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POPULATION DENSITY IN THE
UNITED STATES URBANIZED AREAS

By

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SUMMARY

Optimizing the design of a blast shelter program based on the principle of a "balanced defense" (Ref. 1) requires a fairly accurate knowledge of the distribution of the population density in the urbanized areas on a micro-scale using areas as small as one square mile.

Although the U.S. Census Bureau has furnished average population densities for the urbanized areas and their central cities, there is no such information available for tracts as small as one square mile. Using the census tract data made available by the Census Bureau and the Office of Civil Defense, this paper develops a model of the micro-population density distribution throughout the urbanized areas of the United States. The definition of city, urbanized area, and urban fringe are the same as that of the U.S. Census Bureau.

The results are based upon (1) a detailed examination of the five largest central cities, (2) a combination of micro-examination and statistics for the rest of the cities, and (3) a crude sub-model for the urban fringe areas which are generally of low density and consequently less critical for the civil defense purpose of determining the cost of an optimized blast shelter posture. Tables VII and VIII present the final results of our calculations showing, first, the number of people (1960) in each of the selected density categories and second, the cost of providing blast shelters for them close to their residences (based on formulas of Reference 1).

With our findings on population densities, the corresponding estimates of blast shelter costs for a national program covering the 213 major urbanized areas are from 10% to 15% higher than those of Reference 1, which admittedly used a cruder model of population distribution. Actually, our estimates are a bit conservative in that the model does not place extra shelters in large, relatively unoccupied places such as parks or central business districts.

POPULATION DENSITY DISTRIBUTION IN THE UNITED STATES URBAN AREAS

1. INTRODUCTION

In a recent study (Ref. 1) it was shown that the design of a blast shelter program based on the principle of a "balanced defense" required a knowledge of the variation of population density over the urbanized areas of the United States. That paper, in order to make its calculations, developed a simple, crude model of this density distribution. It assumed that the use of this model would not lead to large errors (more than 10%) in the calculation of the national cost of the shelter posture. Since some of the postures discussed were estimated to cost tens of billions of dollars, errors in the population distribution which could affect the program cost by 10% would amount to several billions of dollars. This reason alone made it clear that a more accurate model of the population density distribution was needed.

Unfortunately, it was found that the necessary data for making these calculations easily did not exist. While the Census Bureau had volumes of data on population in different places in the United States, the population densities had been calculated for large areas such as cities, urbanized areas, counties, and states, but not for small tracts within the urbanized areas. The Office of Civil Defense had acquired from the Census Bureau a set of eight volumes of census information known as the National Location Code (Ref. 2), which mapped individual census tracts for the entire United States and gave the population of each tract. Unfortunately, the areas of these tracts were not also available as part of the data. Since there are about 40 or 50 thousand of these tracts, it was clear that measuring the area of each of them (especially when most of them had irregular shapes) would be a very large task. Nevertheless, since the need for the information was great, we decided upon a less laborious way of making an estimate by combining the information in these National Location Codes with a statistical approach.

The various techniques that we used to save labor and obtain a reasonable accuracy in making our estimate of population distribution are given in the subsequent sections of this paper. They include the following factors:

1. the lumping of small census tracts into areas of approximately one square mile;
2. the utilization of the method of "equivalent rectangles" to estimate the area of irregular figures;
3. the use of statistical sampling;
4. the use of a relatively crude sub-model for the urban fringe population in which errors in the detailed distribution could have only very small net effects on subsequent calculations of the costs of blast shelter programs.

Since our basic data is all taken from census information, it should be clear that we are discussing the distribution of the residential population of the U.S. which is a close approximation to the "night-time" population.

This information should enable us to ask and answer some questions about the placement of blast shelters in accordance with distribution of population, so that the principles of providing blast shelters near residences can be investigated. These questions include:

What blast resistance do the hardest shelters have to provide?

What portion of the cost of a program is in the most dense central city areas?

How much can be saved by partial dispersal of the population in congested areas?

II. THE MODEL

A. The Largest Cities

Table I (page 7) shows the 1960 Census breakdown of the urbanized areas of the U.S. into groups of places according to the population. The first group includes places with population of one million and more; this refers to the five largest cities in the U.S. Since each of these cities is relatively unique in its character, a separate detailed (and tedious) computation was made of the population density distribution within each one. From the other groups, a sample was selected and used as a statistical distribution to represent the entire group. The sampling method will be discussed subsequently.

For New York City it was convenient to handle each of the five boroughs as separate units, and a graph of the population distribution for each was developed separately. For each of the other four largest places (central cities of Chicago, Detroit, Los Angeles, and Philadelphia) a separate population distribution graph was developed. These graphs all appear in Appendix B.

Referring again to Table I, there are sixteen cities with populations between 500,000 and one million. It seemed reasonable to choose a sample of four to represent the entire group, making sure that their average population density was approximately the same as the average population density of the group of sixteen. With this restriction, a sample of four cities was randomly drawn from the sixteen and was adopted if it met the mean density criterion. Then the census tracts of each of the cities of this sample were examined in sufficient detail and combined to determine the spectrum of population densities within the sample. Thus a composite "typical" city was devised which was then taken to represent the group of sixteen.

A similar procedure was followed by choosing random samples for the other groups of places shown in Table I. Some summary information relevant to the computations is indicated in Table II.

B. Population Density Categories

It was decided for our purposes that a finite number of population density categories, as given in Table III, would be sufficiently accurate for the underlying purpose of estimating costs of various blast shelter programs. This table shows that we used 33 categories of population density, varying from about 750 people per square mile up to 250,000 people per square mile. While there is as much as a 20% variation in many or most of these categories, it was felt that this would not introduce a significant error because of the tendency of the variation to average out. This assumption was subsequently borne out by occasionally spot checking the detailed calculations which were made, some of which are presented in Appendix B for illustrative purposes.

C. Computation of Areas

The greatest amount of labor was put into computing the areas of census tracts of known population given by Reference 1 in the form of maps. Figure 1, for example, shows part of a map of an area in the Bronx. By way of illustration, we are assuming that we wish to determine the area of tract number 351 and the area of tracts 301 and 299 combined. We drew rectangles over these areas and by "eyeballing them in" made the rectangle approximate the area of the tract as closely as we could estimate. It was then a simple matter to obtain the area of the rectangle and, from the scale of the map itself, the area of the tract. Hence the population distribution within the tract could be calculated. In practice, it was convenient to combine adjacent tracts into clusters which had an area of approximately one square mile. The purpose of this clustering was primarily to save labor. (Secondarily, it might be argued that in a shelter program the distribution of shelters within an area of one square mile would be within ready reach of nearby citizens. That is, if some travel within the clustered areas is required, no one is likely to travel more than one-half mile to reach his designated shelter.) In Manhattan, for example, the smallest tracts were less than .02 of a square mile (and some tracts had population density figures as high as 250,000).

After each population density for a cluster was computed it was converted into one of the standard population density categories designated in Table III. Thus, a population density of 6,342 would be placed in the category, 6,000. The results of a typical calculation of the population density spectrum of a city are shown in Table IV, which gives the results for Manhattan. It will be noticed that about 97% of the people live in population densities varying from 50,000 to 175,000 per square mile, at least on areas of approximately one square mile. (As Appendix A will show, the population density for the smaller areas, of the size of individual tracts, will in some cases be over 250,000.)

D. Typical City Computations

For the group of sixteen places between 500,000 and one million, a "typical" city was defined based on a selected sample of four out of the sixteen. By chance, using a random draw process, this sample was composed of the cities of San Francisco, Dallas, San Antonio and Baltimore. A table of population densities was developed for each of these four cities; the data was then lumped to give a population distribution for the composite. This composite distribution was then converted into one showing the percent, rather than the absolute number, of people in each of the population density categories. Assuming this composite to be a fair representative of the entire group, the total population of the sixteen cities was distributed in density categories according to the percentages given in the composite sample. The results for this group are given in Table V (and in its equivalent graph, Figure 2). In a similar way, typical or composite cities were developed for each of the other groups of Table II, and the results used to represent their density distributions. (See Figures 10, 11, and 12, for graphs of the resulting composites.)

E. Urban Fringe Calculations

Using the Census Bureau's definition, an urbanized area is one which involves a central city of 50,000 population or more and the surrounding area out to where the population density falls to 1,000 per square mile. There are also some other criteria for establishing continuity of boundaries that are not important for our purposes. A typical urbanized area (or at least an illustrative one) is given in Figure 3. It is characteristic of nearly all the urbanized areas that their urban fringes are of substantially lower population density than the central cities. Our model is primarily designed for use in computing blast shelter distributions and costs; it is relatively insensitive to errors in the density distribution of the low density (i.e., fringe) areas as long as the correct mean density is used as an anchor to avoid unnecessary bias in distribution.

It was decided, therefore to save a great deal of labor by making a simple sub-model to represent the distribution of the fringe population densities. Since the census data gave the total population of each of the urban fringe areas and the mean density of these areas, after some experimentation it was decided that, for a reasonable and simple model, each urban fringe would be divided into four unequal areas whose relative size was 10%, 20%, 30% and 40%, respectively, of the total urban fringe area. Then, by assuming that 25% of the total population of the fringe was uniformly distributed over each of these areas, we could quickly determine a population density distribution. Thus, each urbanized fringe was given a population density distribution spectrum consisting of the four categories indicated above. The accuracy of this model was then checked by looking at a few random cities and making a detailed calculation of the population distribution within their urban fringes, using the data in Reference 1. The results of this checking exercise are shown in Table VI, "Urban Fringe Areas."

As Table VI indicates, the composite picture shows less variance between the actual and the estimated population density distribution than that of any single city and should improve as the size of the sample increases. As an additional check on the accuracy of this method, the urban fringes of Detroit and Philadelphia were examined in similar detail in order to show that this model would be reasonable in the urban fringes of a large city (see Tables XI through XIV in Appendix B).

Principally, this examination of the Detroit and Philadelphia fringes was made to determine whether there was a significant amount of the population in areas in which the density would be substantially greater than that given by our model. The examination indicated that this concern was not significant in practice and that, while some isolated spots did occur where population densities were substantially greater than that given by our model the numbers were generally less than 5% of the total of urban fringe population and therefore would not have an important impact on our results.

F. Results

Table VII gives the results of our population distribution computation indicating the number of people within each of the population density categories for the urbanized area of the United States (1960 Census). It may be of interest to compare these results with the figures assumed in Reference 1; these assumptions are also given in the table. Our results indicate that the earlier model is somewhat low in its estimate of the resident population densities at the higher density categories. Figure 4 also presents the final results of these computations in graphic form.

The table or the graph can be used subsequently in making revised calculations of quantities, such as the blast shelter costs, which depend on a knowledge of the population in the various density categories. If we take the population distribution as given in Table VII to be an improved representation of the sheltered configuration rather than that of the simpler population model of Reference 1, then we can calculate the costs of a national blast shelter posture for the urbanized areas by an application of the formula (page 15 of Ref. 1)

$$T = 50N + 20 (150/\beta)^{1/2} \sum_1 \eta_i \rho_i^{1/2},$$

where T is the cost of shelters N = 96 million (for 1960 urbanized area population), β is a parameter describing the vulnerability of the blast shelters and the η_i and ρ_i refer to the number of people in each population density category and are given in

$$\sum_1 \eta_i \rho_i^{1/2} = 282,$$

where the ρ_i are expressed in thousands per square mile and the η_i in millions of people. Applying this to the equation above gives the result,

$$T = 4,800 + \frac{6,900}{\beta^{1/2}} \quad (\text{in millions of dollars}),$$

where the vulnerability number, β , is expressed in thousands (for example for $\beta = 4,000$, we use $\beta = 4$ in the above formula.

The cost estimate, T , as a function of β is given in Table VIII below. It will be observed that these calculations give estimates which are about 10%-15% higher than those of Reference 1. The two major reasons for this are (a) that our population distribution model is much more accurate, and (b) that our computations are more conservative. For example, the micro-examination of the dense portions of the cities often excludes large parks or industrial areas, which in many cases could provide usable shelter sites.

In addition to the above calculations we present in Figures 5 to 20 of this section graphs showing population density of:

- (1) each of the five boroughs of New York City;
- (2) the composite cities of the remaining three groups of cities indicated in Table II, which we are using as representative of the average population density distribution;
- (3) each of the four cities comprising the sample in the 500,000-1,000,000 group;
- (4) each of the four largest cities after New York.

Table 1
POPULATION IN GROUPS OF PLACES WITHIN
URBANIZED AREAS CLASSIFIED ACCORDING TO SIZE: 1960

1960						
Size of Place	Incorporated Places		Unincorporated Places		Urban Towns and Townships	
	Number	Population	Number	Population	Number	Population
Places of 1,000,000 or more	5	17,484,059	-	-	-	-
Places of 500,000 to 1,000,000	16	11,110,991	-	-	-	-
Places of 250,000 to 500,000	30	10,765,881	-	-	-	-
Places of 100,000 to 250,000	79	11,384,755	1	104,270	1	163,401
Places of 50,000 to 100,000	180	12,511,961	9	585,104	12	738,837

Table II

NUMBER IN SAMPLE AND MEAN DENSITY (PEOPLE/SQ. MI.) IN GROUPS
OF PLACES CLASSIFIED ACCORDING TO POPULATION: 1960

Size of Place	Number in Group	Number in Sample	Mean Density
Places of POPULATION 500,000 to 1,000,000	16	4	5,885
Places of POPULATION 250,000 to 500,000	30	5	4,484
Places of POPULATION 100,000 to 250,000	81	9	4,271
Places of POPULATION 50,000 to 100,000	201	10	3,910

Table III

POPULATION DENSITY CATEGORIES (NO. OF PEOPLE PER SQ. MI.)

