

The Status of Wood Pallet Disposal and Recovery at United States Landfills

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Abstract

Each year a large number of wooden pallets are disposed of in US landfills, representing a significant portion of total wood usage. The purpose of this research was to gain an understanding of the numbers of pallets reaching landfills, specifically Municipal Solid Waste (MSW) and Construction & Demolition (C&D) landfills. Also, the research was conducted to determine what, if anything, was done with the pallets once they were received by landfills.

Mail questionnaires were sent to every state licensed MSW and C&D landfill identified in the US, except Alaska. Alaska was omitted because it is known to have many small landfills each representing a single small village. It was thought that these small landfills could skew the results. The questionnaire mailed to the landfills was based on a questionnaire used in a Virginia Tech study of landfills in 1995. Only minor changes were made to the previously used questionnaire so that the data collected would be comparable to previous results.

This study found that, on average, MSW landfills received 138,000 tons of waste and C&D landfills received 36,000 tons of waste in 1998. This amounted to a total of 239 million tons of waste at MSW facilities and 40 million tons of waste at C&D facilities. Average tipping fees at MSW and C&D landfills were \$29.31 and \$16.84 per ton, respectively. Pallets represented 2.8 percent of waste at MSW facilities and 3.3 percent of waste at C&D facilities. This amounts to 138 million pallets reaching MSW landfills and 40 million pallets reaching C&D landfills in 1998. Of these pallets reaching landfills 22 million were recovered from MSW landfills and 16 million were recovered from C&D landfills. Recovered pallets from both types of landfills were typically ground and used for mulch, animal bedding, compost or boiler fuel. Infrequently, pallets were used as-is. But this was infrequent. When pallet material was sold by MSW and C&D facilities, it received between ten and twenty dollars per ton depending on end use and region of the country.

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Preface

This thesis is divided into four major sections and two minor sections. The first major section is an introduction, literature review, and justification of the research done. The second major section describes the methods used to complete the research. The third and fourth major sections discuss the results of this study. The first minor section presents conclusions of this study and recommendations for further research. The second minor section includes the appendices, which presents the questionnaires used to gather data for this study.

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Introduction

Each year a large volume of wood is used to produce pallets in the United States, a volume representing approximately 40% of all hardwood lumber (69). Practically every consumer good purchased in the United States was shipped at one time on a pallet. Frequently, the lives of these pallets are short, only 3-5 shipments (40). When they are no longer considered useful they may be refurbished and reused, but it is more likely they will be discarded. Recently, the volume of pallets being recovered by pallet recyclers has grown (9, 19, 30, 39). This is likely due to the increasing scarcity of the wood resource. However, the volume of pallets recovered within the industry (i.e., by pallet recyclers) does not come close to the volume of pallets being used (4, 16, 40). This study attempts to identify the fate of these pallets and so provide a more complete picture of pallet recovery and disposal in the United States.

To identify the fate of pallets that are not being recovered by the pallet industry, this study questioned operators of both Municipal Solid Waste (MSW) and Construction and Demolition (C&D) landfills. It was thought that the largest volume of pallets available for recycling resided with landfills (4, 16). Previously (1995), a similar study was conducted at Virginia Tech, but as the amount of pallets recycled has likely changed, the need to update the information has arisen again. This study identified trends in disposal and recycling of pallets at landfills. This information should be helpful to all pallet recyclers and landfill operators in identifying where pallets are and value-added options for their reuse. The study was completed in hope that the information will lead to more efficient use of the wood and forest resources.

Discussion of Terms

In this section some important terms will be defined, regarding solid waste and its management, that are pertinent to later sections of this work. The definitions are derived from the United States Environmental Protection Agency (67).

Waste Generation – refers to the weight of materials and products as they enter the waste management system from residential, commercial, industrial, and institutional sources and before materials recovery or combustion takes place. Source reduction activities take place ahead of generation (e.g., backyard composting of yard trimmings).

Source Reduction – activities that reduce the amount or toxicity of wastes before they enter the solid waste management system. Reuse is a source reduction activity involving the recovery or reapplication of a package, used product, or material in a manner that retains its original form or identity. Reuse of products such as refillable glass bottles, reusable plastic food storage containers, or refurbished wood pallets is considered source reduction, not recycling.

Recovery – includes products and yard trimmings removed from the waste stream for the purpose of recycling (including composting).

Recycling – the use of recovered materials to manufacture a new product

Discards – remaining waste after recovery for recycling. These discards would presumably be combusted or landfilled, although some is littered, stored or disposed on-site, or burned on-site, particularly in rural areas.

Tipping Fees – the fees charged by landfills to dispose of refuse. Typically charged by weight, but occasionally by volume.

Municipal Solid Waste Landfill – MSW landfills are typically operated by municipalities or large companies. They must abide by federally set regulations for waste handling. Common requirements are application of a daily cover, containment of the whole site for liquid and gas, and acceptance of most wastes except hazardous.

Construction and Demolition Landfill – C&D landfills are typically operated by independent owners and accept significantly less waste than MSW landfills. C&D

landfills can only accept inert wastes. This means that most C&D facilities are not regulated as extensively as MSW, because there are less toxins to escape.

Chapter 1: Literature Review

Pallets

Pallets are the tool used to ship the majority of consumer goods throughout the world. Pallets came into widespread use about 50 years ago as worldwide commerce increased (45). Pallets are designed so goods may be stacked on them and can be moved by a fork lift truck from location to location within a warehouse or onto and off of transportation modes such as trucks, railroad cars or ships. A typical pallet measures approximately three feet by three feet square and weighs 55 pounds, but they are made in all sizes to accommodate different materials. Typically pallets are made of lumber, but they can also be made of corrugated paperboard, wood composites and plastic (4, 5, 16, 45). Recently, plastic pallets have gained wider acceptance because of their greater durability and for their ease of cleaning (38). A new plastic pallet costs approximately \$40 (44). A new wooden pallet costs approximately \$8-10 US (40).

Estimates suggest that at any time there are roughly two billion pallets in the world, 1.5 billion in the U.S. alone (45, 47). Each year approximately 900 million new pallets of all varieties are produced worldwide (45). The United States accounts for 400 million of the pallets produced every year (47). Hardwood lumber is a major source of pallet material. A volume equivalent to 40% of U.S. hardwood lumber production is dedicated to the manufacture of pallets each year (69). According to the National Wooden Pallet and Container Association, 160 million pallets are disposed of in U.S. landfills each year. A previous study conducted by Virginia Tech found in 1995 that almost 900 thousand tons of pallet material were deposited in landfills. A number of used pallets in the U.S., roughly 35 million per year, were shown to be converted for other low value uses such as fuel or compost (4, 16).

State of Landfills and Waste Management

Production of solid wastes is a consequence of life. Solid waste is defined as “discarded material judged to be of no value for ordinary or normal use”(38). The management of solid waste is defined by Tchobanoglous, Theisen, and Vigil (63) as

“The discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering,

conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes.”

The United States produces more solid waste than any other nation in the world. Per capita production of solid waste is approximately 2750 lbs. each year (31). Since World War II America has seen great increases in growth and prosperity, leading to increased waste production (14). Waste production per capita is steadily increasing yearly (31, 32, 33). Solid waste can be disposed of in four different manners. It can be landfilled, incinerated, composted or anerobically digested (14, 21). It is estimated that between 10-15% of solid waste is incinerated (31). Incineration is not a common disposal practice because of its excessive cost and environmental concerns(31). Anaerobic digestion and composting are used infrequently as forms of waste disposal, but are increasingly used as disposal options (33). Landfilling is by far the most common form of waste disposal and least expensive (14, 63).

At one time, incineration was commonly thought to be the great reducer of solid waste. In the 1980’s many waste to energy facilities were built to turn refuse into electricity (33). Unfortunately the expense of cleaning the gas produced by the process and sorting out materials that can not be burned outweighed the benefits of waste reduction and electricity generation (22). In the incineration process there remains approximately ten percent of the original volume in ash and this must be landfilled, leading to an extra expense (36). During the 1990’s the number of incineration facilities has steadily decreased. Due to the increasing costs and regulations, the number of incineration facilities decreased from 131 in 1997 to 119 in 1998 (31).

Typical solid waste composition includes: paper and paperboard (38.6%), yard waste (12.8%), food waste (10.1%), plastics (9.9%), metals (7.7%), glass (5.5%), wood (5.3%), and other (10.1%) (28). Waste generation and type vary across regions and time of year (63).

According to Biocycles’ (Journal of Composting & Recycling) State of Garbage article for 1999 (31), there are 2300 MSW landfills and 1860 C&D landfills in the United States. The number of C&D landfills has remained steady or slightly increased in recent years. The number of MSW landfills has been steadily decreasing while the amount of

solid waste has been increasing (31). As smaller landfills have reached their capacity and closed it has become more difficult to site landfills near towns because of citizen complaints (22). Due to the need to be farther from towns and the decreasing number of landfills, the average size of MSW landfills has increased, leading to increased hauling distances for solid waste (22). In the future, hauling of waste over great distances and across state borders will likely become a significant issue, as can be seen in Virginia today. Virginia residents are upset over New York City shipping its garbage to their state (17, 18, 35).

This study approaches the pallet issue in landfills by studying MSW and C&D facilities. Each of these two waste facilities has different attributes. MSW facilities (also known as Municipal Solid Waste or sanitary landfills) are typically large and owned by municipalities or large solid waste companies (32). They receive waste from local residents and businesses. The term sanitary landfill has three parameters: applying daily cover to prevent smells and waste being blown by wind, no burning of wastes, and methods installed to prevent pollution of surface or ground water (71).

C&D facilities are typically privately owned and smaller in size than MSW facilities. C&D facilities are designed to accept only inert waste, unlike MSW facilities which accept inert and organic wastes. Hence, C&D sites do not have to worry as greatly about pollution run-off. Inert waste at C&D facilities usually includes: cement, asphalt, metals, plastics, and wood (31, 32, 33). In the previous pallet tracking study in 1995 it was estimated that 38.6 million pallets were sent to C&D landfills, and 185 million pallets were sent to MSW landfills (4, 16).

Tipping fees are the amount charged at a landfill to dispose of waste. They are typically charged on a tonnage basis, but occasionally by the cubic yard of waste. When this study was conducted in 1995, it was found that the national average tipping fee was \$24.20 per ton for C&D and \$34.90 for MSW facilities. Tipping fees varied drastically by region, with the highest being the Northeast at \$57.80 (MSW), \$49.20 (C&D); and the Midwest being the lowest at \$29.40 (MSW), \$19.80 (C&D) (4, 16). Biocycles' State of Garbage survey of 1997 found a national average of \$31.75 for MSW landfills (33).

Waste Legislation

Waste legislation began in 1899 with the Rivers and Harbors Act, which restricted the dumping of waste in navigable waters (63). For many years, waste was simply dumped into open pits, but after WWII, as population and prosperity increased, the need for better waste management became a national issue. In 1965, the Solid Waste Disposal Act was passed. The goals of the act were to: (1). Provide assistance to local governments to improve waste handling; (2). promote national research to better handle waste; and (3). Provide guidelines for management. In 1969 the National Environmental Policy Act was passed, which required an environmental impact statement to be written on all federal construction projects. Due to this Act, all new publicly owned landfills had to write an impact statement, thus increasing costs. In 1970 the Resources Recovery Act was passed, which attempted to shift waste handling from disposal to reuse of recoverable materials, or conversion to energy (14, 27, 59, 63).

Recently, no national laws have been passed that affect solid waste management. However, state and local governments have been creating regulations. For example, in 1984 Minnesota banned tires from being deposited in landfills (32). In 1987, New Jersey banned yard trimmings from being deposited in MSW landfills (32). Currently, 45 states require some form of recycling. It is likely that legislation will continue in the future, and this will increase costs of waste disposal (32). Unfortunately, government legislation may not be the best way to deal with waste. According to Gerry Newcombe (contract administrator for San Bernardino County, CA), “Solid waste staff are often as frustrated as the decision makers in dealing with regulations that, while well-intentioned, often actually result in less efficient operation of facilities.”(1)

State of Recycling

In the U.S. recycling has steadily increased in recent years (27). Increases in recycling can be attributed to increased environmental awareness and increased legislation. Currently 45 states have set recycling goals to be met, or total bans on selected items to be landfilled (31). Biocycle’s 1998 State of Garbage Survey (31) determined that slightly above 30% of solid waste is being recovered in the United States, equating to approximately 118 million tons per year. This is up from only 8% recycling in 1990.

Materials recycling is frequently required by law. Although this sounds good in theory, it typically means that recycling will be subsidized because it is more expensive than other forms of waste disposal (37). For recycling to truly work there need to be real financial incentives for private companies to invest. Recycling is typically more expensive than disposal because separating materials for processing is labor intensive, compared to landfilling, which requires little or no material separation (27). Any individual worker can landfill more material in a day than they can recycle (37).

The value of recycled material must be greater than the costs of recycling. If the expense of using recycled materials exceeds the expense of using virgin materials, recycling should not be chosen. When recycling has financial costs exceeding benefits then it may not be an economically sound concept, although socially likeable (14 36). It has been suggested that a much larger portion of the waste stream could be recycled, but is not because there is no monetary benefit (27). Recycling has been successful, economically, with products such as aluminum cans, where the expense of using new material exceeds the expense of using recycled material to produce the same product. Recycling has not been as successful with products such as plastics, which require a great deal of cleaning and processing as compared to producing virgin material. It has been found in the past that materials collected for recycling have simply been landfilled because the expense of processing them was too great or there were not parties interested in the material (27).

For materials to be recycled there must be a processor willing to take them. In the past there have been inconsistent flows of materials, creating difficulties for processors to remain productive. This inconsistency may be due to seasonal, regional, or economic variability, but it makes for a risky investment for the processor. There must also be a market for recycled materials for recycling to be viable (60). A study at Virginia Tech investigated the feasibility of recovering pallets for repair, other solid products and ground material. It found that it could be economical for an operation to recover wood pallets given that certain parameters could be met. The study also developed a spreadsheet program that would allow perspective recyclers the opportunity to input the constraints of their business and determine if they had the potential to make money recovering wooden pallets (3).

For recycling to work well, materials must be separated at their source. This is a characteristic of pallets. Their large size lends itself to easy separation. Frequently, pallets are stacked together and are delivered to landfills together and not as a mixed waste load. Landfills typically charge a reduced tipping fee for pallets that are separated and are delivered to their processing facility (4, 16). The previous study of this type found that 32 million pallets were processed at MSW facilities and 5.9 million pallets were processed at C&D facilities. Unfortunately, 186 million pallets were also landfilled, leaving a large gap for improvement. Because of their ease of separation and recovery, pallet recycling is a simple way to reduce waste entering landfills.

Wood Recycling and Alternative Markets

Currently, organics represent approximately 30% of the solid waste stream in America. Wood residuals represent 5-7% of all solid waste, and pallets and wood packaging represent 1-3% of all solid waste (27, 29, 31, 67). These percentages are based on national data, and there is no current data on regional statistics. Many states have mandatory levels of wood and organics recycling, and this trend appears to be increasing (31). According to the Solid Waste Association of North America (59), 30 states have regulations affecting wood waste management. Twenty of those states have total bans, or are considering bans on wood of all types entering MSW landfills. It is thought, because of the enormous volumes involved, that wood and organics recycling is one of the easiest ways to cut into the volume of solid waste entering landfills (31). Although it is thought that wood and organics are one of the easiest targets for waste reduction, it is necessary to determine if recycling and recovery of these products is currently being done for profit. The EPA found in 1994 wood products accounted for 14.6 million tons of municipal solid waste. Wood packaging, consisting mainly of pallets, represented 10.2 million tons. In 1996 wood products accounted for only 10.3 million tons, or 6.8% of MSW (67). In 1994, the EPA found that 1.4 million tons of wood waste was recycled or recovered. According to their data, wood recycling has increased over one million tons since 1990. The EPA does not give any indication as to what use was made of recovered wood. They also did not indicate if the recovery was done because of mandatory legislation or because it made good economic sense.

The previous wood pallet study conducted at Virginia Tech in 1995 found that wood waste represented 7.3% of solid waste, or 21.4 million tons, at MSW landfills, an increase from the previous year according to the EPA (4, 66). Wood waste represented 37.8%, or 15.95 million tons of C&D waste according to the 1995 Tech study. The challenge to decreasing the amount of wood waste entering landfills lies in improving communication between generators and processors, and developing markets, where economic benefit exceeds the processing cost (1). One solution that has been found to increase wood waste diversion is to lower tipping fees for sorted materials (9, 61). The previous Tech study found that pallets delivered to a landfill in mixed loads were charged \$34.90 per ton, while sorted pallets delivered to a processing facility were only charged \$23.90 per ton (4, 16).

The markets for wood residuals are varied in their end use and value. Some applications require more processing than others, and some require specific wood conditions for them to be useful. Uses for recovered wood range from reuse as solid products to highly processed products such as mulch or compost. Past literature has shown that wood residuals, specifically pallets, have been used for: mulch, compost, boiler fuel, animal bedding, wood flooring, furniture products, wood pellets for stoves, composite wood products, or they can be repaired and used for shipping once again. Few of the past studies have given an indication that consistent profits are being made on recycled pallets. The real profits to the waste handlers are from saved landfill space.

Mulch and animal bedding are frequently produced products from wood residuals (30). Compost, a similar product, is also gaining acceptance as a recovered product. Composting is a capital intensive process requiring more machinery, land and labor than mulching, which only requires a small area for grinding (24, 26, 30). The positive benefits of composting are that it generates higher revenue and uses other organic material from the waste stream. Mulch or animal bedding, according to the previous Virginia Tech study, were frequently given away, but occasionally sold for an average of \$11 per ton. One New Jersey landfill has been able to receive \$15 wholesale for each cubic yard of colored mulch sold (9).

Animal bedding is a frequent use for wood residual material, but unfortunately pallet grindings don't typically suit this use because of the danger of nails to animals.

There is equipment that is designed to remove nails, but that can increase costs. Because so many landfill recovery facilities give away ground material (69% according to the previous Tech study), there is little incentive for private investment in mulch processing (29). If higher values for mulch can be found, there may be more incentive for wood recyclers to operate these systems. One landfill, which has begun composting, has realized revenues of \$18 per cubic yard of compost, on top of tipping fees they receive for waste handling. Customers for this composted material include farmers, rural residents, gardeners, and nurseries (13). A composting project implemented by the Metro Waste Authority of Des Moines, Iowa has built indoor composting greenhouses designed to handle 20,000 tons of organic waste annually. Separated organic materials delivered to this facility are only charged \$20 per ton while local landfill fees are \$30 per ton. An agreement to sell the material to local grocery and home and garden stores has been reached, but a price is not stated. Unfortunately, the cost of the site was \$1 million, and half of that amount was from a government grant (51).

According to S.P. Mathur (Research Associate, Land Resource Research Centre, Central Experimental Farm, Ontario, Canada) “Composting is the biological conversion of waste materials under controlled conditions, into a hygienic, humus-rich, relatively biostable product that conditions soils and nourishes plants” (24). Material that is suitable for composting is of plant or animal origin. To successfully compost organic material a large area is needed to place windrows. Space is also needed for machinery to turn windrows, as the material needs fresh oxygen for microbial breakdown. The expense of land and equipment are not the only issues that must be dealt with in composting. The composting process takes place at temperatures in excess of 100 Fahrenheit, and the production of gasses in the composting process is a concern (13, 24, 26, 29, 51).

The third most common use for wood residuals is fuel. According to the previous Virginia Tech study a great deal of pallet waste was used as fuel, approximately 34.5% of ground material and 6.7% in pallet form. The study did not differentiate if the material was sold or given away. Wood residuals used for fuel must be clean, untreated and ground (50). “The value of wood for fuel is mainly based on its energy content, cleanliness, particle size and transportation costs” (7). Markets may exist for wood fuel,

but their distance from the source may make transportation costs prohibitive. For wood to be sold as fuel it must also be in the dry condition, as its heating value will not be as great wet. Some experts argue that using wood for fuel is not a method of recycling, but just another form of disposal. They feel it would be better to landfill the material as a form of carbon storage (50).

A more specific form of burning wood waste is through wood pellets for home stoves. Approximately, 296,000 tons of pellet product were sold during the 91-92 winter season (56). This increased to 586,000 tons in the 95-96 winter season. The pellets provide a very high heating value, approximately 8,500 BTUs/lb. The cost of pellet fuel is approximately \$80-\$110 per ton depending on the region of the country. When compared on a BTU/dollar basis, pellets are cheaper than electricity and propane, but higher than natural gas.

There are difficulties associated with using wood residuals for pellet fuel. First, the wood must be ground to a fine material that can be densified into pellets. This fine ground material has to compete with sawdust produced from wood manufacturers that is typically cleaner. Secondly, the cleanliness of the material is very important for wood pellets. Wood pellet stoves tend to clog and require frequent cleanings if the ash content of the pellets exceeds 1-3%. Virgin wood material tends to keep the ash content low, while recycled wood that has been exposed to dirt and other foreign materials tends to have a higher ash content. Currently stoves are being designed that can handle higher ash contents. As these stoves are produced and the amount of wood used for pellets increases, wood residuals will become more attractive for pellet production (7, 56).

