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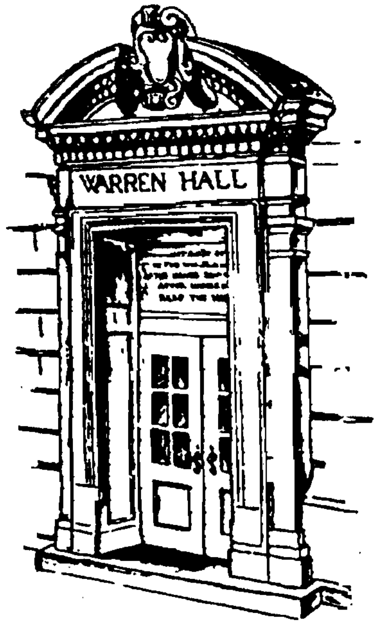

Staff Paper

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U.S. Dairy Sector Simulator— A Spatially Disaggregated Model of the U.S. Dairy Industry

by

James Pratt, Andrew Novakovic, Mark Stephenson, Phil Bishop, and Eric Erba

PREFACE

This document describes the economic and mathematical structure of the U. S. Dairy Sector Simulator (USDSS2) and demonstrates its use in analyzing an efficient market solution for the U.S. dairy sector in 1993. More specifically, shadow prices at U.S. milk processing locations are derived and analyzed and optimal milk and milk product flow patterns are derived. The specific outputs are included in an appendix.

USDSS builds on prior work done at Purdue University by Babb, Banker, Novakovic, and Pratt, on work done at Cornell University by Pratt, Jensen, Novakovic, and others under the auspices of the NE-126 regional dairy research committee, and on more recent work by Pratt and Novakovic and Francis. The following material is organized into four sections: a description of the model and data; a description of the scenarios analyzed; a description of the results; and a summary of the results. The results described in this material report only the annual 1993 base solution. Monthly data for May and October, 1995 is being collected. Additionally, many of the costs and geographic parameters used in this preliminary analysis, such as the transportation and processing costs and actual locations and capacities of dairy processing facilities, were originally constructed or obtained prior to 1990. We continue to update and revise this base information.

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INTRODUCTION

The U. S. Dairy Sector Simulator, (USDSS) is a direct descendant of several previous spatial models of the dairy industry which were completed at Purdue University[1] and Cornell University.[2] It also draws from modeling work done by King and Logan,[3] Beck and Goodin,[4] Boehm and Conner,[5] Buccola and Conner,[6] Kloth and Blakely,[7] Thomas and DeHaven,[8] Fuller, Randolph, and Klingman,[9] and McLean.[10]

USDSS has been designed to be a spatially detailed model of the U.S. dairy industry. It is formulated as a capacitated transshipment model. There are three market levels in USDSS: farm milk supply, dairy product processing, and dairy product consumption. Five dairy product groups are distinguished at processing and consumption: fluid milk products, soft dairy products, hard cheeses, butter, and dry, condensed, and evaporated milk products. USDSS uses a multi-component characterization of milk and dairy products; currently we are using fat and solids-not-fat to account for the supply and use of the valuable constituents in milk. Because the various processed and consumed dairy products rarely use the components of milk in the same proportion as they are available in farm milk supplies, processing plants must "balance" the use of milk components by moving intermediate

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[1] Babb, E.M., D.E. Banker, O. Goldman, D.R. Martella, and J.E. Pratt, 1977. *Economic model of federal milk marketing order policy simulator-model A.* Sta. Bul. no. 158, Purdue Univ., West Lafayette, IN.

[2] Novakovic, A.M., E.M. Babb, D.R. Martella, and J.E. Pratt. 1980. *An economic and mathematical description of the dairy policy simulator.* A.E. Res. 80-21, Cornell Univ. Agr. Exp. Sta., Ithaca, NY.
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Jensen, D.L. 1985. *Coloring and duality:Combinatorial augmentation methods.* Ph.D. thesis, Dept. of Operations Res., Cornell Univ., Ithaca, NY.
Francis, W.G. 1992. *Economic behavior of a local dairy market under federal milk market order regulation.* M.S. Thesis, Dept. of Agr. Econ.

[3] King, G. and S.H. Logan. 1964. Optimum location, number and size of processing plants with raw product and final product shipments. *J. Farm Econ.* 46(3):94-108.

[4] Beck, R.L. and J.D. Goodin. 1980. Optimum number and location of manufacturing milk plants to minimize marketing costs. South. *J. Agr. Econ.*, July, pp. 103-8.

[5] Boehm, W.T. and M.C. Conner 1976. *Technically efficient milk assembly and hard product processing for the Southeastern dairy industry.* Res. Div. Bul. No. 122, VPI&SU, Blacksburg, VA.

[6] Buccola, S.T. and M.C. Conner. 1979. *Potential efficiencies through coordination of milk assembly and milk manufacturing plant location in the northeastern United States.* Res. Div. Bul. No 149, VPI & SU, Blacksburg, VA.

[7] Kloth, D.W. and L.V. Blakely. 1971. Optimum dairy plant location with economies of size and market share restrictions. Amer. *J. Agr. Econ.*, Aug., pp. 461-66.

[8] Thomas, W.A. and R.K. DeHaven. 1977. *Optimum number, size, and location of fluid milk processing plants in South Carolina.* South Carolina Agr. Exp. Sta. Bul. No. 603, Clemson Univ., Clemson.

[9] Fuller, S.W., P. Randolph, and D. Klingman. 1976. Optimizing subindustry marketing organizations: A network analysis approach. *Amer. J. Agr. Econ.*, Aug., pp. 425-36.

[10] McLean, S, A. Kezis, J. Fitzpatrick, and H. Metzger. 1982. *Transshippment model of the Maine milk industry.* Tech. Bul. No. 106, Univ. of Maine, Orono.

dairy products, i.e. by-products of one processing operation, from one processing operation to another for use in a subsequent dairy process.

USDSS simultaneously analyzes the optimal location of processing facilities and farm milk assembly movements, interplant transfers of intermediate dairy products, and dairy product distribution movements. In determining this organization, USDSS considers the unit costs of milk assembly and interplant transfers, the costs of dairy product processing, and the costs of dairy product distribution among over 3,000 economic units covering the 48 states. Milk supply is represented by 240 supply points. There are 234 consumption points, each consuming some amount of each of the five dairy product types noted above. There are 507 potential locations for the processing of each dairy product type. Given estimates of producer milk marketings, dairy product consumption, and assembly, processing, and distribution costs, USDSS finds the least cost organization of milk, interplant, and distribution movements as well as the efficient processing locations.

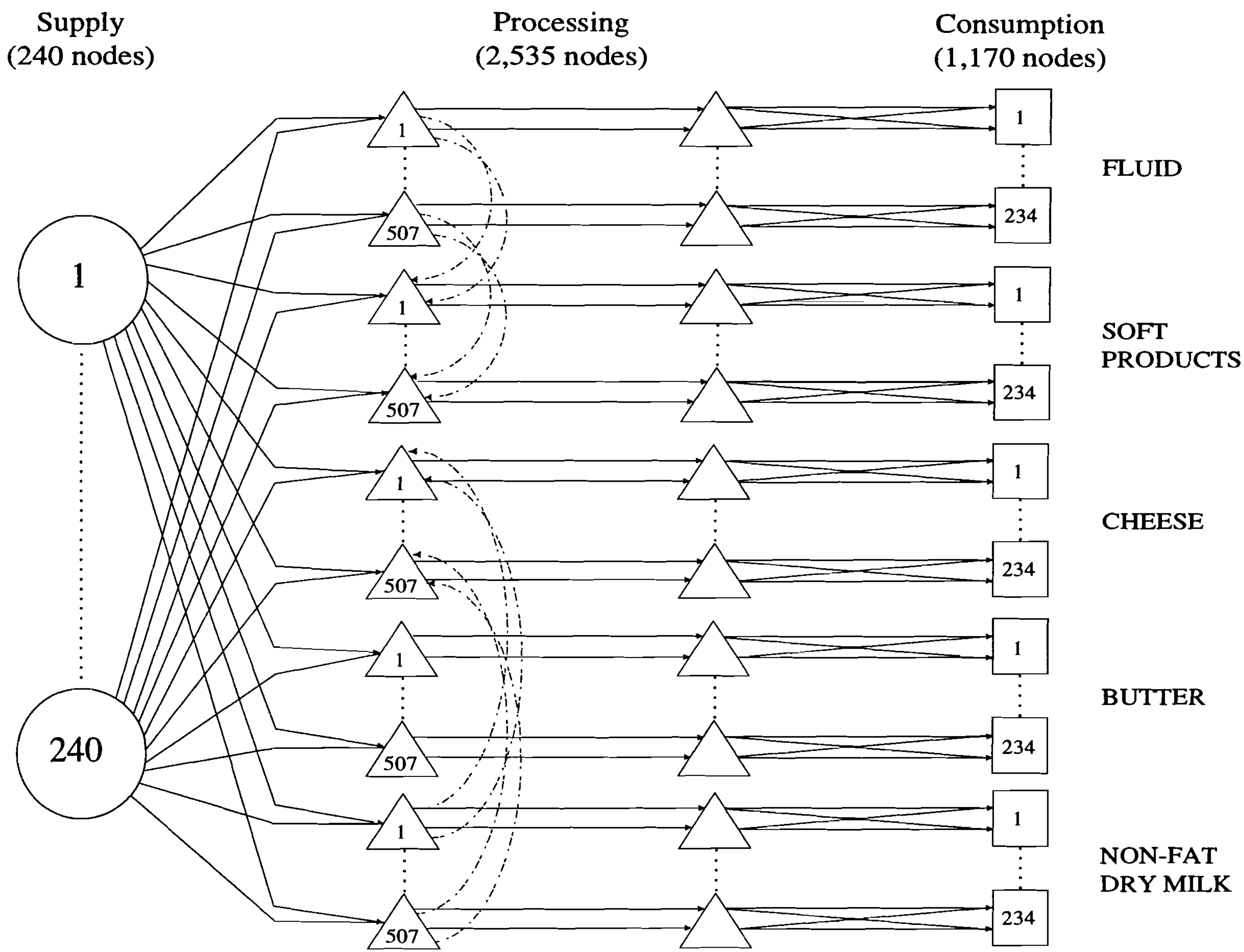
TRANSSHIPMENT FORMULATION

USDSS is formulated as a single-time period, multi-component transshipment model that combines a network flow and facilities location model. It contains three functional market levels; supply, processing, and consumption. These functional market levels are represented by circles, triangles, and squares respectively in Figure 1. Farm-level milk supplies are assumed to be homogeneous with respect to quality and are suitable as input for any of the dairy product groups. Milk supplies do have varying fat and solid-not-fat composition across geographic regions. Flows from supply points to processing points traverse the arcs (the lines connecting points in Figure 1) which connect the circles and triangles. Milk from any supply source is eligible to move to any processing facility of any product group. There are over 600,000 arcs connecting the 240 supply points to the 507 potential processing centers of each product type. Movements over these arcs occur at costs which are assumed to be functions of the distance traveled, i.e. milk assembly and over-the-road costs.

At the processing level (triangles connected to triangles by solid lines in Figure 1), milk is processed into one of five dairy product types; (1) fluid milk and cream products, (2) soft manufactured products, (3) hard cheeses, (4) butter, and (5) dried, condensed, and evaporated products. Processing can be capacitated at specific geographic locations and may incur a point specific unit processing cost. These costs and processing capacities are specified on the arcs between sets of triangles. These arcs represent the conversion of dairy components to consumable dairy products at a geographically specific plant location. In addition to the arcs representing the actual processing of dairy products (solid lines) there are arcs which represent the movements of components transferred between plants in the form of cream, skim, or non-fat dry milk powder (nfdm) between plants of different types (the dashed lines). These arcs also have movement costs associated with them. Movements of liquid intermediate products are assumed to move at the same over-the-road costs of bulk milk. Movements of nfdm moves at nfdm distribution costs. Arcs of these types might represent such movements as excess fat, in the form of 40% cream, from fluid plants to soft manufactured product plants or to butter plants or movements of snf in the form of nfdm from powder plants to cheese plants for standardization of cheese milk. Currently, over 2.5 million arcs represent potential interplant flows.

There are 234 geographic consumption points specified in USDSS. These are depicted as squares in Figure 1. Each of the five product types is consumed at each consumption point, resulting in

Figure 1. Network Structure of USDSS



1,170 distinct consumption units. For each product, all potential processing points (triangles) are connected to all appropriate consumption points (squares). There are over 590,000 possible product distribution movements. Each product movement incurs a distribution cost which is a function of distance.

DATA

A description of the construction of specific data for 1993 follows. This data could be altered or modified to model other years or to assess the impacts of policy changes which can be

specified as changes in the model data. Quantity data, such as point-specific supply and consumption quantities and component composition as well as potential processing capacities, can be changed as input, as long as total milk availability of each milk component (fat and snf) equals or exceeds total milk component requirements for each component. Cost coefficients for processing and transportation of milk and dairy products can be changed in the network generating programs.

MILK SUPPLY

For the transshipment formulation of milk supply in USDSS, each of the 3,111 U.S. counties and independent cities in the 48 contiguous states was aggregated into one of 240 multi-county areas (Figure 2). These aggregation areas were selected on the basis of the spatial distribution of milk cows or milk production within each state. Within each supply area, a single geographic point, a city, was chosen to represent the supply of the entire area (Figure 3). Milk marketings by producers for each state reported for 1993[11] were allocated to the 240 areas on the basis of milk production or cow numbers within each supply area. The reported percent fat in all milk produced in each state was attached to each appropriate region's milk supply and, using the data provided by various federal and state sources, fat percents were used to predict associated snf levels in regional milk supplies using the following equation:

$$SNF\ \% = 6.535 + (.6031 \times FAT\%)$$

CONSUMPTION

For the transshipment formulation of dairy product consumption in USDSS, five product groups were delineated; fluid milk and cream, soft manufactured products, hard cheese, butter, and dried, condensed, and evaporated products. These classes conform, generally, to storability and weight reduction, with fluid products being the least storable and weight-reduced. Each of the 3,111 counties and independent cities in the U.S. was aggregated into one of 234 multi-county consumption areas (Figure 4). These aggregation areas were selected to conform to state and Federal Milk Marketing Order (FMMO) boundaries, as well as to reflect the spatial distribution of population within each state. Within each consumption area, a single geographic point, a city, was chosen to spatially represent to consumption of the entire area (Figure 5). U.S. Census of Population county estimates for 1993 were

[11] Milk used and marketed by producers, by state and United States, 1993. *Milk Production, Disposition and Income, 1993 Summary*.

