Recycling Climate and Markets for the Sandhills Region in NC

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ABSTRACT:

This project was undertaken in an effort to assist Fort Bragg in attaining the goal of zero landfill waste by the year 2025. This report addresses the feasibility for recycling not only at Fort Bragg but also in consortium with its neighbors in the Sandhills Region. The counties surrounding Fort Bragg have minimal recycling at this point with two counties have curbside pickup and other counties rely on drop-off sites. A successful MSW recycling facility would require the cooperation of The City of Fayetteville and Cumberland County as a minimum, with the best option being a six county regional Material Recovery Facility (MRF). This analysis shows that all counties would save money by sending their waste to a proposed regional MRF in Cumberland County. Construction and Demolition (C&D) and Land Clearing and Inert Debris (LCID) recycling facilities do not presently exist. Economically, LCID at Fort Bragg could potentially support itself without the need for participation with other communities. Significant landfill waste reduction could be achieved with the reduction of C&D and LCID wastes. The amount of C&D and LCID wastes is high, but will decline with completion of construction projects at Fort Bragg in ten years. MSW recycling will then have a greater impact on waste reduction.

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Conversion Factors

Non-SI* units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
Acres	4,046.873	Square meters
Cubic feet	0.02831685	Cubic meters
Cubic inches	0.00001638706	Cubic meters
Degrees (angle)	0.01745329	Radians
Degrees Fahrenheit	(5/9) x (°F – 32)	Degrees Celsius
Degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	Kelvin’s
Feet	0.3048	Meters
Gallons (U.S. liquid)	0.003785412	Cubic meters
Horsepower (550 ft-lb force per second)	745.6999	Watts
Inches	0.0254	Meters
Kips per square foot	47.88026	Kilopascals
Kips per square inch	6.894757	Megapascals
Miles (U.S. statute)	1.609347	Kilometers
Pounds (force)	4.448222	Nektons
Pounds (force) per square inch	0.006894757	Megapascals
Pounds (mass)	0.4535924	Kilograms
Square feet	0.09290304	Square meters
Square miles	2,589,998	Square meters
Tons (force)	8,896.443	Newtons
Tons (2,000 pounds, mass)	907.1847	Kilograms
Yards	0.9144	Meters

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* *Système International d’Unités* (“International System of Measurement”), commonly known as the “metric system.”

1 Introduction

Background

The public and private sectors in the United States have come to realize the importance of addressing the long-term consequences of solid waste management. A combination of limited resources and the need to care for the environment has fostered the development of integrated solid waste management (ISWM). The concept of ISWM includes waste reduction, recycling, conversion of the waste and the use of landfilling. Developing the correct hierarchy of these concepts can allow the design of a system that is acceptable for a given condition (Tchobanaglous et al, 1993).

The size of Fort Bragg allows it to be treated as an independent municipality with respect to solid waste generation. With a total population of 180,000 that either work and/or live on the facility and the range of work environments that are encompassed at the facility, the solid waste produced is representative of a typical municipality. Due to the extensive rehabilitation to the facility, the Construction and Demolition (C&D) waste is considerably higher than typical. The approximate makeup of the waste generated onsite is 4% MSW, 32% C&D, and 62% Land Clearing Inert Debris (LCID) (Weston, 2003).

Waste management at Fort Bragg must incorporate federal and state guidelines including Department of Defense (DoD), Army Regulations and Policies, as well as Fort Bragg's own goals for their facility. Additional requirements include several Executive Orders (EOs) which include EO 12780 designed to encourage Federal agencies to exercise waste reduction and recycling, EO 13101 requires agencies to incorporate waste reduction and recycling into daily activities, and EO 13148 listing goals for pollution prevention. In addition to these EOs a memorandum from the Office of the Under Secretary of Defense requires that by the end of 2005 that there would be a diversion rate of 40% (Weston, 2003). Fort Bragg's own environmental sustainability goal stated "The goal is to map out a new vision for the management of our installations, a holistic approach to sustaining our installations well into the 21st Century while simultaneously fostering transformation…", (Fort Bragg Strategic Environmental Plan, June 2001). Attainment of this goal will require addressing all available recycling routes as well as their feasibility and potential costs.

Objective

Fort Bragg is evaluating sustainable practices for their facility. The aspect of sustainability addressed in this report is the goal of zero landfill waste by 2025. To reach such an impressive goal the basics must be covered: reduce, reuse, and recycle. This report will focus on the following tasks:

- Analyze the current recycling climate and markets for the Sandhills region in North Carolina. This includes analysis of both county municipality levels.
- Evaluate and describe the existing recycling facilities available in each county and municipality
- Make recommendations for the overall recycling efforts of this region

Approach

There are four types of landfills permitted in the State of North Carolina. They are Municipal Solid Waste (MSW), Construction and Demolition (C&D), Land Clearing and Inert Debris (LCID), and Industrial (p2pays.org, July 2003). Recycling options will be assessed by each specific type of waste and the respective type of landfill. Industrial waste will not be addressed. The three general classifications of waste that will be addressed in this report will include the MSW, C&D and LCID. MSW will be defined for this report as waste material from residential, commercial, and institutional facilities. C&D is waste generated from the construction and demolition of roads and buildings. LCID includes material from the clearing and grading of land.

A survey of existing landfills and recycling facilities was conducted for a six county region. After this information was obtained the waste streams and quantities from MSW, LCID, and C&D wastes were obtained from the six counties and Fort Bragg. Possible synergies with the six counties and Fort Bragg were evaluated for each waste category. Synergies were evaluated with Fort Bragg being isolated and grouped in combination with its neighbors. Once a beneficial situation was identified market assessments were completed for specific waste streams to determine the economic feasibility of recycling. Where applicable, capital costs and operating costs were then combined to determine the total net gain or loss for each waste category.

2 Current Practices

Background

This study evaluates the potential of recycling Municipal Solid Waste (MSW), Land Clearing and Inert Debris waste (LCID) and Construction and Demolition waste (C&D). MSW waste is a very diverse classification including, residential, commercial and institutional waste. Residential facilities are single and multi-family dwellings, as well as high-rise apartments and dormitory style housing. Residential waste typically includes paper, aluminum cans, ferrous materials, glass, wood, and yard waste. Commercial waste is produced from stores, office buildings, restaurants and other businessses. These commercial facilities can produce waste that includes paper, cardboard, glass, metals and food waste. Institutional waste includes waste generated from schools and hospitals. The waste material from these would resemble the waste from commercial facilities. The waste generated from residential, commercial, and institutional sites are very similar, with the biggest differences being in the percentages of each type of waste (Tchobanaglous et al, 1993).

C&D waste is generated from construction and demolition of roads and buildings. The general types of C&D waste are soil, wood, steel, concrete, and other waste materials expected from a construction site. LCID waste is generated from the clearing and grading of a site and includes stumps, soil, gravel, clay, and rocks (Chang and Cramer, 2003).

Based on Weston's (2003) report 627,722 tons of solid waste were produced at Fort Bragg consisting of 4% MSW, 32% C&D debris, and 62% LCID. The total waste generation for Fort Bragg has increased by 250% in the last seven years. This increase has been due to the large amount of onsite construction.

Fort Bragg's current recycling on site includes curbside recycling programs, concrete grinding, and re-use of excavated dirt (Weston, 2003). As seen in Table 1 in FY 2002 less than 4% of the total waste generated onsite was sent to a MSW landfill. 20% of the waste generated was received at a LCID landfill, and approximately 17% of the waste was transferred to a C&D facility. This indicates that almost 60% by weight of the waste was successfully recycled. Previous data shows that C&D waste made up 32% of the waste generated onsite therefore, successful recycling of C&D waste has allowed the facility to meet the goal of 40% diversion. The remaining steps to achieve the goal of 100% diversion by the year 2025 must now be determined.

Table 1. Waste Generation and Disposal at Fort Bragg, FY 2002 (Weston, 2003)

Waste Type	Ton	% of Waste
Uwharrie MSW Landfill	25,255	3.65%
LCID Landfill	139,173	20.13%
C&D Landfill	116,827	16.90%
Diverted Waste	409,970	59.31%
Total Waste	691,225	100.00%

Recycling Waste Streams

Residential Waste

Residential waste at Fort Bragg is collected from 5,000 single and multi-family dwellings along with permanent and temporary barracks housing 11,000 unaccompanied soldiers. In FY02 25,255 tons of MSW waste were collected for disposal at Uwharrie Environmental Landfill. Of this 5,361 tons were from Army Family Housing and 19,894 tons came from troop facilities. Currently recycled materials include paper, cardboard, plastic containers and aluminum cans. Yard waste is collected and sent to a LCID landfills while the other materials in the waste stream are sent to an on-site transfer station and then to the Uwharrie Landfill. Fort Bragg family housing and Pope AFB family housing residents currently report a 26% average participation in the recycling program. In FY02 this came to 275 tons of recyclables collected from Fort Bragg housing and 215 tons of recyclables collected from Pope AFB housing. This equates to 8% of MSW generated in family housing (490 tons out of 5361 tons) and equals 2% of total MSW landfilled by the installation (490 tons out of 25,255 tons). To try to increase this in the future incentives in the form of housing awards will be given to neighborhoods which meet a 50% participation rate. With a 50% participation rate the total recyclables collected from both Fort Bragg and Pope AFB housing would be 942 tons or a 3.7% rate by installation (Weston, 2003).

Using the current housing participation rate of 26%, the recyclables collected would be 2,042 tons/yr for Army Family Housing (AFH) residents at a capture rate of 35%. A participation rate of 50% would result in 3,926 tons of residential MSW to be diverted from the landfill. This rate would equal a total diversion of 67% of residential MSW from the landfill (Weston, 2003).

LCID Waste

Land Clearing and Inert Debris (LCID) waste includes yard waste as well as land clearing debris generated by civilian, military personnel, and contractors. During FY02 Fort Bragg generated a total of 476,393 tons of LCID waste. Of this 330,000 tons were attributed to dirt that was diverted from landfill disposal by re-use on various projects on post. The remaining 146,393 tons (number from pg 26 of Weston 2003) were disposed of in the LCID landfill in FY02.

In theory yard trimmings, food, wood and other organics collected and disposed of in landfills could be diverted instead to composting programs. Composting is a controlled biological process suitable for decomposable organic wastes and other materials. Decomposition occurs in the presence of microorganisms and invertebrate animals. Organic compostable materials comprise a large portion of the MSW waste stream and if diverted these materials from disposal could provide beneficial reuse also conserve landfill space.

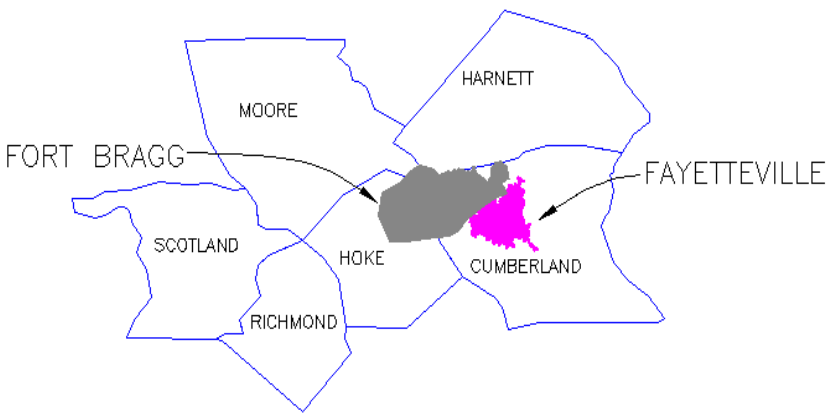
C&D Waste

Construction and Demolition (C&D) waste can be defined as the waste that is produced during the renovation, construction or demolition of facilities. In some states this also includes what is identified as LCID. Under typical conditions C&D waste will represent about 14% of a waste stream (Tchobanoglous et al, 1993). At the Fort Bragg facility construction has caused the C&D waste produced to reach 32% of the waste stream or 221,192 tons of waste in FY02. Recycling of concrete has increased the percentage by weight of recycled material on post to 59% in FY02 (Weston, 2003). Additional increases in the percentage of recycled C&D wastes are possible and would greatly assist Fort Bragg in reaching the goal of 100%. Currently the C&D waste not recycled is typically sent to the Fort Bragg C&D Landfill on Lamont Rd.

3 Existing Practices in the Sandhills Region/ Six Counties

This section evaluates existing conditions and current practices in the Sandhills region. Additionally the potential for increasing participation in recycling programs is addressed

Figure1. Map Showing the Existing Counties in Sandhills Region



It can be seen in Figure 1 that there are six counties that surround Fort Bragg. These include Cumberland, Harnett, Hoke, Moore, Richmond and Scotland counties. Major municipalities within this area include Fayetteville, Southern Pines, Laurinburg, Rockingham, Dunn, as well as others. A review of the six counties and the larger municipalities are included below.

Cumberland County

Cumberland County lies in the southeastern part of the state of North Carolina bounded by Harnett, Sampson, Bladen, Robeson, and Hoke Counties. Fayetteville is the biggest city in Cumberland County.

Cumberland County encompasses approximately 661 square miles and in the year 2001 had a population of 302,965. In the last fiscal year the county generated 403,473 tons of waste. This waste was comprised of 71% residential, 18%

commercial, and 3% C&D. 130,000 tons of MSW was disposed in the county's MSW landfill, 94,784 tons were disposed in the Sampson's MSW landfill, and the remaining 61,684 tons were sent to Uwharrie Environmental Inc in Montgomery County for disposal. A lot of the waste generated in the county is sent to other counties for disposal by private haulers because separation is not required (Cumberland County Solid Waste Division, 2003). LCID landfill waste is split between private permitted landfills and the county's Yard Waste Facility for mulching. From Table 2 below the amount of mulched waste is 27,652 tons. There are 17 drop-off centers for waste and recyclables distributed throughout the county. The county doesn't provide waste pickup from the households and waste disposal centers accept trash and most of the recyclables for $48 per household per year for the county residents. These centers also support the waste exchange/reuse program for items such as paint, and automotive parts. Last year the centers collected 16,000 tons of recyclables on a voluntary basis. The Town of Linden is the only municipality that has a formal recycling program (Cumberland County Solid Waste Division, 2003). Table 2 provides the tonnages of recycled materials from Cumberland County. Table 3 contains a collected waste breakdown for the county. MSW waste is a significant portion of what is collected in Cumberland County representing 286,368 tons or approximately 71% of the total waste.

Generally there is no great demand for the recyclables in the area. There is no MRF in the county, but there are several recycling businesses that collect recycling materials such as newsprint, cardboard, mixed plastics, aluminum cans, and other metals (Cumberland County Solid Waste Division, 2003). These businesses would not provide recycled material sales information.

Table 2. Quantity of Wastes Collected for Recycling in Cumberland County 02/03

Type	Quantity (tons)
Aluminum Cans	7.32
Cardboard	16.82
Newsprint	3.13
White Goods	1,212.40
Other Metal	704.36
Magazines	1.28

Pallets	686.26
Textiles	36.94
Used Oil	12,500 (gallons)
Antifreeze	750 (gallons)
Batteries	3327 (units)
Wood waste (mulched)	27,652

Source: Smith, D. 2003

Table 3. Quantity of Waste Collected in Cumberland County

Type	Quantity (tons)
MSW	286,368
Construction & Demolition waste	12,104
Commercial	72,625
Yard waste	27,652
Recyclables	16,000

Hoke County

Hoke County lies in the southeastern part of the state of North Carolina and is bounded by Cumberland, Harnett, Moore, Robeson, and Scotland counties. Rae-ford is the biggest city in the county. The county has an area of 391 square miles and a population of 34,906 as of 2001.

