**A NEW CHAPTER FOR RECYCLING:**
Using Geographic Information Systems (GIS) to improve the market development and transportation of recycled materials.

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**DISCLAIMER**

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**EXECUTIVE SUMMARY**

The Northeast's recycling infrastructure that processes and manufactures new products from recycled materials includes more than 1500 facilities that handle thousands of tons of recyclables each day. However, this network of facilities could be expanded and could handle more material more efficiently. Suggested sites for new facilities, optimal transportation routes to and from facilities, and information about the supply and demand of materials could be used to improve the infrastructure. To address this challenge, EPA Region 1 sponsored a project to use the Geographic Information System (GIS) Arc-Info to improve the market development of recyclables and determine better transportation routes for recyclables. This project focused on the four most commonly recycled materials: glass, paper, metal and plastic.

GIS is a tool that allows a user to manipulate spatially referenced data. A variety of sources were used to generate recycling data, which were incorporated into GIS coverages. The base map coverages were recycling facilities maps for each state in the Northeast. Transportation coverages were also developed as part of this project for each Northeastern state. For the analysis, more detailed coverages were needed. These analyses focused on Massachusetts (MA) and several MA town coverages were created: 1) tons per type of material, 2) commercial property tax, 3) unemployment rate, 4) population density per block for the town of Natick. Existing land use and transportation coverages for MA were also used.

For the analysis part of the project, GIS was used to do the following: 1) determine suitable locations for a plastic manufacturer using various siting criteria, 2) perform a market analysis to show the potential supply available for an expanding paper manufacturer, and 3) find optimal routes from a processor to a manufacturer using major roads and from a processor to the nearest port using railroads.

Each type of analyses includes many important factors, yet does not account for every influencing factor. For example, in the siting analysis, site availability, proximity to transportation routes, supply and demand of recyclables and cost were considered. Other data were not included primarily because they did not exist or were difficult to represent spatially. The analyses main contribution is that it demonstrates several ways GIS can be used for recycling.

Because so little work has been done in this area, there is tremendous potential for GIS-related applications for recycling. As more data becomes available, the challenge will be to use this body of work to inspire new and more sophisticated contributions using GIS for recycling.

**INTRODUCTION**

Although some states in the Northeast report recycling rates of 30% and above, the region's recycling infrastructure that processes and manufacturers new products from recycled materials needs improvement. In some cases, new processing and manufacturing facilities are needed. In others, better transportation routes to and from processors and manufacturers are required. Finally, in order to maintain existing recycling businesses, important recycling information such as potential supply and optimal transportation routes to and from facilities should be made available. In response to these needs, EPA Region I sponsored this project to use the Geographic Information System (GIS) Arc-Info to determine where investments can be made in the Northeast to enhance the market development of recyclables and make the transportation of recyclables more efficient.[1]

This project is intended to introduce professionals from government and industry to how GIS can be used for recycling, particularly individuals in the fields of solid waste, economic development, private business and GIS technology. In its analyses, the project incorporates recycling data from many sources, but does not include all influencing factors. For this reason, the project serves more as a demonstration of GIS applications for recycling than as a comprehensive recycling analysis.

GIS is a tool that allows a user to manipulate spatially referenced data. In simpler terms, GIS makes it possible to represent data in a map layer, or coverage. Different coverages can be combined, or overlayed. Once overlayed, a user can perform analyses on these map coverages. A recycling facilities map for each Northeastern state was created for this project (see Figure 1). In addition, five maps of Massachusetts (MA) were made showing the location of its recycling facilities (Figure 2), the tons per type of material per town (Figure 3), the commercial property tax rate per town (Figure 4), the unemployment rate per town (Figure 5), and the population density per block map of a particular town (Figure 6). In addition, a map was created showing a 100 mile buffer around a paper mill (Figure 7), and optimal transportation routes using major roads (Figure 8) and railroads (Figure 9). Two other pre-existing coverages were used showing land use and the transportation network of MA.

GIS was used to perform three types of demonstration analyses for this project: 1) siting criteria was used to determine suitable locations for a new recycling facility, 2) a market analysis was performed for a given facility, and 3) the most efficient routes from a processor to a manufacturer and to a port were determined. This project focused on the four most commonly recycled materials: glass, paper, metal and plastic.

Although there is great potential for GIS to improve the market development and transportation of recyclables, the technology has its limitations. Certain information, such as public attitudes, is difficult to represent spatially. In addition, GIS is a means of presenting and analyzing data; without good data, it is impossible to produce meaningful results.

## I. METHODOLOGY

### A. RECYCLING DATA

Federal and state solid waste officials, economic development specialists, GIS experts, statistical agencies, and trade associations were consulted to determine the types of recycling data that exists for each Northeastern state (Appendix 1). The Northeast Recycling Council (NERC) provided the name, address, phone number, fax number, and materials handled by each recycling facility in the Northeast. Efforts were made to determine the exact location, the tons handled per day, and the number of employees for each of these facilities by telephoning each company. On the generation side, the tons of each material (glass, paper, metal and plastic) handled per town was also requested from each state's recycling office.

Although each Northeastern state collects recycling data, very few states collect the type of data mentioned above. Pennsylvania is the only Northeastern state that has used latitude/longitude coordinates to map its recycling facilities and has created a coverage containing about 30% of its facilities; this coverage was not used in this project because it was not made available. MA has mapped its paper mills, glass processors, and plastics processors, but only in the appropriate towns, not using exact latitude/longitudes. Connecticut (CT), Rhode Island (RI), and New York (NY) provided this project with the tons of recyclables handled for some of the facilities located in those states. No state was able to provide the number of employees per facility as this data did not exist or was confidential. Finally, New Jersey (NJ) and MA provided the tons of materials recycled per town, and CT provided the tons recycled per material per town. Because of time constraints, only MA data was entered into the GIS.

In addition, contacts were asked to supply potential study areas based on market development information, transportation data, collection and marketing opportunities, and GIS data. MA was the only state from which this information was collected. The Massachusetts Department of Environmental Protection (MA DEP) shared GIS coverages including the recycling facilities map and a map of the types of collection program (curbside or drop-off) for each town. The recycling facilities coverage was used to verify NERC's list. The EPA Region 1 Solid Waste Library provided transportation and market development information. Specifically, literature was provided that discussed different modes of transportation (truck or rail) and the current market for paper, glass, plastic and metal.

## 1. RECYCLING FACILITIES MAP

Although it is a simplistic approach, this project divided all Northeastern recycling facilities into two categories: processors and manufacturers. A processor is defined as a facility that sorts, bales, separates, crushes or cleans recycled materials and prepares them for market. A manufacturer is characterized as a facility that uses post-consumer paper, plastic, glass or metal to make a new product. A recycled material like a soda bottle may pass through many stages before it reaches a processor -- from the consumer to a drop-off center to a transfer station. In fact, it may not reach a processor at all. However, this project assumes that most recycled materials pass through a processor before being used to make a new product. Thus, this project does not consider all of the stages before the processors but still capturers the bulk of recyclables.

NERC's list of the processors and manufacturers in the Northeast contains approximately 1500 facilities. The facilities are divided into nine categories: glass processors and manufacturers, metal processors and manufacturers, plastic processors and manufacturers, paper processors and manufacturers, and multi-material processors. Some states have more facilities than others. New York (491 facilities), Pennsylvania (463), and New Jersey (267) contain the most and greatly outnumber states like Rhode Island with 18 facilities.

As indicated above, for each facility, NERC provided the name, address, phone number, fax number, and materials handled. The materials handled were divided into the following categories:

**paper** -- HG (high grade), MIX (mixed grade), CARD (old corrugated cardboard), OMG (old magazines), ONP (old newspaper), PULP SUBS (pulp substitutes);

**plastic** -- PET (polyethylene terepthalate), HDPE (high-density polyethylene), LDPE (low-density polyethylene), PVC (polyvinyl chloride), PP (polypropylene), PS (polystyrene);

**metal** -- FERR (ferrous), NON-FERR (non-ferrous);

**glass** -- GLASS.

Due to time constraints, this project only created a detailed map (with a reference list and corresponding numbers beside each facility) of the recycling facilities in MA as a prototype. This map is discussed later. Coverages exist for the other Northeastern states, but detailed maps were not created for each separate state. In addition, a map of the entire Northeast was created, showing the location of each recycling facility. Both maps represent facilities with a symbol so they can be easily identified. It is easy to distinguish processors from manufacturers since processors are represented by solid symbols and manufacturers by the outlines of symbols. See Figure One for a list of how each type of facility is symbolized.

**2. QUESTIONNAIRE**

A questionnaire was sent to all processors and manufacturers of recyclables in VT, DE, and RI asking for the tons of recyclables handled per day and the number of employees (Appendix 2). The other seven Northeastern states did not participate for various reasons, primarily because they had just requested information from recycling facilities. At the time of this writing, few questionnaires have been returned; many businesses consider the information proprietary and are unwilling to share it. Because so few have been returned, the results from the questionnaires will not be included in this report. However, as information is collected, it will be added to the recycling facilities coverages.