Figure 2. 240 Multi–County Milk Supply Areas

Figure 3. Milk Supply Points in USDSS

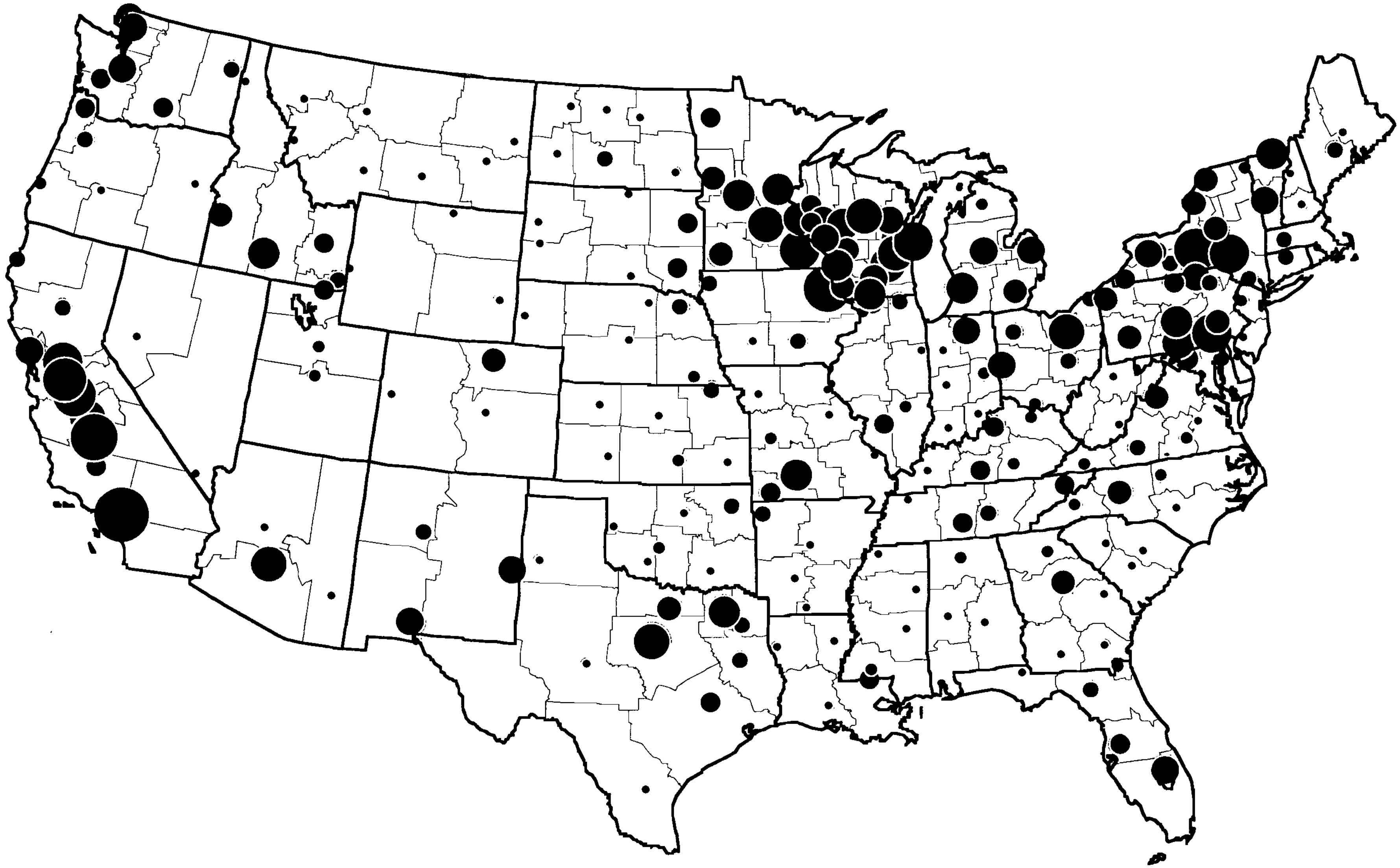


Figure 4. 234 Multi–County Milk Consumption Areas

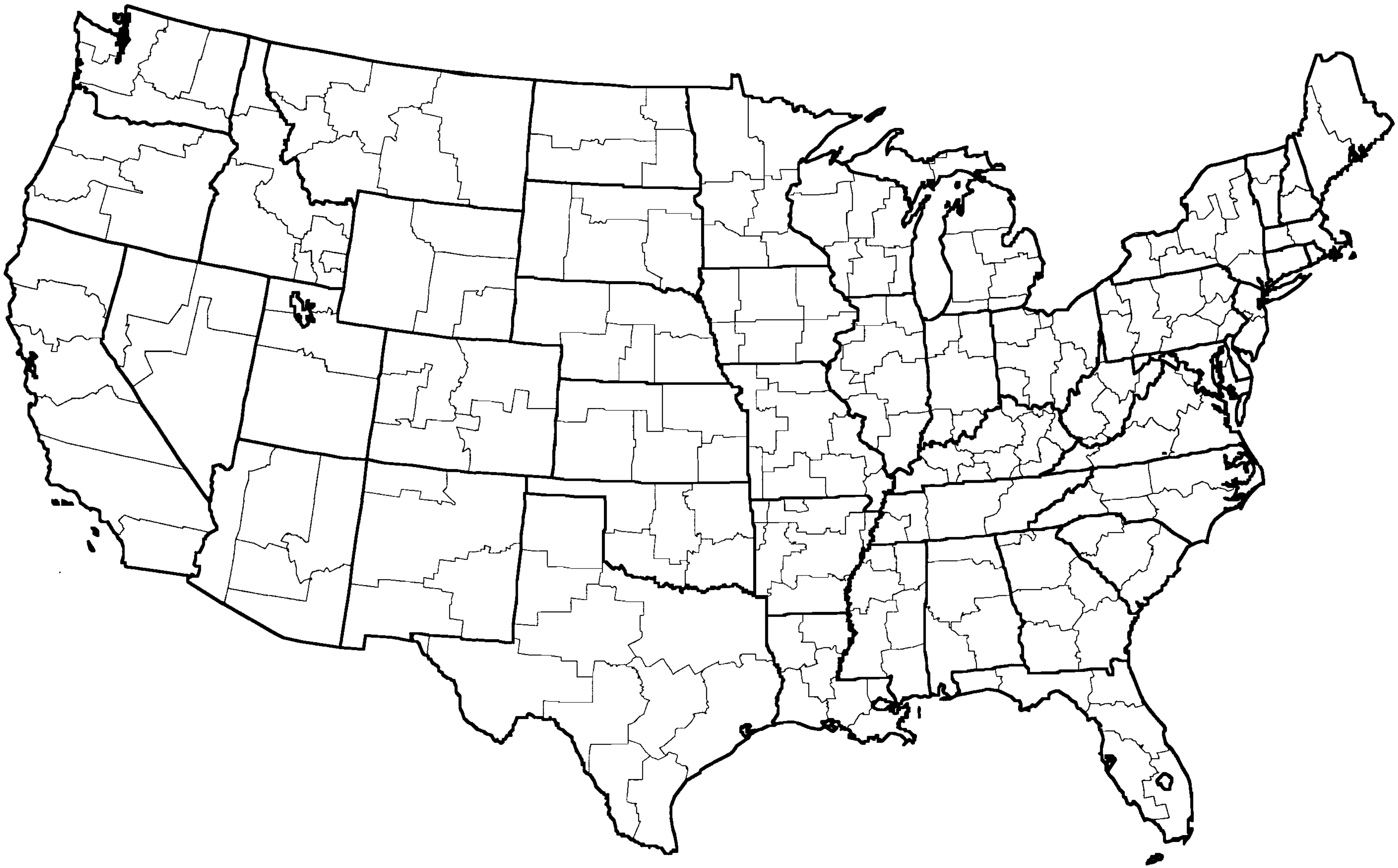
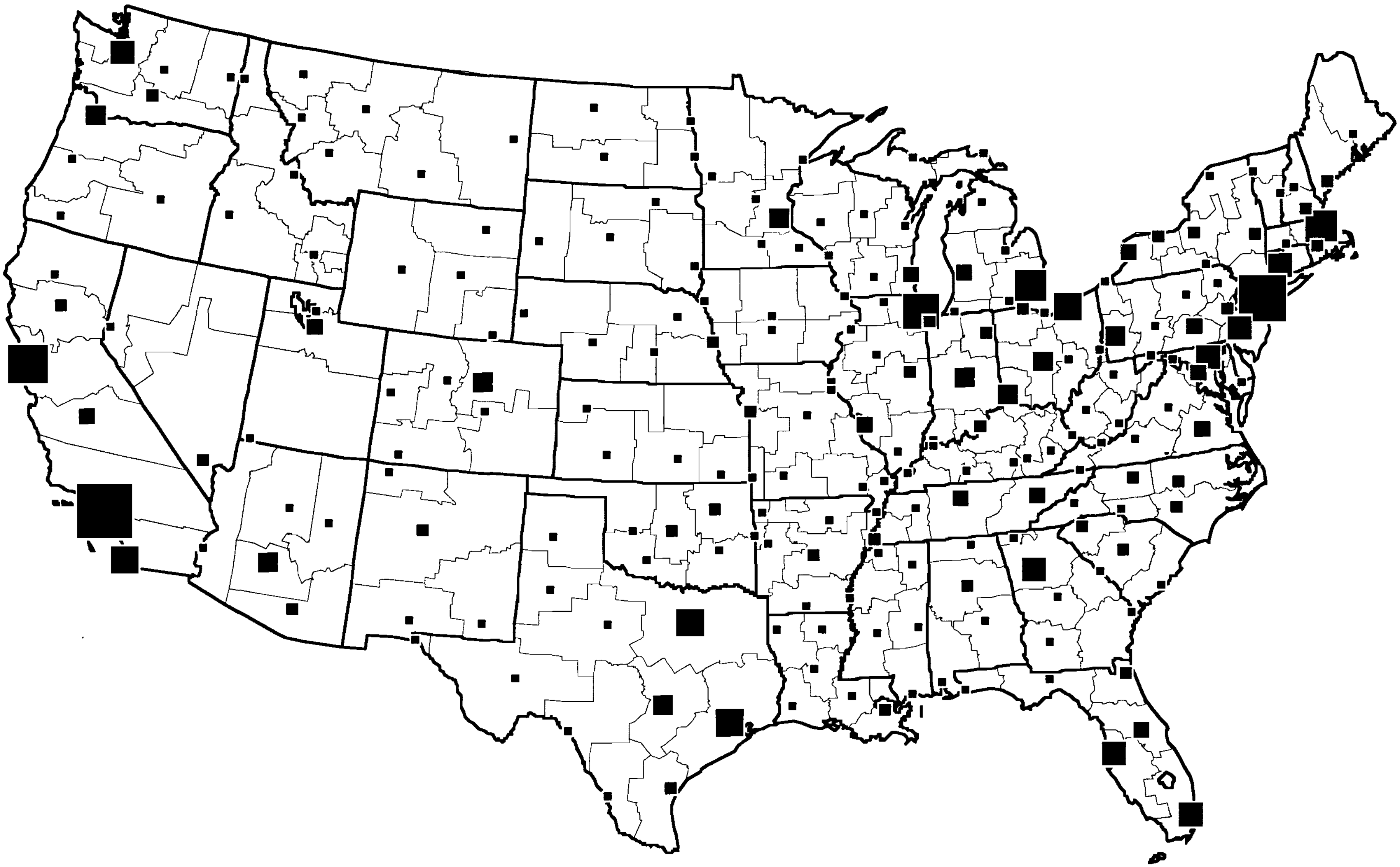


Figure 5. Milk Consumption Points in USDSS



then aggregated to each consumption center for the purpose of generating spatial consumption estimates for each product type.

Demand for Dairy Products

The demand for fluid products in each of the demand areas was based on data from federal milk marketing orders. The demand for soft dairy products, cheese, butter and powder/condensed products in each of the demand areas was developed from a national per capita demand number. This national number was then adjusted to account for temporal and regional differences. The adjustments were based on indices created from the Food Consumption surveys of 1977-78. The four regions used were the Northeast (CT, ME ,MA, NH, NJ, NY, PA, RI and VT), the South (AL,AR,DE, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA and WV), the North Central (IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD and WI) and the West (AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA and WY).

Demand for Fluid Milk Products

Per Capita Demand for Fluid Milk Products

The products included in this group are fluid whole milk products, fluid low fat and skim products, light cream, heavy cream, mixtures and sour cream. The per capita demand for fluid milk products was calculated separately for each federal milk marketing order. This was accomplished using data obtained from the Federal Milk Marketing Order Market Statistics. Total sales in pounds of fluid and cream products for 1993 were calculated for each marketing order. This number was divided by the total population of the marketing order to achieve an annual per capita demand within that order. An example using data from the New England Marketing area is provided below.

Total Sales of Fluid Milk Products[1] (mil. lbs.)	Total Sales of Cream Products[2] (mil. lbs.)	Total Sales of Fluid and Cream Products (mil. lbs.)	1993 Population[3] (1000's)	Marketing Area Per Capita Consumption (lbs.)
2,582.4	180.9	2,763.3	11,074.3	249.52

[1] U.S.D.A./A.M.S./Dairy Division. Statistical Bulletin No. 886, Federal Milk Order Market Statics 1993, Annual Summary, Table 45, p. 103.
[2] U.S.D.A./A.M.S./Dairy Division. Statistical Bulletin No. 886, Federal Milk Order Market Statics 1993, Annual Summary, Table 46, p. 115.
[3] U.S.D.A./A.M.S./Dairy Division. Statistical Bulletin No. 886, Federal Milk Order Market Statics 1993, Annual Summary, Table 4, p. 20.

Indices for Fluid Milk Products

Indices for fluid milk products were calculated by comparing seasonal demand in each of the regions to the annual demand. The calculation of the indices for the Northeast region are presented in the table below.

Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)	Index Relative to Year
Year	2.77	16.39	5.92	1.00
Winter	2.77	16.71	6.03	1.02
Spring	2.73	15.58	5.71	0.96
Summer	2.86	16.94	5.92	1.00
Fall	2.71	16.36	6.03	1.02

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 25, p. 74.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 4, p. 21.

Total Demand for Fluid Milk Products

The demand for fluid milk products in each of the demand areas was calculated by first associating each demand area with a federal milk marketing area. The per capita consumption for the demand area was multiplied by the population of the demand area to arrive at a total demand number. This number was then divided by four and multiplied by the index number to allow for seasonal differences. The calculation of fluid milk product demand for the Bangor, Maine demand area in the spring is presented below. Data from the New England marketing area were used because it was the marketing area closest to Bangor.

Demand For Soft Dairy Products

Per Capita Demand for Soft Dairy Products

The products included in this group were cottage cheese, yogurt, ice cream, ice milk, sherbet and frozen yogurt. Per capita consumption was estimated through the use of monthly production numbers for each product. It was assumed that there were no net exports or changes in stocks of products in this group. Production data was obtained on a monthly basis from the 1993 Dairy Products Summary. The production of frozen products was converted from gallons using standard conversion factors: one gallon of ice cream, ice milk or sherbet was equal to 4.5 pounds and one gallon of sherbet was equal to 6.0 pounds.

Monthly data was aggregated to an annual basis. This annual production was divided by the national population to get a national per capita demand for each product. Similar calculations were made for each of the products in this category.

Season	1993 Production[1] (mil. lbs.)	1993 Population	National Per Capita Consumption (lbs.)
Year	3,898.1	256,133,000	15.22
Winter	876.2	256,133,000	3.42
Spring	1,098.8	256,133,000	4.29
Summer	1,117.3	256,133,000	4.36
Fall	805.8	256,133,000	3.15

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, pp. 9-10.

Indices for Soft Dairy Products

An index to account for seasonal and regional differences in demand was created for ice cream, ice milk, yogurt and cottage cheese. Sherbet and frozen yogurt were assumed to have the same index as ice milk. The data for the creation of the indices came from the Food Consumption Survey of 1977-78. To create the indices, regional consumption was compared to national consumption in each quarter. The calculation of indices for ice cream in the Northeast are provided below. Similar calculations were made for each of the other products in this category.

United States Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)
Year	2.76	1.03	0.373
Winter	2.72	0.90	0.331
Spring	2.78	1.07	0.385
Summer	2.83	1.21	0.428
Fall	2.72	0.95	0.349

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 1, p. 13.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 4, p. 23.

Northeast Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)	Index Relative to United States
Year	2.77	1.07	0.386	1.04
Winter	2.77	1.02	0.368	1.11
Spring	2.73	1.09	0.399	1.04
Summer	2.86	1.21	0.423	0.99
Fall	2.71	0.96	0.354	1.01

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 25, p. 74.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 4, p. 23.

Total Demand for Soft Dairy Products

The demand for soft dairy products in each of the demand areas was calculated by first associating each demand area with one of the four regions. The national per capita consumption number for each product was multiplied by the index number for that region to arrive at a regional per capita demand. These were added together to get a total demand for all soft products. This number was multiplied by the population of the demand area to arrive at a total demand number. The calculation of spring soft dairy product demand for the Bangor, Maine demand area is presented below.

Product	Quarterly Demand (lbs.)	Index	Indexed Demand (lbs.)
Ice Cream	4.29	1.04	4.46
Ice Milk	1.68	0.58	0.98
Sherbet	0.35	0.58	0.20
Frozen Yogurt	0.83	0.58	0.48
Yogurt	1.31	1.90	2.49
Cottage Cheese	1.20	1.10	1.32
Total			9.94

Quarterly Demand (lbs.)	1993 Population	Demand for Soft Dairy Products (lbs.)
9.94	336,108	3,340,914

Demand for Cheese

Per Capita Demand for Cheese Products

The products included in this group were American, Swiss, Muenster, brick, Limburger, Italian, cream, Neufchatel and blue cheese. Per capita consumption was estimated through the use of monthly production numbers for each product. These numbers were adjusted for changes in stocks and net exports. Production data was obtained on a monthly basis from the 1993 Dairy Products Summary. Changes in stocks were obtained from the Cold Storage Report. Net exports were obtained from the United States Dairy, Livestock and Poultry Trade Summary. Monthly data was aggregated to quarters. This quarterly production was divided by the national population to get a national per capita demand for cheese.

Season	Production[1] (1000 lbs.)	Change in Stocks[2] (1000 lbs.)	Net Exports[3] (1000 lbs.)	1993 Population (1000's)	National Per Capita Consumption
Year	6,528,171	3,206	(284,792)	256,133	26.59
Winter	1,572,935	(1,991)	(46,107)	256,133	6.33
Spring	1,701,504	81,216	(58,227)	256,133	6.55
Summer	1,594,742	(41,146)	(66,421)	256,133	6.65
Fall	1,658,990	(34,873)	(114,037)	256,133	7.06

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, pp. 6-8.

[2] U.S.D.A., National Agricultural Statistics Service, Crop Reporting Board. Cold Storage Report, vol. 1-93 through 1-94, p. 3.

[3] U.S.D.A., Foreign Agriculture Service, Circular Series: FDLP 1-93 through 1-94. United States Dairy, Livestock and Poultry Trade, Tables 24 and 39.

Indices for Cheese Products

An index to account for seasonal and regional differences in demand was created for cheese. The data for the creation of the indices comes from the Food Consumpw´3n Survey of 1977-78. Regional consumption was compared to national consumption in each quarter. The calculations of indices for cheese in the Northeast are provided below.

United States Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)
Year	2.76	1.17	0.424
Winter	2.72	1.19	0.438
Spring	2.78	1.16	0.417
Summer	2.83	1.19	0.421
Fall	2.72	1.15	0.423

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 1, p. 13.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 4, p. 24.

Northeast Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)	Index Relative to United States
Year	2.77	1.24	0.448	1.06
Winter	2.77	1.27	0.459	1.05
Spring	2.73	1.26	0.462	1.11
Summer	2.86	1.25	0.437	1.04
Fall	2.71	1.17	0.432	1.02

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 25, p. 74.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 4, p. 24.

Total Demand for Cheese Products

The demand for cheese products in each of the demand areas was calculated by first associating each demand area with one of the four regions. The national per capita consumption number is multiplied by the index number for that region to arrive at a regional per capita demand. This number is multiplied by the population of the demand area to arrive at a total demand number. The calculation of cheese product demand for the Bangor, Maine demand area in the spring is presented below.

Quarterly Demand (lbs.)	Index	1993 Population (lbs.)	Demand for Cheese Products
6.55	1.11	336,108	2,443,673

Demand For Butter

Per Capita Demand for Butter

The products included in this class were butter and anhydrous milk fat. Per capita consumption was estimated through the use of monthly production numbers for each product. These numbers were adjusted for changes in stocks and net exports. Production data was obtained on a monthly basis from the 1993 Dairy Products Summary. Changes in stocks were obtained from the Cold Storage Report. Net exports were obtained from the United States Dairy, Livestock and Poultry Trade Summary. Monthly data was aggregated to quarters. This quarterly production was divided by the national population to get a national per capita demand for butter.

