Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/95/60028-1		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
Developing Transit Availability Measures and an Index of Transit Service Availability	5. Report Date: July 1995 6. Performing Organization Code:
7. Author(s) Russell H. Henk, Sarah M. Hubbard, Timothy J. Lomax and Gordon A. Shunk	8. Performing Organization Report No. Research Report 60028-1
9. Performing Organization Name and Address Texas Transportation Institute Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0079
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

Supported by a grant from the Office of the Governor of the State of Texas, Energy Office

16. Abstract

This study involved the development of an index of transit service availability (ITSA). This index utilizes the factors which most effectively quantify the availability of public transit service (both bus and rail) in an urban area at a macroscopic planning level.

The development of the index consisted of applying over 30 prospective measures of transit service availability of 228 urban area transit systems in the United States. The index utilizes three specific measures which quantify transit service coverage, frequency of transit service, and transit system capacity. The index developed in this study is designed to serve as a planning tool -- it is not intended for use in assessing transit system efficiency and/or performance.

17. Key Words	18. Distribution Statement
Transit, Public Transportation, Transit Service Availability, Availability Index	No Restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	106	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

DEVELOPING TRANSIT AVAILABILITY MEASURES AND AN INDEX OF TRANSIT SERVICE AVAILABILITY

by

Russell H. Henk
Sarah M. Hubbard
Timothy J. Lomax
and
Gordon Shunk

Research Report SWUTC/95/60028-1

Southwest Region University Transportation Center
Texas Transportation Institute
Texas A&M University System
College Station, TX 77843-3135

July 1995

ABSTRACT

This paper summarizes the procedures and results associated with the development of an index of transit service availability. This index utilizes the factors which most effectively quantify the availability of public transit service (both bus and rail) in an urban area at a macroscopic planning level. The factors which are included in the index are based upon Federal Transit Administration Section 15 data and information from the 1990 Census.

The development of the index involved the application of over 30 prospective measures of transit service availability to 228 urban area transit systems throughout the United States. The index utilizes three specific measures which quantify transit service coverage, frequency of transit service, and transit system capacity.

The index presented in this paper is designed to serve as a planning tool--specifically developed to facilitate the comparison of transit service availability between urban areas with similar demographics and allow transit systems to examine service availability over time. The index is not intended for use in assessing transit system efficiency and/or performance.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation, University Transportation Centers program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

ACKNOWLEDGEMENTS

A National Advisory Committee formed in conjunction with this study provided valuable review and guidance throughout this research project. The generous assistance and input provided by the following individuals who served on this National Advisory Committee is gratefully acknowledged.

Mr. Peter Benjamin, Washington Metropolitan Area Transit Authority
Mr. John Cararra, Goodman Corporation
Mr. Lawrence D. Dahms, Metropolitan Transportation Commission
Mr. Barry Goodman, Goodman Corporation
Mr. Larry Heil, McDonald Transit Associates
Dr. Larry Pham, American Public Transit Association
Mr. John Pingree, Utah Transit Authority
Mr. James P. Reichert
Mr. Ron Tober, Greater Cleveland Regional Transit Authority
Mr. Kenneth J. Warren, Milwaukee County Transit System
Mr. Samuel Zimmerman, Federal Transit Administration

This publication was developed as part of the University Transportation Centers Program which is funded 50% in oil overcharge funds from the Stripper Well Settlement as provided by the Texas State Energy Conservation Office and approved by the U.S. Department of Energy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

EXECUTIVE SUMMARY

BACKGROUND

There currently exists a need for a planning-level tool with which to assess the adequacy (and more specifically, availability) of public transit in urban areas. Such tools have successfully been developed for measuring the adequacy of street and highway systems in the form of mobility indices. These roadway mobility measures have utilized generally-available statistics to estimate comparative congestion levels for major urban areas in the United States.

PURPOSE AND SCOPE OF STUDY

The goal of this study was to develop an index of transit service availability (ITSA) which would utilize generally-available statistics, have an urban area focus and be useful for a variety of planning activities (e.g., the need for additional transportation infrastructure, program improvements and funding support). While performance measures exist which are used in assessing transit system efficiency, these measures do not facilitate the assessment of an urban area's transit service availability over time or the comparison of transit service availability in urban areas with similar demographic characteristics. Filling this void was the specific purpose of this study.

STUDY METHODOLOGY

Identifying Prospective Transit Availability Measures

A number of primary issues were considered during the preliminary process of identifying prospective measures of transit service availability. These issues included: 1) transit service coverage; 2) frequency of transit service; 3) transit service capacity; 4) transit system utilization; and 5) directness of transit service. After considering each of these issues, it was concluded that transit service coverage, frequency of transit service, and transit service capacity should be quantitatively assessed in the prospective index. Transit system utilization and directness of service were concluded to be too closely related to transit system performance and/or efficiency (rather than availability).

The next major phase of the study involved the development of quantitative measures for each of the these issues identified as best representing transit service availability. With the aid of the Advisory Committee formed for this project (representatives from Transit Authorities/agencies throughout the country), 20 urban areas were ranked according to their perceived transit service availability. This list was used as a logic check in assessing the application of prospective measures and indices to large urban area transit systems. This logic check was used in conjunction with a statistical analysis (discussed subsequently) to select the best measures and indices to quantify transit service availability.

A series of over 30 measures of transit service availability were applied to 228 urban area transit systems throughout the United States. These measures were based upon Federal Transit Administration (FTA) Section 15 data and demographic statistics from the 1990 Census. The measures examined in this analysis primarily consisted of the following transit system characteristics: 1) directional route-miles; 2) vehicle-miles; 3) seat-miles; 4) vehicle-hours of operation; and 5) mixed right-of-way route miles. These measures were each divided by demographic statistics such as population, population density, and square miles of urban area to form factors representing transit service availability.

One of the most important issues which had to be dealt with during the selection of prospective measures was that of redundancy between factors. Ideally, the factors selected as components of this index would have little-to-no redundancy relative to the explanation of change (for individual measures) when applied to the 228 different urban area transit systems. A Pearson Correlation Analysis was conducted to statistically determine the redundance between prospective measures. The results of the analysis indicated that the least correlation (i.e., redundancy) occurred between the measures of directional route-miles per square mile, vehicle-miles per directional route-mile, and seat-miles per capita. As a result of both the statistical analysis and the logic check (mentioned previously), the measures indicated in Table S-1 were selected as components of the index.

Table S-1. Measures Recommended as Components of an Index of Transit Service Availability (ITSA)

Issue	Recommended Measure
Transit service coverage	Directional route-miles per square mile
Frequency of transit service	Vehicle-miles per directional route-mile
Transit system capacity	Seat-miles per capita

Index Format

The final major phase of the study entailed developing a format by which to utilize the three measures which best quantified transit service availability. One of the primary issues addressed at this stage was dividing the 228 urban areas in the database into groups with similar characteristics. This procedure was considered necessary due to the size of the database and the significant difference between transit systems being examined (e.g., New York City as compared to Clarksville, Tennessee). The urban areas were grouped according to their population density and total population. This stratification process produced the grouping shown in Table S-2.

Table S-2. Urban Area Grouping Based on Population Density and Total Population

Group Description[1]	Population Density (persons/sq.mi.)	Total Population	Group Size[2]	Example Urban Area
High - Very High	greater than or equal to 2,000	greater than 1,000,000	23	Boston, MA
Low - Very High	less than 2,000	greater than 1,000,000	10	Houston, TX
High - High	greater than or equal to 2,000	500,000 - 1,000,000	18	Orlando, FL
Low - High	less than 2,000	500,000 - 1,000,000	8	Nashville, TN
High - Medium	greater than or equal to 2,000	250,000 - 499,999	16	Fresno, CA
Low - Medium	less than 2,000	250,000 - 499,999	20	Charlotte, NC
High - Low	greater than or equal to 2,000	100,000 - 249,999	35	Canton, OH
Low - Low	less than 2,000	100,000 - 249,999	41	Green Bay, WI
High - Very Low	greater than or equal to 2,000	less than 100,000	22	Grand Forks, ND
Low - Very Low	less than 2,000	less than 100,000	35	Athens, GA
TOTAL			228	

[1]The general description of the urban area group based on population density and total population.
[2]The number of urban areas included within a respective group.

Once the urban areas had been categorized into similar groups, the transit availability measures for each urban area transit system were calculated. The average (mean) for each of the three measures was subsequently determined for the 10 different population density/population groups (Table S-2) and assigned a value of 5.0 (i.e., average on a scale of 0 to 10). Rankings above and below the average were then determined based on the variation from the mean value within each group. The goal of this approach was to illustrate the relationship between comparable urban areas and not, necessarily, to develop a scale of 0 to 10. This approach can be expressed as show in Equation S-1 for transit service coverage.

Equation S-1

$$I_{cov} = 5.0 + \left(\frac{X_{cov} - \overline{Y}_{cov}}{S_{cov}} \right)$$

Where: I_{cov} = Transit service coverage (directional route-miles per square mile);

5.0 = Constant, representing the average amount of transit service coverage (directional route-miles per square mile) in urban areas within a specific population density and population group;

X_{cov} = Transit service coverage directional (route-miles per square mile) in an individual urban area;

$\overline{Y}_{cov}$ = Average amount of transit service coverage in urban areas within a specific population density and population group; and

S_{cov} = Standard deviation of transit service coverage for urban areas within a specific population density and population group.

This approach was repeated for transit service frequency and transit system capacity (Equations S-2 and S-3).

Equation S-2

$$I_f = 5.0 + \left(\frac{X_f - \overline{Y}_f}{S_f}\right)$$

Equation S-3

$$I_{cap} = 5.0 + \left(\frac{X_{cap} - \overline{Y}_{cap}}{S_{cap}}\right)$$

Each of the individual index values calculated in Equations S-1 through S-3 were then combined in Equation S-4 to arrive at an overall indication of transit service availability within an urban area.

Equation S-4

$$ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$$

Where: ITSA = Overall index or indicator of transit service availability within an urban area;

I_{cov} = Transit service coverage component (directional route-miles per square mile);

I_f = Frequency of transit service component (vehicle-miles per directional route-mile); and

I_{cap} = Transit system capacity component (seat-miles per capita).

RESULTS

The index values for the 23 urban areas within the high population density and very high population group are shown in Table S-3. As one would expect, the urban area with the greatest amount of transit service availability in 1990 was New York City. San Francisco-Oakland and Washington, D.C. also exhibit transit service availability which is significantly above average for urban areas with similar demographics.

Table S-3. ITSA Values for Urban Areas with High Population Density and Very High Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
New York City, NY	6.4	8.0	8.1	7.5
San Francisco-Oakland, CA	7.7	5.7	6.4	6.6
Washington, D.C.	5.8	5.6	6.8	6.1
Chicago, IL	5.2	6.4	5.9	5.8
Boston, MA	4.0	6.6	5.8	5.5
Seattle-Everett, WA	6.6	4.1	5.1	5.3
Philadelphia, PA	4.7	5.7	5.2	5.2
Portland, OR	5.9	4.5	5.2	5.2
Miami, FL	5.1	5.1	4.8	5.0
Baltimore, MD	4.4	5.3	4.6	4.8
Pittsburgh, PA	5.1	4.5	4.7	4.8
Los Angeles, CA	5.4	4.6	4.3	4.7
Cleveland, OH	4.3	5.0	4.8	4.7
Buffalo, NY	5.8	3.8	4.4	4.6
San Diego, CA	4.7	4.6	4.6	4.6
New Orleans, LA	4.1	5.2	4.5	4.6
San Antonio, TX	4.8	4.5	4.5	4.6
Milwaukee, WI	4.3	4.6	4.6	4.5
St. Louis, MO	4.7	4.1	4.3	4.4
Sacramento, CA	4.3	4.2	4.3	4.3
Detroit, MI	4.2	4.3	4.2	4.2
Ft. Lauderdale, FL	3.5	4.8	4.1	4.2
Riverside-San Bernardino, CA	4.0	3.8	4.0	3.9

NOTE: High population density is defined as ≥2,000 persons per square mile; very high population is defined as >1,000,000 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

APPLICATIONS OF INDEX

As illustrated in Table S-3, the index developed in this study appears to be a potentially valuable planning tool for comparing transit service availability in urban areas with similar population and population density. The proposed index could also be useful in identifying potential needs for funding and/or areas of transit service availability improvement.

While not examined in this analysis, it further appears that the index could be used to identify changes in individual urban area transit systems over time. The general methodology could be used with a different means of grouping comparable urban areas as well. For instance, cities may already have groups of urban areas with which they consider themselves to be comparable. The statistics included in the index could simply be re-calculated and re-grouped to meet the needs and/or opinions of various urban areas.

LIMITATIONS OF THE INDEX

While the index (ITSA) seems to be useful for the purpose described previously, there are several noteworthy limitations. First, the index utilizes population density and total population statistics for the entire urban area rather than the transit service area. This approach may present a problem in cases where the transit service area and defined urban area are substantially different.

An additional concern is that the proposed methodology combines all transit system availability characteristics in an urban area to form one index. In some cases, transit availability characteristics from several different agencies are consequently grouped together. This approach is, therefore, of little use in urban areas within which several transit agencies provide service--at least with regard to the evaluation of the transit service made available by the individual transit agencies.

Finally, the measures used in the index were constrained by the availability of transit data. These limitations required the use of Federal Transit Administration Section 15 data which, due to inconsistencies which occasionally occur in the reporting of local statistics by individual urban areas, are perceived to be somewhat questionable with regard to total reliability.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

Page

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

Page

LIST OF TABLES

I. INTRODUCTION

The National Transportation Policy points out a potential for growing reliance on public transportation to serve both the transit dependent and the commuting market. Evaluation of the role and scope of public transit is, however, hindered due to the absence of a generally accepted measure that can be used to guide the assessment of the adequacy of public transit. The need for such a measure has been noted by numerous transit officials. The development of such a measure or tool is, therefore, an important step in the future provision and management of public transportation service in our nation's urban areas.

There has been little research regarding the development of measures to evaluate the availability of public transit service in an urban area. Significant progress has, however, been made in recent years in the development of mobility measures for street and highway systems. These measures have received wide national attention and are being used to justify improvement programs and to quantify trends in urban congestion levels (1).

Roadway congestion measures have used generally-available statistics from the Federal Highway Administration and local sources to estimate comparative daily traffic levels for major urbanized areas in the United States. The generally-available statistics, urban area focus, and macroscopic approach to congestion measurement have made the indices and estimates of the economic impact of congestion useful for a variety of planning activities. The need for transportation infrastructure, program improvements and additional funding are some of these planning activities. These ideas are frequently conveyed to elected officials and the public with an area or regional focus.

PURPOSE OF STUDY

The goal of this study was to develop an index of transit service availability (ITSA). This index utilizes the factors that most effectively quantify the availability of public transit service in an urban area at a macroscopic planning level--which, at present, is not adequately addressed by the performance measures used to assess transit service efficiency (e.g., cost effectiveness). It is envisioned that (similar to the roadway congestion measures cited previously) this index will provide transit professionals and decision makers with a valuable tool for planning and managing urban area transit systems.

INTENDED SCOPE OF INDEX

As alluded to previously, this analysis involved the macroscopic evaluation of transit availability in an urban area. The proposed index is not intended to be an indicator of transit efficiency, nor is it a tool to be used for detailed operational decisions (e.g., the optimum location of specific transit routes). The index is designed for assessing an urban area's transit service availability over time and comparing transit service availability in urban areas with similar demographic characteristics.

ORGANIZATION OF REPORT

Following this introductory chapter is a discussion of how the proposed index relates to the initial objectives of the study. This discussion focuses on the differences between transit mobility (the initial focus of the study) and transit availability (the focus of the proposed index).

Chapter 3 addresses key issues related to transit availability. This section presents all of the major issues examined in this analysis--including those issues quantified in the index, as well as other issues and/or measures that were considered during the stages of preliminary evaluation.

The potential measures (i.e., the transit-related issues in their analytical form) examined for use in the ITSA are discussed in Chapter 4. This section examines both the rationale behind the use of these measures, and some of the limitations associated with their use.

Chapter 5 discusses the development of the index. This section also addresses potential applications and limitations of the prospective index.

The final section of this report addresses the conclusions and recommendations associated with this study. Included in this section are the key issues addressed in this study, suggested and potential uses of the index, and identification of areas where further research may be warranted.

Several appendices are included at the end of the report which provide additional information on the methodology and values developed in this study, as well as a glossary of terms used throughout this report.

II. MOBILITY VS. AVAILABILITY

The initial objective of this study was the development of mobility measures for public transit. This objective was discussed at an Advisory Committee Meeting at the beginning of this project. This Advisory Committee consisted of transit experts (primarily General Managers and Planning Directors from major transit systems) from around the nation to provide guidance and review throughout this analysis. While this peer group agreed that the provision of mobility measures and, ultimately, a public transit mobility index would be desirable, they concurred that the measures included in the index produced in this study (the focus of which was transit service availability) should not be performance-related.

It was recognized in the early stages of this project that there are currently several transit measures which focus on performance and are used by the Federal Transit Administration (FTA) and local transit agencies, and that additional measures focusing on performance would be of little benefit, and perhaps even undesirable. It was further felt that the development of an index quantifying the general availability of transit service was more appropriate, given the macroscopic nature of this analysis. Because the peer group discouraged the use of performance measures in the index being developed in this study, the research team felt it was necessary to reconsider the formal objective of this study--specifically, the usage of the term "mobility" index to describe the final product of this study.

It was anticipated that the use of the term "mobility" index would be interpreted as a performance measure when, in fact, it had been recommended that performance measures not be included as components of the index.

It was, therefore, suggested that the prospective product of this study be referred to as an index of transit service availability (ITSA). The term availability index was recommended because it would hopefully avoid any interpretation that might suggest this was a performance-related index.

While the use of the term availability will not likely attract as much attention as mobility, the term availability more adequately represents the index that resulted from this study. The material presented in this report reflects that opinion.

III. TRANSIT AVAILABILITY ISSUES

A number of primary issues were considered during the process of identifying prospective measures of transit service availability. These issues included: 1) transit service coverage; 2) frequency of transit service; 3) transit service capacity; 4) transit system utilization; and 5) directness of transit service. A discussion of each of these issues and why each issue is (or is not) considered important in the quantification of transit availability is presented below.

TRANSIT SERVICE COVERAGE

Transit service coverage refers to the spatial proximity of transit service to both the origin and destination of a trip. Transit service coverage represents the transit density of relative coverage of transit service and provides some measure of the access to transit throughout an urban area. If one were comparing two different urban area transit systems, greater service coverage would imply shorter distances of travel required to reach transit service and, thus, better transit access for a greater number of people. Clearly, an increase in the accessibility or service coverage of transit reflects an increase in transit availability. The issue of transit service coverage was, therefore, considered essential in a transit availability index.

FREQUENCY OF TRANSIT SERVICE

The frequency of transit service (as considered in the context of this study) refers to both the total hours of daily transit operation, and the frequency with which this service is provided (headways between transit vehicle). Longer transit operating hours imply more service throughout the day, while an increase in the frequency of transit service implies a decrease in initial wait time. Both of these factors would clearly affect the availability of transit. It was, therefore, considered appropriate for this issue to also be addressed in the prospective index.

TRANSIT SERVICE CAPACITY

The ability of public transportation systems to serve a large number of commuters naturally influences the availability of transit especially during peak periods of travel. This service to commuters is generally referred to as mass transit and is closely related to the general capacity of a transit system. Transit service capacity is especially critical in large urban areas where there is typically not enough roadway capacity to rely on the personal automobile during peak periods of travel. Due to the important role that mass transit plays in many urban areas and its impact on the availability of transit to large numbers of commuters, including the issue of transit service capacity in the index was deemed appropriate.

TRANSIT SYSTEM UTILIZATION

Transit system utilization was considered in the early stages of this study, when the emphasis was on developing a "mobility" index. It was postulated that a well-utilized transit system would reflect the provision of good mobility. In addition, it was thought that examination of transit system utilization might help quantify factors that could not otherwise be measured (e.g., factors such as whether transit routes are appropriately distributed, and whether transit services are appropriately scheduled). Once the focus of the study became developing an availability index, however, it was concluded that the quantification of this issue would be too closely related to transit system performance and/or efficiency. Including a factor associated with transit system utilization in the index was, therefore, dropped from further consideration.

DIRECTNESS OF SERVICE

Another factor examined in the early phases of this analysis was the directness of service provided by a transit system. This factor was initially considered as a potential indicator of the quality of service provided by transit systems. As was the case with transit system utilization, however, directness of service was believed to reflect transit system efficiency and/or performance. Directness of service was, therefore, considered an inappropriate factor in the index being developed in this study.

SUMMARY

After considering the potential issues cited previously, it was concluded that the issues regarding transit service coverage, frequency of transit service, and transit service capacity should be quantitatively assessed in the prospective index. Transit system utilization and directness of service were not recommended for further analysis, since any factors developed to quantify these issues would be closely related to transit system performance and/or efficiency rather than availability.

IV. TRANSIT AVAILABILITY MEASURES

The next major phase of this study involved the development of quantitative measures for each of the three issues identified as best representing transit service availability--transit service coverage, frequency of transit service, and transit capacity. In order to prioritize prospective measures, a logic check was developed. This logic check specifically consisted of selecting 20 urban areas representing a variety of sizes, population and density. The Advisory Committee then ranked these areas according to their perception of the general availability of service offered by the transit systems in these urban areas. This list was developed at the initial Advisory Committee Meeting and is included in Table 1.

Table 1. Perceived Rank of Urban Areas Based on Transit Service Availability

Rank	Urban Areas	Rank	Urban Areas
1.	New York City	11.	St. Louis
2.	Boston	12.	Salt Lake City
3.	San Francisco	13.	Houston
4.	Washington, D.C.	14.	Dallas
5.	Atlanta	15.	Kansas City
6.	Seattle	16.	Fort Worth
7.	Portland	17.	Phoenix
8.	Minneapolis	18.	San Antonio
9.	Los Angeles	19.	Charlotte
10.	Denver	20.	Tampa Bay

With regard to the list of areas shown above, New York City was perceived to have the greatest availability of transit service, while Tampa Bay was perceived to have the least. As prospective measures were applied to the 228 urban area transit systems examined in this study, the results were compared to this list as a test of general reasonableness.

While many sources of data were examined in this analysis, FTA Section 15 data were considered the best available data for making comprehensive assessments of transit systems throughout the nation(2,3). A fundamental concern relative to FTA Section 15 data was that, historically, these data have not been completely reliable due to inconsistencies in data collection at the local urban-area level. There was, however, general agreement among the members of the Advisory Committee and research team that the macroscopic nature of the prospective index was consistent with the limitations presented by the utilization of FTA Section 15 data. It is important to note that the transit system statistics examined in this analysis include bus and rail service provided during 1990, while the demographic statistics were taken from the 1990 Census(4).

TRANSIT SERVICE COVERAGE

Transit service coverage refers to the spatial proximity of transit throughout the urban area. An ideal measure of service coverage would be the average distance traveled to reach transit services, such as the average distance from developments of some minimum density to the nearest transit stop. Such data have not, however, been collected in most urban areas.

Many measures were, nonetheless, identified which provided reasonable assessments of transit system coverage (Table 2). As is noted in Table 2, the potential measures considered in this study included a variety of transit system availability characteristics gauged by urban area demographic characteristics (i.e., population, urbanized land area, and population density).

An important consideration in selecting an appropriate measure of transit service coverage was that of redundancy between components of the prospective index. In other words, it was important that the three measures included in the index were not based upon the same transit system characteristics. The transit service coverage measure which directly addressed neither transit service capacity nor the frequency of transit service (i.e., the other two issues to be assessed in the index) and also produced reasonable results (when compared to Table 1) was directional route-miles per square mile. This measure was, therefore, recommended for quantifying transit service coverage (Table 2). Definitions of the measures examined in this study are included in a glossary at the end of this report (Appendix A).

Table 2. Measures Examined as Potential Transit Service Coverage Factors.

Issue	Ideal Measure	Measures Examined[1]	Recommended Measure
Service Coverage	Average distance that urban area residents must travel to reach transit service (average distance from developments of some minimum density to the nearest transit stop)	Directional route-miles per capita Directional route-miles per square mile Directional route-miles per capita per square mile Vehicle-miles per capita Vehicle-miles per square mile Vehicle-miles per capita per square mile Seat-miles per capita Seat-miles per square mile Seat-miles per capita per square mile Mixed ROW route-miles per capita Mixed ROW route-miles per square mile Mixed ROW route-miles per capita per square mile	Directional route-miles per square mile

[1]Mixed right-of-way (ROW) miles were examined as a separate factor because this type of service would be more accessible than total directional route-miles--which includes exclusive ROW miles.

FREQUENCY OF TRANSIT SERVICE

An ideal measure of the frequency of transit service availability would quantify average headway between vehicles as well as the daily hours of service provided by a transit system. Data constraints, however, limited the potential measures of transit service frequency to those included in Table 3.

Table 3. Measures Examined as Potential Frequency of Transit Service Factors.

Issue	Ideal Measure	Measures Examined	Recommended Measure
Frequency of service	Average vehicle headway gauged by a component normalizing hours of service for different system	Vehicle-miles per route-mile Vehicle-hours per route-mile Vehicle-hours per capita Vehicle-hours per square mile Vehicle-hours per person per square mile Seat-miles per route-mile	Vehicle-miles per route-mile

Vehicle-miles per directional route-mile and seat-miles per directional route-mile were the measures which produced the most reasonable results in comparison to the list of 20 urban areas developed with the aid of the Advisory Committee. The measure of seat-miles per directional route-mile was, however, considered to have a greater propensity for redundancy with potential transit system capacity factors. Vehicle-miles per directional route-mile was, therefore, recommended as the best available measure of transit service frequency (Table 3).

TRANSIT SYSTEM CAPACITY

Since transportation systems are usually congested only during peak periods of travel, an ideal measure of transit system capacity would quantify the portion of peak hour/peak period travel demand which could be served by transit. Data limitations prevented the development of such a specific measure. The number of vehicles operated in the peak period divided by the vehicles operated on a daily basis was believed to be a potentially reasonable surrogate measure. This measure did not, however, produce reasonable results.

A number of measures reflecting general transit system capacity were also examined (Table 4). After analyzing all of the factors shown in Table 4, seat-miles per capita was considered to be the best available measure of transit system capacity. While producing the most reasonable results, this measure also utilized statistics different from those used in the recommended measures for transit service coverage and frequency of service.

Table 4. Measures Examined as Potential Transit System Capacity Factors.

Issue	Ideal Measure	Measures Examined	Recommended Measure
System capacity	Percentage of peak-hour and/or peak period demand which could be served by transit	Seat-miles per route-mile Seat-miles per capita Seat-miles per square mile Seat-miles per capita per square mile Vehicle-miles per route-mile Vehicle-miles per capita Vehicle-miles per square mile Vehicle-miles per capita per square mile Vehicle-hours per capita Vehicle-hours per square mile Vehicle-hours per capita per square mile Vehicles operated in peak period per vehicles operated on daily basis	Seat-miles per capita

STATISTICAL ANALYSIS

In addition to the logic test described previously (Table 1), a statistical analysis was conducted to determine which measures were most appropriate as components of the index. This analysis was specifically directed at identifying the measures which had the lowest correlation between one another (i.e., the least redundancy) and was accomplished using a Pearson Correlation Analysis. This procedure was conducted for all of the prospective measures indicated in Tables 2 through 4 when applied to 228 different urban area transit systems in the U.S.

The results of this analysis indicated that the lowest correlation occurred between route-miles per square mile and vehicle-miles per route-mile (Table 5). As is indicated in Table 5, the measures of route-miles per square mile and seat-miles per capita also exhibited very low correlation (perfect correlation/complete redundancy would be reflected by a coefficient of 1.0). The correlation coefficients for most of the measures examined in this analysis were typically greater than 0.7 (Table 5) -- meaning most measures exhibited a high level of redundancy between one another. This statistical analysis further supported the measures recommended as a result of the logic test (Tables 2 through 4) to which all prospective factors were subjected.

Table 5. Example Correlation Coefficients Between Prospective Measures.

Measures	Correlation Coefficient(r)[1]
Route-miles per square mile and vehicle-miles per route-mile[2]	0.11
Route-miles per square mile and seat-miles per capita[2]	0.20
Vehicle-miles per route-mile and seat-miles per square mile	0.79
Vehicle-miles per square mile and vehicle-miles per route-mile	0.79
Vehicle-miles per square mile and seat-miles per capita	0.91

[1]The correlation coefficient was used as an indicator of redundancy between measures. A correlation coefficient of 1.0 would reflect measures that were completely redundant.
[2]Measures with the least redundancy and, therefore, selected for the index of transit service availability (ITSA).

SUMMARY

Over 30 different factors were examined as potential quantitative measures of transit service coverage, frequency of service, and transit system capacity. Analysis of these factors resulted in the recommendation of one specific measure for each issue. The specific measures recommended as components of the index are shown in Table 6.

Table 6. Measures Recommended as Components of an Index of Transit Service Availability (ITSA).

Issue	Recommended Measure
Transit service coverage	Directional route-miles per square mile
Frequency of transit service	Vehicle-miles per directional route-mile
Transit system capacity	Seat-miles per capita

V. DEVELOPING THE INDEX

Once the desirable components of the index had been identified, the next phase of this study involved combining these measures to form an index and developing the guidelines for applying the index. The first issue addressed at this phase was dividing the 228 urban areas in the database into groups with similar characteristics. This procedure was deemed necessary due to the large size of the database and, more importantly, the significant differences between the transit systems being examined (e.g., the transit system in New York City compared to the system in Clarksville, Tennessee).