Range of Population Density	Population Density Category	Range of Population Density	Population Density Category
Under 750	< 750	17,000 - 19,000	18,000
750 - 1,250	1,000	19,000 - 21,000	20,000
1,250 - 1,750	1,500	21,000 - 23,500	22,000
1,750 - 2,250	2,000	23,500 - 27,500	25,000
2,250 - 2,750	2,500	27,500 - 32,500	30,000
2,750 - 3,250	3,000	32,500 - 37,500	35,000
3,250 - 3,750	3,500	37,500 - 45,000	40,000
3,750 - 4,250	4,000	45,000 - 55,000	50,000
4,250 - 4,750	4,500	55,000 - 70,000	60,000
4,750 - 5,500	5,000	70,000 - 90,000	80,000
5,500 - 6,500	6,000	90,000 - 112,500	100,000
6,500 - 7,500	7,000	112,500 - 137,500	125,000
7,500 - 9,000	8,000	137,500 - 162,500	150,000
9,000 - 11,000	10,000	162,500 - 187,500	175,000
11,000 - 13,000	12,000	187,500 - 225,000	200,000
13,000 - 15,000	14,000	Over 225,000	250,000
15,000 - 17,000	16,000		

Table IV

MANHATTAN--DISTRIBUTION OF GROUPED TRACTS WITHIN
THE POPULATION DENSITY CATEGORIES

Number of People	Area (sq. mi.)	Population Density (People/sq.mi.)	Population Density Category (People/sq.mi.)	Per Cent of Total Population
--	--	--	750	--
--	--	--	1,000	--
--	--	--	1,500	--
2,236	1.0	2,200	2,000	.1
--	--	--	2,500	--
--	--	--	3,000	--
--	--	--	3,500	--
1,207	.30	4,000	4,000	.1
--	--	--	4,500	--
--	--	--	5,000	--
--	--	--	6,000	--
--	--	--	7,000	--
8,935	1.0	8,900	8,000	.5
3,545	.34	11,800	10,000	.2
--	--	--	12,000	--
--	--	--	14,000	--
--	--	--	16,000	--
--	--	--	18,000	--
--	--	--	20,000	--
--	--	--	22,000	--
31,073	1.14	27,000	25,000	1.8
--	--	--	30,000	--
--	--	--	35,000	--
--	--	--	40,000	--
201,937	3.9	52,000	50,000	11.9
171,852	2.9	57,000	60,000	10.1
248,457	3.0	83,000	80,000	14.6
229,822	2.1	109,000	100,000	13.5
493,966	4.1	120,000	125,000	29.1
141,718	1.0	142,000	150,000	8.3
163,533	1.0	164,000	175,000	9.6
1,698,281	21.7			

Table V

COMPOSITE CITY

(Composed of cities with
Population 500,000 to 1,000,000)

Population Density Categories (People/sq. mi.)	Population	Per Cent of Total
750	38,205	1.3
1,000	49,719	1.7
1,500	77,407	2.6
2,000	83,006	2.8
2,500	65,098	2.2
3,000	37,763	1.3
3,500	66,435	2.3
4,000	62,649	2.1
4,500	16,523	0.6
5,000	150,160	5.1
6,000	244,577	8.3
7,000	168,488	5.7
8,000	169,776	5.8
10,000	244,040	8.2
12,000	200,716	6.8
14,000	154,601	5.2
16,000	160,391	5.4
18,000	85,997	2.9
20,000	103,621	3.5
22,000	160,125	5.4
25,000	119,709	4.1
30,000	92,852	3.2
35,000	102,336	3.5
40,000	173,200	5.9
50,000	69,542	2.4
60,000	49,806	1.7

Table VI

URBAN FRINGE AREAS

Population Density Categories	Phoenix, Arizona		Columbus, Georgia		Wichita, Kansas		Rochester, N.Y.		Scranton, Pa.		Total	
	Actual Pop.* Dist.**	Estimated Pop. Dist.	Actual Pop. Dist.	Estimated Pop. Dist.	Actual Pop. Dist.	Estimated Pop. Dist.	Actual Pop. Dist.	Estimated Pop. Dist.	Actual Pop. Dist.	Estimated Pop. Dist.	Actual Pop. Dist.	Estimated Pop. Dist.
750			533						11,710		12,243	
1,000		28,218		10,401	16,871	18,720	36,500		22,200	49,616	75,571	106,955
1,500	24,897	28,218	35,770	10,401	7,182	9,360	10,634	43,698	14,112	24,808	92,595	116,485
2,000	62,254			10,401			4,664	43,698	27,845		94,763	54,099
2,500		28,218						43,698	7,904		7,904	71,916
3,000					11,167	9,360	67,656			24,808	78,823	34,168
3,500	25,722		4,087	10,401	2,220				15,462		47,491	10,401
4,000			1,213				55,337				56,550	
4,500		28,218						43,698				28,218
5,000												43,698
Totals	112,873	112,872	41,603	41,604	37,440	37,440	174,791	174,792	99,233	99,232	465,940	465,940

*Population
**Distribution

Table VII

POPULATION DENSITIES IN THE
UNITED STATES URBANIZED AREAS--1960*

Population Density Categories (ρ_1) (People/sq. mi.)	Number of People (η_1)	Number of People from Model of Ref. 1**
750	1,021,715	--
1,000	3,352,573	4,000,000
1,500	4,465,598	--
2,000	8,491,623	10,000,000
2,500	6,170,110	--
3,000	5,743,825	20,000,000
3,500	3,244,133	--
4,000	3,642,199	15,000,000
4,500	3,960,050	--
5,000	5,430,699	10,000,000
6,000	5,033,139	8,000,000
7,000	5,489,183	--
8,000	6,854,373	7,000,000
10,000	5,363,084	6,000,000
12,000	4,576,670	--
14,000	3,492,349	4,000,000
16,000	2,787,924	--
18,000	1,489,954	--
20,000	1,958,703	6,000,000
22,000	1,345,287	--
25,000	1,657,794	--
30,000	1,696,953	--
35,000	1,389,235	--
40,000	2,057,383	4,000,000
50,000	1,587,547	--
60,000	1,395,261	--
80,000	1,025,333	2,000,000
100,000	325,570	--
125,000	493,966	--
150,000	141,718	--
175,000	163,533	--
TOTAL	95,847,484	96,000,000

*The calculations are based upon areas of about one square mile in the dense areas of large cities.

**Ref. 1, page 15 uses a rough estimate of densities to make a rapid calculation of blast shelter costs and is presented here for comparison.

Table VIII

ESTIMATED COST OF 96 MILLION BLAST SHELTER SPACES
(AS A FUNCTION OF THE VULNERABILITY CRITERION, β)

β (Thousands)	Cost (\$ Billions)	Comparison Cost From Ref. 1 (\$ Billions)
1	73.8	64.8
2	53.5	47.2
3	44.6	39.4
4	39.3	34.8
5	35.6	31.6
8	29.2	26.0
10	26.6	23.8
15	22.6	20.3
20	20.2	18.2
25	18.6	16.8
30	17.4	15.8
40	15.7	14.3
50	14.6	13.3
60	13.7	12.5
80	12.5	11.5

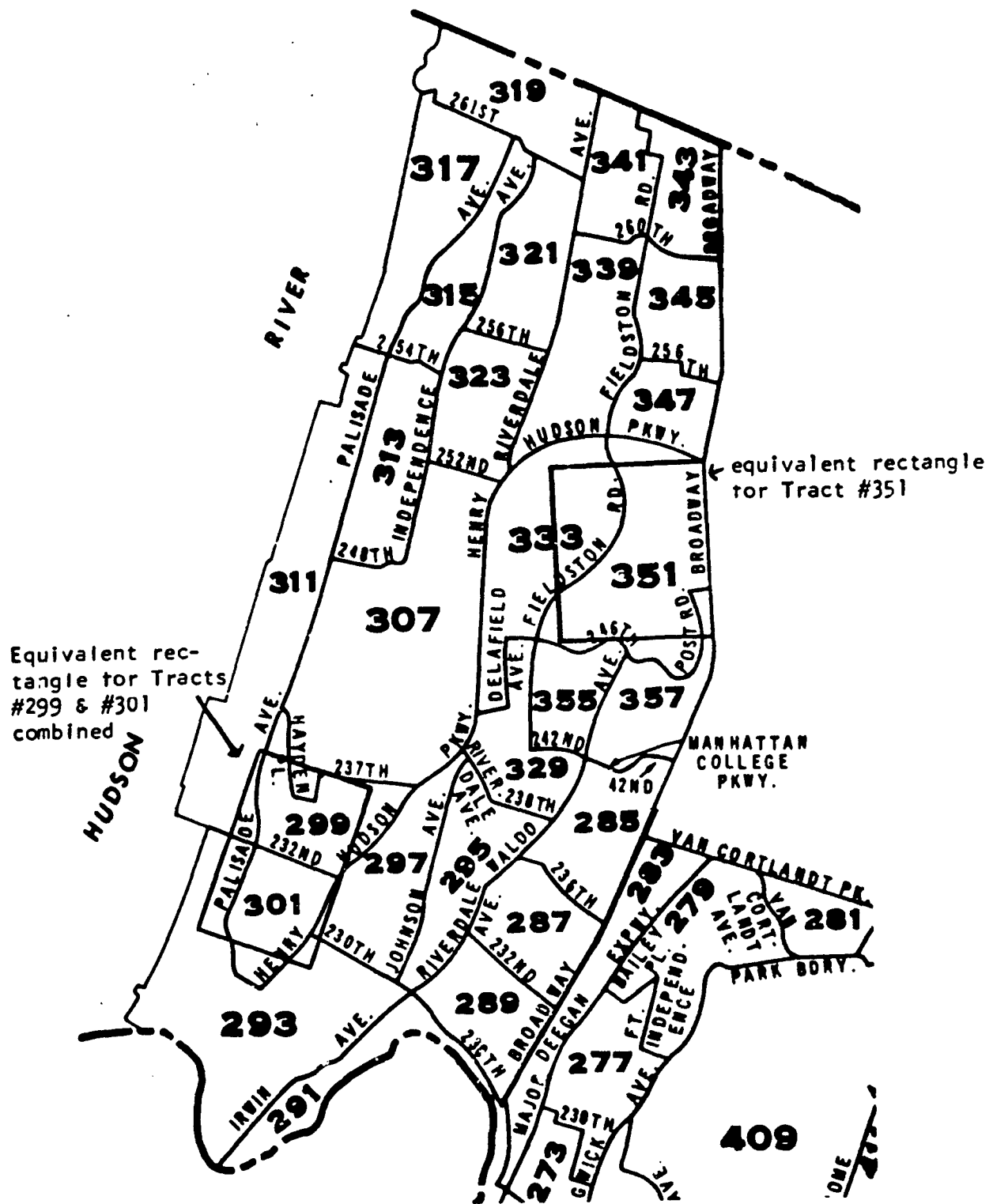


Figure 1. BRONX--SECTION OF THE AREA--ILLUSTRATING "EQUIVALENT RECTANGLES"