Recycled wood has been gaining in popularity for use in furniture. Companies have been using used railroad ties and bridge trestles to produce home furnishings of high value. A company in New York City, known as Big City Forest (now out of business), has used used pallets to produce butcher blocks, tables and furniture for environmentally-oriented stores, and hardwood flooring for affordable housing projects (8, 61). Big City Forest was contacted by other organizations throughout the U.S. which were interested in their program, suggesting that this could be a growing use for recycled pallets. Little is known about the amount of pallet material going to these products, where it comes from, or if there is a profit to be made.

Wood fiber composite products such as fiber-reinforced cements, wood plastic composites and particleboard have been gaining popularity in recent years. These products offer such advantages over solid products as increased strength to weight ratios and more efficient use of material (23, 41, 43). Some wood plastic composites have great advantages over solid plastic because they reduce production time and form at a lower temperature, reducing energy costs. As these composite products grow in popularity they will require more raw material. Wood residues have the ability to fill this need. Natural Fiber Composites (NFC) of Baraboo, Wisconsin has been making a wood fiber plastic extruded product since 1996 (41). NFC requires wood residue to be species separated. It is difficult for wood recovery operations to separate by species because they typically receive diverse loads of material, but it can provide an opportunity for wood recovery if the economic benefits are great enough to make sorting an option.

A large and growing market for discarded pallets is pallet repair and reuse (9). A spokesperson for the National Wooden Pallet and Container Association has stated that “recycling is the fastest growing segment within the pallet industry” (72). The spokesperson goes on to mention the importance of locating and determining large quantities of disposed wood pallets. Typically, a repaired pallet will sell for \$3-\$7, whereas a new wood pallet sells for approximately \$8-10 (40).

A study by VA Tech in 1993 found that 83 million pallets were received for repair and recovery (4, 16). Pallet Express Inc. of Pennsylvania repaired and sold 800,000 pallets in 1992 (19). They purchased used pallets for a dollar each. Another company, Alexander’s Pallet Inc. of New Jersey, repairs and sells in excess of one million pallets a year. They also grind another 1.5 million pallets for mulch, fuel, and animal bedding. Alexander’s Pallet Inc. found that high landfill tipping fees forced them to recover as much waste wood as possible. Alexander’s is located outside New York City in a warehouse district, so obtaining pallets is not difficult (11). Operations such as Pallet Express and Alexander’s Pallet are located in areas where pallets are readily available locally and landfill tipping fees are high. For other pallet recovery operations to be successful, it is important that they be located where discarded pallets are available. The 1995 VA Tech pallet study showed that many landfill operations were giving pallets away, which indicates the availability of material for pallet repair operations (4, 16).

Wood recycling is increasing, but better information and infrastructure is needed to handle the resource. The American Forest & Paper Association created the National Wood Recycling Directory in 1996 to match suppliers with markets. It found that pallets were the material of choice for wood recyclers (20). The directory located many wood recyclers, but did not address landfills, which the previous VA Tech study found has a great deal of wood available. A survey by Ed Brindley (editor and publisher of Pallet Profile Weekly) of pallet recyclers found that respondents were uncertain of future availability of used pallets. The respondents also were concerned about increased tipping fees at landfills (15).

Justification

The pallet industry and pallet recycling are constantly changing. Since 1995, when a similar study was last conducted, many more pallets have been placed into use. Also during this period, new uses for waste pallet material have been investigated. Users of waste wood material have stated their concerns about obtaining material in the future. This study should help estimate future demand for wood material as well as demand for landfill space.

The importance of this study is to determine the quantity of pallet material available, and where it is located regionally. A determination of the amount and location of wood material is increasingly important for wood processors. This study is designed to find new opportunities, geographic and processing, for recovery and recycling operations. It is hoped that by comparing this study to the data collected from the previous study, trends in the amount of pallet and wood material entering landfills can be identified. If this study can find trends, it can be interpreted that pallet waste is being produced or used in a different manner. It is also hoped that this study will be able to identify new markets for used pallet material, possibly at greater gains to the processor. As increased environmental activism and legislation limit the amount of waste wood that may enter landfills, it is important to determine where this material can be used.

Objectives

In this study an attempt was made to identify the volume of pallets entering landfills in the U.S.. Because landfills (MSW and C&D) have been identified as a large receiver of waste pallets (4, 16) the study concentrated on these facilities. The major objectives were as follows:

1. Estimate the volume of wood pallets reaching MSW and C&D landfills in the United States (excluding Alaska), in 1998.
2. Determine the number of landfills which operate their own pallet recovery facilities, uses for the recovered pallets and associated wood, and prices realized for recovered wood pallets and products.
3. By incorporating data from the study conducted in 1995, determine trends in the volume of pallets received at landfills and trends in recovery.
4. Identify barriers to increased recovery of pallets and to increased recovery for higher-value uses.
5. Formulate strategies for overcoming these barriers and stimulate increased recovery of pallets.

Chapter 2: Methods

Population and Sample Frame

The population for this study was all MSW and C&D landfills through out the United States, excluding Alaska. Hawaii was also excluded after no usable responses were received from landfills in that state. The sample frame for this study was all state licensed MSW and C&D landfills. The sample used for this study was a census. In other words, a questionnaire was sent to every MSW and C&D landfill that was licensed by a state. Because the response rate was not one hundred percent, the sample became smaller than a census, as discussed below.

Data Collection

Primary data collection consisted of two questionnaires that were sent to operators of both Construction and Demolition (C&D) and Municipal Solid Waste (MSW) landfills. C&D landfill operators and MSW landfill operators received slightly different questionnaires to reflect their differing situations. MSW landfills are typically much larger than C&D facilities and receive different waste compositions. The questionnaires can be found in Appendix A. The questionnaire from a previous 1995 Virginia Tech landfill study (4, 16) was used as a template for the current questionnaire. Many of the questions from the previous study were used directly so that information received in this study could be compared to the previous information received. New questions that reflect changes in landfilling practice since the last study were developed for this iteration of the research.

An address list was compiled for each state, excluding Alaska. Compilation of the address list required contacting each state's landfill permitting agency. In some cases this was the state's environmental protection agency (EPA), while in other cases it was the state's solid waste agency. Once each state had been contacted and an address list had been received, the appropriate addresses for MSW and C&D landfills were entered into a Microsoft Access database. A census of the population was conducted, consequently every address that fell into the MSW or C&D category was entered into the database. If information on a landfill was lacking on the state list, the landfill was contacted by phone in an attempt to obtain the correct information.

Once the final two surveys were completed, copies of each questionnaire were printed so that each landfill could be surveyed twice, if necessary. Besides the questions, the survey had a prepaid postage stamp and a return address printed on the outside to make it easier for landfill operators to return.

The questionnaire and a cover letter briefly explaining the nature of the questionnaire and asking for the recipients' help were mailed to all C&D and MSW facilities. Copies of the cover letters and questionnaires can be found in Appendix A. The cover letter provided a contact name, phone number and e-mail address to which questionnaire recipients could direct any questions. Each survey received an individual number stamped on the cover. An identical number was placed alongside the corresponding address the survey was sent to in an address book. When the surveys were returned their number was checked off in the book to ensure that no surveys were sent to that address in the future.

If a landfill had not returned its survey after two weeks, a reminder post card was sent. A copy of the post card can also be found in Appendix A. After two weeks if a landfill had still not returned the questionnaire, a second questionnaire and a letter asking for help were once again sent. If a landfill did not respond after three mailings it was considered a non-respondent.

It was expected that addresses received from states were not all correct, resulting in surveys being returned undeliverable. If an address correction stamp was placed on the survey envelope, the address was corrected on the master list and the survey was re-mailed. If no address correction stamp had been placed on the envelope the survey was considered undeliverable and that address was removed from the master list. After an address was removed from the master list for this purpose it was considered a non-existent landfill and the population size was decreased.

Estimated Population Size and Response Rate

The estimations for populations of MSW and C&D landfills can be found in Table 1 and Table 2. These estimations were made because the response rate was not one hundred percent. Questionnaires were returned that never reached the intended recipient. Questionnaires were also returned stating no landfill was in operation. These two factors had to be accounted for when estimating the total landfill population. The population

estimation for MSW landfills was 1669. The population estimation for C&D landfills was 1095. The regional population estimations for MSW landfills were 393, 398, 169, and 709 for the West, Midwest, Northeast, and South respectively. The regional population estimations for C&D landfills were 116, 374, 83, and 522 for the West, Midwest, Northeast, and South respectively.

A total of 619 usable surveys were received from MSW operations. After subtracting undeliverable surveys and surveys indicating that no landfill existed, the adjusted number of MSW landfills in the United States, excluding Alaska and Hawaii, was 1587. Dividing the number of usable responses by the adjusted total MSW landfills gave a response rate of 39 percent. The adjusted number of landfills per region was 373, 380, 161, and 673 for the West, Midwest, Northeast, and South respectively. The adjusted response rate by region was West (39.1%), Midwest (45.8%), Northeast (40.4%), and South (34.8%). The tabulation of response rates can be found in Table 1.

A total of 321 usable surveys were received from C&D operations. After subtracting undeliverable surveys and questionnaires indicating that no landfill was managed, the adjusted number of C&D landfills in the United States, excluding Alaska and Hawaii, was 1017. Dividing the number of usable responses by the adjusted total C&D landfills gave a response rate of 31.6 percent. The adjusted number of landfills per region was 107, 348, 77, and 487 for the West, Midwest, Northeast, and South respectively (Table 2). The adjusted response rate by region was West (37.4%), Midwest (33.6%), Northeast (40.3%), and South (27.3%).

Table 1. Population Estimation and Survey Response Rate for MSW Landfills, Nationally and by Region.

	Region				
Population Estimation	West	Midwest	Northeast	South	Total
Number of Landfills in the Population List	424	410	178	795	1807
Number of Responses that no MSW Landfill was Managed	-31	-12	-9	-86	-138
Number of Landfills to use for Population	393	398	169	709	1669
Response Rate Estimation	West	Midwest	Northeast	South	Total
Number of landfills to Which Questionnaires were Mailed	424	410	178	795	1807
Number of Questionnaires Returned Undeliverable	-20	-18	-8	-36	-82
Number of Responses that no MSW Landfill was Managed	-31	-12	-9	-86	-138
Adjusted Number of Landfills for Response Rate	373	380	161	673	1587
Number of usable surveys received	146	174	65	234	619
Adjusted response rate	39.1	45.8	40.4	34.8	39.0

Table 2. Population Estimation and Survey Response Rate for C&D Landfills, Nationally and By Region.

	Region				
Population Estimation	West	Midwest	Northeast	South	Total
Number of Landfills in the Population List	140	413	102	579	1232
Number of Responses that no C&D Landfill was Managed	-24	-39	-19	-55	-137
Number of Landfills to use for Population	116	374	83	522	1095
Response Rate Estimation	West	Midwest	Northeast	South	Total
Number of Landfills to Which Questionnaires were Mailed	140	413	102	579	1232
Number of Questionnaires Returned Undeliverable	-9	-26	-6	-37	-78
Number of Responses that no Landfill was Managed	-24	-39	-19	-55	-137
Adjusted Number of Landfills for Response Rate	107	348	77	487	1017
Number of Usable Questionnaires Received	40	117	31	133	321
Adjusted response rate	37.4	33.6	40.3	27.3	31.6

Data Analysis

Each returned questionnaire was examined for usability. Usable questionnaires, those confirming the correct type of landfill was surveyed, were entered into SPSS® statistical data analysis computer spreadsheet. The spreadsheet was designed specifically to consider the questions asked in the survey. SPSS provided summary statistics and comparison statistics for the various responses such as means and frequencies. Occasionally, when the database frequencies were rechecked for quality, it was found that questionnaire responses did not make any sense. In these cases, the questionnaire was checked to assure that data had not been entered incorrectly. If the questionnaire was the problem, the landfill was contacted to clarify the problem. If the landfill could not be contacted, the survey was discarded and the data was removed from the database.

It was necessary to sample for non-response bias in this study. This sampling was done to determine if non-responding landfills differed significantly from responding landfills. Non-response sampling was conducted by asking approximately 5-7 questions over the phone to a random selection of non-respondents. The questions used for non-response sampling can be found in Appendix B. Random non-response sampling continued until 40 usable responses were received. The results of this non-response study are provided in Table 3. It was found that non-respondents did not differ significantly from respondents based on waste per landfill or average tipping fee. The other questions asked of non-respondents were not analyzed statistically. They were used to assure that the landfill was the same type and dealt with the same waste materials. Based on the

statistical results it was assumed that there were no significant differences between respondents and non-respondents. Therefore, the sample was considered to be representative of the population of interest.

Table 3. Statistical Comparison of Respondents and Non-Respondents Based on Average Waste Per Landfill and Average Tipping Fee.

Average Waste Per Landfill	Number of Cases	Mean (tons)	Probability (p)*
Respondents	541	187,944	0.369
Non-Respondents	38	271,401	
Average Tipping Fee	Number of Cases	Mean (dollars)	Probability (p)
Respondents	533	29.31	0.921
Non-Respondents	39	29.59	

* Based on a 2-tailed t-test

Statistical methods were required to analyze and compare much of the data received in this current study to the data received in the 1995 study. Statistical analysis was not used where questions could not be compared or where the responses on the questionnaire were not numerical. Typically parametric t-tests were used to compare the two data sets. When parametric assumptions for t-tests were violated, non-parametric tests were used to compare the data sets. A typical violation of the parametric assumptions was having non-normal data. All data was checked for normality by testing for skewness and kurtosis. When non-parametric statistics was required, the Mann-Whitney U test was used to determine if two independent samples are from the same population. Parametric statistics were typically used when analyzing data for this study, but when non-parametric statistics were required, they were used for comparing all on the population parameter.

The goal of data analysis was to meet the objectives stated earlier in this thesis. The first objective was to estimate the volume of wood pallets reaching MSW and C&D landfills in the United States (excluding Alaska) in 1998. Responses to two of the questions on the survey, “How much waste was received at your landfill in 1998?” and “What percentage of waste landfilled at your facility was wood pallets?” were used to determine an average volume of pallets entering each landfill. The average volume of pallets per landfill was then extrapolated by the estimated number of landfills regionally, to give an estimate of the total volume of pallets entering landfills in each region.

Regional estimates were then summed to give an estimate of total pallet waste received. Calculations for determining estimates are shown in Appendix C.

The second objective of the study was to determine trends in pallets received at landfills and trends in recovery. Trends were identified by comparison to the results of the 1995 study (4, 16). This was done similarly to the first objective. Data from the previous study and the manner by which it was obtained were observed, and questions in this study were designed to obtain similar information. In the previous study, much of the data were divided regionally, so that approach was used in this study. Questionnaires included a question with a map of the U.S. divided into regions (Northeast, South, Midwest, and West, with an option for other) for the respondents to check off. Figure 1 is an example of the map found in the questionnaires. The other option on the map was for Hawaii. Because no responses were received from Hawaii, it was not considered in the data analysis. All questionnaires received were entered into the same database, but were later divided by region to develop regional estimates. Once the data was computed from this survey it was simple to compare averages and estimates to the related ones from the previous study.

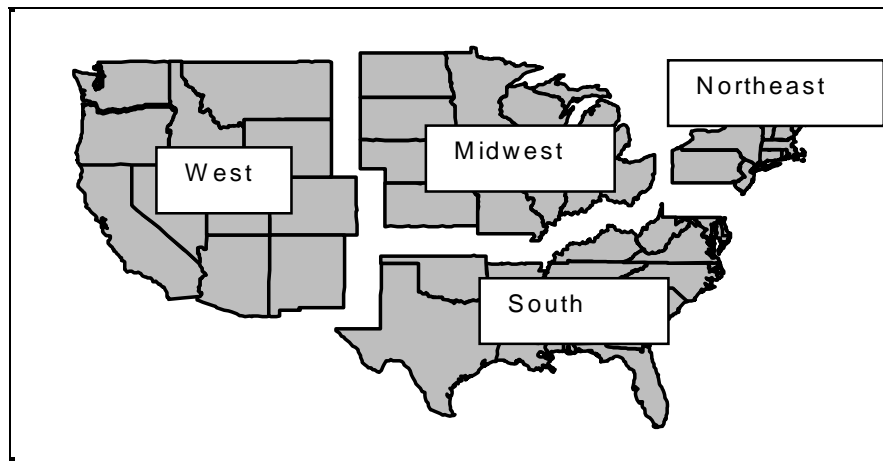


Figure 1. Regional Groupings of States.

The third objective of the study was to determine the number of landfills which operate their own pallet recovery facilities, identify uses for the recovered pallets and associated wood, and determine prices realized by landfills for wood pallets. This information was obtained in a similar manner as the first objective. A question was asked

“Do you have the ability to recover pallets, and if not do you plan on beginning within the next two years?”. The average number of landfills responding yes to this question were extrapolated by the total estimate of landfills to determine the number of facilities with the ability to recover pallets. In this case, the average was just as important as the total, because the number of landfills nationwide is decreasing (31, 32, 33).

To determine uses for the recovered pallets and the revenues realized from them, questions were asked regarding what was done with the pallet material and selling prices. The question of what was done with the material had five or six options to choose from, plus an “other” used to find additional uses for pallet material. The question of how much was earned for the material had each of the options from the previous question with a dollar sign next to it to be filled in, plus an “other” space. It was expected that landfill operators may be hesitant to provide monetary figures for this answer, in an attempt to protect their business interests, but sufficient responses were received so estimates could be made.

The final objectives were to identify barriers to increased recovery of pallets and to increased recovery for higher-value uses. Also these objectives included formulating strategies for overcoming these barriers and stimulating increased recovery of pallets. Some of this objective was covered in the literature review. With the trends determined from this and the previous study it should become clear if the barriers are becoming more or less complicated. As for stimulating increased recovery of pallets, it is hoped that this study will be published and the monetary figures that are being received for recovered material will be enough of an incentive for increased recovery.

Chapter 3: Results and Discussion for Municipal Solid Waste Landfills

Waste Received

The following section will discuss the average waste received by MSW (Municipal Solid Waste) landfills between 1995 and 1998. Estimates for the total waste received by all MSW landfills excluding Alaska and Hawaii are also discussed. Statistical comparisons were made between the mean waste received per landfill in 1995 and 1998. The probability level for a change for this test and all tests in this study was .10.

The mean volume of waste received by MSW landfills in the United States in 1998 was approximately 138,400 tons (Table 4). The approximate mean waste received in 1998 per landfill in each region was 145,400 tons in the West, 109,500 tons in the Midwest, and 182,000 tons in the Northeast, and 151,600 tons in the South.

The mean volume of waste received by MSW landfills in 1995, as reported in the previous Virginia Tech study (4), was approximately 103,300 tons (Table 4). The 1998 mean was approximately 35,000 tons higher than the 1995 mean waste received. There was a statistically significant increase in waste received per landfill nationwide and in three of the four regions of the country (Midwest, Northeast, and West) between 1995 and 1998. The regional increases in waste received per landfill were 38,000 tons in the West, 36,000 tons in the Midwest, and 84,500 tons in the Northeast. The mean waste received per landfill in the South was 151,600 tons in 1998 and this did not differ statistically from the 1995 mean.

The increase in mean waste per landfill is most likely due to the decreasing number of landfills nationwide. According to the literature (28, 31, 32), the rate of waste generation in the US has remained constant or is increasing slightly. This suggests that a decrease in the number of landfills would increase the mean waste received per landfill, as seen in Table 4.

The total waste for all MSW landfills was determined by multiplying the number of landfills in a region by the mean waste received per landfill in that region. The regional estimates were then summed to give a national estimate. The total MSW waste generated in the US in 1998 was approximately 239 million tons. The estimates for total waste generation by region in 1998 were approximately 57 million tons in the West, 44 million tons in the Midwest, 31 million tons in the Northeast, and 107 million tons in the South (Table 5).

The estimate for total nationwide waste generation in this study is slightly different from other estimates for waste generation (28, 31, 32, 52, 67). The number of landfills used for

determining total waste received in 1998 was 1669. The total number of MSW landfills used for determining total waste received in 1995 was 2829. This decrease in the number of landfills is supported in the literature (31, 32, 33). This significant decrease in number of MSW landfills between 1995 and 1998 along with the 35,000 ton per landfill increase in waste generation, lead to the difference in waste generation estimates (Table 5).

Tipping Fees

Tipping fees are the amount landfills charge to deposit waste. They are important because they can signify changes in landfilling trends. Statistical t-tests were run to determine if any changes in tipping fees occurred between 1995 and 1998.

Nationwide, tipping fees per ton of waste were estimated to be \$29.31 in 1998 (Table 6). Mean tipping fees in 1998 by region were \$22.24 in the West, \$29.70 in the Midwest, \$46.02 in the Northeast, and \$30.34 in the South. All regions except the Northeast were close to the nationally estimated tipping fee. Fewer landfills are located in the Northeast to affect the nationally estimated tipping fee and tipping fees have traditionally been higher there.