The three factors considered the stratifying urban areas were total population, land area, and population density. It was determined that stratifying urban areas by population density and total population was the best approach. All urban areas with a population density greater than or equal to 2,000 persons per square mile were classified as high density, while urban areas with less than 2,000 persons per square mile were classified as low density. The urban areas within these two groups were then further divided according to total population with divisions at: 1.) 1,000,000; 2.) 500,000; 3.) 250,000; and 4.) 100,000 persons. This procedure produced the groups shown in Table 7.

Table 7. Urban Area Groupings Based on Population Density and Total Population.

Group Description[1]	Population Density (persons/sq.mi.)	Total Population	Group Size[2]	Example Urban Area
High - Very High	greater than or equal to 2,000	greater than 1,000,000	23	Boston, MA
Low - Very High	less than 2,000	greater than 1,000,000	10	Houston, TX
High - High	greater than or equal to 2,000	500,000 - 1,000,000	18	Orlando, FL
Low - High	less than 2,000	500,000 - 1,000,000	8	Nashville, TN
High - Medium	greater than or equal to 2,000	250,000 - 499,999	16	Fresno, CA
Low - Medium	less than 2,000	250,000 - 499,999	20	Charlotte, NC
High - Low	greater than or equal to 2,000	100,000 - 249,999	35	Canton, OH
Low - Low	less than 2,000	100,000 - 249,999	41	Green Bay, WI
High - Very Low	greater than or equal to 2,000	less than 100,000	22	Grand Forks, ND
Low - Very Low	less than 2,000	less than 100,000	35	Athens, GA
TOTAL			228	

[1]The general description of the urban area group based on population density and total population.
[2]The number of urban areas included within a respective group.

INDEX FORMAT

In order to make the index easy to understand and use, the basic format illustrated in Equation 1 was used. This approach combines the measures used to quantify transit service coverage, frequency, and capacity to form an indicator of overall transit availability within an urban area. Weighing certain measures greater than others (e.g., multiplying the service coverage factor by 1.5 to give it greater influence on the ITSA) was examined. No justifiable method for doing so was identified, however, and the measures in Equation 1 are weighted equally.

Equation 1:

$$ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$$

Where: ITSA = Overall index or indicator of transit service availability within an urban area;

I_{cov} = Transit service coverage component (directional route-miles per square mile);

I_f = Frequency of transit service component (vehicle-miles per directional route-mile); and

I_{cap} = Transit system capacity component (seat-miles per capita).

INDEX METHODOLOGY

Once the urban areas had been categorized into the groups shown in Table 7, the transit service coverage, frequency, and capacity measures for each urban area transit system were calculated. The average (mean) for each of the three measures was subsequently determined for the 10 different population density/population groups (Table 7) and assigned a value of 5.0 (i.e., average on a scale of 0 to 10). Rankings above and below the average were then determined based on the variation from the mean value within each group (i.e., the number of standard deviations above or below the mean). The goal of this approach was to illustrate the relationship between comparable urban areas and not, necessarily, to develop a scale of 0 to 10. This approach can be expressed as shown in Equation 2 for the transit service coverage component.

Equation 2:

$$I_{cov} = 5.0 + \left(\frac{X_{cov} - \overline{Y}_{cov}}{S_{cov}} \right)$$

Where: I_{cov} = Transit service coverage (directional route-miles per square mile);

5.0 = Constant, representing the average amount of transit service coverage (directional route-miles per square mile) in urban areas within a specific population density and population group;

X_{cov} = Transit service coverage (directional route-miles per square mile) in an individual urban area;

$\overline{Y}_{cov}$ = Average amount of transit service coverage in urban areas within a specific population density and population group; and

S_{cov} = Standard deviation of transit service coverage for urban areas within a specific population density and population group.

This approach was repeated for the transit service frequency and capacity components (Equations 3 and 4, respectively). Each of the index values calculated in Equations 2 through 4 were subsequently used in Equation 1 to arrive at an indicator of transit service availability within an urban area.

Equation 3:

$$I_f = 5.0 + \left(\frac{X_f - \overline{Y}_f}{S_f} \right)$$

Equation 4:

$$I_{cap} = 5.0 + \left(\frac{X_{cap} - \overline{Y}_{cap}}{S_{cap}} \right)$$

The application of this methodology is illustrated in the following example.

Example 1. The ITSA needs to be calculated for Washington, D.C. (which had a population density >2,000 and a total population >1,000,000 in 1990). The following transit system statistics (for bus and rail service during 1990) are known for 23 urban areas in the United States with high population density ($\geq$2,000 persons per square mile) and very high population (>1,000,000 persons).

Average transit service coverage,	$\bar{Y}_{cov}$	=	3.3 route-miles/square mile;
Average transit service frequency,	$\bar{Y}_{f}$	=	16,315 vehicle-miles/route-mile;
Average transit system capacity,	$\bar{Y}_{cap}$	=	1,408 seat-miles/capita;
Standard deviation of service coverage,	S_{cov}	=	1.30;
Standard deviation of service frequency,	S_{f}	=	8,779; and
Standard deviation of system capacity,	S_{cap}	=	1,110.

Washington, D.C. exhibited the following transit characteristics (bus and rail combined) during 1990.

Route-miles/square mile	=	4.3
Vehicle-miles/route-mile	=	22,000
Seat-miles/capita	=	3,350

The calculations to determine the ITSA can, therefore, be made.

$$I_{cov} = 5.0 + \left(\frac{4.3 - 3.3}{1.3}\right) = 5.8$$

$$I_{cov} = 5.0 + \left(\frac{22,000 - 16,315}{8,779}\right) = 5.6$$

$$I_{cap} = 5.0 + \left(\frac{3,350 - 1,408}{1,110}\right) = 6.8$$

$$ITSA = \frac{5.8 + 5.6 + 6.8}{3} = 6.1$$

Thus, the ITSA indicated that transit service availability in Washington, D.C. is significantly above the average (approximately one standard deviation) for urban areas with high population density and very high population.

The ITSA values for all 23 urban areas within the high population density and very high population group are included in Table 8. As expected, the urban area with the greatest amount of transit service availability in 1990 was New York City (Table 8). The ITSA values for the remaining population density and population groups are included in Appendix B.

Table 8. ITSA Values for Urban Areas with High Population Density and Very High Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
New York City, NY	6.4	8.0	8.1	7.5
San Francisco-Oakland, CA	7.7	5.7	6.4	6.6
Washington, D.C.	5.8	5.6	6.8	6.1
Chicago, IL	5.2	6.4	5.9	5.8
Boston, MA	4.0	6.6	5.8	5.5
Seattle-Everett, WA	6.6	4.1	5.1	5.3
Philadelphia, PA	4.7	5.7	5.2	5.2
Portland, OR	5.9	4.5	5.2	5.2
Miami, FL	5.1	5.1	4.8	5.0
Baltimore, MD	4.4	5.3	4.6	4.8
Pittsburgh, PA	5.1	4.5	4.7	4.8
Los Angeles, CA	5.4	4.6	4.3	4.7
Cleveland, OH	4.3	5.0	4.8	4.7
Buffalo, NY	5.8	3.8	4.4	4.6
San Diego, CA	4.7	4.6	4.6	4.6
New Orleans, LA	4.1	5.2	4.5	4.6
San Antonio, TX	4.8	4.5	4.5	4.6
Milwaukee, WI	4.3	4.6	4.6	4.5
St. Louis, MO	4.7	4.1	4.3	4.4
Sacramento, CA	4.3	4.2	4.3	4.3
Detroit, MI	4.2	4.3	4.2	4.2
Ft. Lauderdale, FL	3.5	4.8	4.1	4.2
Riverside-San Bernardino, CA	4.0	3.8	4.0	3.9

NOTE: High population density is defined as ≥2,000 persons per square mile; very high population is defined as >1,000,000 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

APPLICATIONS OF THE INDEX

In addition to facilitating relative comparisons of overall transit service availability between similar urban areas, the proposed methodology could be used to identify potential needs for funding and/or areas of transit service improvement. For instance, when considering areas with high population density and very high population, the transit system in Buffalo, New York offered very good coverage (route-miles per square mile) during 1990 (Table 8). The frequency of service (vehicle-miles per route-mile) associated with this system was, however, well below average (3.8 or roughly one standard deviation below average); thus, giving Buffalo an overall index that was below average.

The use of generally available statistics and the urban area focus will presumably make the index useful for a variety of planning and evaluation activities. It specifically appears that, when applied in the manner illustrated previously, the proposed index provides a reasonable tool for making relative comparisons between urban areas with similar demographic characteristics. While not examined in this analysis, it further appears that the ITSA presented herein could be used to identify changes in individual urban area transit systems over time. The validity of this second application was not verifiable due to time limitations associated with this study.

The general methodology utilized in this study could also be used with a different means of grouping comparable urban areas. For instance, cities may already have groups of urban areas with which they consider themselves to be comparable. The statistics included in the index could simply be re-grouped to fit the needs and/or opinions of various urban areas.

LIMITATIONS OF THE INDEX

While the ITSA seems to be useful for the purposes described previously, there are several noteworthy limitations associated with this index. First, the index utilized population density and total population statistics of the entire urban area rather than the transit service area. Approximate urban area boundaries used for major urban areas are included in Appendix C.

This approach may not present a problem in some cases (e.g., small urban areas where transit systems typically provide service over the entire urban area). In certain urban areas, however, this methodology could lead to misleading results. For example, in Minneapolis-St. Paul, Minnesota, the Metropolitan Transit Commission (MTC) can only provide transit service within the municipal urban service area (MUSA), the boundaries of which are dictated by the Metropolitan Council and the State Legislature. In this case, the MUSA is significantly smaller than the urban area defined in the 1990 census(4).

Having recognized the limitations of using urban area (rather than service area) boundaries in determining the ITSA, it is worthwhile to point out an advantage of doing so. The objective of the ITSA is the determination of transit service availability on a macroscopic level (i.e., within an entire urban area). If transit service is not provided in portions of an urban area, it will be reflected in the proposed index.

An additional concern is that the currently proposed methodology combines all transit system availability characteristics in an urban area to form one index. In some cases, transit availability characteristics from several different transit agencies are consequently grouped together. This approach is, therefore, of little use in urban areas within which several transit agencies provide service. For instance, nine different transit agencies provide transit service in Los Angeles, California. None of these agencies can determine and/or track their individual level of transit service availability using the proposed approach.

A related concern involves transit agencies which provide service for more than one urban area. This particular problem was investigated using data provided by the Utah Transit Authority (which provides service for the Salt Lake City, Ogden, and Provo-Orem urban areas). As is indicated in Table B-3 (Appendix B), the index for Salt Lake City is 6.1 (i.e., significantly above average for urban areas with high population and low population density). If, however, the transit service availability characteristics for Salt Lake City, Ogden, and Provo-Orem are considered, the index for this entire region becomes 4.8 (i.e., slightly below average). This reduction in the index is likely due to less comprehensive service (at least compared to that provided in Salt Lake City) such as demand-response service being provided in Ogden and Provo-Orem. This analysis seems to indicate that using the proposed approach could be an advantage for transit agencies providing service to many urban areas by facilitating the assessment of transit service availability on an individual urban area basis.

Finally, as presented in this report, the index can only be utilized to compare urban areas of similar population density and total population. Making comparisons between urban areas which are not within the same groups (Table 7) would not be appropriate.

VI. CONCLUSIONS AND RECOMMENDATIONS

The development of the index of transit service availability (ITSA) provides a new tool for transit agencies and decision makers to use in their evaluation of the transit service available in their urban area. By focusing on transit availability, the index provides an alternative to previous transit measures that focused primarily on efficiency and performance.

SUGGESTED AND POTENTIAL USES

A number of potential uses of the index have been identified. For example, the index may be used by transit agencies and decision makers to evaluate the level of transit service available; such evaluations may be used to gauge deficiencies in the existing transit service available (i.e., service coverage or frequency of service), and to demonstrate adequacy in areas where the transit service available is sufficient.

The index also allows the level of transit service available in an urban area to be compared to the transit service available in other urban areas of similar size and population density, and to be tracked over time, which will allow an examination of trends in transit availability.

Because the index is relatively easy to understand and can be calculated for any urban area, transit agencies may find that the index is a valuable tool for communicating with funding agencies and the public. The index may be used by policy makers, to determine the relative levels of transit availability in urban areas of similar size and density in their jurisdiction; such comparisons may be used to identify urban areas with deficiencies in service so that resources can be appropriated to alleviate these deficiencies. The proposed index may also be used to verify the improvements that result from increased resources, and, thus, assure policy makers and the public that the expenditures were justified and money was well spent.

Finally, the index may be used by transit agencies to communicate and demonstrate the impacts that changes in funding will have on transit operations and the level of transit service available. The index may be used to illustrate the increase in transit service availability that would result from an increase in funding; similarly, the negative impact of a funding cut on the level of transit availability may be demonstrated.

RECOMMENDATIONS FOR FURTHER RESEARCH

As alluded to in the discussion of this study in previous chapters, there are a number of areas related to the development of the ITSA that would benefit from further research. It is important to note that all further research in the field of public transit would profit from the collection of additional and more reliable data. It is suggested that standards be established for both the kind of data that should be collected, as well as the methods of data collection. Implementation of consistent practices for all urban areas would provide a more comprehensive and reliable data base from which research could be conducted.

It is recommended that additional research be conducted to increase the usefulness of the index developed in this study. This research should evaluate how the existing index is being used by transit agencies and decision makers, identify limitations and identify needs that the index does not address.

Further research to track the changes in transit availability in various urban areas is warranted for a number of reasons. The results of this research (regarding the changes in the availability of transit service) could be correlated with a number of factors (e.g., employment opportunities for inner city residents) to better understand the contribution of public transit in an urban area. An understanding and quantification of the changes in the provision of public transit availability is also necessary in order to ascertain how often the index should be "re-calibrated" to reflect changes in transit service availability (re-calibration refers to the revised calculations of the index based on the current measures in the urban areas in each density and population stratification).

Additional research should also be conducted to facilitate modification of the ITSA for application to urban areas whose service area is different from the urban area boundary as defined by the census, and where multiple transit agencies provide service to a single urban area. In its present form, the index is of little benefit to transit agencies in either of these circumstances. Additional research could also address the differences in transit needs in urban areas with different characteristics. For example, mass transit (the provision of transit for a large number of commuters during the peak period) obviously plays a more important role in a large city than in a smaller city; however, the calculation of the current index does not differentiate between the two. Additional research, which is based on more extensive and reliable data, may be better able to address such issues.

The development of the index raised a number of issues. One of the most important issues was the reliability and availability of transit data. The measures used in the index were constrained by the availability of data; and the scope of the index was constrained by the perceived reliability of the data (i.e., the index developed provides a macroscopic measure of transit service availability in an urban area utilizing FTA Section (15 data). An improved index could be developed with more accurate and reliable data which could be brought about by improved data collection and reporting procedures at the local urban-area level.

Finally, it is recommended that further transit research be extended to include the development of a mobility index for transit service. Such an index would quantify not only transit availability, but also transit mobility, in an urban area. Eventually, the transit mobility index could be used in conjunction with the roadway congestion index, which provides a measure of mobility on urban freeways and arterials, to provide a comprehensive picture of mobility in an urban area.

VII. REFERENCES

1. Texas Transportation Institute. Estimates of Urban Roadway Congestion-1990, Research Report 1131-5, March 1993.
2. Office of Capital and Formula Assistance, Federal Transit Administration. Data Tables for the 1990 Section 15 Report Year, December 1991.
3. American Public Transit Association. Transit Operating and Financial Statistics, Transit System Statistics for Calendar/Fiscal Year 1990, November 1991.
4. U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. 1990 Census of Population and Housing Summary Population and Housing Characteristics, United States, 1992.

APPENDIX A

Glossary of Terms Used in Report

Formal Definitions for Frequently-Used Terms

Directional route miles:

The mileage service operates in each direction over routes which public transportation vehicles travel while in revenue service. Directional route miles are a measure of the facility or roadway, not the service carried on the facility (the service carried on the facility would be represented by the number of routes or vehicle revenue miles). Directional route miles are determined by direction of service, but not by the number of traffic lanes or rail tracks existing in a given right-of-way. If vehicles travel in both directions, each mile (or respective unit of distance) is counted twice.

Vehicle miles:

Annual actual vehicle revenue miles; the number of miles that transit vehicles are available for service. The difference between vehicle miles and vehicle revenue miles represents deadheading.

Seat miles:

Annual vehicle revenue capacity miles; the number of annual vehicle revenue miles times the average capacity of transit vehicles. An indication of the capacity of the transit service supplied.

Mixed right-of-way (ROW) miles;

Non-rail direction route miles on mixed ROW, which means the transit service shares the roadway with mixed flow traffic (private automobiles). Mixed ROW miles does not include non-rail directional route miles on controlled ROW or exclusive ROW, such as exclusive bus lanes.

The following are tables summarizing verbal explanations of measures examined as potential components of the index developed in this study.

Table A-1. Service Coverage Factors

Measure	Numerator	Denominator
Directional route-miles per capita	number of miles on transit routes	number of people in the urban area
Directional route-miles per square mile	number of miles on transit routes	number of square miles in the urban area
Directional route-miles per capita per square mile	number of miles on transit routes	density of the urban area (persons per square mile)
Vehicle-miles per capita	number of miles transit vehicles travel on their routes	number of people in the urban area
Vehicle-miles per square mile	number of miles transit vehicles travel on their routes	number of square miles in the urban area
Vehicle-miles per capita per square mile	number of miles transit vehicles travel on their routes	density of the urban area (persons per square mile)
Seat-miles per capita	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	number of people in the urban area
Seat-miles per square mile	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	number of square miles in the urban area
Seat-miles per capita per square mile	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	density of the urban area (persons per square mile)
Mixed ROW route-miles per capita	number of miles on transit routes that are shared with non-transit vehicles[1]	number of people in the urban area
Mixed ROW route-miles per square mile	number of miles on transit routes that are shared with non-transit vehicles	number of square miles in the urban area
Mixed ROW route-miles per capita per square mile	number of miles on transit routes that are shared with non-transit vehicles	density of the urban area (persons per square mile)

[1]Mixed ROW miles were examined as a separate factor because this type of service would be more accessible than total directional route-miles which includes exclusive ROW miles that may only be accessible at certain locations.

Table A-2. Frequency of Transit Service Factors

Measure	Numerator	Denominator
Vehicle-miles per route-mile	number of miles transit vehicles travel on their routes	number of miles on transit routes
Vehicle-hours per route-mile	number of hours transit vehicles are in service	number of miles on transit routes
Vehicle-hours per capita	number of hours transit vehicles are in service	number of people in the urban area
Vehicle-hours per square mile	number of hours transit vehicles are in service	number of square miles in the urban area
Vehicle-hours per capita per square mile	number of hours transit vehicles are in service	density of the urban area (persons per square mile)
Seat-miles per route-mile	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	number of miles on transit routes

Table A-3. Transit System Capacity Factors

Measure	Numerator	Denominator
Seat-miles per route-mile	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	number of miles on transit routes
Seat-miles per capita	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	number of people in the urban area
Seat-miles per square mile	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	number of square miles in the urban area
Seat-miles per capita per square mile	number of seats on transit vehicle multiplied by the number of miles the vehicle traverses	density of urban area (persons per square mile)
Vehicle-miles per route-mile	number of miles transit vehicles travel on their routes	number of miles on transit routes
Vehicle-miles per capita	number of miles transit vehicles travel on their routes	number of people in the urban area
Vehicle-miles per square mile	number of miles transit vehicles travel on their routes	number of square miles in the urban area
Vehicle-miles per capita per square mile	number of miles transit vehicles travel on their routes	density of urban area (persons per square mile)
Vehicle-hours per capita	number of hours transit vehicles are in service	number of people in the urban area
Vehicle-hours per square mile	number of hours transit vehicles are in service	number of square miles in the urban area
Vehicle-hours per capita per square mile	number of hours transit vehicles are in service	density of urban area (persons per square mile)
Vehicles operated in peak period per vehicles operated on daily basis	number of vehicles operated during the peak period	number of vehicles operated throughout the day

APPENDIX B

ITSA Values for Additional Population Density/Population Groups

Table B-1. ITSA Values for Urban Areas with Low Population Density and Very High Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
Atlanta, GA	4.5	7.4	7.7	6.6
Denver, CO	5.6	5.2	5.2	5.3
Minneapolis-St. Paul, MN	6.4	4.4	5.1	5.3
Cincinnati, OH	6.6	4.3	4.9	5.3
Houston, TX	4.5	5.8	4.8	5.0
Dallas, TX	5.3	4.0	4.7	4.7
Kansas City, MO	4.7	4.8	4.6	4.7
Phoenix, AZ	4.8	4.4	4.5	4.5
Norfolk-Tidewater, VA	3.9	4.8	4.3	4.3
Fort Worth, TX	3.6	4.7	4.2	4.2

NOTE: Low population density is defined as <2,000 persons per square mile; very high population is defined as >1,000,000 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-2. ITSA Values for Urban Areas with High Population Density and High Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
Honolulu, HI	7.5	7.7	8.5	7.9
Tucson, AZ	4.4	6.2	5.3	5.3
Dayton, OH	5.8	4.4	5.6	5.3
Providence, RI	4.2	6.5	4.9	5.2
Hartford, CT	5.7	4.3	5.5	5.2
Albany, NY	6.6	4.1	4.9	5.2
Rochester, NY	5.3	4.9	5.1	5.1
Louisville, KY	5.2	4.6	5.3	5.0
Columbus, OH	5.1	5.0	4.8	5.0
El Paso, TX	4.5	5.3	4.8	4.8
Omaha, NE	5.1	4.5	4.7	4.8
Memphis, TN	4.4	4.9	5.0	4.8
Albuquerque, NM	5.8	3.6	4.7	4.7
Akron, OH	3.8	5.7	4.5	4.7
Indianapolis, IN	4.5	4.5	4.7	4.5
Orlando, FL	4.2	4.9	4.1	4.4
Las Vegas, NM	3.8	4.7	3.9	4.1
West Palm Beach, FL	4.0	4.1	3.8	4.0

NOTE: High population density is defined as ≥2,000 persons per square mile; high population is defined as 500,000-1,000,000 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-3. ITSA Values for Urban Areas with Low Population Density and High Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
Salt Lake City, UT	6.6	5.4	6.3	6.1
Austin, TX	4.7	6.4	6.1	5.8
Richmond, VA	4.4	6.5	5.0	5.3
Tampa, FL	6.4	4.2	5.3	5.3
Jacksonville, FL	5.3	4.2	5.3	4.9
Nashville, TN	4.3	4.4	4.5	4.4
Springfield, MA	4.3	4.9	4.1	4.4
Oklahoma City, OK	3.9	4.0	3.4	3.8

NOTE: Low population density is defined as <2,000 persons per square mile; high population is defined as 500,000-1,000,000 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-4. ITSA Values for Urban Areas with High Population Density and Medium Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
Spokane, WA	6.9	5.7	7.8	6.8
Syracuse, NY	4.9	7.4	6.2	6.1
Toledo, OH	5.5	5.7	5.8	5.7
Monterey-Salinas, CA	6.7	4.4	5.7	5.6
Fresno, CA	4.7	6.4	5.1	5.4
Bakersfield-Golden, CA	4.9	5.9	4.8	5.2
Stockton, CA	6.4	4.2	4.8	5.1
Lansing, MI	5.4	4.5	4.9	4.9
New Haven, CT	4.7	4.8	5.0	4.8
Worcester, MA	4.6	4.8	4.6	4.7
Wichita, KS	4.5	4.6	4.5	4.5
Wilmington, DE	4.4	4.6	4.5	4.5
Allentown, PA	5.1	3.5	4.3	4.3
Bridgeport, CT	4.4	3.9	4.4	4.2
Youngstown, OH	3.4	4.8	3.9	4.0
Oxnard, CA	3.6	4.6	3.8	4.0

NOTE: High population density is defined as $\geq$2,000 persons per square mile; medium population is defined as 250,000-499,999 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-5. ITSA Values for Urban Areas with Low Population Density and Medium Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
Charlotte, NC	5.7	6.0	6.5	6.1
Corpus Christ, TX	7.3	4.6	6.0	5.9
Shreveport, LA	5.6	5.0	6.2	5.6
Harrisburg, PA	4.0	7.0	4.9	5.3
Columbia, SC	4.1	6.1	5.7	5.3
Colorado Springs, CO	5.6	4.7	5.5	5.3
Chattanooga, TN	4.6	4.7	6.5	5.3
Charleston, SC	3.3	7.6	4.7	5.2
Grand Rapids, MI	4.5	5.5	5.4	5.1
Little Rock, AR	5.3	4.6	5.1	5.0
Knoxville, TN	5.5	4.3	5.3	5.0
Tulsa, OK	5.1	4.7	5.2	5.0
Baton Rouge, LA	5.4	4.5	5.1	5.0
Raleigh, NC	5.3	4.7	4.9	5.0
Des Moines, IA	5.8	4.4	4.7	5.0
Mobile, AL	4.8	4.5	4.5	4.6
Scranton, PA	6.0	3.7	4.0	4.6
Augusta, GA	3.7	5.1	3.9	4.2
Jackson, MS	5.2	3.7	3.4	4.1
Jackson, MI	3.1	4.5	2.6	3.4

NOTE: Low population density is defined as <2,000 persons per square mile; medium population is defined as 250,000-499,999 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-6. ITSA Values for Urban Areas with High Population Density and Low Population.

Urban Area	I_{cov} [1]	I_f [2]	I_{cap} [3]	ITSA [4]
Champaign-Urbana, IL	6.4	6.2	8.0	6.9
Madison, WI	4.8	7.0	7.6	6.5
Reno, NV	4.6	6.7	6.6	5.9
Santa Barbara, CA	5.5	6.7	5.6	5.9
New Bedford, MA	5.6	6.4	5.8	5.9
Lafayette, IN	4.7	6.6	6.2	5.8
Reading, PA	7.5	3.9	5.4	5.6
Salem, OR	4.2	6.8	5.6	5.6
Erie, PA	5.6	4.9	5.8	5.4
Gainesville, FL	5.5	4.5	6.0	5.4
Elgin, IL	6.1	4.3	5.2	5.2
Ypsilanti-Ann Arbor, MI	5.5	5.1	4.9	5.2
Brownsville, TX	7.6	3.6	4.2	5.2
Laredo, TX	5.7	4.7	4.9	5.1
Lincoln, NE	6.0	4.3	4.8	5.0
Brockton, MA	4.2	5.9	4.9	5.0
Springfield, IL	5.1	4.6	5.3	5.0
Norwalk, CT	4.1	5.6	5.2	5.0
Modesto, Ca	5.0	5.2	4.5	4.9
Lancaster, PA	5.1	4.3	5.0	4.8
Sioux Falls, SD	6.5	3.5	4.2	4.8
Appleton, WI	4.1	5.4	4.7	4.7
Manchester, NH	5.4	3.9	4.6	4.6
Saginaw, MI	4.1	4.9	4.7	4.6
Lexington-Fayette, KY	3.9	5.4	4.4	4.6
Fort Wayne, IN	4.8	4.4	4.6	4.6
Santa Rosa, CA	3.9	5.4	4.3	4.5
Canton, OH	3.7	5.2	4.3	4.4
Evansville, IN	4.5	4.4	4.1	4.3
Boise, ID	4.6	4.0	4.2	4.3
Pueblo, CO	4.0	4.5	4.2	4.2
Lowell, MA	4.3	4.3	4.0	4.2
York, PA	4.2	4.4	3.8	4.1
Fargo, ND	4.2	4.0	3.7	4.0
Simi Valley, CA	3.9	4.2	3.7	4.0

NOTE: Low population density is defined as $\geq$2,000 persons per square mile; low population is defined as 100,000-249,999 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-7. ITSA Values for Urban Areas with Low Population Density and Low Population.