In FY 01/02 the county generated 21,457 tons of solid waste. Of this waste, 45% was from residential source, 10% from commercial, 5% industrial and remaining 40% was construction and demolition waste. The county doesn't offer pick-up service from the houses and the residents have to take their own waste to one of six available locations in the county. Residents are allowed to dump up to five bags of wastes at a time and for additional bags a charge is assessed. Residential waste is collected by county and private haulers whereas commercial and industrial are hauled by private haulers only. The cost involved in solid waste collection and disposal is $ 59.26 / ton. Yard waste is accepted free of charge from each household once a week. More frequent disposal is charged $19.00 a ton. All collected wastes and recyclables are sent to the county transfer station where it is reloaded in large trucks and sent to Uwharrie Environmental regular landfill in Troy, NC in Montgomery County. C&D disposal is free for Hoke County residents, but commercial businesses C&D waste is charged at a rate of $19.00/ton. (Hoke County Website, 2003). All the C&D waste is disposed in the Uwharrie Environmental facility, Montgomery County.

The county collected 10.40 tons of aluminum cans, 320 tons of white goods, 329.6 tons of other metals, 25.5 tons of newsprint, 91.6 tons of cardboard, 700 gal of used oil, and lead acid batteries comprising 777.10 tons for FY 00/01. LCID waste was taken to a LCID grinding point at the county's transfer station site. (Hickman, 2003)

Moore County

Moore County is located in the south central part of North Carolina bounded by Randolph, Chatham, Lee, Harnett, Cumberland, Hoke, Richmond and Montgomery Counties. The County has a total area of 705.23 square miles and a population of 77,935 in 2001. Southern Pines and Carthage are Moore County's largest towns.

The county has six waste and recyclables drop-off centers within the county. Aluminum (15.89 tons), glass (120.19 tons), cardboard (228.26 tons), newspapers (332.19 tons), magazines (105.91 tons), white goods, metal (1240.14 tons), and mixed paper (41.49 tons) are the recyclable materials collected. No plastics are recycled. Roughly 88,500 tons of solid waste were generated in the county in 2001/02. Out of this waste only 26,675 tons were landfilled in the county's C&D landfill. The county's transfer station reloaded 57,166 tons of MSW to Uwharrie landfill and only 1,624 tons were sent to the Uwharrie MRF for recycling (Moore County Website, 2003). Aluminum cans, cardboard, glass, and mixed paper are collected by Wagram Paper Stock using county trucks. The county gets paid for the aluminum cans and cardboard based on the market price. Similarly, Sandhills Recycling Inc. pays the county for white goods and metals collected at the county C&D landfill (Boles, 2003). Furthermore, Raleigh News and Observer

Recycling Inc. operates drop-off centers in the county and collects newspapers and magazines at no cost to the county.

Southern Pines

The City of Southern Pines has one recycling drop-off center. They collect newspaper (32.19 tons), magazines (9.37 tons), cardboard (5.2 tons), aluminum cans, tin cans, PET and HDPE plastics (combined at 7.75 tons). The newspapers and magazines are collected by Raleigh News and Observer Recycling, Inc. All other recyclables are handled by Waste Management. Waste Management charges $30/ton for pickup with additional costs for transportation. The other recyclables are collected commingled and are sent to Uwharrie Environmental, Inc., at a cost of $30 / ton (Teague, 2003).

Harnett County

Harnett County is located in the central part of the State of North Carolina bounded by Lee, Chatham, Wake, Johnston, Sampson, Cumberland and Moore Counties. The County has a total area of 601.18 square miles, and a population of 96,153 persons as of year 2002. The largest towns in the county are Dunn and Lillington.

The county generated a total waste of 72,126 tons in FY02. Out of this waste 25,359 tons were C&D waste. This was disposed at Harnett County C&D Landfill (CDLF) and Harnett County Anderson Creek C&D Landfill. The remaining 46,592 tons were municipal solid waste which was sent to the county's transfer station and hauled to Uwharrie Environmental Inc. There is no formal recycling program in place in the county, but there are recycling collection points for newspapers and magazines from which Raleigh News and Observer Recycling Inc., collects at no cost. The landfill has separate collection bins for glass, aluminum cans, white goods, scrap metals, batteries, newspapers and magazines. The Raleigh News and Observer Recycling Inc, handles the newspaper and magazines at no cost to the county. Republic Waste Services Inc. charges the county to collect the other recyclables. White goods, scrap metals, and aluminum recycled in FY02 were 272.49 tons, newspapers had 38.20tons, magazines 5.57tons, and batteries 463 units (Blanchard, 2003).

Richmond County

Richmond County is located in the south central section of the State of North Carolina and is bounded by Anson, Stanly, Montgomery, Moore, Hoke, Scotland Counties and the State of South Carolina. It has a population of 46,991 and an area of 479.52 square miles. The largest city in the county is Rockingham.

The County has four drop-off centers with an attendant in each center to make sure that the law is enforced. There is a container for each type of recyclable. The drop-off centers accept aluminum and steel cans, brown, amber, and green glass, all types of paper, and white goods. When the container is full it is sent to the county's transfer station where and the wastes is reloaded and hauled to Uwharrie Environmental facility in Montgomery County for recycling. Wastes are picked up from the cities of Rockingham, Ellerbe, Hamlet and Hoffman. In the FY 01/02 the county generated 43,000 tons of waste, 3,000 tons of which are collected recyclables sent to Uwharrie MRF. Collected recyclables are well separated at the drop-off centers, but upon arrival at the transfer station the waste is dumped along with the garbage and the recyclables are easily contaminated. Improved housekeeping at county's transfer station would allow more than 65% of the waste could be separated versus 18%, which is the current recycling rate. The city of Rockingham, the largest city in the county, has no current practices for recycling. Table 4 illustrates the breakdown of recycled material in the county (Clyde Smith, 2003). This table shows that approximately 7% of what is received at Uwharrie Environmental Inc. from this county is successfully recycled. The total amount successfully recycled is made up mostly of old corrugated cardboard (OCC).

Table 4. Tonnage Report for Recyclable for Richmond County FY 02/03

Tons Received	Paper	Corrugated Cardboard	Steel Cans	Aluminum cans	Plastics	Scrap	Total
3702.58	2.63	258.63	0.28	4.06	1.54	6.29	273.43

Scotland County

Scotland County is located in Southeastern part of North Carolina adjacent to the South Carolina line and bounded by Richmond, Moore, Hoke, and Robeson counties. The population of this county in 2002 was more than 35,000 with nearly half of them living in Laurinburg, the largest city in the county. The other large cities and towns in the county are Gibson, Wagram, East Laurinburg and Maxton.

The waste generated in FY02/03 was approximately 52,000 tons. About 45 % of this waste is C&D waste which is disposed of at the county landfill. The remaining wastes are shipped to the transfer station in the county. From the transfer station roughly six trucks with a capacity of 20-23 tons of waste are shipped daily to the Uwharrie Environmental facility. The cost involved in the transportation of the waste from the county's transfer station to the Uwharrie facility is $35/ton.

Scotland County has five recycling drop-off centers serving more than 5,700 households in the county. The centers accept most of the recyclable material at no charge and garbage at very low cost. The recycling program only costs the county the attendant's salary. Residents drop-off their waste at these centers and Wagram Paper Stock, Inc. picks the recyclables using its own trucks at no charge to the county. According to Mr. Steve Edge, Scotland County Solid Waste Management director, due to the current value for recycled material they do not receive any revenue for the material they collect. The total quantity collected for recycling from the five centers in the county in the FY 02/03 is 1,477 tons (Edge, 2003). Table 5 presents the breakdown of the collected recyclables in Scotland County for the year 2002/03 (Scotland County, 2003). Metals, cardboard and papers contribute significantly to the total recycled amount.

Table5. Breakdown for the Collected Recyclables in Scotland County in FY 02/03

Program	Tons
PET	7.10
HPDE	8.00
Aluminum cans	4.29
Steel Cans	8.80
White goods	217.08
Other metals	369.00
Cardboard	110.60

Mixed paper	753.00
Total	1,477.87

Source: Scotland County Solid Waste Management Annual Report 2002-2003

City of Laurinburg:

The City of Laurinburg is Scotland County's largest city. The city does curbside collection for recyclable materials once a week. The recyclables are placed in separate bins in the truck and sorted in a small material recovery center in the city from where they are sold directly to markets. Items collected are newspapers, cardboard, plastics, milk jugs, aluminum and steel cans, green, clear and brown glass. In the FY 01/02 the city collected a total amount of 664 tons of recyclables. Table 6 shows the prices paid to the City of Laurinburg for the processed recyclable material.

Table 6. Prices of Processed Recycled Material at the City of Laurinburg, Scotland County

Material	Quantity (tons)	Price
Green Glass	4.00	$12/ton
Clear glass		$22/ton
Brown glass	6.00	$12/ton
Steel Cans	5.00	$30/ton
Aluminum Cans	3.00	Not sold recently but the price is $0.45/lb
Other Metals	187.00	
Soft drink bottles	7.00	$0.10/lb
HDPE (Milk Jugs)	8.00	$0.08-0.10/lb
Newspapers	135.00	$55/ton
Cardboard	91.86	$50/ton

Source: Scotland County records, solid waste management director

Summary of the Sandhills Area

Almost all of the studied counties sent their MSW to Uwharrie Environmental facilities in Montgomery County, Chamber Development's MSW landfill, and Sampson County's MSW landfill. Cumberland, Richmond, and Moore send their recyclable waste to the Uwharrie MRF at a cost of $30-$37/ton and an average transportation cost of $35/ton totalling almost $70/ton for disposal of their recyclables. The quantity of the recyclable waste generated in the area is about 22,820 tons per year. Table 7 summarizes recyclable material for each county in the Sandhills Region.

Table 7. Quantity of Recyclables Produced in the Sandhills Area for FY 02

County	Quantity recycled (tons)
Cumberland	16,000
Harnett	4,600
Hoke	1,700
Richmond	3,720
Scotland	1,477
Moore	1624
Total	22,821

4 Recycling of MSW Waste

MSW waste as defined in this report consists of residential, commercial and institutional waste. Residential facilities are single and multifamily dwellings as well as high rise apartments/dormitories. The types of solid waste that can be expected from these residential facilities include: food, paper, aluminum cans, ferrous materials, glass, wood, plastics, etc. Commercial waste is waste generated from stores, office buildings, restaurants, as well as other facilities. Commercial facilities produce waste that includes paper, cardboard, glass, metals, etc. Institutional waste include waste generated from schools and hospitals. The waste generated from residential, commercial, and industrial sites are with the biggest differences being the relative proportion of each type of waste (Tchobanaglous et al, 1993). The information on typical waste streams presented in this section was obtained from the “1998 North Carolina Market Assessment of the Recycling Industry and Recyclable Materials”.

The price of recyclables varies greatly depending on the market demand. The following websites contain information on current pricing of recyclables. It is important to remember that pricing can change on a daily or sometimes hourly basis.

Websites that list market prices of recyclables include:
- recyclingmarkets.net
- ncwastetrader.org
- americanreycler.com
- epa.gov/wastewise/wrr/br-links.htm
- redo.org,
- recycleexchange.com
- surplusexchange.org
- commodities.wm.com/wmx/exchange.nsf.

Typical Waste Stream

PET Plastic

One of the most popular resins used by the plastics industry is PET (polyethylene terephthalate also known as polyester). It is extensively used in different variety of applications e.g. plastic soda bottle. It is heavily used as polyester fiber in the manufacturing of clothing and carpeting. PET usage has grown rapidly due to the growth of soft drink container business recycled. The single-serve container is the fastest growing market for PET bottles.

Table 8 provides EPA estimates for PET generation in the United States and the share of North Carolina generation. North Carolina estimates are based on 2.78% of the United States population and that population should be directly proportional to PET usage. Because generation varies state-to-state North Carolina figures should be considered as rough estimates.

Soft drink bottles represent more than 40 % of the PET generated in United States. Recovery would therefore target the largest portion of generated PET. Plastics industry studies have shown that the use of PET for making containers is growing dramatically. Table 9 demonstrates the rapid increase in PET bottle sales between 1994 and 1996 and shows the national recovery estimates for PET. During the early 1990s PET container recovery increased dramatically before suffering a severe decline in 1996.

Table 8. PET Generation (tons) in the United States and North Carolina (1996)(NCDENR, 1998)

Product Category	Estimated United States Generation	Estimated North Carolina Share
Durable goods	340,000	9,500
Non-durable goods	180,000	5,000
Soft drink bottles	680,000	18,900
Other plastic containers	390,000	10,800
Other plastics packaging	110,000	3,100
Total Generated PET	1,700,000	47,300

Table 9. National PET Bottle Sales and Recovery (tons)

	1994	1995	1996
Sales	837,000	975,000	1,099,900

Recovery	282,500	311,000	286,000
Recovery Rate	34%	32%	26%

In North Carolina recovered PET bottles are the primary source of PET recovery. Some municipalities in North Carolina stopped or slowed collection efforts due to low market prices. Most of the recovered PET material was recovered through local government programs. The contribution of the private sector in North Carolina for PET bottles recovery was very small. Table 10 shows the different product categories from which PET is recycled in North Carolina. The majority of PET generation is derived from soft drink bottles and plastic packaging. The 2002 generation amounts for PET are based on a 10% average increase over the 1996 numbers.

Table 10. PET Generation (tons) for North Carolina

Product Category	1996 North Carolina	Estimated 2002 North Carolina
Durable goods	9,500	16,800
Non-durable goods	5,000	8,900
Soft drink bottles and other containers	29,700	52,600
Other plastic containers	3,100	5,500
Other plastics packaging	47,300	83,800

Price and capacity are the main elements of PET market dynamics. They are very sensitive to fluctuations in virgin and off-spec markets. These fluctuations are directly related to international economic conditions and supply/demand balances. Recycled PET markets declined sharply from $354 per ton in 1995 to between $40 and $80 per ton in 1996. The reason for this severe decline was due the high increase in virgin capacity. In early 1998 prices remained steady or rose slightly. Markets have also expanded to match the large excess virgin capacities that appeared between 1997 and 1998. PET waste generation is also increasing due to the share of the PET in the packaging market. Table 11 illustrates the amount of PET recovered by local governments in North Carolina between 1992 and 1997. There has been a general increase over time in the amounts of PET recycled. Table 12 shows the generation and recovery rate for PET in 1996 with an estimated generation of 30,600 tons and a recovery rate of 24% or 7,342 tons.

Table 11. North Carolina Local Government Recovery of PET (tons)

	FY 1992-93	FY 1993-94	FY 1994-95	FY 1995-96	FY 1996-97
PET	4,857	5,308	6,883	9,660	7,342

Table 12. North Carolina PET Generation and Recovery Estimates for 1996

Estimated Generation	30,600 tons
Recovery	7,342 tons
Recovery Rate	24%

Table 13 shows the PET plastic recycling demand. End users for recovered PET may include engineered resins, fiber, food and beverage containers, non-food containers, sheet, film, and strapping.

The market and price for recycled plastics are affected by the demand of the plastics industry to use the recycled resin. The use of recycled plastics becomes favorable when the recycled PET market strengthens as a result of raw resin cost being higher than the price of off-spec resin. Table 14 presents estimates of the recycled resin demand in each of these categories for 1996 and 1997 (NCDENR 1998). The largest percentage increase was in the use of recycled resin in food and beverage containers. The largest percentage drop in use was related to the export of recycled resin.