**B. LATITUDE/LONGITUDE COORDINATES FOR EACH FACILITY**

In order to obtain the latitude/longitude coordinates for each facility on NERC's list, various methods were considered. These included searching the EPA's RCRA database, sending each facility a map and asking them to identify their location on the map, calling each facility and finding its location on a 1:250,000 or 1:24,000 7.5 X 15 Minute Quadrangle U.S. Geological Survey (USGS) Topographical map as an employee described the location over the phone (the "USGS" method), hiring a consultant to find coordinates, or searching through the Dun and Bradstreet directory of businesses.[2]

Searching the Dun and Bradstreet directory was determined to be the most efficient method, and was then used to obtain each facility's latitude/longitude coordinate. A search was conducted of the Dun and Bradstreet directory using 8 Standard Industrial Codes (SIC).[3] This search captured about 65% of the facilities. For the rest of the facilities, coordinates were obtained by searching the directory for each facility separately.

Surprisingly, the facilities were classified under seventy other SIC codes ranging from 5181 (Beer and Ale) to 5033 (Roofing, Siding and Insulation).[4]

The Dun and Bradstreet directory also contains the number of employees per facility. This data was collected for each facility.

**II. MASSACHUSETTS: THE NORTHEASTERN STATE SELECTED FOR STUDY**

This project focused on one state, MA, since a ten state region was too large an area to study. MA was selected for practical purposes -- MA data was easiest to collect since this project was done in Boston. In addition, the MA DEP collects a considerable amount of recycling data, particularly on the publicly owned Springfield Materials Recovery Facility, and the total tons and types of materials recycled by each town. This project used MA as a model; the same analyses can be done for any other state if the data exists.

For MA, Dun and Bradstreet data was used to obtain latitude/longitude coordinates for 60% of the facilities. The other 40% were located using the "USGS" method. This method produced accurate latitude/longitude coordinates, usually within one quarter of a mile of a facility's location. The USGS method was also used to verify a random sample of thirty Dun and Bradstreet coordinates.[5]

Seven types of coverages were created for the MA analysis portion of this project: 1) a recycling facilities coverage, 2) a tons per type of material per town coverage, 3) a coverage showing commercial property tax rates per town, 4) an unemployment rate per town coverage, 5) a population density per block coverage of the town of Natick, 6) a coverage showing a 100 mile buffer around a paper mill, and 7) a coverage indicating optimal transportation routes using roads and railroads. Existing land use and transportation coverages were also used. Below is a description of each of these coverages and of potential coverages.

**A. MASSACHUSETTS RECYCLING FACILITIES COVERAGE**

In addition to the symbology for facilities described above, each Massachusetts facility is assigned a number. Along the right hand side of the map, a reference list gives the name and number of each facility, making it easy to identify each facility by name.

The MA facility coverage also contains the following data obtained from phone calls made to the facilities: tons of glass, paper, plastic and/or metal handled per day. Additionally, in order to verify the Dun and Bradstreet employee data, firms were also asked to report the number of employees. The Dun and Bradstreet data proved to be relatively accurate, although it was not used if employee data were received over the phone.

Eighty-six of the 131 facilities reported both their tons handled per day and the number of employees at the site. These figures were used to estimate the average tons per day per employee for each type of facility (Appendix 3). A similar technique was used by Roy F. Weston, Inc. in **Value Added to Recyclable Materials in the Northeast**, a study conducted for NERC. All calculations were based on 250 working days per year. Interestingly, this reports' estimates are close to those found in Weston's report.

**B. GENERATION - TONS OF PAPER, GLASS, PLASTIC, ALUMINUM AND STEEL PER TOWN COVERAGE**

The tons of paper, glass, plastic and metal recycled per town was estimated using the 1994 Massachusetts Solid Waste Master Plan (MA SWMP).[6] Using this data, a map was created which shows the estimated tons of glass recycled by each town's residential sector. The more glass recycled by a town, the darker the color assigned to that town. As expected, the map indicates that the most glass was recycled in areas of high population, such as Boston, Worcester and Springfield. However, it was interesting that large quantities of glass were recycled in Attleboro and Chicopee, towns with populations of 38,383 and 56,632 respectively. The data exists to create similar maps for the tons of residential paper, plastic, aluminum and steel recycled per town.

**C. COMMERCIAL/INDUSTRIAL PROPERTY TAX PER TOWN COVERAGE**

In Massachusetts the operator of a privately owned or operated "resource recovery facility" is required to pay a state tax of approximately one dollar per ton of solid waste processed at their facility. A resource recovery facility is defined as "a solid waste disposal facility utilizing processes for reclaiming the materials or energy values from solid wastes," and refers to both processors and manufacturers of recyclables. The one dollar per ton fee is paid "in lieu of all taxes, fees, charges or assessments imposed by the city or town in which the said facility ... is located, except for real estate taxes.[7]" Thus, a town's commercial/industrial property tax is a factor that an owner must consider when deciding where to locate their recycling facility and so a map was created showing the commercial/industrial property tax rate per MA town. The MA Department of Revenue supplied Fiscal Year 1994 commercial/industrial tax rates for every town but two, Hancock and Norwood.

On the map, the towns are shaded based on their property tax rate; the higher the rate, the darker the color. The highest property taxes are found in the most urban areas, as can be expected considering that commercial property in these areas is in higher demand. Notable exceptions are Clinton and Florida.

**D. UNEMPLOYMENT RATE PER TOWN COVERAGE**

A fourth coverage shows the unemployment rate for each MA town. The purpose of this map is to highlight areas that MA's state government may want to target for economic development. Through tax assistance and other incentives, MA can help locate a recycling facility in an economically depressed area. This map used the most recent MA unemployment rates, May, 1994, obtained from the U.S. Department of Labor's Bureau of Labor Statistics (BLS). The BLS calculates unemployment by polling a random sample of households across Massachusetts, surveying employers, and accessing the state unemployment insurance system. According to the BLS, an unemployed person is someone over the age of 16, jobless, available for work and looking for work.[8]

The map assigns a light color to all towns with an unemployment rate below 6%, since these are areas at or slightly above the state's mean rate of 5.8%. Darker colors are assigned to higher unemployment rates with a dark blue representing towns with a rate greater than 20%. Interestingly, only Provincetown and Gay Head have rates above 20%. Aside from these two towns, the map indicates that western, southeastern and northeastern Massachusetts are the regions with the highest unemployment rates. Lawrence, Chester, Monroe and Rowe warrant special attention since all have a rate greater than 12%.

**E. LAND USE DATA LAYERS**

Land use coverages for 55 of Massachusetts' 351 towns were available for this project, mostly for towns in Northeastern MA.[9] This limited the scope of the facility siting analysis. The data layer uses 22 possible categories, ranging from cropland to recreation, to describe the land use of each town. The information was mapped by the Resource Mapping Project at the University of Massachusetts, Amherst in 1985 using photo-interpretation and automation.

This project was most interested in the regions zoned for commercial purposes, defined as "light and heavy industry," since they would be areas where a new recycling facility would be sited. Of the 55 available towns, only 16 towns had at least 200 acres of commercially zoned land.[10]

**F. POPULATION DENSITY**

Using 1990 census data, a map was created that shows the population density of each block in Natick, MA. This map is part of the siting analysis discussed later in which Natick was selected as a potential site for a plastic facility. The data exists to create a map that shows population density across MA by block, block group, or census tract. Population density is defined as the number of people in residence per square kilometer. A block is "a small area bounded on all sides by visible features such as streets, roads, streams, and railroad tracks, and by invisible [political] boundaries such as a city [line]....[11]

Many studies have documented the "Not In MY Backyard (NIMBY)" phenomena, where people strongly oppose living near an industrial facility. The population density map aims to avoid NIMBY opposition by indicating sparsely populated areas, regions where a recycling facility would have the best chance of being sited.

The 1990 Census data could also be used to estimate the tons of materials recycled per town. EPA has estimated that an average person produces 4.3 lbs of garbage per day.[12] This figure could be multiplied by a town's population and 365 days per year to estimate the total municipal solid waste produced by a town in a year. A recycling rate, such as 28%, can be applied to this number to estimate the total tons recycled by a town. Furthermore, a process like the one described in estimating the tons of glass per town map of MA could be used to estimate the tons of paper, glass, plastic, steel and/or aluminum recycled by each town in the US.

**G. TRANSPORTATION AND PORTS COVERAGES**

Maps of the major roads, railroads and ports in the Northeast were used in the transportation analysis and facility siting sections of this project. The road coverage used divides MA's roads into several categories: primary, secondary, and road or street. The map was created by the USGS and is a 1:100,000 scale digital line graph map, meaning it contains line map information in digital form. In addition, a map of the major railroad lines in MA was used. The railroad coverage is also a

USGS 1:100,000 digital line graph map. Finally, the ports coverage includes seventeen major ports on the east coast.[13]

## H. OTHER POTENTIAL COVERAGES

### 1. WAGE RATES

Wage rates are another factor that a business owner must consider when deciding where to locate their facility. Periodically, the BLS conducts surveys of randomly selected employees in five areas of Massachusetts to calculate an average wage rate for various jobs. The five regions are the Boston Metropolitan Area, the Worcester Metropolitan Area, the Lawrence-Haverhill Metropolitan Area, Western Massachusetts, and Southeastern Massachusetts.[14] The BLS surveys used were conducted between March and October of 1993.