Urban Area	I_{cov} [1]	I_f [2]	I_{cap} [3]	ITSA [4]
Santa Cruz, Ca	9.0	6.1	7.8	7.6
Richland, WA	6.3	5.4	8.3	6.7
Charleston, WV	6.9	5.9	6.5	6.4
Duluth, MN	4.8	6.8	6.6	6.1
Cedar Rapids, IA	4.5	8.1	5.5	6.0
Tallahassee, FL	5.7	5.7	6.3	5.9
Savannah, GA	5.0	6.3	5.9	5.7
Anchorage, AK	6.0	4.8	6.4	5.7
Green Bay, WI	4.8	6.2	5.9	5.6
South Bend, IN	5.3	5.7	5.4	5.5
Springfield, MO	5.6	5.3	5.0	5.3
Kalamazoo, MI	5.6	5.1	5.1	5.3
Peoria, IL	5.9	4.5	5.1	5.2
Winston-Salem, NC	5.0	5.4	5.0	5.1
Topeka, KS	5.7	4.6	4.9	5.1
Roanoke, VA	5.7	4.6	4.9	5.1
Greenville, SC	3.9	6.9	4.4	5.1
Lubbock, TX	4.5	5.8	4.8	5.0
Portland, ME	4.8	5.3	4.8	5.0
Columbus, GA	4.9	4.9	4.8	4.9
Monroe, LA	5.2	4.5	4.9	4.8
Lakeland, Fl	5.0	4.8	4.7	4.8
Amarillo, TX	4.4	5.8	4.3	4.8
Montgomery, Al	4.3	5.0	5.1	4.8
Asheville, NC	5.1	4.3	4.8	4.8
Muskegon, MI	6.3	3.4	4.5	4.7
Lafayette, LA	4.5	4.9	4.5	4.6
Fort Collins, CO	5.1	4.3	4.4	4.6
Beaumont, TX	4.1	5.1	4.5	4.6
Huntington, WV	5.5	3.8	4.2	4.5
Wilmington, NC	4.2	4.7	4.6	4.5
High Point, NC	4.4	4.3	4.6	4.4
Petersburg, VA	4.3	4.5	4.3	4.3
Abilene, TX	3.9	4.8	4.2	4.3
Fayetteville, NC	4.0	4.6	4.0	4.2
Tuscaloosa, AL	4.9	3.3	4.1	4.1
Poughkeepsie, NY	3.8	4.5	4.0	4.1
Port Arthur, TX	4.4	3.7	4.0	4.0
Lake Charles, LA	3.9	3.9	4.0	4.0
Waco, TX	4.0	3.8	4.0	3.9
Gastonia, NC	4.0	3.7	3.9	3.9

NOTE: Low population density is defined as <2,000 persons per square mile; low population is defined as 100,000-249,999 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-8. ITSA Values for Urban Areas with High Population Density and Very Low Population.

Urban Area	I_{cov} [1]	I_f [2]	I_{cap} [3]	ITSA [4]
Medford, OR	6.8	4.5	7.8	6.4
Sheboygan, WI	4.3	7.7	6.7	6.2
Oshkosh, WI	4.2	7.1	6.2	5.9
Williamsport, PA	6.2	4.5	5.9	5.5
La Crosse, Wi	3.9	6.6	5.4	5.3
Bloomington, IN	6.3	4.6	4.8	5.2
Muncie, IN	4.5	5.7	5.4	5.2
St. Cloud, MN	4.8	5.3	5.2	5.1
Dubuque, IA	7.0	3.6	4.7	5.1
Bloomington-Normal, IL	5.2	4.9	5.0	5.0
Janesville, WI	6.1	3.9	5.0	5.0
Wheeling, WV	4.7	5.1	5.1	5.0
Missoula, MT	5.7	4.4	4.7	4.9
Kenosha, WI	4.7	4.8	5.0	4.8
Grand Forks, ND	5.2	4.4	4.7	4.7
Great Falls, MT	5.2	4.7	4.3	4.7
Charlottesville, NC	4.9	4.6	4.7	4.7
Yakima, WA	4.3	4.9	4.6	4.6
Owensboro, KY	3.9	5.4	4.1	4.4
Greeley, CO	4.8	4.3	4.0	4.4
Visalia, CA	4.0	4.6	3.7	4.1
Merced, CA	3.3	4.5	3.2	3.7

NOTE: High population density is defined as $\geq$2,000 persons per square mile; very low population is defined as <100,000 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

Table B-9. ITSA Values for Urban Areas with Low Population Density and Very Low Population.

Urban Area	I_{cov}[1]	I_f[2]	I_{cap}[3]	ITSA[4]
Bellingham, WA	7.6	5.5	8.9	7.3
Rome, GA	9.4	3.2	6.3	6.3
Lynchburg, WA	4.5	7.1	6.3	6.0
Wausau, WI	5.3	5.2	6.6	5.7
Billings, MT	6.1	4.6	6.2	5.6
Annapolis, MD	4.2	8.0	4.5	5.6
Athens, GA	5.2	5.4	5.8	5.4
Decatur, IL	5.2	5.5	5.5	5.4
Las Cruces, NM	4.2	7.5	4.5	5.4
Sioux City, IA	5.2	4.9	5.9	5.3
Jackson, TN	5.0	5.1	5.8	5.3
Eau Claire, WI	5.0	5.6	5.2	5.3
Battle Creek, MI	4.7	5.9	5.0	5.2
Albany, GA	4.3	6.2	5.0	5.2
Alexandria, LA	4.7	5.4	5.0	5.0
Terre Haute, IN	5.1	5.2	4.7	5.0
St. Joseph, MO	5.5	4.4	5.0	5.0
Beloit, WI	5.2	4.4	5.1	4.9
Bangor, ME	4.6	4.9	4.8	4.8
Pocatello, ID	5.2	4.4	4.5	4.7
Pine Bluff, AR	4.8	4.5	4.7	4.7
Anderson, IN	4.7	4.6	4.5	4.6
Columbia, MO	4.9	4.3	4.6	4.6
Longview, WA	4.9	4.4	4.4	4.6
Glen Falls, NY	5.1	4.0	4.5	4.6
Danville, IL	4.6	4.6	4.5	4.6
Wichita Falls, TX	4.6	4.8	4.3	4.5
Clarksville, TN	4.5	4.8	4.3	4.5
Johnson City, TN	4.4	4.7	4.4	4.5
San Angelo, TX	4.5	4.9	4.0	4.4
Bristol, TN-VA	4.4	4.4	4.1	4.3
Middletown, OH	4.3	4.6	4.0	4.3
Hattiesburg, MS	4.3	4.3	4.0	4.2
Lewiston, ME	4.1	4.2	4.2	4.2
Steubenville, OH	4.8	3.6	3.9	4.1

NOTE: Low population density is defined as <2,000 persons per square mile; very low population is defined as <100,000 persons.

1 $I_{cov} = 5.0 + \left(\frac{X_{cov} - \bar{Y}_{cov}}{S_{cov}}\right)$; where: I_{cov} = the transit service coverage component (route-miles per square mile).

2 $I_f = 5.0 + \left(\frac{X_f - \bar{Y}_f}{S_f}\right)$; where: I_f = the transit service frequency component (vehicle-miles per route-mile).

3 $I_{cap} = 5.0 + \left(\frac{X_{cap} - \bar{Y}_{cap}}{S_{cap}}\right)$; where: I_{cap} = the transit system capacity component (seat-miles per capita).

4 $ITSA = \frac{I_{cov} + I_f + I_{cap}}{3}$; where: ITSA = the index of transit service availability.

APPENDIX C

Approximate Urban Area Boundary Definitions Used for Major Urban Areas

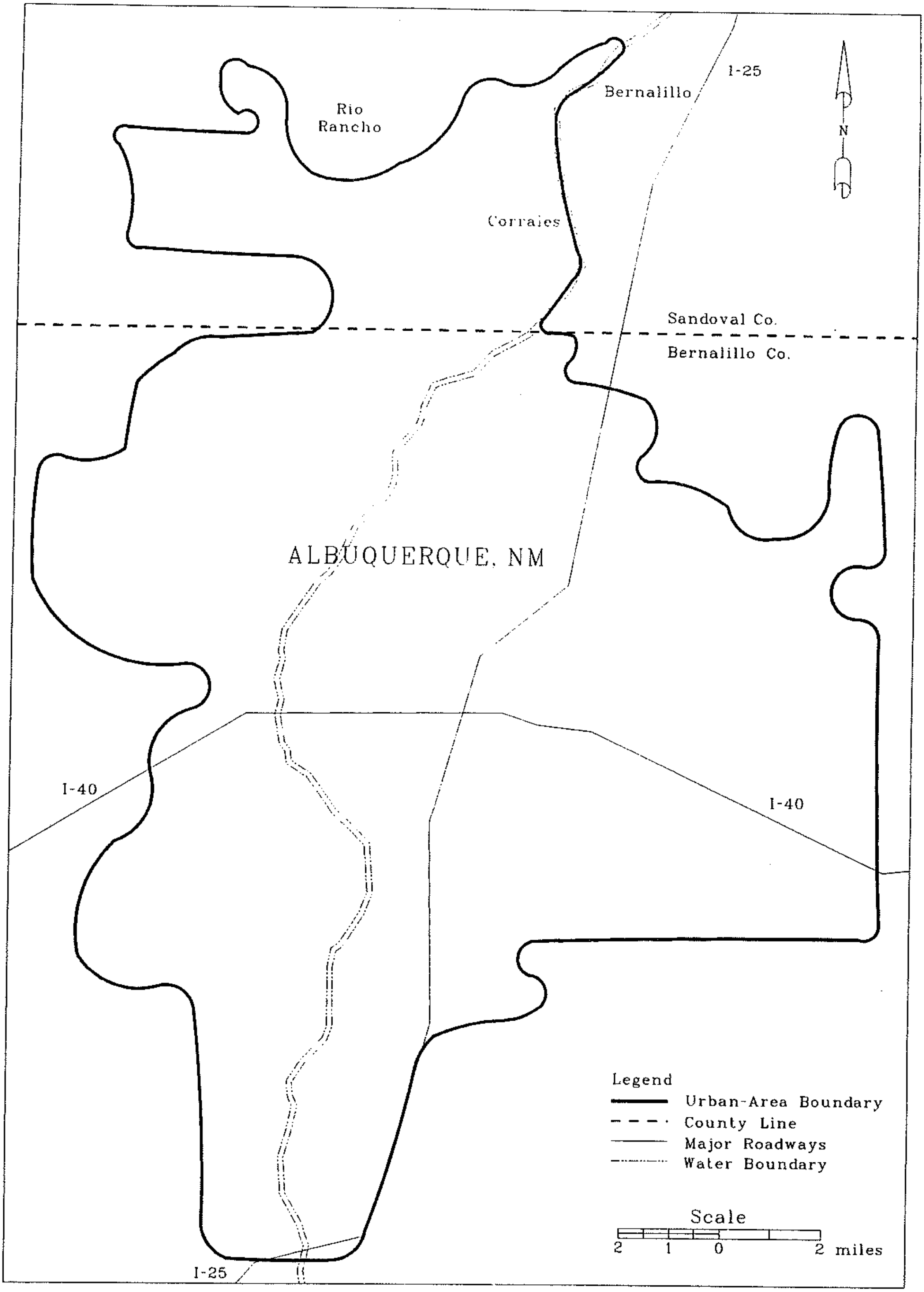

Figure C-1. Approximate Urban-Area Boundary Used for Albuquerque, New Mexico

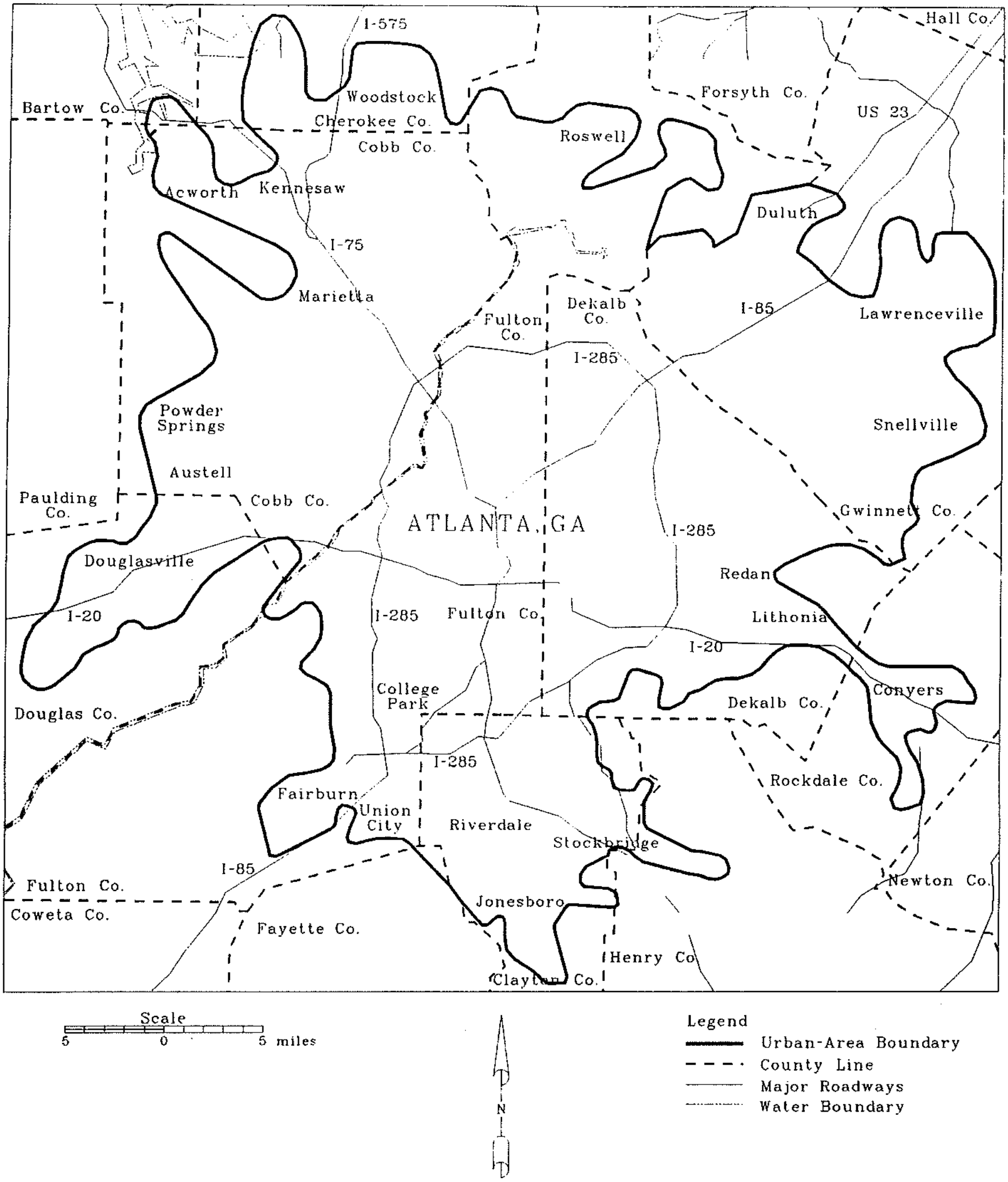

Figure C-2. Approximate Urban-Area Boundary Used for Atlanta, Georgia

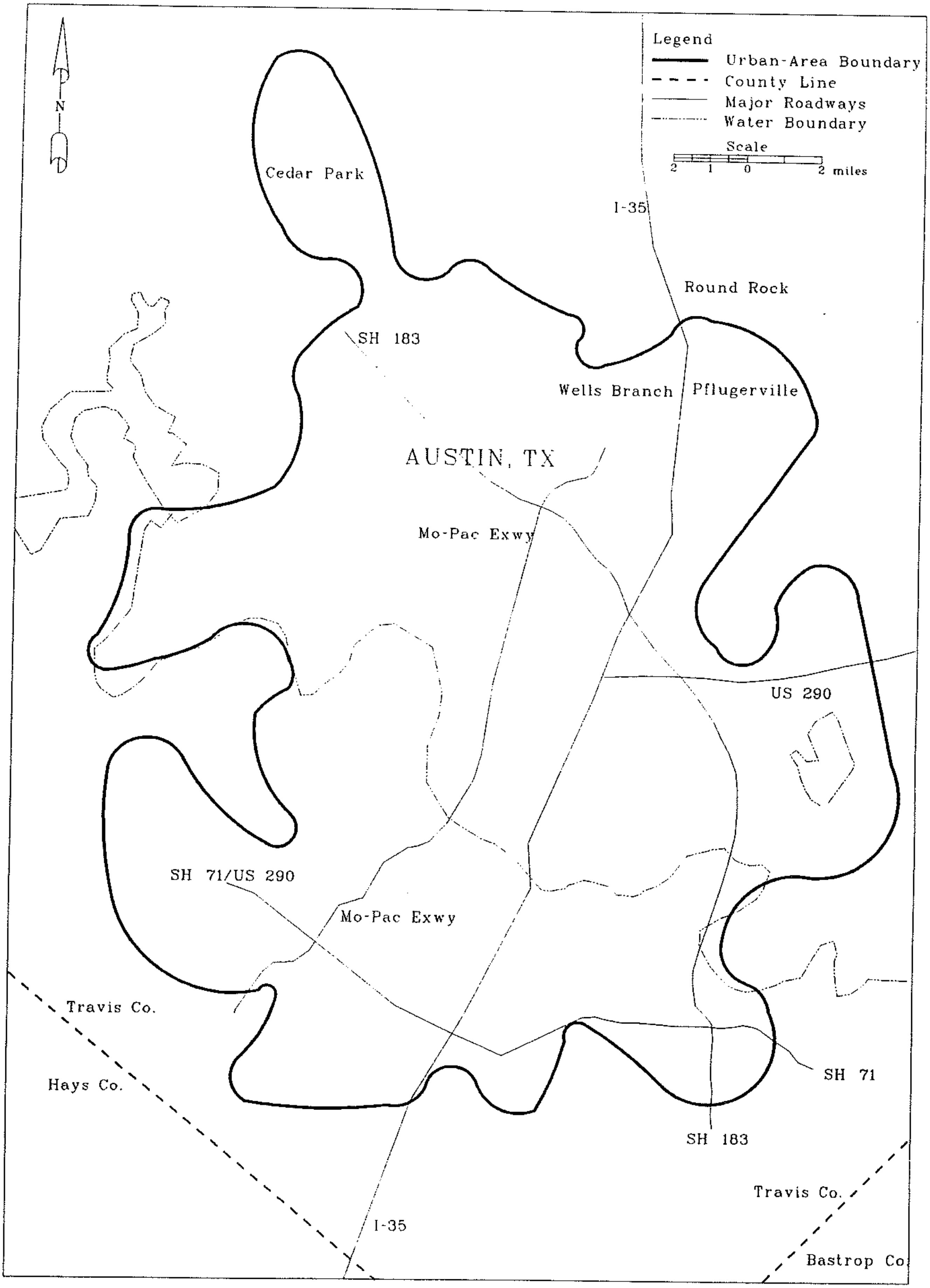

Figure C-3. Approximate Urban-Area Boundary Used for Austin, Texas

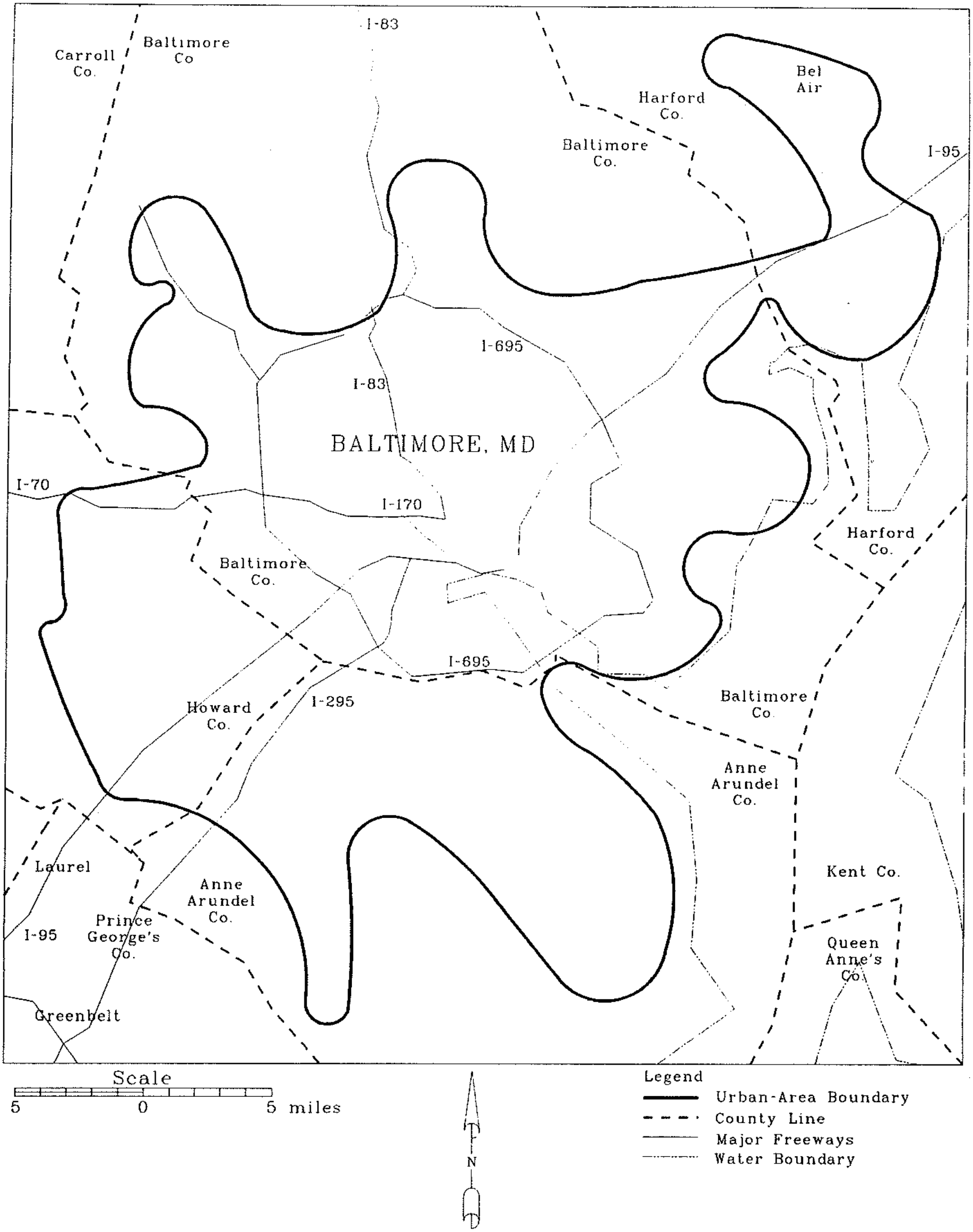

Figure C-4. Approximate Urban-Area Boundary Used for Baltimore, Maryland

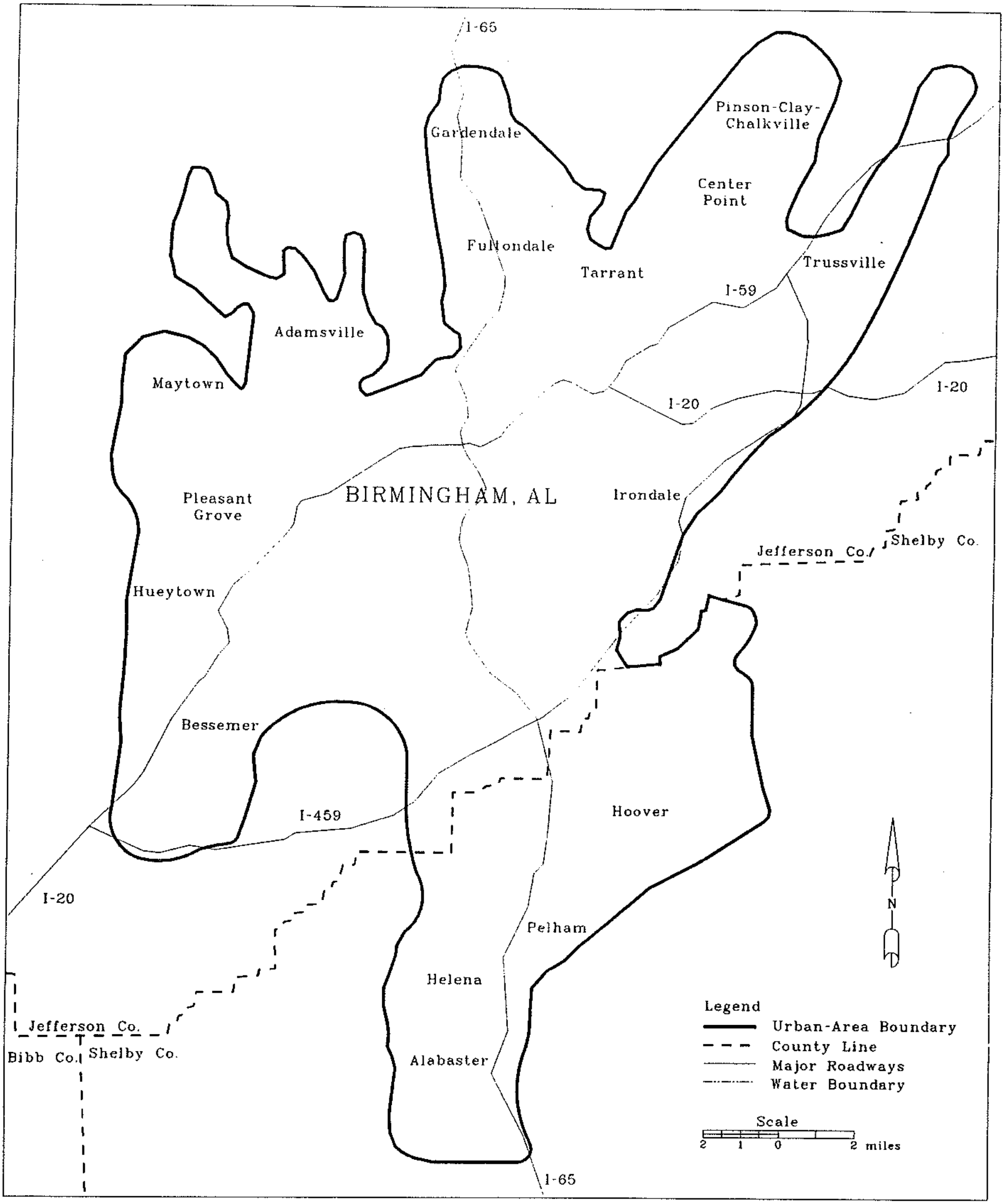

Figure C-5. Approximate Urban-Area Boundary Used for Birmingham, Alabama

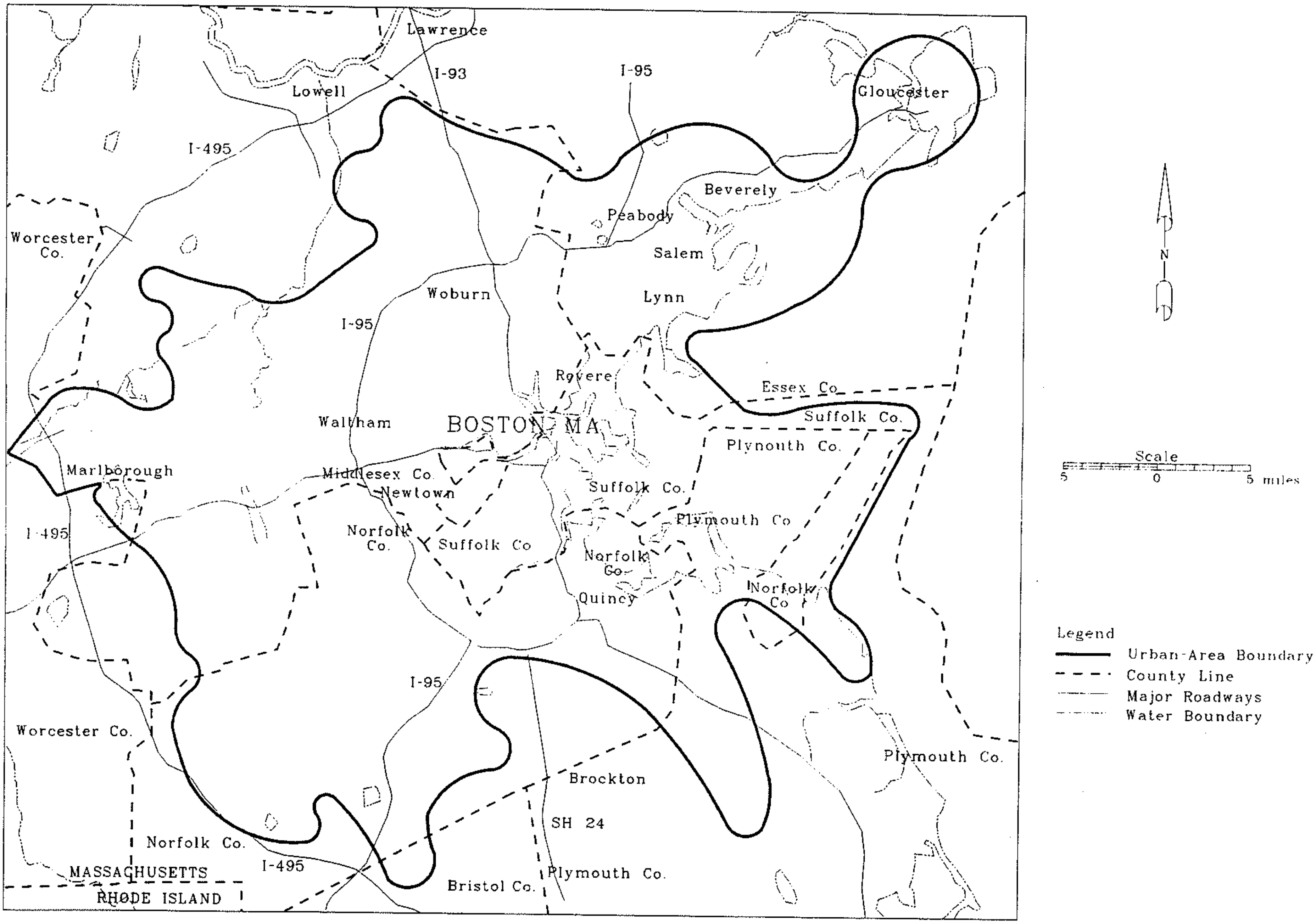

Figure C-6. Approximate Urban-Area Boundary Used for Boston, Massachusetts

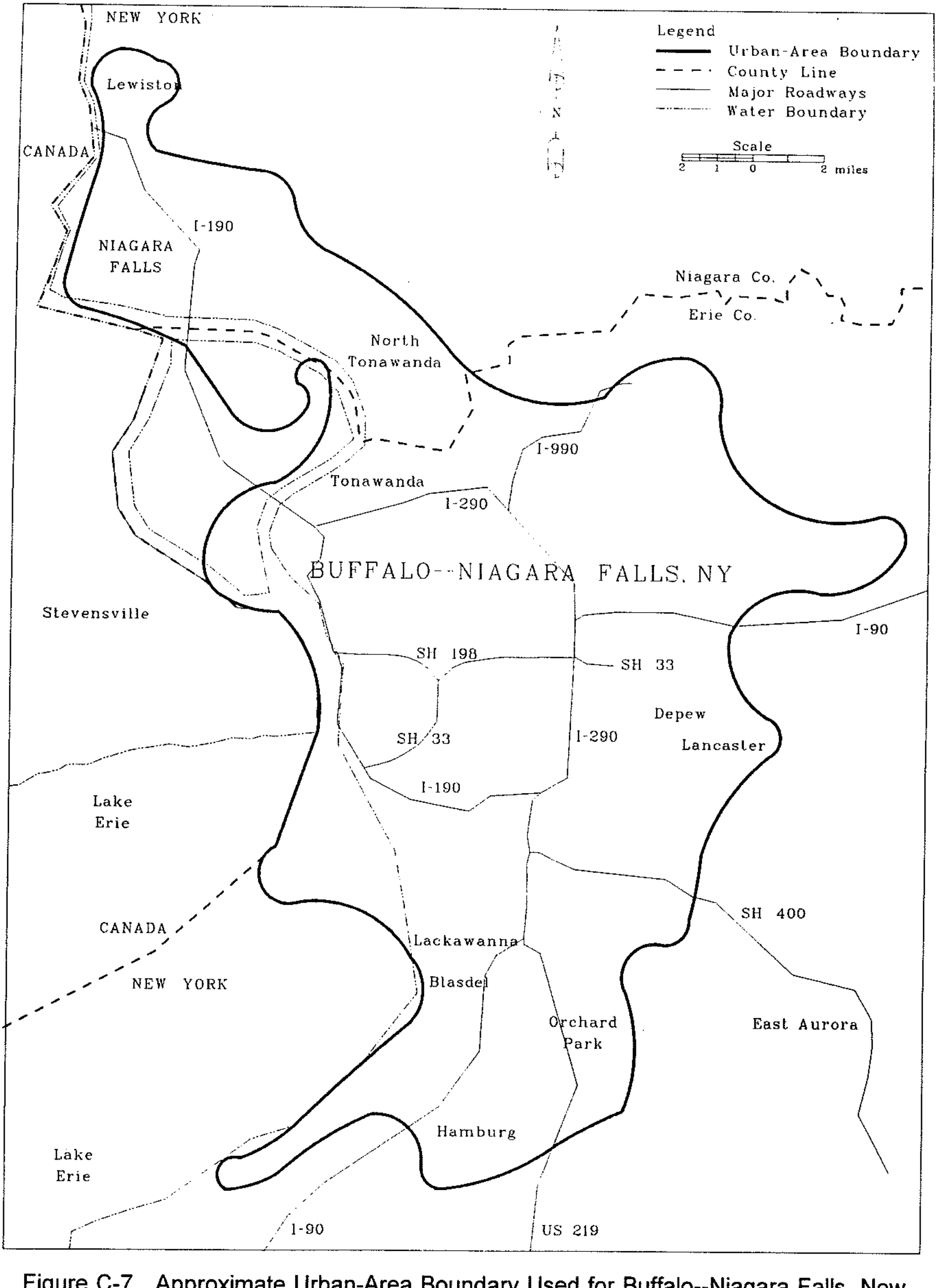

Figure C-7. Approximate Urban-Area Boundary Used for Buffalo--Niagara Falls, New York