Season	Production[1] (1000 lbs.)	Change in Stocks[2] (1000 lbs.)	Net Exports[3] (1000 lbs.)	1993 Population (1000's)	National Per Capita Consumption
Year	1,315,198	(212,518)	(260,427)	256,133	4.95
Winter	406,139	77,795	40,932	256,133	1.12
Spring	340,452	64,351	24,609	256,133	0.98
Summer	253,207	(200,509)	52,354	256,133	1.57
Fall	315,400	(154,155)	142,532	256,133	1.28

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, pp. 6-8.
[2] U.S.D.A., National Agricultural Statistics Service, Crop Reporting Board. Cold Storage Report, vol. 1-93 through 1-94, p. 3.
[3] U.S.D.A., Foreign Agriculture Service, Circular Series: FDLP 1-93 through 1-94. United States Dairy, Livestock and Poultry Trade, Tables 24 and 39.

Indices for Butter

An index to account for seasonal and regional differences in demand was created for butter. The data for the creation of the indices comes from the Food Consumption Survey of 1977-78. Regional consumption was compared to national consumption in each quarter. The calculations of indices for butter in the Northeast are provided below.

United States Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)
Year	2.76	0.19	0.069
Winter	2.72	0.19	0.070
Spring	2.78	0.17	0.061
Summer	2.83	0.19	0.067
Fall	2.72	0.20	0.074

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 1, p. 13.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 5, p. 25.

Northeast Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)	Index Relative to United States
Year	2.77	0.30	0.108	1.57
Winter	2.77	0.32	0.116	1.66
Spring	2.73	0.27	0.099	1.62
Summer	2.86	0.31	0.108	1.61
Fall	2.71	0.30	0.111	1.50

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 25, p. 74.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 5, p. 25.

Total Demand for Butter

The demand for butter in each of the demand areas was calculated by first associating each demand area with one of the four regions. The national per capita consumption number is multiplied by the index number for that region to arrive at a regional per capita demand. This number is multiplied by the population of the demand area to arrive at a total demand number. The calculation of butter demand for the Bangor, Maine demand area in the spring is presented below.

Quarterly Demand (lbs.)	Index	1993 Population (lbs.)	Demand for Cheese Products
0.98	1.62	336,108	534,412

Demand for Powdered and Condensed Products

Per Capita Demand for Powdered and Condensed Products

The products included in this class were evaporated, condensed and dry whole milk, evaporated, condensed and dry skim milk and condensed and dry buttermilk. Per capita consumption was estimated through the use of monthly production numbers for each product. Production data was obtained on a monthly basis from the 1993 Dairy Products Summary. These monthly figures were adjusted for changes in stocks, net exports and use in other dairy products. The percentage of production used in other dairy products was determined using data from the 1993 Dry Milk Products Utilization and Production Trends.

Product	Total Production[1] (mil. lbs.)	Use in Dairy Products (mil. lbs.)	Percentage Reused in Dairy Products
Condensed Whole Milk	291.3	23.8[2]	8.17
Condensed Skim Milk	1,316.3	231.4[2]	17.58
Condensed Buttermilk	46.5	19.5[2]	41.91
Dry Whole Milk	153.8	4.2[3]	2.73
Nonfat Dry Milk	948.1	360.2[4]	37.99
Dry Buttermilk	51.0	31.6[5]	61.97

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, pp. 6-8.

[2] American Dairy Products Institute, Bulletin No. 1000. Dry Milk Products Utilization and Production Trends, 1993, p. 9.

[3] American Dairy Products Institute, Bulletin No. 1000. Dry Milk Products Utilization and Production Trends, 1993, p. 2.

[4] American Dairy Products Institute, Bulletin No. 1000. Dry Milk Products Utilization and Production Trends, 1993, p. 7.

[5] American Dairy Products Institute, Bulletin No. 1000. Dry Milk Products Utilization and Production Trends, 1993, p. 8.

Monthly data was aggregated to quarters. This quarterly production was divided by the national population to get a national per capita demand for each product. An example for nonfat dry milk is provided below. Similar calculations were made for each of the other products in this category.

Season	Production[1] (1000 lbs.)	Change in Stocks[2] (1000 lbs.)	Net Exports[3] (1000 lbs.)	Returned to Dairy (lbs.)	1993 Population (1000's)	National Per Capita Consumption
Year	948,117	8,400	164,072	360,000	256,133	1.91
Winter	250,338	(2,700)	42,722	95,053	256,133	0.45
Spring	286,508	65,100	51,446	108,787	256,133	0.29
Summer	204,376	(43,600)	42,214	77,602	256,133	0.45
Fall	206,895	(10,400)	27,691	78,558	256,133	0.63

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, pp. 6-8.

[2] U.S.D.A., National Agricultural Statistics Service, Crop Reporting Board. Cold Storage Report, vol. 1-93 through 1-94, p. 3.

[3] U.S.D.A., Foreign Agriculture Service, Circular Series: FDLP 1-93 through 1-94. United States Dairy, Livestock and Poultry Trade, Tables 24 and 39.

Indices for Powdered and Condensed Products

An index to account for seasonal and regional differences in demand was created for powdered products and condensed products. The data for the creation of the indices comes from the Food Consumption Survey of 1977-78. Regional consumption was compared to national consumption in each quarter. The calculation of indices for both categories in the Northeast are provided below.

Powdered Milk United States Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)
Year	2.76	0.11	0.040
Winter	2.72	0.13	0.048
Spring	2.78	0.10	0.036
Summer	2.83	0.10	0.035
Fall	2.72	0.11	0.040

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 1, p. 13.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 4, p. 22.

Powdered Milk Northeast Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)	Index Relative to United States
Year	2.77	0.14	0.051	1.27
Winter	2.77	0.16	0.058	1.21
Spring	2.73	0.12	0.044	1.22
Summer	2.86	0.09	0.031	0.89
Fall	2.71	0.16	0.059	1.47

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 25, p. 74.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 4, p. 22.

Condensed Milk United States Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)
Year	2.76	0.36	0.130
Winter	2.72	0.38	0.140
Spring	2.78	0.32	0.115
Summer	2.83	0.38	0.134
Fall	2.72	0.36	0.132

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 1, p. 13.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-6, Food Consumption: Households in the United States, Seasons and Year 1977-1978, Table 4, p. 22.

Condensed Milk Northeast Season	Household Size[1]	Quantity Per Household Per Week[2] (lbs.)	Quantity Per Capita Per Week (lbs.)	Index Relative to United States
Year	2.77	0.28	0.101	0.78
Winter	2.77	0.31	0.112	0.80
Spring	2.73	0.33	0.121	1.05
Summer	2.86	0.28	0.098	0.73
Fall	2.71	0.20	0.074	0.56

[1] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 25, p. 74.

[2] U.S.D.A., Human Nutrition Information Service, Consumer Nutrition Division. Nationwide Food Consumption Survey 1977-1978, Report No. H-7, Food Consumption: Households in the Northeast, Seasons and Year 1977-1978, Table 4, p. 22.

Total Demand for Powdered and Condensed Products

The demand for powdered and condensed products in each of the demand areas was calculated by first associating each demand area with one of the four regions. The national per capita consumption number for each product category is multiplied by the index number for that region to arrive at a regional per capita demand. These were added together to get a total demand for all powdered and condensed products. This number was multiplied by the population of the demand area to arrive at a total demand number. The calculation of powdered and condensed product demand for the Bangor, Maine demand area in the spring is presented below.

Product	Quarterly Demand (lbs.)	Index	Indexed Demand (lbs.)
Evaporated Whole Milk	0.53	1.05	0.56
Evaporated Skim	0.02	1.05	0.02
Condensed Whole	0.25	1.05	0.26
Condensed Skim	1.20	1.05	1.26
Condensed Buttermilk	0.03	1.05	0.03
Dry Whole Milk	0.09	1.22	0.10
Nonfat Dry Milk	0.24	1.22	0.29
Dry Buttermilk	0.02	1.22	0.03
Total			2.55

Quarterly Demand (lbs.)	1993 Population	Demand for Powdered and Condensed Products (lbs.)
2.55	336,108	857,075

Product Components

The fat and solids content of each of the product groups was determined by taking a weighted average of the components of each of the products that make up that category.

Components in Fluid Milk

The data for calculating the component content of fluid milk was found in information provided by the federal milk marketing orders. The products included in this category were fluid whole milk products, fluid lowfat and skim milk products, milk and cream mixtures, light cream, heavy cream and sour cream. The determination of the fat content of fluid milk within the New England marketing area is presented below.

Product	Total Sales[1] (mil. lbs.)	Percentage Fat[1]	Pounds of Fat (mil. lbs.)
Whole Milk	1,092.6	3.18	34.75
Lowfat and Skim Milk	1,489.8	1.19	17.72
Milk and Cream Mixtures	99.1	10.92	10.82
Light Cream	49.4	18.04	8.91
Heavy Cream	18.7	37.04	6.93
Sour Cream	13.7	16.22	2.22
Total	2,763.3	2.94[2]	81.35

[1] U.S.D.A., Agricultural Marketing Service, Dairy Division. Statistical Bulletin No. 886, Federal Milk Order Market Statistics 1993, Annual Summary, Table 46, p. 116.
[2] Determined from dividing the total pounds of fat into the total sales.

Components in Soft Products

To compute the solids and fat content for this category, a weighted average was taken of the solids and fat content of the products that make up this category. The products included in this category are: creamed cottage cheese, lowfat cottage cheese, yogurt, ice cream, ice milk, sherbet and frozen yogurt. The weighted average was obtained by multiplying the total demand for these products by their fat and solids percentage. The total pounds of fat and solids in these products was then divided into the total demand for these products. Frozen yogurt was assumed to have the same component percentages as ice milk.

Product	Total Demand[1] (mil. lbs.)	Percentage Fat	Pounds of Fat (mil. lbs.)
Creamed Cottage Cheese	431.6	4.51[2]	19.47
Lowfat Cottage Cheese	317.8	1.93[2]	6.13
Yogurt	1,285.8	1.60[3]	20.57
Ice Cream	3,898.1	13.59[3]	529.75
Ice Milk	1,464.1	3.47[3]	50.80
Sherbet	304.9	1.98[3]	6.04
Frozen Yogurt	674.7	3.47[3]	23.41
Total	8,377.1	7.83[4]	656.17

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, pp. 8-10.
[2] U.S.D.A., Handbook No. 8-1, Composition of Foods: Dairy and Egg Products.
[3] Selinsky, Cox and Jesse. Estimation of U.S. Dairy Product Component Yields, Appendix A, p. 13.
[4] Determined from dividing the total pounds of fat into the total sales.

Product	Total Demand[1] (mil. lbs.)	Percentage Solids Not Fat	Pounds of Solids Not Fat (mil. lbs.)
Creamed Cottage Cheese	431.6	16.53[2]	71.34
Lowfat Cottage Cheese	317.8	18.76[2]	59.62
Yogurt	1,285.8	11.12[3]	142.98
Ice Cream	3,898.1	8.04[3]	313.41
Ice Milk	1,464.1	11.36[3]	166.32
Sherbet	304.9	31.95[3]	97.42
Frozen Yogurt	674.7	11.36[3]	76.65
Total	8,377.1	11.07[4]	927.64

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, pp. 8-10.
[2] U.S.D.A., Handbook No. 8-1, Composition of Foods: Dairy and Egg Products.
[3] Selinsky, Cox and Jesse. Estimation of U.S. Dairy Product Component Yields, Appendix A, p. 13.
[4] Determined from dividing the total pounds of solids into the total sales.

Components in Cheese Products

To compute the solids and fat content for this category, a weighted average was taken of the solids and fat content of the products that make up this category. The products included in this category are: cheddar, American, part skim, Swiss, Muenster, brick, Limburger, mozzarella, other Italian, cream, Neufchatel, blue and other cheese. The weighted average was obtained by multiplying the total demand for these products by their fat and solids percentage. The total pounds of fat and solids in these products was then divided into the total demand for these products.

Product	Total Production[1] (mil. lbs.)	Percentage Fat[2]	Pounds of Fat (mil. lbs.)
Cheddar	2,376.1	33.14	787.44
Other American	581.2	28.82	164.58
Part Skim	3.7	13.65[3]	0.51
Swiss	231.4	27.45	63.53
Muenster	117.5	30.04	35.29
Brick	12.5	29.68	3.71
Limburger	0.9	28.36[4]	0.25
Mozzarella	1,948.0	23.12	450.38
Other Italian	546.5	21.70[5]	116.35
Cream	460.7	29.15	134.30
Neufchatel	79.2	29.15	23.08
Blue	33.3	29.69	9.89
Other	137.2	28.36	38.91
Total	6,528.2	28.01[6]	1,828.21

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, p. 8.
[2] Selinsky, Cox and Jesse. Estimation of U.S. Dairy Product Component Yields, Appendix A, p. 14.
[3] Based on fat content of other Italian cheese.
[4] Based on fat content of the other cheeses in the other cheese category.
[5] Weighted average of fat content of provolone, Romano, Parmesan and ricotta cheeses. See table below.
[6] Determined from dividing the total pounds of fat into the total sales.

Product	1990 Per Capita Production[1] (lbs.)	Percentage Fat[1]	Pounds of Fat (lbs.)
Provolone	0.63	26.62	0.17
Romano	0.21	26.94	0.06
Parmesan	0.43	27.93	0.12
Ricotta	0.79	12.98	0.10
Total	2.06	21.70[3]	0.45

[1] Selinsky, Cox and Jesse. Estimation of U.S. Dairy Product Component Yields, Appendix A, p. 14.
[2] Determined from dividing the total pounds of fat into the total sales.

Product	Total Production[1] (mil. lbs.)	Percentage Solids Not Fat[2]	Pounds of Solids Not Fat (mil. lbs.)
Cheddar	2,376.1	30.11	715.45
Other American	581.2	29.01	168.59
Part Skim	3.7	27.43[3]	1.02
Swiss	231.4	35.34	81.79
Muenster	117.5	28.19	33.11
Brick	12.5	29.21	3.65
Limburger	0.9	27.73[4]	0.24
Mozzarella	1,948.0	25.62	499.08
Other Italian	546.5	30.28[5]	165.49
Cream	460.7	12.87	59.30
Neufchatel	79.2	12.87	10.19
Blue	33.3	29.42	9.80
Other	137.2	27.73	38.05
Total	6,528.2	27.37[6]	1,785.75

[1] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, p. 8.
[2] Selinsky, Cox and Jesse. Estimation of U.S. Dairy Product Component Yields, Appendix A, p. 14.
[3] Based on solids content of other Italian cheese.
[4] Based on solids content of the other cheeses in the other cheese category.
[5] Weighted average of solids content of provolone, Romano, Parmesan and ricotta cheeses. See table below.
[6] Determined from dividing the total pounds of solids into the total sales.

Product	1990 Per Capita Production[1] (lbs.)	Percent Solids Not Fat[1]	Pounds of Solids Not Fat (lbs.)
Provolone	0.63	32.43	0.20
Romano	0.21	42.15	0.09
Parmesan	0.43	48.67	0.21
Ricotta	0.79	15.39	0.12
Total	2.06	30.28[2]	0.62

[1] Selinsky, Cox and Jesse. Estimation of U.S. Dairy Product Component Yields, Appendix A, p. 14.
[2] Determined from dividing the total pounds of solids into the total sales.

Components in Butter

The components in butter were derived from the study by Selinsky, Cox and Jesse. The value given for the fat content of butter was 81.11%. The value given for the solids content was 3.02%.

Components in Powdered and Condensed Products

To compute the solids and fat content for this category, a weighted average was taken of the solids and fat content of the products that make up this category. The products included in this category are: evaporated and condensed whole milk, evaporated and condensed skim milk, condensed and dry buttermilk, dry whole milk and nonfat dry milk.

The weighted average was obtained by multiplying the total demand for these products by their fat and solids percentage. The total pounds of fat and solids in these products was then divided into the total demand for these products.

Product	Total Demand[1] (mil. lbs.)	Percentage Fat[2]	Pounds of Fat (mil. lbs.)
Evaporated Whole Milk	534.51	7.9	42.26
Evaporated Skim	22.24	0.2	0.04
Condensed Whole	267.49	8.2[3]	21.91
Condensed Skim	1,061.02	0.2	2.12
Condensed Buttermilk	27.02	1.5	0.41
Dry Whole	66.80	26.5	17.70
Nonfat Dry Milk	415.65	0.8	3.33
Dry Buttermilk	20.81	5.3	1.10
Total	2,415.52	3.68[4]	88.83

[1] Total production less production used in other dairy products, net exports and changes in stocks.
[2] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, Table 1, p. 2.
[3] Weighted average of sweetened condensed and unsweetened condensed whole milk.
[4] Determined from dividing the total pounds of fat into the total sales.

Product	Total Demand[1] (mil. lbs.)	Percentage Solids Not Fat[2]	Pounds of Solids Not Fat (mil. lbs.)
Evaporated Whole Milk	534.51	18.1	96.75
Evaporated Skim	22.24	29.8	6.63
Condensed Whole	267.49	18.7[3]	50.07
Condensed Skim	1,061.02	29.8	316.18
Condensed Buttermilk	27.02	26.4	7.13
Dry Whole	66.80	71.0	47.43
Nonfat Dry Milk	415.65	96.2	399.85
Dry Buttermilk	20.81	91.9	19.12
Total	2,415.52	39.05[4]	943.16

[1] Total production less production used in other dairy products, net exports and changes in stocks.
[2] U.S.D.A., National Agricultural Statistics Service, Agricultural Statistics Board. Dairy Products, 1993 Summary, Table 1, p. 2.
[3] Weighted average of sweetened condensed and unsweetened condensed whole milk.
[4] Determined from dividing the total pounds of solids into the total sales.