This project was interested in the average wage rate for "material handling laborers" and "maintenance electronic technicians," jobs comparable to those at a recycling facility.[15] The wage rate for material handlers was highest in the Boston area ($10.87 per hour), followed by Lawrence-Haverhill ($10.66), Western MA ($10.42), Worcester ($7.78) and Southeastern MA ($7.76). The wage rate for Level III (of VI levels) technical workers varied in almost the exact same way with the highest wages in Boston ($15.00), followed by Western MA ($14.47), Lawrence-Haverhill ($14.37), and Southeastern MA ($13.42). Only level I and II information was available for Worcester. This data was used in the project's analyses although a map was not created. It would not be difficult to create this map; each area's towns would be assigned an average wage rate and shaded accordingly.

### 2. UTILITY RATES

Utility rates are yet another factor that a recycling business must consider when deciding where to locate. Phone calls were made to various utility companies and trade associations in an effort to create a map that shows how utility rates vary across Massachusetts. Unfortunately, it was not possible to create this map because each company offers several rates for different levels of use, making it difficult to determine a generic recycling facility rate. In addition, different types of facilities use different amounts of electricity -- a glass manufacturer, being more industrial-based, uses more electricity than a glass processor, which may rely more heavily on human labor. However, if each type of facility was considered separately and an average wattage figure was estimated for each, it may be possible to create a utility rate map.

**3. ABANDONED INDUSTRIAL SITES**

It would have been interesting to create a map showing the location of the abandoned industrial buildings in the Northeast. In many cases, it is less expensive to renovate an abandoned building than to build a new recycling facility. EPA Region I's librarian has actively searched for the addresses and/or latitude/longitude coordinates of states' abandoned industrial buildings but has been unable to find this information.

**4. OTHER RECYCLING PROCESSORS**

Other coverages showing transfer stations and/or regional drop-off centers could be created using the USGS method if the locations are known. Such coverages would make possible the collection analysis discussed later.

## III. HOW DATA IS FILED AND CAN BE ACCESSED

All of the recycling facility data was built in Dbase III and then converted to an Info file for use in Arc-Info. For every state but Massachusetts, a Dbase III file exists with the name, address, phone number, fax number, latitude longitude coordinate, number of employees and materials handled (HG, MIX, HDPE, etc.) by each facility. There is also a field which indicates whether each facility is a processor (P) or a manufacturer (M) and handles paper (PA), glass (GL), metal (ME), plastic (PL) or multi-materials (MU). The Massachusetts Dbase file contains all of this information as well as the tons of paper, glass, metal, plastic and/or multi-materials handled be each facility. All latitude/longitude coordinates were projected to NAD 1983 albers, a commonly used map projection.

The tons per town data was calculated in Lotus 2.3, converted to Dbase III and then to an Info file. The data was then related to a pre-existing Massachusetts town coverage so it could be used in Arc-Info. The property tax and unemployment per town information was entered directly into an Info file and was also related to the Massachusetts town coverage.

## IV. ANALYSIS

GIS has far-reaching potential as an analytical tool, particularly in the recycling domain. As more data becomes available, the number of GIS applications will grow indefinitely, hindered mainly by the user's imagination. However, there are limits to what can be accomplished through GIS since certain information is difficult to represent spatially or may not be available.

This project presents three ways that a GIS can be used to assist in or improve the market development of recyclables.

Although the analyses focuses on Massachusetts, the same type of analyses can be used for other states if the data exists.

**A. PERFORMING A MARKET ANALYSIS FOR A GIVEN FACILITY**

A GIS can be used to show an area's supply and demand of recyclables and help perform a market analysis for a given facility. For example, in addition to showing the location and type of each recycling facility, the MA coverage contains the total materials supplied by MA's processors and demanded by its manufacturers. Although the data may have inaccuracies and may not capture **all** of the materials recycled in MA, it provides a good estimate of the supply and demand in MA.

A GIS can also be used to provide important information to recycling facilities -- data that could be made available through state recycling offices. For example, suppose a paper mill in MA is considering expanding its operations and accepting an additional 100 tons of post-consumer paper per day. A GIS can help show whether such a move is feasible, considering the existing supply and demand of recycled paper and competing facilities in the area.

As a demonstration, the American Tissue Mill of MA located in Templeton, MA was selected because it is the most centrally located paper mill in MA. The mill currently uses approximately 91 tons of post-consumer paper per day to make tissue paper products. It receives almost every type of post-consumer paper available: high grade, low grade, mixed paper, old newspaper, old magazines, old corrugated cardboard, and carbon paper. The ARC command CALCULATE was used to add each processor's totals and it was estimated that the supply of paper per day in MA is 1,757 tons. Likewise, the estimated demand in MA, including the 91 tons demanded by American Tissue, is 2,256.8 tons per day. The tons of paper handled per day was collected for all 22 paper manufacturers and 31 of the 33 paper processors in MA.

According to this data, the American Tissue Mill should contact paper processors outside of MA, since the current demand inside MA exceeds supply. A GIS can help in this search by identifying all processors within a 100 mile radius of the mill (see Figure 7). One-hundred miles was selected because it is a reasonable distance for a supplier to travel to the mill -- an approximately two hour drive by truck. To perform this analysis, a buffer of 100 miles was created around the American Tissue Mill. This buffer was overlayed onto a map of the paper processors and manufacturers in MA, CT, RI, NY, NH and VT.

If the tons of paper handled per day were available for each facility within the buffer zone, it would be possible to calculate the total supply and demand within 100 miles of the mill (some of this data exists for CT although it was not entered into GIS and made available for this analysis). Instead, it is only possible to provide the names, addresses and phone numbers of potential suppliers and competitors.

Within the buffer zone, there were 20 paper processors in CT, 1 in RI, 11 in NY, 11 in NH and 4 in VT. Without tonnage figures, it is difficult to determine which state offers the most potential supply, although CT appears to have the most facilities and probably more supply because of its high population. Of the 33 processors in MA, only three process at least 150 tons but 10 process at least 100 tons, indicating that large processors exist within a relatively short distance. A total of 18 competitors were within the zone, 5 in CT, 1 in RI, 6 in NY, 2 in NH and 4 in VT. A GIS can also be used to calculate the tons of paper generated by the residential sector in every MA town at 366,957.92 tons. A map was not created to show which towns generated the most paper, although the towns with the highest populations probably generated the most.

Thus, due to a lack of data on the tons handled by each facility, it is unclear whether the American Paper Mill should expand its operations by 100 tons. Information concerning the flow of paper from processors to manufacturers is also lacking, which further limits the analysis. Because of its proprietary nature, data on the flow of recyclables may be impossible collect. Finally, this analysis does not consider the price and availability of virgin wood fibers, which would also be a competing interest. Nevertheless, once more data becomes available, this type of GIS analysis could provide a business with valuable information.

**B. SITING A RECYCLING MANUFACTURING FACILITY**

In order to make the Northeast's recycling infrastructure more effective and efficient, new recycling facilities are needed. A GIS can help determine what types of facilities are needed and where those facilities should be located.

Based on discussions with recycling officials, it was determined that before an owner of a facility settles on a location, there are four major factors to consider: the supply of recyclables, site availability, access to transportation routes, and the costs (such as taxes and wage rates) associated with locating in an area. Below is a description of how GIS was used to consider these factors and find a site for a plastic manufacturer.

**1. PLASTICS DEMONSTRATION - HOW TO LOCATE A MANUFACTURING FACILITY USING A GIS**

Natick was selected as a potential site for a plastic manufacturer because of its close proximity to major roads and railroads, its considerable acreage of land zoned for commercial/industrial purposes, its low commercial property tax rate and its location relative to plastic processors.

Using CALCULATE, it was estimated that 555 tons of post-consumer plastic is processed each day in MA, a conservative estimate since data was collected from 10 of 14 processors. Only 56.2 tons of post-consumer plastic is used by MA's manufacturers each day. These figures suggest that MA may be a suitable state for a new plastic manufacturer. The following analysis shows how a GIS can be used to identify a specific site in MA for the facility.

As indicated above, there appears to be an adequate supply of post-consumer plastic in MA. The MA recycling facilities coverage shows that 536 of the 555 tons are processed in Eastern Massachusetts (East of Sturbridge). The region between Worcester and Boston (near Framingham) is a roughly the center of Eastern MA, making it a good potential site for a facility.

If land use data had been available for each MA town, GIS could have been used to calculate the total acres zoned for commercial/industrial purposes for each town. Land use data was only available for 55 towns, but eleven of these towns were in the Framingham area. The GIS command RESELECT was used to show that seven towns in this area had at least 150 acres of land zoned for industry: Shrewsbury (196 acres), Northborough (169), Hudson (258), Marlborough (269), Westborough (154), Hopkinton (190) and Natick (272). Natick deserves special attention since it has the most land zoned for industry.

In addition to its land use, a business owner must consider a town's commercial property tax rate. According to the commercial property tax map, of the seven towns listed above, Shrewsbury has the lowest rate at 12.73%. Natick has the next lowest tax at 14.92%, followed by Northborough (15.97%), Westborough (16.53%), Hopkinton (16.70%), Hudson (27.50%) and Marlborough (27.50%). Again, Natick appears to be a good potential site.