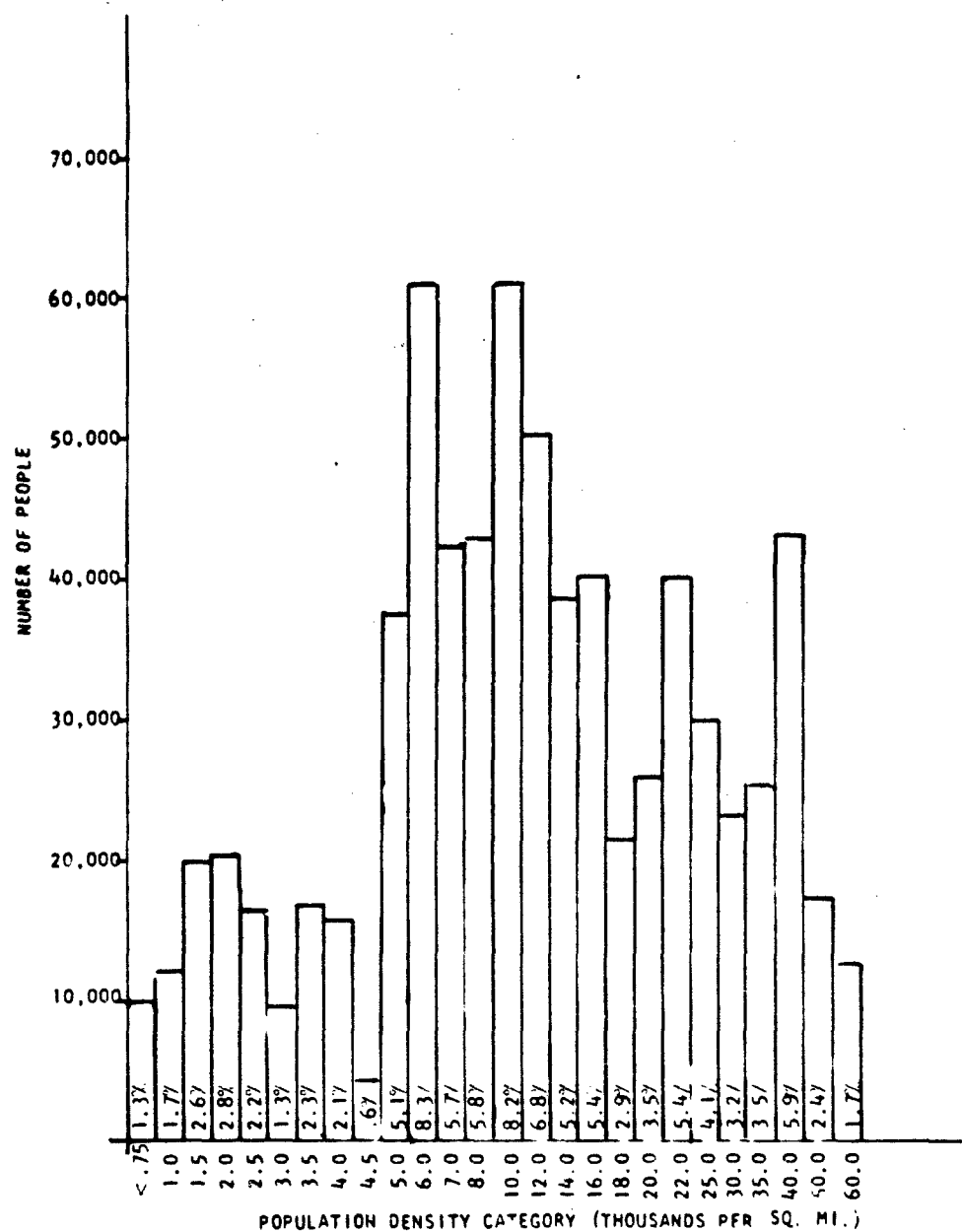


Figure 2. COMPOSITE CITY--COMPOSED OF CITIES
WITH POPULATION FROM 500,000 TO 1,000,000

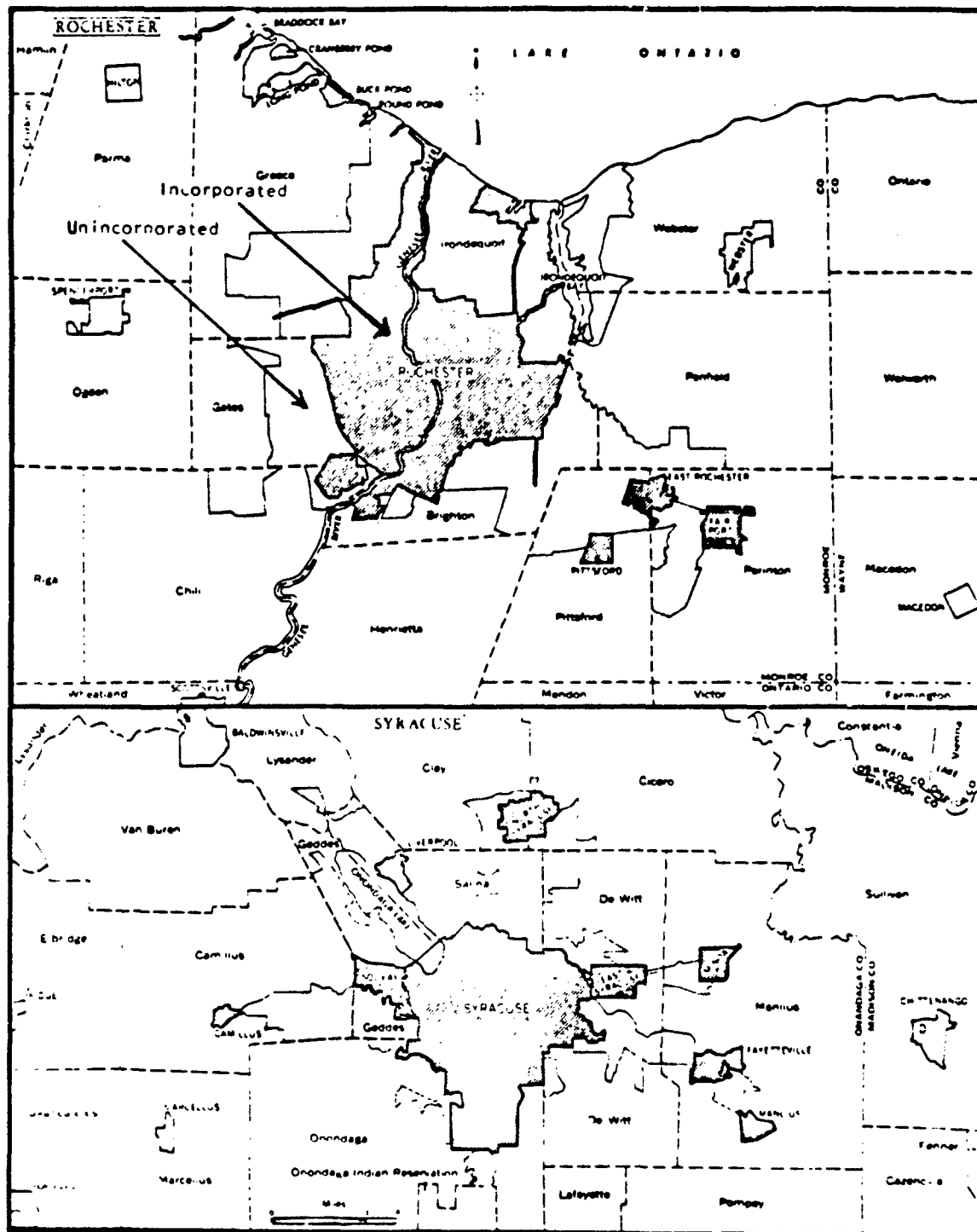


Figure 3. URBANIZED AREAS --NEW YORK

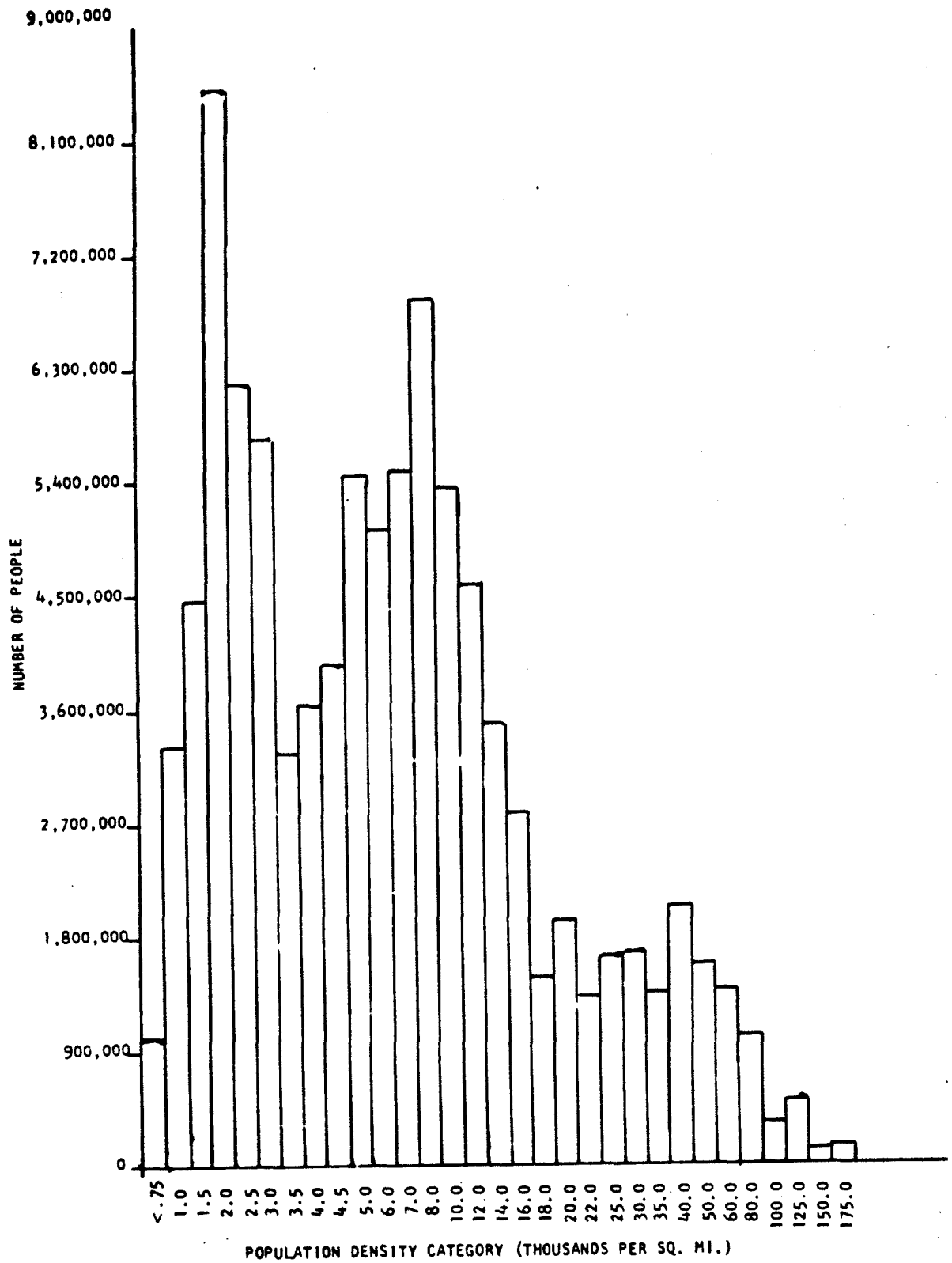


Figure 4. POPULATION DISTRIBUTION OF UNITED STATES--URBANIZED AREAS

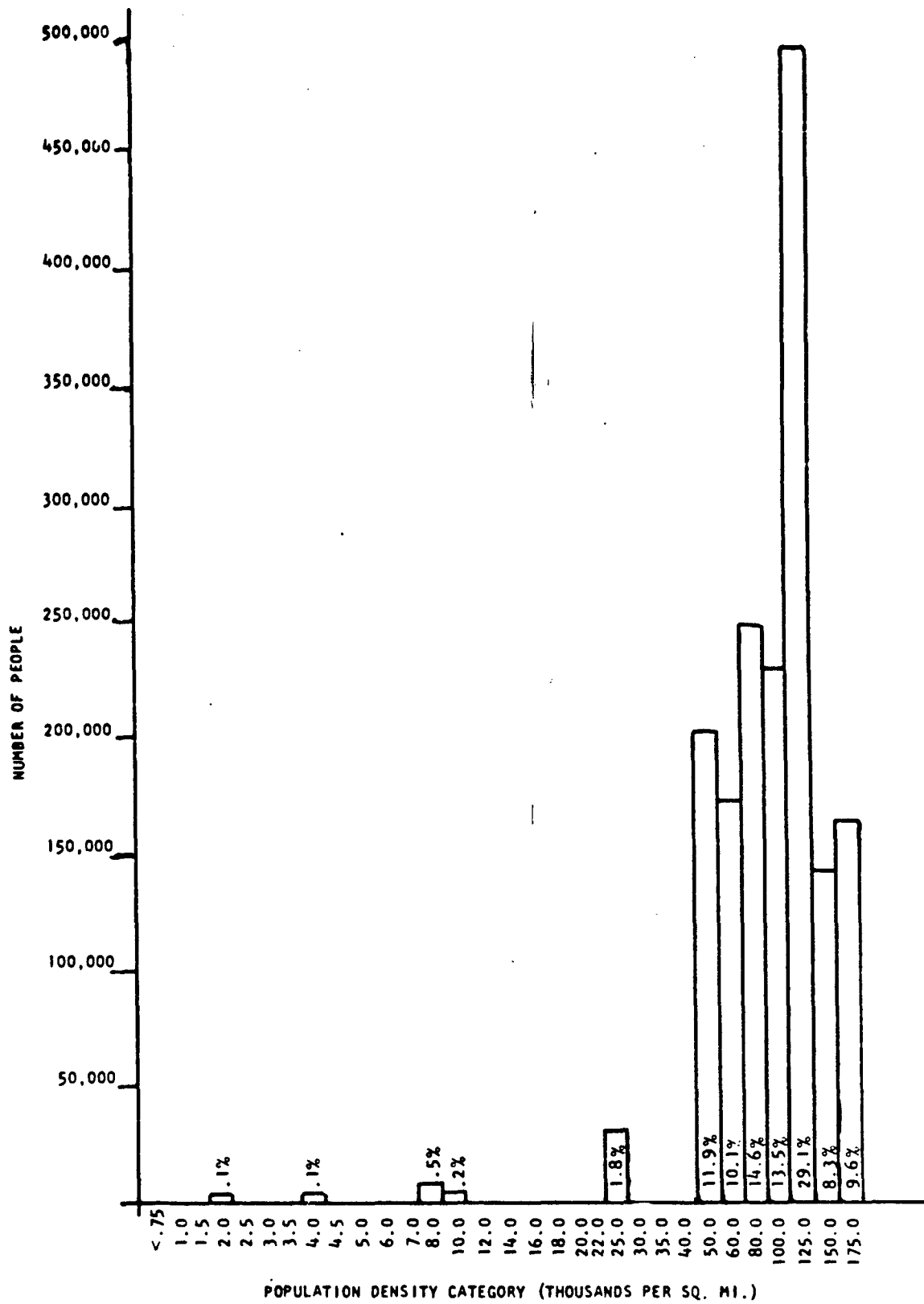