Nationally, tipping fees were estimated to be \$29.31 per ton in 1998, not a statistically significant change from 1995. The West region showed a statistically significant decreased tipping fee. The estimated tipping fee in the West decreased from \$26.40 in 1995 to \$22.24 per ton in 1998. The Midwest also showed a statistically significant decrease in average tipping fee between 1995 and 1998. The tipping fee in the Midwest was \$31.40 in 1995 and \$29.70 per ton in 1998. The decrease in tipping fees in the West and Midwest are likely due to the increase in mean waste accepted at the landfills in those regions. This increased in waste received can lead to economies of scale and decreased tipping fees.

Wood Waste Received

Wood waste received at MSW landfills was measured as a percentage of total waste received at the landfill. This section discusses the percentage of landfill waste that was wood, the corresponding tonnage of wood waste per landfill, and an estimate of the total wood waste received in each region and nationwide.

The nationwide wood waste percentage at MSW landfills for 1998 was 10.9 percent (Table 7). The 10.9 percent mean corresponds to approximately 11,820 tons of wood waste entering each MSW landfill in 1998. The percent of waste that wood represented in each of the

regions in 1998 was 12.2, 8.9, 11.5, and 11.3 percent in the West, Midwest, Northeast, and South, respectively.

The percentage of wood waste received at MSW landfills in 1998 showed a statistically significant increase from 1995 figures Nationwide and in the West and South regions. Nationwide, the mean percent wood waste increased from 7.3 percent in 1995 to 10.9 percent in 1998. The West increased from 7.3 percent wood waste per MSW landfill in 1995 to 12.2 percent in 1998. The corresponding wood waste per landfill went down in the West from 12,650 tons in 1995 to 9,500 tons in 1998. This decrease in tonnage with the increase in percentage is awkward because it suggests that wood waste would have increased as the total waste per landfill increased in the same period (Table 4). It is possible that MSW landfills responding to the percentage of wood waste received had lower total waste generation than the MSW landfills that did not respond to the wood waste percentage question. The South showed a statistically significant increase from 6.0 percent wood waste per MSW landfill in 1995 to 11.3 percent in 1998. The corresponding wood waste per landfill increased from 11,000 tons in 1995 to 14,700 tons in 1998 (Table 7).

This increased percentage that wood waste accounts for at landfills is important. It suggests two different things. First, wood waste at landfills is increasing. It can be seen that this is not the case in Table 8, which shows that every region remained constant in wood waste production except the West which decreased. This suggests that the second option is more likely. The second option is that other types of waste are playing a less significant roll in the solid waste stream. If wood is becoming a more significant portion of the solid waste stream, it will be a material that will be targeted more often for recovery and reuse, because it will be seen as reducing what is landfilled. That is an important part of this study because it can help to alert possible recyclers to a material that represents a significant portion of the waste stream that landfill operators would like to keep from placing in the landfill.

The Midwest and Northeast showed no statistical change in the percentage of wood waste received between 1995 and 1998 (Table 7). The mean percent wood waste received in the Midwest and Northeast in 1998 was 8.9 and 11.5, respectively. The tonnage of wood waste received in the Midwest and Northeast in 1998 was 7,600 and 21,650 tons, respectively.

It is estimated that the total wood waste received by all MSW landfills in 1998 was 20,840 thousand tons (Table 8). The estimates for total wood waste received by region in 1998

were: 3,734 thousand tons in the West, 3,025 thousand tons in the Midwest, 3,659 thousand tons in the Northeast, and 10,422 thousand tons in the South.

Pallet Waste Received

The main purpose of this study was determining numbers of pallets reaching landfills. This sections discussion begins with estimates of the percentages of MSW landfills that accept pallets for disposal. It continues with the percentage of waste at landfills that pallets represent. This section finishes with estimates of the total tonnage of pallets and number of pallets received by region and nationwide at MSW landfills in 1995 and 1998.

In 1998, 83.7 percent of MSW landfills nationwide accepted wood pallets to be landfilled. In the West, Midwest, Northeast, and South, 86.1, 86.8, 67.4, and 83.8 percent of landfills accepted wood pallets for landfilling, respectively (Table 9). As can be seen in the table, a higher percentage of landfills accepted wood pallets in 1998 than did in 1995. This percentage cannot be shown to be statistically different because the way the question was asked does not allow direct comparison. The question asked simply required a yes or no response and could not be compared statistically. It is likely that the decreased number of landfills from 1995 to 1998 (31, 32, 33) influenced the percentage of landfills accepting wood pallets. The landfills that closed in this three-year period were smaller, and thus were less likely to have the capability to accept or handle wood pallets. It is apparent that the landfills that closed were smaller because the average waste handled per landfill increased between 1995 and 1998 (Table 4). This is very important because it indicates that the typical landfill is changing. With the typical landfill being much larger, it can have more capabilities to sort and store waste differently, thus possibly leading to greater reduction of wastes actually entering the ground.

In 1998, pallets represented 2.8 percent of total nationwide waste or approximately 138 million pallets (Table 10). In the West in 1998, pallets represented three percent of total waste or 56.8 million tons. Pallets represented 2.2 percent of MSW waste in the Midwest or 28.9 million pallets in 1998. In the Northeast in 1998, pallets represented five percent of MSW waste or 12.4 million pallets. In the South in 1998 pallets represented 2.6 percent of MSW waste of 40.2 million pallets.

The percentage of MSW waste that pallets represented between 1995 and 1998 showed a statistically significant increase nationwide and in the West and Northeast regions (Table 10). Nationwide, pallets increased from 1.5 to 2.8 percent of MSW waste between 1995 and 1998.

During the same period the estimate of total pallets received decreased from 153 million to 138 million. In the West, pallets increased from .8 to three percent of MSW waste between 1995 and 1998. In the Northeast, pallets increased from .8 to five percent of MSW waste between 1995 and 1998. The Midwest and South regions showed no change in pallets as a percentage of total MSW waste received from 1995 to 1998.

Although pallets as a percent of total waste at MSW landfills increased, the number of MSW landfills and total waste received at MSW landfills also decreased. This resulted in a decrease in the number of pallets received at MSW landfills. It is likely that the decrease in the number of pallets reaching MSW landfills is due to increased retrieval by pallet recyclers and community mandates for waste reduction (1, 14, 27, 32, 59, 63). This decrease in total pallets landfilled is a significant finding. Because it has been seen that pallet production and the requirements for pallets have decreased in no way, it suggests that more pallets are being captured before they reach the landfill. It is likely that pallet recyclers could be the parties capturing these pallets. The previous VA Tech pallet landfill study published results in pallet trade magazines. It is possible that that information reached the correct parties and they are the ones reducing the amount of pallets sent to landfills. If this is true it is very important because communication between the landfillers and recyclers appears to be one of the barriers to increased recovery of wood pallets. It is possible that the communication gap is decreasing.

Wood Waste Recovery

In this section, the percentage of MSW landfills that had the ability to recover wood waste in 1998 will be discussed. This section also contains an estimate of the volume of wood waste recovered per recovery facility and the total wood waste recovered by all recovery facilities, regionally and nationwide.

In 1998, over 33 percent of landfills nationwide had the ability to recover wood (Table 11). The Northeast had the highest percentage of landfills that could recover wood in 1998, over 45 percent. It is logical for the Northeast to have a greater percentage of landfills that can recover wood because landfill space in this region is at a premium and tipping fees are high. The other three regions were right at the national average for percent of landfills with the ability to recover wood. In the West, over 30 percent of landfills were capable of recovering wood in 1998. In the Midwest, 32 percent of landfills were capable of recovering wood in 1998. In the South, almost 34 percent of landfills had the ability to recover wood in 1998.

In 1998, a mean of 15,500 tons of wood waste was received per MSW recovery facility nationwide (Table 12). The West had the highest wood waste recovery with a mean of 35,000 tons recovered per recovery facility. The Midwest and South regions received a mean of 5,750 and 14,700 tons of wood waste per MSW recovery facility, respectively. The Northeast recovered a mean of 6,570 tons of wood waste per recovery facility in 1998.

Wood recovery at MSW recovery facilities changed little between 1995 and 1998. Only the Northeast region showed a statistically significant increase in the volume of wood waste recovered per recovery facility. The Northeast recovered 6,570 tons of wood waste per recovery facility in 1998, up from 5,330 tons in 1995.

Figure 2 shows the total wood waste received at MSW recovery facilities broken down by percentage for each region. The estimated total wood waste received for recovery in 1998 was 8,930 thousand tons. In 1998, the South and the West recovered the majority of wood waste. The South recovered 38 percent or approximately 3.5 million tons of wood waste in 1998. The West recovered 48 percent or approximately four million tons of wood waste in 1998. The Northeast and Midwest accounted for a small portion of the wood waste received at MSW recovery facilities in 1998. The Northeast recovered five percent or approximately 500 thousand tons of wood waste in 1998. The Midwest recovered nine percent or approximately 700 thousand tons of wood waste in 1998 (Table 13).

It is not surprising that the Northeast recovers such a small percentage of wood waste, as less waste is received in the Northeast. According to the literature (17, 18), a great deal of waste generated in the Northeast is landfilled elsewhere. What is surprising is that the Midwest recovers so little wood waste. The Midwest has almost exactly the same number of MSW landfills as the West (Table 1), but wood waste recovery is five times greater in the West. The West does receive more wood waste per MSW landfill than does the Midwest (Table 7). This does not completely account for the significant difference in wood waste recovered. It is possible that the Midwest does not recover as much wood because of lack of equipment or labor to sort the wood, or lack of monetary incentive.

The South has almost twice as many MSW landfills as the West (Table 2), but recovers less wood waste. This is also most likely due to a lack of labor or equipment to sort the wood waste. It is also possible that landfills in the South simply do not have an outlet or know of an option for recovered wood material. One of the goals of this study is to find these options. It is

likely with the population in the South and the large forest products industry that markets can be found for recovered wood material. It is simply a matter of educating the landfill operators on these options. Options for wood recovery are discussed later in this paper. The West is by far the leader in wood waste recovery. Approximately the same percentage of landfills can recover wood waste in each region (Table 11), further suggesting that the West is much better at recovering wood waste than any other region, possibly due to legislation requiring wood to be kept from landfills as seen in Oregon (32). The high wood recovery in the West certainly is not a result of lack of landfill space.

Tipping Fees at Recovery Facilities

As discussed earlier, tipping fees can be a signal to changes in landfilling of wastes. This section discusses tipping fees charged for sorted loads of waste at MSW recovery facilities. Tipping fees at the recovery facilities were compared to tipping fees from 1995 and to standard tipping fees in 1998.

Nationwide, tipping fees per ton for sorted loads of waste at MSW recovery facilities showed no statistical change between 1995 and 1998. The national mean tipping fee for sorted waste at MSW recovery facilities in 1998 was \$23.55. The individual regions also showed no statistically significant change in tipping fees for sorted loads at recovery facilities between 1995 and 1998. The tipping fees in 1998 for the West, Midwest, Northeast, and South were \$21.73, \$22.19, \$32.43, and \$23.53 respectively (Table 14).

Nationwide, tipping fees for sorted loads were statistically lower than that charged for mixed loads at MSW landfills in 1998 (Table 15). The tipping fees for sorted waste at recovery facilities in 1998 were almost six dollars less per ton than tipping fees for mixed loads, nationally. In the West, tipping fees per ton for sorted loads and mixed loads did not show a statistical difference between 1995 and 1998. The remaining three regions showed a statistically significant difference in tipping fees for sorted and mixed loads of waste. In the Midwest, the tipping fees for sorted material were seven and a half dollars less per ton than for mixed loads of waste in 1998. In the Northeast, tipping fees for sorted materials at recovery facilities were over thirteen dollars less per ton than that charged at the landfill in 1998. In the South, tipping fees for sorted loads at recovery facilities were almost seven dollars less per ton than for mixed loads at landfills.

It is apparent that a majority of MSW landfills with a recovery facility are charging less per ton for sorted loads of waste received at the recovery facility than for mixed loads of waste. This decreased tipping fee per ton for sorted loads could lead to more wood and pallet recovery at MSW facilities. It is definitely an incentive for large waste generators to sort wood material.

Pallet Recovery

The following section is one of the most important of this paper. It will cover pallet recovery changes between 1995 and 1998. Pallet recovery topics consist of the percent of MSW landfills that plan to begin recovering wood pallets within the next two years, the mean tonnage of pallet waste recovered per recovery facility, the percentage of wood waste recovery that pallets represented, and an estimate of the total number of pallets recovered between 1995 and 1998. This section also examines the percentage of recovery facilities reporting a change in the number of pallets recovered and the percent change. Finally, this section discusses how recovered pallets were used and what any sales of recovered pallets generated.

In 1998, 11.8 percent of MSW landfills nationwide that did not recover wood pallets planned to add this capability within two years (Table 16). Regionally, 13.3, 8.9, 13, and 12.5 percent respectively, of landfills in the West, Midwest, Northeast, and South that did not recover pallets in 1998 planned to do so within two years.

In 1998, a mean of 1158 tons of pallets were recovered per MSW recovery facility nationwide (Table 17). The mean tonnage of pallet waste recovered per MSW facility in the West, Midwest, Northeast, and South was 663, 1,535, 1,354, and 949 tons, respectively in 1998. Statistically, none of the regions showed a change in the mean tonnage of pallets recovered between 1995 and 1998.

The number of landfills nationwide dropped from 1995 to 1998 (31, 32, 33). The percentage of landfills that can recover wood pallets did not change from 1995 to 1998. This means that the number of landfills that can recover wood pallets decreased from 1995 to 1998. The mean tonnage of pallets recovered per MSW facility did not change from 1995 to 1998. This suggests that the total number of pallets recovered decreased from 1995 to 1998, as will be seen later in Table 19.

The percent of total wood waste recovered at MSW facilities that pallets represented showed a statistically significant increase from 1995 to 1998 (Table 18). In 1995, pallets represented 9.5 percent of wood waste recovered at MSW facilities. In 1998, pallets represented

23.5 percent of wood waste recovered at MSW facilities. The percent of total wood waste recovered at MSW facilities that pallets represented statistically increased in all regions except the Northeast from 1995 to 1998. Pallets represented 39 percent of wood waste recovered at MSW facilities in the Northeast in 1998. In the West, pallets increased from 6.5 in 1995 to 10.3 percent of wood waste recovered at MSW facilities in 1998. In the Midwest, pallets increased from 14.3 in 1995 to 39.4 percent of wood waste recovered at MSW facilities in 1998. In the South, pallets increased from 9.2 in 1995 to 15.3 percent of wood waste recovered in 1998.

Pallets increasing as a percentage of total wood waste recovered could be due to several factors. First, as discussed in the literature review (31, 32, 37, 59), many community programs have been initiated to decrease the amount of leaves and brush that residents send to landfills. These programs could be having an effect, and could increase pallets as a percentage of wood waste recovered. Second, landfills charge less for sorted loads of wood (Table 15). Possibly, more sorted loads of pallets are entering recovery facilities, and they are simply easier to recover than loose brush. The third option is that landfill operators have realized that pallets are relatively easy to sort from other materials and they have profitable markets for resale. This is a strong incentive, because landfills are in business to make money just like any other type of business. Plus precious landfill space is being saved by excluding pallets.

The estimated number of wood pallets recovered nationwide in 1998 was 22 million. This is a decrease from the estimate of 32 million pallets recovered in 1995 (Table 19). As seen earlier in Table 10, the estimated number of pallets received at landfills decreased from 1995 to 1998. Since it is thought that the number of recovery facilities has decreased and the tonnage of pallets recovered per facility has not changed (Table 17) it is logical that the estimated total amount of pallets recovered in 1998 was less than that estimated for 1995. It is estimated that approximately 2.9, 7.1, 3.8, and 8.2 million pallets were recovered from MSW facilities in 1998 in the West, Midwest, Northeast, and South regions respectively (Table 19).

The percentage of pallets received versus the percentage recovered at MSW landfills dropped slightly. This is likely due to the decrease in the number of landfills that have the ability to recover wood pallets. In 1995, 21 percent of pallets reaching MSW landfills were recovered. In 1998, 16 percent of pallets reaching MSW landfills nationwide were recovered. In 1998, the West, Midwest, Northeast, and South recovered 5, 25, 30, and 20 percent of the pallets received in their respective regions.

Of the MSW facilities reporting on pallet recovery, 27 percent reported an increase in the number of pallets recovered in the past two years (Table 20). Nine percent reported a decrease in the number of pallets recovered in the past two years. Fifty-nine percent reported no change in the amount of pallets recovered in the past two years. Four percent reported they had been recovering pallets for less than two years. Of the MSW facilities reporting an increase in the number of pallets recovered, the mean increase was 21 percent. Of the facilities reporting a decrease in the number of pallets recovered, the mean decrease was 30 percent (Table 20).

Most of the wood pallets recovered in 1995 and 1998 were ground and sold or given away (Table 21). In 1998, approximately 25 percent of pallets were used in solid form. Solid form categories in Table 21 were Re-used as Pallets, Fuel as-is, and Repaired at facility for reuse. This is an increase from only ten percent of pallets being used in solid form in 1995. In Table 21, it is assumed that Other is a ground form. This is assumed because the majority of Other responses on surveys were accompanied with explanations that pallets were ground for other uses. Many of these other uses were for a type of fuel or mulch that the respondent did not feel fit into any other category. This can explain some of the increase in the Other category, and the decrease in the Ground for fuel and mulch categories. The other responses for other uses for recovered pallets were; burned, diverted to other facilities, and used again for shipping other recycled products from the landfill. The other explanation for the drop in the ground categories is an increase in pallets used in solid form. This is encouraging because a solid wood use can bring more value to the discarded pallet. Only .35 percent of pallets were repaired at the MSW facilities. This is likely due to the expense of labor and equipment needed to repair pallets.

Table 22 shows average monetary return for pallets sold. This table was not separated into regions because of low responses about monetary value. Obviously, ground pallets used for mulch or animal bedding received the most at \$20.44 per ton. This was also the category that got the most responses with 24. Pallets sold as-is for reuse by the ton received the second highest amount at \$15.60. Pallets sold ground for fuel and other uses received approximately twelve dollars.

Individual pallets sold for reuse received \$1.51 on average. If one assumes a 55 lb. average pallet, this results in almost \$55 per ton of pallets. This appears to be the most profitable use for the recovered pallets. If landfill operators can find a pallet recycler that pays this amount, it would likely be in their best interest to sort out the best pallets for this use.

It is easy to see that pallet material in a number of forms is generating income for landfill operators. This is a very positive result for this study. It can indicate to the other 60 to 70 percent of landfills that do not operate a recovery facility, that it may be profitable for them to do so.

Other uses for recovered pallet material that landfill operators stated were done broke down into four categories. First, recovered pallets could be sent to other landfills. Respondents gave no indication to the fate of the pallet material at that point. Second, recovered pallets were burned. This was typically done for various reasons such as heat at the landfill facility, ashes for daily cover, or just to reduce volume in the landfill. Third, recovered pallets were used by the landfill for shipping. A few facilities said they were associated with material recovery facilities and used the pallets to ship plastic bottles or newspapers for recycling. Finally, recovered pallets were given away to local farmers, landfill employees and businesses for undisclosed uses.

Conclusions and Implications

The mean waste generated per MSW landfill in 1998 was 138,000 tons, up 35,000 tons from 1995. All regions except the South showed an increase in mean waste per landfill from 1995 to 1998. Waste received per landfill in the West, Midwest and Northeast were 145,400, 109,500, and 182,000 respectively. There was no change in the South where 151,600 tons of waste was received per landfill. It is likely that the increase in waste per landfill was due to the decrease in number of active landfills during the same period. The estimate for total waste generated at all MSW landfills in 1998 was 239 million tons. This is reduced from the 1995 estimate of 293 million tons, but similar to the 1998 EPA estimate of 220 million tons (66). Although the list of state licensed landfills was generated in the same manner in 1995 and 1998, it is possible that the estimate of landfills could have been too high in 1995 or too low in 1998, causing the estimate for total MSW waste generation to be off. Both estimates of numbers of MSW landfills were close to EPA estimates for the same periods. It is possible that the decrease in MSW waste generation could be due to diversion to other types of landfills or recovery of waste. If the amount of waste has decreased at landfills, this is a very positive result. It suggests that waste diversion strategies in communities and businesses have begun to take effect. It also suggests that state legislation may be having an impact on the amount of waste reaching landfills. Regionally total waste generation estimates were 57, 44, 31, and 107 million tons in the West, Midwest, Northeast and South, respectively.

Nationwide, tipping fees did not change from 1995 to 1998. In 1998, the mean MSW tipping fee was \$29.31. Tipping fees did decrease in the West and Midwest regions. In 1998 the tipping fees in the West and Midwest were \$22.24 and \$29.70. The Northeast and South showed no change in tipping fees from 1995 to 1998. Tipping fees in the Northeast and South were \$46.02 and \$30.34 in 1998. Because the MSW landfills in the West and Midwest were accepting more waste per year than they previously did, lower tipping fees could be charged because of economies of scale. Although waste per landfill increased dramatically in the Northeast, tipping fees did not decrease. This could be a result of the high cost of land there. In the South, tipping fees and waste per landfill did not change. The decrease in tipping fees in the West and Midwest could create barriers to increased recovery of waste in those regions. If waste generators are charged less per ton to deposit waste in a landfill, it may not be worthwhile for them to sort waste to send to recovery facilities.