A town's average wage rates is yet another factor to consider, specifically rates for material handling laborers and mid-level (level II) technicians. Shrewsbury, Westborough, and Northborough are in the Worcester Metropolitan Area where the average laborer's wage is $7.78 per hour (range: $6.90 - $8.52) and technician's wage is $14.17 per hour. Natick, Hopkinton, Hudson and Marlborough are in the Boston Metropolitan Area with an average laborer's wage of $10.87 (range: $9.36 - $11.70) per hour and a technician's wage of $12.35 per hour (range: $11.50 - $13.10). Compared to the Worcester area towns, Natick has high laborer's wages and low technician's wages; statistics taken from Boston where rates are high may have skewed both averages, though.

A map was created of Natick showing the areas zoned for commercial/industrial purposes, major roads, railroads, and population densities per block. Major highways such as I-90 and Route 9 pass through the town, providing trucks with easy access in and out of town and to the nearby Boston port. The map also shows railroads passing through the center of town, within close proximity of several commercial zones. This gives a facility the option of shipping recyclables by rail. The population density information indicates which parcels of commercially zoned land are surrounded by few people. The map also indicates the size of each parcel of commercially zoned land. When this map is overlayed with the property tax and the recycling facilities maps, it is clear that Natick is the best site in the Framingham area for a plastic manufacturer, given that not all of the area's land use coverages were available.

More specifically, the Natick map suggests that the parcel in the Northwest corner of the town is the best site. It is the largest site, 113.492 acres, and has direct access to railroads and major roads. The population density data also indicates this is the best site, since it's surrounded by the fewest people. At least theoretically, locating a site there would minimize the impact of the facility on Natick's citizens.

Although limited by the lack of land use data and other information, this analysis demonstrates how a GIS can be used to help site a recycling manufacturer; for a more complete analysis, other factors would have to be considered. The analysis would be made stronger by incorporating regional utility rates and the location of abandoned industrial buildings, etc. as part of the spatial representation. A siting decision would also need additional subjective information such as public attitudes.

**C. SITING A RECYCLING PROCESSING FACILITY**

The same basic procedure can be used to site a processing facility, since land use restrictions, wage rates, access to roads and railroads, and population density are still relevant considerations. In siting a processor, however, it is important to measure supply by how much different towns are generating. The tons per material per MA town has been entered into a GIS and can be used to find areas where large quantities are recycled, making them suitable locations for a processor.

Similarly, a GIS can help identify potential sites for a multi-material regional processing facility once the participating towns are identified. Such cooperation lowers transportation costs to secondary markets and provides larger, more reliable quantities of materials to processors. This analysis would require a map layer containing the region's transfer stations. Suitable sites would be selected based on proximity to each town's transfer station and other previously mentioned criteria.

### 1. GOVERNMENT-ASSISTED SITING OR EXPANSION OF A RECYCLING FACILITY

Most, if not all, state governments have programs to provide assistance to economically depressed areas. For example, the Massachusetts Office of Business Development (MA OBD) has developed a Municipal Economic Development Incentive Program which has targeted sixteen areas for assistance. Through a combination of municipal tax benefits and investment tax credits, the MA OBD hopes to attract businesses to the designated areas. Recycling facilities are one type of business that can provide jobs and an increased tax base to a distressed community. State efforts to encourage existing facilities to expand in these areas would achieve similar ends.[16]

The map of a state's unemployment rate per town and recycling facilities can help policymakers identify where to locate a recycling facility. In addition, a map can be created portraying a state's economic target areas and recycling facilities to further enhance policymakers' efforts. Other previously mentioned criteria such as access to transportation routes and ports, land use restrictions, population density, and wage rates should be considered.

## D. TRANSPORTATION OF RECYCLABLES TO SECONDARY MARKETS

When shipping recyclables to a manufacturer it is imperative that a processor minimizes his transportation costs. A GIS can be used to help determine the most efficient and cost-effective route from a processor to a manufacturer. To illustrate this, Clean Environment Company, a recycling processor of glass and metal located in Chicopee, MA, north of Springfield was selected. Clean Environment Co. primarily processes glass, 30 tons a day, although 8 tons a day of metal is also processed. The GIS was used to find the most efficient route from Clean Environment Co. to MA's only glass manufacturer, Foster-Forbes, located in Milford. The GIS was also used to find the best railroad route from Clean Environment Co. to the Boston port for the metals.

To do this analysis, the computer is first told where to begin its journey (Clean Environment Co.) and where to end it (Foster-Forbes). The GIS command PATH instructs the computer to consider all available major highways between the two locations in search of the "least-distance," or shortest distance route. Figure Eight shows the selected route between Clean Environment Co. and Foster-Forbes using major roads. GIS showed this path to include Route 20, Route 21, Route I-90 and Route 140, and the CALCULATE command determined that the route is about 65 miles long. Figure Nine shows the least-distance route between Clean Environment Co. and the Boston port, a distance of approximately 104 miles.

MA DEP has developed a cost model that determines the approximate cost of shipping recyclables given the distance traveled. A similar cost model could be developed to estimate the cost of shipping recyclables by rail, incorporating that rail is a less expensive means of shipping heavier loads longer distances. As indicated above, a GIS could provide the distances traveled for the road and rail routes, which could then be entered into the cost model to estimate dollar values.

A GIS can also be used to determine the "least-cost" route between two points another way. First, the computer must be programmed to assign a different "cost value" to the various routes (highways, secondary roads, streets, and railroads) based on how much it costs in dollars to ship recyclables using those routes. When the computer finds the least-cost route between two locations, it simply chooses the transportation route that accumulates the lowest total cost value. Determining the relative cost values between highways, secondary roads, streets and railroads is difficult but can be done -- a group of businesses could be asked how much they pay to ship recyclables by these various routes. From this data, cost models could be developed.

Finally, many rural recycling programs have inefficient collection routes. A GIS can be used to determine "least-distance" or "least-cost" routes to collect recyclables from given locations, saving the hauler time and money. For example, a GIS could help a hauler find the most efficient route between five rural drop off centers, once those locations have been entered into the computer.

## V. CONCLUSIONS AND RECOMMENDATIONS

Improving the market development of recyclables in the Northeast is a complex and challenging task. This project has demonstrated how a GIS can be used to help meet this challenge, through siting new manufacturing and processing facilities, assisting existing ones and determining optimal transportation routes. Because so little work has been done in this area, there is tremendous potential for further GIS applications for recycling.

By mapping the Northeast's recycling facilities and describing various types of analyses, this project broke new ground. However, it was limited by the lack of recycling data available for the Northeast. Specific information about the tons handled by recycling facilities, the flow of recyclables, and the amount generated by the commercial sector is difficult to collect, and will continue to limit the use of a GIS for recycling. In addition, this project's analyses do not intend to account for every influencing factor; instead, the project serves as an initial demonstration of how a GIS can be used when some of the factors are available.

One challenge for those who continue in this area is to maintain and update the coverages developed for this project. In addition, states should continue to improve their data collection efforts, because as more recycling data is available, GIS technology could be used to make additional contributions to recycling.

## FOOTNOTES

1. Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

2. Dun and Bradstreet uses five methods to determine coordinates. BLOCKFACE is the most accurate method. Given a street address, the computer searches a street segment dictionary file created from the Bureau of Census' TIGER files. When the matching segment is found, the computer interpolates a latitude/longitude based on the house numbers in the street segment. BLOCKFACE usually provides a coordinate within 0 to 250 meters of the actual location. BLOCKFACE works best in urban areas, where roads are most carefully mapped. The second method, STREETSEG, is similar to BLOCKFACE but is used when there are no house numbers for the street segment in the dictionary file. An average latitude/longitude coordinate is calculated for the entire segment. Coordinates found using STREETSEG are usually within 500 meters of the actual site.

BLOCKGROUP or "block group centroid" is the third geocoding method used by Dun and Bradstreet. It is used if a street address is outside the TIGER street network but within a block group. A block group has roughly 300 households. The latitude/longitude coordinate for the center of the block group is assigned to the address. CENSUS or "census tract centroid" is the next most accurate method and is used if a street address is outside the TIGER street network but within a census tract. If this is the case, the latitude/longitude coordinate of the center of the census tract is assigned. A census tract contains roughly 1200 households. ZIP or "zip code centroid" is the final and least accurate geocoding method. This method assigns the same latitude/longitude coordinate to all addresses within a given zip code.

Most of the recycling facility coordinates were obtained using STREETSEG, BLOCKFACE and BLOCKGROUP; thus, most of the coordinates used are within 2 miles of the actual location. If a facility could not be located in Dun and Bradstreet's directory, the latitude/longitude coordinate of a business from the same street -- and in a few cases, the same city -- was used.

3. 5093 (Scrap and Waste Materials), 4953 (Refuse Systems), 2621 (Paper Mills), 2679 (Converted Paper/Paperboard Products), 3089 (Plastics, Products), 3221 (Glass Containers), 3229 (Glass and Glassware), 3312 (Steel Works, Blast Furnaces and Rolling Mills) and 5085 (Industrial Supplies)

4. 9511, 5531, 2086, 5181, 3564, 2493, 5046, 5399, 7389, 8741, 2652, 8742, 8731, 7819, 3411, 5099, 6719, 4212, 5149, 2671, 3339, 5013, 2679, 2676, 2499, 3321, 3341, 5113, 6531, 2631, 5033. 5039, 5084, 3081, 5531, 8221, 3365, 2819, 3356, 5199, 4952, 4226, 1795,

3599, 6221, 5032, 8748, 5023, 2899, 8111, 9532, 9121, 9111, 3353,3082, 3229, 7519, 3949, 2951, 2842, 5191, 1799, 3499, 8732, 7538, 3547, 3364, 3354, 5149, 4225.