Figure 5. MANHATTAN-- DISTRIBUTION OF POPULATION

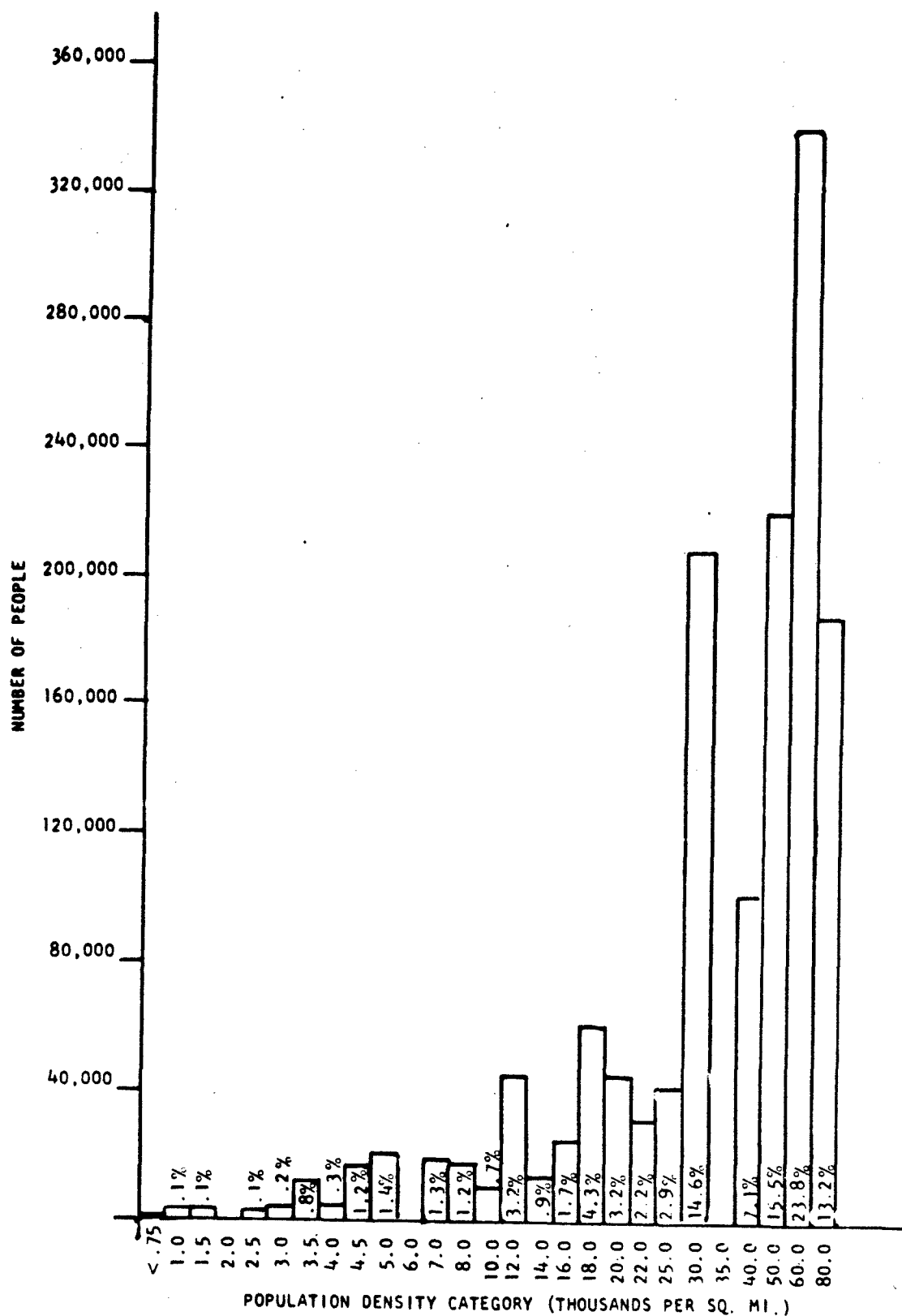


Figure 6. BRONX--DISTRIBUTION OF POPULATION

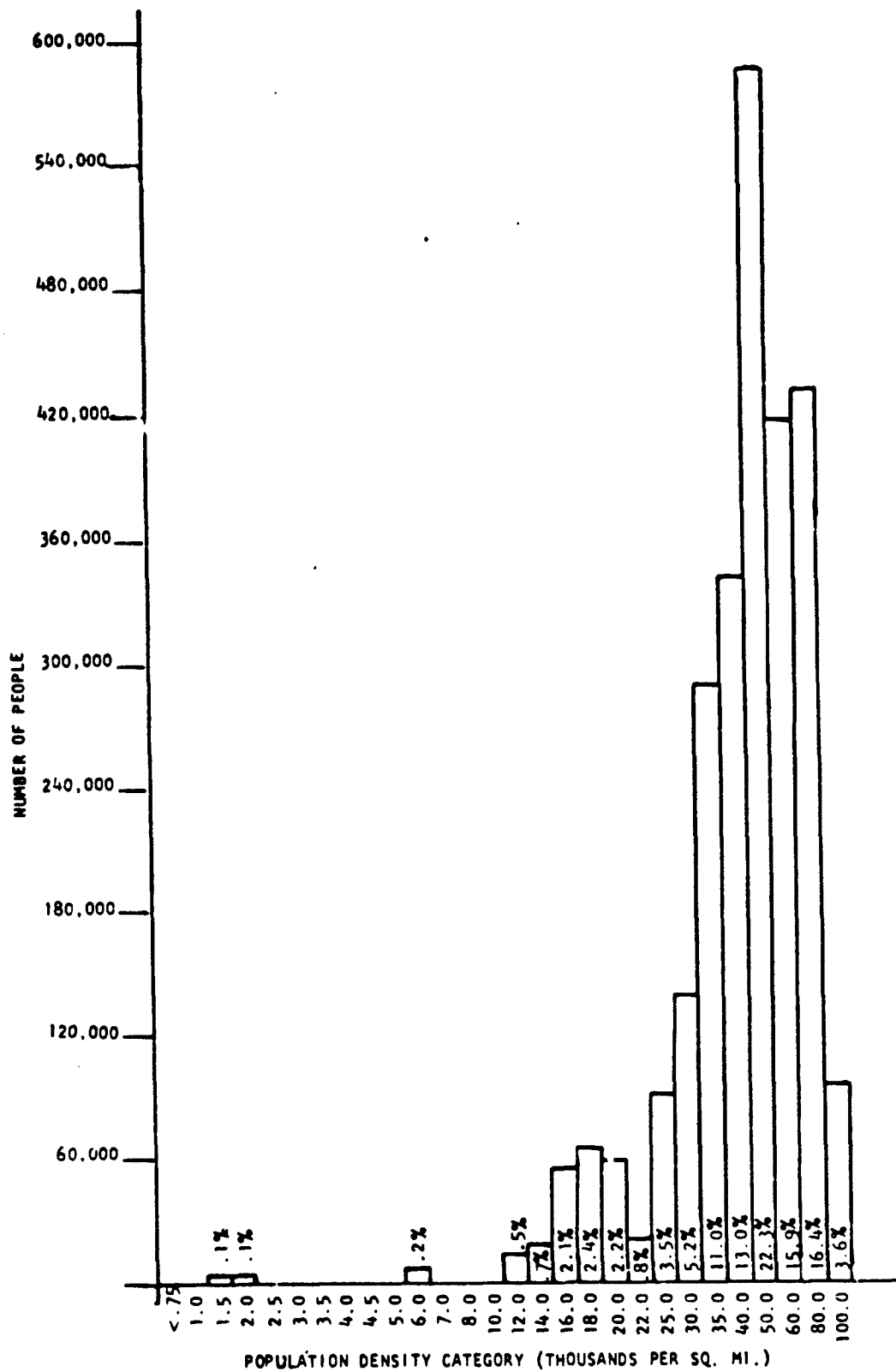


Figure 7. BROOKLYN--DISTRIBUTION OF POPULATION

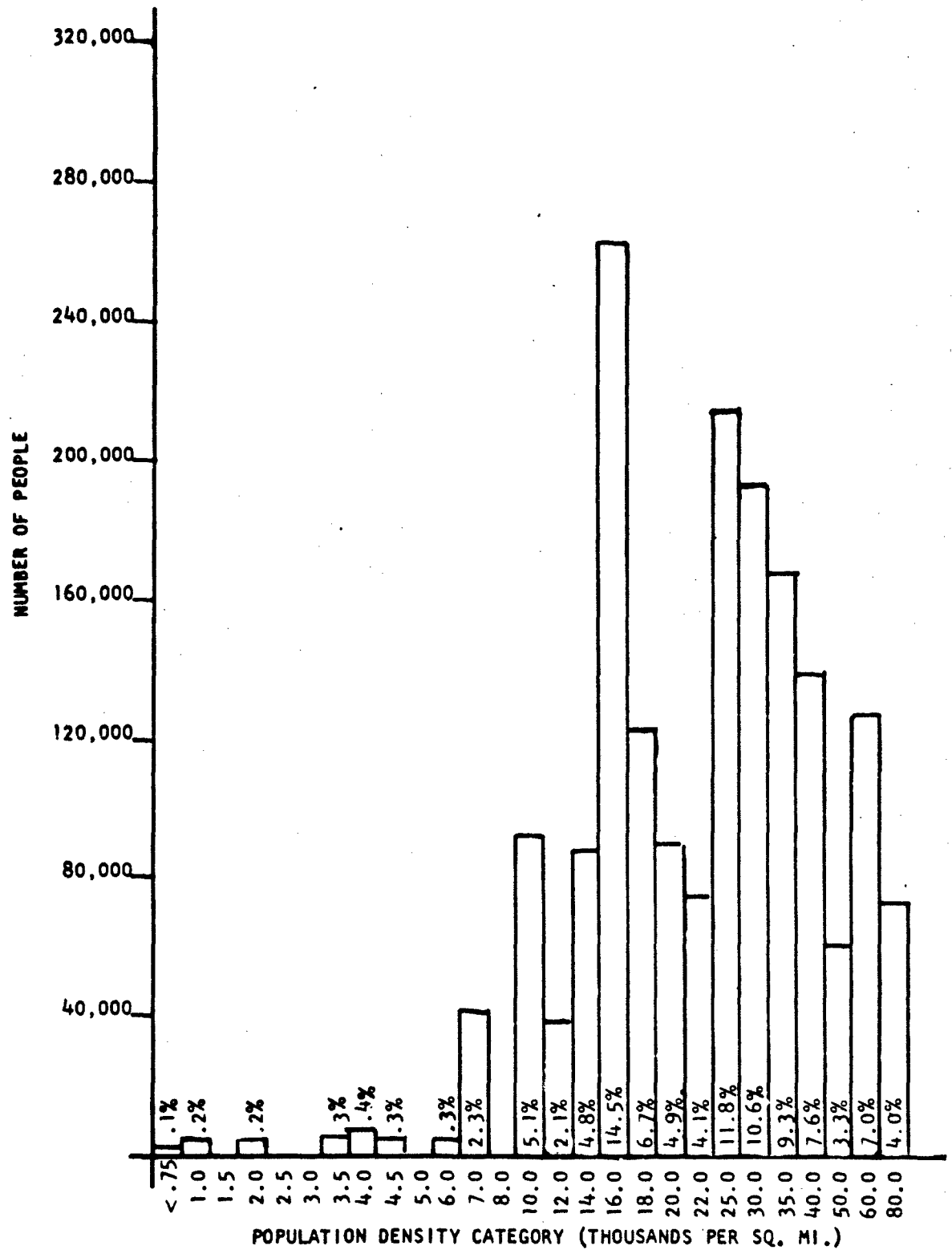


Figure 8. QUEENS--DISTRIBUTION OF POPULATION

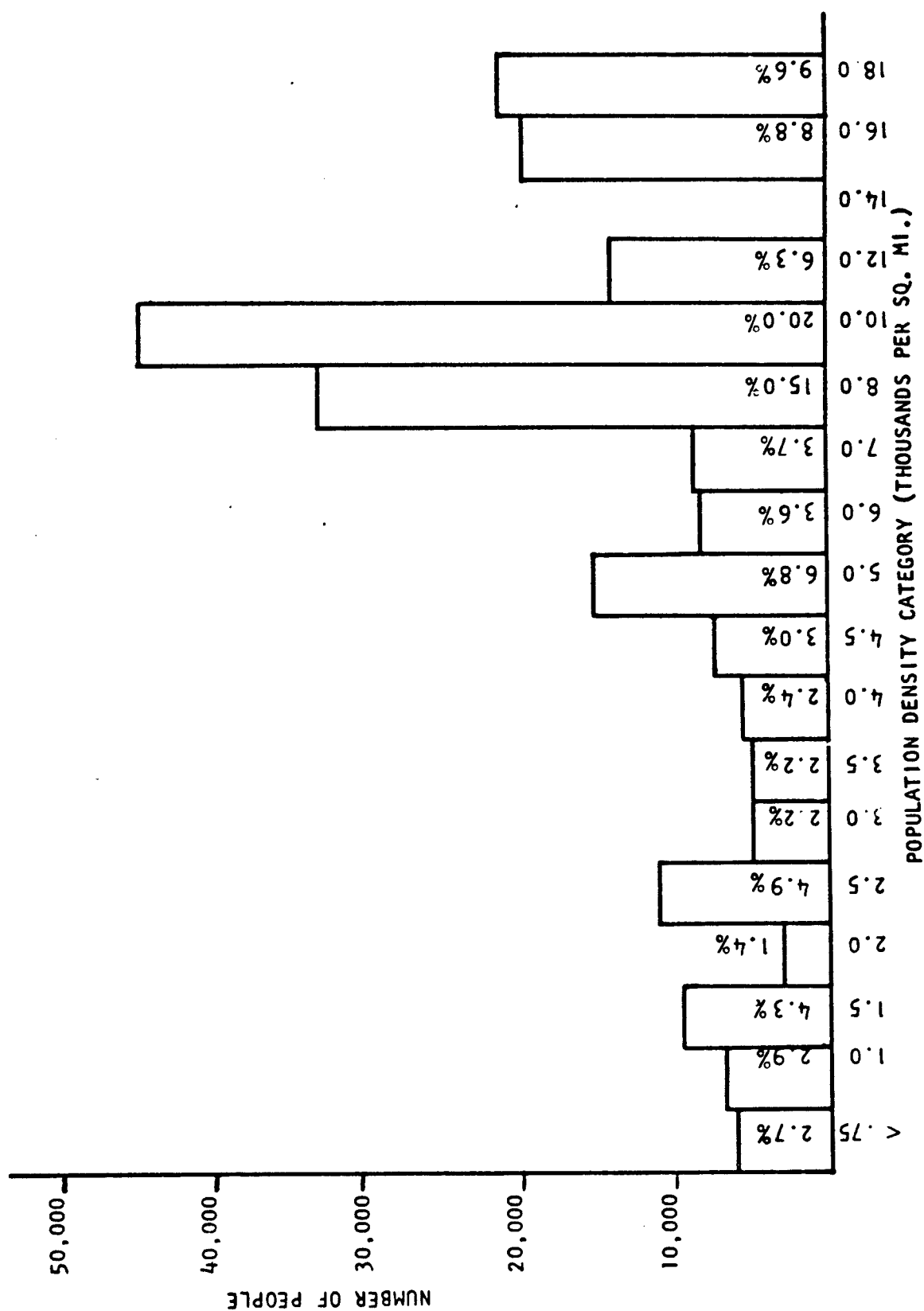
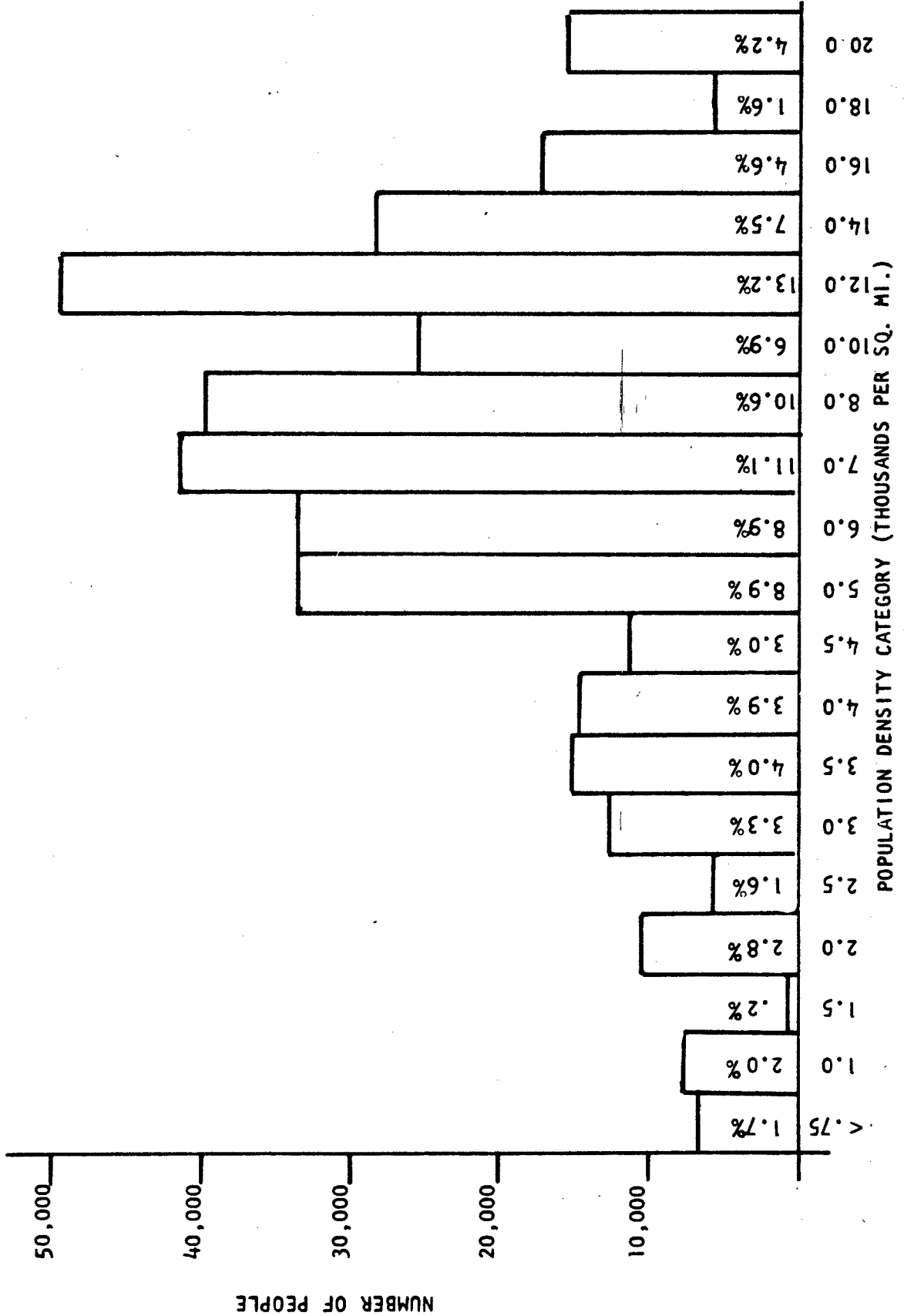