Table 13. Demand for Recycled PET to 2005

	Recycled PET demand (tons)	Percentage growth from previous year	Overall virgin plastic demand (1000 tons)	Recycled PET to virgin plastic % demand
1985	50,000	NA	22,100	0.22%
1989	90,000	80%	26,900	0.33%
1995	262,500	192%	35,550	0.73%

2000	450,000	71%	41,800	1.07%
2005	725,000	61%	48,300	1.50%

Table 14. Recycled PET Consumption (tons)

End Use	1996	1997	Percent Change
Engineered resins and molding compounds	12,000	13,000	8
Fiber	146,000	160,000	10
Food and beverage containers	12,000	20,500	71
Non-food containers	35,500	26,500	-25
Sheet and film	34,500	35,500	3
Strapping	33,000	29,500	-11
Other	500	500	0
Domestic Subtotal	273,500	285,500	4
Export	67,000	46,000	-31
Total Consumption	340,500	331,500	-3

HDPE

High-density polyethylene (HDPE) is obtained by polymerizing ethylene gas. The most common item that is manufactured from HDPE is milk jugs. Most of the current recovered HDPE is accomplished through local government collection programs. The most common form recovered of HDPE is blow-molded bottles and HPDE grocery bags.

The national recovery of HDPE was 330,000 tons in 1992. Recovery amounts increased by 62% between 1992 and 1996. In 1996 almost 25% of the generated HDPE bottles in North Carolina were recycled. Table 15 shows the HDPE generation sources and quantities produced in North Carolina for 1996 and 2002. Table 16 presents the quantity of HDPE recovered by these programs from 1992 to 1997. Recycled HDPE resin prices are always less than the prices for HDPE raw material and off-spec resin. The demand for recycled resin is steadily increasing.

Table 15. HDPE Generation Sources in North Carolina (tons)

Product Category	North Carolina generation 1996	North Carolina generation 2002
Durable goods	12,500	15,800
Trash bags	6,400	8,100
All other non-durables	9,700	12,300
Soft drink bottle base cups	600	800
Milk and water bottles	18,100	22,900
Other plastics containers	18,600	23,500
Bags, sacks, and wraps	14,500	18,300
Other plastics packaging	34,200	43,300
Total Generated HDPE	114,600	145,000

Table 16. North Carolina Local Government Recovery of HDPE (tons)

	FY 1992-93	FY 1993-94	FY 1994-95	FY 1995-96	FY 1996-97
HDPE	3,501	4,118	5,390	6,046	4,240

Steel cans

The estimated supply for steel cans in 1997 was 2.8 million tons in the United States. The national percentage of recycled steel cans was 60.7 % in 1997. In

North Carolina 8,383 of 77,858 tons of steel cans generated were recovered by the private sector. In 1997 the average price per unit ton of steel can scrap was $62.13.

Table 17 shows the domestic supply rates for steel cans between 1993 and 1997. The generation and recovery estimates for steel cans in North Carolina are illustrated in Table 18. The generation and recovery amounts are directly related to population growth.

Table 17. Supply of Steel Cans in the United States (1993-1997)

Year	Tons of Steel Cans Shipped	Million Pounds	United States Population	Pounds Per Person
1993	2,787,600	5,575	257,752,702	21.63
1994	2,929,500	5,856	260,292,437	22.51
1995	2,693,400	5,385	262,760,639	20.49
1996	2,818,100	5,636	265,179,411	21.25
1997	2,848,700	5,697	267,636,061	21.29
Average	2,815,260	5,631	262,724,250	21.43

Table 18. Estimated Generation and Recovery of Steel Cans in North Carolina

Year	Generation (tons)	Recovery (tons)
1997	77,858	8,383
1998	78,971	8,503
1999	80,004	8,614
2000	80,961	8,717
2001	81,787	8,806
2002	82,617	8,895

The total amount of recycled steel cans represents only 5% of the total obsolete scrap recycled domestically in 1997. Junked automobiles, demolished structures, worn-out railroad cars and tracks, appliances, and machinery are the major sources of obsolete scrap. The decrease in the percentage of the recycled steel is due the increase in the production of durable steel products. In North Carolina, 11% of the total quantity of steel cans was recovered in 1997. The national and North Carolina recovery rates are presented in Table 19. 35% of the existing recycling programs in North Carolina do not include steel cans.

Table 19. Estimated North Carolina and National Recovery Rates for Steel Cans

	1991	1992	1993	1997
Estimated NC Recovery	3.9%	6.1%	10.5%	11%
Estimated US Recovery	34%	40.9%	48%	60.7%

The value of steel scrap is affected by the demand for finished products. As the demand expands the needs for more scrap steel will continue. The demand for steel is typically affected by the demand for cars. Efforts are underway to enhance the growth of other steel markets and new technologies in steel production have increased the dependence on scrap.

Recycled steel can exports market is very small and is not tracked separately from other steel scrap. The international demand is considered because the steel cans prices are developed in part by the demand for all other steel scrap.

Nationally the demand for steel can scrap is always more than the supply. The total demand for all steel scrap is much more than the part supplied through steel can recycling.

No steel can mills exist in North Carolina, but there are some in the surrounding states. There are several scrap processing facilities throughout the state. The prices for steel can scrap (end user prices) in the Southern Region of the United States are presented in Table 20. The fluctuation in the prices is directly connected to the supply and demand for finished steel products. The average price for steel cans between 1993 and 1997 was $62.87 per ton (NCDENR 1998).

Table 20. Steel Can Pricing in the South Region of the United States ($/ton)

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Average

1993	$83.50	$72.50	$71.50	N/A	$75.83
1994	N/A	N/A	N/A	N/A	$69.73
1995	$50.00	N/A	$55.00	$55.00	$53.33
1996	$60.00	N/A	$57.50	$42.50	$53.33
1997	$57.50	$61.00	$65.00	$65.00	$62.13

Office Paper

Sorted Office Paper (SOP) is defined as paper generated by offices. Other paper types can meet this definition but are generated and recovered from houses and other commercial facilities. Offices can also generate paper wastes that cannot be considered as office paper for example Magazines and newspapers. In 1997 North Carolina generated almost 187,000 tons of office paper of which almost 30 % was recovered. 90% of the recovered office paper came from the private sector. The office paper generation during the 90's has remained almost flat due to the growth of electronic forms of information processing.

Table 21 shows the generation and recovery of office paper in North Carolina for 1997 and 2002. The recovery rate has greatly increased from 1997 to 2002. In 1997, North Carolina recovered almost 55,000 tons of office paper with a recovery rate of 30 %. In 2002, 95,000 tons were recovered with a recovery rate of 48 % which is similar to the average national recovery rate. The private sector contributed almost 50,000 tons of the recovered 95,000 tons.

Table 21. Estimated Generation and Recovery of Office Paper in North Carolina

	1997	2002
Generation (tons)	186,773	198,189
Recovery (tons)	54,722	95,131
Recovery Rate (%)	30	48

The primary markets for recovered papers are tissue, new Printing & Writing (P&W) papers, and recycled paperboard. Typically, the recovered P&W papers is consumed by the following manufacturers:

- 25.5 % by tissue manufactures
- 25.5 % by paperboard manufactures
- 23.4 % by P&W paper manufacture
- 15.9 % by net exports
- 4.6 % by newsprint manufacture
- 5.1 % by all other uses

The main driver for sorted office paper demand is the strength of the de-inked pulp (DIP) market. The growing de-inking facilities nationwide led to the increase of office paper consumption in recent years. Contamination also affects the successful production of DIP. Generally more than one-third of sorted office paper exceeds the allowable levels of prohibited materials. To avoid such contamination quality control is set at high levels.

Similar to the trend of most paper grades, mixed office paper prices increased in the late 1994 and early 1995 and declined in late 1995. Since that time prices seem to be steady at about $50-60/ton (NCDENR 1998).

Mixed Paper

Mixed paper includes discarded mail, telephone books, catalogs, and cereal boxes. Mixed paper may include all types of paper generated in offices and houses. Packages coated with plastics such as frozen food and tissue containers are not acceptable for recycle.

Usually mixed papers may include other types of paper that is normally collected separately such as office paper or old magazines. In 1997 North Carolina generated more than 678,000 tons of mixed paper and recovered only 17% of this quantity. The private sector was responsible for more than 80 % of the recovered quantity.

The generation of mixed paper in North Carolina increased from 678,384 tons in 1997 to 719,849 tons in 2002. This amount doesn't include other types of paper such as office paper and old magazines. Table 22 presents the generation and supply for the state and the southeastern region for 1997 and 2002. With a 6% increase in the amount generated, the 25% increase in recovery becomes significant relative to generation.

More than 115,000 tons of mixed paper were recovered in the state in 1997, and the recovered in 2002 was almost 144,000 tons. In the southeastern region more than 929,000 tons of mixed paper were recovered in 1997 and 986,000 tons were recovered in 2002. The private sector recovered 92,543 tons in North Carolina, which represents 80 % of total mixed paper and the remaining 20 % was collected through the local government recycling programs.

Table 22. Estimated Supply of Mixed Paper in North Carolina (tons)

	1997	2002
Generation	678,384	719,849
Recovery	115,182	143,970

Mixed paper is the fastest growing recovered paper category during the last three years. This growth means that the industry is recovering a wide range of papers, but some paper grades may reach their maximum achievable levels quickly. Residential mixed paper (RMP) serves as a secondary fiber source in the production of new paper and paperboard and can be used partially to replace more expensive recovered fiber. In paperboard applications RMP usually replaces old corrugated carton and old newspaper.

The two major end users of RMP are producers of recycled paper and paperboard. The potential for producers of gypsum wallboard, roofing felt, chipboard to use RMP is high.

A considerable gap exists between the supply and demand of RMP in North Carolina. Table 23 shows that supply is less than the demand. During the same Period of 1994 and 1995 the prices for mixed paper were almost $100/ton and subsequently the prices fell to less than $20/ton. Since 1995 prices have remained consistently below $20 per baled ton (NCDENR 1998) and beginning in 2003 prices started to pick up and reached $35/ton (Winston-Salem 2003).

Table 23. Estimated Supply and Demand for Mixed Paper in North Carolina (tons)

	Supply	Demand
1997	115,182	143,970
2002	142,200	167,800

Old Magazines (OMG)

Magazines and catalogs are collectively referred to as Old Magazines (OMG) since they are made of the same materials and are equally useful for end users. OMG like other mixed paper has traditionally been used as a low grade paper supply for production of paperboard and tissue paper. Recently OMG has emerged to become a valuable ingredient for recycled newsprint production which has resulted in its collection separately from recovered paper. In 1997, 138,000 tons of OMG were generated in North Carolina constituting 6% of the total paper generated. 92,000 tons of this material were generated by North Carolina residences and 46,000 tons were generated from commercial sources. Out of a total of 138,000 tons, 79,000 tons consists of magazines with the remaining 59,000 tons being catalogs. OMG recycling has increased due to the new flotation deinking technology at newsprint mills that have a 11% recovery rate. This number is expected to grow even more in the coming years.

Old Newspapers (ONP)

Old newspapers (ONP) recovered from the waste stream have a wide variety of applications. These applications include providing feedstock for a variety of recycled products such as newsprint, paperboard, tissue, containerboard, molded pulp, animal bedding, cellulose insulation and a bulking agent for compost. Among the available grades of ONP grade No. 8 commands the highest price because it has the least contaminants relative to other grades. In 1997, 282,000 tons of ONP were generated in North Carolina of which 57% was recovered. This figure is well above the national average of 54%.

Of the tonnage recovered roughly 76% (121,000 tons) was collected by local governments. The remaining 24% (38,000 tons) came from the private sector. Although the percentage recovery is well above the national average, the quality of the recovered ONP has declined over the years. The primary reason for this decrease in quality is due to local governments not emphasizing source separation of papers. Commingling of ONP and Residential Mixed Paper (RMP) has resulted in a higher tonnage of recovery for ONP.

Old Corrugated Cardboard (OCC)

The generation of Old Corrugated Cardboard (OCC) in 1997 in North Carolina was 852,770 tons of which 424,456 tons recovered. The supply of OCC is from retail/commercial sources with 50% contribution, the manufacturing sector with 28% residential at 13%, and pre-consumer supplies at 8%. Of the waste contributed by the retail/commercial sources 75% is recovered the manufacturing sector had 70% recovered, residential sources had 5% recovered and finally pre-consumer supplies with nearly 90% recovered. The primary market for OCC is the paperboard industry which uses OCC for corrugating medium, linerboard, recycled paperboard and other paper products. About 63.5% of recovered OCC is used to make new containerboard, 17.4% to make recycled paperboard, 12.1% to exports and 1.1% tissue paper. There is increasing demand for OCC in the paperboard industry and this demand can only be met if the recovery rate can be increased from each of the supply sources.

Glass Container

Most of the glass recovered in North Carolina is due to local government collection efforts. Although large quantities of glass are generated from commercial sources, quantities recovered from non-residential locations are far below 10 % of the total glass recovered in the state. The glass waste can roughly be characterized as 58 % flint (clear), 33 % amber (brown), and 9% green.

Glass containers marketers are classified into primary and secondary end-users. Primary end-users reuse the glass cullet (broken/crushed glass) to manufacture glass containers. Secondary end-users use the glass for different purposes other than making glass containers. The glass container industry is the largest consumer for glass cullet in the United States.

Contamination is a major concern in glass recycling. The Institute of Scrap Recycling Industries specifications prohibit materials such as ferrous and non-ferrous metals, ceramics, other glass and other materials (bricks, rocks, etc.) from being present in glass cullet. Flint cullet must have not more than 5 % non-flint cullet. Amber can withstand up to 10 % non-amber cullet in the mix, and green can withstand up to 30 % non-green cullet.

Expanded local recycling programs have increased the quantity of the cullet supplied to glass manufacturers. With increased quantities the quality has decreased which has created problems. The quality of the supplied glass is a key issue. Contamination concerns led to the expansion of the use of intermediate processors which improved the quality of the glass.

The glass container industry is very competitive and keeps production, capacity, and other proprietary measurements private. Production levels are given on a state and regional level only. These figures are presented in Table 24. Supply and demand for individual glass cullets is listed in Table 25. It can be seen in Table 25 that there is an increase in both supply and demand over time, with demand sometimes outpacing the supply.

Table 24. Estimated Production of Glass (tons) in North Carolina and Surrounding States, 1997

State	Flint Glass	Amber Glass	Green Glass

North Carolina	203,695	64,324	0
Georgia	66,707	171,533	0
Virginia	59,560	50,626	0
Total	329,962	286,483	0

Table 25. Supply and Potential Demand for glass in North Carolina (tons)

North Carolina	Flint		Amber		Green		Total	
	1997	2002	1997	2002	1997	2002	1997	2002
Supply	23,134	24,542	11,499	12,231	10,392	11,048	45,026	47,821
Demand	112,033	117,635	45,027	47,258	10,392	11,048	167,452	175,961

Green glass is accepted for processing but is either sent outside the state or used to produce amber glass. Generally the production of green glass is decreasing in the United States. On the other hand increases in the percentage of cullet used, the ability to utilize some green cullet in the production of amber glass, exports of green cullet to other countries and an increase in secondary markets may have offset this decrease in production. Nevertheless, the future supply of green glass in the U.S. will likely exceed demand.

The supply of processed flint and amber cullet in North Carolina and the southeast is well below the potential demand. Whereas the supply and demand for green cullet are equal.

The percentage of the recovered glass in North Carolina is only 16 %, which is about half of the national recovery rate. Many factors rather than economic factors affect supply and demand. The first and most important is public education. To meet high standards of glass is expensive and results in a low price paid for glass by the processor which makes it less profitable for generators. Transportation for long distances further increases the cost of glass recycling (NCDENR 1998).

Aluminum Cans

In 1997, 3.6 million metric tons of primary aluminum and 3.7 million metric tons of secondary aluminum were produced from scrap material. Of this recovered metal, 59 % came from new (manufacturing) scrap and 41 % came from old (discarded aluminum products) scrap. Old scrap accounted for approximately 17 % of the total apparent domestic consumption. Used (aluminum) beverage can (UBC) scrap is the major component of processed old scrap which accounts for approximately one-half of the old aluminum scrap consumed in the United States.