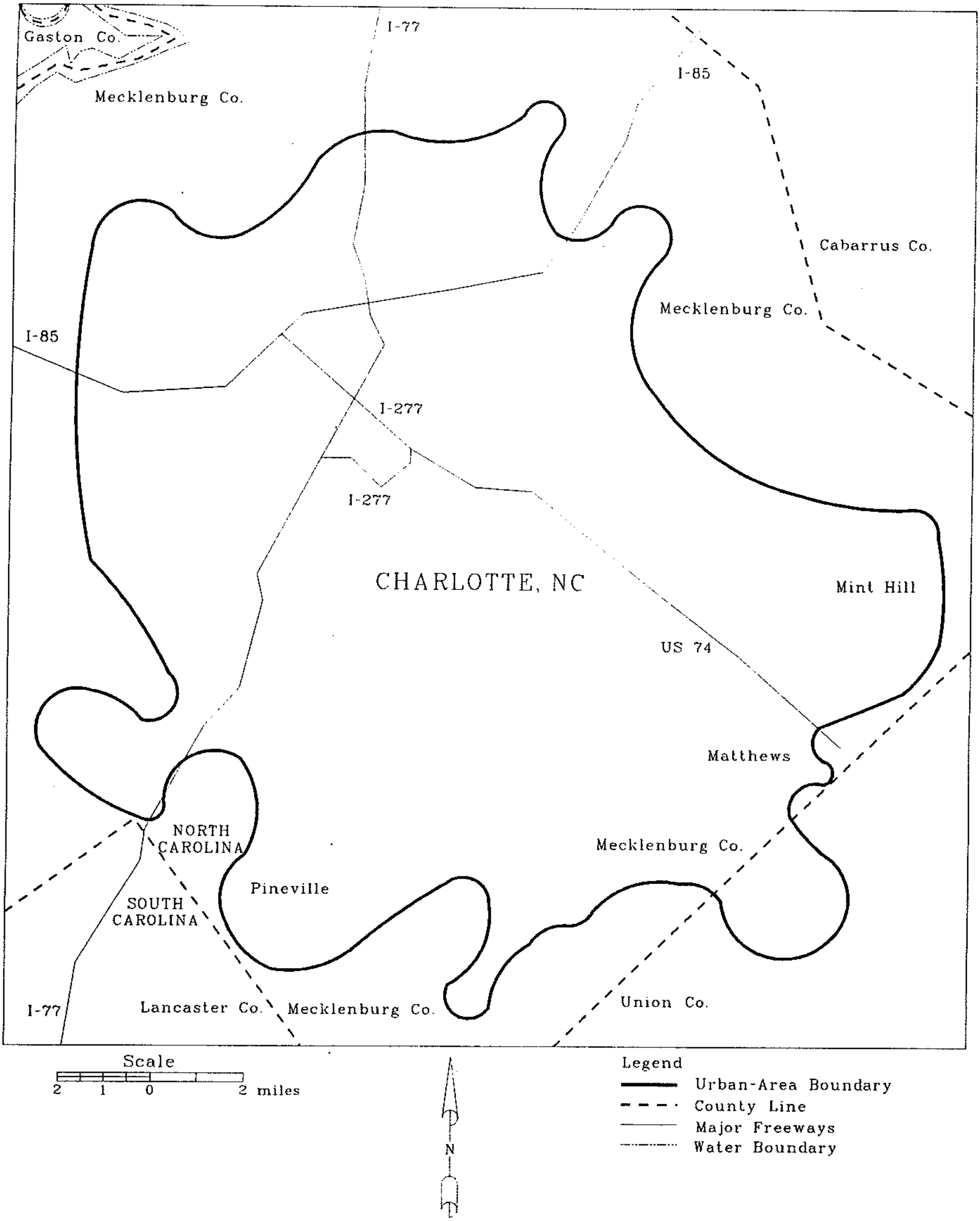

Figure C-8. Approximate Urban-Area Boundary Used for Charlotte North Carolina

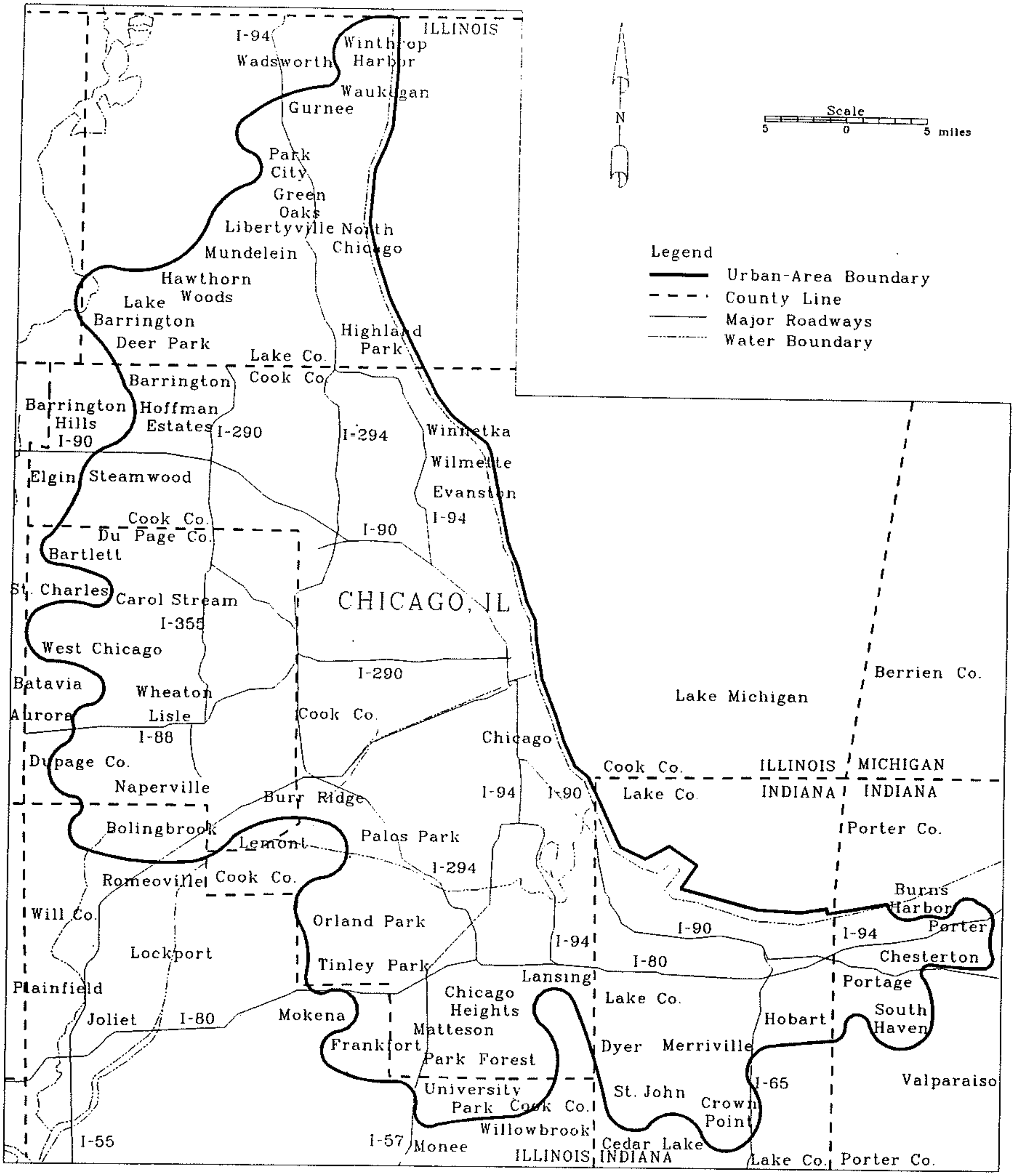

Figure C-9. Approximate Urban-Area Boundary Used for Chicago, Illinois

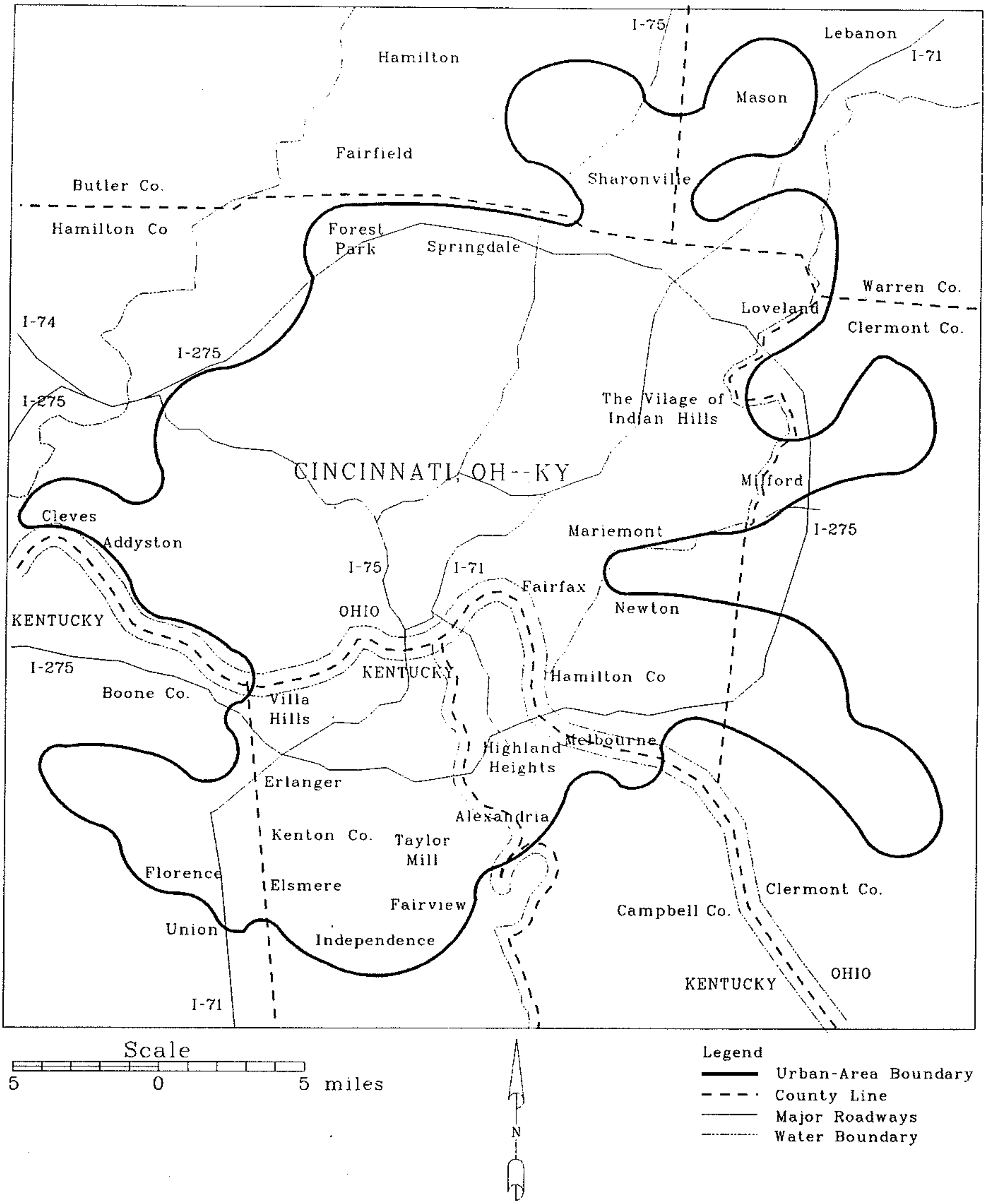

Figure C-10. Approximate Urban-Area Boundary Used for Cincinnati, Ohio--Kentucky

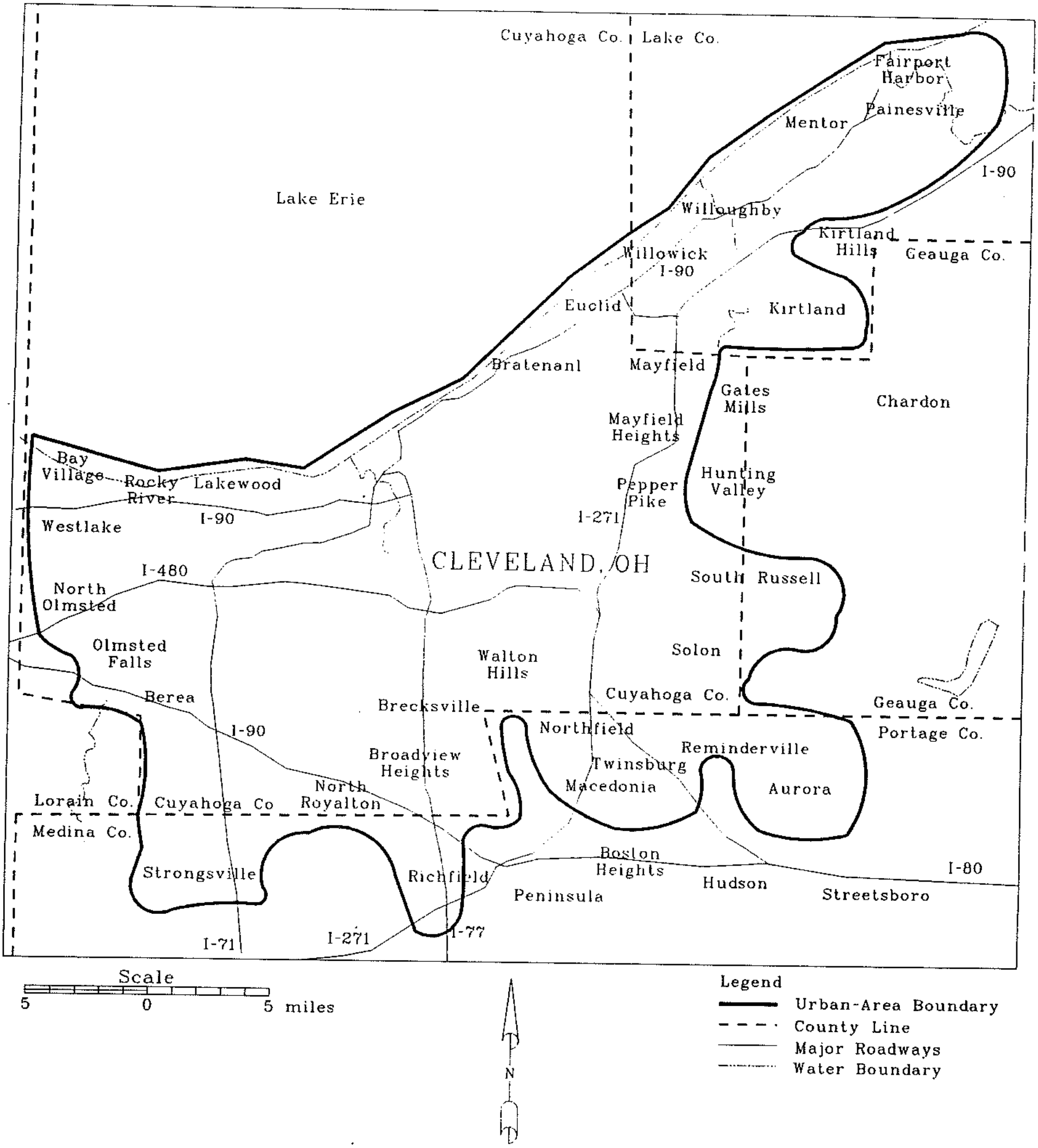

Figure C-11. Approximate Urban-Area Boundary Used for Cleveland, Ohio

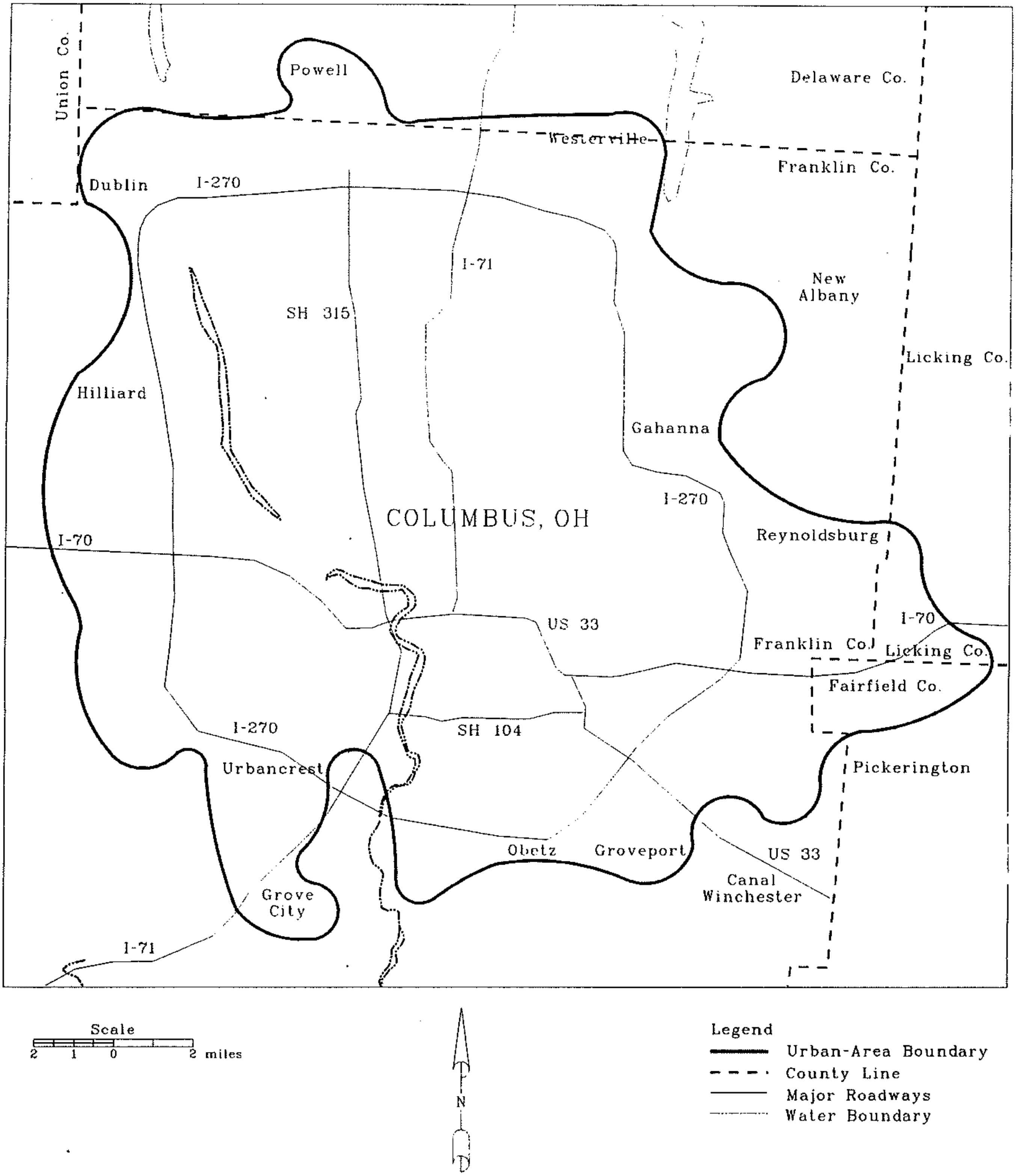

Figure C-12. Approximate Urban-Area Boundary Used for Columbus, Ohio

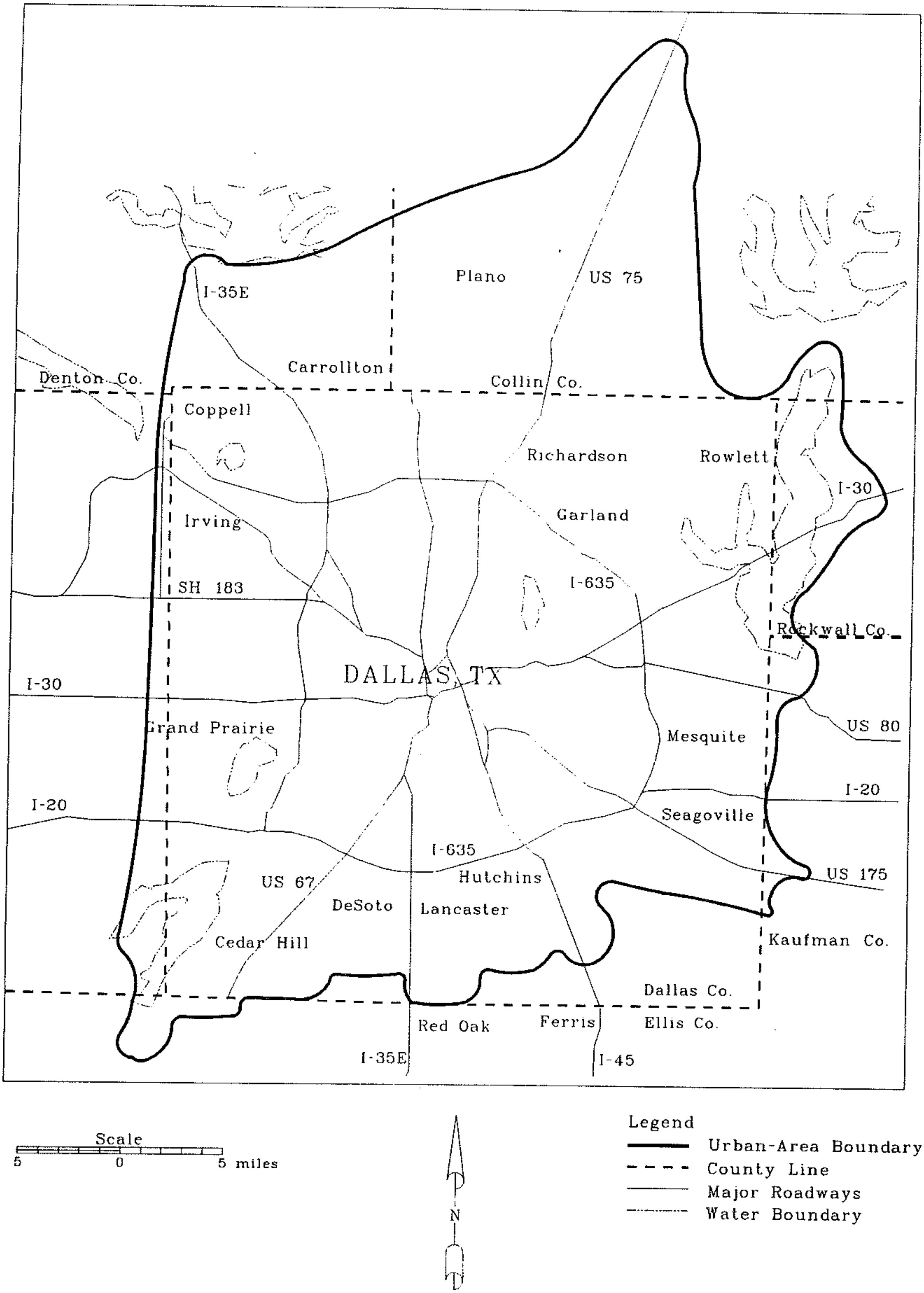

Figure C-13. Approximate Urban-Area Boundary Used for Dallas, Texas

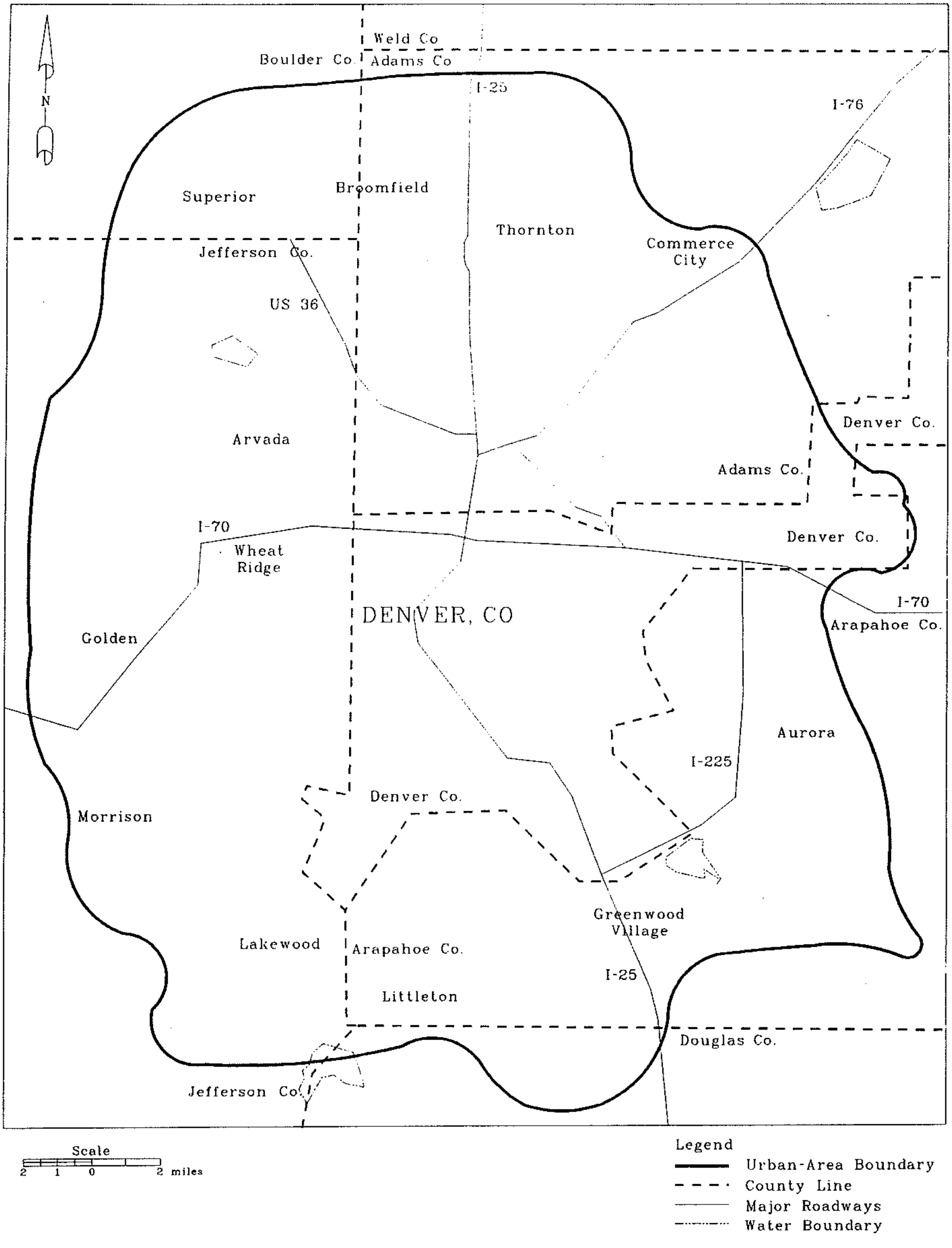

Figure C-14. Approximate Urban-Area Boundary Used for Denver, Colorado