Nationwide, wood waste as a percent of total MSW waste received increased from 1995 (7.3%) to 1998 (10.9%). Regionally, wood waste as a percent of total waste received increased in the South (11.3%) and West (12.2%) and did not change in the Midwest (8.9%) and Northeast (11.5%). It is likely, as seen earlier, that other waste types entering landfills have decreased causing wood to represent a higher proportion of the waste stream, even though volumes may remain steady. This is a possibility that this study did not cover, but is important because if wood represents a larger portion of the waste stream it could become a more obvious target for increased recovery.

In 1998, 84 percent of MSW landfills accepted pallets to be landfilled. It is estimated that 2.8 percent, an increase from 1995, of nationwide MSW waste was pallets, corresponding to 138 million pallets reaching landfills in 1998. This is down from the estimate of 153 million pallets reaching landfills in 1995. This is important because it suggests that more used pallets are being captured before they enter landfills. Hopefully this is due to increased awareness created by the results of the previous VA Tech study. Regionally in 1998, the estimated number of pallets received at MSW landfills was 56.8, 28.9, 12.4, and 40.1 million in the West, Midwest, Northeast, and South, respectively. In 1995, pallets only represented 1.5 percent of waste nationwide, but because there was a great deal more landfills and total waste generation in 1995, the estimate of pallets received was higher. The increase in pallets as a percent of total waste could be the force driving the increase in wood percent at MSW landfills. It could also be that

the questionnaire respondents were making estimations of what they received and could have erred. It would be helpful the next time this study is conducted to ask landfill operators if they have seen a decrease or increase in the amount of pallets reaching the landfill rather than just a percentage of their waste that pallets represent.

Nationwide, 33 percent of MSW landfills had the ability to recover wood in 1998. Ten percent of MSW landfills that could not recover wood, planned to within two years. Tonnage of wood waste recovered per MSW recovery facility nationwide did not change from 1995 to 1998. Wood waste recovery per recovery facility did increase in the Northeast region between 1995 and 1998. It is estimated that 15,500 tons of wood waste was recovered per MSW recovery facility nationwide, or nine million tons in total. Total wood waste recovered by region in 1998 was as follows; 4,205 thousand tons in the West, 721 thousand tons in the Midwest, 506 thousand tons in the Northeast, and 3,500 thousand tons in the South. Wood waste increased as a percent of total waste from 1995 to 1998, but wood waste recovery per facility did not change during the same time period. This suggests a few different alternatives. First, that there may be a limit to what facilities can recover due to machinery, space constraints or labor barriers. Second, there is no use for the recovered material. This is not likely because many uses were identified in this study, as well as many landfills stating they can market all they can recover. Or third, that landfill space is cheap and it is not cost effective to recover more material.

If there is a finite amount of waste that can be recovered per recovery facility, one of the barriers to increased recovery of wood is that only 33 percent of landfills have recovery facilities. It appears that to increase recovery more landfills must start recovery facilities. One of the best ways to accomplish this is to prove to landfill operators that money can be made from recovering wood material. An important factor to doing this is to link users of recovered material to the landfills. This could be done through publication of this material in trade journals to point out the opportunities to recyclers.

Regionally, the South and West recovered more than 85 percent of all wood waste. It is not surprising that the South recovered so much. The sheer volume of landfills and waste received in the South suggests that it would recover a great deal even if it only recovered a small percentage of what it received. What is surprising is the West recovered so much. This suggests that landfills in the West are very good at wood recovery. The reason for this high recovery could be due to state mandates not allowing some wastes into landfills. What is also surprising is

that the Midwest recovers so little wood waste. The Midwest has almost the same number of landfills as the West, yet it recovers only a small fraction of what the West does. It could be that the labor and machinery required to recover wood in the Midwest, just is not available or affordable. It is also possible that markets for recovered material have not been developed in the Midwest. It is a hope of this study that it can alert users of recovered wood material to the potential resource opportunity at landfills.

Tipping fees for pallets and sorted loads of waste at MSW recovery facilities did not change from 1995 to 1998. In 1998, the mean tipping fee nationwide per ton for a sorted load of waste at an MSW recovery was \$23.55. This was significantly less than the tipping fees charged for mixed loads at the same MSW facilities. This suggests that MSW landfills are encouraging waste generators, through monetary incentives, to sort waste before it is brought to the landfill. At almost six dollars less per ton for sorted material versus mixed material, it could be quite an incentive for large waste producers to sort waste. Regional tipping fees for sorted loads of waste were \$21.72 in the West, \$22.19 in the Midwest, \$32.43 in the Northeast, and \$23.53 in the South. All regions except the West charged less for sorted loads than for mixed loads. This decreased tipping fee for sorted loads of wood material could be one of the best ways for overcoming barriers to waste recovery. It is likely if more markets for recovered material can be found, that fees for sorted loads can be further reduced, thus greatly increasing recovery. It would be a good study to determine the price sensitivity of waste producers to decreased tipping fees for sorted waste. There certainly have to be cut off points where they will invest the time and effort to sort loads to save money.

On average every MSW facility that recovered pallets recovered 1158 tons or 42,000 pallets in 1998. This represented no change from what was recovered per landfill in 1995. What did change was the percentage of wood waste recovered that pallets represented. In 1995, pallets represented only ten percent of wood waste recovered. In 1998 pallets represented 24 percent of wood waste recovered. This suggests that other wood materials were recovered less frequently in 1998, and pallets were a more important material to be recovered. The pallets could be recovered more frequently than other wood because they have more value than other materials. It is outside the realm of this study to suggest what type of other wood or why it was recovered less. In 1998, it was estimated that 22 million pallets were recovered from MSW landfills. This is down from the estimate of 32 million recovered in 1995, but the total number of pallets

reaching MSW landfills also decreased during the same period. Also, during the same period the number of landfills recovering pallets went down. This could be a good reason for the estimated number of recovered pallets decreasing. It could also be a good reason to promote to encourage more landfills to operate recovery facilities.

Of the landfills reporting that had a wood recovery facility, 27 percent said the number of pallets recovered increased in the past two years. The average increase was 21 percent. Nine percent of landfills said the number of pallets recovered decreased in the past two years, by approximately 30 percent. Overwhelmingly, 60 percent of recovering landfills said the number of pallets recovered in the past two years had not changed.

Pallets that were recovered in 1998 were used for various purposes. Eight percent of recovered pallets were reused as pallets. Eleven percent of recovered pallets were used for fuel as-is. Less than one percent of recovered pallets were repaired at the landfill and sold. Seventeen percent of recovered pallets were ground and used as landfill cover. Fourteen percent of recovered pallets were ground and sold for fuel. Twenty-four percent of recovered pallets were ground for mulch and animal bedding. The remaining 20 percent of recovered pallets were ground for other uses. Obviously, the most frequent use for recovered pallets was in ground form. On average, pallets resold as-is from landfills received \$1.51 each or \$15.60 per ton. It is assumed that pallets receiving \$1.51 individually were in good condition and had to be sorted from many other poorer pallets. If pallet recyclers are ever in need of pallets for their business, landfills seem to be a prime place to look. The cost is relatively low, and there is an abundance of pallets reaching landfills. It appears that some communication between pallet recyclers and landfills would benefit both parties. Pallets sold ground for fuel received \$11.42 per ton. Pallets sold ground for mulch, compost and animal bedding received \$20.44 per ton. This was by far the most frequently used form of recovered pallets, as well as the most frequent that received a monetary return from the recovered pallets.

It is apparent that pallet material is creating income for landfills. Because the monetary return question of the questionnaire was the least answered question of the questionnaire while questions of amount recovered were answered frequently, it is assumed that other landfills were receiving money for recovered pallet material. The question was likely not answered as frequently because of confidentiality issues or fear of losing proprietary information. It is likely that a good number of landfills are earning returns on recovered pallet material. If this is true, it

could be very good encouragement for the 60-70 percent of MSW landfills that do not currently operate a recovery facility to start one. This could have a significant impact on the pallet industry if a greater number of landfills begin recovering pallets. In turn that would have a great influence on the amount of virgin wood material required to produce pallets.

Table 4. Mean Tons of Waste (all types) Received per US MSW Landfill in 1995 and 1998. Parametric Statistical Test for Comparison of Means.

Region	Mean Waste Received Per Landfill		Probability ¹ (p)
	1995 (Tons)	1998 (Tons)	
All Regions	103,300	138,400	0.017
West	107,100	145,400	0.040
Midwest	73,200	109,500	0.022
Northeast	97,500	182,000	0.027
South	119,000	151,600	0.159

1. Based on levene's t-test for comparison of means. The value shown is the probability of computing a different 1998 value given the distribution of 1995 data. All probabilities are based on a 90% confidence interval.

Table 5. Estimated Total Waste (all types) Received By US MSW Landfills in 1995 and 1998.

Region	Total Waste Received in 1995 (Thousand Tons)	Total Waste Received in 1998 (Thousand Tons)
All Regions	293,010	238,960
West	91,420	57,150
Midwest	39,260	43,600
Northeast	35,750	30,720
South	126,580	107,490

Table 6. Tipping Fees of US MSW Landfills in 1995 and 1998. Parametric Statistical Test for Comparison of Means.

Region	Mean Tipping Fee in 1995 (\$ Per Ton)	Mean Tipping Fee in 1998 (\$ Per Ton)	Probability ¹ (p)
All Regions	32.22	29.31	0.481
West	26.40	22.24	0.098
Midwest	31.40	29.70	0.034
Northeast	53.30	46.02	0.570
South	29.30	30.34	0.704

1. Based on levene's t-test for comparison of means.

Table 7. Percentage of Total Waste Received at MSW Landfills That Was Wood and the Corresponding Estimated Mean Tonnage of Wood Waste Received Per Landfill in 1995 and 1998. Parametric Statistical Test for Comparison of Mean Percentages.

Region	1995		1998		Probability ¹ (p)
	Mean Percentage Wood	Estimated Tons of Wood Waste	Mean Percentage Wood	Estimated Tons of Wood Waste	
All Regions	7.3	9,980	10.9	11,820	0.025
West	7.3	12,648	12.2	9,500	0.056
Midwest	8.0	5,939	8.9	7,600	0.280
Northeast	6.6	7,110	11.5	21,650	0.189
South	6.0	11,127	11.3	14,700	0.018

1. Based on levene's t-test for comparison of means.

Table 8. Estimated Total Wood Waste Received at MSW Landfills in 1995 and 1998.

Region	Wood Waste Received in 1995 (Thousand Tons)	Wood Waste Received in 1998 (Thousand Tons)
All Regions	28,220	20,840
West	10,179	3,734
Midwest	3,154	3,025
Northeast	3,107	3,659
South	11,780	10,422

Table 9. Estimated Percentage of MSW Landfills That Accepted Wood Pallets for Disposal in 1995 and 1998.

Region	1995 Percent Accepting	1998 Percent Accepting
All Regions	67.9	83.7
West	77.3	86.1
Midwest	71.0	86.8
Northeast	55.9	67.4
South	63.6	83.8

Table 10. Mean Percentage of Total MSW Waste that Pallets Represented in 1995 and 1998. The Estimated Total Tonnage of Pallets Received at MSW Landfills and the Corresponding Number of Pallets Based on 55 lb. Per Pallet. Parametric Statistical Test for Comparison of Mean Percentages.

Region	1995			1998			Probability ¹ (p)
	Mean Percent	Estimated Tonnage of Pallets	Estimated Number of Pallets	Mean Percent	Estimated Tonnage of Pallets	Estimated Number of Pallets	
All Regions	1.5	4,126,000	152,745,000	2.8	3,805,000	138,360,000	0.004
West	0.8	701,000	25,480,000	3.0	1,562,000	56,800,000	0.091
Midwest	1.8	696,000	26,490,000	2.2	795,000	28,910,000	0.943
Northeast	0.8	337,000	10,560,000	5.0	342,000	12,440,000	0.005
South	1.9	2,391,000	90,215,000	2.6	1,105,000	40,180,000	0.425

1. Based on Levene's t-test for comparison of mean percentages.

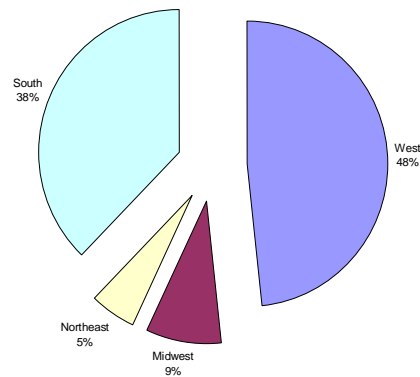
Table 11. Estimated Percentage of MSW Landfills That Had the Ability to Recover Wood in 1995 and 1998.

Region	1995 Percentage	1998 Percentage
All Regions	37.9	33.4
West	27.0	30.6
Midwest	30.8	32.2
Northeast	38.2	45.5
South	49.0	33.6

Table 12. Comparison of Mean Wood Waste Received Per MSW Recovery Facility in 1995 and 1998. Non-Parametric Statistical Tests Used for Comparison.

Region	1995 (Tons)	1998 (Tons)	Probability ¹ (p)
All Regions	12,866	15,498	0.936
West	21,536	35,037	0.362
Midwest	3,418	5,748	0.596
Northeast	5,329	6,568	0.091
South	14,978	14,659	0.150

1. The non-parametric Mann-Whitney U test was used to evaluate the hypothesis that the distribution of data for 1998 was no different than that of 1995. The probability is the chance of getting the 1998 results given the same distribution as 1995.

**Figure 2. Regional Percentage of MSW Wood Waste Recovery in 1998****Table 13. Estimates of Total Wood Waste Recovered at MSW Recovery Facilities in 1995 and 1998.**

Region	1995		1998	
	(Thousand Tons)	Percentage of Total	(Thousand Tons)	Percentage of Total
All Regions	10,320	100	8,932	100
West	2,386	23.12	4,205	47.08
Midwest	449	4.35	721	8.07
Northeast	730	7.07	506	5.67
South	6,755	65.46	3,500	39.18

Table 14. Mean Tipping Fees for Sorted Waste Received at MSW Wood Recovery Facilities in 1995 and 1998. Statistical Tests for Comparison of Tipping Fees.

Region	1995 (\$ Per Ton)	1998 (\$ Per Ton)	Non-Parametric Probability (p) ¹
All Regions	22.40	23.55	0.690
West	18.89	21.73	0.682
Midwest	17.95	22.19	0.273
Northeast	31.16	32.43	0.607
South	22.88	23.53	0.806

1. The non-parametric Mann-Whitney U test was used to test the hypothesis of no difference between distributions.

Table 15. Comparison of Mean Tipping Fees For Standard Waste Loads at MSW Landfills and Sorted Loads at MSW Wood Recovery Facilities in 1998. Non-parametric Statistical Test for Comparisons of Tipping Fees.

Region	Standard Tipping Fee (\$ Per Ton)	Tipping Fee at Recovery (\$ Per Ton)	Probability (p) ¹
All Regions	29.33	23.44	0.000
West	22.24	21.72	0.767
Midwest	29.70	22.19	0.000
Northeast	46.02	32.43	0.043
South	30.34	23.53	0.001

1. The non-parametric Mann Whitney test was used to test the hypothesis of no difference between distributions.

Table 16. Estimated Percentage of MSW Landfills That Did Not Recover Wood Pallets in 1995 and 1998, But Planned to Within Two Years.

Region	1995 Percentage	1998 Percentage
All Regions	10.00	11.8
West	11.75	13.3
Midwest	12.26	8.9
Northeast	7.24	13.0
South	7.00	12.5

Table 17. Estimated Mean Tons of Pallets Recovered per MSW Recovery Facility in 1998. Non-Parametric Statistical Tests for Comparison of Pallet Waste Received in 1995 and 1998.

Region	1995 Mean Recovery (Tons)	1998 Mean Recovery (Tons)	Non-Parametric Probability (p) ¹
All Regions	1269	1158	0.459
West	1322	663	0.158
Midwest	810	1535	0.477
Northeast	961	1354	0.613
South	1357	949	0.420

1. The non-parametric Mann-Whitney U test was used to test the hypothesis of no difference between distributions.

Table 18. Recovered Pallets as a Percentage of Total Wood Waste Recovered at MSW Recovery Facilities in 1995 and 1998. Parametric and Non-Parametric Statistical Tests for Comparison 1995 and 1998 Estimates.

Region	1995 Mean Percentage	1998 Mean Percentage	Non-Parametric Probability (p) ¹
All Regions	9.58	23.65	0.005
West	6.55	10.28	0.002
Midwest	14.3	39.43	0.000
Northeast	20.37	39.05	0.114
South	9.17	15.3	0.000

1. The non-parametric Mann-Whitney U test was used to test the hypothesis of no difference between distributions.

Table 19. Estimates of Total Tonnage of Pallets and Number of Pallets Recovered at MSW Recovery Facilities in 1995 and 1998.

Region	1995 Recovery		1998 Recovery	
	(Thousand Tons)	Pallets	(Thousand Tons)	Pallets
All Regions	990	32,030,000	607	22,052,000
West	156	5,670,000	80	2,894,000
Midwest	64	2,460,000	197	7,146,000
Northeast	148	4,500,000	104	3,794,000
South	620	19,400,000	226	8,218,000

Table 20. Percentage of Responding MSW Recovery Facilities Reporting a Change in the Volume of Wood Pallets Recovered in the Period Between 1996 and 1998. Estimate of How Much Recovered Pallets Have Increased or Decreased at MSW Recovery Facilities in the Same Period.

Response Category	Percentage Reporting by Category	Mean Percent Change
Increased	27.2	20.82
Decreased	9.2	30.43
No Change	59.2	
Not In Operation Over Two Years	3.8	

Table 21. Percentage Breakdown of How Recovered MSW Pallets Were Used in 1995 and 1998. 1998 Figures are Shown Regionally and Nationally. 1995 Figures are only Shown Nationally.

Use	Percent of Total Pallet Recovery					
	1995	1998				
	Nation	Nation	West	Midwest	Northeast	South
Re-used as pallets	3.17	9.93	7.86	17.46	3.84	6.76
Fuel as-is	6.80	4.07	8.06	3.09	11.56	0.59
Repaired at facility for reuse	0.00	0.35	0.00	1.22	0.00	0.00
Landfill cover	7.90	16.23	16.92	7.98	26.80	20.54
Ground for fuel	34.70	10.92	18.90	3.45	0.05	12.44
Ground for mulch	37.90	43.59	31.57	50.31	32.95	50.00
Other	9.53	14.91	16.69	16.49	24.80	9.67

Table 22. Nationwide Mean Values Received For Recovered MSW Pallets in 1998. Numbers of Responses Received for Each Pallet Use.

	Mean Selling Price	# Of Responses
\$/Individual Pallet Sold For Reuse	1.51	11
\$/Ton of Pallets Sold For Reuse	15.60	5
\$/Ton of Pallets Sold As-Is For Fuel	N/A	0
\$/Ton of Pallets Sold Ground Or Chipped For Fuel	11.42	6
\$/Ton of Pallets Sold Ground Or Chipped For Other Uses (Animal Bedding, Mulch, Compost, Etc.)	20.44	24
\$/Ton of Pallets Sold In Other Forms	12.50	2

Chapter 4: Results and Discussion for Construction and Demolition Landfills

Waste Received

The following section will discuss the average waste received by C&D (Construction & Demolition) landfills between 1995 and 1998. Estimates of total waste received by all C&D landfills excluding Alaska and Hawaii are also discussed. Statistical comparisons were made between the mean waste received per landfill in 1995 and 1998. The probability level for a change for this test and all tests in this study was .10.

The mean waste received by C&D landfills in the United States in 1998 was 36,200 tons per landfill (Table 23). The mean waste received per C&D landfill by region in 1998 was 67,200 tons in the West, 32,800 tons in the Midwest, 55,500 tons in the Northeast, and 29,800 tons in the South.

There was a statistically significant increase in waste received per C&D landfill on the national level and in the West and Northeast regions between 1995 and 1998 (Table 23). The Midwest and South regions did not show a change in waste received per C&D landfill between 1995 and 1998. Nationally, waste received per C&D landfill increased from 29,300 to 36,200 tons between 1995 and 1998. In 1998, the West received 67,200 tons of waste per C&D landfill, up from 28,800 tons in 1995. In 1998, the Northeast received 55,500 tons of waste per C&D landfill, up from 13,700 tons in 1995.

It is not surprising that waste received per C&D landfill increased for the period between 1995 and 1998. During the same period the number of C&D landfills nationwide, except for Alaska and Hawaii, decreased from 1436 to 1095. Waste production during the same period was shown not to have changed drastically (31, 32), so it is logical that fewer landfills would receive more waste each. What is interesting is that the number of landfills in the West did not change between 1995 and 1998 (116 landfills), but waste per landfill went up dramatically from 29,000 tons to 67,000 tons per facility. This indicates a dramatic increase in the amount of C&D waste generated in the West. This increased C&D waste could be coming from other regions, MSW facilities in the West, or C&D waste production could be going up.

