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ENERGY, LAND USE, AND GROWTH POLICY: IMPLICATIONS FOR METROPOLITAN WASHINGTON. SECOND EDITION

James S. Roberts

Real Estate Research Corporation

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August 1975

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This report analyzes the interaction of metropolitan land use change and energy consumption by examining alternative development scenarios. Using the Washington, D.C. metropolitan area as the area of study, varying densities and spatial relationships are evaluated for their energy implications. Growth management issues raised by the analysis are discussed for their relevance to the metropolitan growth management process being conducted by the Council of Governments and its constituent local jurisdictions.

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Second Edition

Prepared for the

Metropolitan Washington Council of Governments

by

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FOREWORD

The interaction of land use and energy resources management is a new subject now facing local governments and metropolitan planning agencies. Elected officials are increasingly confronted by the necessity of evaluating the energy consumption impacts of land use decisions. Conversely, land use constraints that may be occasioned by future energy shortages and/or higher prices must also be faced.

This paper was prepared for the purpose of stimulating discussion and further exploration into this interaction, and to introduce energy resources management into the Metropolitan Growth Policy Program being conducted by the Council of Governments and its constituent jurisdictions. It is hoped that this paper will assist the Transportation Planning Board, COG Policy Committees, and local jurisdictions in defining the boundaries of land use/energy resources interaction in metropolitan Washington.

The future metropolitan development scenarios discussed in this paper are intended to illustrate the boundaries of energy impacts occasioned by several metropolitan arrangements of household and employment activities. They do not represent existing or proposed policies of the Council of Governments or any of its member jurisdictions. They are intended, however, to supply "benchmark" information with which to analyze existing and future policies from an energy resources viewpoint.

This second edition includes numerous editorial revisions made to the original report dated June, 1975. In addition, certain quantitative revisions and corrections have been made as well.

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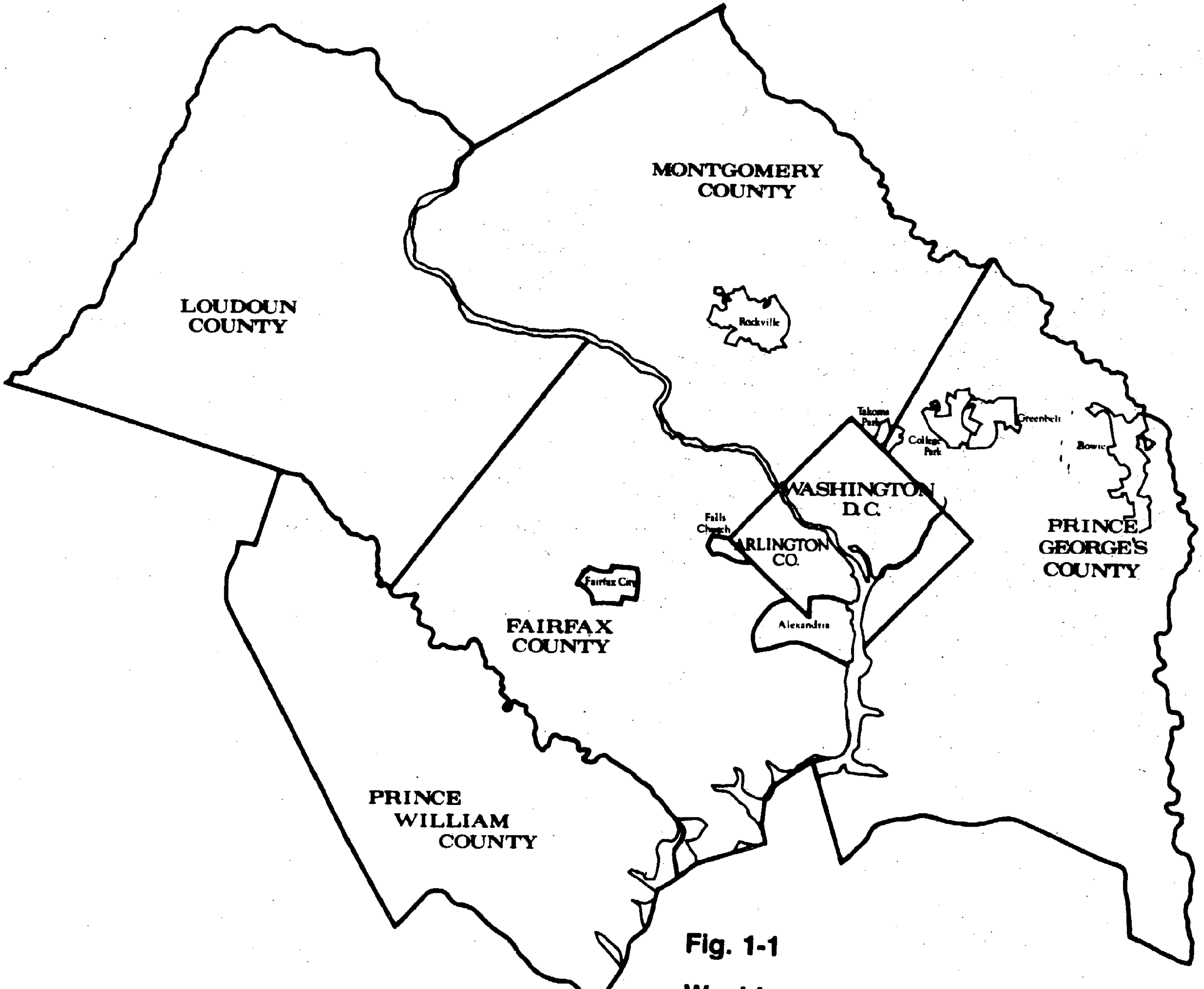

