://www.recyclingcenters.org/Rhode_Island/

South Carolina

Recycling Markets Directory

<http://www.recyclinginsc.com/directory>

South Carolina Recycling Directory Search

<http://www.sccommerce.com/SearchRecycling.aspx>

South Dakota

South Dakota Department of Environment and Natural Resources: Concrete and Asphalt Recyclers

<http://denr.sd.gov/des/wm/recycle/recycleconcrete.aspx>

South Dakota Reuse and Recycling Centers

<http://denr.sd.gov/des/wm/recycle/recycleguide.aspx>

Tennessee

Construction and Demolition Material Recycling Directory

http://www.nashville.gov/pw/docs/recycle/Construction_Directory.pdf

Texas

Recycling Alliance of Texas

<http://www.recycletx.com/affiliatedcouncils/goldencrescent.htm>

Recycling Construction Demolition Debris

<http://www.recyclecddebris.com/rCDd/Handbook/>

Texas Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/cl/all3455.htm>

Utah

Recycling Coalition of Utah: Recycling Guide

<http://utahrecycles.org/recycling-guide/?UTAHRECYCLES=oh4im4iqih9i29cb06evl590m1>

Vermont

Vermont Construction Site Reuse and Recycling Database

http://www.anr.state.vt.us/dec/cf/wm/CandD_SearchList.cfm

Virginia

EPA: Markets Development Information

<http://www.epa.gov/itr/state/va.htm>

Virginia Construction and Demolition Debris Recycling Centers

<http://www.thebluebook.com/wsnsa.dll/WService=wsbrk1/viewpg.htm?docsstart=0&ncls=3455&bkid=20&cache=3455>

Washington

King County: Construction Recycling

<http://your.kingcounty.gov/solidwaste/greenbuilding/construction-demolition.asp>

King County: Online Materials Exchange

<http://your.kingcounty.gov/solidwaste/exchange/index.asp>

Resource Venture: Waste Prevention and Recycling

<http://resourceventure.org/green-your-business/waste-prevention-recycling>

West Virginia

West Virginia Recycling Directory

<http://www.wvdo.org/media/recycling06.pdf>

West Virginia Solid Waste Management Board

<http://www.wv.gov/Offsite.aspx?u=http://www.state.wv.us/swmb>

Wisconsin

WasteCap Wisconsin

<http://www.wastecapwi.org/>

Wisconsin Department of Natural Resources: Recycling Markets Directory

<http://www4.uwm.edu/shwec/wrmd/search.cfm>

Wyoming

Wyoming Department of Environmental Quality: Recycling Database

<http://deg.state.wy.us/shwd/recycling/2009%20Wy%20Rec%20Dir.pdf>

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