The number of landfills in the Midwest decreased from 400 to 374 between 1995 and 1998. During the same period waste received per C&D landfill did not change, which is not surprising because the number of landfills changed little. In the Northeast, between 1995 and 1998 the number of C&D landfills decreased from 220 to 83. Not surprisingly during the same

period waste received per C&D landfill in the Northeast increased from 14,000 tons to 56,000 tons per year. In the South, the number of C&D landfill facilities decreased from 700 in 1995 to 522 in 1998. During the same period, waste generation per landfill did not change in the South (Table 23). This suggests that C&D waste production either decreased in the South or was diverted elsewhere between 1995 and 1998.

The decrease in numbers of landfills and increase in waste received per landfill could have a significant influence on the landfill environment. Fewer, larger landfills can have more capability to sort and recover waste materials. This is an important finding for this study. It is also important because as the landfill community becomes smaller it is an easier audience to reach. If the landfill community is easier to reach, findings from studies that can help reduce waste to landfills such as this one, can be disseminated to landfills more easily.

Estimates for total C&D waste generation were determined for each region and added to get the national estimate. All estimates of total C&D waste generation were made by multiplying the mean waste per landfill in a region and the number of landfills in the associated region. Numbers of landfills per region can be found in Table 2.

It is estimated that 40,341 thousand tons of waste entered all C&D landfills in 1998. Of this estimate, 7,800 thousand tons were received in the West region, 12,280 thousand tons were received in the Midwest region, 4,600 thousand tons were received in the Northeast region, and 15,650 thousand tons were received in the South region.

In the period between 1995 and 1998 the estimates for total C&D waste received did not change much. It was estimated that C&D waste production in 1995 was 42 million tons (Table 24). In 1998, C&D waste production was estimated at 40 million tons. During the same period the C&D waste generation shifted regions. In 1995, the South received 60 percent of national C&D waste production. In 1998, the South received only 39 percent of national C&D waste. During the same period, the West increased from seven to 19 percent of C&D waste. The Midwest and Northeast also received slightly larger proportions of C&D waste generated nationally. Again, it appears that C&D waste production either decreased in the South or was diverted elsewhere. Either way, it signifies that the waste environment is changing in the South.

Tipping Fees

It is important to discuss mean tipping fees charged by region and nationally at C&D landfills in 1995 and 1998. These fees are good indicators of landfill activities as well as

income. Hence, statistical tests were run to determine if differences existed between 1995 and 1998 tipping fees.

The mean tipping fee at C&D landfills nationwide in 1998 was \$16.84 (Table 25). Mean tipping fees by region in 1998 were \$25.48 in the West, \$14.19 in the Midwest, \$24.87 in the Northeast, and \$16.52 in the South.

Tipping fees at C&D landfills showed no change between 1995 and 1998 on the national level. Of the four regions only the Northeast showed a statistically significant decrease in tipping fees between 1995 and 1998 (Table 25). In 1995 tipping fees at C&D landfills in the Northeast were \$49.20 per ton. In 1998, tipping fees at C&D landfills in the Northeast were \$24.87. It is unclear what caused this large decrease in tipping fees in the Northeast in such a short period of time. As discussed earlier, the number of C&D landfills in the Northeast decreased from 220 to 83 between 1995 and 1998. It is possible that the remaining landfills in the Northeast are so much greater in size that they are able to charge lower tipping fees because of economies of scale. This significant decrease in tipping fees in the Northeast could have a negative impact on the recovery of materials from C&D landfills. It could definitely create a barrier to recovery of wood and pallets. If Northeast landfills are charging significantly less for mixed loads of waste, it provides little incentive for waste generators to sort materials. The three remaining regions showed no statistically significant change in tipping fees between 1995 and 1998.

Wood Waste Received

One of the focuses of this study was to determine the amount of wood entering landfills. This section addresses the percentage of total waste that wood represented at C&D landfills in 1995 and 1998. It also estimates the tonnage of wood waste received per C&D landfill. It concludes by discussing the make up of the wood waste received at C&D landfills.

Nationwide in 1998, wood represented 40.3 percent of waste received at C&D landfills (Table 26). The estimated amount of wood waste received per C&D landfill in 1998 was 11,300 tons. Regionally, wood represented 20.9 percent of waste in the West, 40.8 percent of waste in the Midwest, 44.5 percent of waste in the Northeast, and 43.3 percent of waste in the South. The estimates of mean wood waste received per C&D landfill in 1998 were 10,500, 10,400, 13,600, and 12,200 tons in the West, Midwest, Northeast, and South, respectively.

Nationwide and regionally, only the Northeast region showed a statistically significant increase in the percent of waste received at C&D landfills that wood represented between 1995

and 1998. In 1995, wood represented 21.3 percent of total C&D waste received in the Northeast, 44.5 percent in 1998. It is possible that a regulation is keeping other types of waste out of C&D landfills in the Northeast and thus increasing the percent of waste that wood represents, or other materials may simply have been landfilled less. It is also possible that the increase in the percent of wood waste per C&D landfill in the Northeast is due wood waste increasing. This could be due to the results of a strong economy, such as increased home building and repair and remodeling.

As can be seen in Table 26, the tons of wood waste received per landfill were higher in 1995 than in 1998. When comparing the estimates for total waste received at C&D landfills in 1995 (Table 26) to the estimates for wood waste received, the estimates for wood waste received are higher for the same period. Logically it doesn't make sense that landfills averaged more wood waste received than total waste received. It is likely that the way calculations were made concerning this question in 1995 were not sound.

Various types of wood waste received at C&D landfills are summarized in Table 27. As can be seen in the table, residential and industrial wood waste create a major influence on wood waste nationwide with over 60 percent. What is interesting is comparing the individual regions. The West receives a much higher percent of industrial wood waste, almost 44 percent. The West also receives the highest percentage of wood pallets, 18 percent. Other regions do not receive over ten percent of their wood waste as pallets. These high percentages for industrial and pallets in the West suggests that C&D landfills in the West are used more for business and industrial purposes rather than residential purposes. The Northeast receives a high percentage of residential waste, almost 43 percent. The Midwest receives over 65 percent of its wood waste in residential and industrial wood waste. All of these differences in make up of wood type entering C&D landfills regionally suggest that they are used for different purposes by region.

Pallet Waste Received

The focus of this study was on the number of pallets entering landfills. This section addresses that focus at C&D landfills. The discussion begins with estimates of the percentages of C&D landfills that accept pallets for disposal. It continues with the percentage of waste at C&D landfills that pallets represent. This section finishes with estimates of total tonnage of pallets and number of pallets received by region and nationally in 1995 and 1998.

In 1998, 71.5 percent of C&D landfills nationwide accepted wood pallets for disposal (Table 28). As can be seen in the table, the percentage of C&D landfills accepting wood pallets for disposal did not change much between 1995 and 1998. In the West, 58 percent of C&D landfills accepted wood pallets for disposal in 1998. In the Midwest, 71 percent of C&D landfills accepted wood pallets for disposal in 1998. In the Northeast, 50 percent of C&D landfills accepted wood pallets for disposal in 1998. In the South, 77.5 percent of C&D landfills accepted wood pallets for disposal in 1998.

In 1998, pallets represented 3.3 percent of C&D waste nationwide (Table 29). This corresponded to an estimate of 40 million pallets received at C&D landfills nationwide in 1998. Regionally, pallets represented .95, 3.17, 1.43, and 4.07 percent of waste received at landfills in the West, Midwest, Northeast, and South, respectively. The estimates of numbers of pallets received were 960 thousand in the West, 12 million in the Midwest, 2.2 million in the Northeast, and 25.3 million in the South.

Nationwide, the percent of waste that pallets represented between 1995 and 1998 did not show a statistically significant increase. All regions, except the Northeast, showed an increase in the percent of waste received that pallets represented between 1995 and 1998 (Table 29). In the West in 1998, pallets represented .95 percent of C&D waste received, up from .84 percent in 1995. It was estimated that 960 thousand pallets were received in the West in 1998. This is less than the estimate of one million pallets received at West landfills in 1995. This can be accounted for by the fact that a smaller proportion of West C&D landfills accepted wood pallets in 1998 than in 1995. In the Midwest in 1998, pallets represented 3.2 percent of waste received at C&D landfills, up from 1.3 percent in 1995. In the South in 1998, pallets represented 4.1 percent of C&D waste received, up from 2.7 percent in 1995. This increase in percentage and lack of change in total pallets in the South can be accounted for by the decrease in the number of landfills accepting wood pallets.

The increase in pallets as a percent of total waste received in three regions is an important finding. It shows that pallets are becoming a more significant portion of the C&D waste stream. If pallets are a more significant portion of the waste stream they become more identifiable as a material to recover.

Wood Waste Recovery

This section discusses the percentage of C&D landfills that had the ability to recover wood waste in 1995 and 1998. It also estimates the volume of wood waste recovered per C&D recovery facility and total wood waste recovered by all recovery facilities regionally and nationwide. The section continues with estimates of the types of wood recovered. It concludes by observing other types of waste that are recovered by C&D facilities.

In 1998, 27 percent or 307 C&D landfills nationwide had the ability to recover wood pallets (Table 30). Forty-six percent or 53 C&D landfills in the West had the ability to recover wood pallets in 1998. Twenty-three percent or 86 C&D landfills in the Midwest had the ability to recover wood pallets in 1998. Thirty-three percent or 27 C&D landfills in the Northeast had the ability to recover wood pallets in 1998. In the South, 27 percent or 141 C&D facilities had the ability to recover wood pallets in 1998. These percentages changed little from 1995, but because the number of landfills decreased from 1995 to 1998, the number of recovering facilities also decreased.

The mean amount of wood waste recovered nationwide per C&D recovery facility was 11,800 tons in 1998 (Table 31). Regionally, the mean wood waste recovered per C&D recovery facility was 16,200 tons in the West, 8,000 tons in the Midwest, 3,700 tons in the Northeast, and 13,500 tons in the South.

Nationwide, mean wood waste recovered per recovery facility showed a statistically significant increase from 9,100 tons per facility in 1995 to 11,800 tons in 1998. Regionally, only the Midwest showed an increase in the tons of wood waste received per C&D recovery facility between 1995 and 1998. C&D recovery facilities in the Midwest received 8,000 tons of wood waste in 1998, up from 2,600 tons in 1995. This increase could be a result of smaller C&D landfills closing, and the larger remaining C&D landfills being able to recover more waste. It could also be due to mandates requiring more wood waste be recovered from landfills (31). Finally, the increased wood waste recovery could be due to more profitable uses for the material such as saved landfill space and sales of mulch or animal bedding. This could be a very significant finding for this study. If landfills are finding that recovering wood material can result in income, it could quickly lead to increased recovery. Proving to landfills that recovering wood material can be profitable is one of the major barriers to increased recovery. The West,

Northeast, and South regions showed no change in the amount of wood waste received per C&D recovery facility from 1995 to 1998.

Wood waste received at C&D recovery facilities in 1998 was divided into five categories as seen in Figure 3. Yard waste represented 27 percent, the largest portion of wood waste received at C&D recovery facilities in 1998. Residential wood waste represented 25 percent of wood waste received at C&D recovery facilities in 1998. Pallets represented 24 percent of wood waste received at C&D recovery facilities in 1998. Industrial wood waste represented 20 percent of wood waste received at C&D recovery facilities in 1998. The remaining four percent of recovered wood waste at C&D facilities in 1998 was considered other.

Other uses for recovered wood material that landfill operators stated were done broke down into two categories. First, it could be sent to other landfills. Respondents gave no indication to the fate of the material at that point. Second, recovered it was burned. This was typically done for various reasons such as heat at the landfill facility, ashes for daily cover, or just to reduce volume in the landfill.

Figure 4 shows the regional breakdown of C&D wood waste recovery in 1998. With 49 percent, the South was by far the region with the greatest C&D wood recovery. In the South in 1998, 1,910,000 tons of C&D wood waste were recovered (Table 32). The West region recovered the second highest percentage of C&D wood waste in the nation in 1998 with 28 percent or 858,000 tons. The Midwest had the third highest C&D wood waste recovery in the nation in 1998 with 21 percent or 691,000 tons. The Northeast recovered the least C&D wood waste in the nation in 1998 with only two percent or 101,000 tons. Overall, 3,560,000 tons of wood waste were recovered at US C&D landfills in 1998.

In 1998, C&D landfill facilities were questioned about other waste products that they may recover and if they planned on recovering any in the future. In 1998, 30 percent of C&D landfills had the ability to recover wood other than pallets (Table 33). Seven percent of C&D landfills that did not recover wood other than pallets in 1998 planned to within two years. In 1998, 35 percent of C&D landfills had the ability to recover concrete, of those that did not, three percent planned to within two years. In 1998, 28 percent of C&D landfills had the ability to recover asphalt, two percent planned to within two years. Fifty-four percent of C&D landfills had the ability to recover metals in 1998, three percent planned to within two years. In 1998, nine percent of C&D landfills had the ability to recover roofing materials, five percent planned to

within two years. Eight percent of C&D landfills had the ability to recover gypsum wallboard in 1998. Three percent planned add this capability within two years. Eighteen percent of C&D landfills had the ability to recover plastic in 1998, four percent planned to within two years. In 1998, 28 percent of C&D landfills had the ability to recover brick, two percent planned to within two years.

From Table 33 it can be seen that some materials are sorted and recovered more frequently. Metals were the most frequently recovered material at C&D facilities in 1998. This is logical because ferrous metals can be sorted with magnets, requiring less labor, and they also bring higher values when recycled. Roofing materials, gypsum wallboard and plastics were hardly recovered by any landfills. This was most likely due to the fact that they bring little for resale and are difficult to separate. Wood, concrete, asphalt, and bricks were recovered by approximately the same amount of landfills (30 percent). This suggests there are markets for these materials, but because of difficulty of separation or low return they are not recovered more frequently.

Tipping Fees at Recovery Facilities

As discussed earlier, tipping fees can be a good indicator of changes in landfilling. This section discusses tipping fees charged for sorted loads of waste at C&D recovery facilities. Tipping fees at the C&D recovery facilities are compared to tipping fees from 1995 and to standard tipping fees at the associated C&D landfill in 1998.

In 1998, nationwide tipping fees at C&D recovery facilities were \$18.57 per ton (Table 34). Tipping fees for sorted waste loads at C&D recovery facilities by region were, \$30.50 in the West, \$17.69 in the Midwest, \$7.21 in the Northeast, and \$15.83 in the South.

Tipping fees charged at C&D recovery facilities nationwide in 1998 did not show a statistically significant change from those charged in 1995 (Table 34). Tipping fees at C&D recovery facilities did decrease from 1995 to 1998 in the Northeast and South regions. Tipping fees in the Northeast at C&D recovery facilities decreased from \$35.63 to \$7.21 per ton between 1995 and 1998. This is a very dramatic decrease. A large decrease was also seen for standard tipping fees in the Northeast (Table 25). Again, this decrease could be due to smaller C&D landfills in the Northeast closing, and the larger ones being able to charge lower tipping fees because of economies of scale. The Northeast also had very few responding landfills that managed C&D recovery facilities. This could also be the reason for the low mean tipping fees.

Too few respondents could have resulted in poor data. Tipping fees in the South at C&D recovery facilities decreased from \$22.44 to \$15.83 per ton between 1995 and 1998. Tipping fees at C&D recovery facilities in the West and Midwest did not change between 1995 and 1998.

Tipping fees for sorted loads at C&D recovery facilities were less than tipping fees for standard loads at the same facilities nationwide in 1998 (Table 35). This was also true in the West, Midwest, and South regions. The Northeast region did not report enough data to make comparisons. Tipping fees for sorted C&D loads averaged almost \$3.50 less per ton nationwide than what was charged for standard loads of waste bound for the same landfill. In the West, sorted loads of C&D waste averaged \$3.50 less per ton than what was charged for mixed loads at the same facilities in 1998. In the Midwest, sorted loads of C&D waste averaged \$2.50 less per ton than what was charged for mixed loads at the same facilities in 1998. In the South, sorted loads of C&D waste were charged \$1.00 less per ton than what was charged for mixed loads at the same facilities in 1998.

It is logical that sorted loads at C&D recovery facilities were charged less than what was charged at the same facilities for mixed loads. Sorted loads are easier to handle and recover for the C&D operators, because of reduced labor costs. It is apparent that C&D recovery facilities are trying to encourage waste producers to sort waste before delivering it to the landfill. The reduced tipping fee could be a good incentive for large waste producers to sort materials. This could have a significant influence on the wood resource for pallets and other products if the decreased tipping fees truly increase sorted loads of wood.

Pallet Recovery

Determining pallet recovery and the uses for recovered material was one of the major objectives of this study. The following section will discuss pallet recovery at C&D recovery facilities between 1995 and 1998. The section will begin by covering the percentage of landfills that do not have a recovery facility but plan to within two years. The section will continue with the percentage of wood waste recovered that pallets represent. The percentage of other types of wood recovered will then be discussed. Estimates of total pallets recovered will be given. Finally, uses for recovered pallets and any dollar values received for those uses will be discussed.

Thirteen percent of C&D landfills nationwide that did not recover wood pallets in 1998 planned to within two years (Table 36). Eleven percent of C&D landfills in the West that did not

recover wood pallets in 1998 planned to within two years. Twelve percent of C&D landfills in the Midwest that did not recover wood pallets in 1998 planned to within two years. No C&D landfills in the Northeast that did not already recover wood pallets in 1998 planned to within two years. Sixteen percent of C&D landfills in the South that did not recover wood pallets in 1998 planned to within two years.

In 1998, pallets represented 23.5 percent of wood waste recovered at C&D facilities nationwide (Table 37). Regionally in 1998, pallets represented 13.75 percent of wood waste recovered in the West, 44.23 percent of the wood waste recovered in the Midwest, and 15.06 percent of the wood waste recovered in the South. The Northeast did not have landfills reporting for this question in 1998.

Nationwide, the percentage of recovered wood waste that pallets represented did not show a statistically significant change between 1995 and 1998 (Table 37). The only region that showed a change in the percent of C&D wood waste recovered that pallets represented between 1995 and 1998, was the Midwest. In the Midwest, recovered pallets increased from 23 to 44 percent of wood waste recovered between 1995 and 1998. The Midwest also increased the amount of wood waste recovery per C&D facility (Table 31). The increased recovery of wood pallets could have been the basis for total wood recovery increasing. The West and South showed no change in the percent of C&D wood waste recovered that pallets represented between 1995 and 1998.

The remaining wood waste recovered from C&D facilities in 1998 was divided into four categories: Yard Waste, Residential Wood Waste, Industrial Wood Waste, and Other Wood Waste. Nationwide in 1998, yard waste represented 28 percent of recovered wood waste (Table 38). Residential wood waste represented 25 percent of recovered wood waste. Industrial wood waste represented 18 percent of recovered wood waste. Four percent of recovered wood waste was designated other. The remaining percent of wood waste recovery at C&D facilities came from pallets, as seen in Table 37. Table 38 also shows wood recovery percents by region. There was no data reported in the Northeast region.

By observing the data on Table 38 it can be seen that recovered C&D wood waste differs by region. In the South, much more recovered wood comes from yard waste and residential building waste. In the West, much more recovered wood comes from industrial waste. These trends were also evident for the wood waste received at the C&D landfills (Table 27). These

trends could be a result of the type of waste generators that bring sorted loads to C&D landfills in the different regions, or it could be an indication that C&D landfills play a different role in the waste stream in the four regions.

It is estimated that 16 million wood pallets were recovered from C&D facilities nationwide in 1998 (Table 39). Sixteen million pallets recovered represents 40 percent of the total number of wood pallets received at C&D facilities nationwide in 1998. It was estimated that 5.9 million pallets or 18 percent of the total number of wood pallets received at C&D facilities nationwide in 1995 were recovered. The jump from 18 percent of pallets recovered in 1995 to 40 percent recovered is tremendous. This suggests that much emphasis at C&D facilities has been placed on keeping pallets out of C&D landfills. This emphasis could be due to the need to conserve space in landfills or because recovered pallets are generating more income for landfills.

Summing the wood pallet recovery from each individual region generated this estimate of 16 million pallets recovered. No estimate could be generated for the Northeast region, as no data was received. It is estimated that 540,000 wood pallets were recovered from C&D facilities in the West in 1998. In the Midwest in 1998, 5,320,000 wood pallets were recovered. In the South in 1998, 10,044,000 wood pallets were recovered from C&D facilities.

Of the C&D landfills that had the ability to recover wood pallets in 1998, 27 percent stated the amount they recover had increased in the past two years (Table 40). Fifteen percent of C&D landfills that recovered pallets in 1998 said the amount of pallets they recover had decreased in the past two years. Fifty-two percent of recovering C&D landfills in 1998 stated there was no change in the volume of pallets they had recovered in the past two years. Five percent of the C&D landfills that recovered wood in 1998 had not recovered wood pallets for more than two years. Of the C&D landfills that saw an increase in the amount of pallets recovered, the average increase was 34 percent. Of the C&D landfills that saw a decrease in the amount of pallets recovered in the past two years, the average decrease was 50 percent.