Fig. 1-1

Washington, D.C. Metropolitan Area

CHAPTER 1

SUMMARY AND CONCLUSIONS

A new era has begun within our economic, social and political order. It has been termed an "age of scarcity" and applies to a number of resources and resource uses. Two of our nation's most critical resources are land and energy, the subjects of this paper. Awareness of land as a scarce resource preceded energy by some time into the public consciousness, and numerous attempts to manage the use of land so that adequate supplies will be available at the right time and in the right locations have been launched on a broad front. These efforts have culminated in a number of current programs of growth management which are intended to guide the orderly development and redevelopment of land. In this sense, growth management is resource management.

The recent shortages and shifts in supplies of traditional energy sources have forced considerable thought and action as to how to manage this increasingly scarce resource. The concern for energy resource management seems to have gone through several phases: the first phase was a concern for increasing supplies; the second was a concern for conserving present supplies and reducing the growth of demand for future supplies; and the present phase links the concern for the use of land with the use of energy. That linkage is the subject of this report.

This paper considers the implications of energy consumption and conservation in relation to land use and growth management in the metropolitan Washington area. Although precise shifts in energy supplies and demands cannot be fully predicted, anticipation of the character of such shifts and possible reactions is in the long-term public interest and will serve the purposes of those public agencies and private organizations whose decisions define the growth policy of the metropolitan Washington area. The purpose of this study, then, is to raise issues, to identify trade-offs, and to state the likely impacts and relationships that connect energy, land use, and development.

Framework and Organization

The approach to this assignment consists of two phases: the first analytical, and the second policy-oriented. The findings from the analysis of six alternative development scenarios will indicate the direction and degrees of variation in energy consumption that may be expected from alternative future land use arrangements and densities. The policy and issue-related implications of that analysis are intended to stimulate discussion: e.g., the relative weight of energy in influencing land development; how energy conserving measures might be incorporated in land use control mechanisms; and impacts that might be expected from changes in the availability of energy supplies and in patterns of consumption.

The progression of the report is presented below for the reader's orientation and to provide an overview for the conclusions that follow:

Chapter Two: "Current Context of Growth Policy"

In order to understand how energy is related to development processes, those market forces and governmental policies which interact to shape the quality, pace, and ultimate character of development are described. This chapter reviews the demographic, housing, and employment factors that affect growth; it further summarizes the present status of growth management in the metropolitan Washington area.

Chapter Three: "Current Pattern of Energy Consumption"

Current levels of energy consumption by source and end use are estimated for the metropolitan Washington area. This chapter presents basic information, which, when combined with the discussion of factors affecting growth and development, will assist in the analysis of future magnitudes of energy consumption.

Chapter Four: "Projection of Planning and Development Context: Alternative Development Scenarios"

In order to determine how land use relates to energy consumption, six alternative development scenarios are examined:

A. "Wedges and Corridors" (as currently interpreted by local governments)
B. "Dense Center"
C. "Transit-Oriented"
D. "Wedges and Corridors with Income Balance"
E. "Sprawl"
F. "Beltway-Oriented"

These variations represent alternative arrangements and densities of households and jobs, which are linked by the same assumed transportation systems for the forecast year.

Chapter Five: "Projection of Energy Consumption and Future Energy Balances"

Using the alternative futures created in Chapter Four, energy consumption associated with each scenario is estimated. Since the analysis assumes no changes in technology, nor any attempts to conserve energy, the implications of varying these critical assumptions are presented. This chapter also presents information as to the degree of energy consumption associated with alternative land use arrangements.

Chapter Six: "Energy and Land Use"

This chapter relates the specific findings of Chapter Five with a generalized discussion of the impacts of density and spatial arrangements upon area-wide energy consumption. A definition of an energy-efficient land use pattern is presented.

Chapter Seven: "Statement of Issues"

If energy considerations were the only factors that determined land use and growth, certain idealized patterns would result and policy implications would be clear. However, many environmental, political, economic, and institutional variables--of which energy is only one --influence the location, character, and pace of development. This chapter organizes the issues implied in this interaction.

Chapter Eight: "Implications for Metropolitan Growth and Development"

The issues and analysis of Chapters Six and Seven are combined into a discussion of the likely future growth that might occur under constrained supplies of energy.

Chapter Nine: "Policies and Implementation Strategies"

As a concluding chapter, the previous analysis and discussions are translated into statements of policies and implementation strategies that will contribute to long-range energy balances in metropolitan Washington, particularly through control over land use activities by growth management practices.

Findings and Conclusions

The differences in energy consumption among the scenarios that were calculated in the course of this assignment are reported in Table 1-1, below. The percentage increase in energy consumption for each scenario from the base year to the forecast year defines the apparent boundaries of control over energy consumption through land use and growth policy means.