5. The USGS method showed BLOCKFACE to be the most accurate geocoding method, as the Dun and Bradstreet literature suggests, producing points very close to the USGS locations. STREETSEG and BLOCKGROUP also proved to be accurate geocoding methods, within one-half mile of the USGS positions.

6. Massachusetts Department of Environmental Protection. **Massachusetts Solid Waste Master Plan**. 1994 Update.

The SWMP contains data on the total waste generated by the residential sector in each town in 1992. To get an estimate of the total residential tons generated per town, a 28% recycling rate was applied to the 1992 data. Twenty-eight was selected because it is approximately halfway between MA's 1992 reported recycling rate of 23% and 1996's goal of 34%.The tons of paper, glass, metal and plastic recycled by each MA town was estimated from these numbers.

The SWMP lists the total tons of glass, aluminum, paper, steel, and plastic recycled by MA's residential sector. The Master Plan also indicates the materials (glass, steel, aluminum, old newspaper, cardboard, and plastic) that each town recycles. The MA totals were used to create ratios between the amount of materials recycled by each town. For example, Mattapoisett recycles glass, steel, aluminum and plastic. A ratio was developed between these materials using the Massachusetts totals: 40% glass, 40% steel, 6% plastic, and 14% aluminum. This ratio was applied to the total materials recycled by Mattapoisett's residential sector at 28% to yield an estimate of the total tons of glass (836 tons), steel (836 tons), plastic (155.40 tons) and aluminum (362.60 tons) recycled by Mattapoisett's residential sector.

7. Massachusetts General Laws. 16:24A.

8. US Department of Labor, Bureau of Labor Statistics. **How the Government Measures Employment**. Report 864. March 1994.

9. Amesbury, Andover, Ashburnham, Ashby, Billerica, Boxford, Chelmsford, Dracut, Dunstable, Groton, Groveland, Harvard, Haverhill, Holden, Hopkinton, Hudson, Lancaster, Lawrence, Leominster, Lexington, Littleton, Lowell, Marlborough, Maynard, Merrimac, Methuen, Natick, Newburyport, North Andover, Northborough, Paxton, Pepperell, Princeton, Rutland, Salisbury, Sherborn, Shirley, Shrewsbury, Southborough, Sterling, Stow, Sturbridge, Sudbury, Tewksbury, Townsend, Tyngsborough, Wayland, West Boylston, West Newbury, Westborough, Westminster, Wilmington.

10. Andover, Billerica, Chelmsford, Haverhill, Hudson, Lawrence, Leominster, Littleton, Lowell, Marlborough, Methuen, Natick, Newburyport, North Adams, Tewksbury, Wilmington.

11. US Department of Commerce, Bureau of the Census. 1990 Census of Population and Housing. Summary Tape File 3.

12. US EPA. **Characterization of Municipal Solid Waste in the United States: 1992 Update.** July 1992.

13. **NH**: Portland, Portsmouth; **MA**: Boston, Fall River, New Bedford; **RI**: Providence; **CT**: New London, New Haven; **NY**: New York; **NJ**: Newark, Jersey City; **PA**: Philadelphia; **DE**: Wilmington; **MD**: Baltimore; **Washington, DC**; **VA**: Newport News, Richmond.

14. **Boston Metropolitan Area:** Suffolk County, 3 communities in Bristol County, 4 in Essex County, 44 in Middlesex County, 26 in Norfolk County, 16 in Plymouth County, and 9 in Worcester County;

**Worcester Metropolitan Area:** Worcester City and the following towns in Worcester county: Auburn, Barre, Boylston, Brookfield, Charlton, Clinton, Douglas, Dudley, East Brookfield, Grafton, Holden, Leicester, Millbury, North Brookfield, Northborough, Northbridge, Oxford, Paxton, Princeton, Rutland, Shrewsbury, Spenser, Sterling, Sutton, Uxbridge, Webster, West Boylston, and Westborough.

**Lawrence-Haverhill Metropolitan Area:** Haverhill, Lawrence, and Newburyport Cities, and Amesbury, Andover, Boxford, Georgetown, Groveland, Merrimac, Menthuen, Newbury, North Andover, Salisbury, and West Newbury Towns in Essex County.

**Southeastern Massachusetts**: Barnstable, Bristol, Dukes, Nantucket, Norfolk, and Plymouth Counties except cities and towns included in the Boston and Pawtucket-Woonsocket-Attleboro metropolitan areas.

**Western Massachusetts**: Berkshire, Franklin, Hampden, Hampshire, and Worcester Counties, except cities and towns included in the Boston, Worcester, and Pawtucket-Woonsocket-Attleboro metropolitan areas.

15. U.S. Department of Labor, Bureau of Labor Statistics. **Regional Occupational Compensation Surveys.**

**material handling laborer**: performs physical tasks to transport or store materials or merchandise.

**maintenance electronics technician (level II):** applies comprehensive technical knowledge to solve complex problems by interpreting manufacturers' manuals or similar documents. Work requires familiarity with the interrelationships of circuits and judgement in planning work sequence and in selecting tools and testing equipment.

**maintenance electronics technician (level III):** applies advanced technical knowledge to solve unusually complex problems that typically cannot be solved by referencing manufacturers' manuals or similar documents.

Below are the sample sizes of workers surveyed for the BLS' survey in each region.

| | **Mat. Handl. Laborer** | **Technical Laborer** (level II) | (level III) |
|---|---|---|---|
| Boston | 802 | 830 | 844 |
| Worcester | 86 | 25 | N/A |
| Lawrence-Haverhill | 171 | 28 | 36 |
| Southeastern MA | 171 | N/A | 65 |
| Western MA | 934 | N/A | 88 |

16. Executive Office of Environmental Affairs. Massachusetts Office of Business Development. **Economic Development Incentive Program.**

## Appendix 1

### GIS CONTACTS

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**OTHER FEDERAL CONTACTS**

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(202) 606-6220

US Department of Commerce
International Trade Administration
14th Street and Constitution Ave., NW
Washington, DC 20330

**TRADE ASSOCIATIONS**

Recycled Products International Trade Assoc.
2044 Oak Dr.
St. Louis, MO 63131
(314) 966-7355

Institute of Scrap Recycling Industries (ISRI), Inc.
1627 K Street, NW
Washington, DC 20006
(202) 466-4050

American Paper Institute (API)
260 Madison Ave.
New York, NY 10016
(212) 340-0654

Glass Packaging Institute
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Partnership for Plastics Program
Society of the Plastics Industry, Inc.
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Aluminum Recyclers Association
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Aluminum Association
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Steel Manufacturers Assoc.
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American Forest and Paper Association
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Aspectic Packaging Council
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NYNEX Information Resources Co.
Yellow Pages Publishers Assoc.
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Association of Post-Consumer Plastics Recyclers
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National Association for Plastic Container Recovery (NAPCOR)
3770 NationsBank Corporate Center, 100 North Tryon St,
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The Council for Textile Recycling
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International Cartridge Recycling Assoc.
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**Appendix 2: Part 1**

[Facility Name]
[Date]

Dear [Facility Name],

The United States Environmental Protection Agency (EPA) is embarking on a project with the ten states in the Northeast to enhance market development for recycling. The project is intended to identify where investments can be made in the recycling infrastructure and to address transportation inefficiencies. The project will be an invaluable tool for EPA and the [State Solid Waste Department] as we attempt to help businesses like yours be more productive and efficient.

The project involves mapping the processors of recycled materials and the manufacturers of recycled products in a Geographical Information System. All processors and manufacturers of glass, metal, paper and plastic in the Northeast will be mapped. Existing transportation and population maps for each state in the region will be combined with the recycling facilities map. Different types of analysis will then be performed to identify where assistance is needed in market development.

I have included a simple survey on the reverse side of this letter which requests information critical to the success of this project. I ask that you fill it out as accurately as possible and return it to my attention by [Date]. You can fax your response to me at [fax number] or mail it to the above address.

Please feel free to contact either myself at [phone number] or [Name], the EPA official assigned to the project, at [phone number] with any questions or concerns. I encourage you to participate in this worthwhile project. Thank you.

Sincerely,

[Name]

**If your company processes or manufactures recycled paper, glass, metal or plastic, please answer the questions below and return this form by [Date]. If your company does not process or manufacture any of these recyclables, please note this in the comments section and still return this form by [Date].**

Name: ______________________________________________

Company Name: ________________________________________

Please check: Manufacturer ☐ Processor ☐

1. Estimate the average TONS/DAY handled by your facility, (the post-consumer material used to manufacture a product if you are a manufacturer or the material processed for market if you are a processor) for each item listed below. If you are unable to provide the information in the manner requested (i.e., clear, brown ...), please provide aggregate tonnages (i.e., all glass).