In 1998, 23 percent of recovered C&D wood pallets nationwide were reused as pallets (Table 41). Four percent of recovered C&D wood pallets were used as-is for fuel in 1998. In 1998, no recovered pallets were repaired for reuse at C&D facilities. Twelve percent of recovered C&D wood pallets were ground and used as landfill cover in 1998. Nine percent of recovered C&D wood pallets were ground and used for fuel in 1998. In 1998, the largest

portion, 35 percent, of recovered C&D wood pallets were ground and used for mulch and animal bedding. This was also the largest use for recovered pallets in 1995. Eleven percent of recovered C&D wood pallets were used for other purposes. From many of the responses of landfill operators it is assumed that other purposes were most frequently in ground form. Regional breakdown of recovered C&D wood pallet uses were very similar to the national average. No responses were received for the Northeast region, so no estimates were generated. Regional uses for recovered C&D wood pallets can also be found in Table 41.

Table 42 gives an idea of revenues that C&D landfills realized for recovered wood pallets in 1998. The table also shows the number of nationwide responses for each category to give an idea of the number of landfill operators generating revenue from recovered pallets. The number of responses may have been low because operators did not want to give away proprietary information. The question concerning revenues from recovered pallets was the least frequently answered question on the questionnaire. It was also the last question on the questionnaire, which may have caused it to be answered less frequently.

In Table 42, individual pallets sold for reuse earned an average of \$2.17 a piece in 1998. Assuming an average 55-pound pallet, that amounts to approximately \$78 per ton if pallets are sold individually. Pallets sold by the ton as-is for reuse earned \$20 per ton. Pallets sold by the ton as-is for fuel earned \$17.25 per ton. Pallets that were ground and sold for fuel earned \$8.50 per ton. Pallets that were ground and sold for animal bedding, mulch, or compost earned the greatest value at \$22.50 per ton. This was also the most frequently used form of recovered C&D wood pallets.

Conclusions and Implications

The average waste received per C&D landfill in 1998 was 36,200 tons, up 7,000 tons from 1995. Regionally, the West and Northeast showed increases in the amount of waste received per landfill. The South and Midwest did not show any change in the amount of waste received per landfill between 1995 and 1998. During the same three-year period, the number of C&D landfills decreased (32). This could have had the affect of increasing the waste received per landfill. The estimate for total waste received by C&D landfills in 1998 was 40 million tons. This varied little from the estimate of 42 million tons in 1995 and was not found to be statistically different. Obviously, waste received at C&D landfills was very steady during the three-year period.

The decrease in number of C&D landfills and increase in waste received per landfill is an important finding in this study. If a landfill can accept more yearly waste then it is obviously larger or it is filling at a greater rate. If there are now more larger C&D landfills and fewer smaller landfills, the larger are more likely to have greater capability to sort and recover materials. Also with a smaller number of operating landfills, they are a smaller audience to reach with important information.

Regionally, C&D waste generation changed between 1995 and 1998. The South went from receiving 60 percent of C&D waste in 1995 to 40 percent in 1998. During the same period, the other three regions all received a larger portion of C&D waste. It is possible that C&D waste is moving from region to region or not moving to the South as much. It is also possible that C&D landfills are becoming a more popular outlet for waste material in regions other than the South.

Tipping fees at C&D landfills did not change between 1995 and 1998 except in the Northeast, where they dropped from \$50 to \$25 per ton. Nationwide, tipping fees at C&D facilities averaged \$16.84 per ton. Tipping fees at C&D landfills in 1998 were \$25.48, \$14.19, and \$16.52 in the West, Midwest, and South respectively. The number of C&D landfills in the Northeast decreased from 220 to 83 from 1995 to 1998. It is possible that the remaining landfills were much greater in size and were capable of charging lower tipping fees.

Landfills in the Northeast are charging much less for tipping, this could be a large barrier to increasing wood waste recovery there. If it costs waste generators half as much as it previously did to landfill it, they could be less likely to sort material to keep it from the landfill.

Nationwide, wood waste as a percent of total waste received at C&D landfills did not change between 1995 and 1998. In 1998, wood waste represented 40 percent of waste entering C&D landfills or 11,000 tons of wood per landfill. Only the Northeast region showed an increase from 1995 to 1998 in the percent of waste that wood represented. In 1995 wood represented 22 percent of waste at Northeast landfills. In 1998, it represented 44 percent. This increase could be due to the large increase in total waste at C&D landfills in the Northeast being mostly wood, or it could be due to other types of waste being kept from C&D landfills. Regardless, wood represents a major portion of the waste entering C&D landfills and a readily available opportunity for landfills to recover.

Pallets were accepted for disposal at 71 percent of C&D landfills. It is estimated that 3.3 percent of C&D waste was pallets, corresponding to 40.5 million pallets reaching landfills in 1998, assuming 55 pounds per pallet. This is up from the estimate of 32.7 million pallets reaching C&D landfills in 1995. Nationwide, the percentage of waste that was pallets did not change between 1995 and 1998, but it did increase in all regions except the Northeast. This increase in percent of waste that was pallets and the steady amount of total waste suggests that pallets have become a greater part of the C&D waste picture. This could be due to the fact that pallet waste at MSW landfills decreased during the same time period and pallets are being diverted to C&D landfills instead. It could also be due to the increased business activity of a strong economy.

Pallets increasing in numbers and in percentage of waste at C&D landfills make them a strong target for recovery. The more prevalent a material is a landfill the more easily it can be targeted for recovery. Hopefully, with the publication of this work it can be seen by pallet recyclers how prevalent pallets are at C&D landfills and they in turn can target landfills as a source of material for their operations.

Approximately 27 percent of C&D landfills could recover wood in 1998. Nationwide, wood waste recovered at C&D recovery facilities increased by approximately 2,500 tons per facility between 1995 and 1998. In 1998, C&D recovery facilities recovered an average of 11,800 tons of wood waste each. This corresponds to a total of 3.5 million tons of wood waste recovered at C&D facilities in 1998. Thirteen percent of C&D facilities that did not recover wood in 1998 planned to within two years. Wood waste as a percent of total waste did not increase between 1995 and 1998, but the amount of wood waste recovered did increase. This suggests that C&D facilities have found incentives to recover more wood. Possible incentives could be saving landfill space, legislative mandates, or receiving more income from the wood waste. As a result, C&D landfills are diverting more wood waste from being placed into the landfill. Hopefully, this is due to C&D landfills identifying markets for the material and generating profits. If this is true, this is one barrier to increased recovery that is already being overcome.

Although more wood recovery is occurring at C&D landfills, it is only occurring at 27 percent of C&D landfills. Encouraging more landfills facilities to recover wood material is a good way to increase wood recovery. Obviously, the remaining 73 percent of C&D landfills

need incentives to open recovery facilities. This is definitely a barrier to increased recovery. Hopefully the results of this study show that landfills are finding markets for recovered wood material and are generating profits from it. This could be quite an incentive to opening a recovery facility.

Regionally, the South recovered almost 50 percent of the total wood waste recovered. This is not surprising because the South received a great deal more wood waste than any other region. The West and Midwest each recovered approximately 24 percent of the total wood waste recovered. The Northeast recovered only two percent of the total recovered wood waste in 1998. This is not surprising because the Northeast did not receive a great deal of wood waste in 1998.

Nationwide, tipping fees for pallets and sorted loads of waste at C&D recovery facilities did not statistically change from 1995 to 1998. The average tipping fee for a sorted load of wood waste at a C&D recovery facility in 1998 was \$18.57 per ton. Tipping fees for sorted loads of waste did decrease in the Northeast and South from 1995 to 1998. In every region, the tipping fee charged for sorted loads was less than that which was charged for mixed loads at the same C&D facilities. This suggests that C&D landfills are encouraging waste producers, through monetary incentives, to sort waste. This is an important step to overcoming barriers to increased wood waste recovery. If new markets can be found for recovered wood material another barrier could be overcome. If landfills can find these new markets, partly through studies such as this one, tipping fees could be reduced further, giving more incentive for waste producers to sort material.

Wood pallets represented 24 percent of wood waste recovered in 1998, which was unchanged statistically from 1995. The other recovered wood wastes at C&D facilities in 1998 were yard waste (28%), Residential wood waste (25%), Industrial wood waste (19%), and Other wood waste (5%). It was estimated that 16 million wood pallets were recovered from C&D facilities in 1998. This was a large increase from the estimate of 5.9 million in 1995. This is a significant finding for this study. It suggests the possibility that landfills and wood recyclers are finding markets for recovered wood material. As discussed earlier, the amount of wood waste recovered at C&D facilities increased between 1995 and 1998. It appears that pallet recovery had a great deal to do with this increased wood recovery. It is likely that C&D landfills have found monetary benefits to promote this increased pallet recovery. The benefits could be through saved landfill space or revenues from sales of pallet material.

Thirteen percent of C&D landfills that did not recover wood pallets in 1998 stated they planned to within two years. Of the landfills reporting that had a wood recovery facility, 27 percent said the number of pallets recovered increased in the past two years. The average increase was 34 percent. Fifteen percent of landfills said the number of pallets recovered decreased in the past two years. The average decrease was approximately 50 percent. The majority of landfills, 52 percent, said the number of pallets recovered had not changed in the past two years.

Pallets recovered from C&D landfills in 1998 were used for various purposes. Typically recovered pallets were used in ground form. It is estimated that more than 65 percent of recovered pallets were ground for uses such as; mulch, animal bedding, compost, fuel, and landfill cover. Mulch and animal bedding were by far the most common use. On average, pallets sold as-is from C&D landfills received \$2.17 each or \$20 per ton. Obviously, every pallet can not be sold for \$2.17, but this appears to be a very profitable way for landfills to recover pallets. Further investigation may be necessary to determine what percentage of pallets could be sold to pallet recyclers and what returns could be realized from sorting pallets at the landfill.

Pallets sold ground for fuel received \$8.50 per ton. Pallets sold ground for mulch and animal bedding received \$22.30 per ton. This was by far the most frequently used form for recovered pallets, as well as the most frequently used form that generated income.

It is obvious that recovered pallet material is creating income for C&D landfills. The question of monetary return was the least frequently answered question of this survey. This suggests that more landfills are generating income from recovered pallets, but do not want to divulge this information. Because one of the barriers to increased wood and pallet recovery is monetary incentives, the information that landfills are generating income could be a good incentive for the 70 percent of C&D landfills are not currently recovering wood material.

Table 23. Mean Tons of Waste (all types) Received per US C&D Landfill in 1995 and 1998. Non-Parametric Tests Used for Comparison.

Region	Mean Waste Received Per Landfill		
	1995 Tons	1998 Tons	Non-Parametric Probability (p) ¹
All Regions	29,307	36,226	0.036
West	28,828	67,207	0.059
Midwest	25,715	32,840	0.428
Northeast	13,687	55,549	0.042
South	36,540	29,871	0.202

1. The non-parametric Mann-Whitney U test was used to evaluate the hypothesis that the distribution of data for 1995 was no different than that of 1998. The probability is the chance of getting a different estimate for 1998 given the same distribution for 1995.

Table 24. Estimated Total Waste (all types) Received by C&D Landfills in 1995 and 1998.

Region	Total Waste Received in 1995 (Thousand Tons)	Total Waste Received in 1998 (Thousand Tons)
All Regions	42,169	40,341
West	3,132	7,796
Midwest	10,843	12,282
Northeast	2,939	4,611
South	25,255	15,652

Table 25. Tipping Fees of US C&D Landfills in 1995 and 1998. Non-Parametric Tests Used for Comparison .

Region	Mean Tipping Fee in 1995 (\$ Per Ton)	Mean Tipping Fee in 1998 (\$ Per Ton)	Non-Parametric Probability (p) ¹
All Regions	24.18	16.84	0.000
West	20.60	25.48	0.847
Midwest	19.80	14.19	0.001
Northeast	49.20	24.87	0.006
South	22.50	16.52	0.003

1. The Non-Parametric Mann-Whitney U test was used to test the hypothesis of no difference between distributions.

Table 26. Percentage of Total Waste Received at C&D Landfills That Wood Represented and the Corresponding Estimated Mean Tonnage of Wood Waste Received Per Landfill in 1995 and 1998. Non-Parametric Tests Used for Comparison.

Region	1995		1998		NonParametric Probability (p) ¹
	Mean Percentage Wood	Estimated Tons of Wood Waste	Mean Percentage Wood	Estimated Tons of Wood Waste	
All Regions	38.2	38,265	40.3	11,300	0.333
West	18.4	31,283	20.9	10,500	0.454
Midwest	46.4	41,960	40.8	10,400	0.112
Northeast	21.3	20,319	44.5	13,600	0.006
South	38.9	42,223	43.3	12,200	0.149

1. The non-parametric Mann-Whitney U test was used.

Table 27. Percent of Wood Waste by Type Received at C&D Landfills in 1998.

Region	1998 Wood Waste Type				
	Yard Waste	Residential	Industrial	Pallets	Other
All Regions	21.78	32.88	29.28	9.51	6.46
West	12.17	19.25	43.50	18.83	6.17
Midwest	17.58	36.75	30.65	10.01	4.87
Northeast	29.23	42.62	18.15	6.08	3.92
South	25.76	30.25	27.16	8.53	8.22

Table 28. Estimated Percentage of C&D Landfills that Accepted Wood Pallets for Disposal in 1995 and 1998

Region	1995 Percent Accepting	1998 Percent Accepting
All Regions	67.11	71.48
West	62.71	58.33
Midwest	70.83	70.87
Northeast	48.78	50.00
South	70.78	77.50

Table 29. Mean Percentage of Total C&D Waste that Pallets Represented in 1995 and 1998. The Estimated Total Tonnage of Pallets Received at C&D Landfills and the Corresponding Number of Pallets Based on 55lb. Per Pallet. Non-Parametric Statistical Tests Used for Comparison.

Region	1995			1998			
	Mean Percent	Estimated Tonnage of Pallets	Estimated Number of Pallets	Mean Percent	Estimated Tonnage of pallets	Estimated Number of Pallets	Non-Parametric Probability (p) ¹
All Regions	2.12	894,461	32,690,000	3.29	1,113,250	40,484,000	0.136
West	0.84	26,241	1,020,000	0.95	26,400	960,000	0.094
Midwest	1.33	143,722	4,960,000	3.17	327,400	11,907,000	0.000
Northeast	1.89	55,508	2,070,000	1.43	61,850	2,249,000	0.200
South	2.65	668,990	24,640,000	4.07	697,600	25,368,000	0.000

1. The non-parametric Mann-Whitney U test was used.

Table 30. Estimated Percent of C&D Landfills That Had the Ability to Recover Wood Pallets in 1995 and 1998.

Region	1995 Percentage	1998 Percentage
All Regions	32	27
West	27	46
Midwest	25	23
Northeast	46	33
South	36	27

Table 31. Comparison of Mean Wood Waste Received Per C&D Recovery Facility in 1995 and 1998. Non-Parametric Statistical Tests Used for Comparison.

Region	1995 (Tons)	1998 (Tons)	Non-Parametric Probability (p) ¹
All Regions	9,109	11,834	0.031
West	7,402	16,198	0.193
Midwest	2,615	8,039	0.098
Northeast	3,813	3,751	0.837
South	15,371	13,549	0.412

1. The non-parametric Mann-Whitney test was used for comparison.

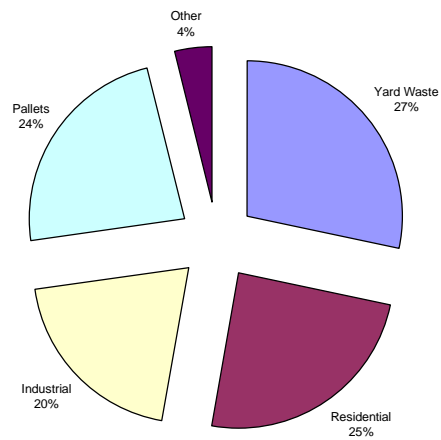


Figure 3. Percentage Breakdown of Types of C&D Wood Waste Recovery Nationwide in 1998.

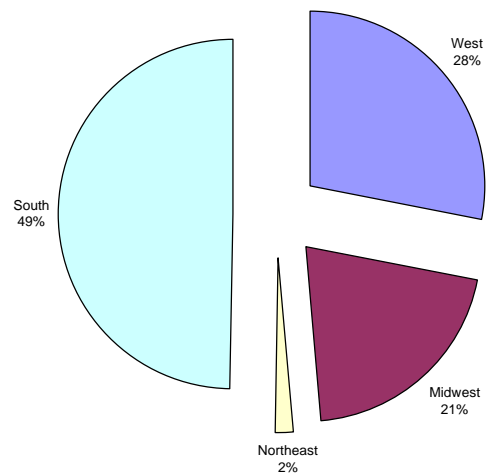


Figure 4. Regional Percentage of C&D Wood Waste Recovery in 1998.

Table 32. Estimates of Total Wood Waste Recovered at C&D Recovery Facilities in 1995 and 1998.

Region	1995		1998	
	Tons	Percentage of Total	Tons	Percentage of Total
All Regions	619,323	100	3,560,000	100
West	136,142	21.98	858,000	24.10
Midwest	25,366	4.10	691,000	19.41
Northeast	164,635	26.58	101,000	2.84
South	293,180	47.34	1,910,000	53.65

Table 33. Percent of C&D Landfills That Had the Ability to Recover Materials Other than Wood Pallets in 1998. The Percent of C&D Landfills That Did Not Have the Ability to Recover These Materials in 1998, but Planned to Within Two Years.

Material Type	Percent of Landfills With Ability to Recover Material	Percent Of Landfills That Plan To Recover Material
Wood Other Than Pallets	29.6	7.0
Concrete	35.4	3.1
Asphalt	28.4	2.3
Metals	53.7	2.7
Roofing	8.9	4.7
Gypsum Wallboard	8.2	3.5
Plastics	18.3	3.9
Brick	28.4	2.3

Table 34. Mean Tipping Fee for Sorted Waste Received at C&D at Recovery Facilities in 1995 and 1998. Non-Parametric Statistical Tests Used for Comparison.

Region	1995 (\$ Per Ton)	1998 (\$ Per Ton)	Non-Parametric Probability (p) ¹
All Regions	21.94	18.57	0.129
West	14.90	30.50	0.115
Midwest	14.53	17.69	0.502
Northeast	35.63	7.21	0.031
South	22.44	15.83	0.007

1. The non-parametric Mann-Whitney test was used for comparison.

Table 35. Comparison of Mean Tipping Fees for Standard Waste Loads at C&D Landfills that Managed Recovery Facilities and Sorted Loads at the Associated C&D Recovery Facility in 1998. Non-Parametric Statistical Tests Used for Comparison.

Region	Standard Tipping Fee (\$ Per Ton)	Tipping Fee at Recovery (\$ Per Ton)	Non-Parametric Probability (p) ¹
All Regions	19.71	17.89	0.000
West	31.38	27.94	0.007
Midwest	20.62	17.97	0.000
Northeast	no data		
South	17.28	16.17	0.000

1. The non-parametric Mann-Whitney U test was used.

Table 36. Estimated Percentage of C&D Landfills That Did Not Recover Wood Pallets in 1995 or 1998, But Planned to Within Two Years.

Region	1995 Percentage	1998 Percentage
All Regions	11	13
West	8	11
Midwest	14	12
Northeast	18	0
South	5	16

Table 37. Recovered Pallets as a Percentage of Total Wood Waste Recovered at C&D Recovery Facilities in 1995 and 1998. Non-Parametric Statistical Tests Used for Comparison of 1995 and 1998 Estimates.

Region	1995 Percent	1998 Percent	Non-Parametric Probability (p) ¹
All Regions	18.66	23.52	0.307
West	14.97	13.75	0.560
Midwest	23.05	44.23	0.018
Northeast	23.97	No Data	
South	17.04	15.06	0.965

1. The non-parametric Mann-Whitney U test was used.

Table 38. Percent of Wood Recovery Other Than Pallets at C&D Recovery Facilities in 1998. No Responses were Received for the Northeast Region for this Question.

Region	1998 Wood Waste Type			
	Yard Waste	Residential	Industrial	Other
All Regions	28.43	24.84	18.43	4.14
West	24.13	24.13	34.38	1.13
Midwest	20.49	15.23	15.55	2.88
Northeast	No data			
South	32.72	29.3	17.31	5.91

Table 39. Estimates of Total Tonnage of Pallets and Number of Pallets Recovered at C&D Recovery Facilities in 1995 and 1998. No Responses from the Northeast Were Received for this Question.

Region	1995 Recovery		1998 Recovery	
	(Tons)	Pallets	(Tons)	Pallets
All Regions	37,712	5,887,300	437,500	15,904,000
West	10,059	400,000	15,000	540,000
Midwest	3,201	112,300	146,300	5,320,000
Northeast	18,429	814,000	No Data	No Data
South	6,023	4,561,000	276,200	10,044,000

Table 40. Percentage of Responding C&D Recovery Facilities Reporting a Change in the Volume of Wood Pallets Recovered in the Period Between 1996 and 1998. Estimate of How Much Recovered Pallets Have Increased or Decreased at C&D Recovery Facilities in the Same Period.

Response Category	Percentage Reporting by Category	Mean Percent Change
Increased	27.4	34.35
Decreased	15.1	49.6
No Change	52.1	
Not In Operation Over Two Years	5.4	

Table 41. Percentage Breakdown of How Recovered C&D Pallets Were Used in 1995 and 1998. 1998 Figures are Shown Regionally as well as Nationally. 1995 Figures are only Shown Nationally. No Responses from the Northeast Were Received for this Question.