PROCESSING

An effort was undertaken to identify all dairy processing facilities operating in the contiguous 48 states in 1993. As a result of this effort, 1,596 individual dairy processing facilities, their geographic locations, and their principle products were identified. Table 1 gives a summary list of identified plants, by state, by major product group. To integrate this information with the USDSS spatial structure, these actual processing plant locations were assigned to representative cities. Each plant which was identified was associated with the nearest city in a list of cities which was put together for the purposes of calculating distances. As such, in the output listings which accompany the results section of this material, all processing facilities are accounted for, but they may be associated with a city which is near, but not at, their actual location. Similarly, if more than one facility is associated with a particular city, the processing which is done at that city is not identified as to the particular facility which is involved. Only the city location is determined, not the plant.

While USDSS is capable of analyzing problems in which processing capabilities at each potential location can be constrained to be less than some fixed amount, for this analysis, it was felt that insufficient individual capacity data were available to implement these constraints. USDSS cities which were identified as potential processing centers for each product (i.e. an actual facility was associated with a particular city) were given unlimited capacities, while those cities having no actual processing locations assigned to them were constrained to zero capacities (i.e. not allowed to process that product group). In this way, even though quantities processed at any particular center were not constrained, only those centers which had processing capabilities of a particular type in 1993 were allowed to become active processors. Because of this, the solution results for particular products at particular plant locations may vary substantially from actual observations.

COSTS

Unit costs of moving milk, intermediate products, and final dairy products, as well as processing costs are specified for each arc in Figure 1. These costs are specified in units of the actual flow.

Dairy producers are assessed hauling charges which vary across a wide range. Hauling rates vary according to farm location, milk volume, and the competitive environment. Milk moved over long distances is often actually moved between plants rather than between farms and plants. No one transportation cost function can accurately reflect transportation costs in all situations. Differences in initial truck costs, labor and fuel costs, driving conditions, and maintenance policies all affect transportation costs for a specific haul. While USDSS could incorporate a very complete set of geographically specific cost functions, data to support such a specification do not exist. After consultation with USDA and cooperative economists and other knowledgeable persons, it was decided to use a single cost function to represent all milk movements:

Milk Transportation Cost = .35 cents/hundred lbs/mile.

In the network, milk moving on arcs between geographic supply points and processing points will incur this charge. Liquid intermediate products, skim milk and cream, also incur this costs with an added 3 cents for handling.

Table 1. Number of Dairy Product Processing Plants, by State, by Product, 1993.

	Product Category				
	Fluid	Soft	Cheese	Butter/Powder/ Other	Total
AL	11	4	3	0	18
AZ	10	3	1	1	15
AR	8	3	2	0	13
CA	70	40	53	16	179
CO	16	3	1	0	20
CT	18	4	6	0	28
DE	2	0	1	0	3
FL	16	2	0	0	18
GA	8	6	2	0	16
ID	5	2	6	2	15
IL	23	19	27	2	71
IN	14	5	2	1	22
IA	9	8	15	6	38
KS	3	4	5	1	13
KY	8	2	4	2	16
LA	14	7	2	1	24
ME	7	0	1	0	8
MD	9	6	1	1	17
MA	28	10	3	1	42
MI	27	13	7	3	50
MN	15	3	24	23	65
MS	9	2	3	2	16
MO	8	3	7	3	21
MT	13	0	2	0	15
NE	4	0	8	2	14
NV	3	0	0	0	3
NH	3	1	0	0	4
NJ	13	1	4	0	18
NM	10	0	1	1	12
NY	44	23	34	2	103
NC	12	7	1	1	21
ND	7	0	4	1	12
OH	26	2	19	5	52
OK	7	1	1	2	11
OR	13	3	4	2	22
PA	99	12	21	6	139
RI	6	2	1	0	9
SC	6	0	0	0	6
SD	4	1	12	2	19
TN	9	4	1	1	15
TX	34	6	2	0	42
UT	12	8	6	1	27
VT	10	1	11	1	23
VA	12	1	0	1	14
WA	34	3	9	4	50
WV	4	1	0	0	5
WI	17	8	174	28	227
WY	2	0	1	2	5
TOTAL	743	234	492	127	1,596

It is possible to specify individual processing costs for each geographic processing location used in USDSS. Using the King and Logan procedure, a heuristic solution to optimal plant locations under conditions of decreasing unit processing costs can also be obtained. For the analysis report here, however, it was decided that available information on regional differences in processing costs was insufficient to warrant inclusion at this time. Because USDSS ensures that all geographic consumption requirements for each product group are met, changing the level of processing costs for any product group, when all regions have equal costs, has no effect on optimal movements or plant locations. For the analysis reported here, no processing costs are specified.

U.S. ANNUAL RESULTS

Given 1993 annual estimates of milk supplies at each of 240 geographic supply points and the fat and snf composition of these supplies, estimates of dairy product consumption for each of five product groups at 234 geographic consumption points, as well as estimates of bulk milk, intermediate interplant product, and packaged product transportation costs noted earlier, USDSS was used to generate optimum, minimum cost processing center activity and milk and dairy product flows. While this solution is cost minimizing, it does not replicate actual 1993 flows and processing activities, even though the quantity and cost estimates, as well as the location data were meant to duplicate actual 1993 conditions as closely as possible. Differences in regional transportation, processing, and distribution costs as well as institutional marketing constraints could result in optimum flows and processing activity differing from actual flows and activities. Figures 6 to 13 depict the optimal 1993 annual flows of milk and finished dairy products. As in Figure 1, triangles represent processing locations active in the optimal solution and the solid lines represent flows of milk to those processing centers (in the case of supply to processing maps) or flows of dairy products (in the case of processing to consumption maps). The size of the triangles indicate the relative magnitude of processing activity at each location. Generally, fluid processing center activity follows population distribution patterns, with non-local milk being transported to these processing centers when necessary (Figures 6 and 7), i.e. there are relatively few packaged milk distribution movements outside of local consumption areas, but relatively many movements of milk to serve these processors. Fluid distribution is mainly local with a few longer distance movements in the Great Plains area, Rocky mountains, and West coast. Soft product processing center activity is generally located outside, but near, population centers (Figure 8), with nearly all supplies of milk going to these processing locations being local. Finished soft product movements are mainly local with a few longer distance movements in the Southwest and West (Figure 9). Cheese processors are oriented much more to milk supplies than to consumption (Figure 10) Cheese processing, like soft products, is located outside the population centers with many long distance distribution movements resulting (Figure 11). (Movements outside the U.S. indicate exports, government purchases, and additions to stocks.) Butter and dried-evaporated-condensed products show similar distribution pattern to cheese (Figures 12 to 13) with even more supply orientation. In addition to these milk and product movements, there are interplant movements of cream and skim. Some plant sources of inputs consist entirely of interplant movements such as excess cream from fluid plants being used in butter or soft products. Figure 12 reveals the manufacturing plants which received milk as input, but Figure 13, depicting processed manufactured product movements, shows additional plants shipping manufactured products. These plants did not use milk as an input, but used cream or skim. These movements reflect the models attempt to best utilize fat and snf components which are in excess at processing facilities. Other interplant flow types, such as movements of snf from powder plants to cheese plants, are also part of the optimal solution.