2. Enter the number of employees at your facility, if this information is available. No. Employees: _____

3. Enter "N/A" for materials that you do not handle.

4. Include any other pertinent information in the comments column.

| ITEM | | TONS/DAY | COMMENTS |
|---|---|---|---|
| GLASS | CLEAR | | |
| | BROWN | | |
| | GREEN | | |
| PLASTIC | PET | | |
| | HDPE | | |
| METALS | ALUMINUM | | |
| | STEEL | | |
| PAPER | HIGH GRADE OFFICE | | |
| | MIXED GRADE OFFICE | | |
| | OLD NEWSPAPER | | |
| | CORRUGATED | | |
| | OLD MAGAZINES | | |

GENERAL COMMENTS:

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

**Appendix 3**

**Data Collected for Total Tons Per Employee Estimates**

| Type of Facility | Number of Facilities Providing Data | Average Tons/Employee/ Year |
|---|---|---|
| Paper Processors | 17 | 2.75 |
| Paper Manufacturers | 17 | .60 |
| Plastic Processors | 4 | 1.62 |
| Plastic Manufacturers | 2 | .39 |
| Metal Processors | 22 | 3.82 |
| Metal Manufacturers | 5 | .88 |
| Glass Processors | 2 | 33.00 |
| Glass Manufacturers (1) | 1 | 10.52 |
| Multi-Material Processors (2) | N/A | N/A |

(1) Since there is only one glass manufacturer in MA, this average ton/employee figure was not used to estimate any tonnages.

(2) All Multi-Material Processors reported tonnages, making it unecessary to estimate a different ton/employee for each material.

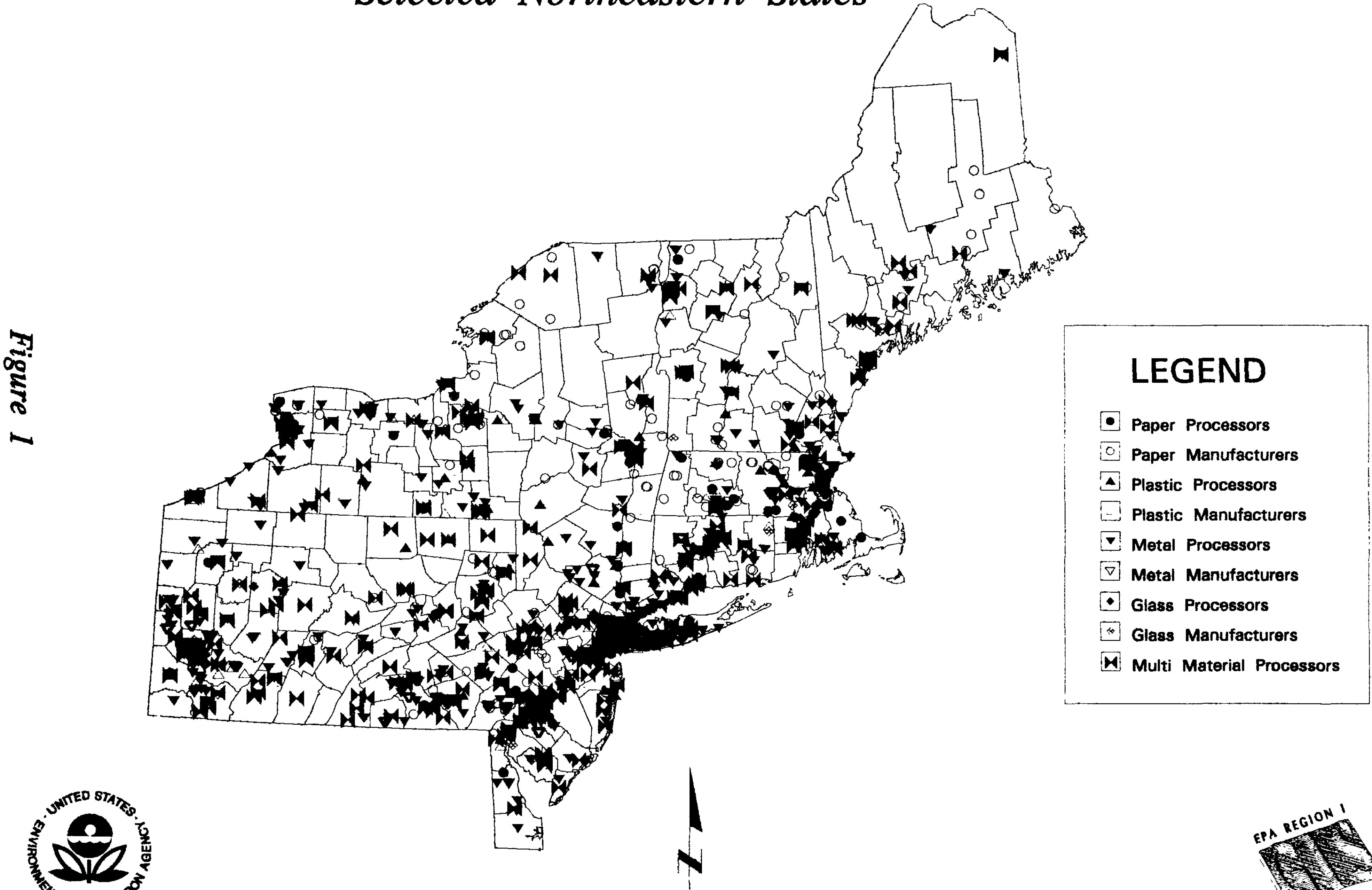
**REGIONAL MAP OF PROCESSORS AND MANUFACTURERS**
**FIGURE 1**

Number of Processors and Manufacturers in the 10 States= 1,482

By material:
Processor - Paper = 191
Manufacturer - Paper = 151
Processor - Plastic = 84
Manufacturer - Plastic = 46
Processor - Metal = 592
Manufacturer - Metal = 46
Processor - Glass = 11
Manufacturer - Glass = 17
Multi-Processor = 341