Use	Percent of Total Pallet Recovery					
	1995	1998				
	Nation	Nation	West	Midwest	Northeast	South
Re-used as pallets	30.37	21.80	21.27	18.09	No Data	23.57
Fuel as-is	3.18	4.30	9.09	4.70		2.94
Repaired at facility for reuse	3.59	0.02	0.00	0.08		0.00
landfill cover	7.28	12.40	14.50	19.79		6.03
ground for fuel	18.77	10.48	31.05	7.13		5.59
ground for mulch	31.92	29.70	15.91	28.30		36.50
other	4.89	21.30	8.18	21.91		25.37

Table 42. Nationwide Mean Dollar Values Received For Recovered Pallets in 1998. Numbers of Responses Received for Each Pallet Use.

	Mean Selling Price	# of Responses
\$/Individual Pallet Sold For Reuse	2.17	3
\$/Ton of Pallets Sold For Reuse	20.00	3
\$/Ton of Pallets Sold As-Is For Fuel	17.25	2
\$/Ton of Pallets Sold Ground or Chipped For Fuel	8.50	4
\$/Ton of Pallets Sold Ground or Chipped For Other Uses (Animal Bedding, Mulch, Compost, Etc.)	22.30	12
\$/Ton of Pallets Sold in Other Forms	10.00	1

Chapter 5: Conclusions

In 1998, both MSW and C&D landfills received more waste on a per landfill basis than they did in 1995. Each MSW landfill received 138,000 tons of waste in 1998, up 35,000 tons from 1995. Each C&D landfill received 36,200 tons of waste in 1998, up 7,000 tons from 1995. During the same three-year period, the number of MSW and C&D landfills decreased dramatically. This suggests the reason for waste per landfill increasing.

Estimates for total waste received in 1998 were 239 million tons at MSW landfills and 40 million tons at C&D landfills. The EPA estimate for waste received at MSW landfills in 1998 was 220 million tons (66). The similarity of waste generation estimates between this study and the EPA lend credibility to this study.

It appears that the decreasing number of landfills and the increasing amount of waste received per landfill are the greatest changes occurring at MSW and C&D landfills currently. This means that average landfill size is increasing and creates positive and negative effects for the recovery of waste material. The positive effect is that larger landfills are likely to have more space, equipment and labor to sort and recover material. Also, fewer landfills are more easily targeted and given information on trends in recycling and recovery, such as the results of this study. The negative effect is that larger landfills are capable of charging lower tipping fees, as seen in this study. These decreased tipping fees are a disincentive for waste producers to sort or reduce the amount of waste they send to landfills.

Tipping fees at MSW and C&D landfills in 1998 averaged \$29.31 and \$16.84, respectively. The 1998 average MSW tipping fee was not statistically different from the 1995 figure. However, the 1998 C&D fee statistically decreased from the 1995 figure. Tipping fees on a regional basis decreased between 1995 and 1998 in the West and Midwest for MSW landfills and in the Northeast for C&D landfills. It is possible that the decrease in number of landfills in each of these regions left the region with larger landfills that were capable of charging lower tipping fees.

Wood waste as a percent of total waste received increased at MSW landfills but did not exhibit a statistically significant change at C&D landfills between 1995 and 1998. Wood waste represented 10.9 percent of waste at MSW landfills and 40 percent of waste at C&D landfills in 1998. These percentages lead to estimates of 11,800 tons of wood waste reaching each MSW landfill and 11,000 tons of wood waste reaching each C&D landfill. The increased percent of

waste that was wood at MSW landfills could be a result of the following two factors. First, wood waste reaching landfills could be increasing. This could be a result of a booming economy that produces more wood waste. Or second, other types of waste could be decreasing at MSW landfills. Regardless, wood represents a larger portion of waste at MSW landfills and an already large portion of waste at C&D landfills. This could be a very important result in terms of increasing the amount of wood recovered. If wood represents a larger portion of the waste stream, it becomes a more obvious target for recovery. The barrier to greater recovery then becomes finding accessible markets for the recovered material. Finding these markets is something this study attempted to do, and will be discussed later in this section.

In 1998, 84 percent of MSW landfills and 71 percent of C&D landfills accepted wood pallets for disposal. Pallets represented 2.8 percent of waste at MSW landfills and 3.3 percent of waste at C&D landfills. These percentages represent an increase (as compared to 1995) at MSW landfills but not a statistically significant change at C&D landfills. The estimates of total pallets received at MSW and C&D landfills in 1998 were 138 and 40.5 million, respectively. The estimate of pallets received at MSW landfills was down from 153 million in 1995. The estimate of pallets received at C&D landfills was up from 38.4 million in 1995. This means that the estimate for total pallets received at MSW and C&D landfills was down over 10 million pallets between 1995 and 1998. This suggests that an increased number of pallets are being diverted before they reach landfills, unless fewer pallets are being discarded. As with wood waste, pallets increasing as a portion of total waste at MSW landfills could make them a more visible and obvious target for recovery. This information now needs to be disseminated to pallet recyclers and recovered wood users so that they may target landfills for material. This exchange of information would be an important step to overcoming barriers to increased wood recovery.

In 1998, 33 percent of MSW landfills and 27 percent of C&D landfills had the ability to recover wood waste. It is estimated that each MSW recovery facility recovered 15,500 tons of wood waste and each C&D recovery facility recovered 11,800 tons of wood waste in 1998. This corresponds to a total of nine million tons of wood waste recovered at MSW facilities and 3.5 million tons recovered at C&D facilities. Wood waste recovery increased at C&D facilities, but not at MSW facilities between 1995 and 1998. It is possible that there is a limit to what a recovery facility can process in a given year, because recovery was flat at MSW facilities and still increasing at C&D facilities. It is also possible that there simply is not a market for any

more recovered wood waste, so it was not recovered in greater volumes at MSW facilities. Obviously a barrier to increased recovery could be that each recovery facility has limits to its capability to recover wood. It is possible that these limits could be increased because the average size landfill has increased. The true barrier to increased wood recovery is that only 30 percent of landfills currently have recovery facilities. To overcome this barrier it is important to encourage the remaining 70 percent of landfills to operate recovery facilities. Encouraging other landfills to recover wood can be accomplished by proving that there are markets for recovered wood material and revenue can be generated from this material. This study has found that these markets exist and that landfills are currently receiving income from recovered wood and pallets.

Tipping fees for sorted loads of waste at MSW and C&D recovery facilities averaged \$23.55 and \$18.57, respectively. Neither of these estimates statistically different from 1995. Tipping fees were statistically lower for sorted loads at recovery facilities than for mixed loads at both MSW and C&D facilities. This suggests that both MSW and C&D landfills are trying to encourage waste producers to sort waste before bringing it to the landfill. Discounts for sorted loads were as high as six dollars per ton for C&D and thirteen dollars per ton for MSW, which could be quite an incentive for large waste producers to sort waste. It is likely that if more markets can be found for recovered wood material, landfills could further reduce the tipping fee for sorted loads, thus increasing the incentive to waste producers to sort materials.

At both MSW and C&D recovery facilities, pallets represented 24 percent of the wood waste recovered in 1998. This was up at MSW facilities and unchanged at C&D facilities as compared to 1995. It was estimated that 22 million wood pallets were recovered at MSW facilities and 16 million wood pallets were recovered at C&D recovery facilities in 1998. The estimated number of wood pallets recovered at MSW facilities was down and the number at C&D facilities was up in 1998 as compared to 1995. The estimated total number of wood pallets recovered at MSW and C&D facilities combined, 36 million in 1995 and 38 million in 1998, was statistically unchanged. What is significant is that the number of pallets recovered went down at MSW facilities and up at C&D facilities, suggesting different objectives at each type of landfill. C&D landfills appear to be placing a great deal of emphasis on recovering wood pallets. Hopefully this is due to the fact that they have identified markets and generated revenue from the recovered materials. It could also be due to legislation requiring greater percentages of wood to be kept from the landfill.

Twenty seven percent of both MSW and C&D landfills in 1998 reported an increase in the number of pallets recovered in the past two years. The average increase was 21 percent at MSW facilities and 34 percent at C&D facilities. Nine percent of MSW facilities and 15 percent of C&D facilities reported a decrease in the number of pallets recovered. The average decrease was 30 percent at MSW facilities and 50 percent at C&D facilities. However, 60 percent of MSW facilities and 52 percent of C&D facilities said there was no change in the number of pallets recovered.

Pallets recovered in 1998 at MSW and C&D facilities were used for various purposes. Frequently, recovered pallets were used in ground form. Approximately 65 percent of recovered pallets at both MSW and C&D facilities were in ground. The typical uses were for fuel, animal bedding, mulch, compost, or landfill cover. The remaining 35 percent of recovered pallets were used as-is for fuel, reused as pallets, or repaired and sold. Ground pallets that were sold at MSW and C&D facilities typically received between \$10 and \$20 per ton. Pallets sold as-is received approximately the same value per ton (\$10-\$20). Occasionally, pallets sold individually received \$1.50 to \$2.00. This was rare and likely required some sorting on the part of the recovery facility.

It is apparent that pallet material is creating income for landfills. Because the monetary return question of the questionnaire was the least answered question of the questionnaire it is assumed that other landfills were receiving money for recovered pallet material. The question was likely not answered as frequently because of confidentiality issues or fear of losing proprietary information. It is likely that a good number of landfills are earning returns on recovered pallet material. If this is true, it could be very good encouragement for the 60-70 percent of MSW and C&D landfills that do not currently operate a recovery facility to start one. This could have a significant impact on the pallet industry if a greater number of landfills begin recovering pallets. In turn, it would have a great influence on the amount of virgin wood material required to produce pallets.

Recommendations for Further Research

To better understand various parts of this study, some further research could be helpful. A better understanding of state legislation that can restrict the amount of wood waste and other types of waste entering landfills could be helpful. It could be helpful to understanding why certain types of waste increase or decrease in their percentage at the landfills.

Determining if there are other types of landfills in operation that receive wood and wood pallets could also be helpful. The format of this study was to investigate only state licensed MSW and C&D landfills. It could be possible that other types of landfills or licensing exist and could be distorting the waste stream. It would have been helpful to this study to know if these other types of landfills existed.

It could also be helpful to determine what caused the decrease in number of pallets that reached MSW landfills between 1995 and 1998. Could it be more used pallets were claimed before they entered the waste stream. Could less pallets be in use because of the increase in just-in-time delivery of smaller packages. Could plastic pallets be having an influence on the number of pallets discarded. Or could it simply be that fewer pallets were taken out of service in 1998 than in 1995.

Determining who purchases recovered pallets could be very important. This could help landfills identify places to market recovered pallets, and could help end users of recovered pallets to find more material if they require it. This could be a very difficult task because the landfill operators were not very forthcoming with information on any monetary value they received from recovered pallets. It is likely that they felt they had a strategic advantage with the party they sold to and did not want to divulge that information.

Literature Cited

1. American City & County. 1997. Talking trash: five solid waste pros tell you what they think you should know. 112(11):40-58.
2. Anderson, Deborah D. and Laurie Burnham. 1992. Toward sustainable waste management. *Issues in Science and Technology* 9(1):65-72.
3. Araman, et al. 1998. Wood pallets and landfills – status and opportunities for economic recovery and recycling. In proceedings of WASTCON/ISWA World Congress 1998, SWANA's 36th Annual International Solid Waste Exposition. Charlotte, NC. Pp. 345-358.
4. Araman, Philip A., Robert J. Bush, and Vijay S Reddy. 1997. Municipal solid waste landfills and wood pallets – what's happening in the United States. *Pallet Enterprise* 17(2):50-56.
5. Araman, Philip A., Robert Bush, and Vijay S. Reddy. 1997. Potential material sources for board products: used pallets and wastewood at landfills. Proceedings: 31st International Particleboard/Composite Materials Symposium.
6. Aruna, P.B., et al. 1997. Used pallets as a source of pellet fuel: current industry status. *Forest Products Journal* 47(9):51-56.
7. Badger, Phillip C. 1995. Marketing wood waste for fuel. *Biocycle* 36(1):71-74.
8. Biocycle. 1997. Bringing added value to recycled wood products. *Biocycle* 38(9):63-64.
9. Biocycle. 1995. Recovery options for wood and C&D. *Biocycle* 36(7):30-33.
10. Biocycle. 1995. Wood recycling at municipal centers. *Biocycle* 36(10):38-39.
11. Biocycle. 1993. Whittling away at wood waste. *Biocycle* 34(1):52-53.
12. Blackman, Ted. 1991. Recycling: not just for papers and bottles anymore. *Forest Industries* 118(8):19-20.
13. Block, Dave. 1998. Wood fiber reuse strategies. *Biocycle* 39(7):38-39.
14. Bradshaw, A.D., Sir Richard Southwood, and Sir Fredrick Warner, ed. 1992. *The Treatment and Handling of Wastes*. Chapman & Hall, London, U.K.
15. Brindley, Ed. 1993. Pallet recyclers: what are they thinking. *Pallet Enterprise* 13(3):18-22.
16. Bush, Robert J., Vijay S. Reddy, and Philip A. Araman. 1997. Construction & demolition landfills and wood pallets – what's happening in the U.S. *Pallet Enterprise* 17(3):27-31.

17. Campbell, Tom. 1999. Judge may forgo trash trial. *Richmond Times Dispatch*. 12(4):B-1.
18. Campbell, Tom. 1999. Judge rules against VA. In trash suit Spencer rejects motion to bring NYC into case. *Richmond Times Dispatch* 8(3):A-1.
19. Condon, James P. 1992. Recycling skids into profits. *Biocycle* 33(9):60.
20. Darrow, Carl. 1996. On wood recovery. *Resource Recycling* 12(2):69-70.
21. Daskalopoulos, E., O. Badr, and S.D. Probert. 1998. An integrated approach to municipal solid waste management. *Resources, Conservation and Recycling* 24(1):35-50.
22. Delong, James V. 1994. Of mountains and molehills: the solid waste "crisis". *Brookings Review* 12(2):34-40.
23. Demma, G., et al. 1995. Functionalization of wood waste and its use in polyester type composite. A preliminary study. *Journal of Polymer Engineering* 14(4):283-293.
24. Diaz, Luis F. 1993. *Compost and Recycling Municipal Solid Waste*. Lewis Publishers, Boca Raton, FL.
25. Dowie, W.A., D.M. McCartney, and J.A. Tamm. 1998. A case study of an institutional solid waste environmental management system. *Journal of Environmental Management* 53:137-146.
26. Farrell, Molly. 1998. County picks composting as best diversion strategy. *Biocycle* 99(9):33-35.
27. Franklin, William E. and Marjorie A. Franklin. 1992. Putting the crusade into perspective: recycling and waste generation both are on the rise. *EPA Journal* 18(3):7-14.
28. Gavzer, Bernard. 1999. What will we do with all our garbage? *Parade* June 13, 1999
29. Glenn, Jim. 1998. Organics recycling takes big chunk out of solid waste. *Biocycle* 99(5):38-40.
30. Glenn, Jim. 1998. Pallet scraps yield mulch and compost. *Biocycle* 39(3):30-31.
31. Glenn, Jim. 1999. The state of garbage in America. *Biocycle* 40(4):60-71.
32. Glenn, Jim. 1998. The state of garbage in America. Part 2. *Biocycle* 99(5):48-52.
33. Glenn, Jim. 1998. The state of garbage in America. Part 1. *Biocycle* 99(4):32-43.
34. Guttentag, Roger M. 1994. Making recovery pallet-able. *Resource Recycling* 12(11):17-22.

35. Hardin, Peter. 1999. Senate garbage hearing held minus key figures; Governors, Gilmore, Pataki are no-shows; so is a solution. *Richmond Times Dispatch* 6(18):A-12.
36. Hester, R.E. and R.M. Harrison. 1995. *Waste Treatment and Disposal*. Royal Society of Chemistry, London, UK.
37. Highfill, Jannett, and Michael McAsey. 1997. Municipal waste management: recycling and landfill space constraints. *Journal of Urban Economics* 41:118-136.
38. Journal of Soil and Water Conservation. 1996. Municipal solid waste management. *Journal of Soil and Water Conservation* 51(1):6-8
39. Malamud-Koenig, Karen. 1996. New emphasis placed on recycling, not dumping of wood waste. *Wood & Wood Products* 101(6):74-78.
40. Label & Narrow Web Industry. 1999. Avery pallet plan promotes recycling. *Label & Narrow Web industry* 4(6):10-112.
41. Lavendel, Brian. 1996. Recycled wood and plastic composites find markets. *Biocycle* 37(12):39-43.
42. Lindeberg, J.D. 1994. Cost efficient MRF design. *Biocycle* 35(8):66-69.
42. Magnuson, Anne. 1991. What happened to waste reduction? While recycling has captured the public's imagination, reducing the amount of waste reaching municipal landfills still holds bright promise for solving the solid-waste crisis. *American City & County* 106(4):30-35.
44. Maldas, D., and B.V. Kokta. 1990. Effect of recycling on the mechanical properties of wood fiber-polystyrene composites. II. Sawdust as a reinforcing agent. *Polymer-Plastic. Technology. Engineering* 29(5&6):419-454.
45. Marsh, Peter. 1999. National news: pallet makers vie for material benefits: battle is raging over the merits of using wood or plastic to produce this common transport device. *Financial Times London Edition* 7(20):13.
46. Martin, A.M. 1991. *Bioconversion of waste materials to industrial products*. Elsevier Applied Science, London, UK.
47. Modern Plastics International. 1998. Plastics set to take a share of market for wood pallets. *Modern Plastics International* 28(7):76-77.
48. Mullet, Etienne. 1998. Risk perception and energy production. *Human and Ecological Risk Assessment* 4(1):153-175.
49. Murphy, Marry Ellen, and Brian Guzzone. 1995. Wood waste processors turn over a new

- leaf. *World Waste* 38(5):40-43.
50. O'Brien, Kathleen. 1991. Wood waste recycling options. *Biocycle* 32(5):82-86.
51. Officer, Kevin, and Tina Mowry. 1996. Landfill operators get a composting model. *Biocycle* 37(8):42-44.
52. Palmer, Karen, Hilary Sigman, and Margaret Walls. 1997. The cost of reducing municipal solid waste. *Journal of Environmental Economics and Management* 33:128-150.
53. Pavoni, Joseph L., John E. Heer, Jr., and D. Joseph Hagerty. 1975. *Handbook of solid waste disposal*. Van Nostrand Reinhold Company, New York, NY.
54. Petree, Jack. 1996. The wood exchange-true recycling gets most value out of both pallets and ground material. *Pallet Enterprise*. 16(4):77-79.
55. Powell, Jane C., et al. 1996. A lifecycle assessment and economic valuation of recycling. *Journal of Environmental Planning and Management* 39(1):97-112.
56. Rice, R.W. and R.M. Willey. 1995. Higher heating values for pellets made from wood waste and recycled newsprint. *Forest Products Journal* 45(1):84-85.
57. Riggle, David and Gaye Wiekierak. 1995. The big and small of woody materials recycling. *Biocycle* 36(7):53-56.
58. Schwartz, Matt. 1996. Used pallets no longer on skids. *The Christian Science Monitor* 88(181):10.
59. Solid Waste Association of North America and National Renewable Energy Laboratory. 1996. An assessment of management practices of wood and wood-related wastes in the urban environment. NREL AAE-4-14077-01.
60. Steuteville, Robert. 1994. Riding high in the processing industry. *Biocycle* 35(8):58-63.
61. Steuteville, Robert. 1996. Wood diversion strategies. *Biocycle* 37(1):37-39.
62. Tawil, Natalie. 1999. Flow control and rent capture in solid waste management. *Journal of Environmental Economics and Management* 37:183-201.
63. Tchobanoglous, George, Hilary Theisen, and Samuel Vigil. 1993. *Integrated solid waste management: engineering principles and management issues*. McGraw Hill., New York, NY.
64. Timber Wood Products. 1998. Recycling offers cost savings. *Timber Wood Products* 981107, p 2.
65. Turley, William. 1998. Recycling C&D in the fight for landfill space. *World Wastes*

32(11):44-50.

66. United States. Environmental Protection Agency. 2000. Municipal solid waste generation, recycling and disposal in the United States: facts and figures for 1998. Report No. EPA530-F-00-024.
67. United States. Environmental Protection Agency. 1998. Characterization of Municipal Solid Waste in the United States: 1997 Update. Report No. EPA530-R-98-007.
68. United States. Environmental Protection Agency, and Department of Energy. 1995. Environmental, Economic, and Energy Impacts of Material Recovery Facilities. Report No. EPA/600/R-95/125.
69. Wall Street Journal. 1998. As old pallets pile up, critics hammer them as a new eco-menace. CCXXXI(63):A1+.
70. White, Marshall S. and John A. McLeod III. 1989. Properties of shredded wood pallets. Forest Products Journal 39(6):50-54.
71. Wilson, David Gordon, Ed. 1977. Handbook of Solid Waste Management. Van Nostrand Reinhold Company, New York, NY.
72. Witt, Clyde E. 1990. Wooden pallets: disposal, design and distribution. Material Handling Engineering 45(10):71-75.