The domestic supply of aluminum cans is presented in Table 26. Due to improved production efficiency, the weight of an individual aluminum can has been decreased and therefore the number of aluminum cans produced by a pound of aluminum has increased. In 1997 North Carolina recovered 21,076 tons of UBCs which represents 49 % of the generated UBCs for an increase of 4% from 1994.

Table 26. Estimated Generation and Recovery of Aluminum Used Beverage Containers (UBCs) in North Carolina (tons)

Year	Generation	NC Population Generation	Estimated NC Recovery
1994	43,740	7,024,000	19,683
1997	42,891	7,436,690	21,076
1998	43,504	7,542,996	21,377
1999	44,073	7,641,684	21,657
2000	44,601	7,733,097	21,916
2001	45,055	7,811,951	22,140
2002	45,513	7,891,238	23,364

Aluminum UBCs continued to make up the largest portion of the scrap aluminum purchased domestically in 1997. However, discarded aluminum products (old scrap) other than UBCs are also a significant source. Table 27 shows the five-year price history for UBCs (NCDENR 1998). These prices per ton almost doubled for over the four year period documented.

Table 27. Price of Aluminum Used Beverage Containers (UBCs), 1973-1977 ($/ton)

Year	Quarter 1 (March)	Quarter 2 (June)	Quarter 3 (Sept)	Quarter 4 (Dec)	Average
1993	$690.00	$660.00	$700.00	$580.00	$657.50
1994	$750.00	$800.00	$1,070.00	$1,310.00	$982.50
1995	$1,390.00	$1,320.00	$1,280.00	$1,150.00	$1,285.00
1996	$1,100.00	N/A	$990.00	$1,010.00	$1,033.00
1997	$1,170.00	$1,130.00	$1,140.00	$1,130.00	$1,142.50

Current Recycling Activities in Fort Bragg

The amount of recycled MSW collected from the installation in FY02 is about 1% of the total produced waste. The following recycling activities have been accomplished through the FY02:

- The Aluminum Can Buyback Center processed aluminum cans dropped off for $0.30 pound.
- The Raleigh News and Observer established eight newspaper and magazine drop-off centers across Fort Bragg. Through these centers 394 tons of newspaper and 58 tons of magazines were recovered.
- A solid waste collection contractor provided curbside collection of recyclables for Fort Bragg Army Family Housing (AFH), Pope Military Family Housing (MFH), and Heritage Village Housing.
- There are fifty cardboard collection dumpsters located at different locations across Fort Bragg.
- Fort Bragg processed 600 tons of paper, 22 tons of plastics, and 10 tons of aluminum.
- Fort Bragg processed 2,042 tons of discarded government materials including cardboard from the commissary, small arms fired brass, scrap metal, and tires (Weston 2003).

Future Recycling Opportunities in Fort Bragg

The total amount of MSW produced in Fort Bragg during FY02 was 25,255 tons. Data pertaining to the waste stream of Fort Bragg was used to determine the amount of recyclables for industrial and commercial wastes. Data from the State of North Carolina waste stream was used to determine the percentage of residential recyclables collected. From the data above an amount of 65% was assumed to be in acceptable condition for recycling.

In order to determine the potential income from recyclables the price/ton information was collected from three different sources. These included Greensboro MRF (O'Donnell, 2003), Winston Salem MRF (Winston Salem, 2003), and Laurinburg City (Haywood, 2003). The information from the six counties was used to determine the amount of total available recyclables. Different scenarios were identified based on the above data and the costs from similar existing MRF's.

Market Prices Associated with Recycled Material Sales

To determine economic feasibility of a MRF system the potential prices for the materials were estimated. Information on marketing prices from three locations was used to determine this estimate. Information from marketing in Winston Salem for the last two years was taken and averaged for each potential recyclable. FCR Inc manages the MRF in Greensboro and provided average prices for each material (O'Donnell, 2003). The City of Laurinburg provided an average amount for which they could sell their material. The lowest number for each material was used. Table 28 shows these numbers for each facility. From the data collected two price groupings were established, a conservative approach, and a more liberal approach. In the column labeled "Low Price", the low end numbers for each material was used while the column stating "High Price" utilized the highest number for each material. Price fluctuations in the sales of recyclables can be very volatile. This limits the ability to state "current" pricing because of daily changes. In Table 28 there are cases where there is a zero or negative price paid for a product. This is true for green glass where there are limited markets for re-use.

Table 28. Summary of Marketing Prices for MSW Materials

	Laurinburg	Greensboro	Winston-Salem	Low Price Utilized	High Price Utilized

Material	Price ($/ton) (1)	Price ($/ton) (2)	Price ($/ton) (3)	Price ($/ton)	Price ($/ton)
Steel Cans	30.00	45.00	45.84	30.00	45.00
Aluminum	900.00	1,000.00	981.64	900.00	1000.00
PET	180.00	190.00	144.55	144.55	190.00
HPDE	200.00	240.00	287.18	200	287.00
Flint	22.00	15.00	24.00	15.00	24.00
Amber	12.00	15.00	14.00	12.00	15.00
Green	12.00	-10.00	0.00	-10.00	12.00
Baled ONT (newspapers)	55.00	55.00	70.91	55.00	71.00
OCC (cardboard)	50.00	60.00	72.27	50.00	72.00
Magazines/Phone Books	20.00	20.00	21.67	20.00	21.00
Junk mail/mixed paper	20.00	20.00	21.67	20.00	21.00
Office Paper	75.00	100.00	85.00	75.00	100.00

(1)Haywood Harold 2003

(2)O'Donell, 2003

(3)Winston-Salem, 2003

Waste Stream Determination

To determine the amounts of waste percentages within the MSW area it is necessary to understand the waste stream characteristics. For this study the percentage of the MSW waste that is associated with the residential areas is 5,142 tons and was obtained from the North Carolina 1998 Market Assessment Report. The waste stream from the commercial and industrial side was based on dumpster dive information for Fort Bragg attained from Weston Solutions (Adam, 2003). This analysis was used to determine the unique breakdown of the commercial and industrial waste streams. Table 29 shows the final waste stream percentages used in this report. Table 30 is based on the amount of residential and commercial waste within the MSW region of recyclables and is used to estimate of the total tonnages of material available for recycle. Table 30 shows the amount based on the total percentage of the material due to the waste stream analysis which has been adjusted for 65% of the material in acceptable condition.

Table 29. Waste Stream Analysis For MSW Waste at Fort Bragg

Post-Consumer Recyclables	North Carolina 1997 Typical Waste Stream (1)	Fort Bragg Waste stream %(2)
Steel Cans	0.35%	1.48%
Aluminum	0.64%	2.70%
PET	0.39%	0.54%
HPDE	0.94%	1.15%
Flint	1.16%	3.19%
Amber	0.56%	1.82%
Green	0.60%	0.50%
Baled ONT (newspapers)	2.32%	3.70%
OCC (cardboard)	7.00%	11.18%
Magazines/Phone Books	1.13%	11.18%
Junk mail/mixed paper	5.57%	8.89%

Office Paper	1.53%	2.45%

(1)NCDENR, 1998

(2) Weston 2003

Table 30. Estimate of the Total MSW Material Available for Recycle (tons) at Fort Bragg

Recyclables	Commercial and Industrial	Residential
Steel Cans	297.67	18.00
Aluminum	543.05	32.91
PET	108.61	20.05
HPDE	231.30	48.33
Flint	641.61	59.65
Amber	365.05	28.79
Green	99.56	30.85
Baled ONT (newspapers)	744.18	119.29
OCC (cardboard)	2,248.64	359.93
Magazines/Phone Books	2,248.64	58.10
Junk mail/mixed paper	1,788.05	286.40
Office Paper	492.77	78.67

Potential Income Associated with Recycling MSW

Based on the market prices and available tonnages of recyclables, an estimate on the values for this material can be made. This information is included in Table 31. The information in Table 31 is broken down into upper and lower prices. The price used to determine the potential income was given a high and low end based on the data from Winston Salem, Greensboro and Laurinburg. The potential net income for the recyclable materials for Fort Bragg varies between $609,000 considering Laurinburg City prices and $711,000 when Winston Salem prices were considered. When the lowest price per item was used, potential revenue was determined to be $601,058. The difference in potential income between the upper and lower prices was approximately $125,000. It can be observed that in both cases the largest income is from aluminum with 56% of the income associated with the lower pricing and 51% of the income from the higher pricing.

Table 31. Calculated Value Estimates for MSW Materials based on Upper and Lower Prices from Table 28

Recyclables	Total Potential Recycled Material (tons)	Lower Price $/ton	Total amount ($)	Upper Price $/ton	Total Amount ($)
Steel Cans	205.19	30	6,156	45	9,233
Aluminum	374.37	900	336,937	1000	374,375
PET	83.63	144.55	12,089	190	15,890
HPDE	181.76	200	36,352	287	52,166
Flint	455.81	15	6,837	24	10,940
Amber	256.00	12	3,072	15	3,840
Green	84.77	-10	-848	12	1,017
Baled ONT (newspapers)	561.26	55	30,869	71	39,849
OCC (cardboard)	1,695.57	50	84,779	72	122,081

Magazines/Phone Books	1,499.39	20	29,988	21	31,487
Junk mail/mixed paper	1,348.40	20	26,968	21	28,316
Office Paper	371.44	75	27,858	100	37,144
Total	7,117.59		601,057		726,339

MRF Capital and Operation cost

There are generally two kinds of MRF's, a mixed or dirty MRF and the clean MRF. A typical dirty MRF consists of a large tipping floor with a material processing area and a storage area for different waste streams. All waste collected from the curbside is delivered to the tipping floor by the collection truck. The waste brought to the facility, is therefore a combination of MSW garbage and recyclables. Easily separated recyclables such as cardboard are removed on the tipping floor before entering the processing center. Material is conveyed into a hopper from the tipping floor via bucket loader. There are a series of screens that separate out the smaller garbage from the recyclables. Recovery of recyclables can either be sorted automatically or manually. Manual sorting usually results in higher-quality materials with less downtime, but can be expensive. Automated sorting is more effective for high throughput. Automated sorting equipment may include magnetic belts or drums for ferrous metal removal, eddy current separators for aluminum removal and classifiers for separating light and heavy materials. Generally a mix of manual and automated sorting is the most appropriate to ensure high-quality materials and minimize processing time. Recovery of recyclables at mixed waste MRF's ranges from 15 to 20% of the input waste stream. Uwharrie Environmental MRF is considered the only existing dirty MRF in North Carolina (Reynolds, 2003).

A clean MRF is very similar to a dirty MRF in that it has a tipping floor, processing, and storage areas. The recycled material is collected separately from the MSW, allowing them to have a higher quality material. There is less separation needed for the recyclables compared to the dirty MRF. Most clean MRFs have two processing lines one for commingled containers such as glass, plastic, and metal with the second for fiber such as cardboard, newspaper, and high grade paper. Similarly, clean MRFs can be manual or highly automated (Reynolds, 2003)

MRF's accept different grades of paper, various plastic grades, and other metals in addition to aluminum and tin cans. Some MRFs don't accept glass because they believe that it can cause equipment damage.

The average size clean MRF may cost approximately between three to four million dollars to construct with two processing lines.

Potential Scenarios for MSW

Four potential scenarios for Fort Bragg MSW recycling have been identified. In MSW Scenario 1, a recycling program would be initiated with only Fort Bragg included. This would not require participation from other members of the Sandhills Region community. It also limits potential future participation from these same communities, since they would not be able to ship their waste on site with ease.

MSW Scenario 2 expands upon the current recycling of MSW waste at Fort Bragg, by adding a commercial and institutional waste program to the existing residential program. This does not require initial capital cost investments by the facility and could potentially increase the recycle percentage on site. This scenario would be relatively simple to setup, but would have no net income associated with it.

MSW Scenario 3 would allow a consortium between Fort Bragg, Cumberland County and Fayetteville. Recycling in some form is going on in this region. Transportation costs would be minimal in this area; however, currently there are no transportation costs, since the material is picked up from drop-off centers by individual organizations. Transportation cost will not be addressed at this time.

MSW Scenario 4 is a regional approach which would allow the six counties and Fort Bragg to share one MRF. A model is developed to determine 1) The optimum location of a MRF if all six counties were included 2) The number of MRF's that would best suit this area, and 3) Whether all six counties should be considered in a regional MRF. The model analyzes the profit at such a facility and costs are compared for each county between sending their recyclables to Uwharrie Environmental, Inc. and sending to a regional MRF.

All scenarios consider only the establishment of a clean MRF.

MSW Scenario 1: Fort Bragg Recycling On Site

MSW Scenario 1 addresses the setup of a MRF that only takes care of Fort Bragg waste. This would not require participation from other members of the Sandhills Region community. This would have a combined effect of taking all the cost and all the benefit of such a facility to Fort Bragg.

This scenario would expand the current recycling on site. This would consider the recycling from residential waste that is sent to Uwharrie Environmental, Inc. and the untapped area of commercial and industrial waste at the site, and process them locally for sale. Table 30 shows the predicted tons of waste that would be capable of recycling from both streams with 100% participation. Table 31 lists the prospective sales from these materials. The total sale from this material is predicted to be $601,058 based on the lower prices. The higher price predicts a total sale of $726,339. If there is a 50% participation rate the lower price boundary becomes $300,530 and the higher price boundary yields $363,170.

Associated costs would include capital costs for the setup of the facility, and operating and maintenance costs. Currently a high estimate for the facility is $3 to $4 million dollars. The capital cost which is assumed as $4 million will be distributed over twenty years with an annual discount rate of 5%, resulting in an annual capital cost of $320,960. The impact to the facility is the loss of natural resources or available land for training associated with the assumption that the facility will be located within Fort Bragg. Operating costs are based eight workers with monthly compensation and benefits of $1,500 each. It was found that $200,000 is a reasonable estimate for the annual maintenance and operation cost to run a clean MRF. Both 100% and 50% recycling participation are included. Table 32 presents the cost analysis for Scenario 1. If 100% participation is assumed, the cost for operating this facility is $63,902 using lower prices. With 50% participation and lower prices, the cost becomes $364,431. Upper prices show that for 100% participation a profit of $61,000 could be realized. With 50% participation there is a loss of -$301,791. 50% participation only becomes an acceptable alternative when analyzing the reduction of landfill waste. This analysis doesn't address any saved costs from not transporting the waste to Uwharrie Environmental Inc. or additional cost with set up of collection points for the commercial and industrial recyclables. If these costs were taken into account, it is possible that the numbers would support development of a local clean MRF.

Table 32. Cost Analysis MSW Scenario 1

Gross Revenue from recycling, 100% Participation, Lower Price Values	$601,058

Gross Revenue from recycling, 50% Participation, Lower Price Values	$300,529
Gross Revenue from recycling, 100% Participation, Upper Price Values	$726,339
Gross Revenue from recycling, 50% Participation, Upper Price Values	$363,170
Annual capital cost of MRF	$320,960
Compensation and Benefit	$144,000
Maintenance and operation	$200,000
Net Annual Benefit, 100% Participation, Lower Prices	-$63,902
Net Annual Benefit, 50% Participation Lower Prices	-$364,431
Net Annual Benefit, 100% Participation, Upper Prices	$61,379
Net Annual Benefit, 50% Participation Upper Prices	-$301,791

MSW Scenario 2: Fort Bragg Recycles at Uwharrie MRF

Uwharrie Environmental Inc. is located 60-70 miles from Fort Bragg and it is the only dirty MRF in North Carolina. The MRF charges $37/ton for commingled waste to be recycled, but if the waste is well separated and the disposer is a landfill customer, the recyclables will be accepted at no charge. In this case the cost associated with this scenario is the collection cost inside the facility, which is common in all scenarios. In addition the transportation from Fort Bragg to the MRF at Troy city, which assumed constant in all scenarios, the only fees considered in this scenario are the tipping fees for the waste and the recyclables. From Table 33 it can be seen that with 100% participation and 65% acceptable material, the cost difference between sending the 7,118 tons to be recycled, compared to landfilled is $92,534. With 50% participation and 65% acceptable material the yearly difference between landfilling and recycling is $46,267. In this case, the more successful the program is, the more it will cost to participate.