Table 1-1

Comparison of Areawide Energy Consumption

Associated with Alternative Land Use Patterns

(Percent Increase from Base Year;
All Fuel Forms on a Btu Equivalent Basis)

	(A) "Wedges and Corridors"	(B) "Dense Center"	(C) "Transit Oriented"	(D) "Wedges and Corridors with Income Balance	(E) "Sprawl"	(F) "Beltway Oriented"
Residential	+41	+34	+36	+41	+46	+42
Transportation (Automobiles only)	+50	+30	+28	+40	+60	+44
Total	+46	+39	+39	+44	+51	+46

Source: Real Estate Research Corporation

Note: "Total" line is inclusive of Commercial/Industrial/Institutional and Public Transit energy consuming sectors which are assumed not to vary by scenario. See Table 5-1 for detail.

Several key findings emerge from this analysis:

- In every scenario tested, there is considerable increase in energy consumption over the base year. Regardless of development patterns, there will be increased demands for energy.

- There is substantial latitude, however, in the increased consumption from the base year among the alternatives. The degree of difference in the increase over base year consumption between the least energy consuming alternative and the most energy consuming alternative is 31 percent in total; 113 percent for transportation by automobile; and 35 percent for residential use. These large differences indicate that substantial conservation in increased consumption is possible.

- The smaller variation in total consumption is due to the fact that transportation by public transit and consumption in the commercial, industrial and institutional employment sectors are assumed not to vary.

- These percentage differences in energy increase over the base year may be made more concrete by converting relative differences in energy consumption increase in the residential sector into annual energy requirements of dwelling units. The least consuming option ("Dense Center") annually provides enough fuel savings compared to the most consuming option ("Sprawl") to supply 109,500 additional single family detached dwelling units. If "Wedges and Corridors" is compared with the "Dense Center" alternative, a savings equal to the annual fuel requirements of 65,500 additional single family detached homes results.

- Similarly, in the transportation sector (automobile only) the differences between the two extreme cases result in an energy consumption level that would fuel 329,600 additional private automobiles (assuming 12,000 miles per year of average use). The difference between the "Wedges and Corridors" and the least energy consuming alternative, "Transit-Oriented Development," amounts to an energy saving sufficient to fuel 232,100 additional automobiles annually.

- These incremental savings are significantly large, even though they are part of a much larger forecast year base. For example, the variation in households must be compared to an increment of almost 500,000 homes. What is more critical is that in both instances there is heavy reliance on fossil fuels from scarce domestic and foreign sources.

- Although such changes are difficult to predict, it seems clear that alternative energy sources will be developed, but reliance on new technologies alone may not prove adequate to meet growing demands. Reducing levels of consumption by other means, therefore, seems necessary. Such reductions can be brought about by alterations in household consumption habits or management practices in operating homes, offices and automobiles; changes in design of buildings; more efficient use of transportation systems; and, of course, changes in technology. In addition, there is potential for reducing energy consumption through land use measures, which may be implemented by growth management processes.

- Such changes have a price, for altering present patterns of development will mean sacrificing some types of consumption or substituting some forms of consumption for others. There are clear tradeoffs involved in deciding whether higher densities are worth the price of energy conservation; whether changes in the use of the automobile are worth the limitation to mobility implied by energy conservation; and whether energy conservation is economically or socially feasible when all relevant factors are weighed.

CHAPTER 2

CURRENT CONTEXT OF GROWTH AND GROWTH MANAGEMENT

The concepts of growth and growth management become more troublesome as they are carefully examined and raise questions that prove relevant to the purposes of this paper. Such questions might include the following:

- What determines growth?
- What factors shape growth and development in particular patterns and intensities of land use?
- What is growth management; and perhaps more important, why is it necessary?
- What are the impacts of growth management on land use and development?

These questions are not raised for rhetorical purposes, but to initiate further discussion and to provide a framework for relating growth, development, and land use to the implications of changes in energy availability.

a. A Look at Growth and Development

Growth, in its most fundamental sense, implies change in activities or levels of activities over time. As it relates to land use, changes occur in the types, locations, intensities, spatial arrangements, and interrelationships among activities or facilities as a result of social, political, and economic forces. Land may be seen as the template upon which growth occurs, so that at any moment in time a particular land use pattern may be described. Over time the pattern may be seen to be evolving; locations and relationships change as a part of growth and development.

The forces which affect both static land use patterns and the processes of growth that link these patterns operate to motivate and to constrain the quality, rate, and nature of changes. There are two primary forces: market or economic forces, and governmental regulation and policy. The operations of private market mechanisms and the guidance of public agencies determine in large measure the form and pace of development. Other elements such as physical or environmental factors, institutional arrangements, social customs, and personal preferences play a role. They are given expression through governmental and market activities, and their influence is indirectly felt.

Market forces reflect shifts in demographic characteristics, employment and housing factors, availability of land, and economic costs. A summary of these factors, and trends associated with them, for the metropolitan Washington area is necessary, then, for a partial understanding of the growth and development occurring at present and likely to occur in the near future.

b. <u>Current Context of Growth</u>

The following characteristics of change found in the metropolitan Washington area directly influence growth and development:

1. Population and demographic characteristics:

- The rate of population growth has dropped from 80,000 persons per year in the 1960's to approximately 38,000 annually in the 1970's.
- Declining birth rates are responsible for most of the decrease, but there appears to have been net out-migration from the area during the early 1970's. Out-migration may be attributed to several factors, including present restrictions on housing construction and the relatively high cost of living. Perhaps the leading factor is

the influence of federal employment-related jobs which have only temporary tenure and promote both movement into and out of the area.