Figure 6. Fluid Milk Supply to Processing Movements

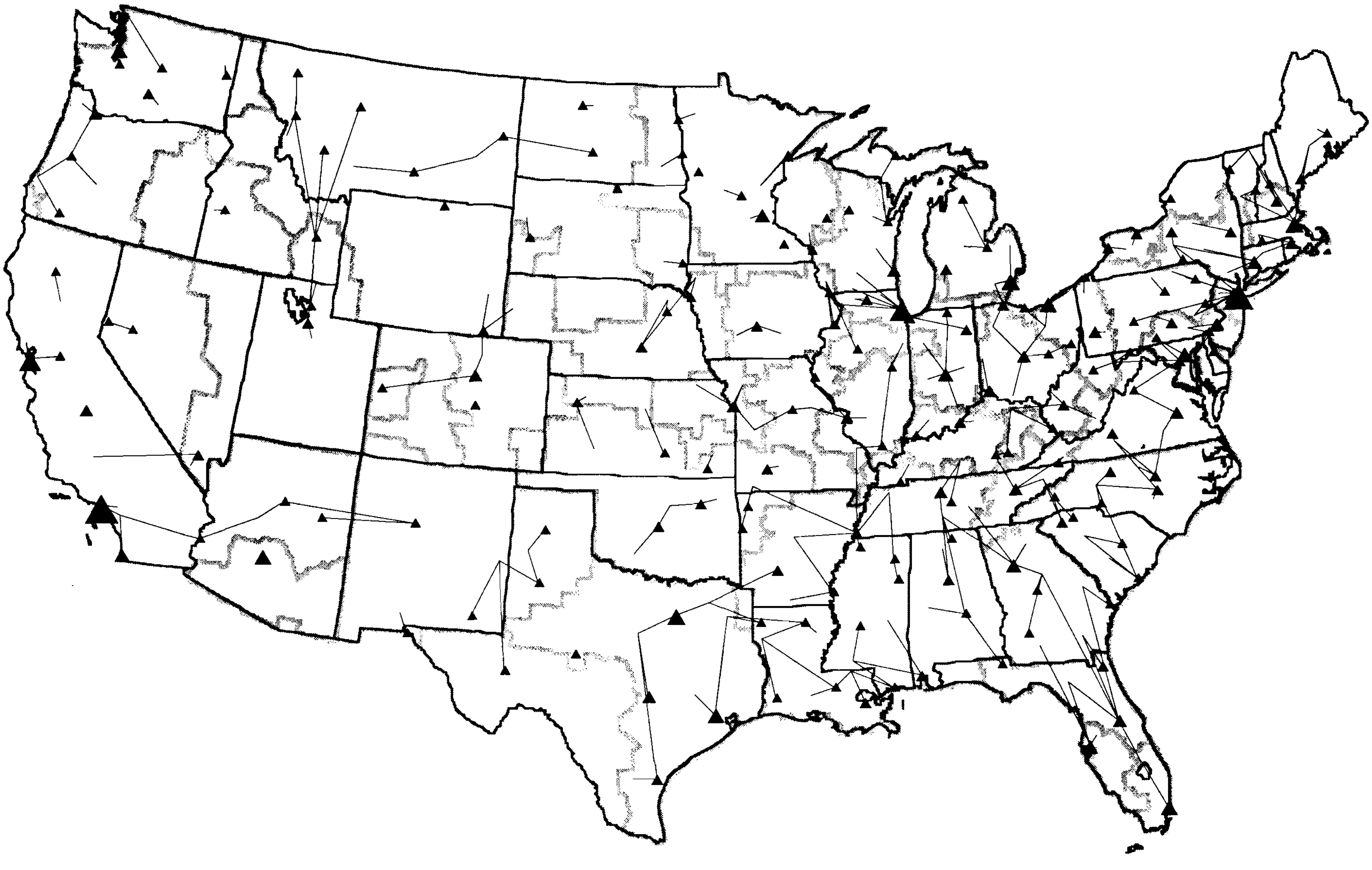


Figure 7. Fluid Milk Processing to Consumption Movements

Figure 8. Soft Product Supply to Processing Movements

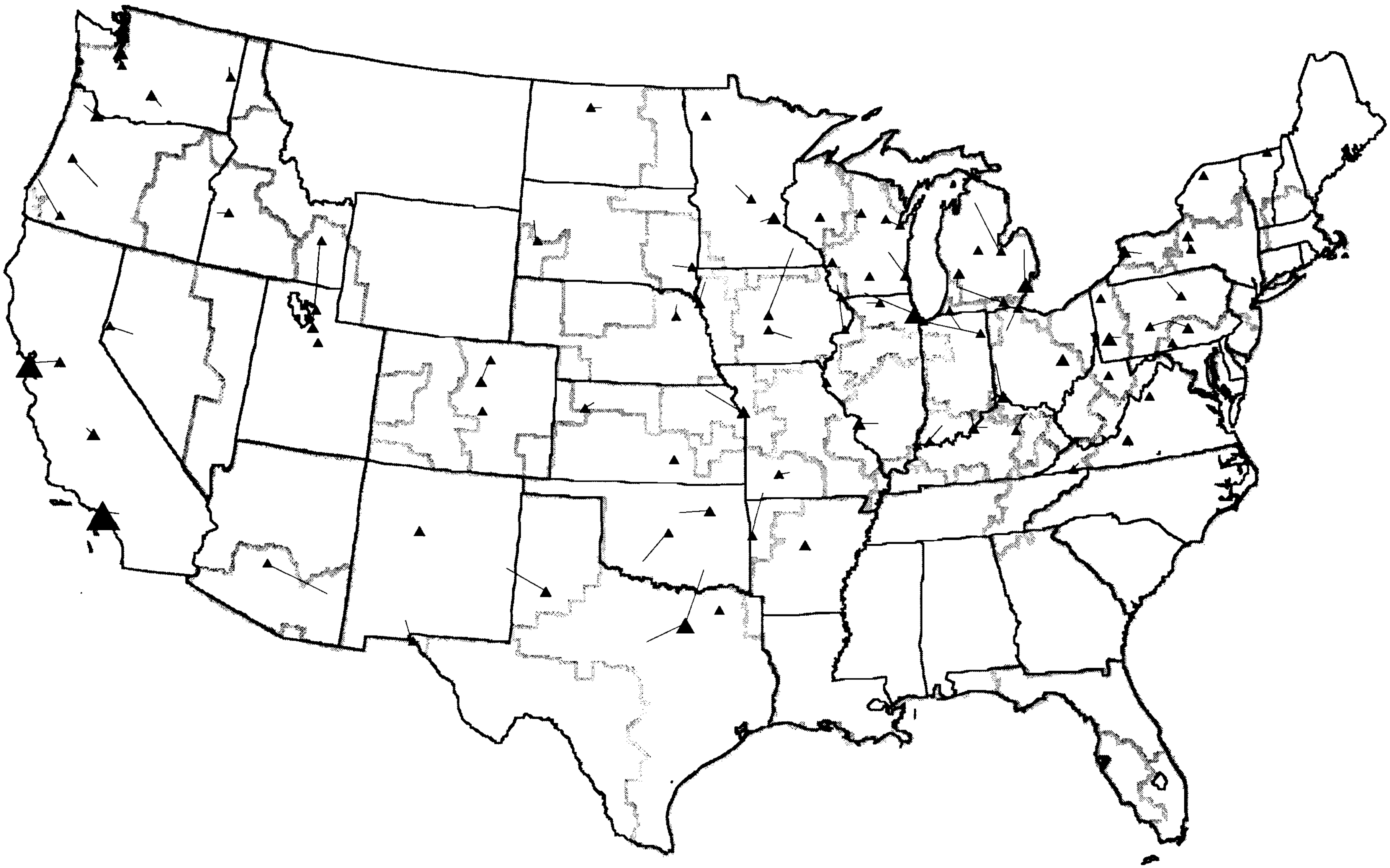


Figure 9. Soft Product Processing to Consumption Movements

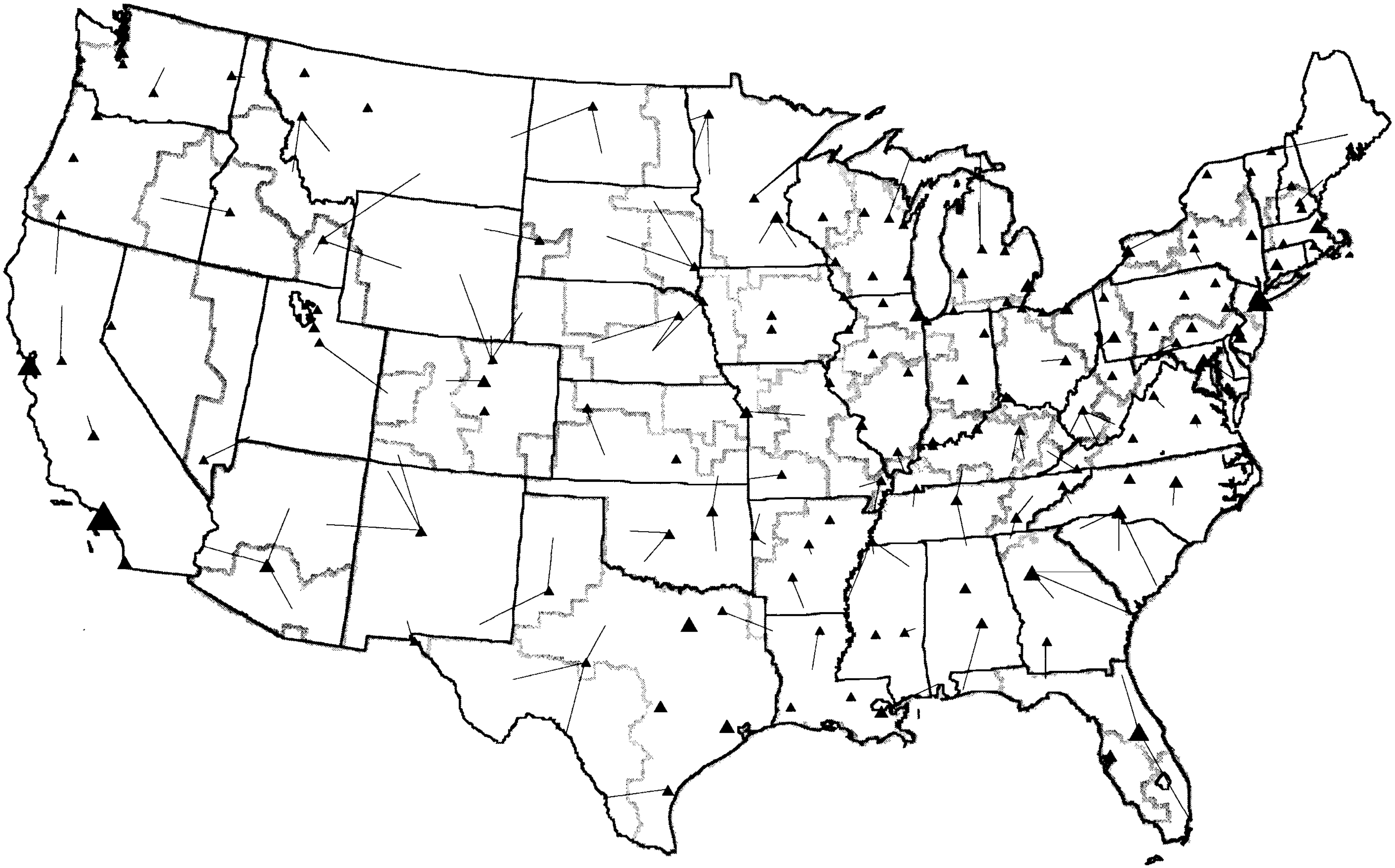


Figure 10. Cheese Supply to Processing Movements

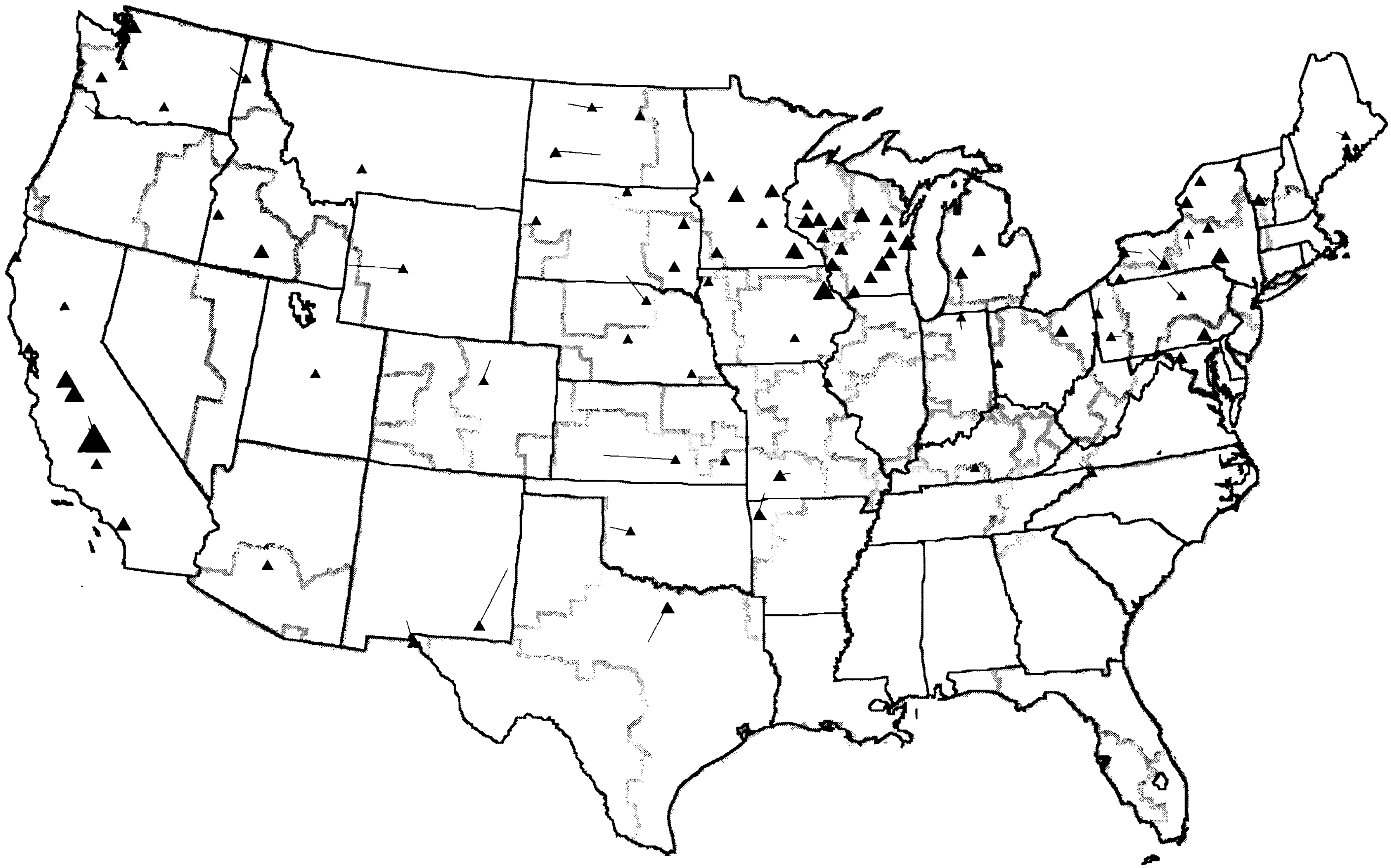


Figure 11. Cheese Processing to Consumption Movements

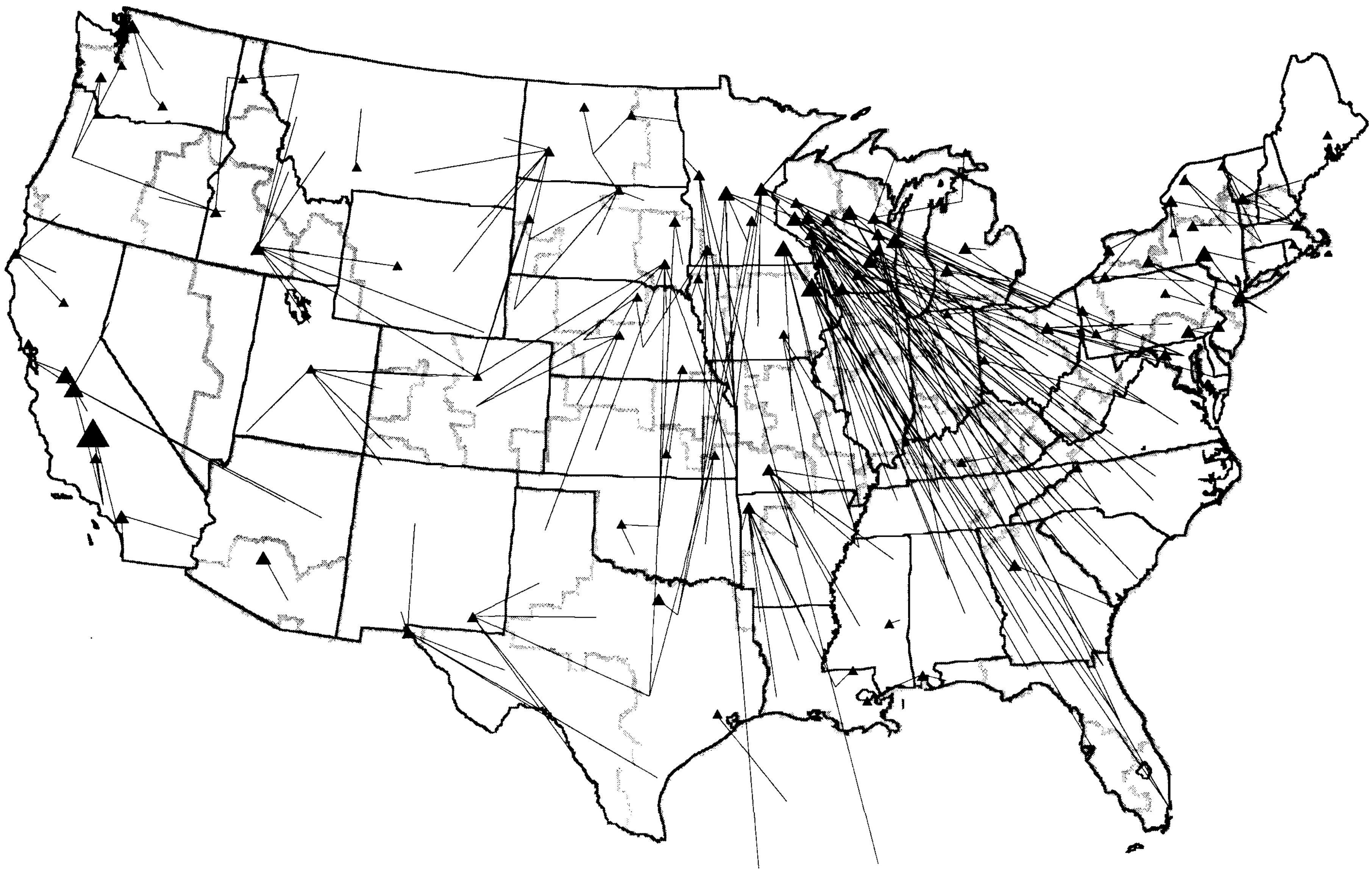


Figure 12. Butter & Dry/Evap/Cond Milk Supply to Processing Movements

Figure 13. Butter & Dry/Evap/Cond Milk Processing to Consumption Movements

Two points need to be kept in mind when looking at these solution results:

1) These movements reflect the optimum set of milk, intermediate product, and final dairy product flows determined by the model and there are numerous reasons that actual movements corresponding to those depicted might differ from the optimum ones. However, if you take market-wide efficiency as one of the goals of a regulatory system, this solution represents a target, to which we would aspire if the industries activities were conducted for public service rather than for profit.
2) This solution represents an annual average. Very few months, weeks, or days of the year are likely to match the results of an annual average. It is natural to expect deviations in optimal behavior due to seasonal/weekly/daily changes in consumption and production.

Finally, one of the most useful and revealing pieces of information obtained from an optimization model such as this are numbers (shadow prices) which reflect the relative value of a resource. In this case, we obtain relative values of milk and milk components at geographic locations.

Besides determining an efficient set of milk and dairy product flows and a corresponding set of efficient dairy processing locations and sizes, the mathematical model previously described can be used to answer a different, but related question about the relative value of milk at the various locations specified in the data—'given milk assembly costs, dairy product processing and distribution costs, the costs of moving bulk cream and skim between plants, the available milk supplies and their composition, and the desired dairy product demands and their composition, what would an additional hundred pounds of milk delivered to a processor at each location be worth?'. These values are known as 'shadow prices'. As is true of any optimization model such as this, it is possible to calculate the marginal benefit of adding additional units of some scare resource. In this case, we can determine the marginal value of an additional one hundred pounds of milk at any given location. These marginal values, or shadow prices, reflect only the costs which are used to allocate the resources in the model. **There are no prices or costs of production in the model**. More or less, the shadow prices reflect the so-called transportation differential component of the class I differential, but do not include a constant grade A differential component. To create numbers that more closely resemble the more familiar class I differentials, we add a constant to the shadow values taken from the model. **For class I differential, the constant is chosen to result in a value at Minneapolis, MN equal to the current Upper Midwest Order differential of $1.20. We take the fluid milk shadow value in Minneapolis, and add whatever value is necessary to achieve $1.20**. This additional arbitrary constant is then added to every class I shadow value throughout the country. The resulting values attain levels more like current class I differentials, but maintain their absolute differences. If the class I shadow value in Miami is $2.10 more than the class I shadow value in Minneapolis, adding the same constant to both values will result in numbers which are still different by $2.10. For the other four types of products, we add an appropriate basic formula price (plus 30¢ for class II products) to the shadow value to achieve values which look more like class prices rather than differentials.

The Appendix contains maps which show these simulated differentials and prices for each type of product. These maps are based on values for 'standardized' milk (3.5% fat and 8.62% snf) delivered to a processing facility which actually processes in the model solution.

APPENDIX

This appendix contains a number of maps which illustrate various outputs that can be generated from a solution of the USDSS model. Below the title of each map is the word "Preliminary" which is there to suggest that these maps represent results at one point in the evolution of the model. At this time, more current data are being collected and more complex model structures are being specified. These preliminary results should not be interpreted as being invalid. Qualitatively, we have generated similar results for more than a decade with data from different time periods and with much simplier models.

Several underlying assumptions pertaining to this particular model solution are worth noting. First, the supply and demand data used in all but the results on page A12 are annual from 1993. Second, an "operational reserve" of 15% is assumed. This means that at least 15% of the milk supply at every supply point in the model must be shipped to a plant type other than fluid. The purpose of this constraint is to reflect the reality that fluid plants do not operate at full capacity all week, rather they must adjust their throughput to match the fluctuations in demand. Third, the processing sector is assumed to be operating uncapacitated and with a uniform cost structure across the entire country. The model chooses to site plants at points from a list of known locations. While this plant list has recently been updated, the list used to generate the 1993 solution is several years old. Some of these plants have, of course, ceased to operate by now. There are 285 such locations for fluid plants, 190 for soft product plants, 174 for cheese, 78 for butter, and 90 for the powder category. The model is not required to use all of these locations; it chooses the least-cost arrangement based on the cost of transporting milk and milk products to, between, and from the chosen processing locations, and the cost of processing milk into milk products. Fourth, there are 3 intermediate product types specified in this model run. They are cream, skim milk, and NFDM.

The transportation costs used are as follows:

Raw Milk Assembly:

$/10,000 lbs = 0.0001 + 0.35(one-way miles) which is equivalent to saying 35 cents per 100 lbs per 100 miles.

Interplant Transfers:

Cream and Skim milk:	$/10,000 lbs = 3.0 + 0.35(one-way miles)
NFDM:	$/10,000 lbs = 0.29(one-way miles)

Final Product Distribution:

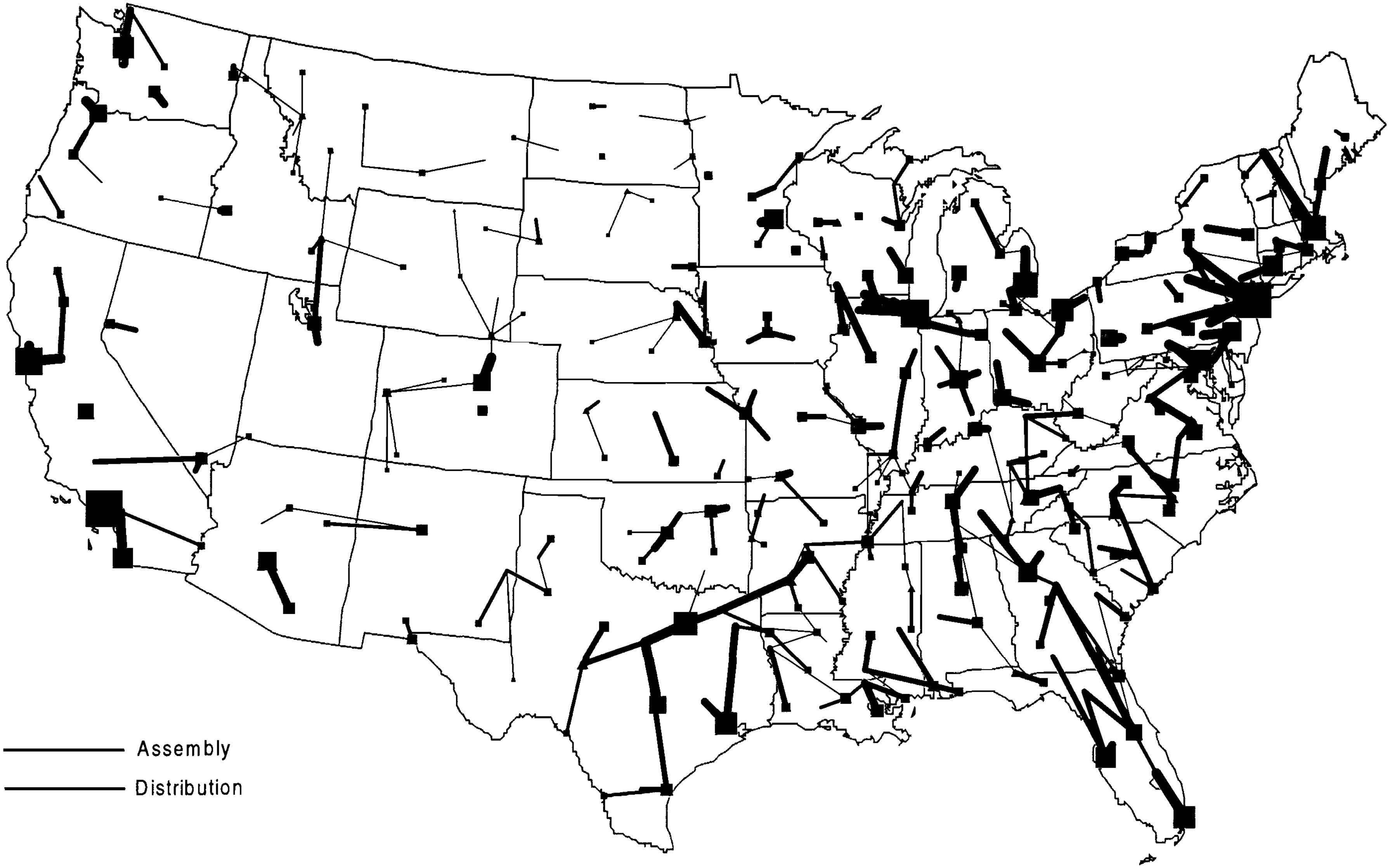
Fluid:	$/10,000 lbs = 1.0006(one-way miles)
Soft:	$/10,000 lbs = 1.1906(one-way miles)
Cheese:	$/10,000 lbs = 14.437 + 1.1064(one-way miles)
Butter:	$/10,000 lbs = 14.437 + 1.1064(one-way miles)
Powder:	$/10,000 lbs = 0.29(one-way miles)

Attention is now focused on the following maps. The first 5 maps depict assembly flows to and distribution flows from each of the five plant types. To avoid cluttering the maps, flows from the import sector and to export markets are not shown. Intermediate product flows are not displayed for the same reason. The size of the black triangles gives an indication of the relative level of processing activity at a particular location. Thus, it is legitimate to compare these symbols on a single map but they are not comparable across maps. The green lines represent flows of raw milk from supply points to plants. The lines are weighted to give an indication of the volume associated with each movement. Heavier, or thicker, lines represent a greater volume than the narrow lines. The width of the lines representing assembly movements have been calibrated across all 5 maps. The orange lines represent movements of final product from plants to consumption points. Again, the lines are weighted to yield a sense of the volume associated with each flow. In the case of the fluid map, orange squares have been added to depict the relative quantities of fluid milk consumed at each location. Also, the width of the distribution lines for fluid only has been calibrated with the raw milk assembly lines. Note that on all flow maps, it is possible to detect black triangles without lines of any color radiating from them. Such symbols represent plants procuring local milk and distributing final products locally. For the manufacturing plants, it is probably also the case that inputs are being received in the form of intermediate products for which lines are not displayed.