Figure 9. RICHMOND--DISTRIBUTION OF POPULATION



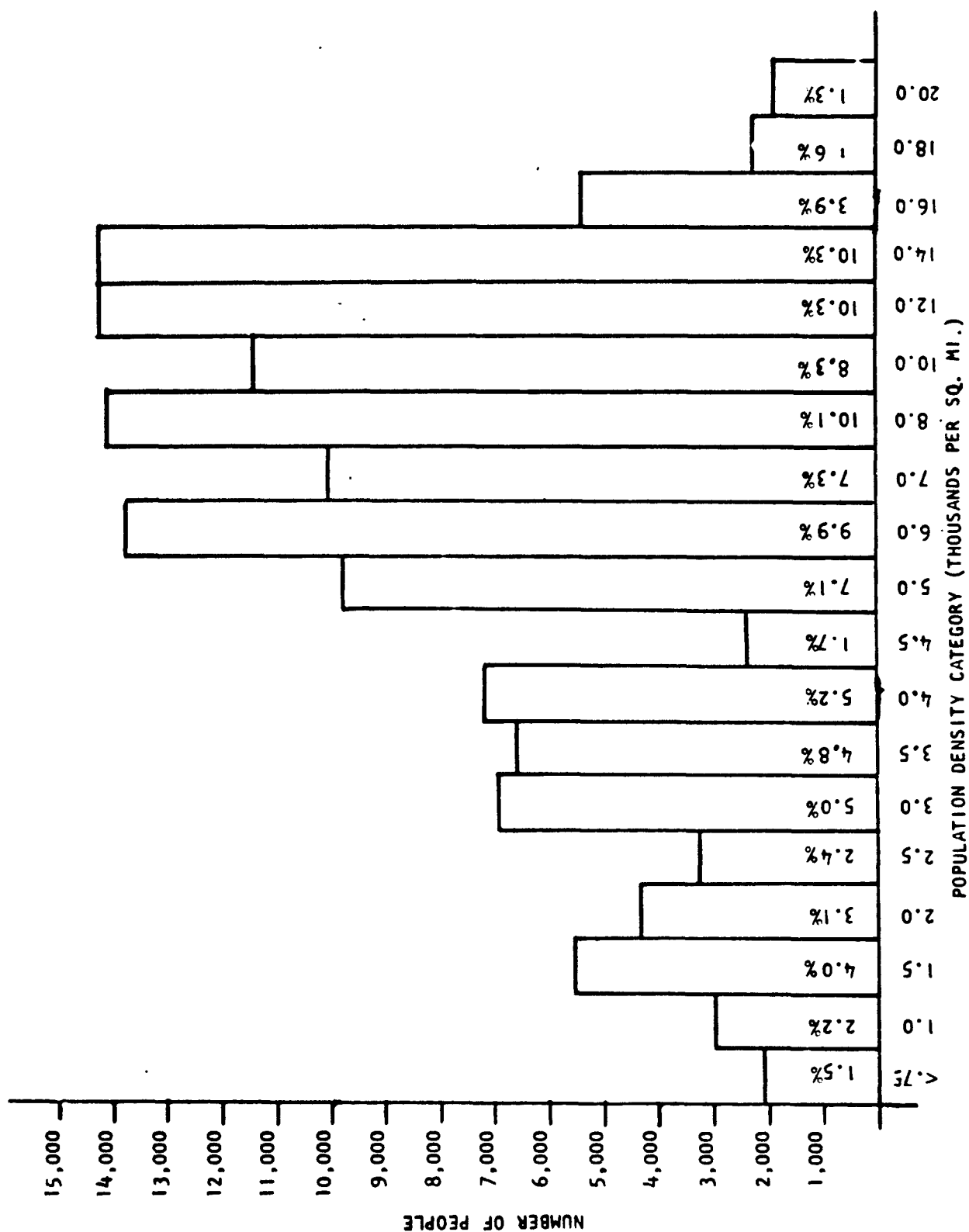
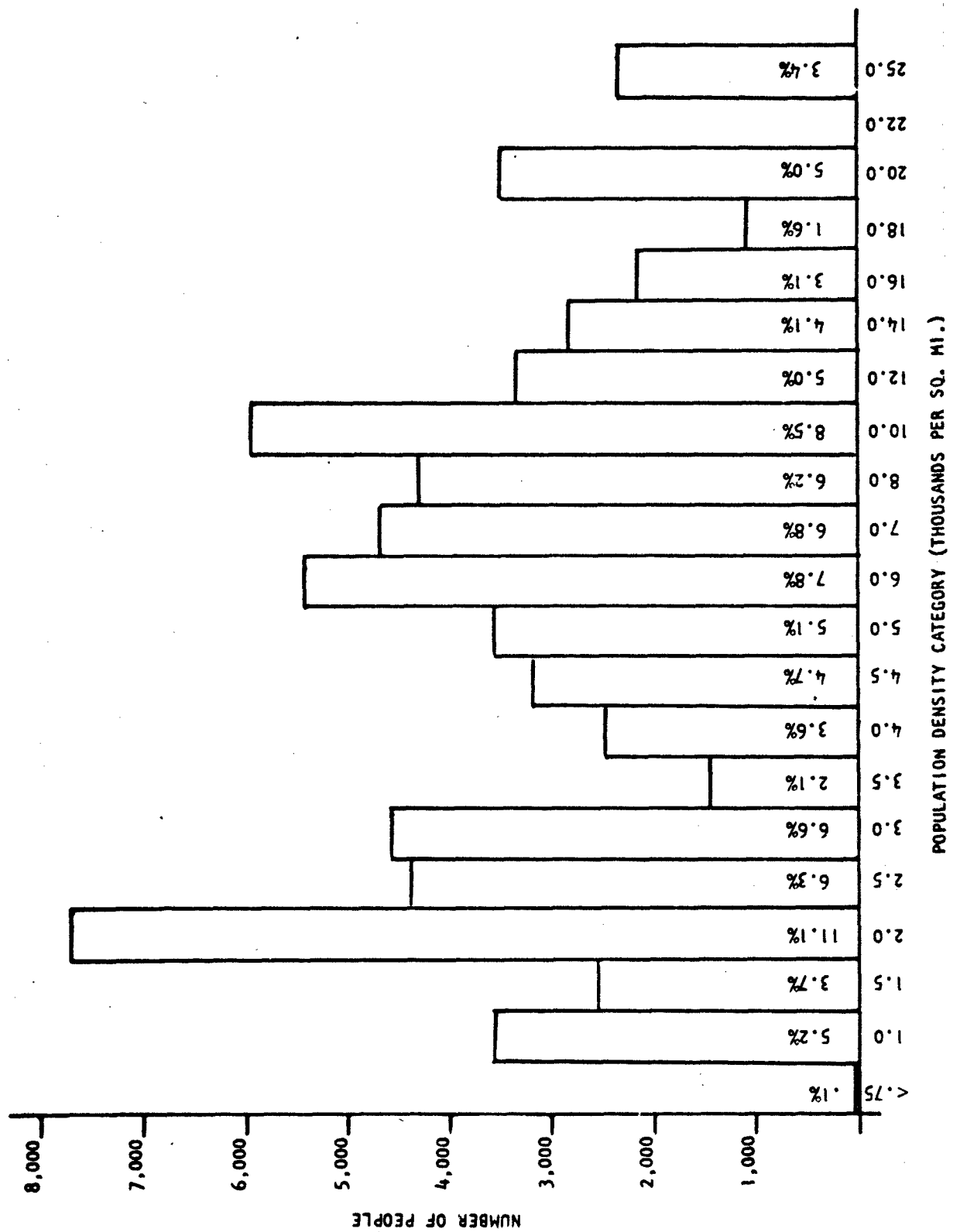