Table 33. Cost Analysis MSW Scenario 2

	Tonnage	Cost to Recycle ($37/ton)	Cost to Landfill ($24/ton)	Additional Cost
Tonnages recyclables, 100% Participation, 65% applicable material	7118	$263,366	$170,832	$92,534
Tonnages recyclables, 50% Participation, 65% applicable material	3559	$131,683	$85,416	$46,267

MSW Scenario 3: Fort Bragg in Conjunction with Cumberland County/Fayetteville

MSW Scenario 3 would allow a consortium between Fort Bragg, Cumberland County and The City of Fayetteville. This combination would keep transportation costs down, while increasing the tonnages of acceptable recyclables. Therefore, capital costs calculated per year will have less impact on the total budget for this project. The effects of transportation will not be addressed at this time.

Table 34 shows the effect of additional waste on the total income that could be expected by merging with Cumberland County. Cumberland County currently recycles about 16,000 tons per year. For estimation purposes the breakdown used previously for Fort Bragg waste stream analysis was applied. From Table 34, it can be seen that the total revenue brought in from the sale of the recyclables would be $1,435,929 using the lower prices. With the upper prices the potential revenue would be $1,808,693. Table 35 shows the cost analysis associated with this scenario. Currently the cost associated with operating, maintenance, compensation and benefits is doubled over the previous assessment in MSW Scenario 1. This shows the potential for net annual benefit at $426,969 using the lower prices. With the upper prices this would become $799,733. This scenario emphasizes the importance on working with the other members of the Sandhills Region in making recycling not only feasible but also potentially profitable.

Table 34. Summary of Fort Bragg and Cumberland County Potential Recyclable and Income

Recyclables	Cumberland County (tons)	Fort Bragg (tons)	Cumberland County, Lower Price	Fort Bragg, Lower Price	Cumberland County, Upper Price	Revenue Fort Bragg, Upper Price
Steel Cans	252	103	$7,560	$3,090	$11,340	$4,635
Aluminum	461	187	$414,900	$168,300	$461,000	$187,000
PET	281	42	$40,618.6	$6,071.1	$53,390	$7,980
HPDE	678	91	$135,600	$18,200	$194,586	$26,117
Flint	836	228	$12,540	$3,420	$20,064	$5,472
Amber	404	128	$4,848	$1,536	$6,060	$1,920
Green	433	42	-$4,330	-$420	$5,196	$504
Baled ONT (newspapers)	1673	281	$92,015	$15,455	$118,783	$19,951
OCC (cardboard)	5047	848	$252,350	$42,400	$363,384	$61,056
Magazines/Phone Books	815	750	$16,300	$15,000	$17,115	$15,750
Junk mail/mixed paper	4016	674	$80,320	$13,480	$84,336	$14,154
Office Paper	1103	186	$82,725	$13,950	$110,300	$18,600
Total	16000	3559	$1,135,447	$300,482	$1,445,554	$363,139

Table 35. Cost Analysis for MSW Scenario 3

Gross Revenue from recycling, Lower	$1,435,929

Prices	
Gross Revenue from recycling, Upper Prices	$1,808,693
Annual capital cost of MRF	$320,960
Compensation and Benefit	$288,000
Maintenance and operation	$400,000
Net Annual Benefit, Lower Prices	$426,969
Net Annual Benefit, Upper Prices	$799,733

MSW Scenario 4: Optimum Location of a MRF in Sandhills Region

MSW Scenario 4 addresses the feasibility of a regional MRF in the Sandhills Region. This was a multi-step process utilizing linear programming modeling to determine the optimum location and number of MRFs. After this information was collected, the financial ability for each county to participate, based on no additional costs to them was determined. A linear programming software LINDO was used to run the model.

Linear Model for Site Selection

Figure 2 illustrates the basic linear model used to determine optimum selection of recycling centers for the Sandhills Region. In this Figure, i={1,2,3,4,5,6} is defined as the counties represented in this study. These were defined as:

- S_i=Total quantity of recyclables collected in the county (tons) where i={1,2,3,4,5,6}
- TS_i=Transfer station locations in the 6 counties where i={1,2,3,4,5,6}
- RC_k=Locations of the recycling centers where k={1,2,3}
- LF_j=Landfill location where j=1
- xr_{ik}=Quantity of recyclable MSW waste transported between a transfer station i and a recycling center j for every i={1,2,3,4,5,6} and k=1,2,3
- xl_{ij} = Quantity of recyclable MSW waste transported between a transfer station i and the landfill j, for every i={1,2,3,4,5,6} and j=1
- yl_{kj} = Quantity of recyclable MSW waste transported between a recycling center k and the landfill j, for every k={1,2,3} and j=1

i={1,2,3,4,5,6} is defined as each of the six counties.

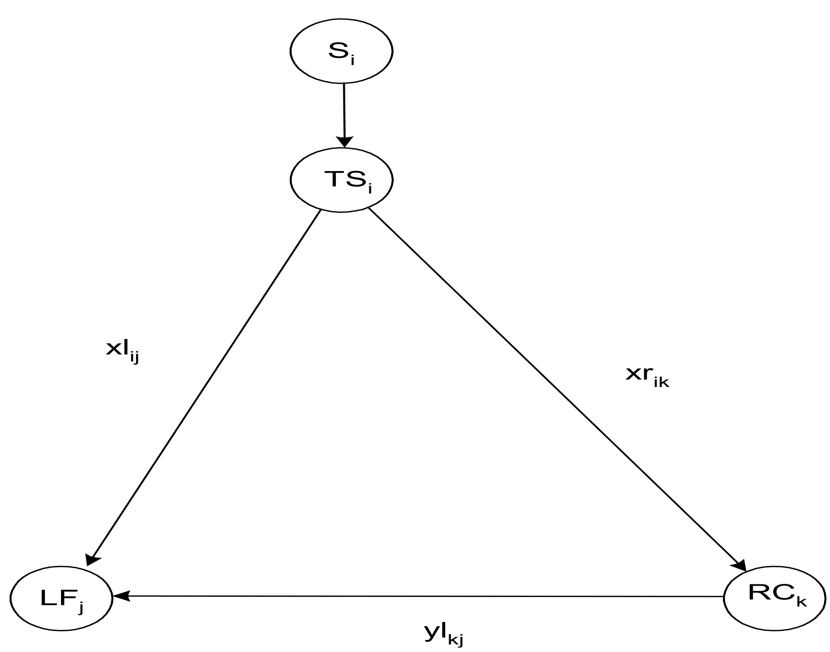
- i=1, represents Cumberland County
- i=2, represents Harnett County
- i=3, represents Moore County
- i=4, represents Scotland County
- i=5, represents Richmond County
- i=6, represents Hoke County

k={1,2,3} is defined as locations of recycling centers/MRFs selected in the model.

- k=1, represents recycling/MRF at Fayetteville, Cumberland County
- k=2, represents recycling/MRF at Raeford, Hoke County
- k=3, represents recycling/MRF at Southern Pines, Moore County

j=1 is defined as the location of the Landfill which is located at Uwharrie Environmental, Inc. in Montgomery County.

Figure2: Pictorial Model Design, MSW Scenario 4



S_i is defined as the recyclables generated in county i. If i=1, then S_1=recyclables from Cumberland County, etc. TS_i is the transfer station for each county, i. Therefore, TS_1=Cumberland County transfer station (currently existing). RC_k is defined as the proposed recycling center to be located at site k. Three counties were identified as possible recycling sites. These were RC_1=Cumberland County,

RC_2= Hoke County, RC_3=Moore County. LF_j is the landfill j, which for this study has j=1, and is identified as Uwharrie Environmental, Inc.

Each waste movement needs to be identified. For this xr_{ik} is recognized as the waste that is transferred from the transfer station i to the recycling center k, where i={1,2,3,4,5,6}, and k={1,2,3}. xl_{ij} would then be the waste that is transferred from the county transfer station, i, to the landfill, j. This will allow the option for each county to not use recycling, and determine how this affects the results. yl_{kj} is then defined as the residue from the recycling center k that needs to be sent on to the landfill.

The linear programming model is defined by the following:

Max Profit

$$= U\left(\sum_{m \in M} zp\right) - \sum_{i \in I} c_{ij} xl_{ij} - \sum_{i \in I} t_j xl_{ij} - \sum_{i \in I} \sum_{k \in K} c_{ik} xr_{ik} - \sum_{i \in I} \sum_{k \in K} t_k xr_{ik}$$

$$- \sum_{k \in K} c_{kj} yl_{kj} - \sum_{k \in K} t_j yl_{kj} \text{ - Capital Cost - O \& M Cost}$$

Subject to

$$\sum_{k \in K} yl_{kj} - 0.35\left(\sum_{i \in I} \sum_{k \in K} xr_{ik}\right) = 0 \ldots\ldots(1)$$

$$S_i - \sum_{j \in J} xl_{ij} - \sum_{k \in K} xr_{ik} = 0, \text{ for i} = 1...6 \ldots\ldots(2)$$

$$\sum_{k \in K} RC_k <= 1 \ldots\ldots(3)$$

$$\sum_{i \in I} xr_{ik} - \sum_{j \in J} yl_{kj} - zp = 0, \text{for k} = 1,2,3 \ldots\ldots(4)$$

Where

zp = total recyclable quantity collected for sale to the end-users

U = Average selling price/ton of the recyclables

C_{ij}= cost of transportation ($/ton/mile) from transfer station i and landfill j

C_{ik} = cost of transportation ($/ton/mile) from transfer station i to recycling center k

C_{kj}= cost of transportation ($/ton/mile) from recycling center k to landfill j

t_j= tipping fee($/ton) for disposal at the landfill for waste coming from either the transfer station or the MRF

t_k=tipping fee ($/ton) for transport of waste from the transfer station to the recycling center (assumed as zero for a regional facility)

The objective function aims to maximize profit as a difference between benefit from the sale of recyclables obtained by multiplying the total amount of recyclables collected from all the 6 counties times the average price for the recyclables and subtracting the transportation and tipping fee costs between the transfer stations, recycling centers and the landfill. Based on the North Carolina state waste stream data, out of the total residential recyclables collected 65% was assumed to be in acceptable condition for recycling. Constraint (1) illustrates that out of the total quantity of recyclables sent to each of the recycling stations an amount equal to 35% of the total quantity of residential recyclables received is non-recyclable or is residue and is sent to landfill for final disposal. Constraint (2) denotes that the total quantity of residential recyclables generated in each county is either transported to the recycling center or landfill or both meaning that no waste generated is stored or retained in a particular county. Constraint (3) restricts the number of transfer stations to one which implies either the recyclable waste from all the 6 counties is sent to the transfer station chosen or no county sends its waste to any of the transfer stations, thus meaning landfilling would be the best option possible. Constraint (4) denotes that the sum of the tonnages of residues transported from the recycling stations to the landfill and those quantities retained at the recycling centers for sale to end-users is equal to the total recyclable waste transported from the transfer stations to the recycling centers.

Result of LP model with LINDO

When this information was put into a LINDO model the waste was preferentially sent to the proposed recycling center in Cumberland County. The model did allow the right for waste to be directly shipped to the landfill, but still preferred the recycling center. The model was then redefined to allow either no recycling center to be chosen, or multiple recycling centers to be defined. This still returned the same results of one recycling center chosen in Cumberland County. The results for this are seen in Table 36. For $0.40/ton/mile and $71 sales price, the profit calculated by this model is -$121,282. This includes the cost to the counties for transportation and the expected profits from such a facility. To determine what would happen if a different alternative was chosen Hoke County was forced as the site for the MRF. This gave a profit of -$234,730. The model was then forced to accept Moore County as the MRF site resulting in a profit of -$239,606. The choice of Hoke County reduced the profit by $113,448 per year. Moore County is an even less appealing option with a reduction from the optimum solution of $118,324 per year.

Since the market price of recyclables fluctuates significantly and the transportation cost cannot be accurately defined, additional sensitivity analysis was done. The transportation cost was varied from $0.13 to $0.50/ton/mile. The potential average sales price was varied from $50-$90/ton. Based on averaging information used in the previous scenarios, $71/ton was considered a reasonable estimate for recyclable sales with a ± $20/ton variation. Numbers from Richmond (Smith, 2003), Scotland (Edge, 2003), Moore (Boles, 2003) and Harnett (Blanchard, 2003) counties supported a transportation rate near $0.10-$0.20/ton/mile. A higher range was analyzed to determine where the break-even point would be found for this scenario. Table 36 illustrates the results from this study. It can be seen from this that for a fixed transportation cost of $0.40/ton/mile that the break-even point in sales needs to be approximately $77/ton on average. Fixing the price of recyclables to $71/ton gives a break-even point for transportation of $0.304/ton/mile.

Table 36. Break-even Assessment for Transportation Costs and Price of Recyclables for MSW Scenario 4

Average price of recyclables ($/ton)	Net Profit ($)	Transportation Cost ($/ton/mile)
50	-518,783	0.4
60	-329,497	0.4
71	-121,282	0.4
80	49,076	0.4
90	238,363	0.4

77	0	0.4
Transportation Cost ($/ton/mile)	Net Profit ($)	Average price of recyclables ($/ton)
0.13	220,024	71
0.2	131,537	71
0.3	5,128	71
0.4	-121,282	71
0.5	-247,691	71
0.304	0	71

Table 37 addresses the transportation costs for each county to ship their waste to the Cumberland County MRF instead of the Uwharrie Landfill. This table calculates the cost based on tons to be transported and number of miles over which it must travel. This is discussed over the range of $0.13-$0.50/ton/mile. Table 38 illustrates the current costs each county must spend to transport and tip their recyclables. Data for Cumberland and Hoke were not known. These numbers were used to compare the calculated potential costs for counties if they were to send their waste to the proposed MRF. Comparisons of the counties that have current transportation costs with predicted costs associated with utilizing a regional MRF demonstrate that with any transportations costs in the range analyzed, all counties would save money.

Table 37. Transportation Costs for MSW Scenario 4 ($/yr)

			Cost to Recycling Center				
	Tons of Recyclables	Miles MRF	0.13	0.2	0.3	0.4	0.5
Cumberland	16,000	1	2,080	3,200	4,800	6,400	8,000
Hoke	1,700	25	5,525	8,500	12,750	17,000	21,250

Moore	1,624	45	9,500	14,616	21,924	29,232	36,540
Scotland	1,477	50	9,600	14,770	22,155	29,540	36,925
Richmond	3,720	60	29,016	44,640	66,960	89,280	111,60 0
Harnett	4,600	30	17,940	27,600	41,400	55,200	69,000

Table 38. Existing Costs for Each County (Transportation and Tipping)

	Unit Cost ($/ton)	Total Cost ($)
Cumberland	Unknown	Unknown
Hoke	Unknown	Unknown
Moore	33.39	54,225
Scotland	35.00	51,695
Richmond	36.00	133,920
Harnett	27.38	125,948

It is necessary to determine whether a regional MRF could potentially support itself. To do this profit was determined without any transportation cost from the counties to the MRF site. Table 39 shows the range in profit from varying the price for the recyclables from $50-$90/ton. This assumes a transportation cost of $0.40/ton/mile from the MRF site to the landfill. Tipping fee for the waste sent from the MRF to the landfill was set at the current cost of $24/ton. The range of potential profit for this would be from $33,739 to $790,885.