Six pages of price contour maps follow the product flow maps. While the content of these contour maps is fairly self-explanatory from the titles, a few explanations are in order. The first two contour maps do not actually derive from this particular solution but have been included to visually demonstrate that the current system of class I differentials is not a literal "Eau Claire plus transportation" as is often purported. The color scheme has been calibrated such that for both maps on page A8, dark yellow indicates \$0.80/cwt, while dark green indicates \$8.40/cwt. The map in the upper panel of page A8 has been arbitrarily scaled to \$1.20/cwt. at Minneapolis, only because the actual differential at Minneapolis is \$1.20/cwt. While doing this more easily enables the price levels to be compared across both maps, the purpose of all the contour maps is to illustrate relative prices rather than price levels.

Page A9 contains maps depicting simulated class I differential and class I price surfaces. Page A12 also contains maps of simulated class I differentials but are derived from more recent data. All three maps depicting class I differential surfaces have been calibrated such that dark yellow represents \$0.60/cwt while dark green represents \$5.60/cwt. As with the maps on page A8, the three class I differential surface maps have been arbitrarily centered on \$1.20/cwt. at Minneapolis, MN.

Finally, pages A10 and A11 contain simulated price surfaces for the other product classes. All four of these maps have been calibrated so that dark yellow represents \$11.80/cwt while dark green represents \$13.90/cwt.

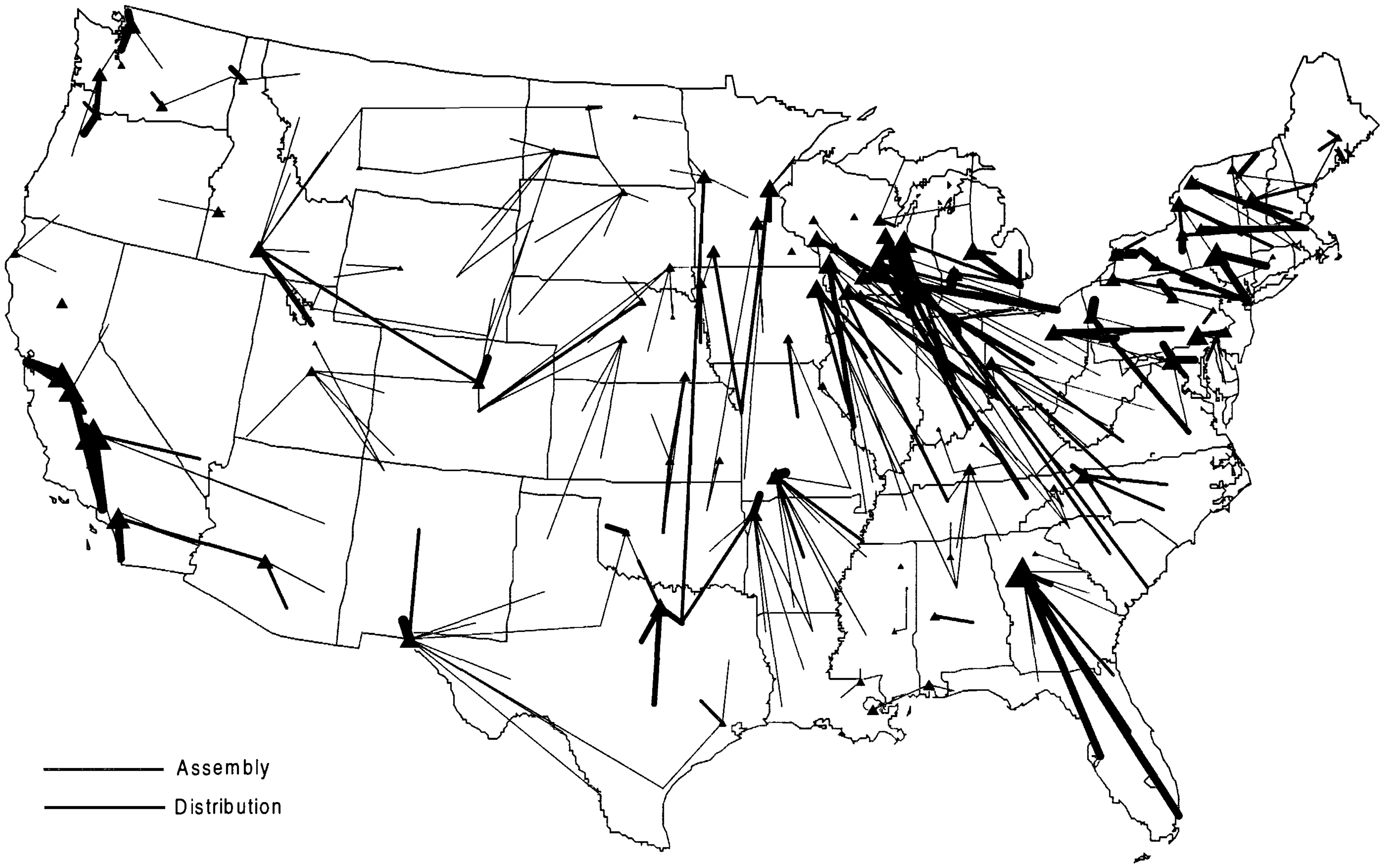


Assembly, Processing, and Distribution; Fluid Plants
Based on 1993 Annual Data
PRELIMINARY

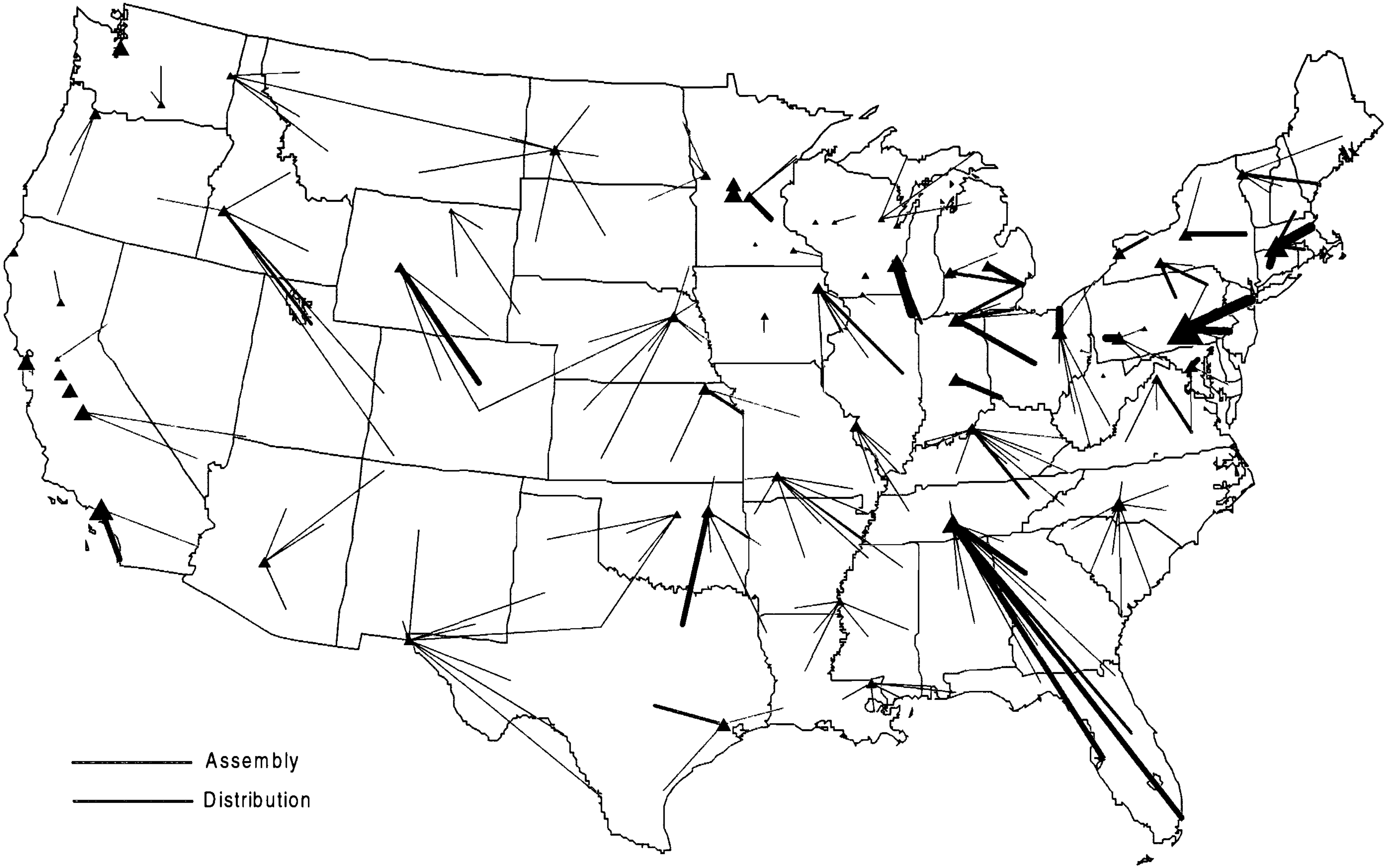
Assembly, Processing, and Distribution; Soft Plants

Based on 1993 Annual Data

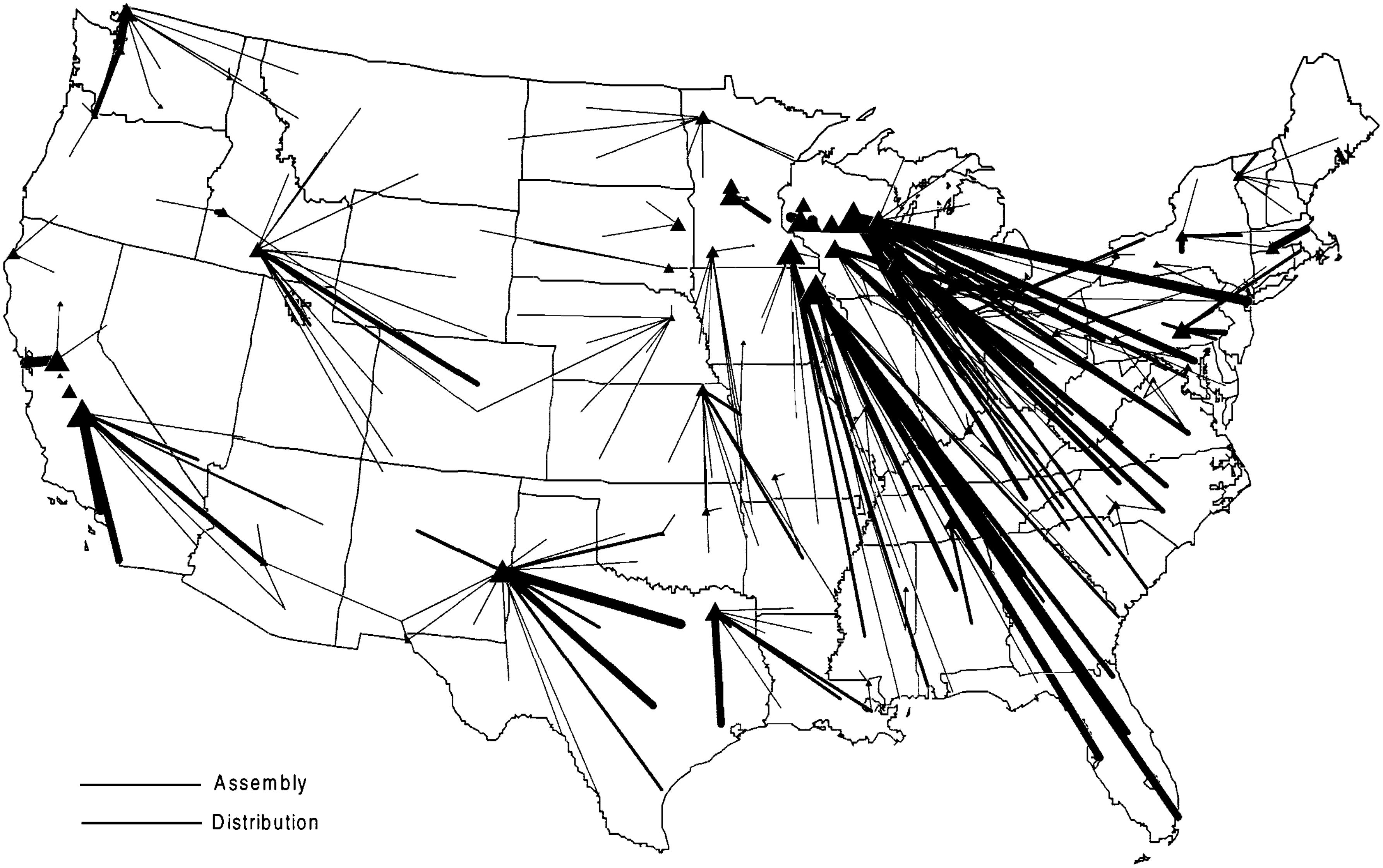
PRELIMINARY



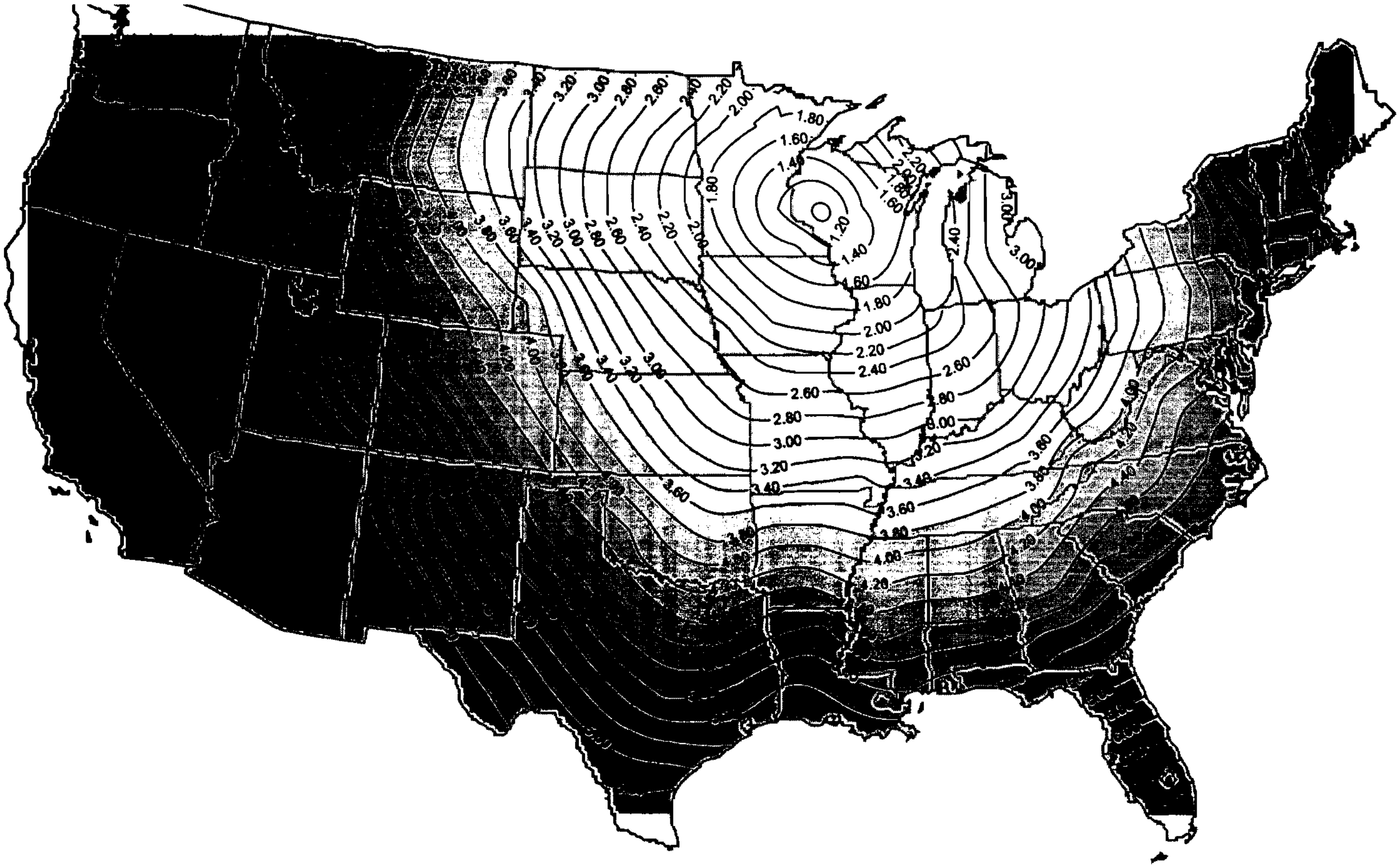
Assembly, Processing, and Distribution; Cheese Plants
Based on 1993 Annual Data
PRELIMINARY