# Processors and Manufacturers of Recycled Materials

## *Selected Northeastern States*

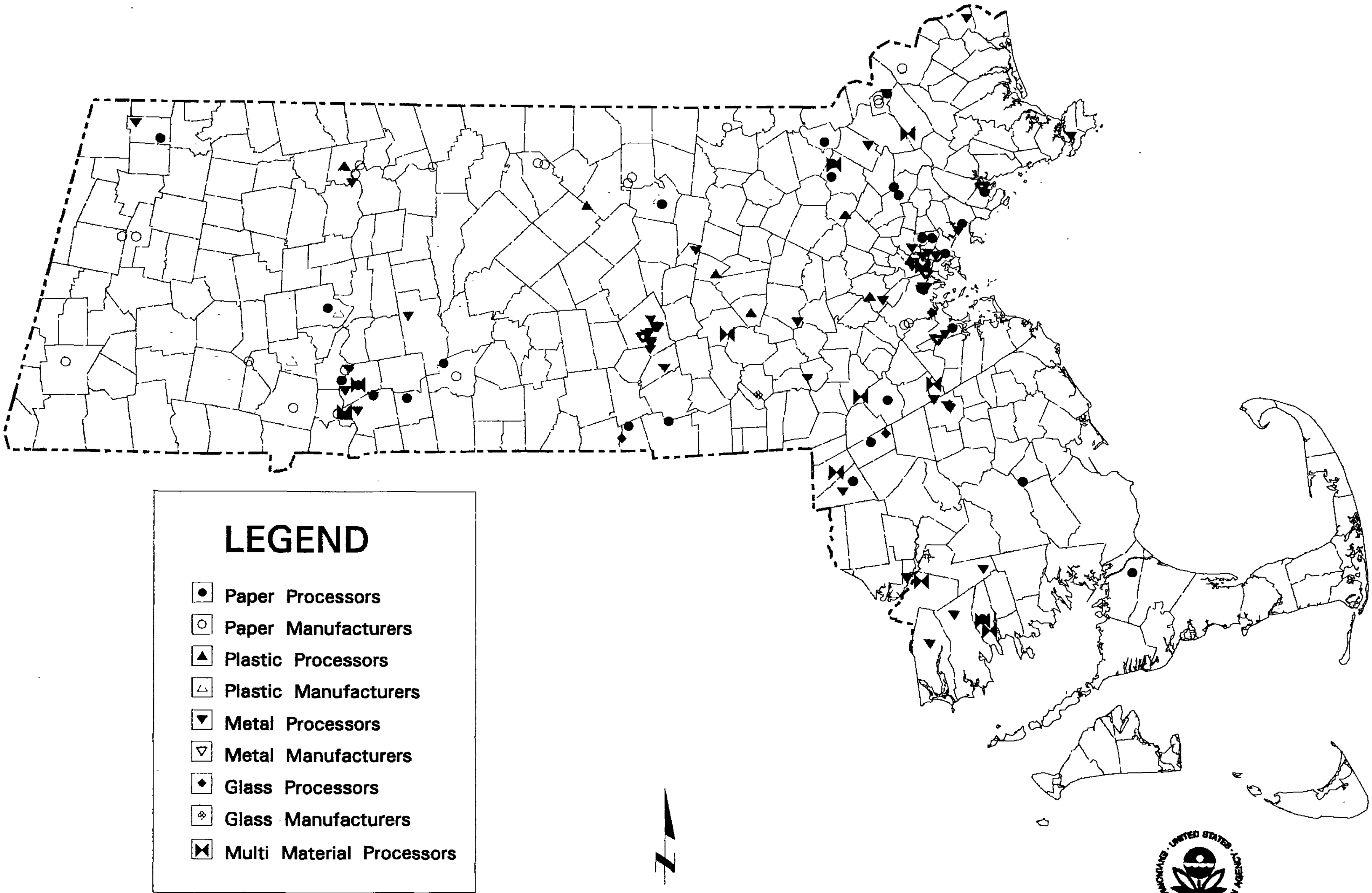



*SCALE = 1:6,300,000*

*Figure 1*

# Processors and Manufacturers of Recycled Materials

*Commonwealth of Massachusetts*




*Scale = 1:1,180,000*

*Figure 2*

# Tons of Glass Recycled per Massachusetts Town

## *All Figures are Estimated from Best Available Data*

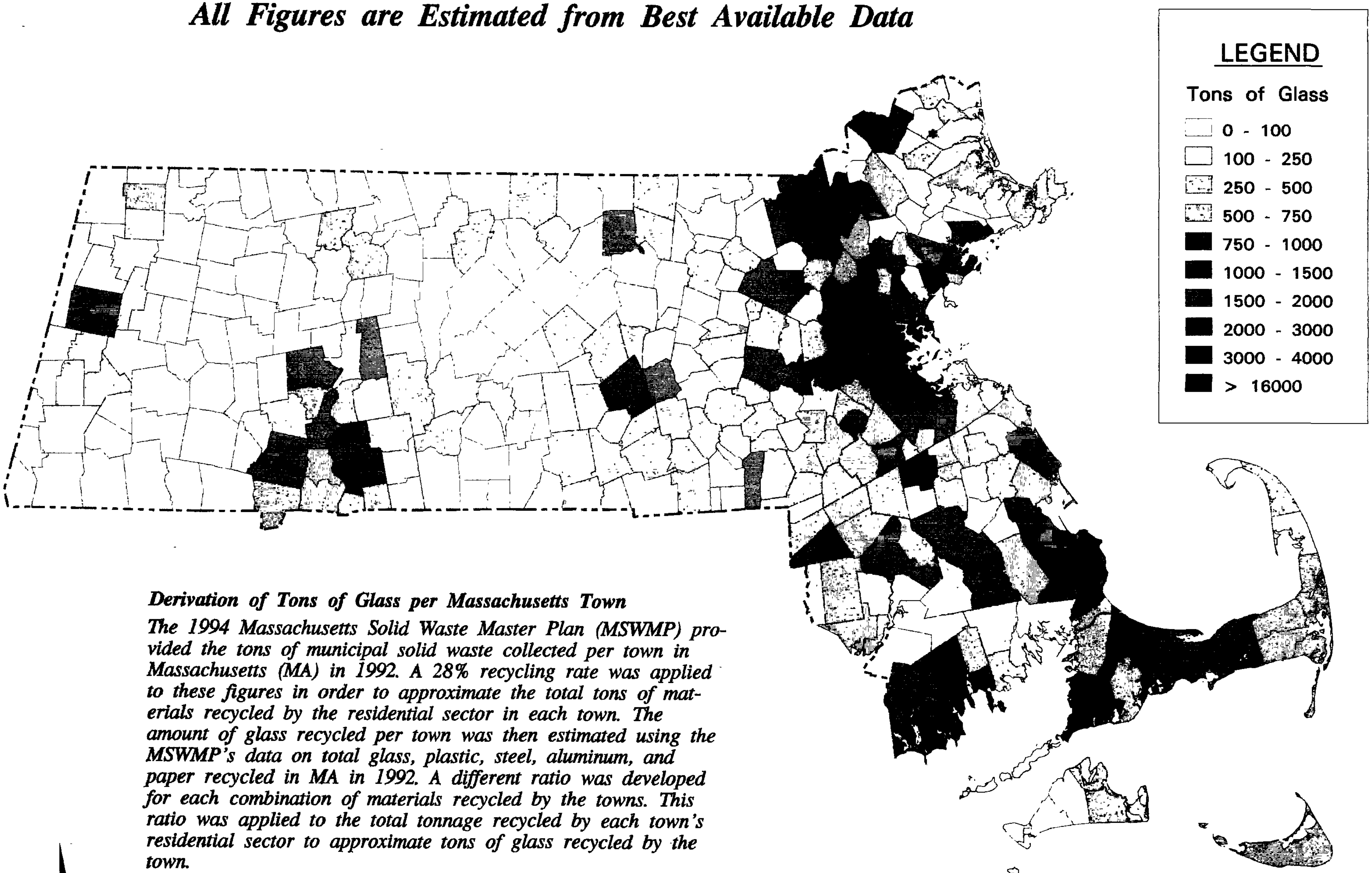



*Figure 3*

***Derivation of Tons of Glass per Massachusetts Town***

*The 1994 Massachusetts Solid Waste Master Plan (MSWMP) provided the tons of municipal solid waste collected per town in Massachusetts (MA) in 1992. A 28% recycling rate was applied to these figures in order to approximate the total tons of materials recycled by the residential sector in each town. The amount of glass recycled per town was then estimated using the MSWMP's data on total glass, plastic, steel, aluminum, and paper recycled in MA in 1992. A different ratio was developed for each combination of materials recycled by the towns. This ratio was applied to the total tonnage recycled by each town's residential sector to approximate tons of glass recycled by the town.*