- The average age of persons in the metropolitan area is relatively low. This fact contributes to the high rate of mobility. It is also noteworthy that the number of children under five years of age is declining. This means that child-bearing and child-rearing are either being deferred or are not being considered.

- The District of Columbia has over 70 percent non-white population (1970 census), and the metropolitan area approximately 26 percent. Although three-quarters of the non-white population lives within the District of Columbia, there is evidence of recent dispersion to suburban areas.

2. Employment characteristics:

- Of all 1973 employees, governments at all levels employed 36.7 percent of the labor force (25.2 percent Federal and 11.5 percent state and local). The second leading employment sector is retail trade with 11.5 percent. Construction constitutes 6.9 percent, and manufacturing only 3.6 percent.

- Although the rate of increase in Federal employment has slowed, the dominance of the Federal government is clear. One-fourth of all jobs is provided by the Federal government, but a vast number of jobs service the Federal government (over 40 percent of employment in the manufacturing sector is in printing and publishing, for example).

- The economy of the metropolitan area remains somewhat insulated from the effects of the current national economic downturn. Area unemployment was 5.5 percent in March of 1975, while nationally it was 8.2 percent.

- Economic activity in construction and related industries, such as real estate and finance, has declined and unemployment is relatively high in these sectors.

- A very large proportion of the area's labor force is well-educated and highly paid. Recruitment is nationwide and mobility, both within and outside the region, is high.

3. Housing characteristics:

- One of the fundamental demand factors related to housing is the mobility of the population. Recent studies show that in some areas as many as 50 percent of current residents did not reside at the same address five years earlier. Tenure is short and turnover high.

- Another fundamental factor in metropolitan growth is the drop in average household size:

Average Household Size
(Source: U.S. Bureau of the Census)

Year	Average Household Size
1950	3.32
1960	3.25
1970	3.09
1975	2.91 (est.)

- The high cost of housing can be attributed to a number of factors, including the high cost of borrowing. Other factors include sewer moratoria in some jurisdictions and limitations on higher density development in others. Coupled with a housing market that traditionally suffers from a short supply, the cost situation is critical.

- Probably the most important factor with regard to housing is the extraordinary rate of increase in housing costs since 1967. The average annual rate of increase in housing costs has been 12 percent, while the overall price level has increased seven percent annually.

- The state of the housing market may be illustrated by the decline in the number of building permits issued in recent years:

Building Permits Issued
(Source: U.S. Bureau of the Census)

1971	37,722
1972	43,290
1973	36,383
1974	16,302

- The market has been further tightened by the expectation of further price increases and the tendency to "trade up" in houses whenever possible, since alternative investments have not been equally attractive.

- In recent years, there have been drastic shifts in the types of dwelling units built in response to these economic factors. A 1974 estimate of the proportions of dwelling units by type shows the dominance of detached single family homes.

  Distribution of all Housing Units by Type of Structure, 1974 (Source: Council of Governments)

Type of Structure	Percent
Detached Single Family	44.0
Attached Single Family	11.0
Garden and Walk-up Apartments	32.7
High Rise Apartments	11.9
Mobile Homes	0.4

  Of new residential structures authorized since 1970, the following distribution is noted:

  Distribution of Authorized Housing Units by Type of Structure 1970-1975 (Source: Council of Governments)

Type of Structure	Percent
Detached Single Family	36.7
Attached Single Family	24.1
Garden and Walk-up Apartments	21.1
High Rise Apartments	18.1

  The proportion of single family detached homes and garden/walkup apartments has declined, while there has been a substantial rise in attached single family homes. The major form of dwelling units in the future may be the townhouse, perhaps under condominium ownership.

This recitation of demographic, economic, employment, and housing factors may indicate directions or trends in development.

It does not completely illustrate the current growth picture. Growth is also influenced by present land use patterns, by availability of public services--particularly sewer and water systems--by transportation systems, and by prevailing land values.

c. Public Facilities, Existing Land Use, and Land Values

Figure 2-1, below, displays the present and planned transportation system, including the planned METRO rapid rail system. It might be expected that more intense development will occur along portions of the system. The transit system will improve access throughout the region, especially to the central core. It will also encourage growth in vacant areas adjacent to or near the system.

Another way of looking at the present development pattern is to review existing household and employment density. Figures 2-2 and 2-3, below, show household and employment densities projected for the base year, 1976, which are presented as proxies for current areawide land use patterns.

Another key determinant of development is the availability--and, therefore, the price--of land. The location, amount, and price of available vacant land in the Washington area have strong implications for market decisions. The developability of land is also influenced by availability of water and sewer facilities, which may be reflected in land values. These relationships are summarized in the following table:

Table 2-1
Availability of Vacant Land*

Location	Amount (Acres)	Price Per Acre - Vacant Land: Range (Thousands)	Price Per Acre - Vacant Land: Average (Thousands)
Inside Ten-Mile Square	9,742	$91.6-144.4	$138.8
Between Ten-Mile Square and Beltway	17,422	17.5- 59.9	24.5
Outside Beltway	497,341	2.1 42.9	3.7

*Source: Metropolitan Washington Council of Governments' 1973 Metropolitan Parcel File. Loudoun County not included.