Table 39. MRF Profits without Transportation Costs for MSW Scenario 4

Average Sales Price $/ton	50	60	71	80	90
Profit ($/yr)	33,739	223,026	412,312	601,599	790,885

5 Recycling of LCID Waste

Land Clearing and Inert Debris (LCID) waste is any material from the land clearing process. This can include yard trimmings, trees, and soil. The two basic ways to recycle LCID waste are composting and mulching. Mulching involves the chipping and grinding of large woody materials to form mulch as a final product. Composting is a more complex process where the material is decomposed with the help of microorganisms to a simpler organic mix that can be used as soil amendments. Both mulch and compost can be sold or given away to landowners, landscaping companies, and farmers for re-use to the betterment of the environment.

Composting

There are many factors that influence the composting process. These include:

- C: N Ratio
- Oxygen concentration
- Moisture content
- Particle size
- Temperature
- pH

Carbon(C) and Nitrogen (N) are essential nutrients for the microorganisms involved in the composting process which allow them to grow and multiply. The ideal C: N ratio should be 30:1. This ratio is critical as a low value could cause material to degrade too rapidly causing unpleasant odors due to anaerobic conditions. Too high a value could slow or halt the process itself. It has been found that green, wet plant materials have a low C: N (high N), and brown, dry materials have a high C: N (high C). A proper blending of materials is thus necessary to achieve the optimum ratio for the process.

Oxygen is needed for aerobic biodegradation wherein microorganisms use oxygen to effectively degrade organic materials into carbon dioxide, humus and inert mineral compounds. Without oxygen the process becomes an anaerobic degradation process. In anaerobic degradation organic materials will still degrade but result in the production of odors due to the presence of methane and noxious sulfur compounds.

Water is an essential element for the composting process helping to dissolve the organic and inorganic nutrients present in the compostable materials and making them available to soil microorganisms and their metabolic processes. The ideal moisture content of the compost pile should be between 40 and 60 % by weight.

The surface area of organic materials exposed to soil organisms also determines the rate of composting. The more finely ground a material, the higher the surface area per unit weight. Hence, large materials should be ground and shredded to smaller sizes. A mixture of materials should be used. When bulky materials are shredded in size the decomposition rate increases while the porosity of the material decreases resulting in anaerobic conditions. Hence a mix of grass clippings and leaves should be used with the bulkier materials.

Ideal temperatures vary between 90 and 140^0 F. Maintaining high temperatures is necessary for rapid composting and destroys weed seeds, insect larvae, and potential plant and human pathogens. The temperature is measured with a long stemmed thermometer at a depth of at least 18 in. into the volume of material collected. Temperatures above 140^0 F will begin to limit microbial activity and temperatures in excess of 160^0 F can kill soil microorganisms.

The pH of materials should be monitored and a value 6.5 to 8 should be maintained. The role of bacteria in composting increases in importance with the increase in pH (Public Works Technical Bulletin, 2000).

Large-Scale Composting

For Army installations four main types of composting have been recognized: static pile, turned windrows, aerated windrows, and in vessel systems.

Static piles are the simplest and least expensive method of large scale composting and involve making a large pile of homogeneous materials ready to be decomposed over time. A static pile should be used exclusively for materials with high carbon content (high C: N ratios).

The turned windrow method is commonly adopted for yard wastes, leaves, wood chips, and manure. They can also be used for food wastes, sewage sludge, and nonrecyclable paper under carefully controlled conditions. They require a large land area for implementation i.e. mixing, stockpiling, and maneuvering the large machinery involved in the process. Because windrows are exposed to the weather, aeration, moisture, and temperature must be monitored and maintained. Turned windrows require environmental permits from state regulators. Composting time is quite variable with this system.

Aerated windrow is a process where compostable materials are piled over a series of perforated pipes to which a blower is attached to supply oxygen. These systems can incorporate electronic controls that adjust the blower based on the internal temperature of the pile. Aerated windrows would also require environmental permits. This process is most applicable for co-composting sewage sludge, municipal solid waste, and yard wastes.

In the in-vessel systems, materials are batch mixed by placing certain proportions of materials together in a container for mixing. A special mixing device is used to achieve the correct C:N and moisture content. Finally the mixture is placed into an enclosed chamber or vessel. Air is blown into the chamber to provide aeration. Because these systems are closed, all the requisite environmental conditions (i.e., aeration, temperature, moisture) are kept at optimal levels throughout the composting process. These systems are modular in nature and can be easily expanded as material volumes increase. The big advantages to in-vessel systems are that there is no runoff to control, they can be used without complex site preparation and as they are containerized they require much less space for operation. These avoided costs may outweigh the high expense of the specialized equipment required for the process.

Equipment for Composting

Size Reduction Equipment

Mechanical reduction equipment:

The particle size of organic materials used in composting must be small enough to promote rapid decomposition. Some fraction of larger pieces should remain to increase porosity and allow for natural aeration. Hence large materials will require some sort of mechanical reduction in size. Mechanical reduction equipment includes high-speed grinders and low speed shredders, which are classified, by the rotational speed of the hammers or cutters.

Tub grinders:

A tub-grinder is a type of high-speed grinder and consists of a large “tub” that rotates over a high speed, horizontal hammer mill. A perforated grate under the hammers controls the output particle size. Tub grinders process organic wastes, especially woody materials, very quickly and produce a uniform chipped product. Presence of metal objects with materials could cause significant damage to the equipment. Disadvantages with these grinders are that they produce a lot of noise and flying debris and the size of the output from the tub grinder is governed by the size of the holes in the grate under the hammers, which usually range in size from about ½ to 3 in.

Horizontal in-feed grinders:

Horizontal in-feed grinders consist of an enclosed horizontal shaft hammer mill with an in-feed conveyor or platform. These machines can handle a wider range of materials than tub grinders, depending on power and configuration. Particle size is determined by a perforated grate like tub grinder. A lighter duty grinder is best suited for preparing mixed yard waste for composting. This process results in non-uniform sizes of materials which is advantageous as it yields a good mix of high surface area and porosity, which are important elements for ventilation.

Shear shredders

A shear shredder consists of a pair of counter rotating knives or hooks that rotate at slow speed with high torque to tear or cut most materials thereby opening up internal structure of particles thereby enhancing opportunities for decomposition (EPA, 1994).

Table 40 illustrates the typical costs and throughput associated with each piece of equipment

Table 40. Summary of Size Reduction Machinery for LCID

Type	Average Throughput (ton/hour)	Cost Range	Notes
Tub grinder	10-25	$160-200k	Good for uniformly chipping woody materials
Horizontal grinder	15-30	$150-190k	Grinds variety of materials; many configurations avail.

Shear shredder	25-45	$300-400k	Shreds anything; not best for yard waste only

SOURCE: Composting at Army Installations, Public Works Technical Bulletin, August 2000.

Turning Equipment/Windrow Turners

Windrow turners are widely used for yard trimmings and MSW compostables. They consist of elongated composting piles, which are turned frequently to maintain aerobic composting conditions. The windrow turner is made up of: wheel loader, towed rotor, elevating face and windrow straddle.

Wheel Loader

A wheel loader is also called a front-end loader. The advantage of using a wheel loader to turn compost is that they are relatively common. They are disadvantageous as they are slow and sometimes do not mix well.

Towed rotor:

A towed rotor is a small specialized piece of windrow turner equipment. It is towed with a tractor or other vehicle and is powered by its own engine. It consists of horizontal drum with flails or knives, which rotates at high speed and rides close to the ground to engage the windrow and shoot it to the rear or to the side. This type of machine is ideal for smaller or startup operations that do not want to make a large capital equipment investment. They are relatively inexpensive and use existing equipment for towing.

Elevating face:

An elevating face is a self-propelled or towed machine using a wide, inclined conveyor to lift the windrow and drop it off the back. It is ideally suited for materials that are relatively homogeneous or materials you wish to avoid scattering (e.g., food wastes), as it does well at aerating and “fluffing” the pile and does not produce high-speed projectiles.

Windrow straddle:

These are the largest, most effective, and the most expensive machines. This self-propelled machines rides over the entire windrow and turns it via a horizontal, high speed, rotating drum with flails by which it thoroughly mixes, aerates, and ejects the composting material out the back, reforming the windrow.

Screening Equipment:

Trommel screens:

The consistency (particle size distribution) of the finished compost from a trommel screen will vary based on the original materials. Some end uses of compost require them to look alike. The best way to accomplish this is to use a trommel screen. A trommel screen is basically a large, rotating, cylindrical sieve. The process involves a wheel loader, which dumps compost on the in-feed conveyor from where the compost goes through the center of the trommel. Fine material passes through the mesh, and the oversize is carried all the way through, and falls out the far end. The trommel screen can use two different sized meshes to separate the compost into three different size classifications smaller than ½in., ½ to 1-in., and larger than 1-in. (Public Works Technical Bulletin, 2000).

Factors to be considered for Composting

A low-technology composting program could prove as a viable alternative for management of yard waste and help to reduce landfilled tonnages and disposal costs. Materials such as grass clippings and leaves collected through semi-annual installation cleanups, riding stables, and shredded classified documents could be useful for initiating a composting program. Dense materials such as trees and limbs are not suitable for composting due to their slow rate of decomposition, which will make the program expensive in operation as a result of long-term use.

Factors to be considered in starting composting programs are as follows:

- Available space
- Available equipment
- Management personnel
- Facility operation cost
- Avoided disposal costs in landfill such as tipping fees and transportation costs
- Avoided cost for purchasing daily cover

If a composting program was started at Fort Bragg it would not fall under EPA regulations since unprocessed composting material comes only from the installation and the end product, which is compost, is used only within the installation boundary. If this material is sold off site, there will be additional regulations to be followed (Public Works Technical Bulletin, 2000).

Food Waste

Food waste generated from Fort Bragg's facilities such as post exchanges and approximately 30 mess halls could also be diverted from landfilling by using composting techniques. Currently dining food waste is disposed of in sink disposals or dumpsters, with some being disposed of in an experimental process for gas generation.

Food waste is ideal for composting because of its high moisture content and susceptibility to odor production and large quantities of leachate. Fruits, vegetables, dairy products, grains, bread, unbleached paper napkins, coffee filters, egg shells, meats and newspaper can be composted. Items unacceptable for composting include condiment packages, plastic wrap, plastic bags, foil, silverware and drinking straws. Red meat, bones and paper are acceptable but they take longer time to decompose and thus are not preferred. Odor can be prevented by keeping the compost pile well aerated and free of standing water. Leachate can be reduced through aeration and adding sufficient amounts of high carbon bulking agent.

Pre-consumer food waste is easiest to compose because it is generally separated from the rest of the waste stream generated thus reducing the possible presence of contaminants in future compost.

Post-consumer food waste is challenging because of separation issues involved as the food waste is already mixed with general waste stream thus increasing the presence of contaminants. This problem can be reduced by having a separate trash can for only food waste.

Food waste composting methods:

- Passive composting or piling: involves simply stacking the materials and letting them decompose naturally. This method is simple and is low cost. The disadvantage of this method is that it is very slow process and results in production of objectionable odors.
- Aerated static piles: involves introduction of air into the stacked pile via perforated pipes and blowers. This method is weather sensitive and thus may result in the loss of microorganisms responsible for the composting process.

- Windrows: are long, narrow piles of material which are turned with windrows turner equipment to reach required temperature and oxygen requirements. The only disadvantage with this method is that it is used for only large volume of material thus requiring abundant space. There could be odor problems and leachate concerns with the application of this method.
- Compost bins: made of wire mesh or wooden frames are inexpensive and allow for good air circulation. This method is typically used for small quantities of food waste and allow for faster compost production utilizing various stages of decomposition.
- In-vessel systems: use perforated barrels, drums, or specially manufactured containers which are simple to use and require minimal labor. These equipments are not weather sensitive and are used for handling small volumes of material. The only disadvantage is that initial cost of equipment setup may be high compared to other methods.
- Vermicomposting is carried out in containers, bins or greenhouses and uses worms to consume the food waste and utilize its castings as high quality compost. Meat products are difficult to compost using this method and also this method is suitable if small quantities of waste are present since too much waste can result in anaerobic conditions.

The factors influencing food waste composting are similar to those for other organic materials such as C: N ratio, moisture content, particle size, pH and temperature. The end usage of food waste compost is also similar to that of the general organic compost.

Wood Pallets, Ammunition Boxes, Lumber, Various Wood Wastes:

Sources of wood waste include yard waste, tree and brush trimming, irreparable wood pallets and crates, emptied ammunition boxes and waste lumber. No programs are currently in place for re-use of wood pallets or used aluminum boxes, which contribute significant amount of wood waste generated by the installation. All the waste is currently being disposed at the C&D Landfill. Wood waste could be processed using a wood grinder or tub or horizontal grinder (rented or purchased by the installation) with a magnetic separator. The latter could help in removing nails and metals from the wood wastes. The materials thus processed could be stockpiled for use as landscape mulch, ground cover, runoff control, dust control etc.

All composting programs help with:

- Extending the calculated LCID Landfill life and lowers the Landfill O&M costs.
- Reducing cost of purchasing topsoil.

- Providing quality soil amendment for installation use.
- Eliminating handling and disposal fees for stable wastes.
- Reducing the amount of wood waste going to MSW Landfills.
- Conserving space in the MSW Landfill.

Market Assessment

The market assessment scenarios for composting material at Fort Bragg were based on programs operated in two different cities. The City of High Point facility, which is owned and operated by the City of High Point, was the basis for Scenario 1. This is an owner operator facility. Winston-Salem's Composting Facility is a private venture with a contract through The City of Winston Salem. This was the basis for Scenario 2 using contracted work.

Composting Scenario 1

Background

The City of High Point runs a Type I composting facility. The personnel at the facility include one supervisor, one scale house operator, one tub grinder operator, four equipment operators needed for front end loaders and the windrows turner equipment, and one laborer. The materials collected at the facility include grass and leaves, limbs, brush, logs of wood etc. No pallets are allowed in this facility. The grass and leaves are used to make the composting material and the other materials are used to make the mulch. Collected grass and leaves are allowed to enter into the dumping area after passing through the weigh station. Front-end loaders help to load the material onto the tub grinder machine. The tub grinder accepts any material less than or equal to 5 ft in diameter. The end product from grinding is the mulch and is stored for period of 2-3 months to attain optimum conditions of air and heat before being sold to buyers. Collected leaves and grass are also fed into the tub grinder resulting in a black color like soil, which is then arranged in windrows of 300 ft long, 15 ft deep and 6 ft wide to attain optimum conditions of air, temperature and moisture content. The windrows turner aerates the windrows once a week. The material after being stored for at least eight months is then passed through a ½ in. screen to remove impurities. The material from the screener is stored and sold as compost material (Pendry, 2003).

Market Assessment

Table 41 lists the various equipments used at the composting facility in High Point. The number of each piece of equipment and the current cost for the equipment are included. This scenario has a total capital cost associated with it of $812,000.

Table 41. Cost of Equipments for Composting Scenario1

Equipment	Number	Cost ($)
Front end loaders	3	$300,000
Tub grinder	1	$400,000
Windrows turner	1	$60,000
Screener	1	$50,000
Lawn mover	1	$2000
Total ($)		$812,000

(Pendry, 2003)

Table 42 provides the financial information of Composting Scenario 1 and considers the total tonnage collected from Fort Bragg with capital and operating costs. Out of the total tonnage collected at Fort Bragg 50% was assumed as grass and leaves to be made into compost material and the remaining consisting of brush, limbs, trees. Yard waste has an estimated weight loss of 50% during the composting process. The number included in Table 42 reflects this weight reduction. Capital costs for the equipment is listed in Table 41 at $812,000. Using a discount rate of 5% and an economic life of eight years (related to shorter lifetime expected for this type of equipment), this gives an annual cost of $125,633. The range of potential income for compost was set at $15/ton to $20/ton. For mulch the price was $10/ton to $12/ton. With an operating cost of $500,000 per year, the total annual cost is $625,633. This gives a potential net profit range of $655,306 to $984,691/yr.