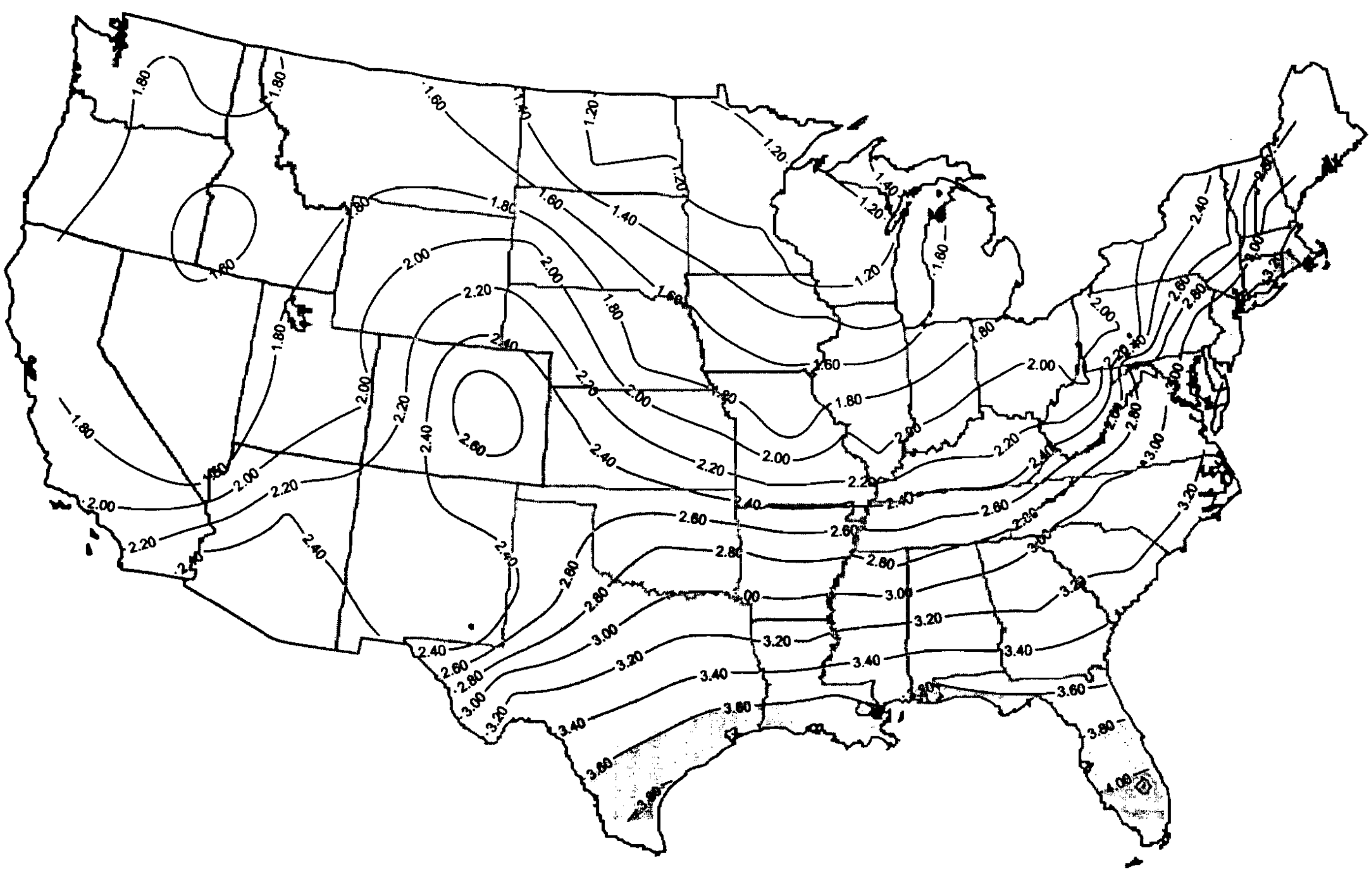
Assembly, Processing, and Distribution; Butter Plants
Based on 1993 Annual Data
PRELIMINARY



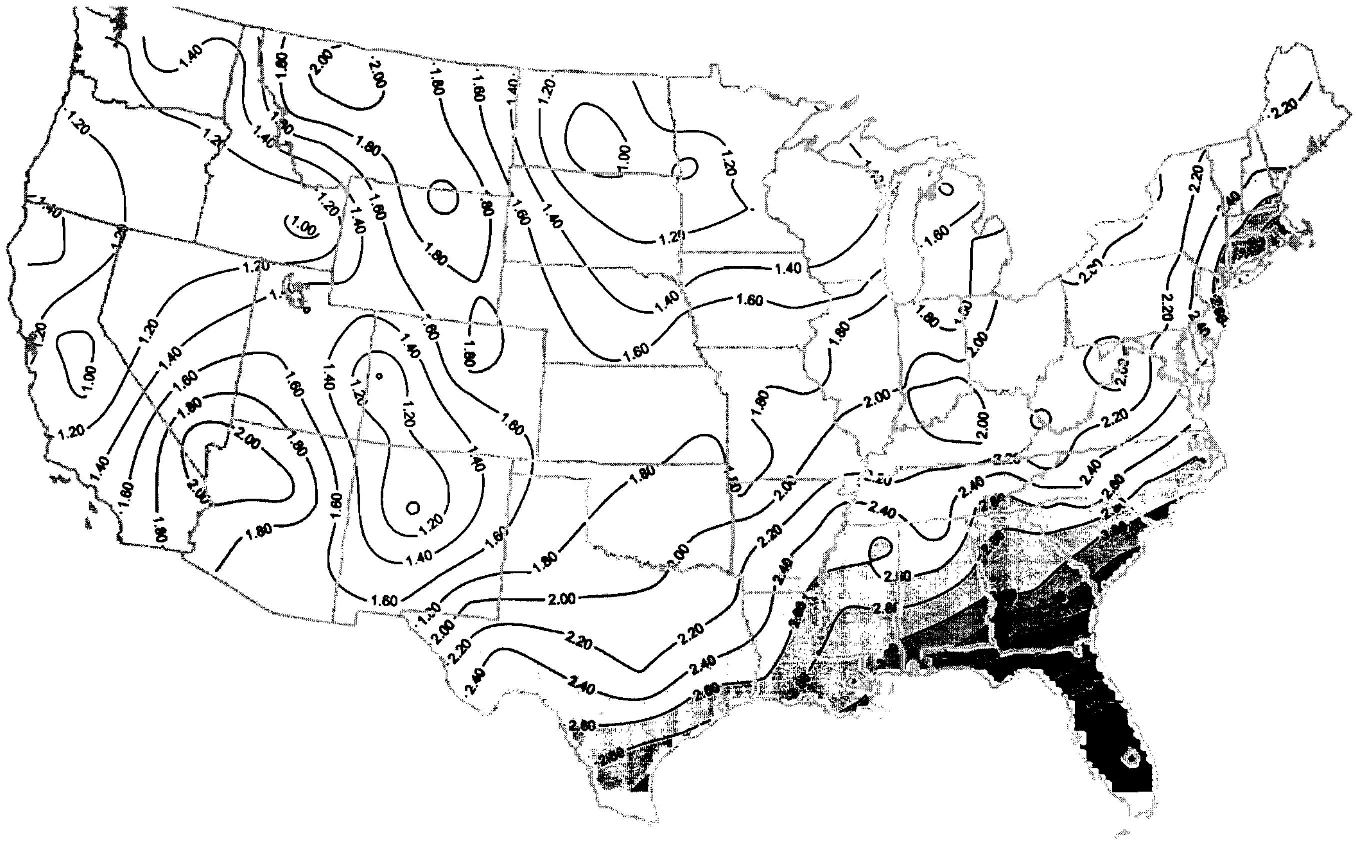
Assembly, Processing, and Distribution; Powder Plants
Based on 1993 Annual Data
PRELIMINARY



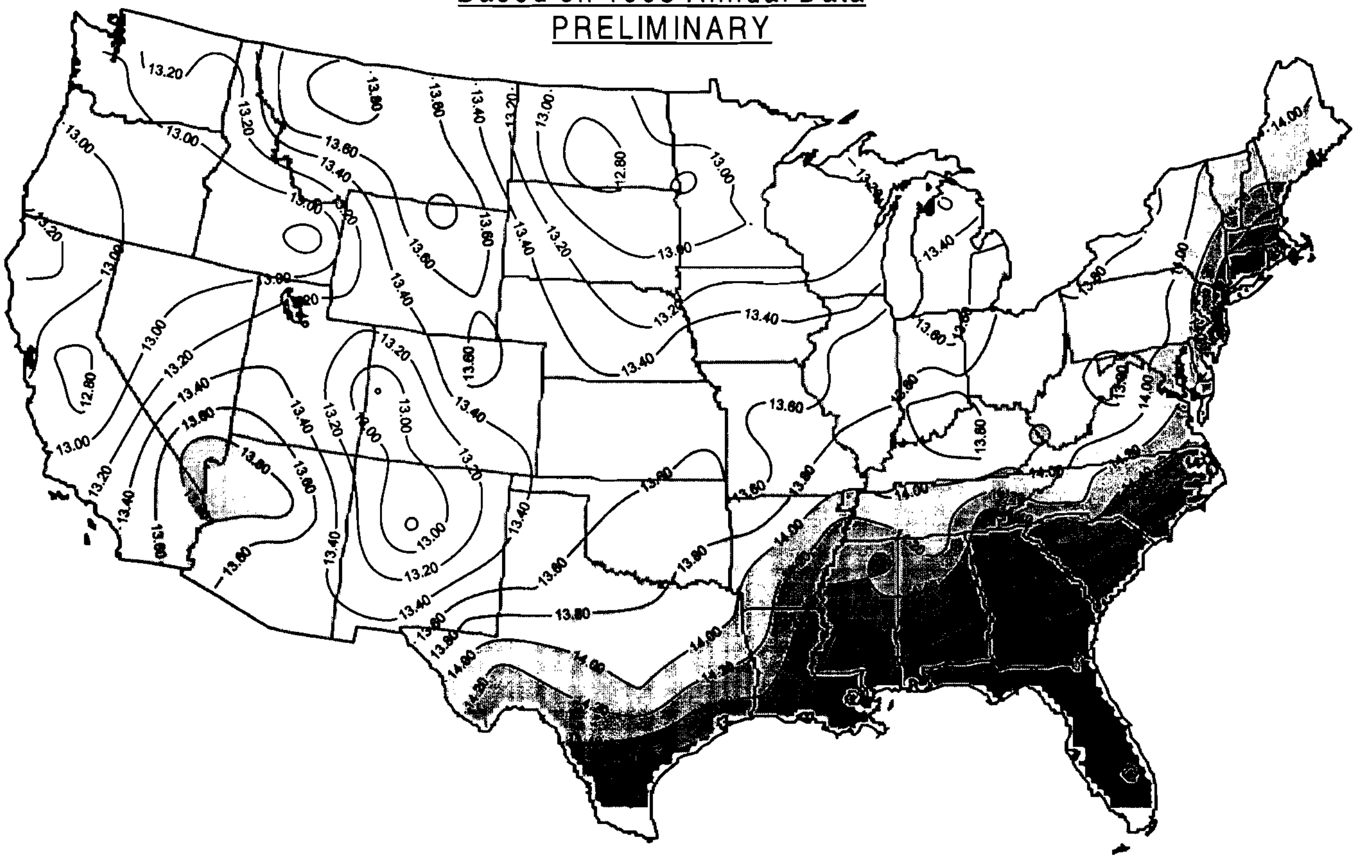
Eau Claire Plus Transportation Cost
35 cents/100 lbs/100 miles plus 91 cents
(Minneapolis = $1.20)



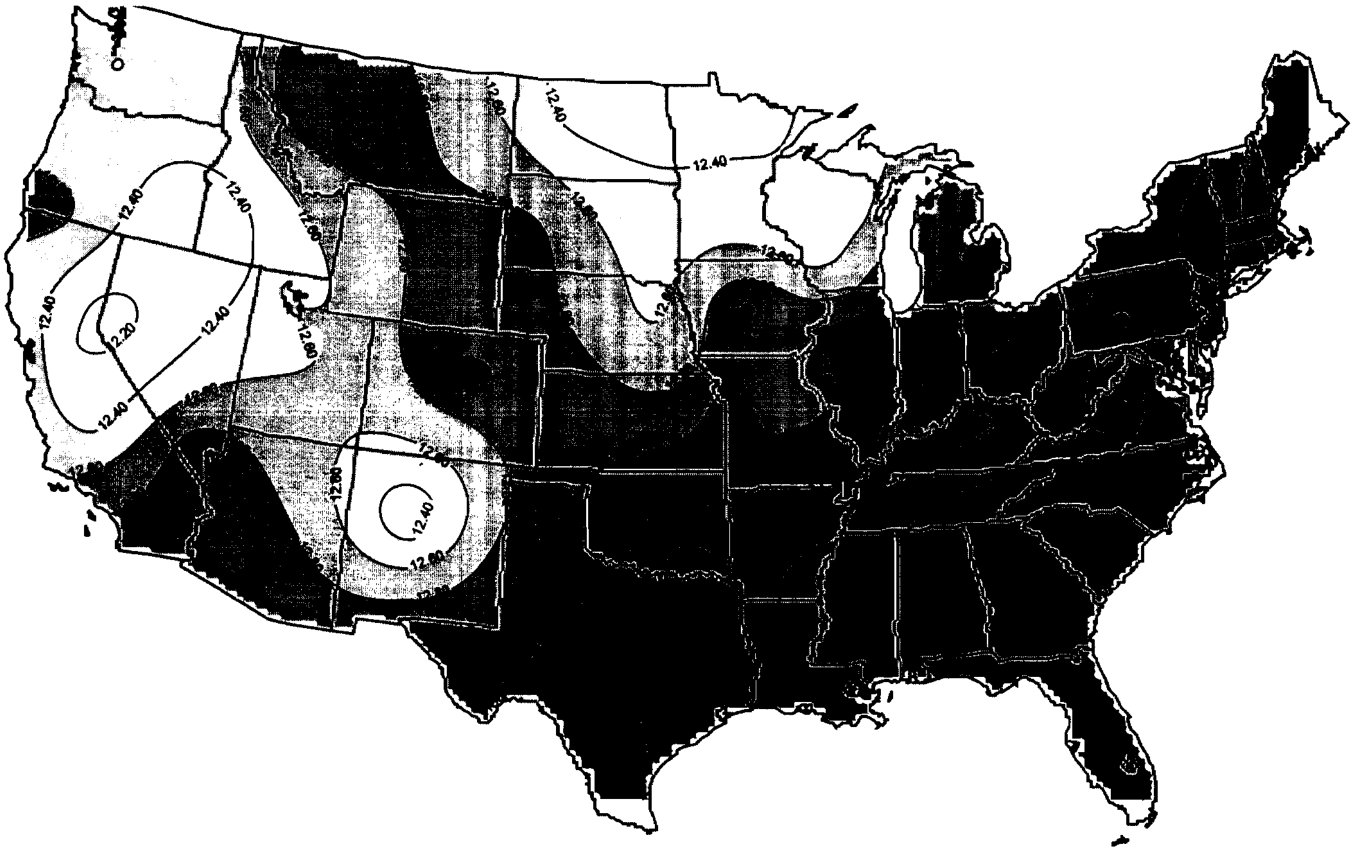
Actual 1995 Federal Order Class I Differentials $/cwt