The large variation in price per acre almost automatically specifies that there are some types of development that will prove uneconomical on a particular site. Particular uses cannot be predicted for given price levels, for there are other determinants in addition to price. But it is obvious, for instance, that it would be costly to build a single family home on the average vacant parcel within the ten-mile square. This information implies that there will be continued pressure to expand development beyond the Beltway, where land costs are relatively low.

d. Current Context of Growth Management

The term "managed growth" is not equivalent to "no-growth." The notion that growth will cease and that the status quo will be preserved is difficult to uphold. Growth does occur. The question is whether its pace, quality, and quantity may be guided for particular purposes. Managed growth is an attempt to channel

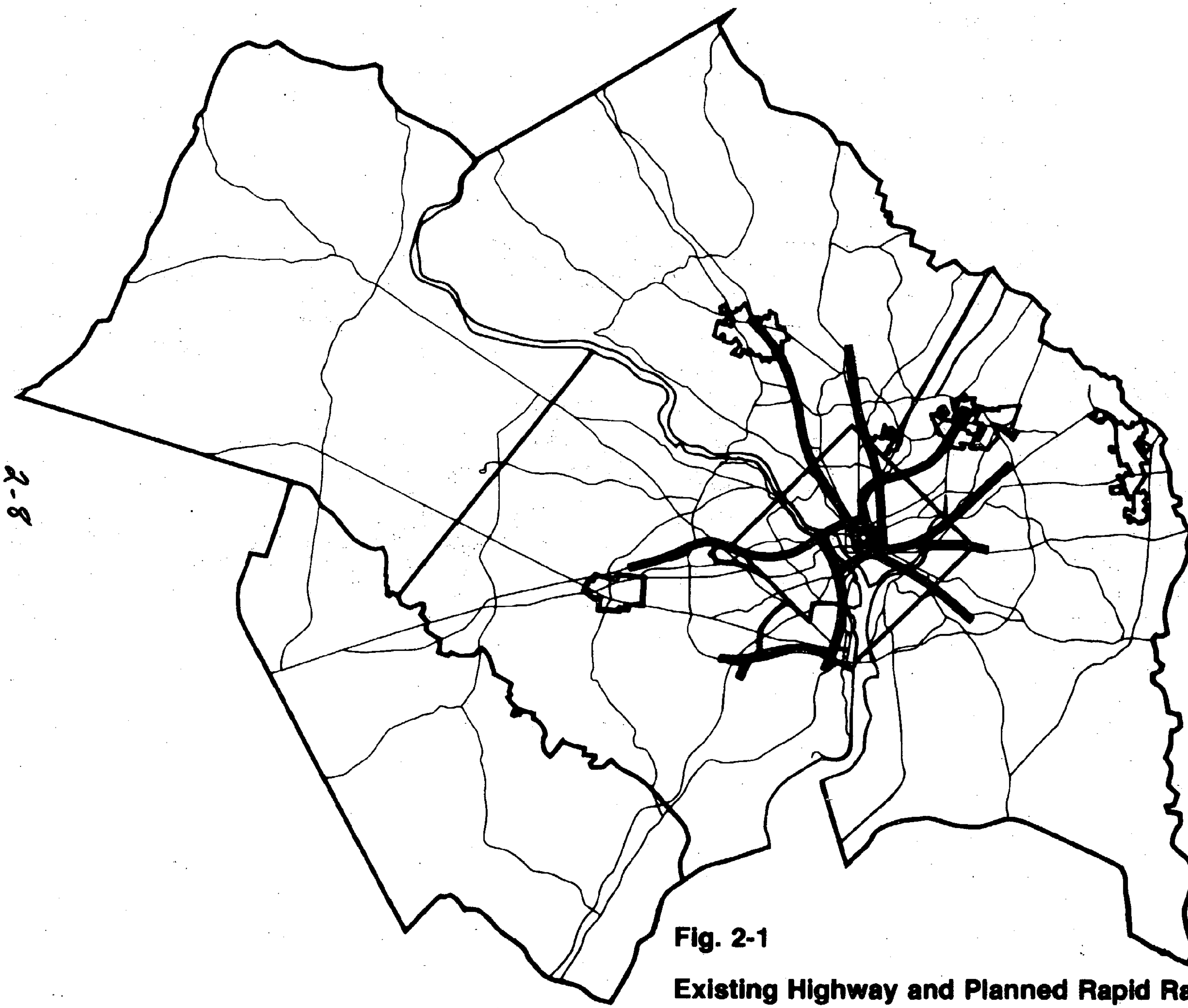

Fig. 2-1

Existing Highway and Planned Rapid Rail Transit Svstem

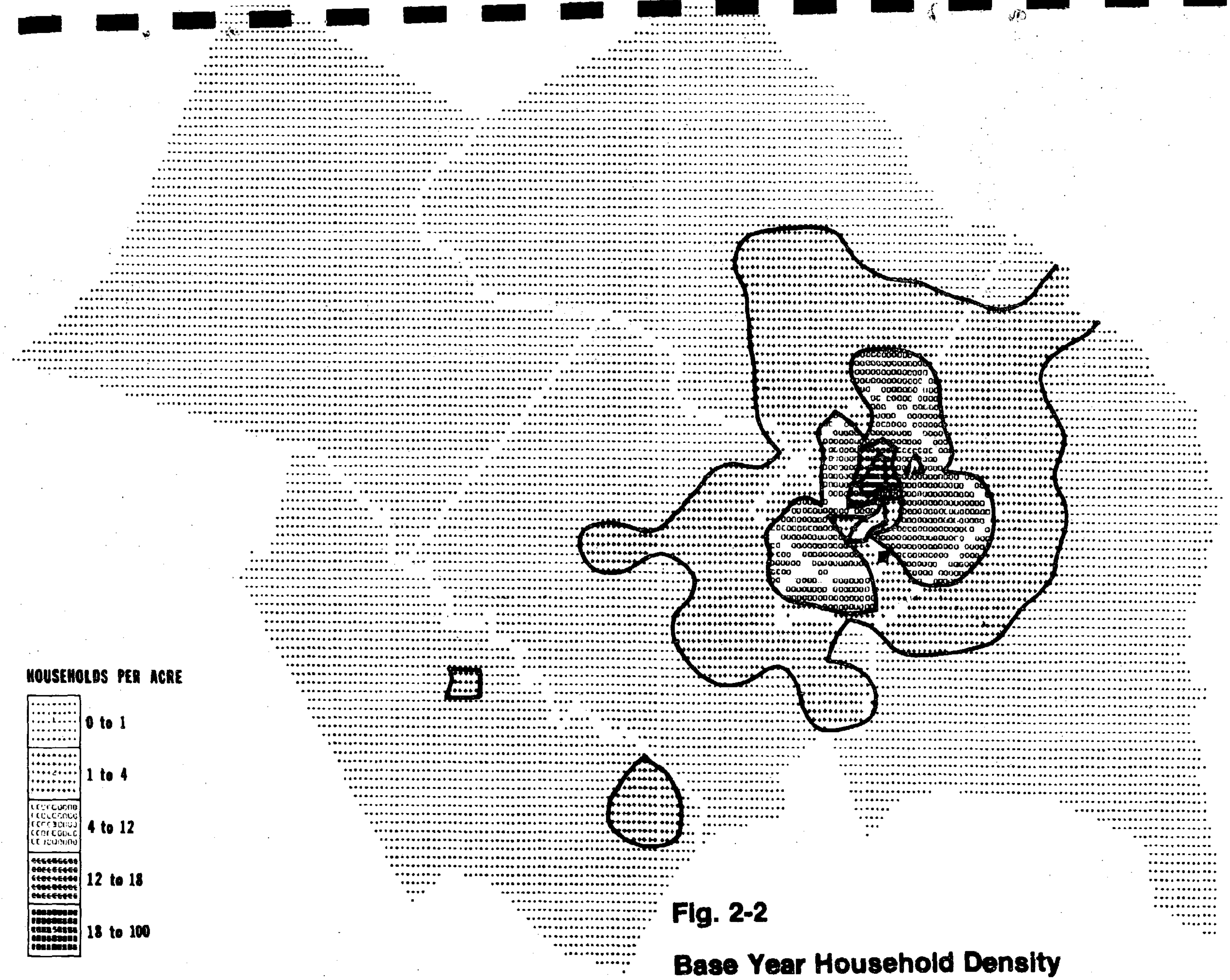

Fig. 2-2

Base Year Household Density

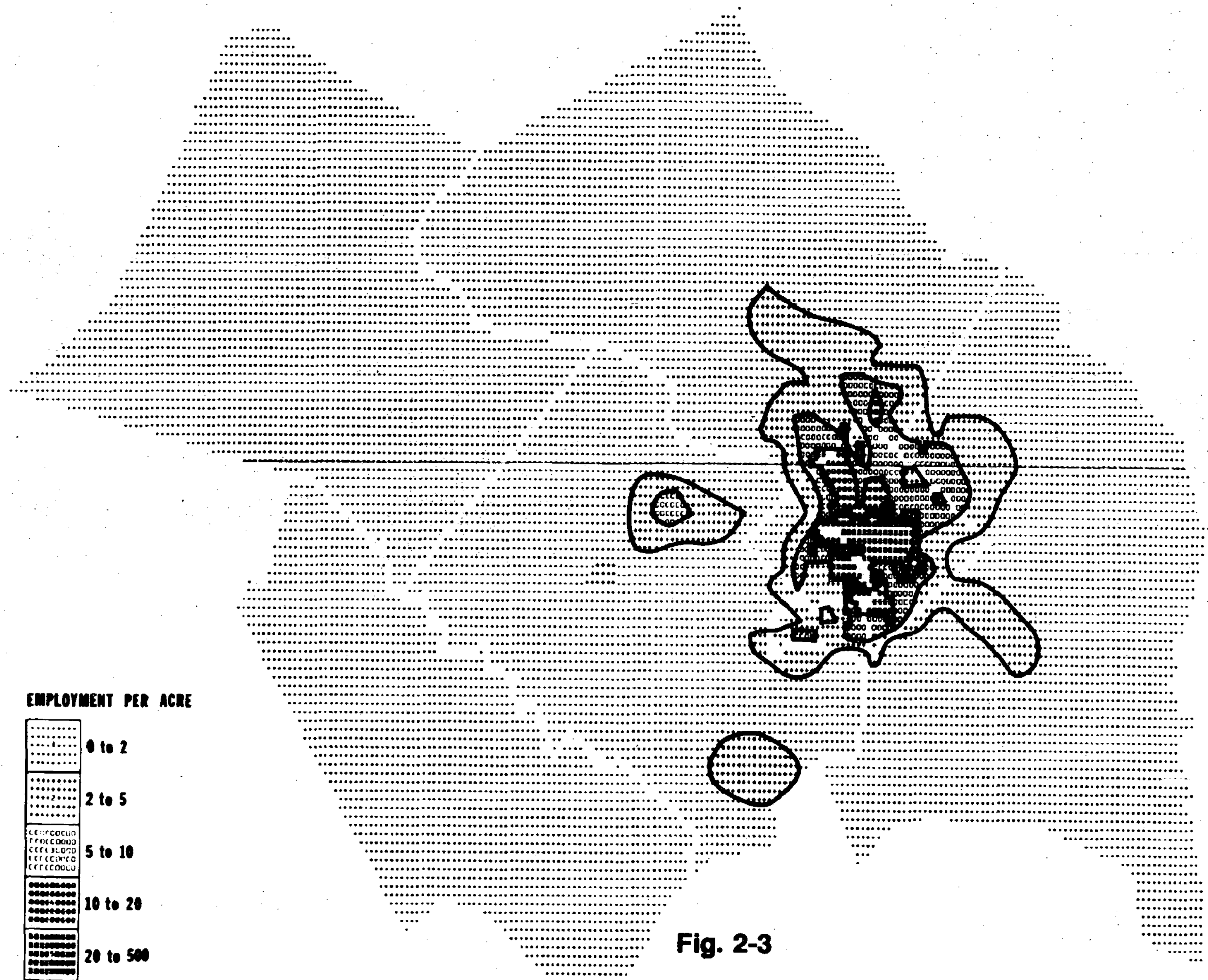

Fig. 2-3

Base Year Employment Density

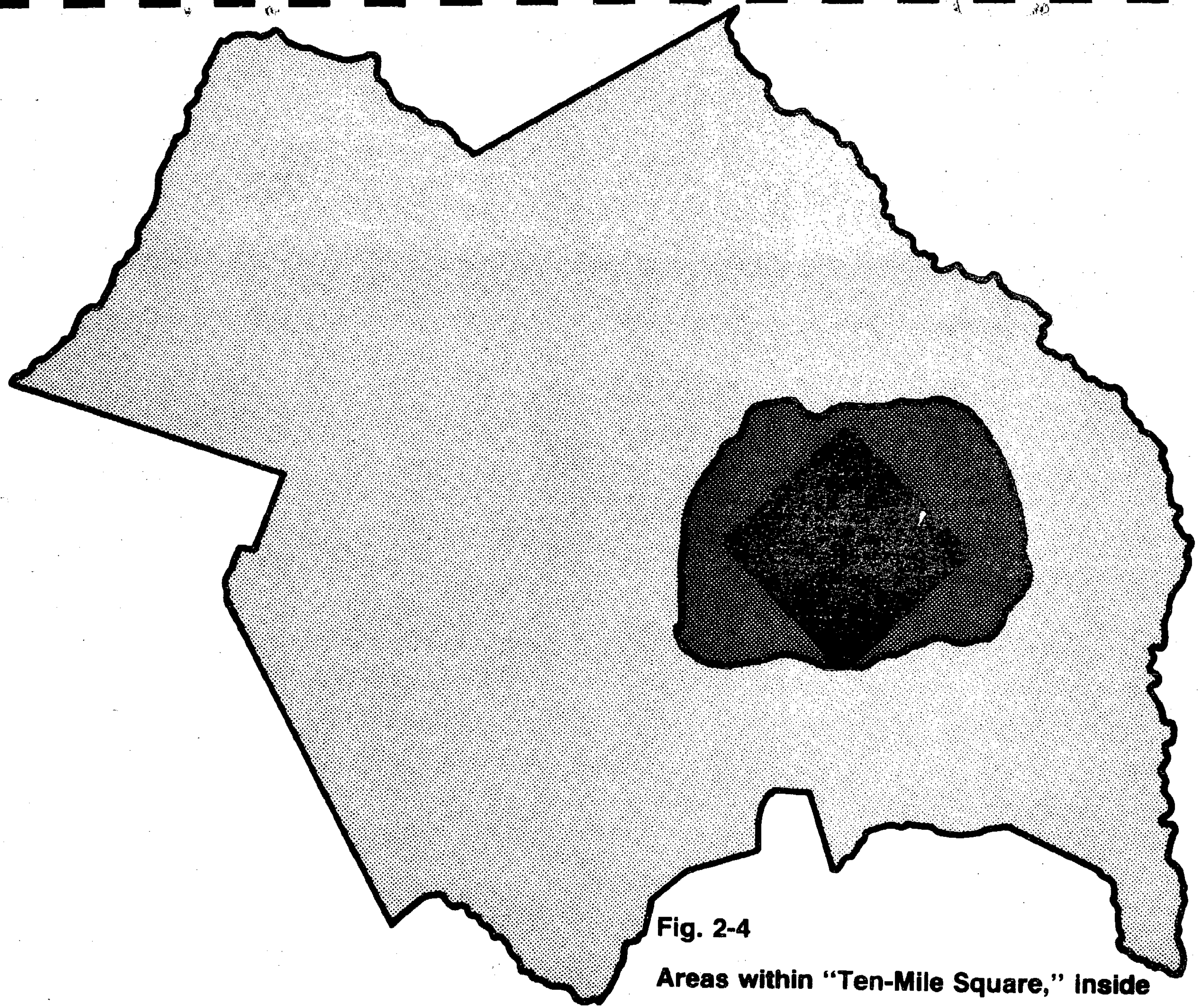

Fig. 2-4

Areas within "Ten-Mile Square," inside Beltway, and beyond Beltway or influence the process of development into more desirable forms and to ensure that resultant land uses, activities, and facilities are compatible with a wider set of objectives than the benefits or costs of the growth itself.

A feature of growth management is that it must be comprehensive in both geographical area and in time. If growth is managed at one place, but not another, a competitive advantage results, and the activity may be shifted elsewhere. Development often follows the line of least resistance in that respect. On the other hand, if growth is managed throughout an area, then the opportunity and the impulse to displace the growth elsewhere is altered. For the successful management of growth there needs to be some areawide cooperative agreement of commonly held interests.