Table 42. Economic Analysis for Composting Scenario1

Total tonnage collected	146,393tons
Tonnages associated with yard waste	36,598 tons
Tonnages associated with brush, limbs, etc.	73,197 tons
Annual cost of equipment	$125,633/yr
Operating costs for labor and maintenance	$500,000/yr
Income from sale of mulch	$731,965/yr-$878,364/yr
Income from sale of compost	$548,974/yr-$731,960/yr
Net profit	$655,306/yr-$984,691/yr

Note: The Capital cost of the equipment of $125,633/yr was calculated based on the total cost of equipment of $812,000 and by assuming a compound discount rate of 5% for capital recovery of eight years, which is the total life cycle of the equipment.

Composting Scenario 2

Background

Composting Scenario 2 was considered with data collected from the City of Winston Salem. In this scenario the land is owned by the city but the operation and maintenance is the responsibility of the contractors operating for the city. The facility accepts grass and leaves, pallets, brush (tree limbs), blocks of wood, trees and stumps. There are six personnel who operate and maintain this facility. The yard waste material after passing through the weigh station is placed on the dumping area on site. The materials from the dumping area are collected by the front-end loader and loaded on to the chain conveyor, which is the first receiving component of the Arasmith Wood Hog machine. The chain conveyor is of vibrating type and as it moves towards the central part of the machine along with the materials. A metal detector detects for likely pieces of metal, which need to be removed manually if found. Once it passes across the metal detector it reaches the central part of the machine consisting of a drum with teeth. The incoming material is ground and then passed on to the West Salem grinding machine. The material already fine ground after having passed through the first grinding falls off whereas the larger pieces pass through the West Salem machine for a second grinding. The fine materials collected at the bottom of the machine are then passed through magnetic roller, which detects and tracts any nails or steel type fragments. The resulting material is a high quality mulch like material which is used as a component of boiler fuel in the adjacent Cone Mills. Roughly six or seven loads each weighing 20 tons of high quality mulch like material is shipped everyday. The grass and leaves are collected separately in the dumping area and are passed through the tub grinder to produce black color soil which is then stored for attaining optimum conditions of air, temperature and light as required by regulations. Once optimum conditions have been attained the material is sold as compost for landscaping purposes (Cooke, 2003).

Table 43 provides a description of the number and types of equipment with present cost value for each equipment used in the City of Winston Salem composting facility.

Table 43. Cost of Equipment for Composting Scenario 2:

Equipment	Number	Cost ($)
CBI Wood Hog	1	$440,000
Windrows Turner	1	$60,000
Stationary Mill	1	$650,000
Wheel loaders	4	$600,000
Husky knuckle boom loader	1	$80,000
Hydraulic excavator	1	$65,000
Road tractors	4	$100,000
Trailers	3	$66,000
Total ($)		$2,061,000

(Cooke, 2003)

Table 44 provides a description of costs and benefits associated with Scenario 2. 50% was assumed to be collected as grass and leaves to be made into compost material and the remaining consisting of tonnage of brush, limbs, and trees, as in the previous scenario. Total costs from Table 44 for capital costs are about two million dollars. The annual cost for the equipment is based on a 5% discount rate, 8-year lifetime, and gives an annual cost of $318,878 as seen in Table 44. A range of potential income prices for compost was set from $15/ton to $20/ton. For mulch the price range was $10/ton to $12/ton. With an operating cost of $350,000 per year, the total annual cost is $668,878. For the lower sales price this gives a potential net profit range of $612,061 to $941,446/yr.

Table 44. Economic Analysis for Composting Scenario2

Total tonnage collected	146,393tons
Tonnages associated with yard waste	36,598 tons
Tonnages associated with brush, limbs, etc.	73,197 tons
Capital cost of equipment	$318,878/yr
Operating cost for labor and maintenance	$350,000/yr
Income from sale of mulch	$731,965/yr - $878,364/yr
Income from sale of compost	$548,974/yr - $731,960/yr
Net profit	$612,061/yr - $941,446/yr

Note: The Capital cost of the equipment of $318,878/yr was calculated based on the total cost of equipment of $2,061,000 by assuming a compound discount rate of 5% for capital recovery of eight years, which is the total life cycle of the equipment.

6 Recycling of C&D Waste

Typical Waste Streams

The most accurate way to assess C&D recycling would be to have some form of waste stream analysis. According to the Sustainable Integrated Solid Waste Management Plan for 2002, each contractor is currently responsible for disposal of the waste from their work. For FY02, 41.95% of the waste in the C&D stream is concrete, 0.24% is asbestos, and 57.81% is other material (Weston, 2002).

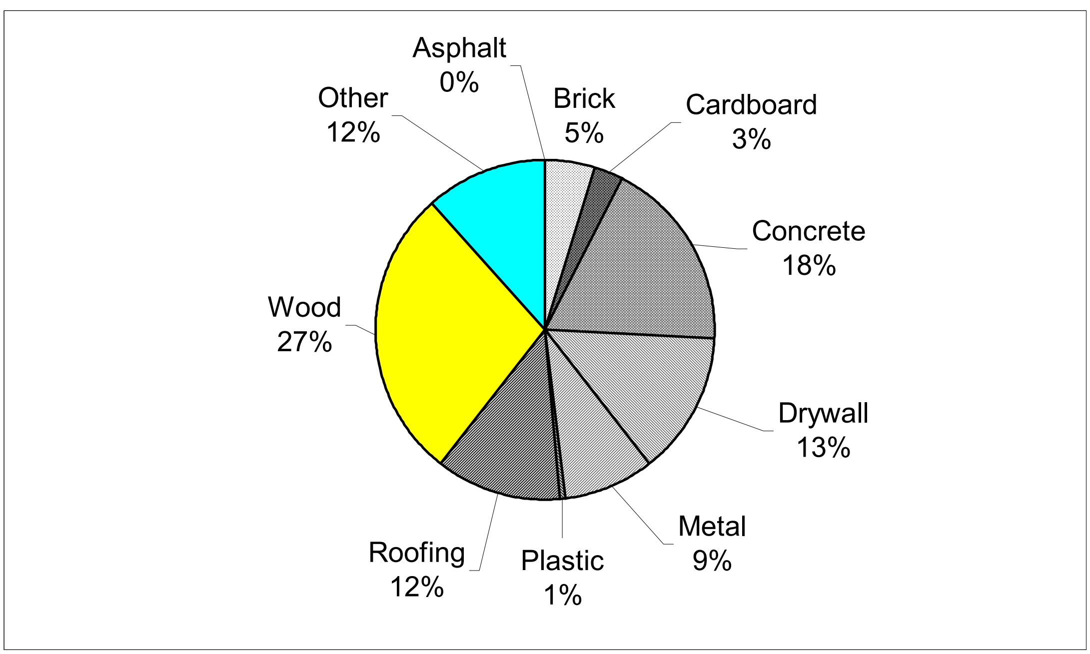
Due to the nature of the data, it is necessary to determine the most appropriate way to treat the C&D waste. In Franklin Associate's (1998) report to the EPA three categories of C&D waste were reported: primary inert fractions, high organic based fractions, and composite materials. The individual materials included were:

- Asphalt
- Brick
- Cinder block
- Concrete with rebar/wire mesh
- Concrete w/o reinforcing
- Masonite/slate
- Ceramic tile
- Glass
- Dirt
- Plastic sheet film
- Plastic pipe
- Porcelain
- Metal-ferrous
- Metal-non-ferrous
- Electrical wiring
- Insulation-fiberglass
- Plastic buckets
- Ceiling tiles
- Corrugated shipping containers
- Insulations-sheathing
- Pallets, etc.
- Chipboard

- Roofing material
- Dimensional lumber
- Plywood, etc.
- Carpeting and padding
- Wallboard
- Electrical fixtures/switches
- Rubber hosing
- Tires
- Painted wood
- Pressure treated wood
- Wood composites

This is a very complete list. For this report, only the most common forms of C&D waste will be reviewed. The percentage of breakdown that best represent this waste stream needs to be determined. Figure 3 demonstrates the general break-down determined in the 1998 market assessment for North Carolina (North Carolina, 1998). From this it can be seen that the state was generally looking at asphalt, brick, cardboard, concrete, drywall, metal, plastic, roofing, wood, and a combined area for all other debris. Potential recyclables in the C&D waste stream will be limited to metal, drywall, asphalt shingles, wood, concrete and brick in this report.

Figure3. Overall Composition of C&D Debris in North Carolina



Metals

Metals comprised 9% of the waste stream in North Carolina's waste stream breakdown. This is made up of aluminum, steel, and copper. Metals are a valuable commodity in the recycling stream, making it one of the most likely fractions of the waste to be recycled for aluminum can be sold for $640/ton, steel for between 20-60 $/ton, and copper for $1,573/ton (NCDENR, 1998).

Drywall

Drywall makes up about 13% of the C&D waste stream in North Carolina. Unfortunately, in demolition, the ability to recycle drywall is limited due to painted surfaces. The amount of refinement needed to market these as a sorbent or soil conditioner is extensive and requires the recycler to charge a tipping fee similar to a landfill tipping fee (NCDENR, 1998).

Asphalt Shingles

Asphalt shingles are 12% of the C&D waste stream. It is possible to recycle shingles into a portion of asphalt pavement. There is the potential that the shingles from older structures could have been made with asbestos. This requires testing before any sales of the product and will increase the cost of the removal. As with drywall, the extensive work needed to make asphalt shingles marketable as a recyclable causes the cost of recycling to be similar to landfill tipping fees (NCDENR, 1998).

Wood

Wood is one of the easier commodities to recycle in the C&D waste stream. At 28% of the waste stream in North Carolina, it is a larger section of the waste stream. If the wood is free of contaminant (i.e. paint, etc.) it is possible to chip and use as mulch. Mulch can range in price from free to $12.00/ton. Dimensional lumber is kiln-dried and is therefore a valuable fuel source. In North Carolina recovered kiln-dried lumber can be marketed at $12-25/ton (NCDENR, 1998).

Concrete/Brick

In North Carolina concrete makes up 18% of the waste stream and brick 5%. This is a lower fraction than in the waste stream at Fort Bragg. Both concrete and brick can be crushed and used as a road base. This is currently being done at Fort Bragg resulting in 100% recycling (Weston, 2003).

Waste Stream Determination for Fort Bragg

It is obvious from the variation in concrete percentage between Fort Bragg and the average state value that the state average will not be representative. The concrete for the state average only makes up 18% of the waste stream. This is much lower than Fort Bragg's concrete percentage of 41.95%. This obviously is not representative of Fort Bragg's waste stream. This is probably due to the unique nature as well as the content of the demolition on site. Franklin Associates Report to the EPA included several waste stream analysis that could be used to determine best approach for Fort Bragg's system. The Riverdale Case Study is a multi-family building case study from the Franklin report and is shown in Table 45. Table 46 is also from the Franklin report and shows an average composition for 19 industrial/commercial demolition projects in the northwest. Figures 4 and 5 illustrate this graphically. Both of these case studies better reflect the percentage of concrete/rubble that is dealt with at Fort Bragg. Since a waste study has not been done on the Fort Bragg C&D waste stream, cost analyses will be done for the site using both of the following waste stream analysis.

Table 45. Riverdale Case Study for C&D , Multi-Family Deconstruction (Franklin, 1998)

Material	Tons	Percent
Wood	17.6	14
Drywall	21.6	17
Roofing	3.5	3
Rubble	66.5	52
Brick	17.9	14
Miscellaneous	1.4	1
	128.5	101

Table 46. Average Composition from 19 Industrial/Commercial Demolition Projects in the Northwest (Franklin, 1998)

Material	Tons	Percent
Wood	28,000	15.5

Roofing	1,400	0.8
Concrete	120,300	66.8
Brick	2,200	1.2
Scrap Iron	8,700	4.8
Asphalt	3,200	1.8
Landfill Debris	16,400	9.1
	180,200	100

Figure 4. Riverdale Case Study for Multi-family C&D Debris

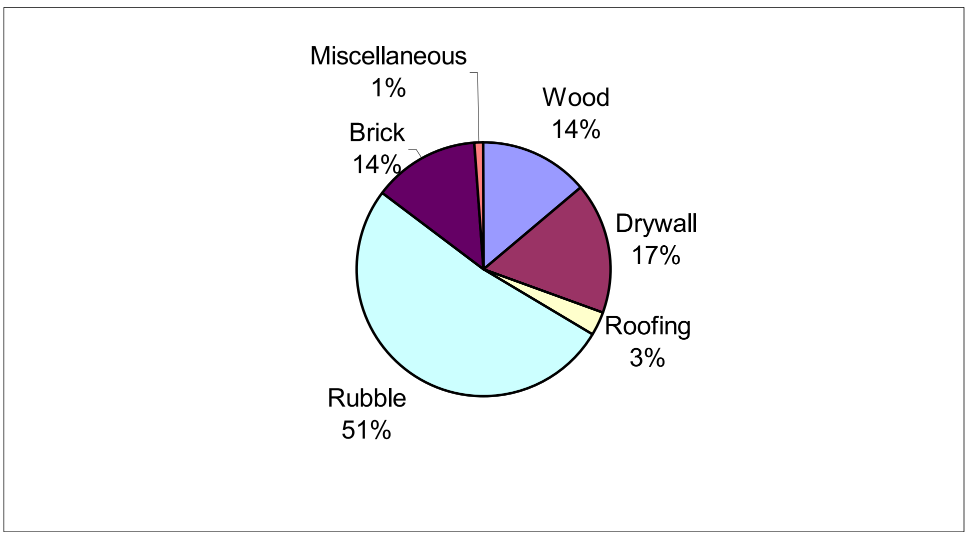


Figure 5. Average Composition of C&D Waste in Northwest Region

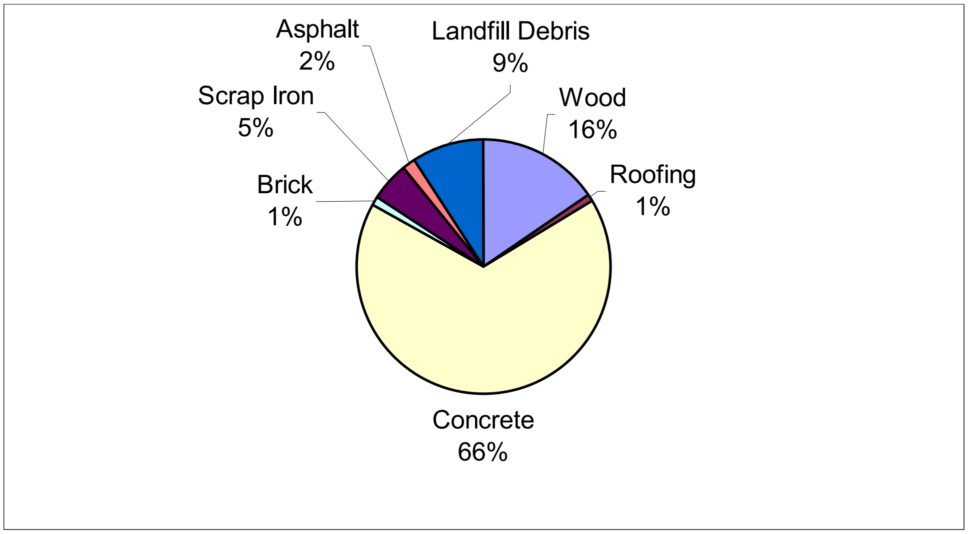


Table 47 shows the predicted waste stream based on the total waste from C&D and concrete for FY02 and using the waste stream numbers from both the Northwest study of commercial and industrial sites, and the multi-family Riverdale study. Table 48 addresses the same issue but uses the Market Assessment for North Carolina. As previously mentioned the percentage of concrete does not match what is currently produced at the site. The concrete was adjusted to the known amount for the site and an assumption was made that the remaining waste would resemble the percentages seen typically in North Carolina with the percentage for each waste stream was adjusted accordingly.