Figure 11. "COMPOSITE CITY"--POPULATION 100,000 to 250,000



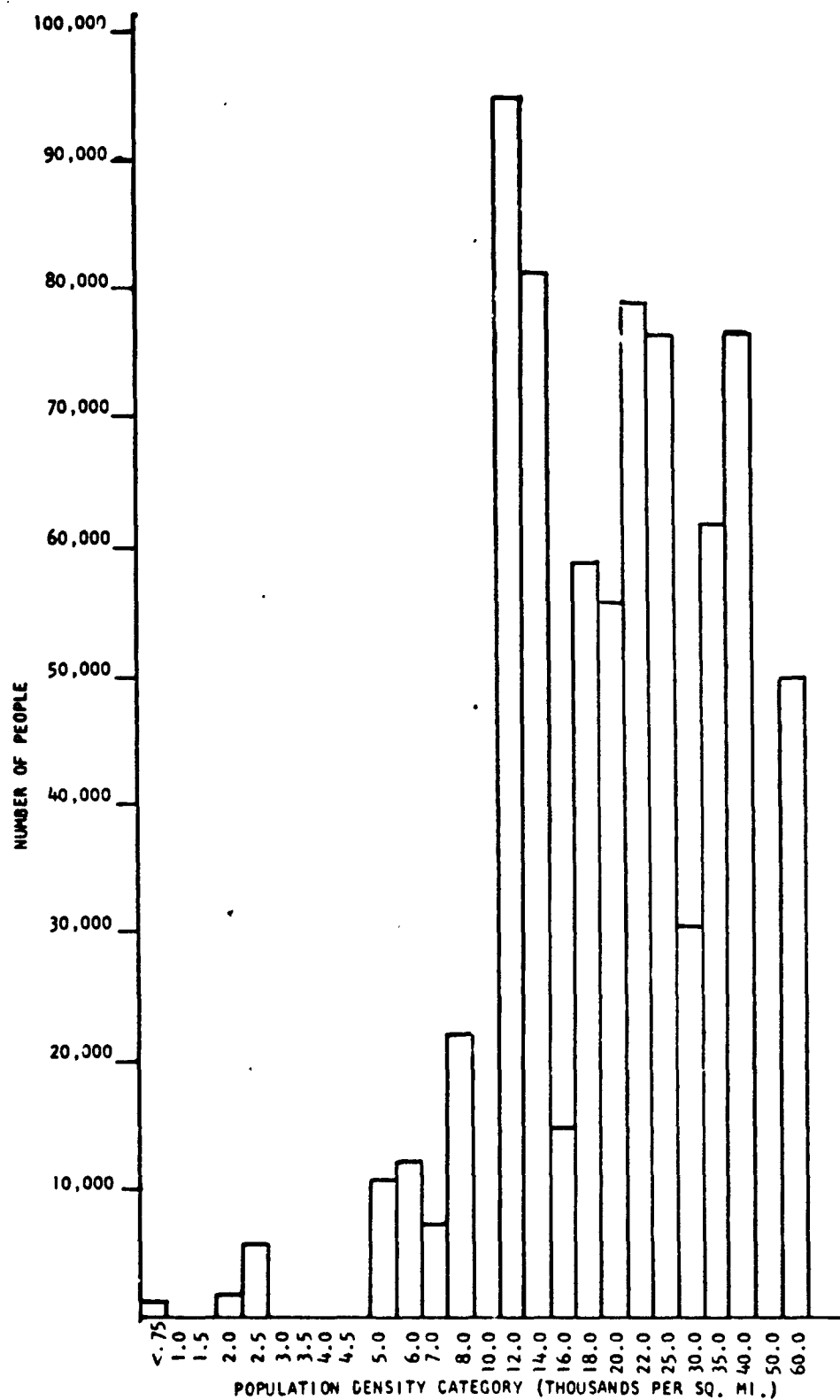


Figure 13. SAN FRANCISCO, CALIFORNIA--POPULATION DISTRIBUTION

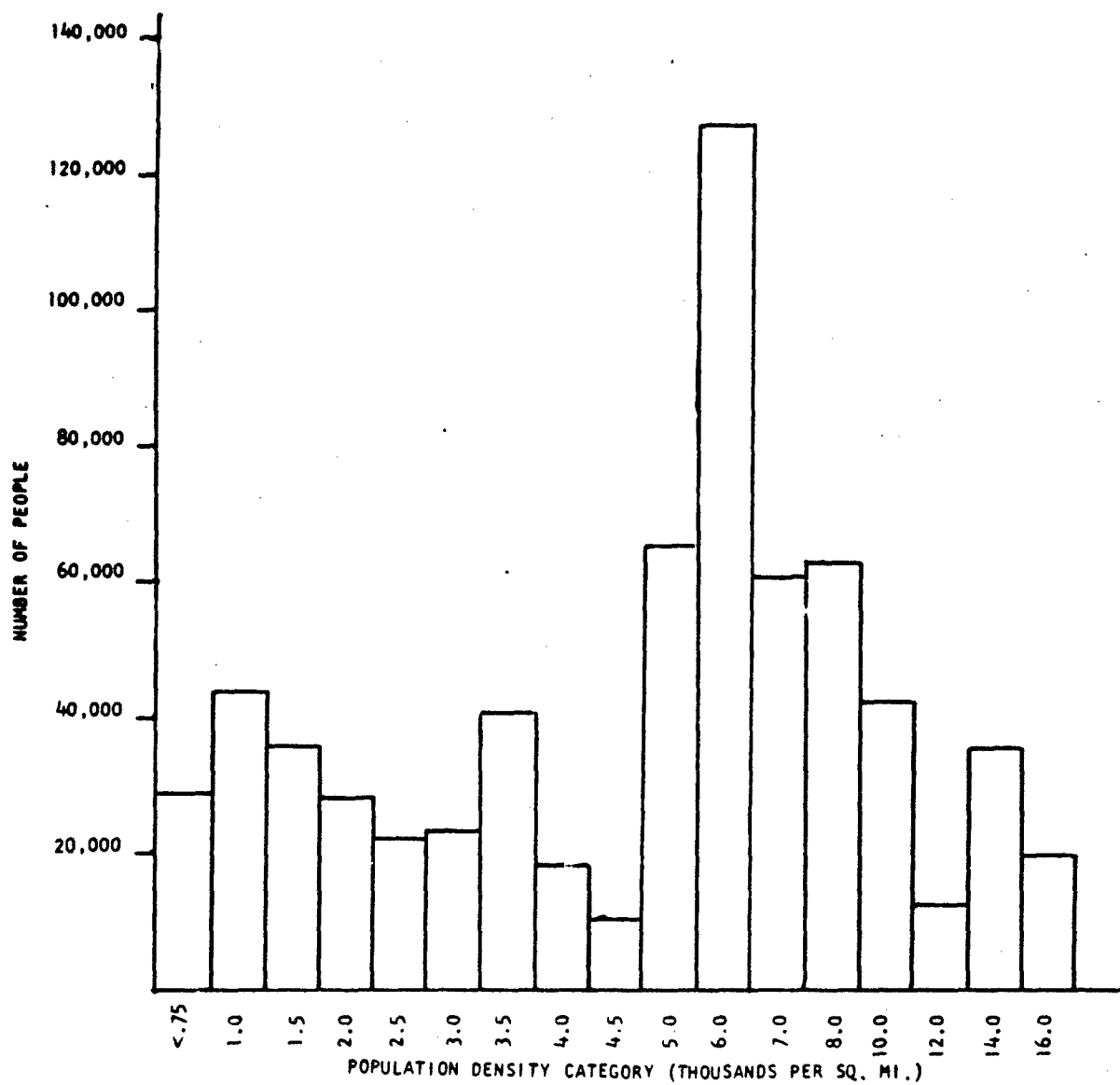


Figure 14. DALLAS, TEXAS--POPULATION DISTRIBUTION

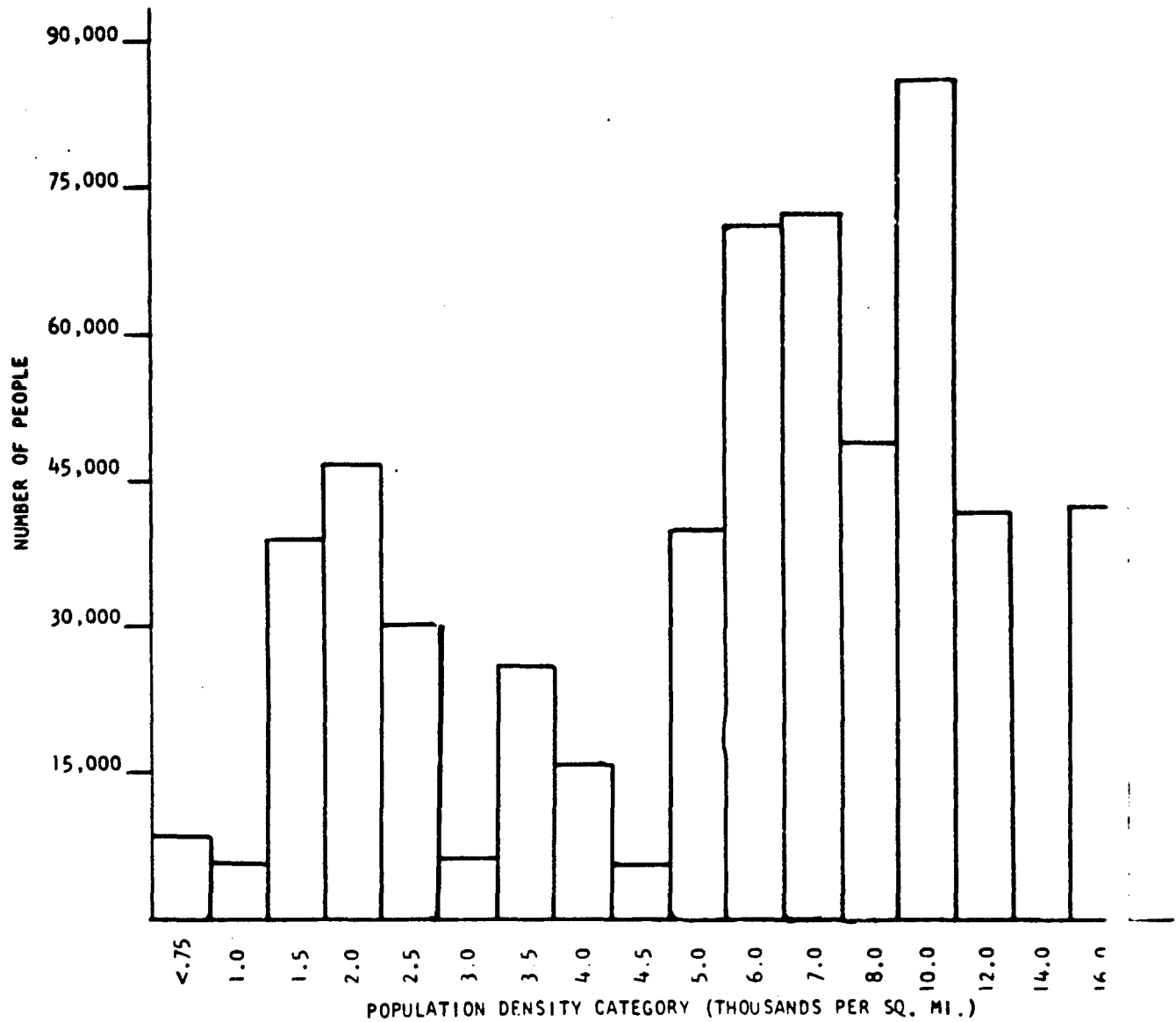
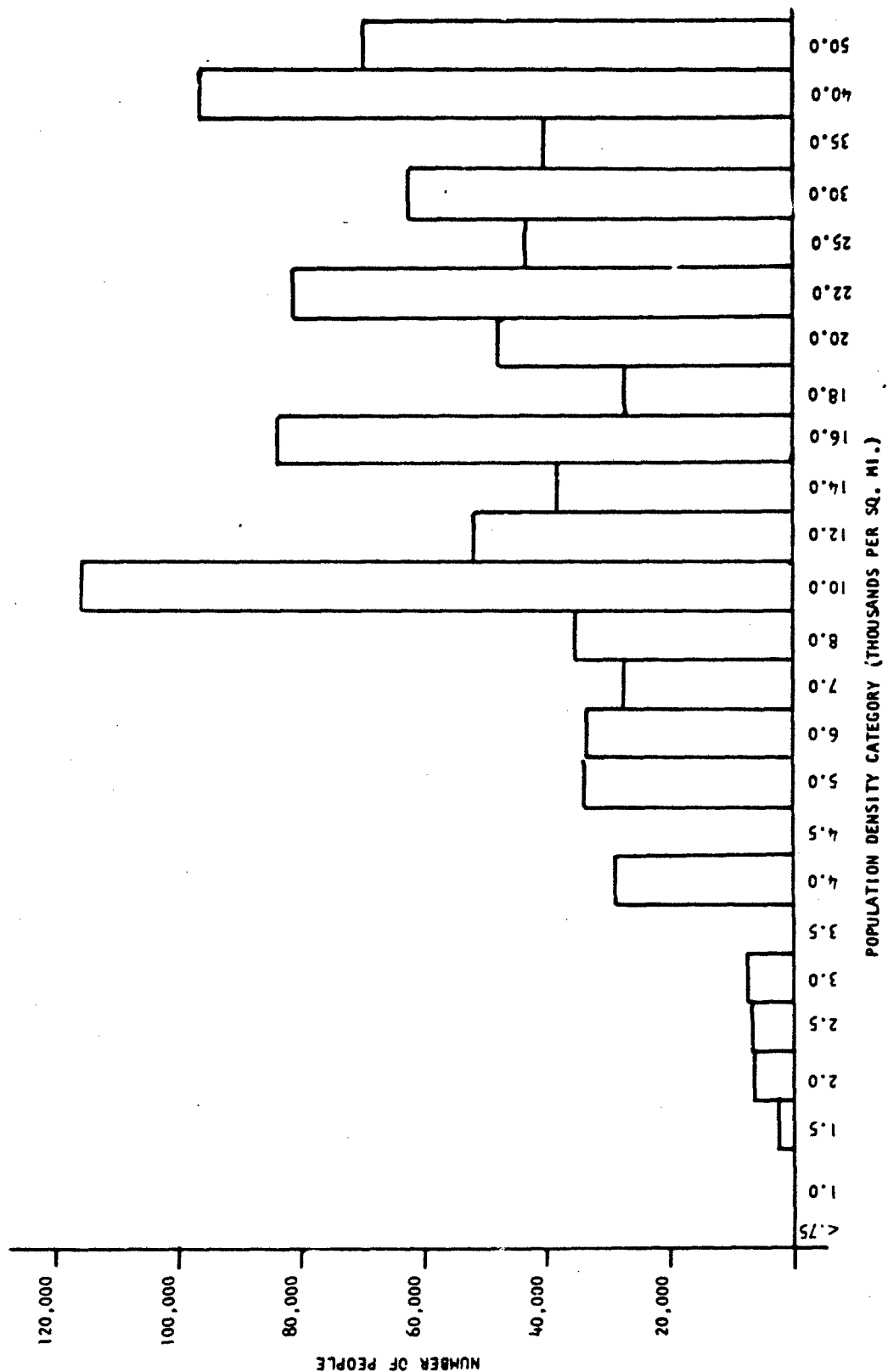


Figure 15. SAN ANTONIO, TEXAS--POPULATION DISTRIBUTION



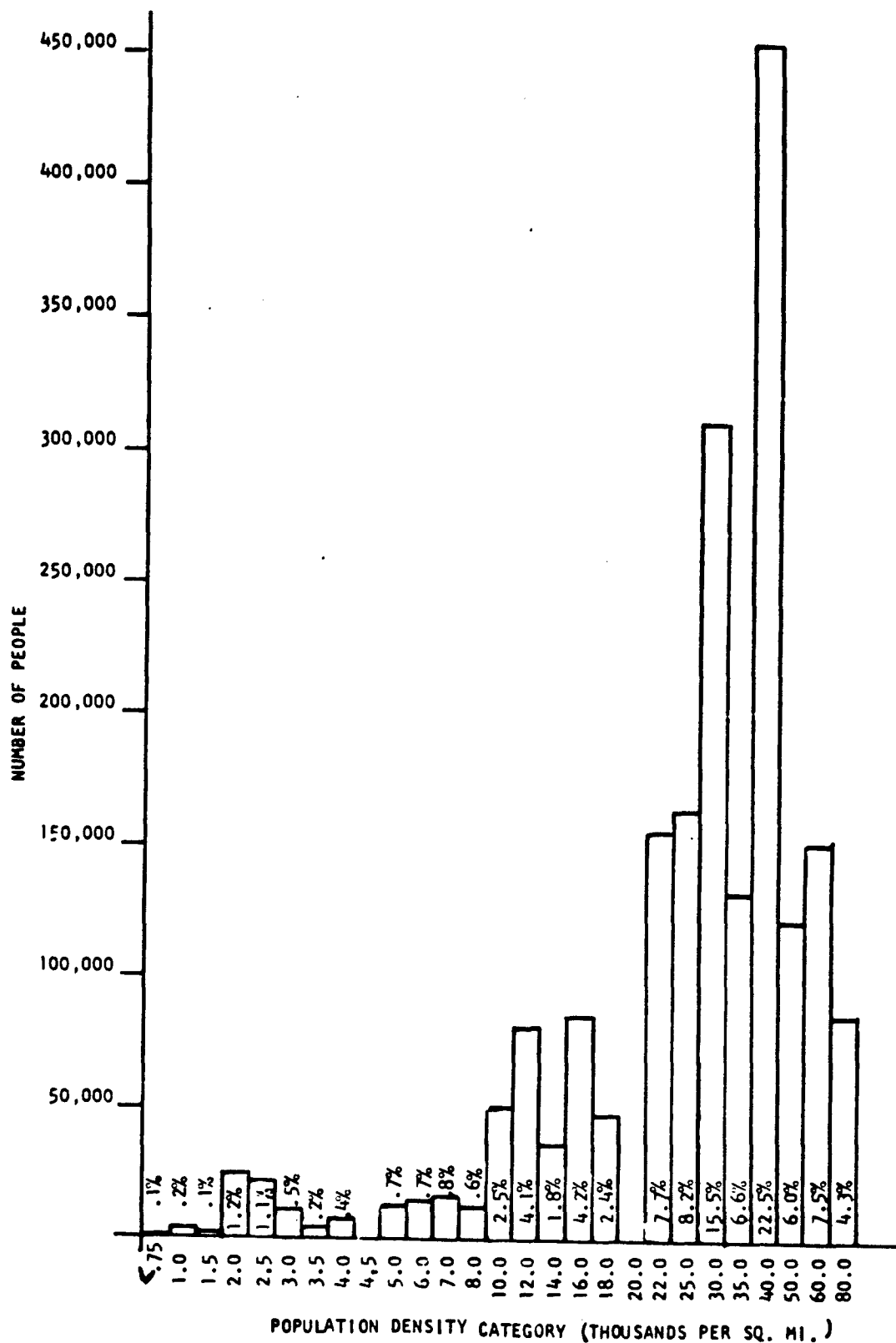
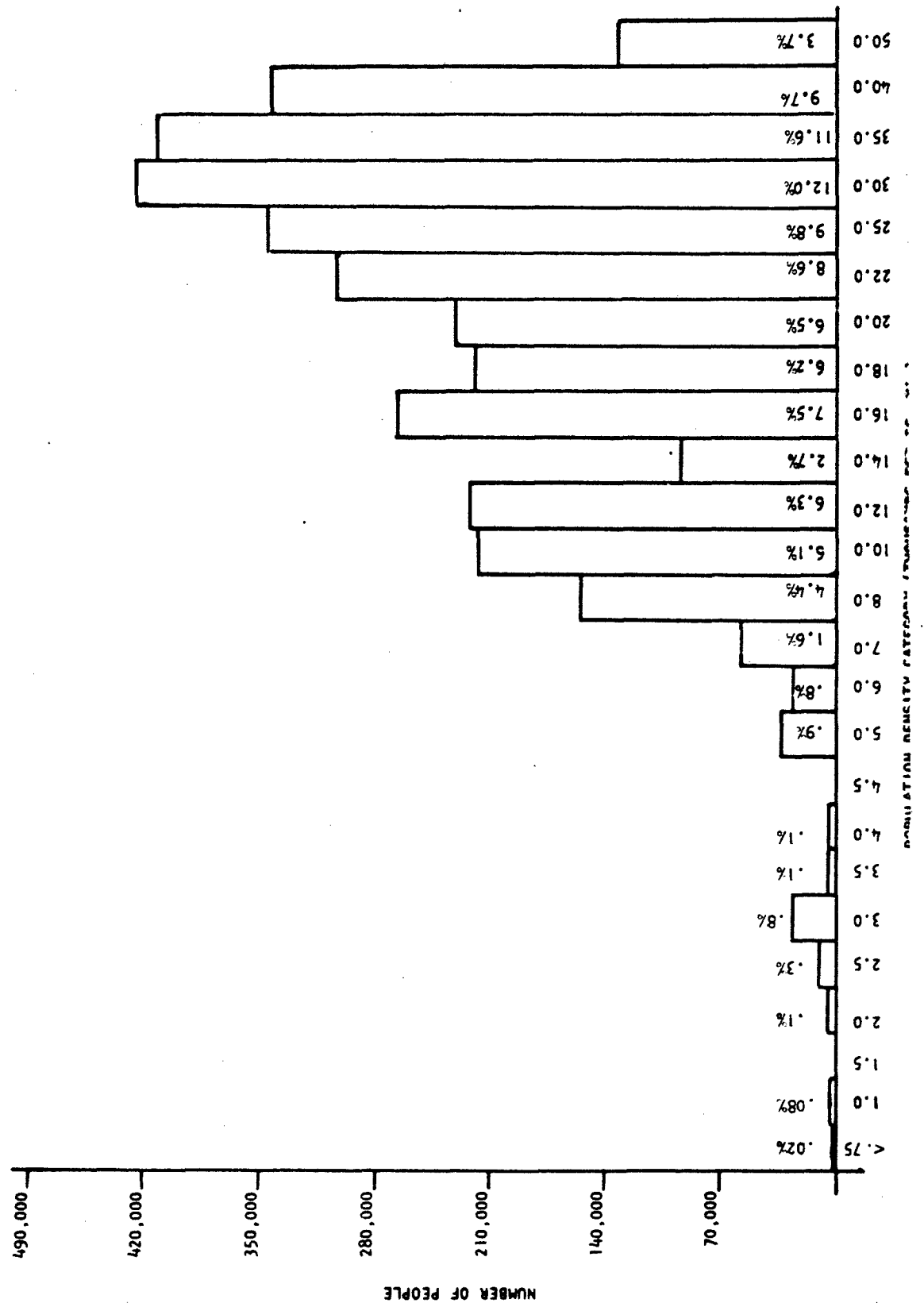