The impulse for growth management has arisen from several sources. In the metropolitan Washington area, as elsewhere, the rate of growth over the past decade has been so rapid that demands for public goods and services outstripped the capabilities of local governments to provide them. New development often threatened the community character or ambience of many areas. The growth that occurred brough burdens as well as blessings, and at times the burdens were viewed as excessive. The added traffic, added costs, added inconvenience, added scale and dimension were all discomforting. The particular problems of the metropolitan Washington area--notably a housing shortage and the necessity of imposing sewer moratoria because of inadequate sewage treatment capacity--were added to this list. A number of jurisdictions paused to look at the growth of their communities, to formulate plans and develop techniques to cope with a pace and type of development that was threatening to overwhelm them.

This was the rationale in many suburban jurisdictions in this metropolitan area for the initiation of growth management programs. Several of those jurisdictions have taken significant strides in managing growth--both in terms of techniques and in comprehensively looking at what they wanted their community or jurisdiction to become and how to get there. But growth management has implications for non-suburban jurisdictions, too. The same logic and the same need for controlling development and coordinating governmental activities prevails in rural and center city areas as well. Since all growth occurs in a systemic context, actions by individual jurisdictions cannot be considered in isolation. Growth management is required, for instance, in formulating redevelopment strategies in the inner city and for determining how to preserve agricultural land in rural areas as well. What is necessary is to view such actions and reactions in a wide enough context.