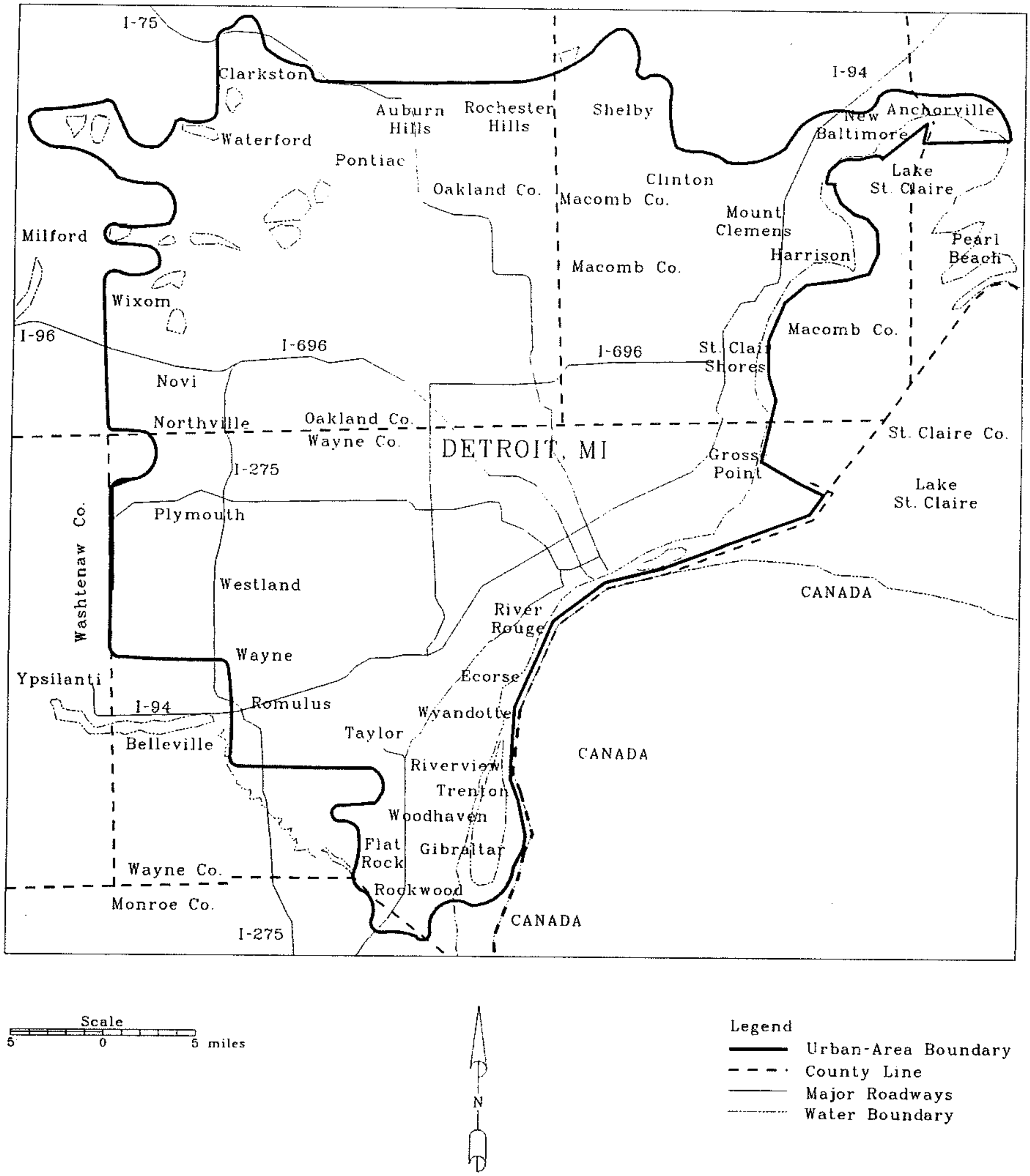

Figure C-15. Approximate Urban-Area Boundary Used for Detroit, Michigan

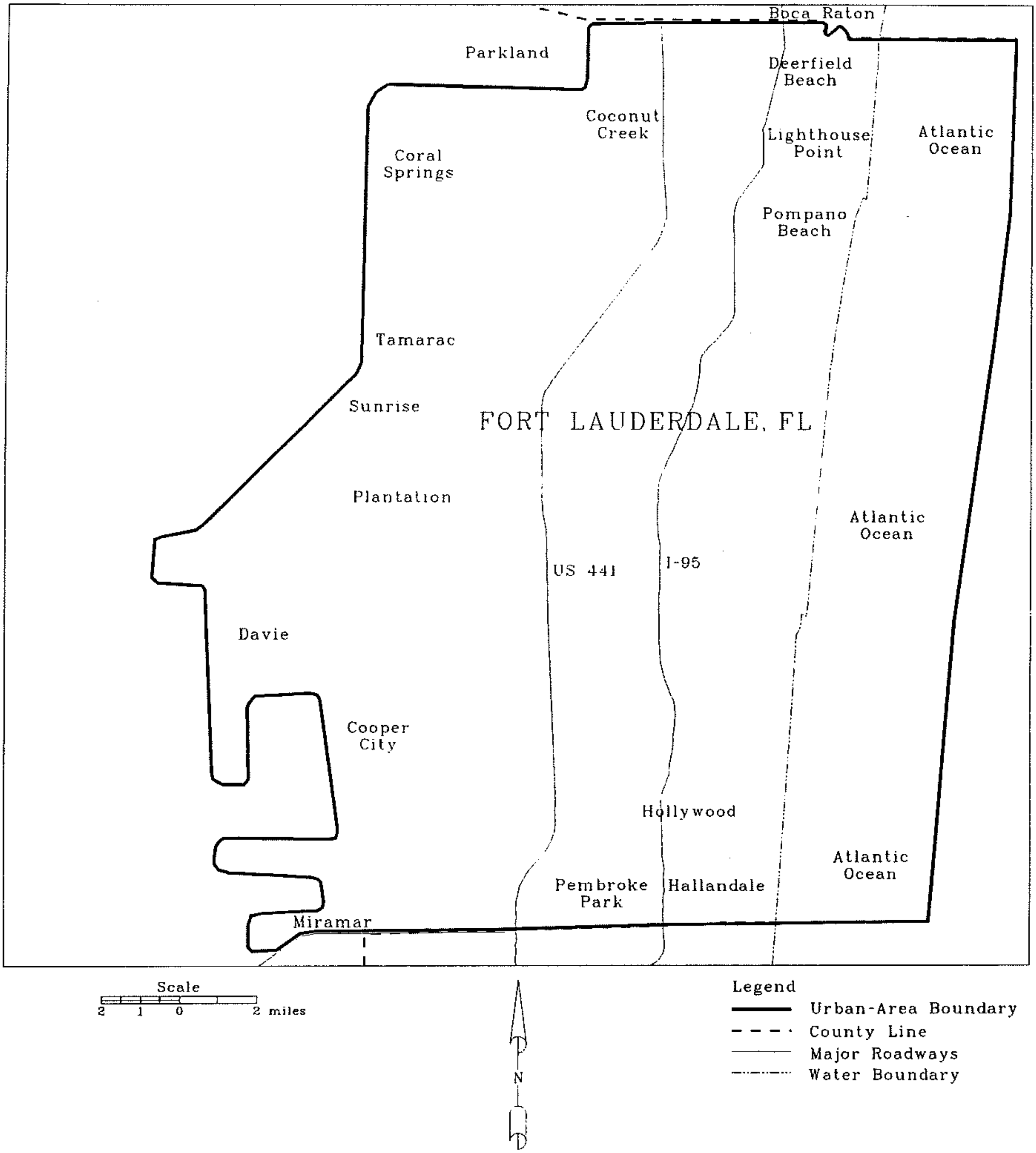

Figure C-16. Approximate Urban-Area Boundary Used for Fort Lauderdale--Hollywood--Pompano Beach, Florida

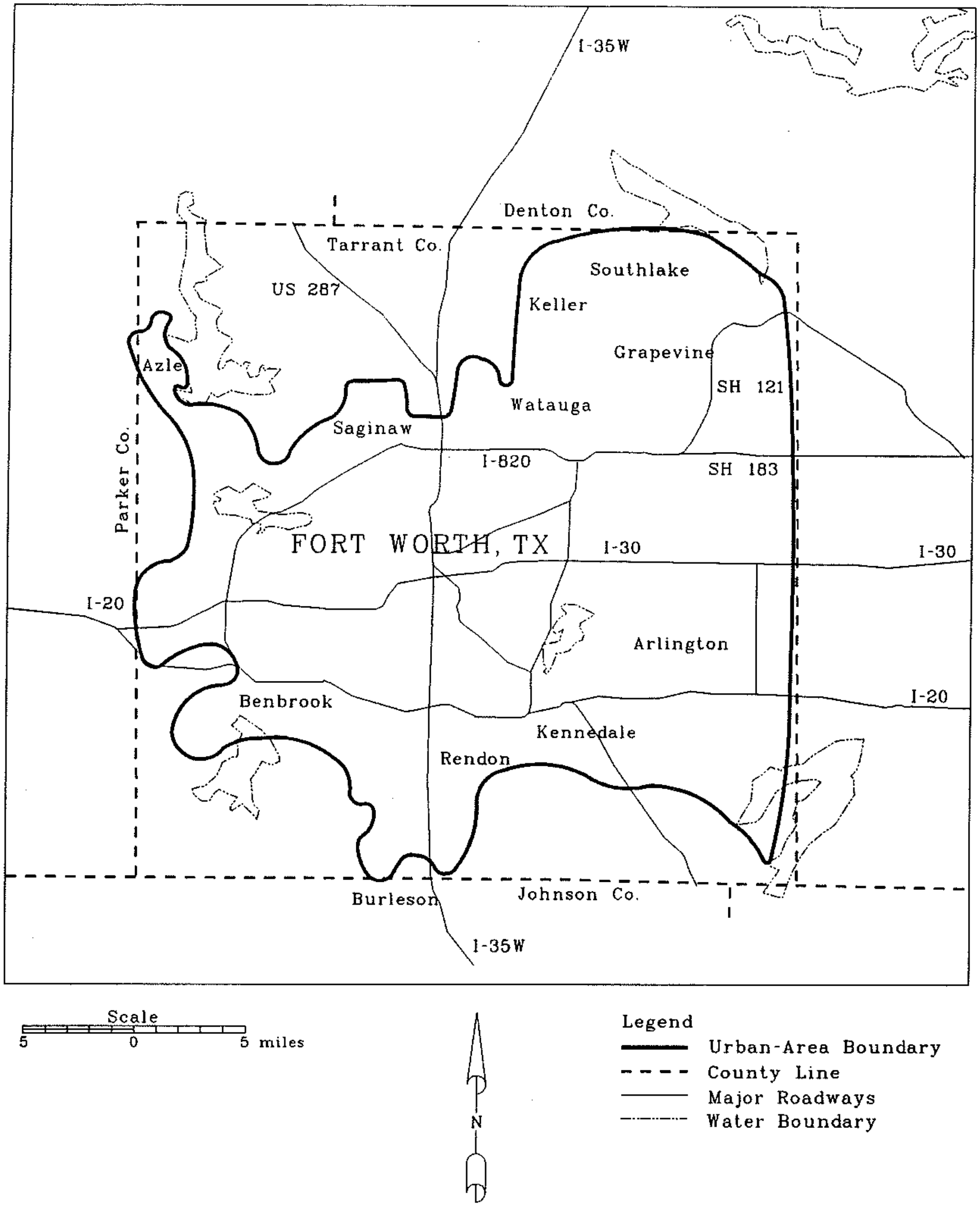

Figure C-17. Approximate Urban-Area Boundary Used for Fort Worth, Texas

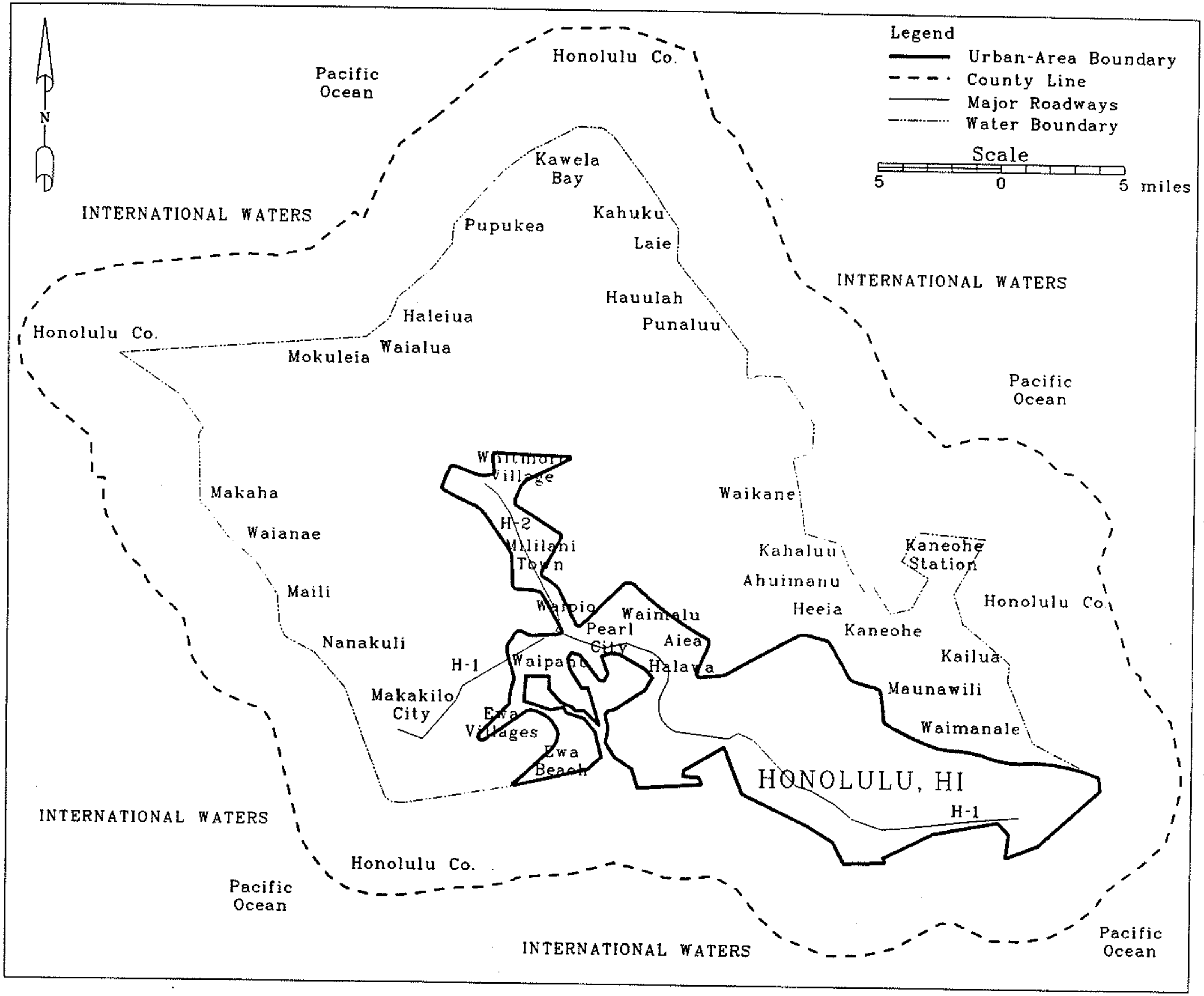

Figure C-18. Approximate Urban-Area Boundary Used for Honolulu, Hawaii

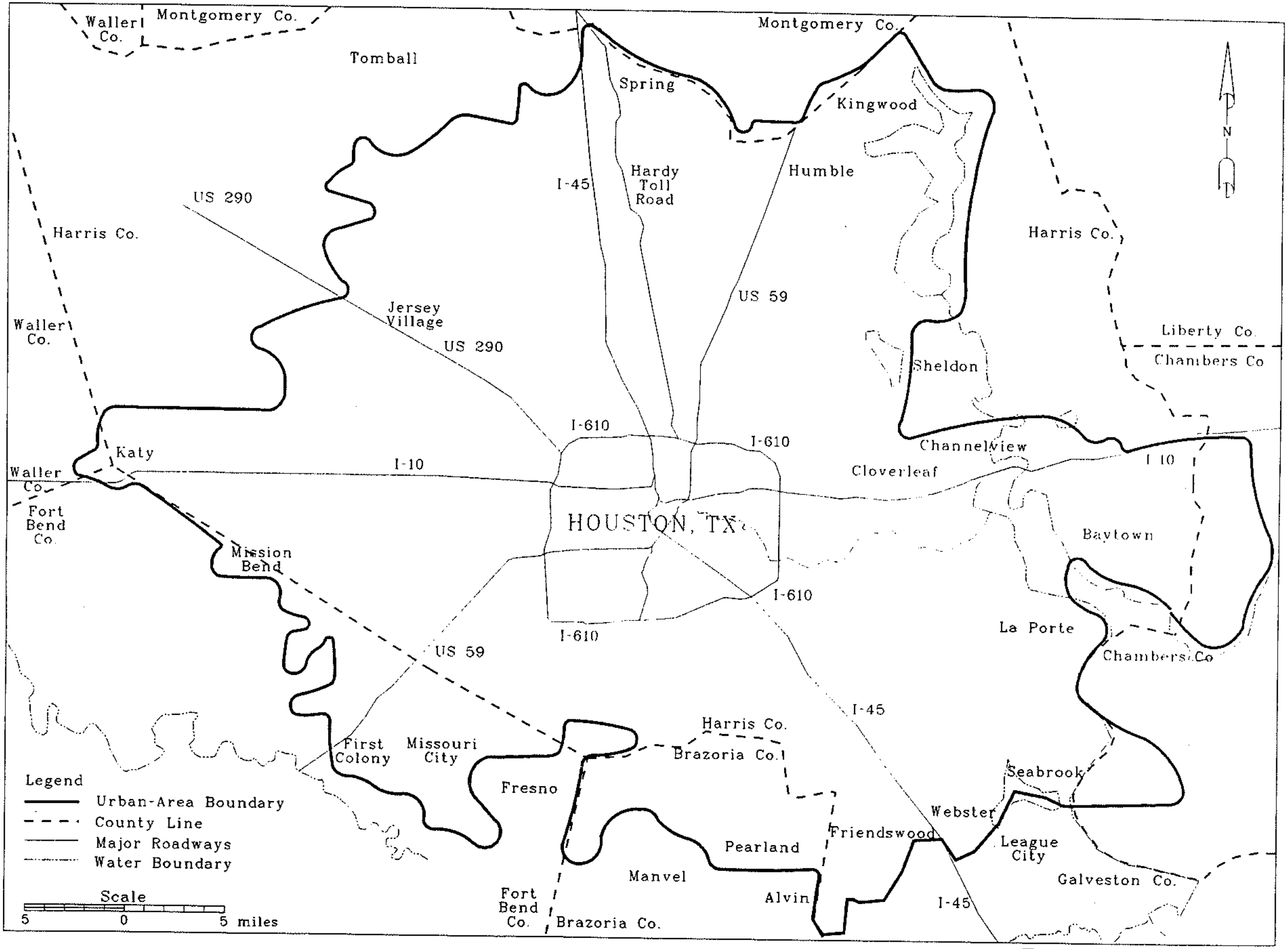

Figure C-19. Approximate Urban-Area Boundary Used for Houston, Texas

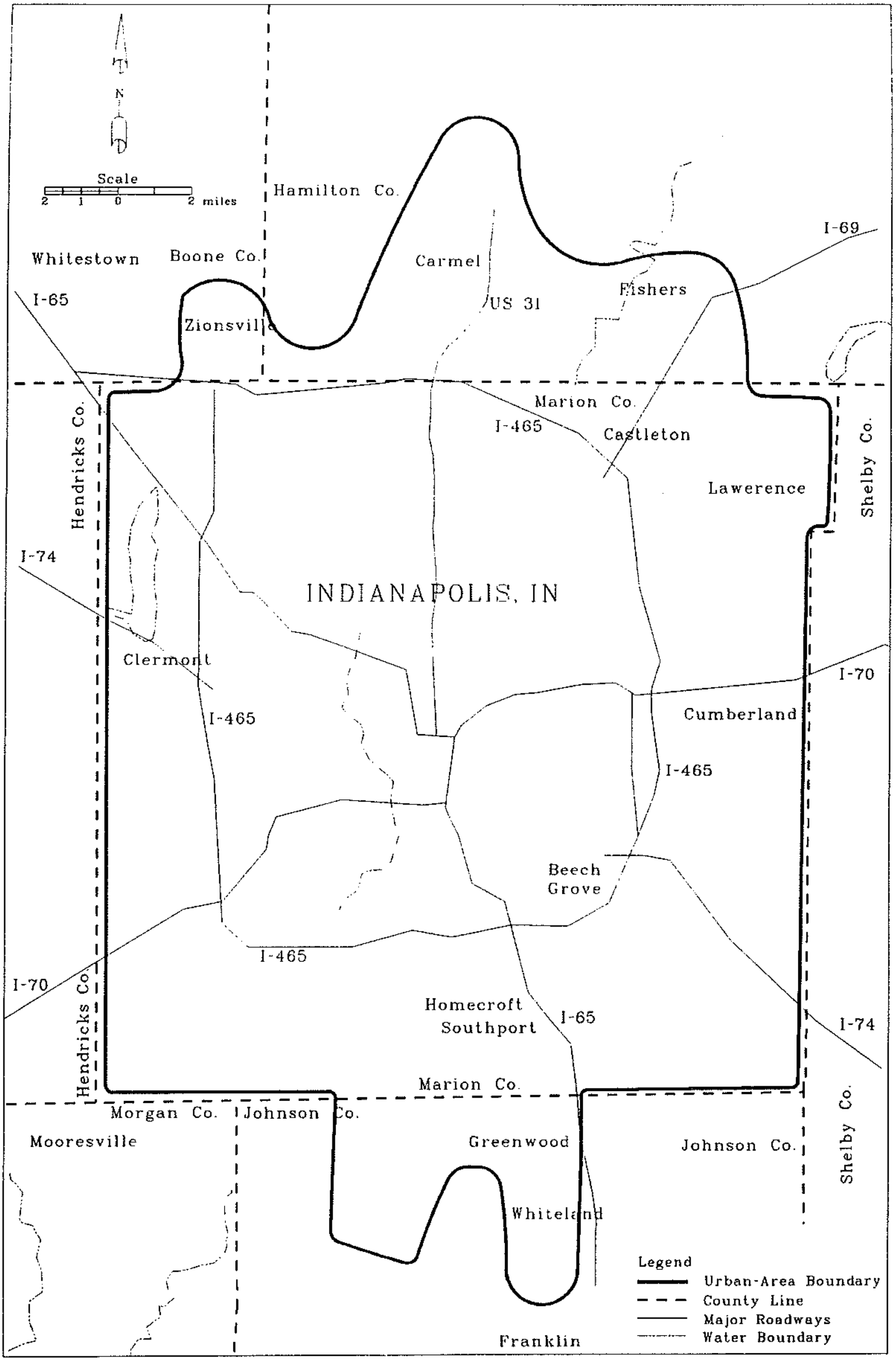

Figure C-20. Approximate Urban-Area Boundary Used for Indianapolis, Indiana

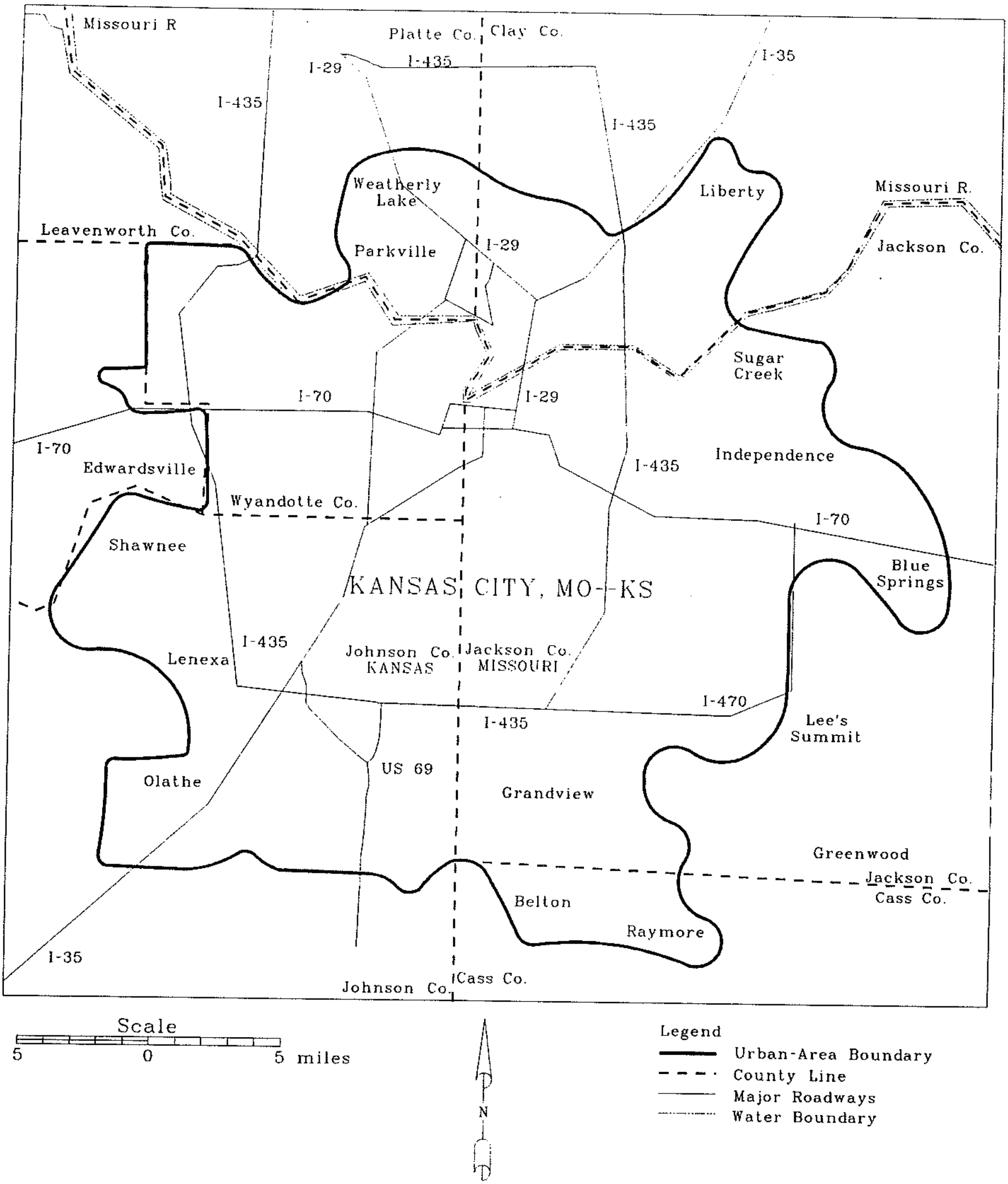

Figure C-21. Approximate Urban-Area Boundary Used for Kansas City, Missouri--Kansas