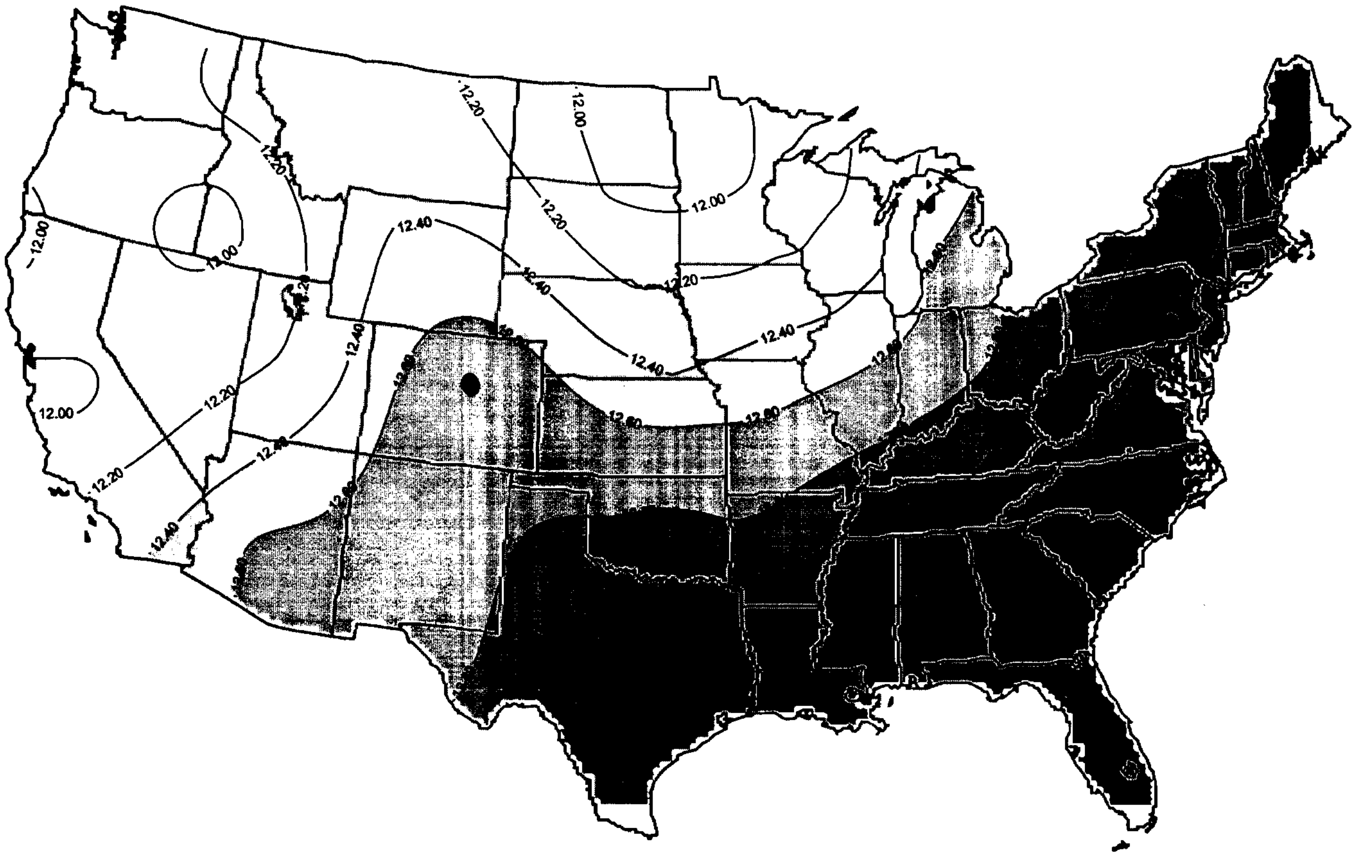
Simulated Class I Differentials (Minneapolis Base), $/cwt.
Based on 1993 Annual Data
PRELIMINARY



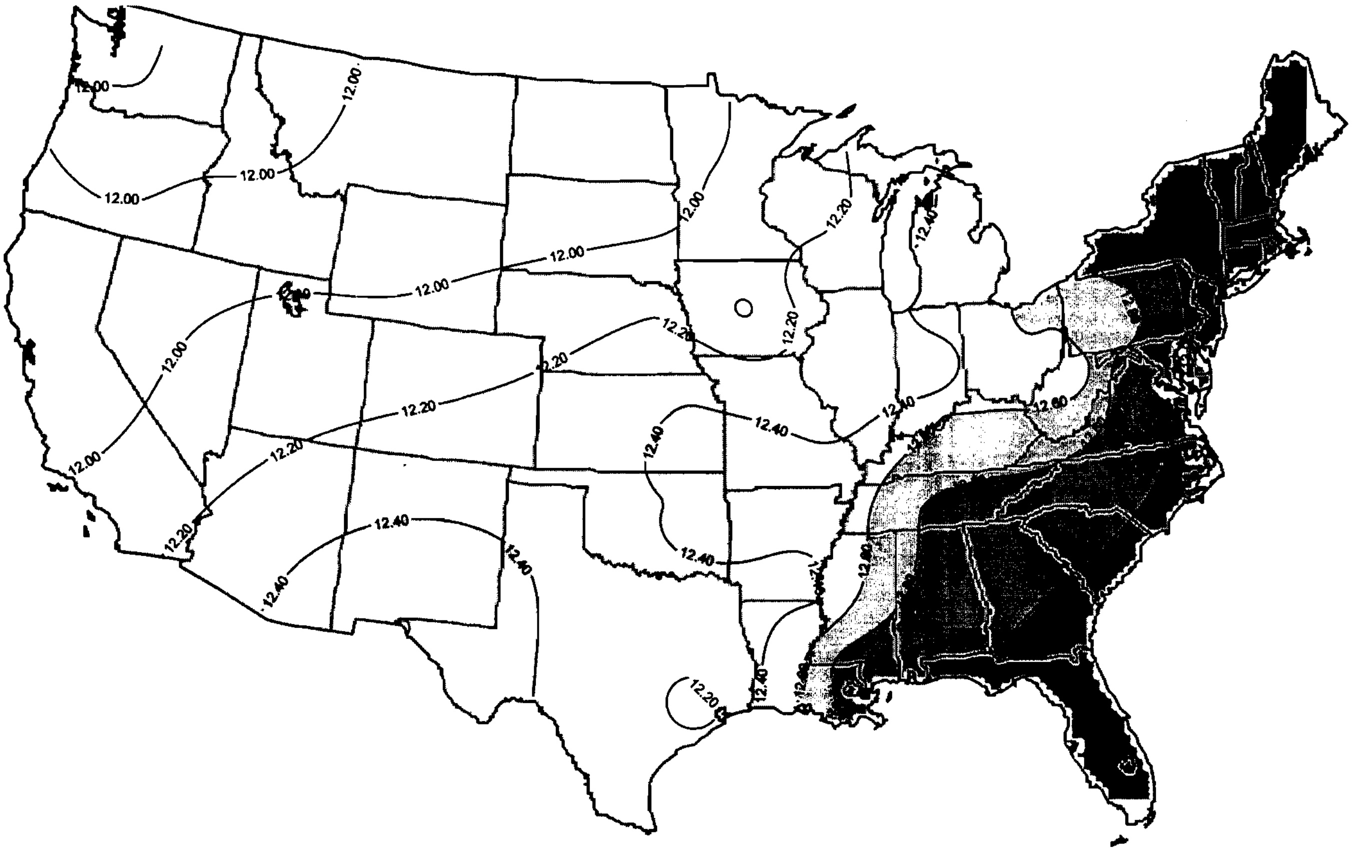
Simulated Class I Price (Minneapolis Base) of Standardized Milk at Fluid Plants, $/cwt.
Based on 1993 Annual Data
PRELIMINARY



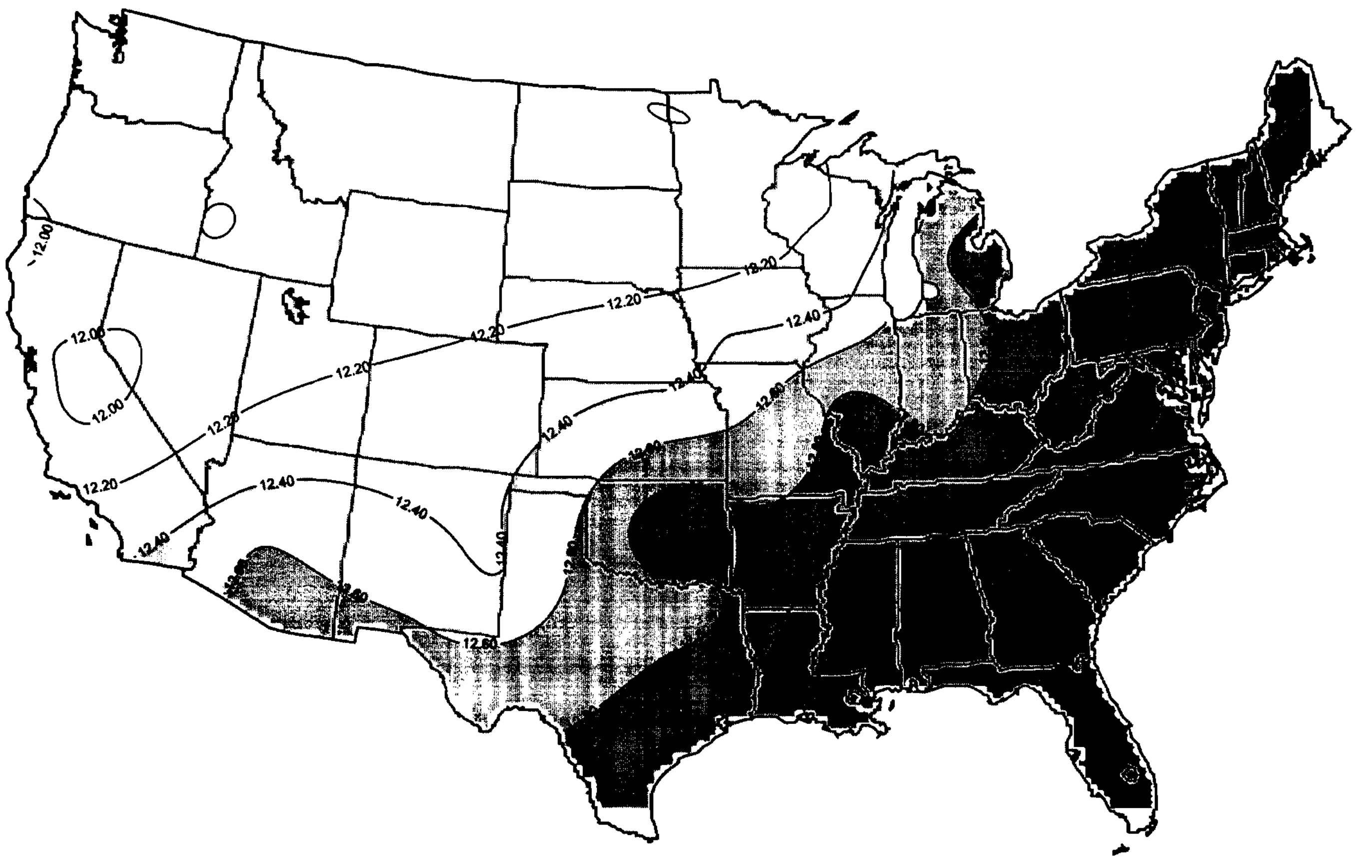
Simulated Class II Price of Standardized Milk at Soft Plants, $/cwt.
Based on 1993 Annual Data
PRELIMINARY



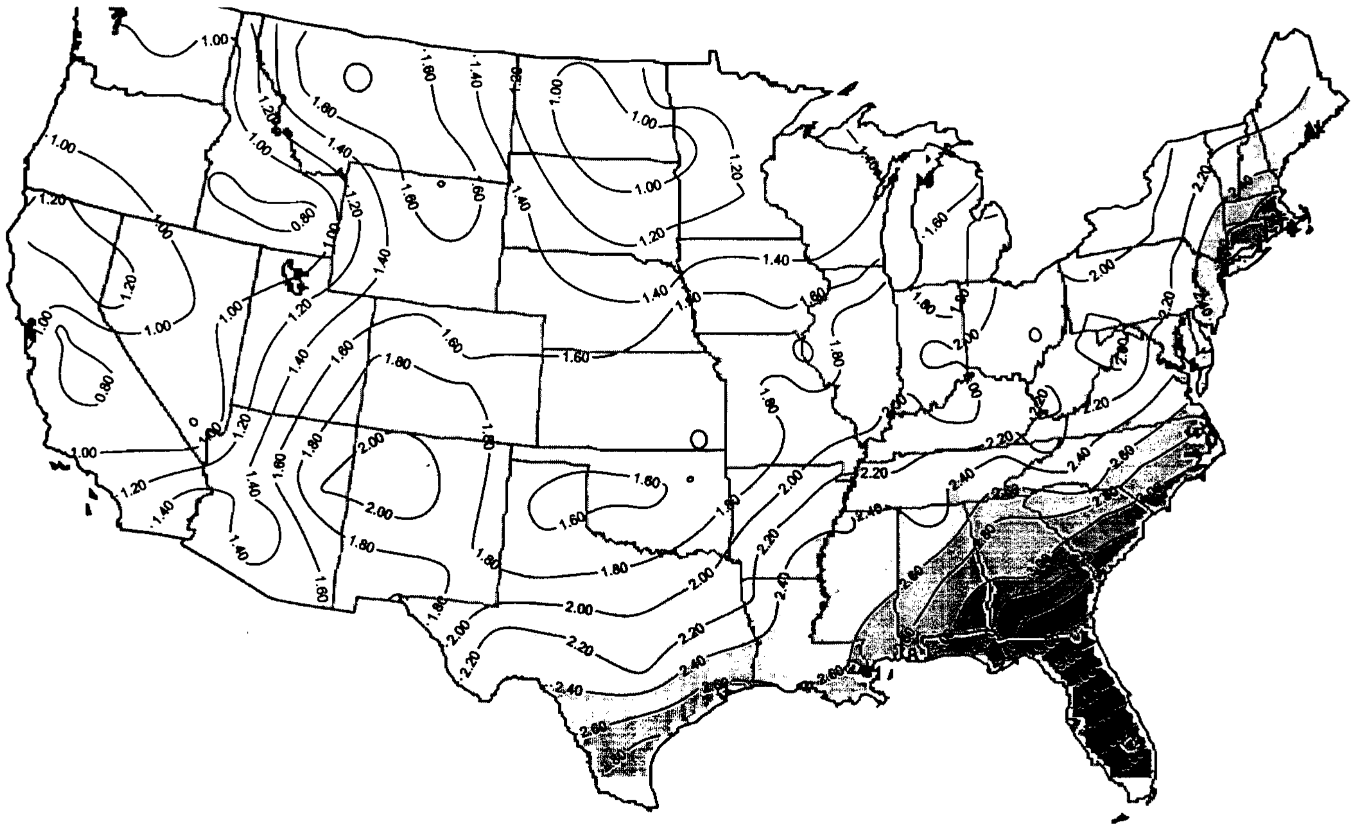
Simulated Class III Price of Standardized Milk at Cheese Plants, $/cwt.
Based on 1993 Annual Data
PRELIMINARY



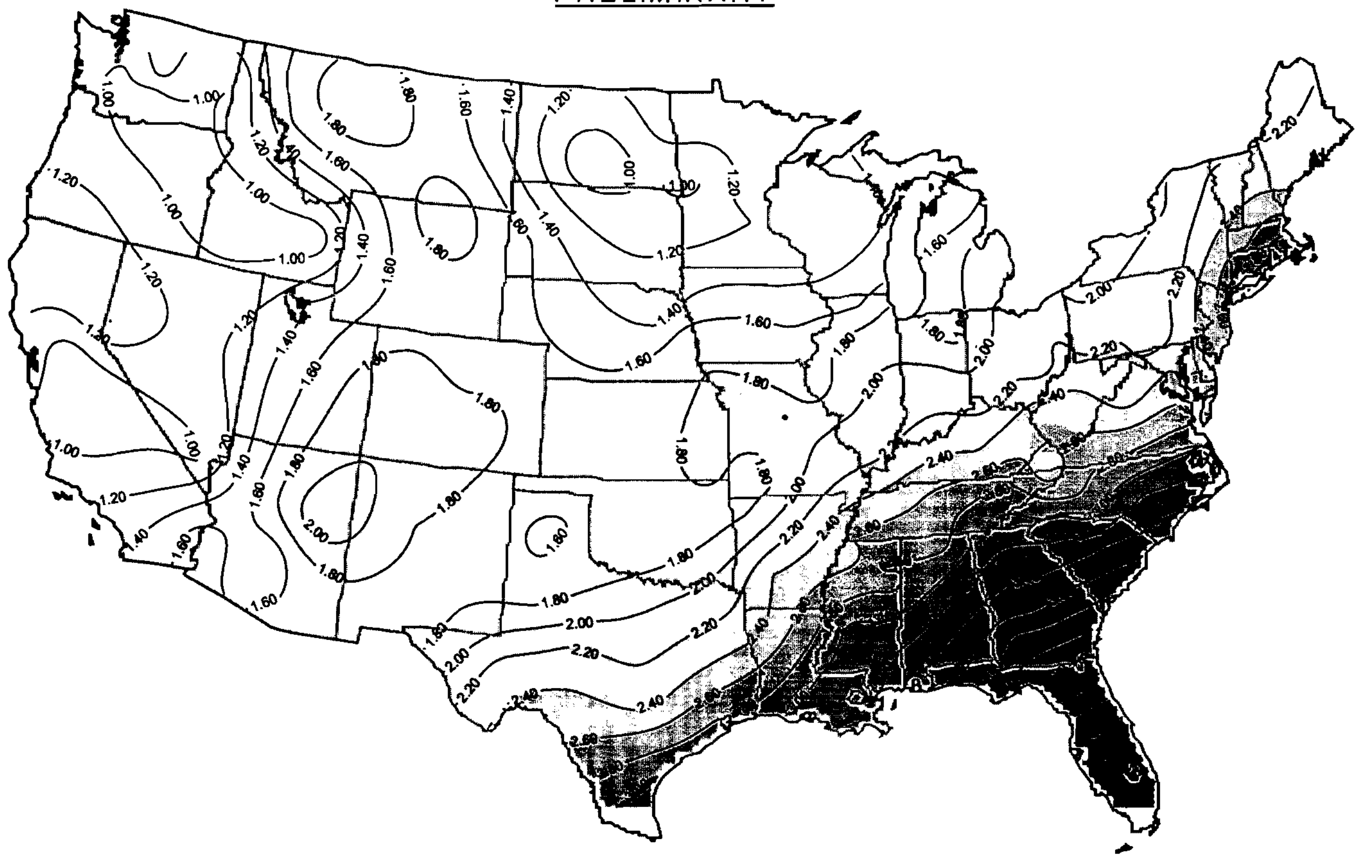
Simulated Value of Standardized Milk at Butter Plants, $/cwt.
Based on 1993 Annual Data
PRELIMINARY



Simulated Value of Standardized Milk at Powder Plants, $/cwt.
Based on 1993 Annual Data



Simulated Class I Differentials (Minneapolis Base), $/cwt.
Based on May 1995 Data
PRELIMINARY



Simulated Class I Differentials (Minneapolis Base), $/cwt.
Based on October 1995 Data

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