*Scale = 1:1,180,000*

## FY 1994 Commercial Property Tax Rates & Processors and Manufacturers of Recycled Materials

*Commonwealth of Massachusetts*

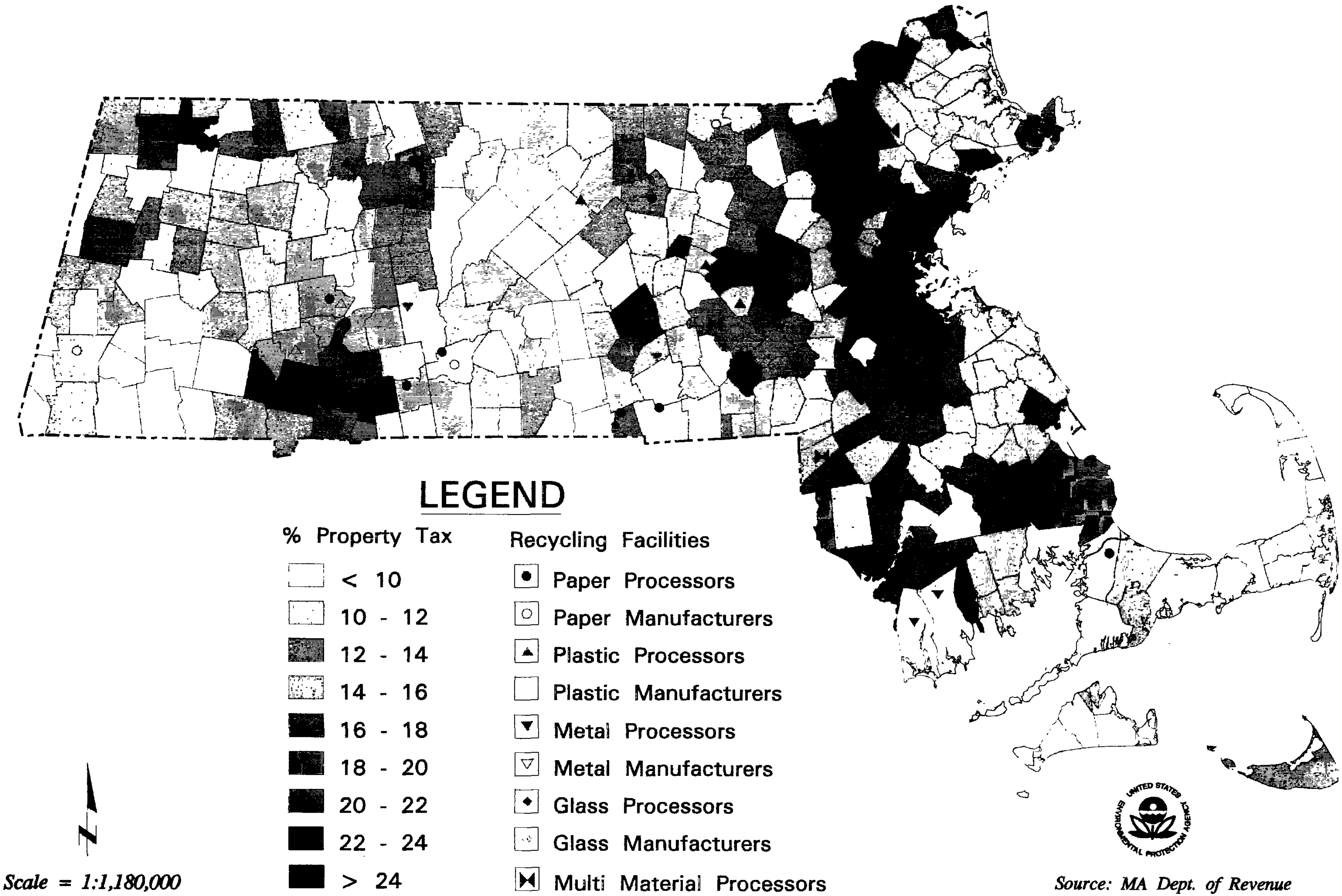



*Figure 4*

# Unemployment as of May 1994 & Processors and Manufacturers of Recyclables
## Commonwealth of Massachusetts

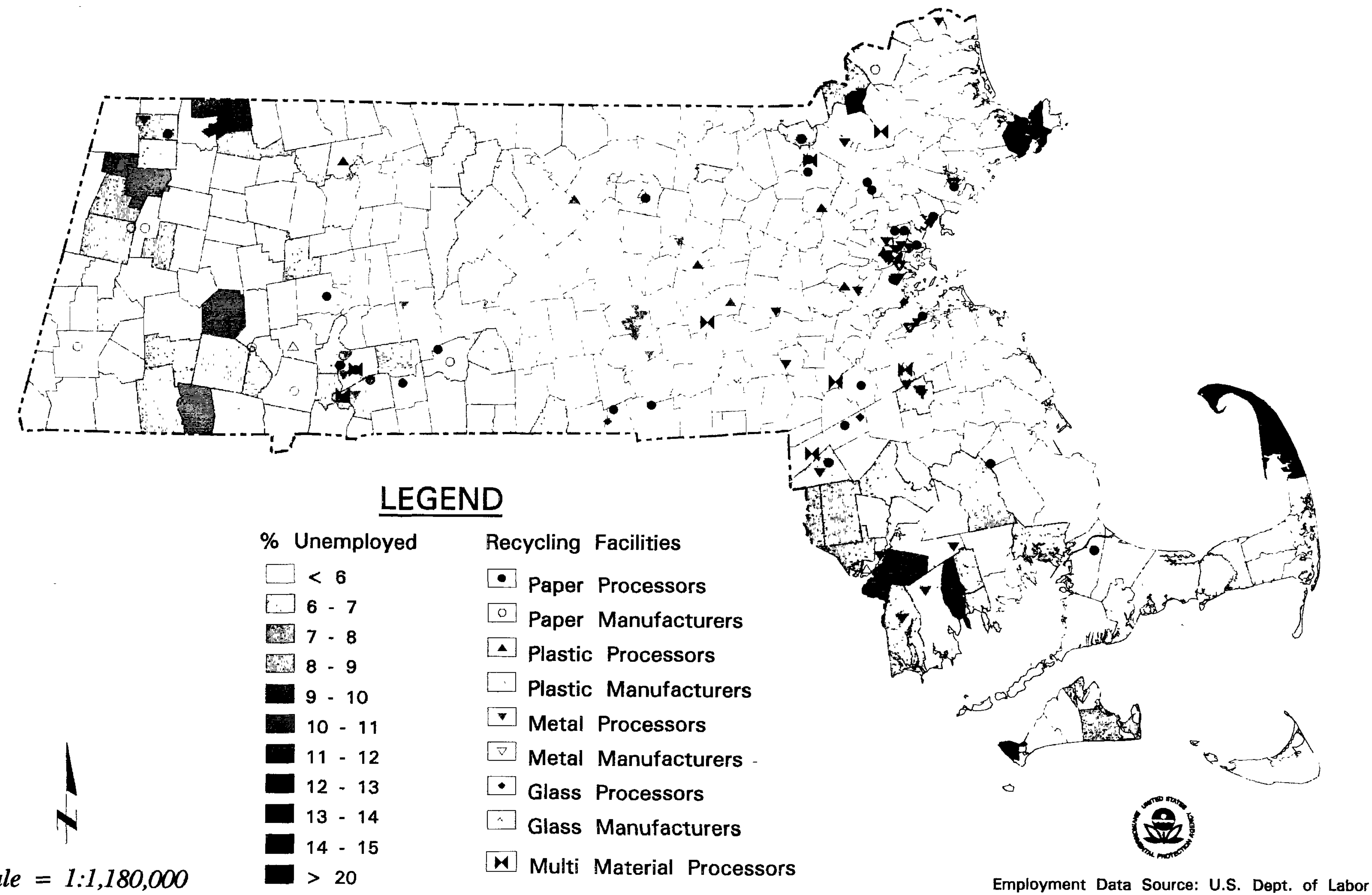



*Figure 5*

# Potential Manufacturing Sites for Recycled Plastic In Natick, Massachusetts


**LEGEND**

- ■ Potential Sites: Commercial/Industrial Zoned Regions

Population Density*

- 0 - 100
- 100 - 500
- 500 - 1000
- 1000 - 4000
- > 4000

- Major Roads
- Railroads

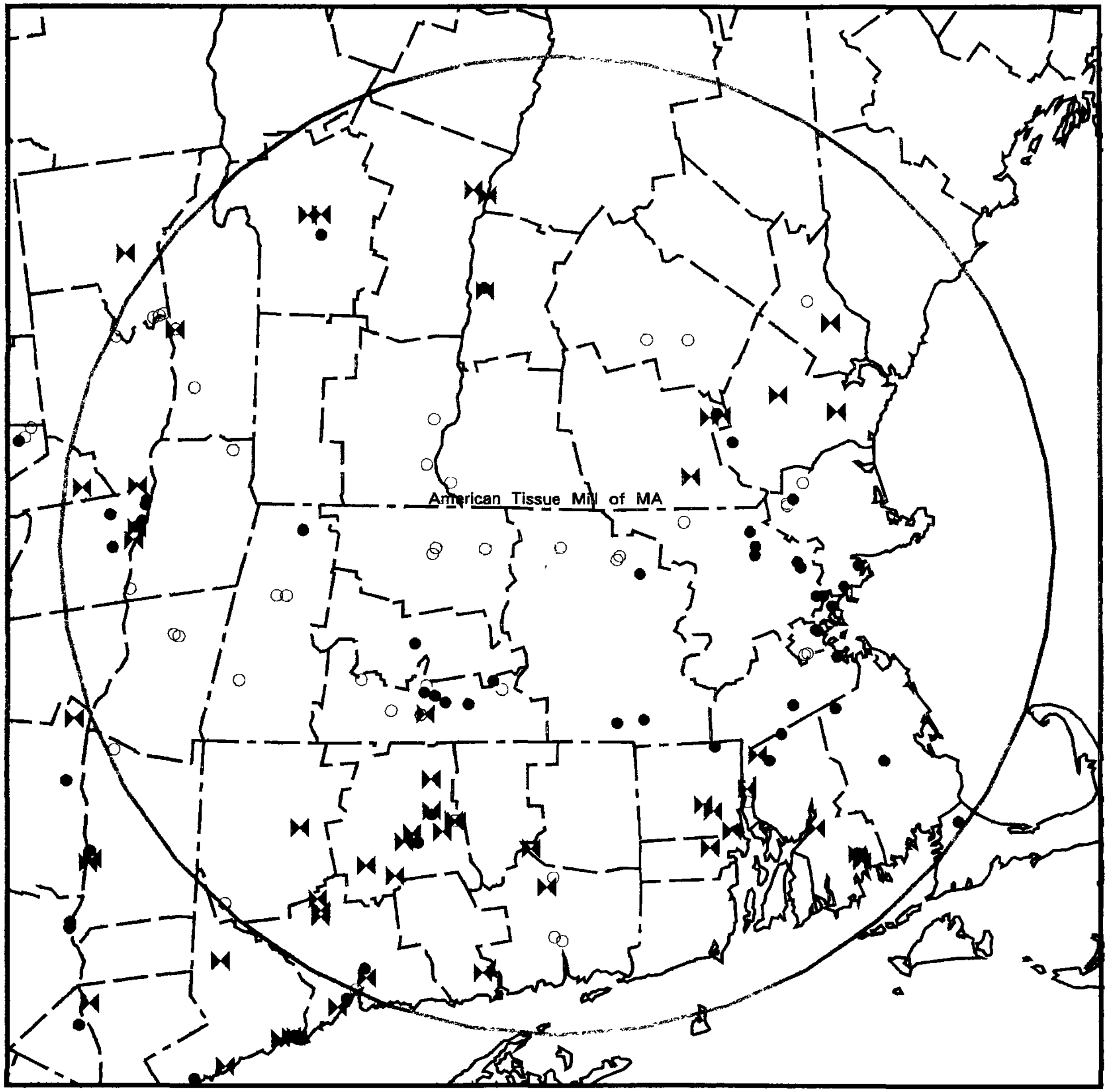
* Population density figures are from the 1990 Census and represent the number of people per square kilometer for each census block

Total acreage per commercial/industrial parcel of land is indicated by numbers inside parcel

*Figure 6*

*Scale: 1 inch = 1 mile*

# Paper Processors and Manufacturers Within 100 Miles Of The American Tissue Mill Of Massachusetts




LEGEND

- American Tissue Mill of MA
- Paper Processor
- Paper Manufacturer
- Multi-Material Processor Handling Paper
- 100 Mile Buffer Around Mill
- Coastline
- County Boundary
- State Boundary

Approximately 1,757 tons of paper is processed and 2,256.8 tons of paper is manufactured per day in Massachusetts. These totals were calculated using reported tonnages and average ton per employee estimates.

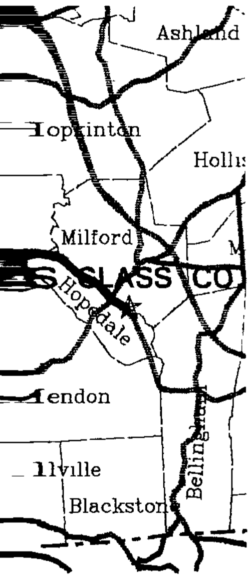
N

*Scale = 1:2,200,000*

*Figure 7*

Glass

ds*




map illustrates
shortest-distance
for transporting
from a multi-
rial processor
n Environment Co.)
glass manfacturer
er Forbes Glass Co.)
primary and sec-
ry roads. The total
nce of the route
5 miles.