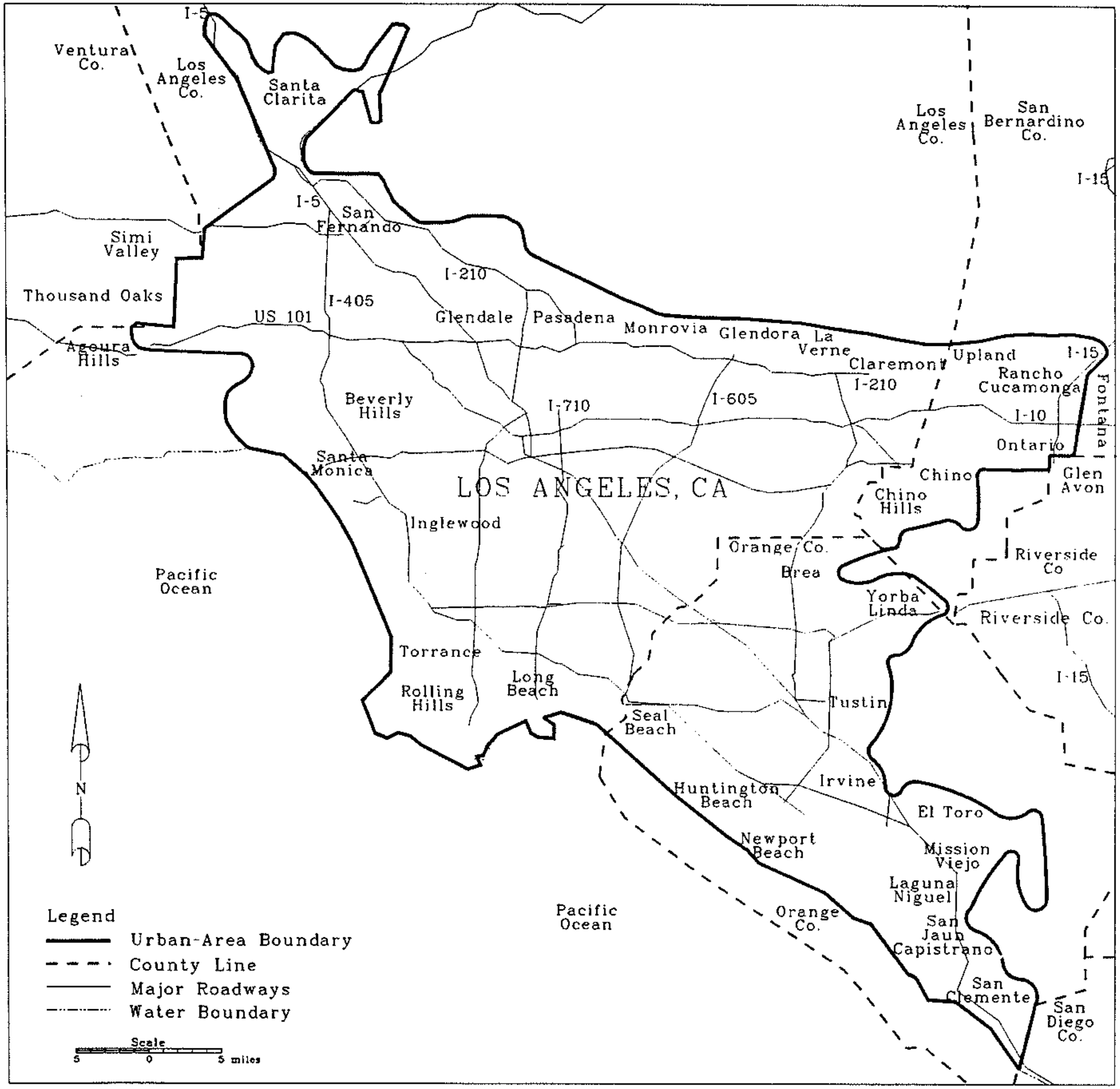

Figure C-22. Approximate Urban-Area Boundary Used for Los Angeles, California

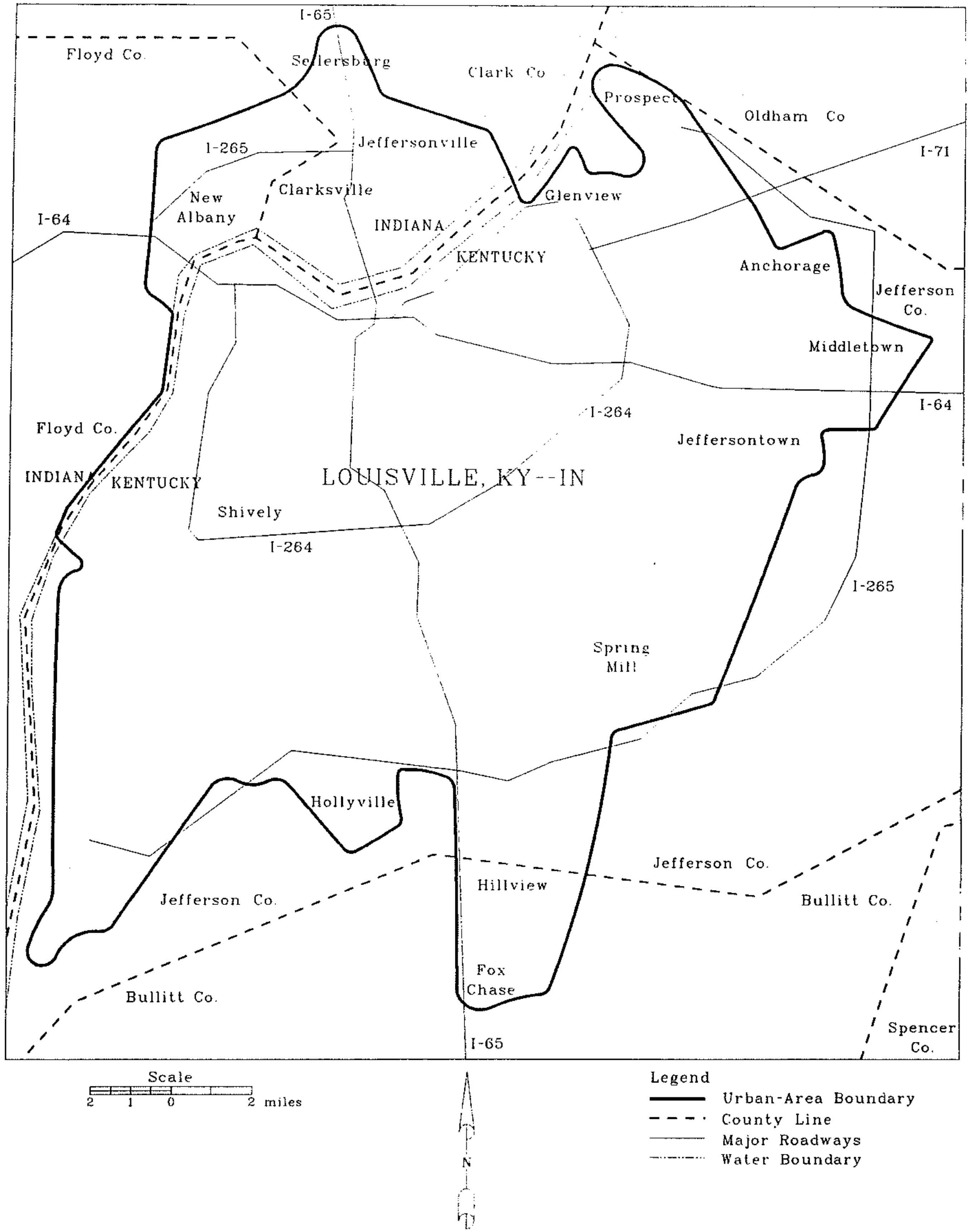

Figure C-23. Approximate Urban-Area Boundary Used for Louisville, Kentucky--Indiana

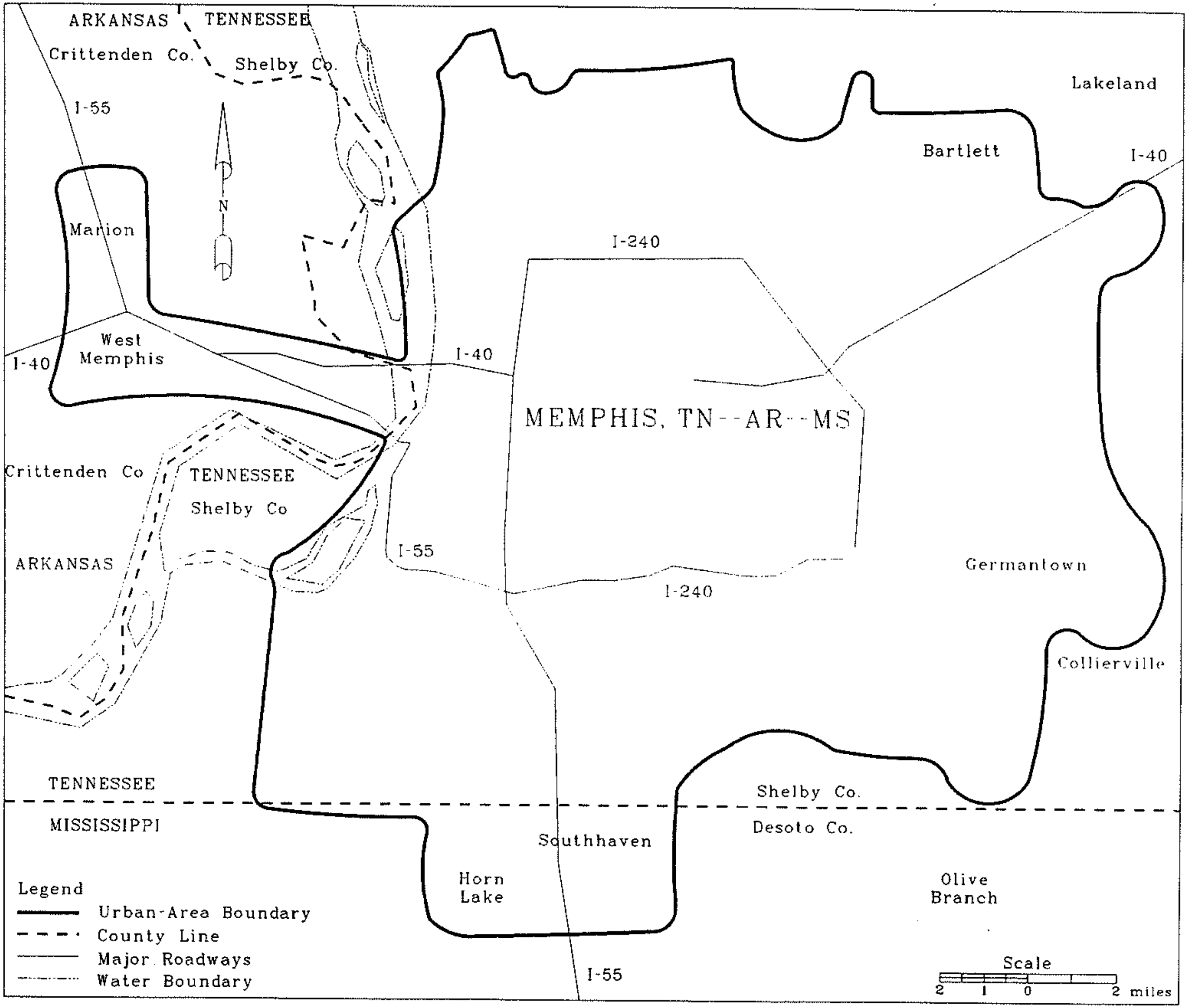

Figure C-24. Approximate Urban-Area Boundary Used for Memphis, Tennessee--Arkansas--Mississippi

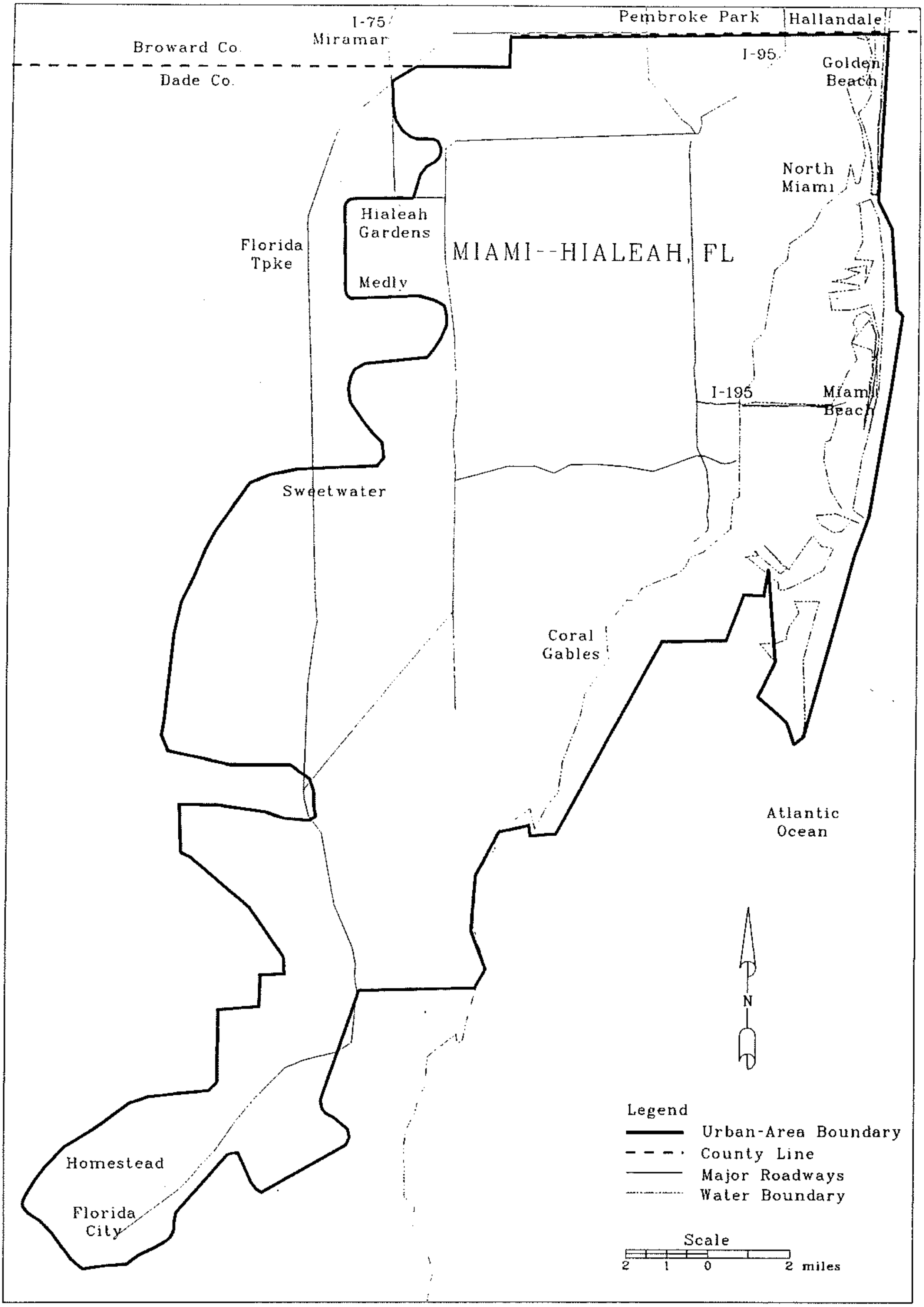

Figure C-25. Approximate Urban-Area Boundary Used for Miami--Hialeah, Florida

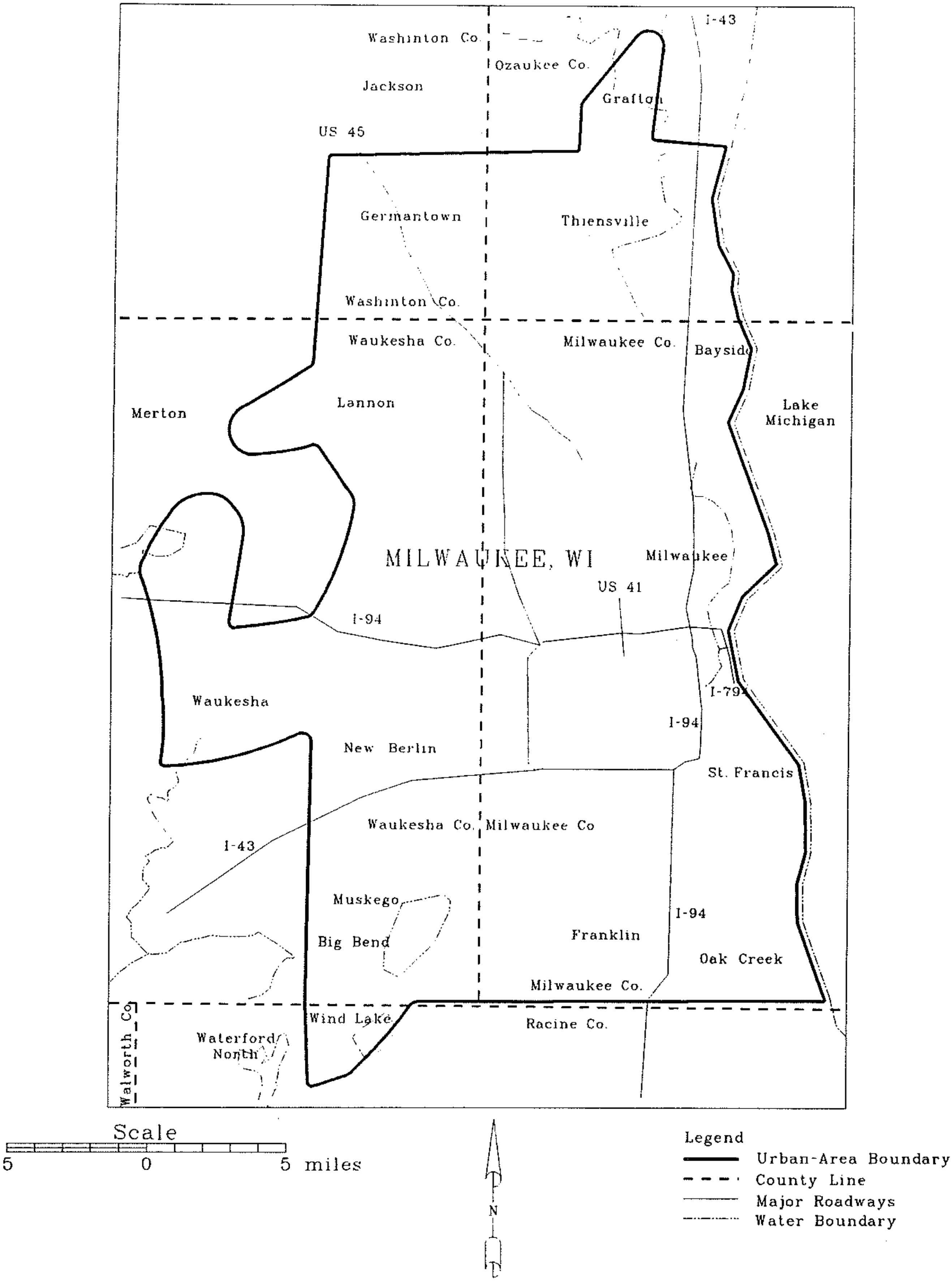

Figure C-26. Approximate Urban-Area Boundary Used for Milwaukee, Wisconsin

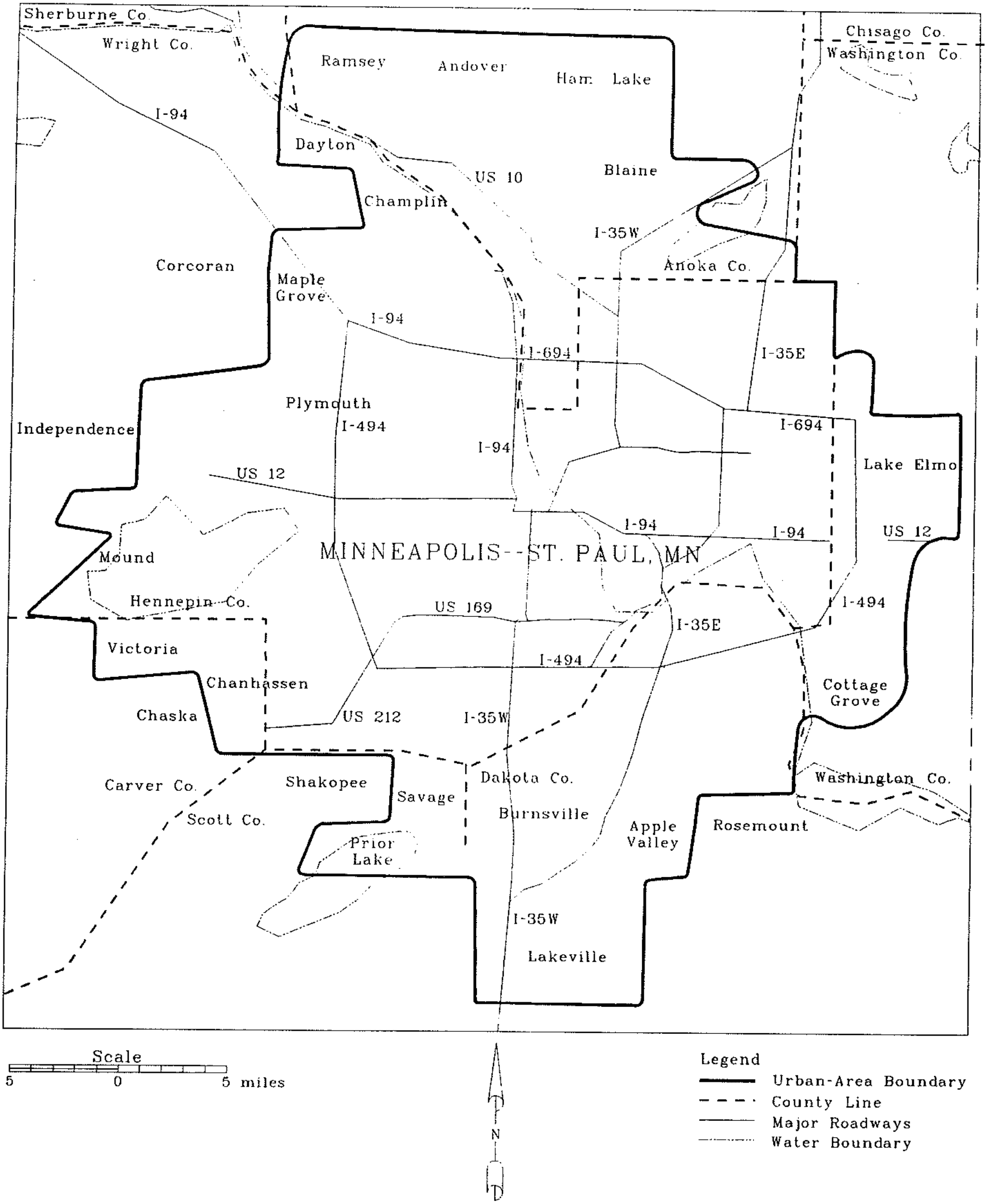

Figure C-27. Approximate Urban-Area Boundary Used for Minneapolis--St. Paul, Minnesota

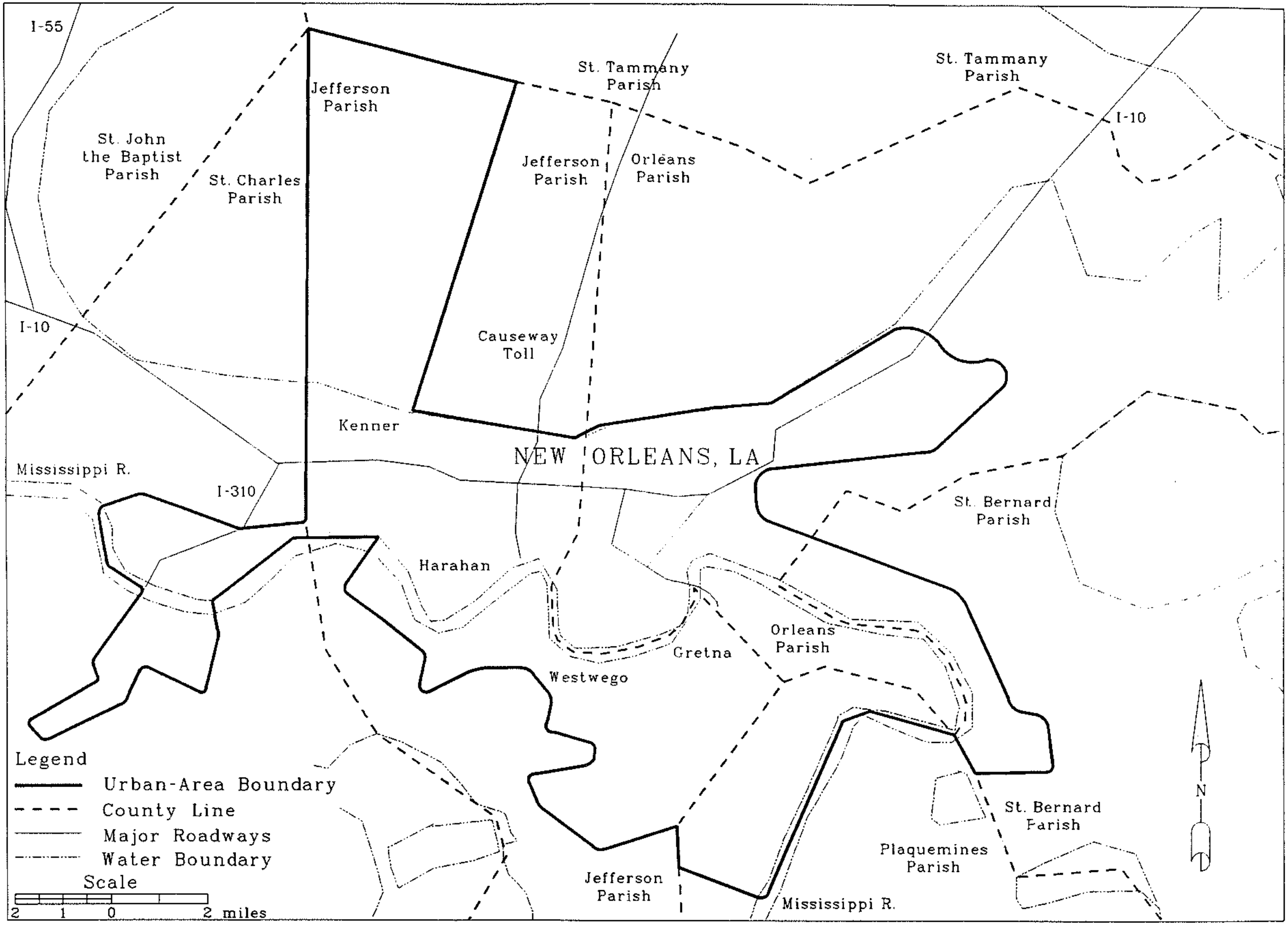

Figure C-28. Approximate Urban-Area Boundary Used for New Orleans, Louisiana

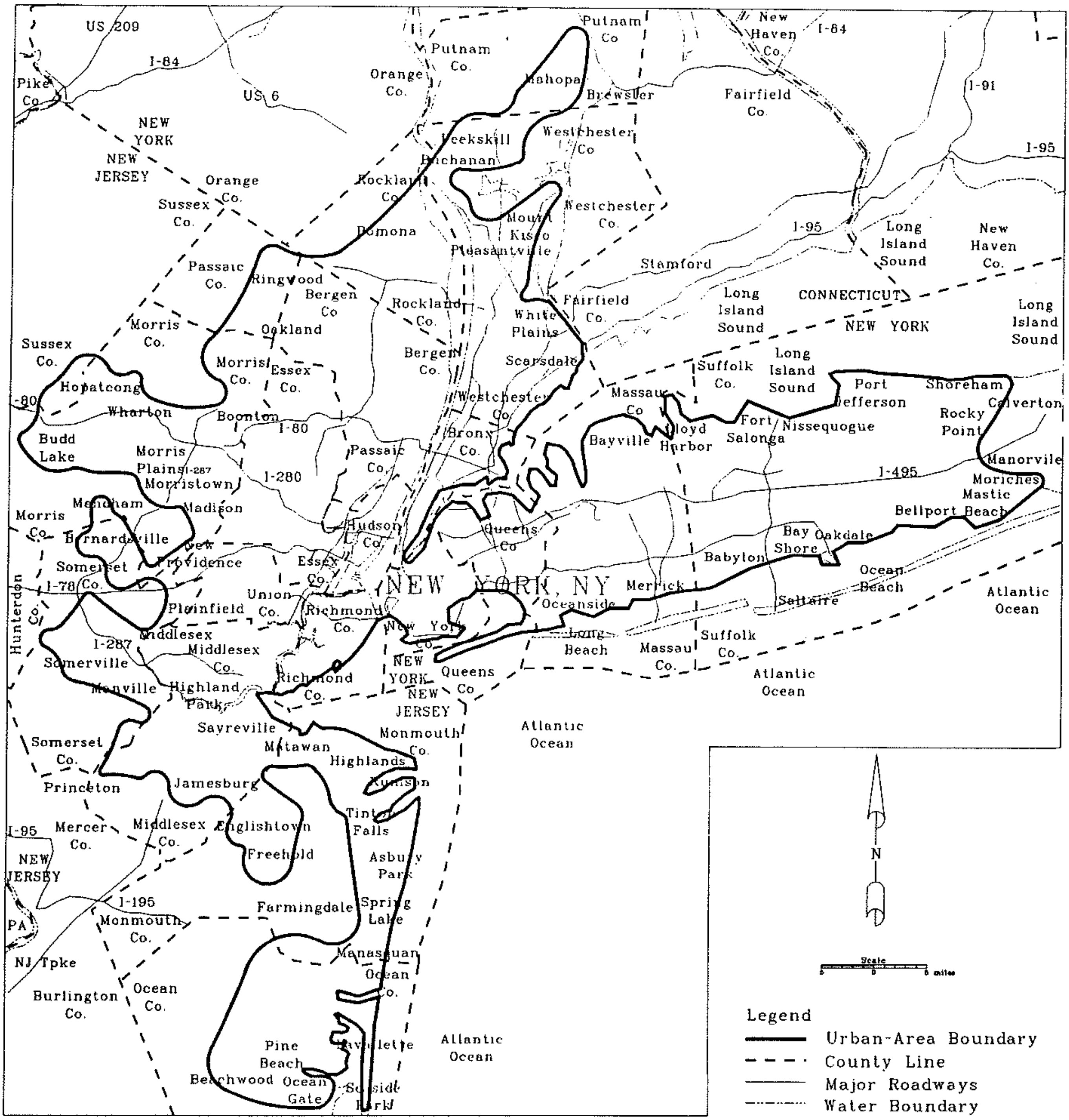

Figure C-29. Approximate Urban-Area Boundary Used for New York, New York--Northeastern New Jersey