Appendix A

Questionnaires and Other Correspondence

Study of Wood Pallet Disposal in the United States



Center for Forest Products Marketing and Management
Department of Wood Science and Forest Products
Virginia Polytechnic Institute and State University
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If you have questions, please contact
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Fax: (540) 231-8868
dcorr@vt.edu

*This questionnaire is part of a project designed to better understand the role of wood pallets in the waste stream. The information you provide will be used to help improve the understanding and management of wood waste. Of course, your response is confidential. Only aggregate results will be reported. If you feel that someone else in your organization is better qualified to answer these questions, please feel free to forward the questionnaire to that person. **Thank you for your help.***

1. Does your organization operate and/or manage any type of landfill?

- ☐ No _____ *Please stop here and return the questionnaire. Postage is prepaid.*
- ☐ Yes _____ *Please continue*

2. How many of each of the following types of landfills does your organization operate or manage? (Please write the number next to each type)

- _____ Municipal Solid Waste (MSW) landfill(s)
- _____ Construction and Demolition debris (C&D) landfill(s)
- _____ Other (please specify) _____

Please answer the remaining questions in regard to the Municipal Solid Waste landfill(s) your organization operates or manages. Please ignore other types of landfills or waste disposal facilities for now. Later in the questionnaire we will ask about wood/yard waste recovery (recycling) facilities.

3. In 1998, approximately how much waste (all types) did you receive at your Municipal Solid Waste landfill(s)? What was the average tipping fee for mixed waste at these landfills?

Waste received in 1998 _____ tons

Average tipping Fee _____ \$/ton

4. Approximately how much of the waste received at your landfill(s) in 1998 was wood? (Please provide the percentage for your Municipal Solid Waste facility.)

Wood waste received in 1998 _____ % of total waste

5. Do you accept **wood pallets** at your Municipal Solid Waste facility(s) for landfilling as-is (i.e., without processing such as grinding or chipping)?

☐ Yes _____

Approximately what percentage of the waste landfilled at your MSW facility(s) in 1998 was wood pallets?

(Please estimate as best you can)

Wood pallets: _____% of MSW landfilled

☐ No

☐ We do not operate or manage a MSW landfill

(Please stop here and return the questionnaire. Postage is prepaid)

Now we would like to ask about facilities or areas set aside for recovery of wood/yard waste. Please answer the following questions related to this facility(s). Please answer question 7 even if your organization does not operate or manage a wood/yard waste facility.

6. Do you have the capability to recycle or reuse wood pallets? In other words, does your organization manage or operate a wood/yard waste recovery facility?

☐ No _____

Do you plan to begin recovering pallets for recycling or reuse within the next two years?

☐ Yes

☐ No

Please skip to the last page (question 17)

☐ Yes _____

Please continue

7. In 1998, how much waste did you receive at your wood/yard waste recovery facility(s)?
(Please include waste that was initially received at your MSW landfill(s) but diverted to a wood/yard waste recovery facility)

_____ (tons)

8. In 1998, approximately what percentage of the waste recovered at your wood/yard waste recovery facility(s) was **wood pallets**? *(Please estimate as best you can)*

Wood pallets: _____(% of total waste recovered)

9. If you did not have a wood/yard waste recovery facility, what do you think would have happened to the wood pallets processed there in 1998?

- ☐ Landfilled as is in a MSW landfill
- ☐ Landfilled as is in a C&D landfill
- ☐ Other: _____

10. How has the volume of wood pallets recovered at your wood/yard waste recovery facility(s) changed over the past two years? (Please check one and provide the percentage change)

- ☐ Increased _____ By what percentage? _____%
- ☐ Decreased _____ By what percentage? _____%
- ☐ No change
- ☐ Our wood/yard waste facility has been in operation for fewer than two years

11. In 1998, what was the average tipping fee for wood pallets at your wood/yard waste recovery facility(s)?

_____ \$/ton

12. What was done with the wood pallets you received in 1998 at your wood/yard waste recovery facility(s)? (Please indicate the percentage of total wood pallets received)

- _____ % Given away or sold as is for reuse as pallets
- _____ % Given away or sold as is for fuel
- _____ % Repaired at your facility(s)
- _____ % Ground/chipped at your facility(s) for use as landfill or road cover
- _____ % Ground/chipped at your facility(s) and given away or sold for fuel
- _____ % Ground/chipped at your facility(s) for other uses (e.g., mulch, animal bedding, compost, or soil amendment)
- _____ % Other (please specify) _____

100%

13. If you sell the wood pallets for reuse, what was your average selling price for this material in 1998? *(Please skip this question if you did not sell any pallets for reuse)*

_____ \$ per ton of pallets

_____ \$ per individual pallet

14. If you sell the wood pallets for fuel as-is, in 1998 what was your average selling price?

_____ \$ per ton of pallets

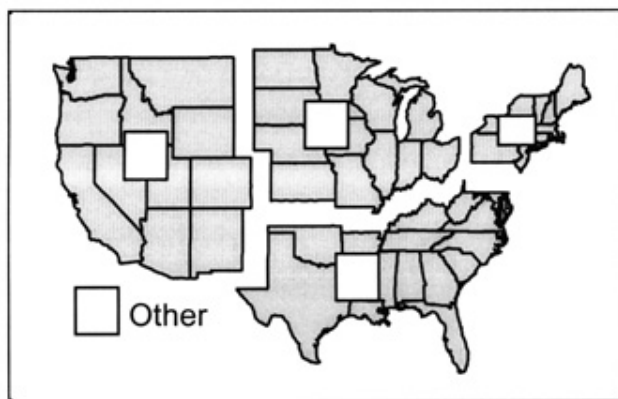
15. If you repair the pallets at your facility, what was your average price for resale in 1998?

_____ \$ per individual pallet

16. If you grind or chip wood pallets, what was your average selling price for this material in 1998? *(Please skip this question if you did not grind or chip wood pallets. If you did not charge for the material, please answer zero)*

_____ \$ per ton of ground or chipped pallets

17. In which region are the majority of your landfills located?
(Please check only one box)



18. **Is there something we should have asked about wood pallets at landfills but did not?**
(Please comment below)

19. **If you would like to receive a summary report of this study, please write your name and address below or attach a business card.**

***Please fold, tape, and return the questionnaire. The postage is prepaid.
Thank you for your help!***

Study of Wood Pallet Disposal in the United States



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Blacksburg, VA 24061-0503

If you have questions, please contact
Daryl Corr
Phone: (540) 231-5876
Fax: (540) 231-8868
dcorr@vt.edu

*This questionnaire is part of a project designed to better understand wood and wood pallets in the waste stream. Information you provide will be used to improve our understanding and management of wood waste. Of course, your response is confidential. Only aggregate results will be reported. If you feel that someone else in your organization is better qualified to answer these questions, please feel free to forward the questionnaire to that person. **Thank you for your help.***

1. Does your organization operate or manage any type of landfill?

- ☐ No —————→ *Please stop here and return the questionnaire. Postage is prepaid.*
- ☐ Yes —————→ *Please continue*

2. How many of each of the following types of landfills does your organization operate or manage? (Please write the number next to each type.)

_____ Construction and Demolition debris (C&D) landfill(s)

_____ Municipal Solid Waste (MSW) landfill(s)

_____ Other (please specify type) _____

3. In 1998, approximately how much waste (all types) did you receive at your Construction and Demolition debris landfill(s)? What was the average tipping fee for mixed waste at your C&D landfills(s)?

Total waste received in 1998: _____ tons

Average tipping fee: _____ \$/ton

- ☐ We do not operate or manage a C&D landfill
(If you checked this box please stop here and return the questionnaire. Otherwise, please continue.)

4. Approximately how much of the waste received at your C&D landfill(s) in 1998 was wood? (Please write the percentage in the space below.)

Wood waste received in 1998 was _____ % of total waste received

5. In 1998, how was the wood waste received at your landfill(s) split among the following categories?

Yard and Land Clearing Wood Debris	_____ %
Residential Construction and Demolition Wood	_____ %
Industrial Construction and Demolition Wood	_____ %
Wood Pallets	_____ %
Other	_____ %

100%

6. Do you accept wood pallets at your Construction and Demolition facility(s) for landfilling as-is ? (That is without processing such as grinding or chipping.)

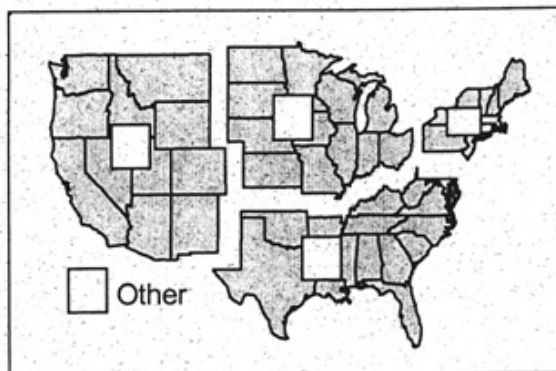
☐ Yes →

☐ No

Approximately what percentage of the total waste landfilled at your C&D facility(s) in 1998 was wood pallets?
(Please estimate as best you can.)

_____ % of landfilled C&D waste

7. In which region are the majority of your landfills located?
(Please check only one box.)



Now we would like to ask about facilities or areas set aside for recovery of construction and demolition waste. When answering, please consider all the C&D facilities which your organization operates or manages. Also, please answer question 8 even if your organization does not operate or manage such a facility.

8. Does your organization operate or manage facilities for the recovery of the following Construction and Demolition materials? If not, do you plan to have such a facility within the next two years?

<u>Material</u>	<u>Operate Now?</u>		<u>Begin in Next Two Years?</u>	
	<u>Yes</u>	<u>No</u>	<u>Yes</u>	<u>No</u>
Wood Pallets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wood (other than pallets)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Concrete	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Asphalt	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Metals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Roofing Materials	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Gypsum Wallboard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Plastics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Brick	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

If your organization does **not** have facilities to recover wood waste, please stop here and return this questionnaire, the postage is prepaid. Otherwise please continue. Thanks.

9. In 1998, how much wood waste did you receive at your construction and demolition waste recovery facility(s) and what was the average tipping fee? (Please include waste that was initially received at your C&D landfill(s) but diverted to a recovery facility.)

_____ tons

_____ \$/ton

10. In 1998, how was the wood waste received at your C&D waste recovery facility(s) split among the following categories? (Please estimate the percentages as best as you can.)

Yard and Land Clearing Wood Debris	_____ %
Residential Construction and Demolition Wood	_____ %
Industrial Construction and Demolition Wood	_____ %
Wood Pallets	_____ %
Other	_____ %

	100%

11. How has the volume of wood pallets recovered at your C&D waste recovery facility(s) changed over the past two years? (Please check one and provide the percentage change.)

- ☐ Increased _____ → By what percentage? _____ %
- ☐ Decreased _____ → By what percentage? _____ %
- ☐ No change
- ☐ Our C&D waste facility has been in operation for fewer than two years

12. What was done with the wood pallets you received in 1998 at your C&D waste recovery facility(s)? (Please indicate the percentage of total wood pallets received.)

_____ %	Given away or sold as-is for reuse as pallets
_____ %	Given away or sold as-is for fuel
_____ %	Repaired at your facility(s)
_____ %	Ground/chipped at your facility(s) for use as landfill or road cover
_____ %	Ground/chipped at your facility(s) and given away or sold for fuel
_____ %	Ground/chipped at your facility(s) for other uses (e.g., mulch, animal bedding, compost, soil amendment)
_____ %	Other (please specify) _____

100%	

13. If you sold recovered pallets or pallet material during 1998, what was the average selling price? (Please skip this question if you did not sell any pallets or pallet material.)

_____ \$/pallet sold for reuse

or

_____ \$/ton pallets sold for reuse

_____ \$/ton of pallets sold as-is for fuel

_____ \$/ton of ground or chipped pallets for fuel

_____ \$/ton of ground or chipped pallets sold for other uses
(e.g., mulch, animal bedding, compost)

_____ \$/ton of pallets sold in other forms

If you would like to receive a summary report of this study, please write your name and address below or attach a business card.

Thank you for your help!



VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

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May 25, 1999

Dear Landfill Operator:

A large number of shipping pallets are produced each year in the United States and many of them are made of wood. Eventually, these pallets are discarded. However, the number of wood pallets reaching solid waste facilities and what is done with them once they arrive is not well understood. Such information is vital in assessing the availability of wood pallet materials for reuse and in planning the management of wood waste.

In 1996, a study similar to this one was conducted by Virginia Tech. Interest in the study was high and the results were presented at several solid waste organization meetings. As a result, some landfill operations have found profitable opportunities for pallet processing.

Much has changed since 1996, we are asking for your help to update the study. Please complete the enclosed questionnaire. Since only a limited number of landfill operations are being contacted, your response to this questionnaire is critical to the success of this study. The questionnaire is relatively short and the questions are easy to answer. For your convenience, the return address is printed on the last page of the questionnaire and the postage is prepaid. You need only fold the form, seal it and drop it in the mail. If your organization does not operate or manage a landfill, please answer the first question and return the questionnaire.

You may notice that the questionnaire has an identification number. This number is used only to remove your name from the mailing list when your response is received. In other words, to avoid bothering you with unnecessary follow-up mailings. All responses are strictly confidential and no individuals or companies will be named in the results. Your response will be reported only in aggregate with those of other respondents.

If you wish to receive a summary of the study results, there is a place on the questionnaire to write your address. Or, you can contact us by mail or telephone to request the results. I would be pleased to forward a copy of the results as soon as they are finished. Should you have any questions about this study, please contact me at (540) 231-5876 or (540) 231-8868 (fax).

Thank you for your help.

Sincerely,

Daryl Corr
Graduate Student
Virginia Tech



VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

CENTER FOR FOREST PRODUCTS
MARKETING AND MANAGEMENT

Department of Wood Science and Forest Products
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dcorr@vt.edu <http://vtwood.forprod.vt.edu/>

June 25, 1999

Dear Landfill Operator:

I am contacting you to ask for your help with the *Study of Wood Pallet Disposal in the United States*. Approximately four weeks ago I sent you a questionnaire and requested your participation in the study. At the current time, I have not received the completed questionnaire from you.

The study is designed to estimate the volume of wood pallets reaching U.S. landfills and the extent of pallet recycling at those landfills. The information you provide will play a vital role in this estimation of pallet quantities. I have been contacting randomly selected waste management facility managers, such as yourself, to gather the information necessary to the completion of this study. Since only a limited number of landfill managers have been contacted your response is critical.

All responses are confidential. The questionnaire is rather brief. Please take a few moments to complete, and return it. The questionnaire provided has the return address printed on the last page, and postage is prepaid. Simply fold it in half, tape it shut and drop it in the mail. If you have already mailed the original questionnaire, please ignore this letter and accept my thanks. If the original questionnaire was somehow misplaced, a second has been included with this letter.

A number has been placed on the front of the questionnaire. This has been done so your name can be removed from any future mailings when your response is received. If you have any questions about this study, please contact me at 540-231-5876 (phone) or 540-231-8868 (facsimile). **Thank you for your help.**

Sincerely,

Daryl Corr
Graduate Student

Encl: Questionnaire

Dear Landfill Operator:

I need your help! Approximately two weeks ago I mailed you a copy of a questionnaire titled "Study of Wood Pallet Disposal in the United States." The questionnaire is designed to gather information about pallets in the solid waste stream, and what is being done with them.

I am contacting you to ask you to complete the questionnaire. If you have returned it, please accept my sincere appreciation. If you have not completed the questionnaire, please take a few minutes now to fill it out.

Your response is critical if the results of the study are to be accurate. The information you provide is strictly confidential. The number on the questionnaire is used only to remove your name from future mailings. If you have any questions, please contact me at 540-231-5876. Our fax number is 540-231-8868. Thank you in advance for your participation.

Sincerely

Daryl Corr
Graduate Student
Virginia Tech

Appendix B

Non-Response Questions

Person Contacted_____

Phone #_____

1. Do you operate a municipal solid waste landfill? Yes No

1. If yes, how many?_____

2. How many tons of total waste did you receive in 1998?_____

3. What was your average tipping fee in 1998 per ton?_____

4. Do you accept wood pallets at your landfill? Yes No

5. Please estimate the quantity of wood pallets received at your MSW facility in 1998. _____

6. Do you have the capability to recover wood pallets? Yes No

7. Do you plan to begin recovering wood pallets within the next 2 years? Yes No

Appendix C

Calculation Explanations

Note for this section. All population estimates were determined by summing regional estimates. All calculations were also done in SPSS. All examples

1. Average waste per landfill. The total waste received per questionnaire was divided by the number of landfills reported on that questionnaire and the output was placed in a new column. This was done for all questionnaires and the average waste was computed from the new column.
2. Total waste was determined by multiplying the estimate of average waste per landfill in each region by the number of landfills in that region. The regional estimates of landfills can be found in are for C&D and MSW.
3. Average tipping fees were determined by averaging all tipping fee responses.
4. Average percent wood waste was determined by averaging all responses for percent wood waste received.
5. Estimates for wood waste received were determined by multiplying the percentage reported by individual landfills by the total waste reported for that landfill and placing the response in a new column. The new column was then averaged to get an estimate of the average wood waste received per landfill.
6. Estimates of percentage of landfills that accept wood pallets for disposal were determined by assigning a 1 to all respondents that did accept pallets and a 2 to all respondents that did not accept pallets. It was then determined what percentage of the time 1's appeared to determine the percentage of landfills accepting wood pallets for disposal.
7. Average percent of waste that was pallets was determined by averaging all responses for percent of total waste that pallets represented.
8. Estimates for total pallets received were determined by multiplying the percent pallets received for each landfill by the total waste received for that landfill and placing the output in a new column. The new column was then averaged to get the tonnage of pallets received per landfill by region. This number was then multiplied by the number of landfills in the same region to get an estimate of the tonnage of pallets received per region. The tonnage by region was then summed to get the total tonnage estimate for pallets received nationwide. Tonnage estimates were multiplied by 2000 to get pound estimates, and divided by 55 lb. (the average pallet weight) to get an estimate of total pallets received by landfills.
9. Average wood waste received at recovery facilities was determined by dividing the tonnage of wood response by the number of landfills for the same questionnaire and placing the output in a new column. The new column was then averaged to get the estimate of wood waste recovered per recovery facility.
10. Total wood waste recovery was determined by first estimating the number of landfills with the ability to recover wood waste. This was arrived at by multiplying the percent of landfills in each region that had the ability to recover wood by the estimated number of landfills in that region. The average wood

waste recovered per facility in each region was then multiplied by the number of facilities with the ability to recover in that region to determine the total wood waste recovered in that region. Regional estimates were summed to get a nationwide estimate.

11. Tipping fees for sorted loads at recovery facilities were estimated identically to standard tipping fees.
12. When comparing tipping fees for sorted loads to tipping fees for standard loads, this was only done on a landfill by landfill basis. Only landfills responding to both tipping fee questions were compared to each other.
13. To determine the average percent of landfills that had the ability to recover wood pallets a 1 was assigned to all respondents that could recover pallets and a 2 was assigned to all respondents that could not recover wood pallets. The percentage of 1's was then used to determine the percentage of landfills that could recover wood pallets.
14. The percentage of landfills that did not recover wood pallets but planned too within two years was done in the same manner as the percent of landfills that could recover wood pallets.
15. The percentage of pallet waste recovered was determined by averaging the responses for average pallet waste received at recovery facilities.
16. The tonnage of pallets recovered per facility was determined by multiplying the percent pallet waste by the total tonnage of waste recovered by each landfill and placing the output in a new column. The new column was then averaged to determine the average tonnage of pallet waste recovered by each recovery facility.
17. The total tonnage of pallet waste recovered was determined by multiplying the average pallet waste recovered per recovery facility in each region by the estimated number of recovery facilities in each region. All regional estimates were summed to get an overall estimate.
18. Tonnage of pallets recovered were multiplied by 2000 lb/ton and divided by 55 lb/pallet to get an estimate of the total pallets recovered.
19. The percentage of recovery facilities reporting changes in pallet volume recovered in the past two years was determined by assigning a 1 to all respondents reporting an increase, a 2 to all respondents reporting a decrease, a 3 to all respondents reporting no change, and a 4 to all respondents reporting they had not operated a recovery facility for two or more years. Percentages of 1's, 2's, 3's, and 4's were then used to determine percentages of facilities that increased, decreased or had no change in the number of pallets recovered in the past two years.
20. Each facility that reported an increase or decrease also reported the percentage change. This percentage change was simply averaged for the increasers and decreasers.
21. How the recovered pallets were used was simply determined by averaging the reported percentages for each use.
22. Monetary returns for recovered pallets were determined by averaging the responses for each type of recovered pallet use and the associated return.

Vita

Daryl T. Corr

Daryl Corr, son of Warren and Sheryl Corr, was born in Winston Salem, North Carolina on December 28, 1973. He was raised in Reston, Virginia where he graduated from South Lakes high school in 1992. He earned a B.S. in forestry from Virginia Tech in May of 1998. In June of 2000, he completed the requirements for an M.S. in Wood Science at Virginia Tech with a focus in forest products marketing. Daryl is currently finalizing his plans to take over the world.