Figure 17. PHILADELPHIA, PENNSYLVANIA--POPULATION DISTRIBUTION



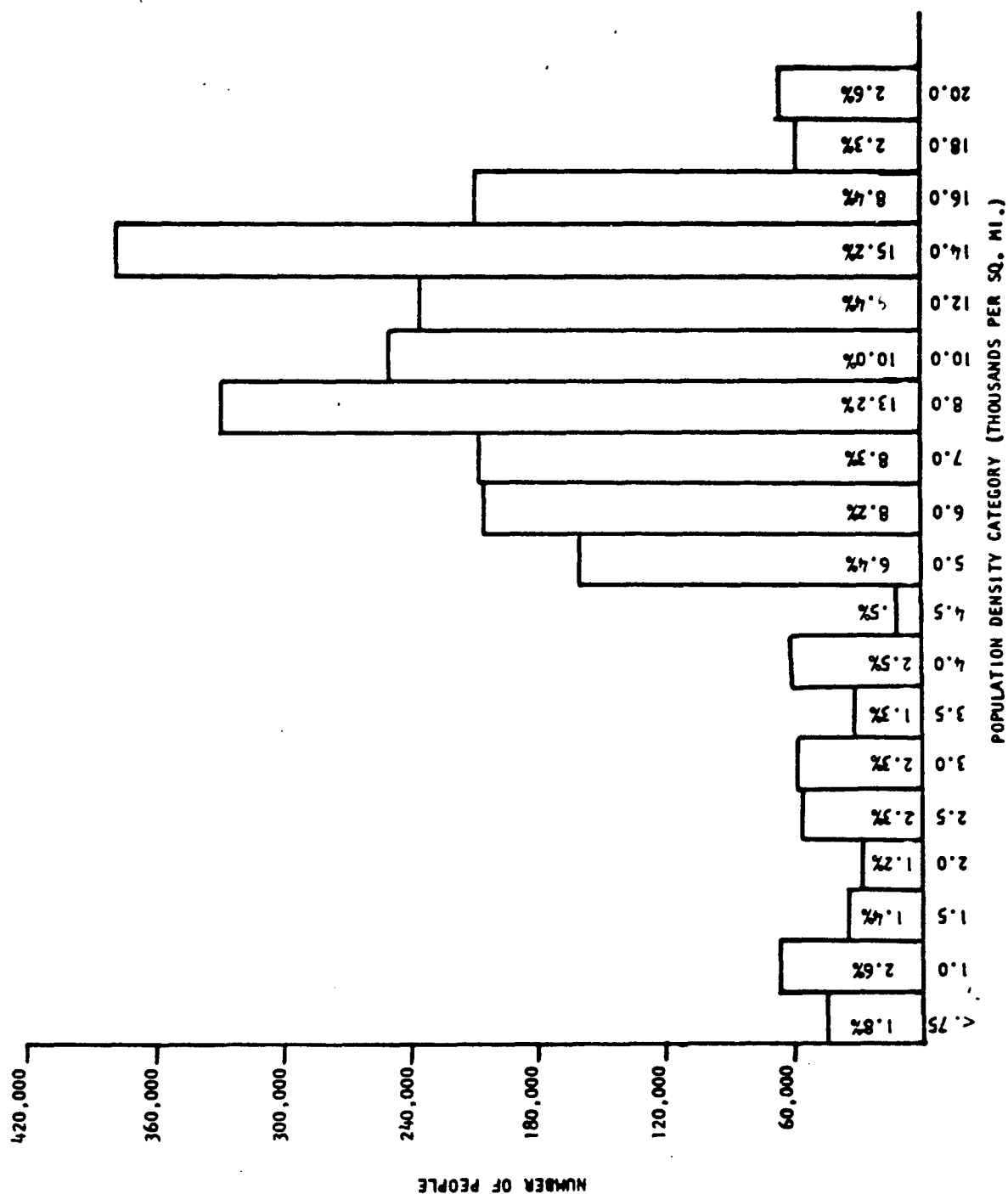
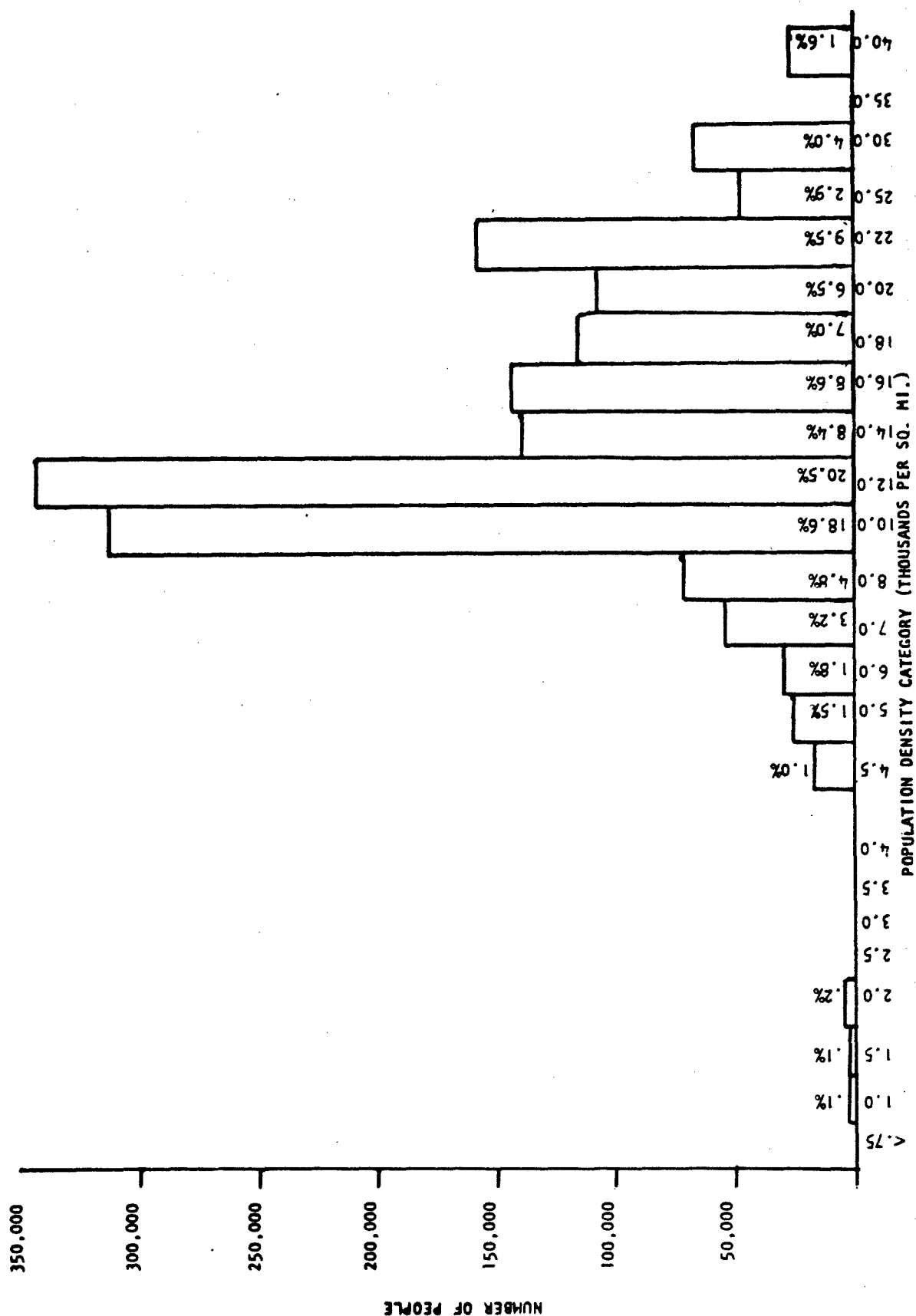


Figure 19. LOS ANGELES, CALIFORNIA--POPULATION DISTRIBUTION



APPENDIX A

Details on Manhattan

Because of the unusual interest many people find in the borough of Manhattan, a special computation was made showing the population density distribution of Manhattan census tract by census tract. The results of this computation are given in this appendix in two forms: (1) a graph (Figure 21) showing the variation of population density running from a very small number (less than 750 per square mile) to the maximum of 250,000 per square mile; and (2) a detailed tabulation (Table IX) of the data, giving the population, the area, and the population densities of each tract. The appendix also contains a map of the Island of Manhattan (Figure 22) showing the various census tract districts by number and a map of Manhattan (Figure 23) with shaded areas indicating the average population densities.

In addition, Table X shows the groups of census tracts which give the composite picture, presented earlier (ungrouped) in Table IX. The area of the groups of tracts over which the density is averaged is approximately one square mile. There are always special problems in doing these groupings, since there is an essential arbitrariness in the choice of the boundaries of the groups of the tracts. Central Park, for example, measures more than half a square mile in area but has no people. The adjacent tracts to which it was grouped have high densities (up to 200,000), giving an area of 1.1 square miles with an over-all density of 60,000. From Figure 22, Figure 23 and Table IX, one can observe where the relatively high and low density population areas are. Areas of low density are associated with some of the business districts, while high density areas are found on the lower East side, Greenwich Village, and West and North of Central Park.

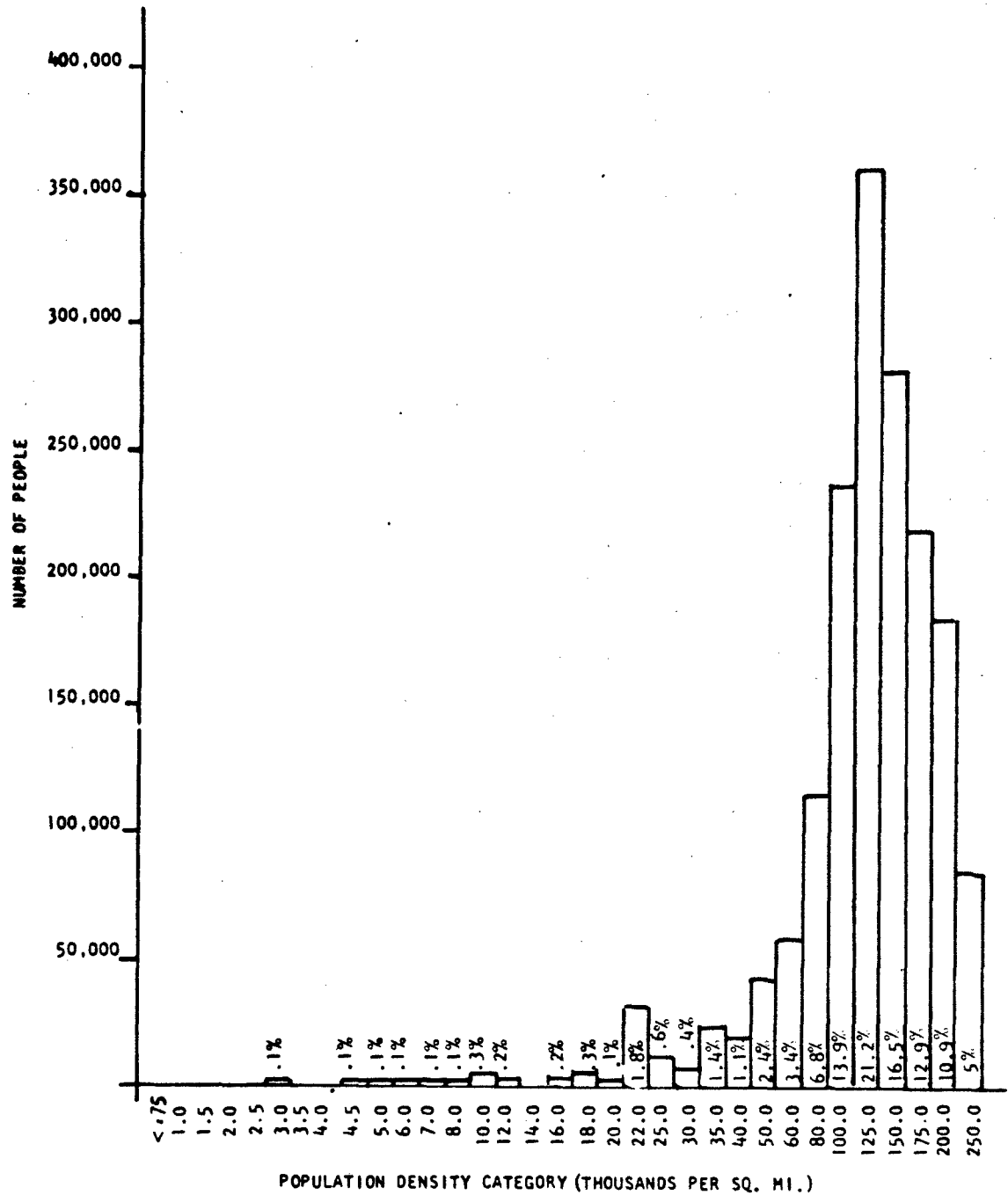


Figure 21. MANHATTAN--POPULATION DENSITIES OF UNGROUPED TRACTS



Figure 22. MANHATTAN CENSUS TRACTS

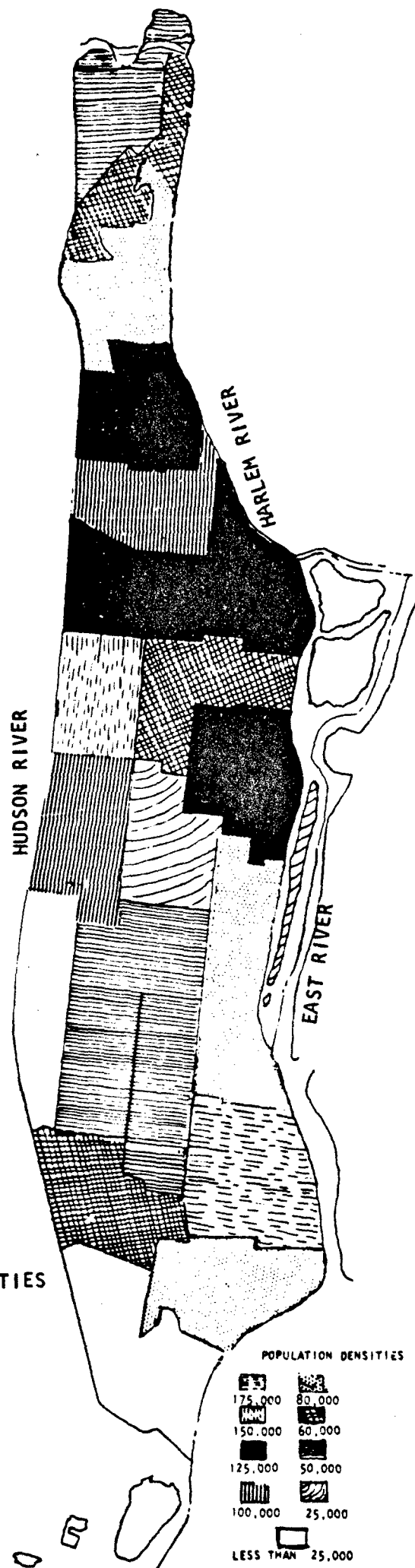


Figure 23. POPULATION DENSITIES
OF GROUPED TRACTS

Table IX

MANHATTAN--POPULATION DENSITIES

Tracts	Population	Area/Sq. Mi.	Population Density	Population Density Category
1	--	.040	--	--
2	13,529	.170	79,582	80,000
3	13	.022	591	750
5	1,207	.273	4,421	4,500
6	8,430	.100	84,300	80,000
7	54	.093	581	750
8	9,085	.095	95,632	100,000
9	736	.116	6,342	6,000
10-0	2,415	.023	105,000	100,000
10-1	8,519	.086	99,058	100,000
11	--	.060	--	--
12	5,719	.032	178,719	175,000
13	386	.122	3,164	3,000
14	6,905	.068	101,544	100,000
15	678	.215	3,153	3,000
16	5,524	.080	69,050	60,000
18	9,359	.072	129,986	125,000
20	7,734	.051	151,647	150,000
21	186	.122	1,525	1,500
22	9,805	.083	118,133	125,000
24	7,721	.068	113,544	125,000
25	8,340	.047	177,447	175,000
26	17,496	.070	249,943	250,000
27	597	.029	20,586	20,000
28	8,201	.060	136,683	125,000
29	7,091	.056	126,625	125,000
30	10,467	.070	149,529	150,000
31	11	.072	153	750
32	10,051	.070	143,586	150,000
33	55	.116	474	750
34	10,359	.060	172,650	175,000
36	9,502	.065	146,185	150,000
38	12,062	.070	172,314	175,000
39	141	.220	641	750
40	10,878	.060	181,300	175,000
41	8,993	.068	132,250	125,000
42	1,062	.033	32,182	30,000
43	5,793	.050	115,860	125,000
44	22,405	.146	153,459	150,000
45	224	.032	7,000	7,000
47	1,959	.056	34,982	35,000
48	6,862	.060	114,367	125,000
49	3,787	.069	54,884	50,000
50	3,658	.062	59,000	60,000

(Continued)

Table IX

MANHATTAN--POPULATION DENSITIES (Continued)

Tracts	Population	Area/Sq. Mi.	Population Density	Population Density Category
51	1,787	.077	23,208	22,000
52	203	.060	3,383	3,500
53	337	.086	3,919	4,000
54	773	.061	12,672	12,000
55	3,605	.079	45,633	50,000
56	1,169	.061	19,164	20,000
57	162	.034	4,765	12,000
58	521	.061	8,541	8,000
59	5,030	.043	116,978	125,000
60	5,784	.060	96,400	100,000
61	2,421	.050	48,420	50,000
62	1,953	.111	17,595	18,000
63	6,762	.067	100,925	100,000
64	5,687	.060	94,783	100,000
65	8,367	.071	117,845	125,000
66	10,658	.060	177,633	175,000
67	7,041	.062	113,565	125,000
68	4,690	.061	76,885	80,000
69	329	.077	4,273	4,500
70	5,417	.060	90,283	100,000
71	6,310	.068	92,794	100,000
72	5,549	.061	90,967	100,000
73	8,369	.063	132,841	125,000
74	3,024	.061	49,574	50,000
75	2,488	.072	34,556	35,000
76	1,553	.061	24,459	25,000
77	6,738	.057	118,211	125,000
78	3,293	.060	54,883	60,000
79	2,385	.129	18,488	18,000
80	5,473	.065	84,200	80,000
81	7,634	.065	117,446	125,000
82	2,919	.065	44,908	40,000
83	4,602	.065	70,800	80,000
84	273	.065	4,200	4,000
85	925	.174	5,316	5,000
86	4,881	.126	38,738	40,000
87	5,955	.065	91,615	100,000
88	6,228	.060	103,800	100,000
89	8,790	.065	135,231	125,000
90	4,206	.060	70,100	80,000
91	3,965	.065	61,000	60,000
92	2,810	.067	41,940	40,000
93	9,765	.065	150,231	150,000
94	446	.055	8,109	8,000
95	1,372	.065	21,108	22,000