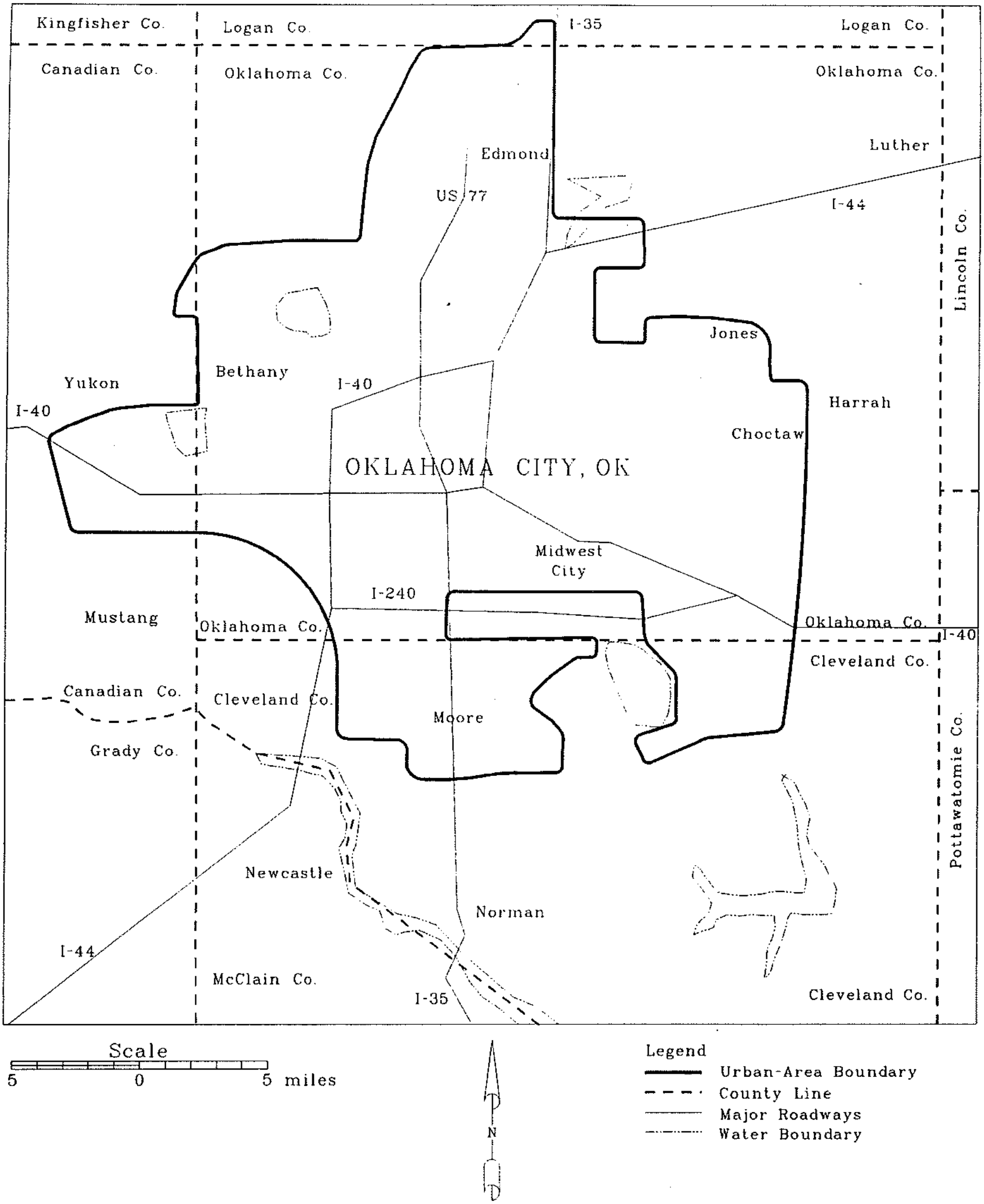

Figure C-30. Approximate Urban-Area Boundary Used for Oklahoma City, Oklahoma

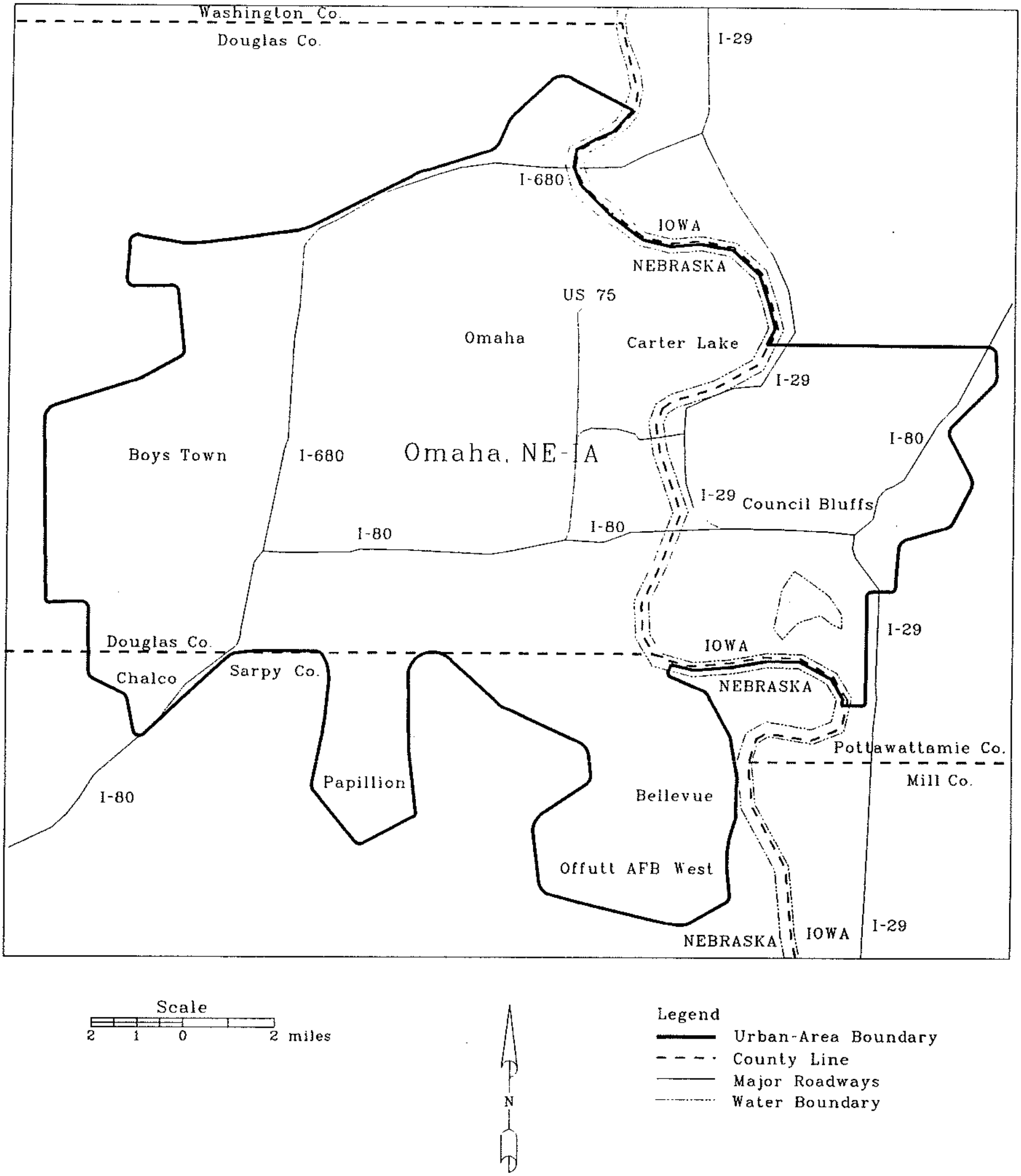

Figure C-31. Approximate Urban-Area Boundary Used for Omaha, Nebraska--Iowa

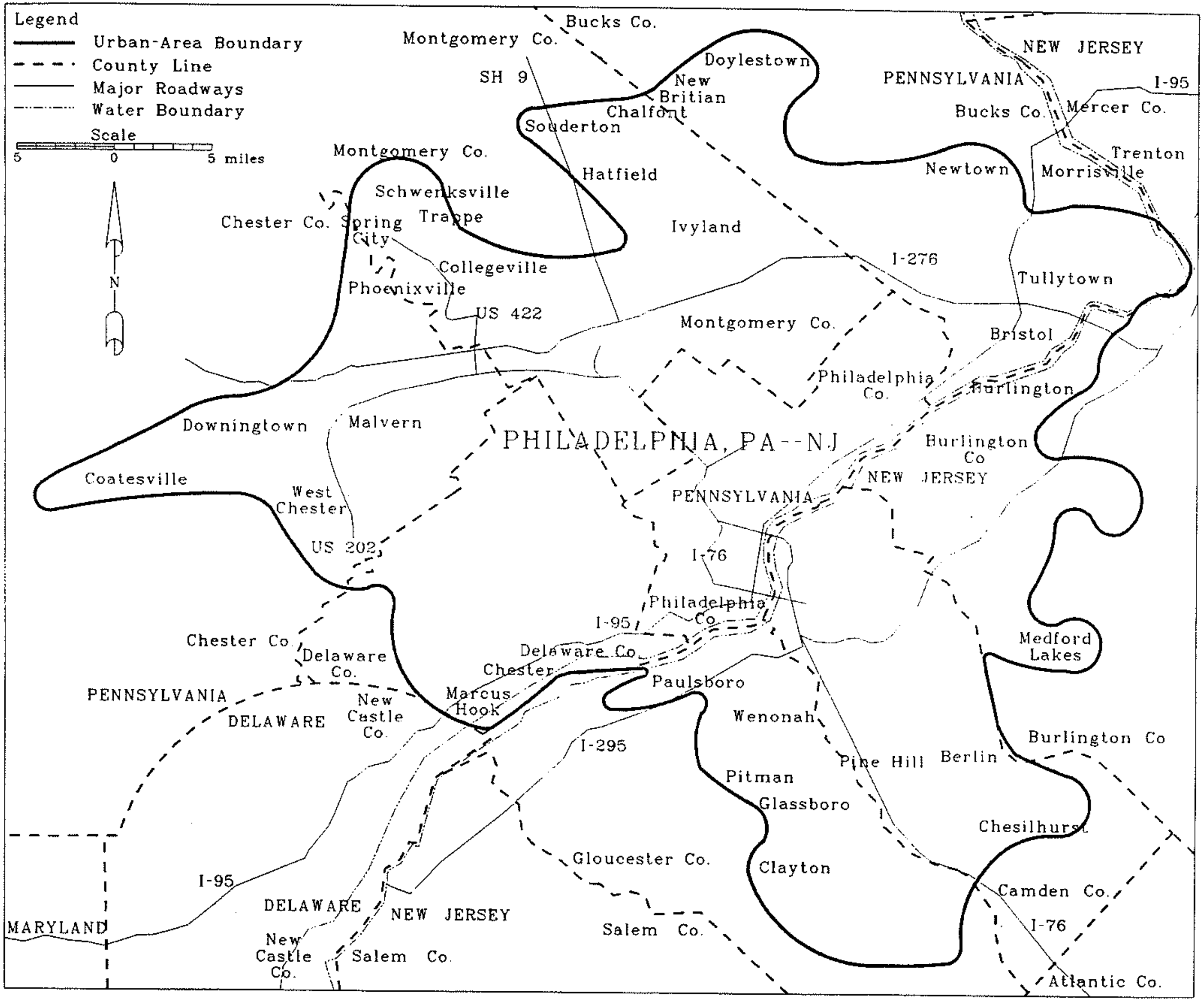

Figure C-32. Approximate Urban-Area Boundary Used for Philadelphia, Pennsylvania--New Jersey

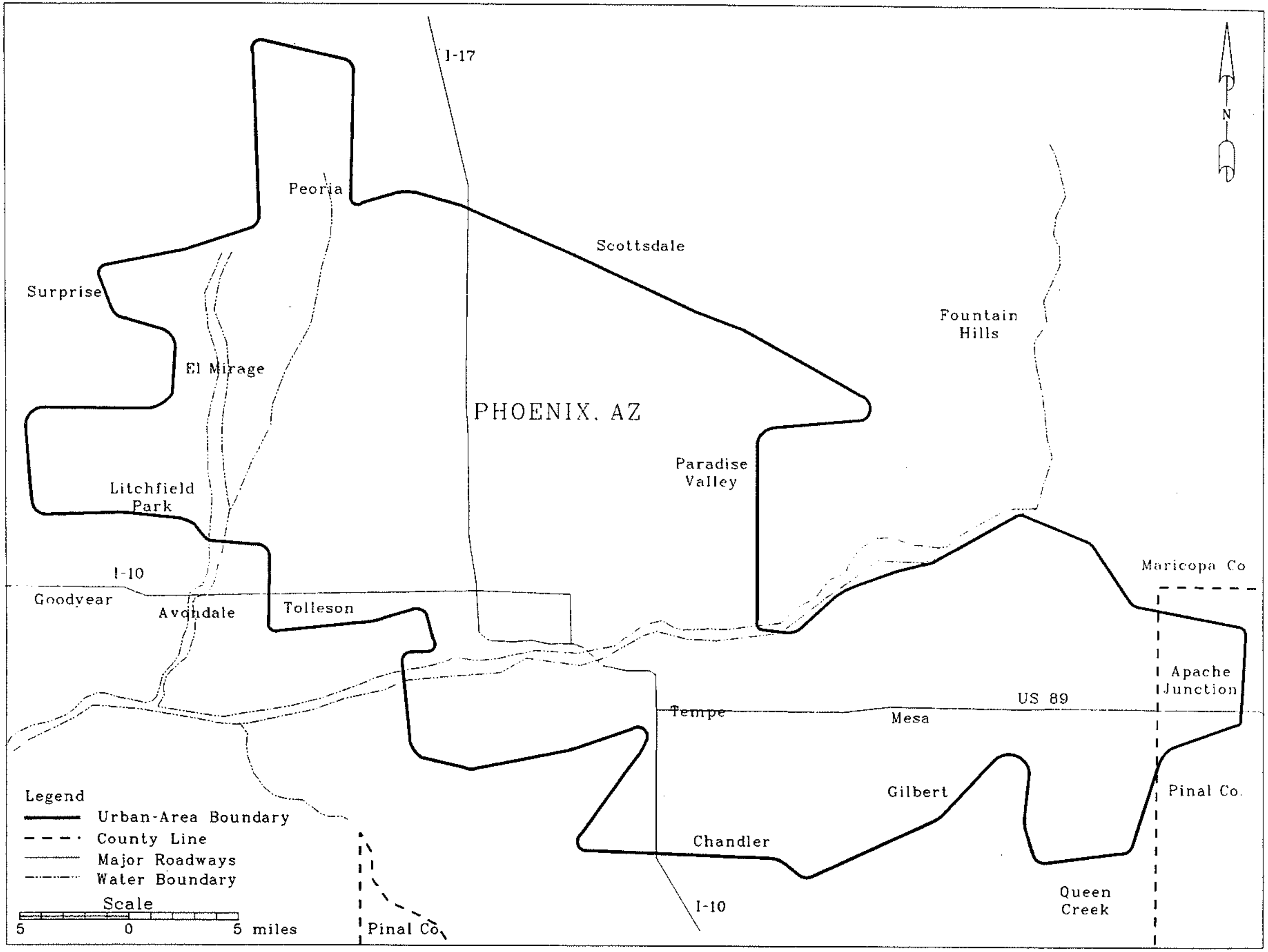

Figure C-33. Approximate Urban-Area Boundary Used for Phoenix, Arizona

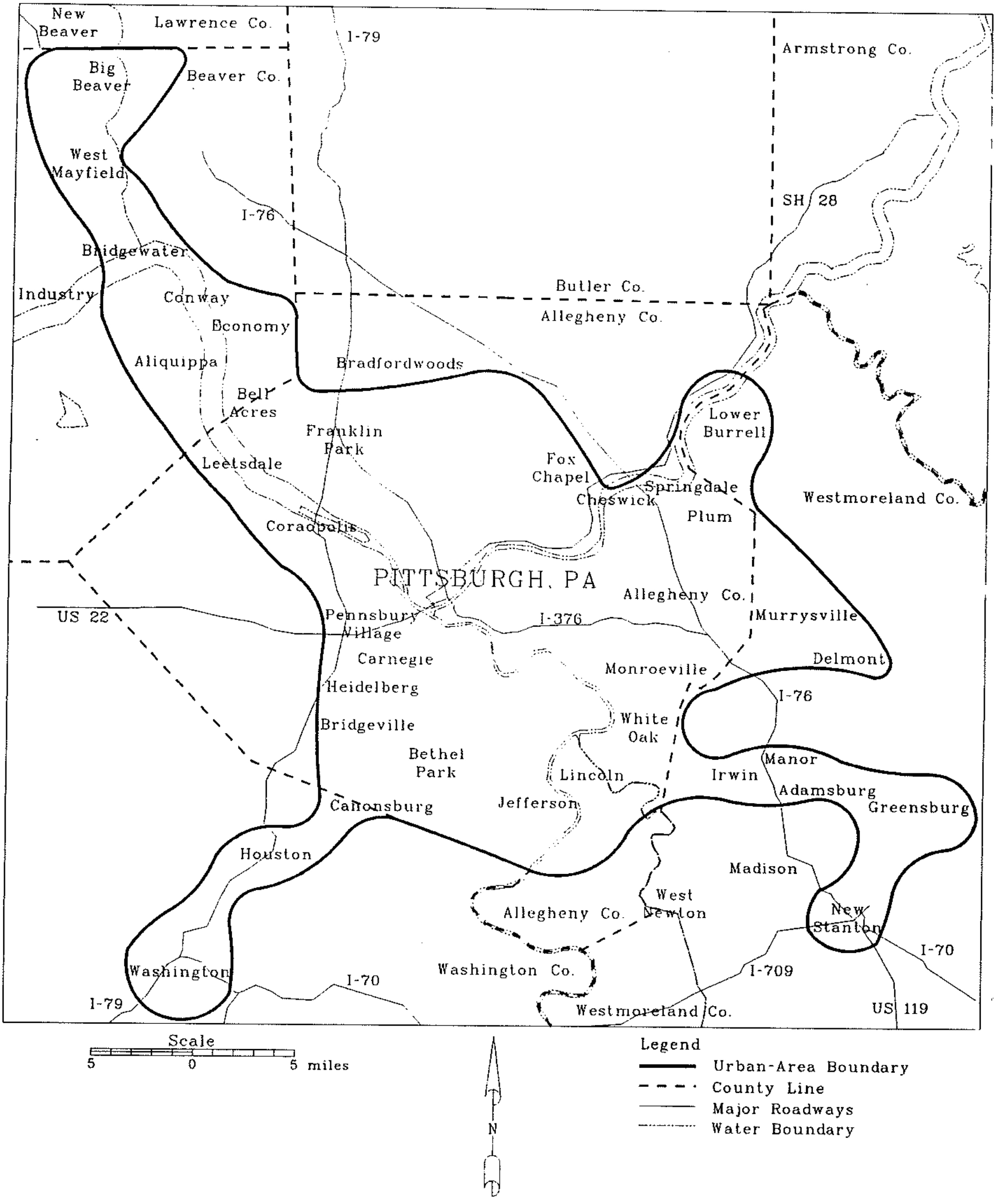

Figure C-34. Approximate Urban-Area Boundary Used for Pittsburgh, Pennsylvania

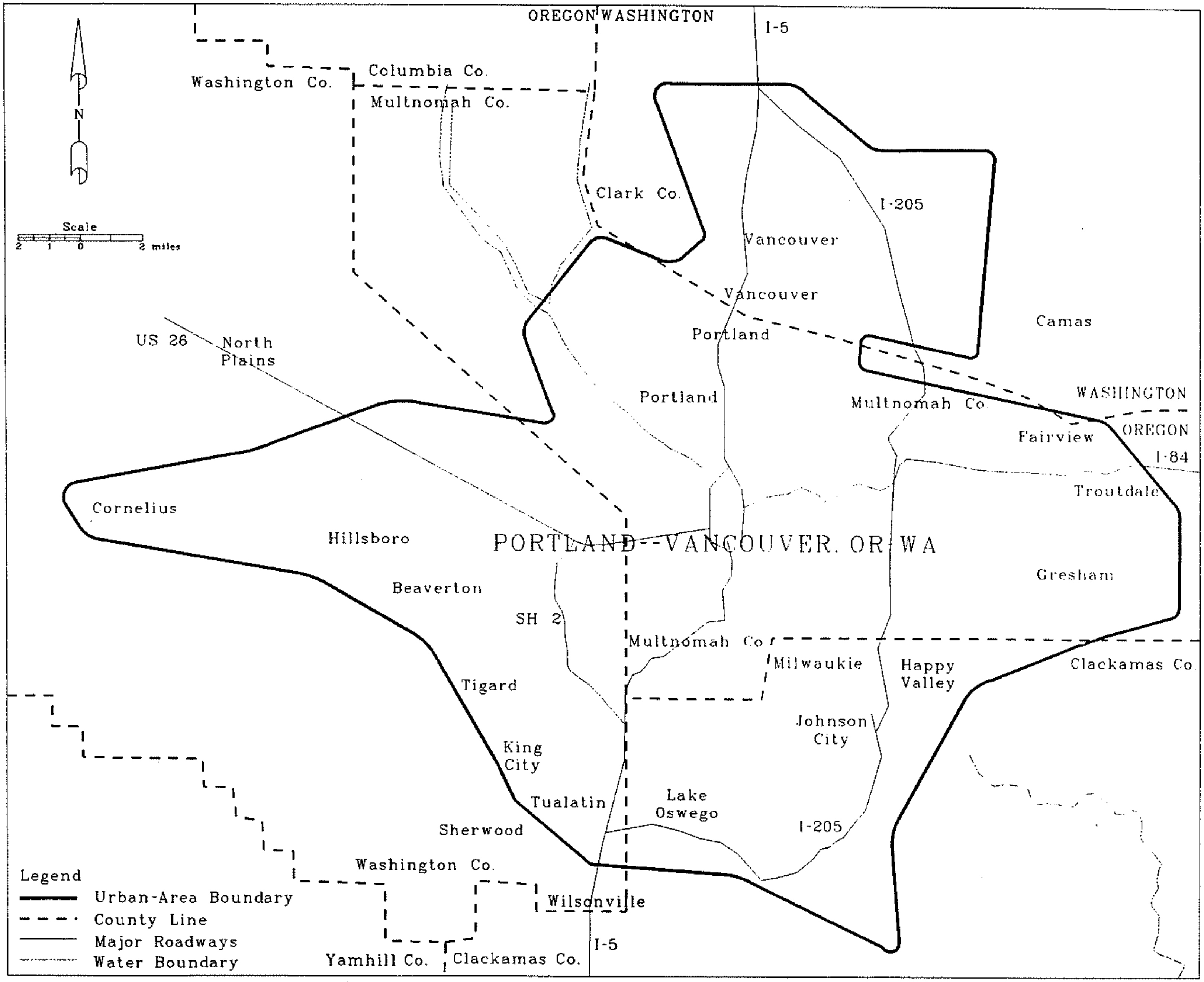

Figure C-35. Approximate Urban-Area Boundary Used for Portland--Vancouver, Oregon--Washington

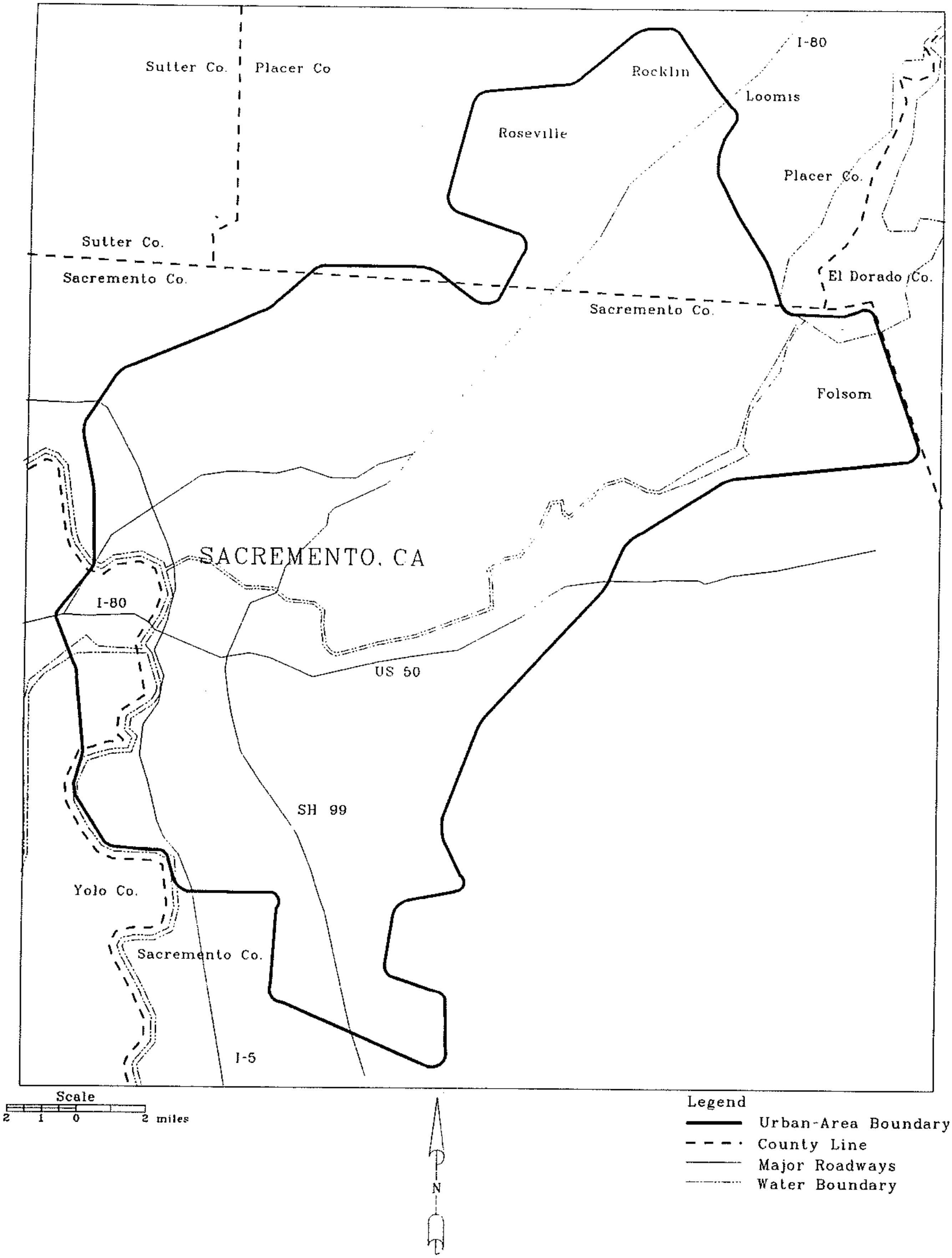

Figure C-36. Approximate Urban-Area Boundary Used for Sacramento, California

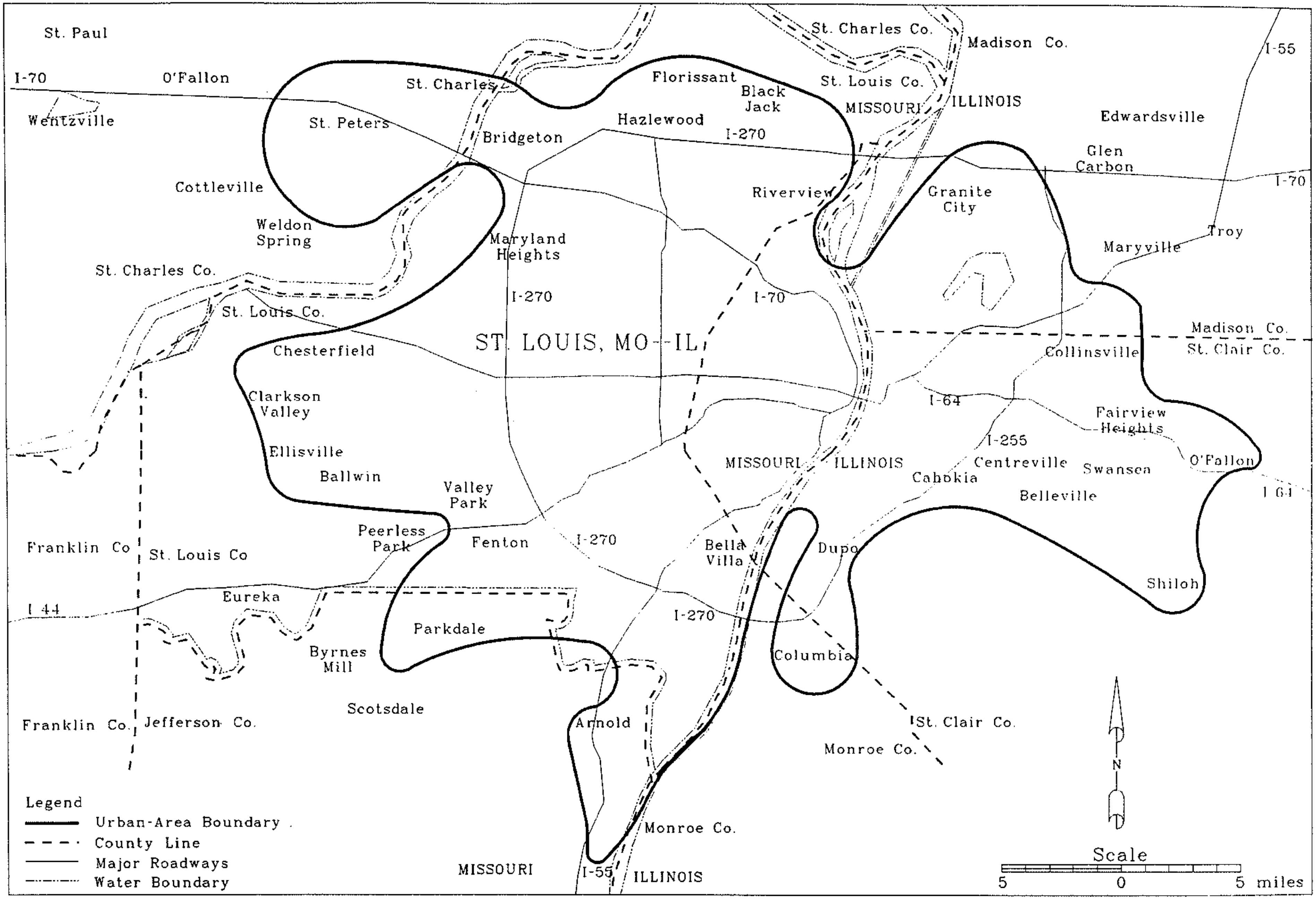

Figure C-37. Approximate Urban-Area Boundary Used for St. Louis, Missouri--Illinois