Table 47. Waste Tonnages Based on Northwest and Riverdale Waste Stream Analyses

Material	% of Waste Stream/ Northwest Study	% of Waste Stream/ Riverdale Study	Waste Stream Prediction/Northwest (Tons)	Waste Stream Prediction/Riverdale (Tons)
Wood	15.5	14	27,647	24,972
Roofing	0.8	3	1,427	5,351
Concrete	66.8	52	119,151	92,752
Brick	1.2	14	2,140	24,972
Metal	4.8	0	8,562	0
Asphalt	1.8	0	3,211	0

Drywall	0	17	0	30,323
Miscellaneous	9.1	1	16,232	1,784
Total	100	101	178,370	180,154

Table 48. Waste Tonnages Based on Adjusted North Carolina Waste Stream Analyses

North Carolina	% of Waste Stream, (NCDENR, 1998)	% of Waste Adjusted for Increased Concrete	Waste Stream Prediction (Tons)
Wood	27	19.1	48,160
Roofing	12	8.5	21,404
Concrete	18	42.0	32,107
Brick	5	3.5	8,919
Metal	9	6.4	16,053
Asphalt	0	0.0	0
Drywall	13	9.2	23,188
Miscellaneous	16	11.3	28,539
	100	100	178,370

At this point a prediction of the recyclable amounts needs to be made. Currently, all concrete rubble is being recycled on site. There is also the potential to do this with brick. Therefore, the numbers for these two waste streams will be set to 100%. According to Chang and Cramer (2003), approximately 70% of the waste from C&D recycling is in an acceptable state for recycling. These numbers are shown in Tables 49 and 50. Table 49 provides the tonnages of waste using the Northwest and Riverdale waste stream analysis. Table 50 provides the same information with the adjusted North Carolina waste stream breakdown.

Table 49. Potential Tonnages of Recyclable Waste, Using Northwest and Riverdale Waste Stream Analyses

Material	Northwest (Tons)	Riverdale (Tons)	% Recyclable	Northwest Recycled Amount (tons)	Riverdale Recycled Amount (tons)
Wood	27,647	24,972	70	19,353	17,480
Roofing	1,427	5,351	70	999	3,746
Concrete	119,151	92,752	100	119,151	92,752
Brick	2,140	24,972	100	2,140	24,972
Scrap Iron	8,562	0	70	5,993	0
Asphalt	3,211	0	70	2,247	0
Drywall	0	30,323	70	0	21,226
Miscellaneous	16,232	1,784	0	0	0

Table 50. Potential Tonnages of Recyclable Waste, Using Adjusted North Carolina Waste Stream Analyses

Material	Tons	% Recyclable	Recycled (Tons)
Wood	48,160	70	33,712
Roofing	21,404	70	14,983
Concrete	32,107	100	32,107
Brick	8,919	100	8,919
Scrap Iron	16,053	70	11,237
Asphalt	0	70	0
Drywall	23,188	70	16,232
Miscellaneous	28,539	0	0

Options for Recycling of New Construction Waste

There are always new creative ideas for recycling that are emerging over time. Options are available for the recycle of new construction waste. This waste, unlike demolition waste, does not face issues related to lead or asbestos contamination, among others. This could allow for extended recycling. Construction companies have contributed new construction waste to organizations like Habitat for Humanity. With governmental organizations this can be more complex. The use of an independent contractor as the middle-man can simplify this process. At least one organization in North Carolina, PCM Construction Services, LLC, has designed a system to allow ease in recycling for new construction waste. According to Terry Evans (2003) of PCM Construction Services LLC they have reached a recycling rate of 50% or greater for the waste that they haul.

PCM Construction Services, LLC provides 30 yard dumpsters for all new construction waste to be placed on the construction site. PCM is then responsible for the disposal of this material. The material is hauled to a transfer station where it is dumped and sorted based on acceptability of the material for multiple markets. The waste that can be used for Habitat for Humanity is then donated to this organization for the construction of new homes. Dimensional lumber that is not of acceptable size for re-use is ground and sent to co-generator for energy production. The cost associated with their system is two-fold. There is a hauling cost that can run around $100-125 dollars per trailer. An additional tonnage fee is also charged at $28-31/ton (Evans, 2003). The benefits to contractors include no responsibility for hauling their waste and no tipping fees associated with the disposal.

Laws have been proposed in the state for several counties that would require a minimum recycled percentage related to new construction waste. Currently Orange and Wake Counties are considering such laws. A similar option could potentially be used on military installations that require new contracts for construction to recycle a minimum percentage of the new construction waste in an effort to encourage additional recycling.

Cost Analysis

Three items are included in the cost analysis. They are capital cost, operating costs of the C&D recycling facility, and the income from the sale of the recycled material. Both drywall and asphalt shingles have negative income associated with them. Brick and concrete can and are being recycled onsite equating to no gain or loss for their sale. There is the additional benefit to new construction that these materials do not have to be purchased, rather the recycled material can be utilized. Any surplus recycled material could then be sold. Metal and wood are marketable and could bring a profit with their sales.

Capital and Operating Costs

Capital costs were outlined in Chang and Cramer's (2003) paper. The equipment outlined in this report were rock crushers, wood hog, excavator, bulldozer, compactor, loader, dump truck, tractor daycab, and a 40 foot topload dumptruck. These capital expenses will be used in the following analysis. Table 51 illustrates the number and cost from each of these. Total capital cost for C&D recycling would be approximately $1.4 million.

Table 51. Capital Costs Associated with the Setup of C&D Recycling (Chang and Cramer, 2003)

Equipment	Number	Cost ($)[1]
Rock Crusher	1	500,000
Wood Hog[2]	1	100,000
Excavators	3	360,000
Bulldozer	1	45,000
Compactor, Chopper Wheels	1	150,000
Loader	1	40,000
Dump Truck	1	90,000
Tractor Daycab	1	85,000
39-40ft Top load Dump Truck	1	44,000
	Total ($)	1,414,000

Table 52 demonstrates predicted cash flows based on the three waste stream characterizations used in this report and the potential sales for each material. The price per tons for the material was based on the NCDENR (1998) assessment. Numbers related to C&D waste are very unpredictable in nature. Concrete and brick were included with a price of zero since they will be used on site. There could be a financial benefit if this decreases the purchases of aggregate for other projects. This potential saving is not reflected in this report. The price for the wood was set at the low end for North Carolina as sold for power not the lower income if it was converted to mulch. Metals were set again for the low end of the available market. Negative numbers related to the average tipping fee for C&D waste was included as the cost for disposing of roofing material, asphalt and drywall to a recycler. This cost is about the same as if it was landfilled.

As seen from the income associated with the three different waste streams, without any revenue for the aggregate, two of the waste streams predict negative income from sales. Only the Northwest waste stream characterization (done for commercial sites) illustrates the ability for a positive income from the waste streams. This is mainly because of less roofing and drywall associated with this waste stream.

Operating cost for a facility capable of handling the current level of C&D waste being produced at Fort Bragg can only be estimated. From Chang and Cramer's (2003) paper on C&D recycling, a similar sized facility could expect to spend approximately 1.5 million dollars a year in operating costs. In a worst case scenario a C&D recycling facility onsite at Fort Bragg could have annual costs associated with it of approximately two million dollars. Further expansion of this analysis will not be done due to the volatile nature of the recycling market for C&D material. The total capital costs associated with the setup of a C&D recycling facility came to $1.4 million. If a discount rate of 5% is applied over a period of eight years, a cost of approximately $219,000 per year is calculated. The operating costs per year for the first year of operation can be expected to be around $1,360,000 (Chang and Cramer, 2003). The total costs for the first year will be approximately $1,579,000.

Table 52. Market Assessments of Fort Bragg's C&D Waste Based on Three Waste Stream Characterizations

Material	Price/ton	North Carolina, Adj.	Northwest	Riverdale	North Carolina, Adj.	Northwest	Riverdale
Wood	$12	33,712	19,353	17,480	$404,544	$232,236	$209,760
Roofing	-$30	14,983	999	3,746	-$449,490	-$29,970	-$112,380

Concrete	$0	32,107	119,151			Waste Recycled (tons)	Income
Brick	$0	8,919	2,140	24,972	$0	$0	$0
Scrap Iron	$20	11,237	5,993	0	$224,740	$119,860	$0
Asphalt	-$30	0	2,247	0	$0	-$67,410	$0
Drywall	-$30	16,232	0	21,226	-$486,960	$0	-$636,780
				Total ($)	-$307,166	$254,716	-$539,400

7 Conclusions and Recommendations

The basic goal for this report was to determine feasibility for recycling programs in the Sandhills Region including Fort Bragg. In addition, Fort Bragg's goal to reduce landfill waste to zero by 2025 was included.

This report addresses the current situation across the Sandhills Region for MSW waste. In the six counties that make up the Sandhills Region there is one recycling facility which is located in The City of Laurinburg. The Laurinburg facility is not an acceptable size for handling materials from extended areas. Moore and Richmond Counties send their recyclables to Uwharrie Environmental, Inc. in Montgomery County. All six of the counties in the Sandhills Region send their MSW waste to Uwharrie Environmental, Inc. for disposal. Three of the counties within this region have collection points for some recyclables which are picked up by independent companies and include Scotland, Cumberland, and Harnett Counties. Fort Bragg sends its MSW waste currently to Uwharrie Environmental, Inc. and has a recycling program in place that sends approximately 1000 tons per year to the MRF located at Uwharrie Environmental, Inc.

There are no current facilities for LCID and C&D wastes recycling in the Sandhills Region with the exception of some small-scale independent contractors. On Fort Bragg LCID waste is partially recycled by individual contractors. This is done in the form of chipping and shredding to make mulch during some construction jobs. C&D recycling is currently taking place only for concrete. Concrete is crushed and reused in new construction jobs at Fort Bragg. During FY02, 75,000 tons of concrete were recycled. LCID and C&D recycling in this report addressed only a localized area in Fort Bragg due to excessive transportation costs.

Four scenarios were addressed for MSW recycling options. MSW Scenario 1 addressed feasibility of Fort Bragg operating its own MRF. MSW Scenario 2 discussed financial aspects of increasing recycling at the Uwharrie Environmental, Inc. MRF by including commercial and industrial facilities in the recycle program. MSW Scenario 3 looked at an option of coordinating Fort Bragg, City of Fayetteville, and Cumberland County. MSW Scenario 4 determined 1) the optimum location of a MRF if all six counties were included, 2) the number of MRF's that would best suit this area, and 3) whether all six counties should be considered in a regional MRF.

MSW Scenario 1 addressed the setup and operation of a MRF at Fort Bragg and resulted in a negative profit of $300,000 to $360,000 per year using a 50% participation rate. The loss in income is due to insufficient recyclables revenue to cover the capital, operating and maintenance costs. If the percentage of recyclables was increased at some point the breakeven point would be exceeded and a profit would be realized.

MSW Scenario 2 assessed increasing the amount of recycling through Uwharrie Environmental, Inc. There is the potential to increase the recycling amount by including commercial and industrial sources. This could increase the amount recycled from 1,000 tons to 3,600 tons per year and the annual costs would increase by approximately $46,000.

MSW Scenario 3 addressed the joint recycling of Cumberland County, The City of Fayetteville, and Fort Bragg. The capital and operating and maintenance costs for this option are about the same as that for MSW Scenario 1. The additional recyclables available with this option increase the revenue from 0.5 to 1.2 million dollars, with a net benefit of $427,000 to $800,000.

MSW Scenario 4 selected Cumberland County as the most cost-effective siting for a MRF with no additional MRF's needed. For $0.40/ton/mile transportation cost and a $71/ton sales price of recyclables, the annual profit calculated by this model was -$121,282. This includes the cost to the counties for transportation and the expected profits from such a facility. To determine what would happen if a different alternative was chosen Hoke County was selected as the MRF site and resulted in a profit of -$234,730. A MRF site in Moore County site gave a net profit of -$239,606. The choice of Hoke County and Moore County for a MRF site reduced the annual profit by $113,448 and $118,324 respectively. This analysis shows that all counties would save money by sending their waste to a proposed MRF in Cumberland County. To determine the economic sustainability of the MRF operation the profit without the cost of transportation from counties to the MRF was calculated by the model. The range of potential profit for the MRF operation ranged from $33,739 to $790,885 with the variation due to the sales price varying from $50-$90/ton.

In terms of economic feasibility MSW Scenarios 3 and 4 are both acceptable and MSW Scenarios 1 and 2 are least desirable. MSW Scenarios 3 and 4 show the ability to be profitable due to the increased prices for and amount of recyclable materials. MSW Scenarios 1,2 and 3 do not take into account transportation costs to either the MRF or the landfill. MSW Scenario 2 is economically a better option than MSW Scenario 1 because as the recycle rate at Fort Bragg increases (Scenario 1) there is proportional increase in cost.

For LCID waste two scenarios were considered based on two existing facilities in the state. Composting Scenario 1 uses less equipment and therefore capital costs were lower. Sensitivity analysis shows that profit from LCID waste recycling at Fort Bragg would range from $655,000 to $985,000. Composting Scenario 2 uses more specialized equipment, hence a higher capital cost. The profit from Scenario 2 ranged from $612,000 to $941,000. Composting Scenario 1 was not concerned as much with quality, since its main primary customer was using the compost material as raw material for boiler fuel. Composting Scenario 2 was a design for a higher quality material to be made available to the general public. Composting Scenario 2 is proposed as the better option considering the fact that it produces higher quality material with minimal increase in cost. Either option will potentially allow a reduction in landfill tonnages of 146,000 per year. There could be difficulty marketing this material and this should be addressed before any final decisions are made

C&D recycling was addressed by evaluating specific waste streams. This evaluation was very challenging due to the volatility of the markets and the variations among waste streams. The capital costs for this type of project is similar to that of LCID and is approximately $1.4 million. Some equipment is common to both C&D and LCID recycling and could be shared between operations. Operating costs were extensive at $1.4 million. Operating costs should be further analyzed to determine the accuracy of the numbers used. Sales of the recycled new construction material did not show a benefit for C&D recycling partly due to the fact that a zero cost was included for crushed concrete. Any cost benefit from recycled concrete could be applied to future construction projects. Total income for this would run about negative 1.5 million dollars.

There is potential for the recycling of new construction waste. New construction waste does not have health issues associated with it due to contamination of lead and asbestos. A requirement in construction contracts stating that a certain recycling rate be met for new construction debris could allow C&D recycling to continue with minimal cost to Fort Bragg. According to Evans (2003) the recycle rate among clean construction waste can be as high as 50%.

With additional recycling there comes another advantage not addressed in this report. This is the reduction of waste for landfilling and thus extending the existing landfill life. Extending landfill life while trying to reach a goal of zero landfill waste will allow Fort Bragg to make better use of their available land.

In approaching the decision to recycle at Fort Bragg there are two directions that can be chosen. One from a point of cost and another from reduced landfill waste. If cost is taken as the most important aspect then LCID would be the best choice, followed by MSW, and then C&D waste. If tonnage reduction to the landfill was considered the most important aspect then LCID would be the most important, followed by C&D, and then MSW. It is important to remember that the construction and demolition, and therefore some of the waste for LCID, is going to reduce as construction activities are completed. When this point is reached MSW tonnages will have a greater impact on the percentage of waste that is landfilled. Keeping this in mind MSW recycling should not be set apart due to cost, but should be looked at as a long-term issue.

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