(Continued)

Table IX

MANHATTAN--POPULATION DENSITIES (Continued)

Tracts	Population	Area/Sq. Mi.	Population Density	Population Density Category
96	967	.061	15,852	16,000
97	4,169	.065	64,138	60,000
98	7,335	.060	122,250	125,000
99	784	.258	3,039	3,000
100	3,267	.065	50,262	50,000
101	333	.065	5,123	5,000
102	695	.065	10,692	10,000
103	1,605	.065	24,692	25,000
104	1,733	.065	26,662	25,000
106-0	7,395	.039	189,615	200,000
106-1	2,970	.046	64,565	60,000
108	6,923	.060	115,383	125,000
109	308	.065	4,738	4,500
110	4,543	.060	75,717	80,000
111	3,975	.065	61,154	60,000
112	3,997	.086	46,478	50,000
113	450	.065	6,923	7,000
114	4,762	.072	66,139	60,000
115	1,849	.065	28,446	30,000
116	5,452	.072	75,722	80,000
117	635	.093	6,828	7,000
118	7,862	.060	131,033	125,000
119	2,337	.065	35,954	35,000
120	3,571	.065	54,938	50,000
121	7,475	.065	115,000	125,000
122	5,684	.065	87,446	80,000
123	796	.093	8,559	8,000
124	7,292	.088	125,724	125,000
125	3,302	.065	50,800	50,000
126	8,890	.060	148,167	150,000
127	10,640	.065	163,192	175,000
128	6,505	.068	95,662	100,000
129	3,062	.097	31,567	30,000
130	6,923	.065	106,508	100,000
131	1,573	.065	24,200	25,000
132	8,590	.070	122,714	125,000
133	7,221	.065	111,092	100,000
134	10,028	.060	167,133	175,000
135	1,482	.097	15,278	16,000
136	13,157	.079	166,544	175,000
137	7,382	.077	95,870	100,000
138	10,177	.060	169,617	175,000
139	9,412	.065	144,800	150,000
140	8,214	.065	126,369	125,000

(Continued)

Table IX

MANHATTAN--POPULATION DENSITIES (Continued)

Tracts	Population	Area/Sq. Mi.	Population Density	Population Density Cat
141	594	.097	6,124	6,000
142	6,370	.065	98,000	100,000
143	2	.608	3	750
144	9,418	.081	116,272	125,000
145	2,171	.065	33,400	35,000
146	9,349	.060	155,817	150,000
147	657	.042	15,643	16,000
148	8,263	.065	127,123	125,000
149	4,809	.065	73,985	80,000
150	9,370	.065	144,154	150,000
151	5,615	.144	38,993	40,000
152	2,664	.072	37,000	35,000
153	8,706	.065	133,938	125,000
154	7,843	.060	130,717	125,000
155	596	.093	6,409	6,000
156	7,305	.060	121,750	125,000
157	13,298	.064	204,585	200,000
158	10,377	.061	170,115	175,000
159	10,625	.090	118,056	125,000
160	9,346	.061	153,213	150,000
161	9,251	.052	177,904	175,000
162	5,850	.090	65,000	60,000
163	10,281	.086	119,547	125,000
164	13,339	.060	222,317	200,000
165	10,421	.065	160,323	150,000
166	11,014	.065	169,446	175,000
167	8,689	.086	101,035	100,000
168	9,772	.072	135,722	120,000
169	14,920	.065	229,538	250,000
170	6,302	.060	105,033	100,000
171	12,922	.086	150,256	150,000
172	10,129	.061	166,049	175,000
173	12,702	.065	195,415	200,000
174	9,031	.050	180,620	175,000
175	12,175	.079	154,114	150,000
176	--	.585	--	--
177	15,073	.065	231,892	250,000
178	8,370	.105	79,714	80,000
179	11,387	.079	144,139	150,000
180	12,306	.065	189,323	200,000
181	10,582	.052	203,500	200,000
182	12,519	.065	192,600	200,000
183	10,847	.079	137,304	125,000
184	9,495	.065	146,077	150,000
185	1,561	.048	32,521	35,000

(Continued)

Table IX

MANHATTAN--POPULATION DENSITIES (Continued)

Tracts	Population	Area/Sq. Mi.	Population Density	Population Density Category
186	9,783	.043	227,512	250,000
187	12,810	.079	162,152	150,000
188	8,794	.047	187,106	175,000
189	19,613	.087	225,437	250,000
190	7,922	.036	220,056	200,000
191	12,313	.079	155,861	150,000
192	6,374	.068	93,735	100,000
193	12,126	.068	178,324	175,000
194	10,263	.060	171,050	175,000
195	10,529	.079	133,278	125,000
196	7,851	.065	115,456	125,000
197-0	118	.050	2,360	2,500
197-1	3,915	.027	145,000	150,000
198	5,289	.065	81,369	80,000
199	12,627	.079	159,835	150,000
200	6,101	.065	93,862	100,000
201-0	2,769	.036	76,917	80,000
201-1	6,604	.032	206,375	200,000
202	3,127	.070	44,671	40,000
203	4,221	.072	58,625	60,000
204	3,301	.057	57,912	60,000
205	6,019	.100	60,190	80,000
206	7,890	.054	146,111	150,000
207-0	3,900	.036	108,333	100,000
207-1	6,443	.036	178,972	175,000
208	10,368	.054	192,000	200,000
209-0	5,698	.048	118,708	125,000
209-1	2,224	.022	101,091	100,000
210	8,824	.068	129,765	125,000
211	13,001	.129	100,783	100,000
212	6,721	.065	103,400	100,000
213-0	5,615	.048	116,979	125,000
213-1	2,228	.016	139,250	150,000
214	2,644	.050	52,880	50,000
216	14,015	.061	131,393	125,000
217-0	2,208	.065	33,969	35,000
217-1	2,679	.014	191,357	200,000
218	12,255	.061	200,902	200,000
219	4,230	.118	35,847	35,000
220	10,924	.061	179,082	175,000
221-0	1,388	.060	23,133	22,000
221-1	4,541	.039	116,436	125,000
222	6,629	.061	108,672	100,000
223	10,305	.086	119,826	125,000
224	12,904	.067	192,597	200,000
225	10,692	.086	124,326	125,000

(Continued)

Table IX

MANHATTAN--POPULATION DENSITIES (Continued)

Tracts	Population	Area/Sq. Mi.	Population Density	Population Density Category
226	9,442	.055	171,673	175,000
227-0	6,661	.051	130,608	125,000
227-1	2,630	.014	187,857	200,000
228	9,375	.061	153,689	150,000
229	9,604	.090	106,711	100,000
230	12,766	.061	209,279	200,000
231-0	7,956	.065	122,400	125,000
231-1	3,859	.014	275,643	250,000
232	12,706	.061	208,295	200,000
233	8,695	.094	92,500	100,000
234	7,766	.061	127,311	125,000
235-0	6,453	.060	107,550	100,000
235-1	3,438	.013	264,462	250,000
236	5,103	.069	73,957	80,000
237	8,162	.112	72,875	80,000
238	3,626	.143	25,357	25,000
239	2,929	.032	91,531	100,000
240	3,545	.344	10,305	10,000
241	7,618	.077	98,935	100,000
243-0	4,943	.059	83,780	80,000
243-1	3,652	.067	54,507	50,000
245	14,457	.090	160,633	150,000
247	6,661	.114	58,430	60,000
249	1,682	.136	12,368	12,000
251	3,062	.053	57,774	60,000
253	11,298	.058	194,793	200,000
255	6,937	.072	96,347	100,000
257	--	.159	--	--
261	10,324	.065	158,831	200,000
263	6,563	.065	100,969	100,000
265	7,990	.071	112,535	125,000
267	2,495	.113	22,080	22,000
269	9,036	.072	125,500	125,000
271	8,168	.059	138,441	150,000
273	7,247	.065	111,492	100,000
275	3,382	.146	23,164	22,000
277	5,547	.058	95,638	100,000
279	9,962	.064	155,656	150,000
281	2,988	.064	46,688	50,000
283	6,121	.057	107,386	100,000
285	6,524	.046	141,826	150,000
287	4,383	.129	33,977	35,000
289	5,346	.105	50,914	50,000
291	10,188	.060	169,800	175,000
293	7,800	.055	141,818	150,000
295	7,744	.057	135,860	125,000
297	453	.297	1,525	1,500
301	3	.115	26	750
303	4,686	.063	74,381	80,000
307	4,696	.069	68,058	60,000
309	8,128	.115	70,678	80,000

Table X

MANHATTAN--POPULATION DENSITIES OF GROUPED TRACTS

Tracts	Population	Area per Sq. Mi.	Population Density	Population Density Category
7,9,11,13,15,21,33,39	2,236	1.1	2,033	2,000
2,6,8,10,0,12,14,16,18,25, 27,29,31,41,45	86,235	1.0	86,235	80,000
10,1,20,22,24,26,28,30,32, 34,36,38,40,44,48,60,64	163,533	1.0	163,533	175,000
62,66,70,78,86,88,90,98,106,0, 106,1,108,110,116,118,126	88,006	1.0	88,006	80,000
43,47,49,51,53,55,65,67,69,71, 73,75,77,79	59,295	1.0	59,295	60,000
42,50,52,54,56,57,58,59,61, 63,68,72,74,76,80,82,84	45,242	1.0	45,242	50,000
81,83,87,89,91,93,95,97,101, 103,109,111,113,115	54,772	1.0	54,772	50,000
85,99,117,123,129,135,141,147	8,935	1.0	8,935	8,000
92,94,96,100,102,104,112,119, 121,125,127,131,133,137	53,845	1.0	53,845	50,000
114,120,122,128,130,143	27,447	1.0	27,447	25,000
139,145,149,151,153,155,157, 159,161,163,165,167,169,171	121,716	1.1	110,651	100,000
173,175,177,179,181,183,185, 187,189,191,193,195	141,718	1.0	141,718	150,000
124,132,134,136,138,140,142, 144,146,148,150,152,154, 156,158,160	137,763	1.1	125,239	125,000
162,164,166,168,170,172, 174,176	65,437	1.1	59,488	60,000
238	3,626	.14	25,971	25,000
240	3,525	.34	10,426	10,000
178,180,182,184,186,188,190, 192,194,196,198,202,204, 206,210	122,108	1.0	122,108	125,000

(Continued)

Table X

MANHATTAN--POPULATION DENSITIES OF GROUPED TRACTS (Continued)

Tracts	Population	Area per Sq. Mi.	Population Density	Popu De Cate
197.0, 197.1, 199, 200, 201.0, 201.1, 203, 205, 207.0, 207.1, 209.0, 209.1, 211, 216, 218, 220, 222	117,463	1.0	117,463	125,
208, 212, 214, 213.0, 213.1, 217.0, 217.1, 219, 221.0, 221.1, 223, 224, 225, 226, 228, 230	108,106	1.0	108,106	100,
227.0, 227.1, 229, 231.0, 231.1, 232, 233, 234, 235.0, 235.1, 236.1, 237, 239, 241, 243.0, 243.1, 245	116,632	1.0	116,632	125
247, 249, 251, 253, 255, 257, 261, 263, 265, 267, 269, 271	74,216	1.0	74,216	80
273, 275, 277, 279, 281, 283, 285, 289, 301	47,120	.8	58,900	60
287, 291, 293, 295, 297, 303, 307, 309	48,078	.9	53,420	50
5	1,207	.3	4,023	4
TOTAL	1,698,281	21.7		

APPENDIX B

Relevant Data

This appendix presents two items of data which may be useful to people concerned with some of the details of the calculations. First, there is a tabulation showing the cities chosen in our random sample from which the composite cities were developed. This is given in Table XI.

Secondly, some details of the calculations of the population densities in the urban fringes of Detroit and Philadelphia are presented for examination. As discussed previously, this data was generated as a check on whether the model for the population densities of the urban fringes was reasonable.

Table XI

SAMPLE CITIES FROM EACH POPULATION GROUP

Size of Place	Sample
Places of 500,000 to 1,000,000	Baltimore, Maryland Dallas, Texas San Antonio, Texas San Francisco, California
Places of 250,000 to 500,000	Columbus, Ohio Louisville, Kentucky Oklahoma City, Oklahoma Phoenix, Arizona Rochester, New York Wichita, Kansas
Places of 100,000 to 250,000	Columbus, Georgia Evansville, Indiana Lincoln, Nebraska Lubbock, Texas Mobile, Alabama Scranton, Pennsylvania Syracuse, New York Youngstown, Ohio
Places of 50,000 to 100,000	Albany, Georgia Alexandria, Virginia Ann Arbor, Michigan East Chicago, Illinois Euclid, Ohio Gadsden, Alabama Meriden, Connecticut North Little Rock, Arkansas Raleigh, North Carolina Wilmington, Delaware

Table XII

DETROIT, MICHIGAN
Urban Fringe Area--Detailed Computation

Population Density Category	Area (Square Miles)	Number of People
750	71.2	28,489
1,000	84.9	95,696
1,500	86.7	126,360
2,000	50.8	98,257
2,500	45.7	120,695
3,000	15.2	45,118
3,500	2.0	6,881
4,000	39.2	151,480
4,500	31.6	146,913
5,000	68.9	353,156
6,000	45.7	294,693
7,000	19.8	135,563
8,000	22.8	192,114
10,000	--	---
12,000	6.0	72,200

Table XIII

DETROIT--APPROXIMATION OF URBAN FRINGE DENSITIES

Population of Urban Fringe -- 1,867,565; Land area -- 592.3 sq. mi.;
Average Population Density -- 3,153

Population	466,891	466,891	466,891	466,891
Area	59.2	118.5	177.7	236.9
Population Density	7,887	3,940	2,627	1,971
Population Density Category	8,000	4,000	2,500	2,000

Table XIV
PHILADELPHIA, PA.
Urban Fringe Area--Detailed Computation

Population Density Category	Total Area Per Square Mile	Number of People
750	3.2	1,731
1,000	21.9	21,640
1,500	170.3	250,657
2,000	46.7	98,004
2,500	15.6	39,355
3,000	42.1	126,144
3,500	25.8	87,740
4,000	27.3	112,418
4,500	15.5	68,042
5,000	20.5	102,259
6,000	18.0	103,979
7,000	15.0	102,232
8,000	7.0	57,374
10,000	28.3	279,768
12,000	13.4	167,362
14,000	1.0	14,059

Table XV

PHILADELPHIA--APPROXIMATION OF URBAN FRINGE DENSITIES

Population of Urban fringe -- 1,632,764; Land area -- 477.0 sq. mi.;
Average Population Density -- 3,423

Population	408,191	408,191	408,191	408,191
Area	47.7	95.4	143.1	190.8
Population Density	8,557	4,280	2,852	2,139
Population Density Category	8,000	4,500	3,000	2,000

REFERENCES

1. William M. Brown, The Design and Performance of "Optimum" Blast Shelter Programs, HI-361-RR/2, Harmon-on-Hudson, N.Y., Hudson Institute, June 11, 1964.
2. U.S. Department of Commerce, Bureau of the Census, National Location Code, OCD-OEP Regions 1-8, Washington, D.C., 1962.