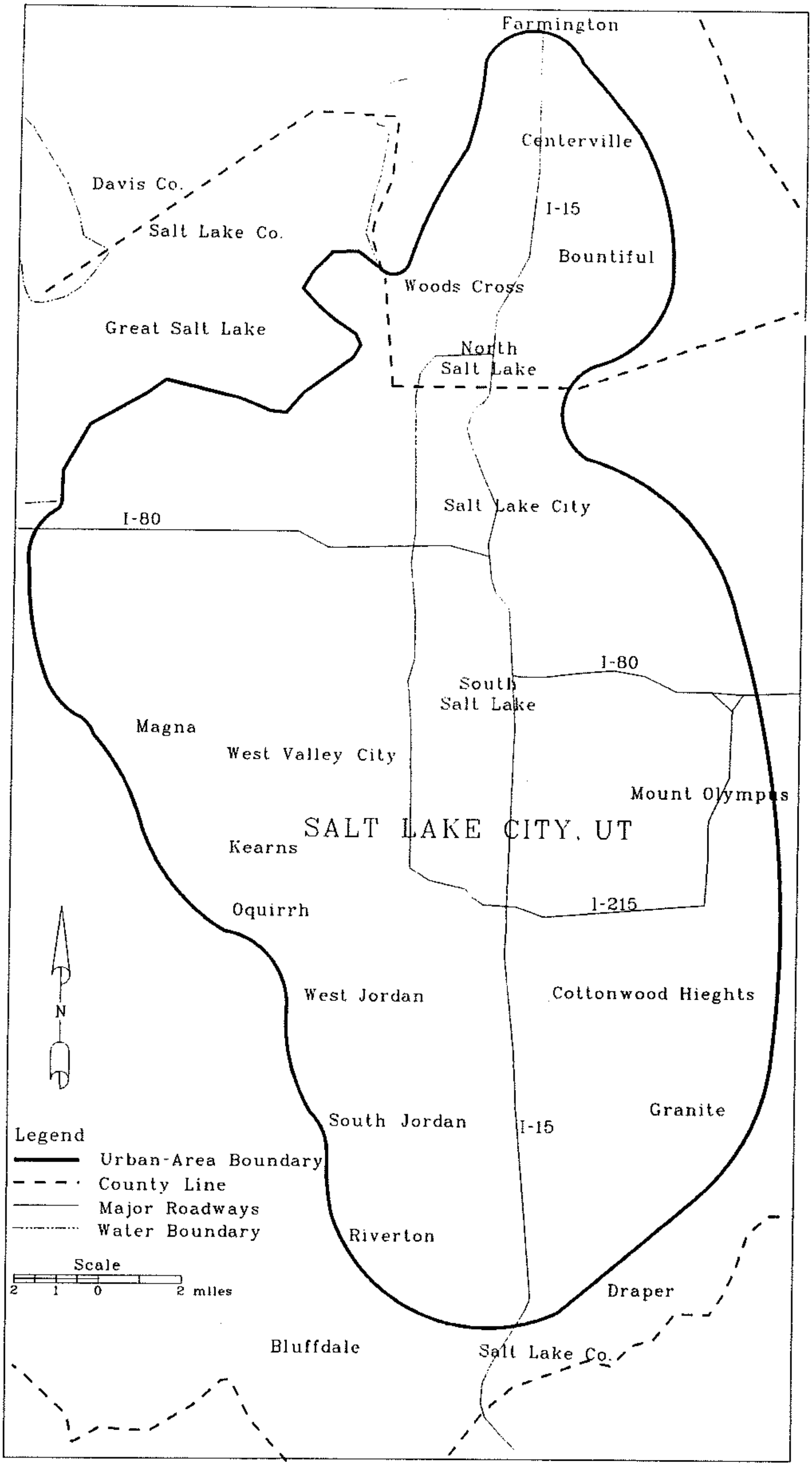

Figure C-38. Approximate Urban-Area Boundary Used for Salt Lake City, Utah

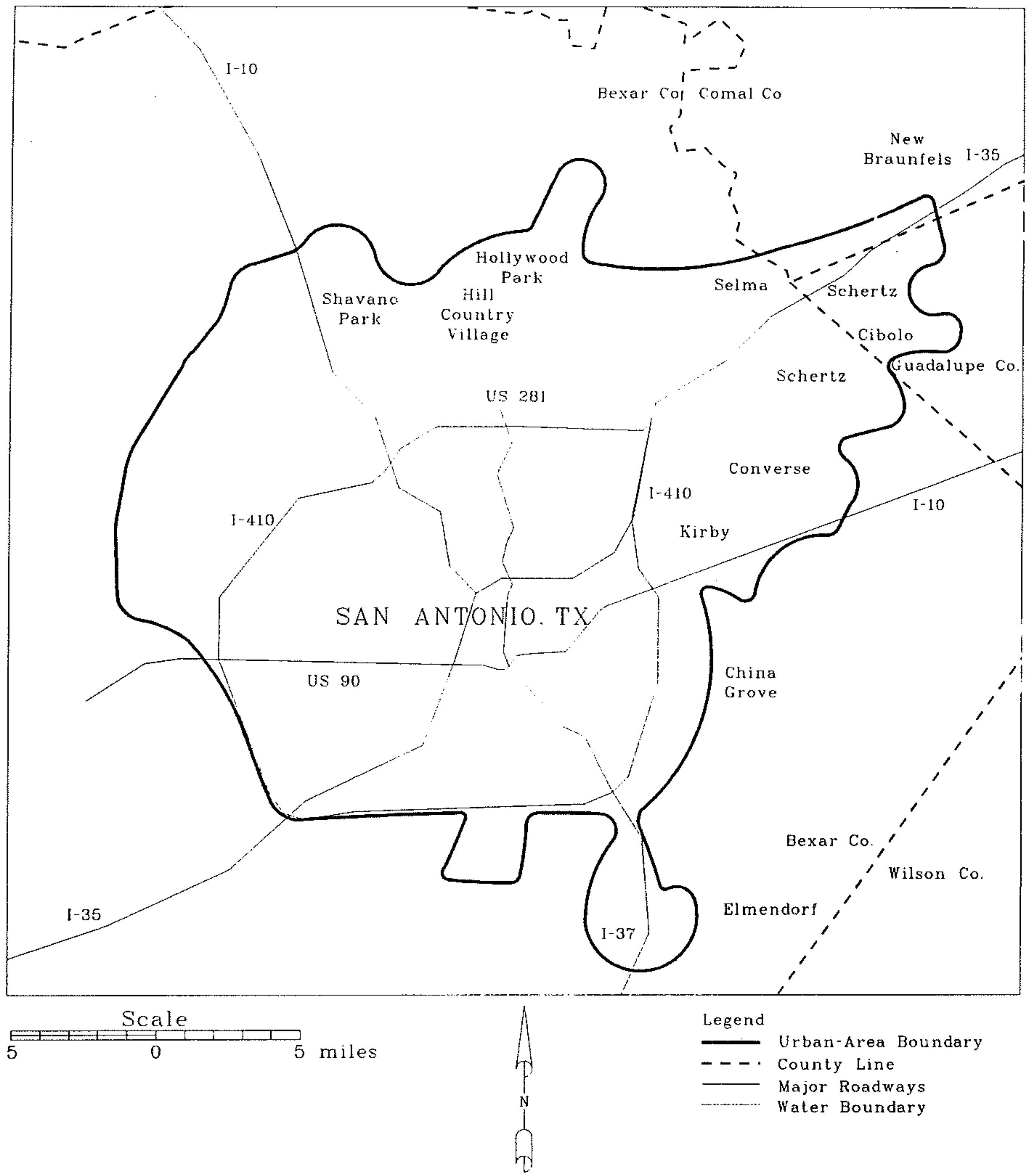

Figure C-39. Approximate Urban-Area Boundary Used for San Antonio, Texas

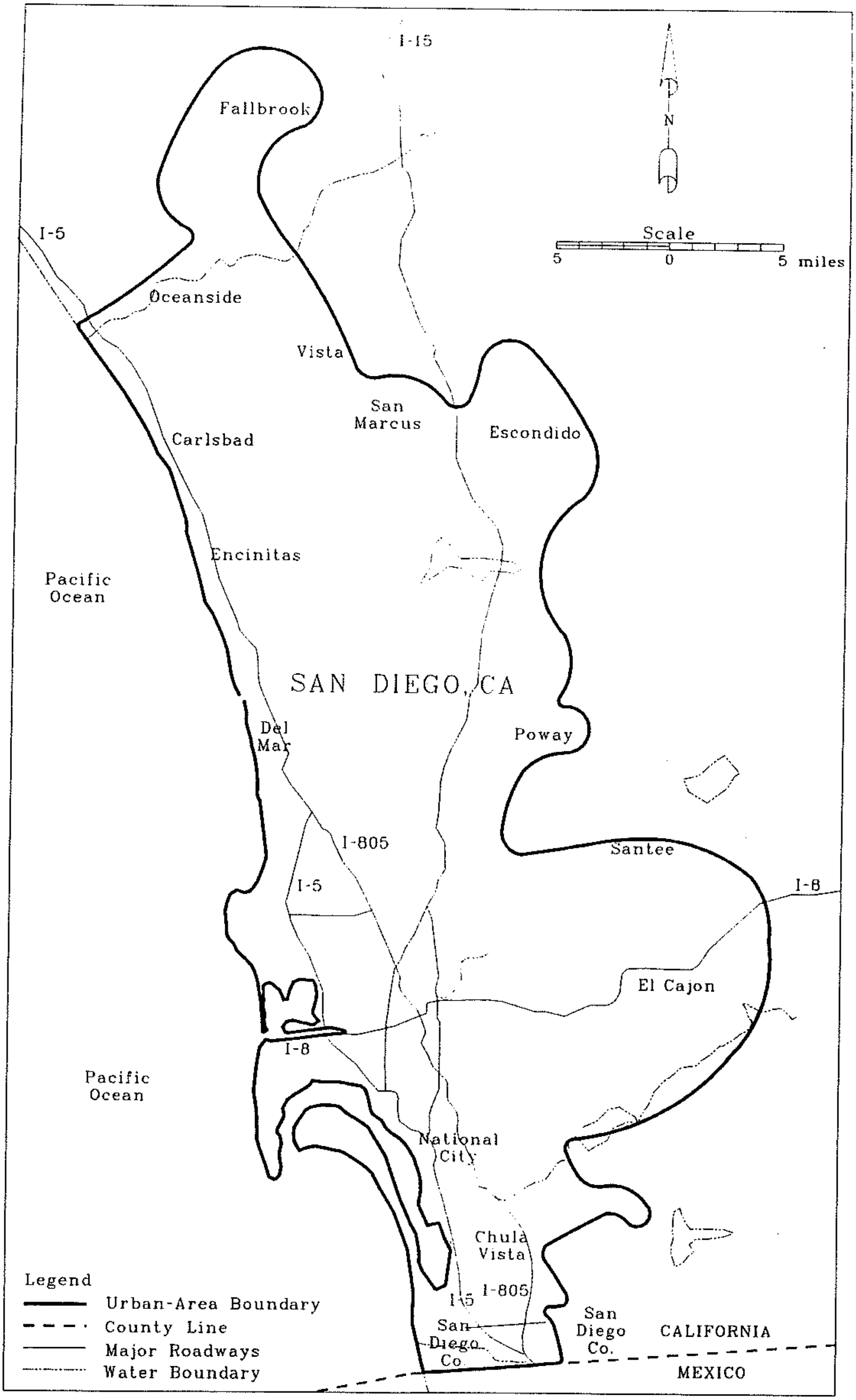

Figure C-40. Approximate Urban-Area Boundary Used for San Diego, California

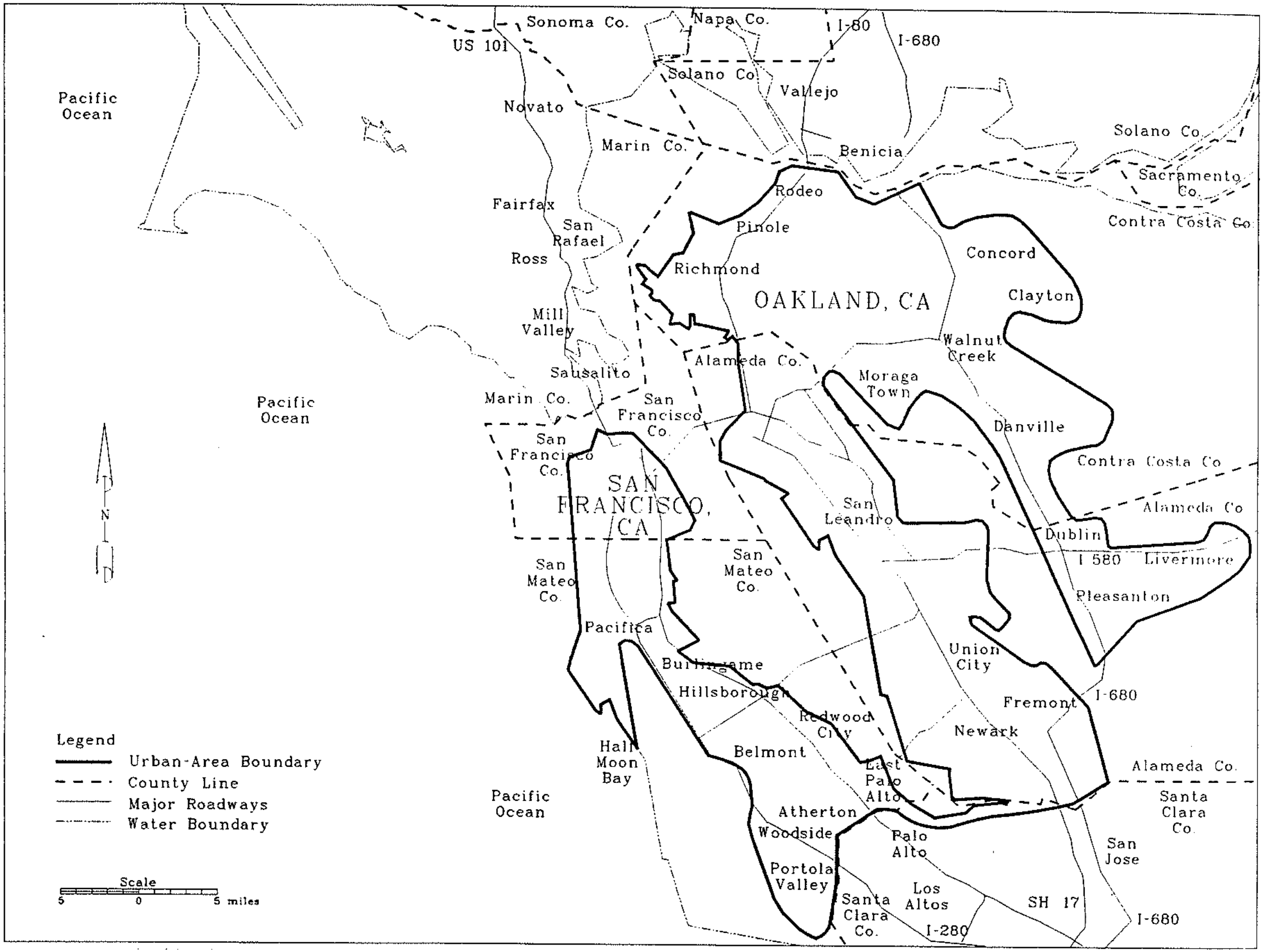

Figure C-41. Approximate Urban-Area Boundary Used for San Francisco--Oakland, California

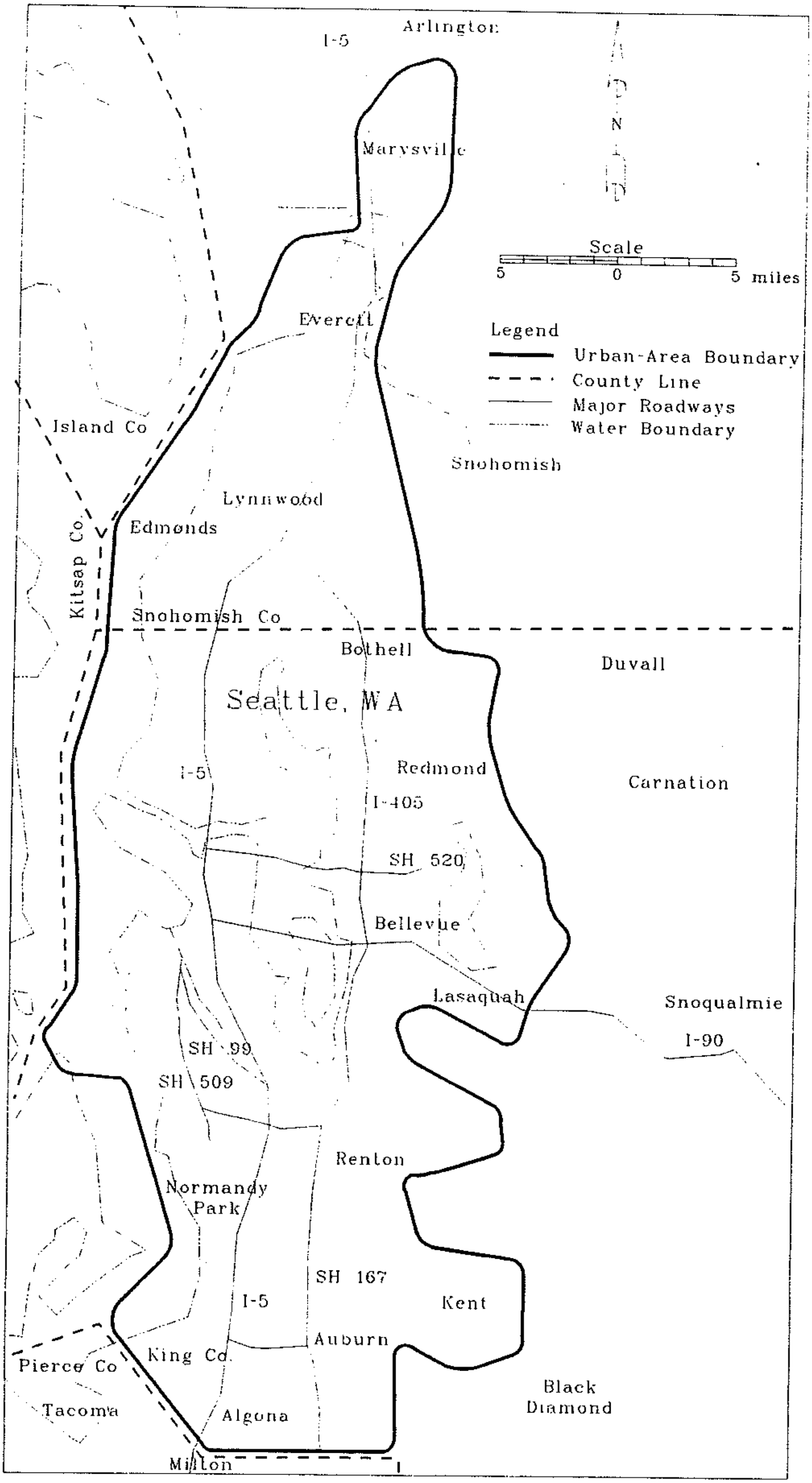

Figure C-42. Approximate Urban-Area Boundary Used for Seattle, Washington

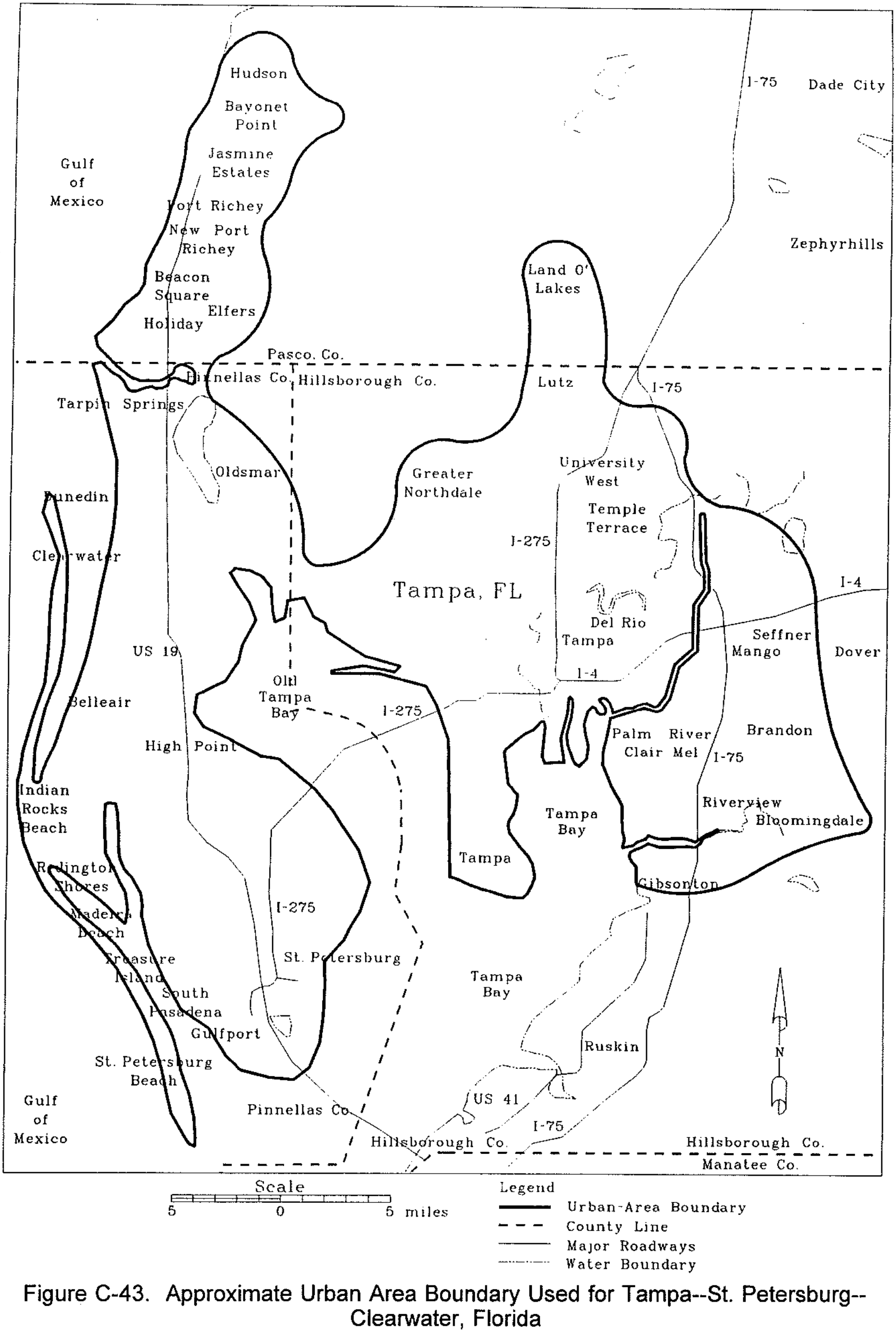

Figure C-43. Approximate Urban Area Boundary Used for Tampa--St. Petersburg--Clearwater, Florida

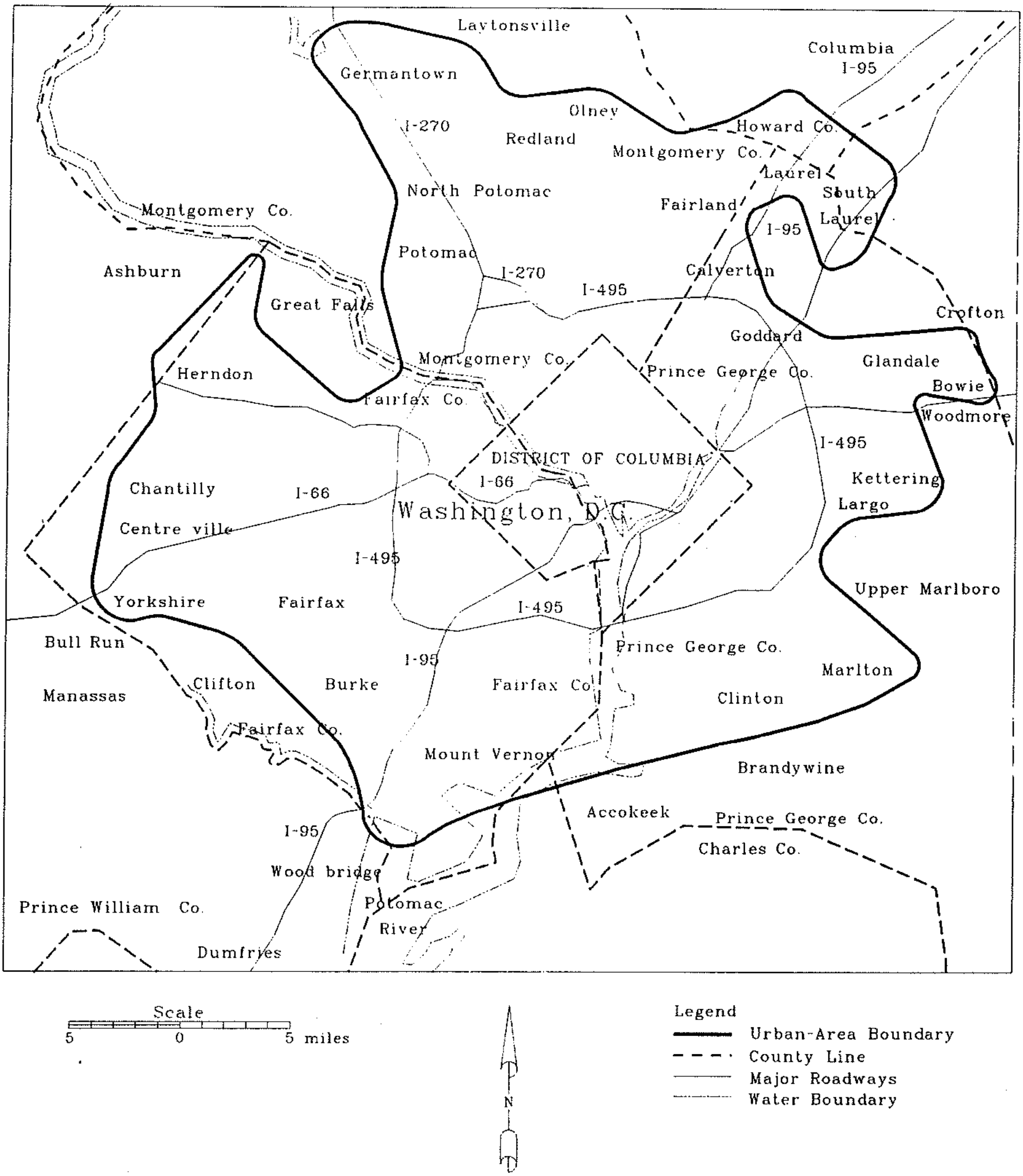

Figure C-44. Approximate Urban-Area Boundary Used for Washington, D.C.