This brings us to the current context of growth management. Given the operation of market forces and the accompanying problems, it was considered desirable for local governments to take the initiative in using their powers of regulation to ensure that desirable development occurred. Major efforts to manage growth are now under way in virtually every jurisdiction in metropolitan Washington. Fairfax and Montgomery Counties, for example, have undertaken programs of significant and comprehensive scope.

What gives growth management an added dimension are parallel efforts at other levels of government. The need for a regional or metropolitan-based approach to growth was mentioned previously, and the necessity for coordinated and comprehensive planning at an interjurisdictional level seems apparent. An integrated approach is being considered by the Metropolitan Washington Council of Governments in its proposed Metropolitan Growth Policy Program. This program consists of three major elements: (1) a cooperative forecasting program, so that consistent data might be used in local and areawide planning and so that short and long range growth might be analyzed; (2) an impact assessment or analysis mechanism, so that the implications of future growth might be measured for changes resulting from the cooperative forecasts--changes in fiscal, environmental, and social factors; and (3), an action program, consisting of a metropolitan improvement program related to growth and development, and establishment of agreements among all jurisdictions on how the burdens and benefits of growth might be equitably shared.

In summary, demographic, employment, and housing factors contribute to growth, but so does the operation of governmental planning processes and policy formulation. How these will affect land use patterns in the years ahead is the subject for speculation, but it is first necessary to complicate the growth and development process a bit more by adding the constraints of changes in the availability of energy.

CHAPTER 3

CURRENT PATTERN OF ENERGY CONSUMPTION

There seems to be common understanding that growth and development are the results of economic and governmental activities. There may not be agreement as to the desirable form and pace of that growth, but it would be agreed that the two interact. What is not well understood is how energy consumption relates to and, in a final sense, influences how growth and development may occur. Not only is the relationship unclear, but there has been little attention given to the pattern of energy consumption, and insufficient analysis and information are available as to where the problems of energy supply and the opportunities of reducing demands are found. The purpose of this chapter is to relate energy consumption to the growth context suggested in the previous chapter, and to report information concerning the magnitudes of current energy use in the metropolitan Washington area.

In determining the pattern of energy consumption on an area-wide basis, there are two possible approaches. It might be possible to estimate metropolitan energy sources and then allocate those sources to the appropriate geographical areas or sub-areas. This will result in aggregated data defining total energy use, but it will not display very well the variations among end-use sectors or on a per-unit basis. On the other hand, it is possible to derive per-unit energy consumption and then aggregate upward according to the number of units. The difficulties here are determining how per-unit consumption levels vary and determining the numbers of units--especially if projections of future activities are involved. The information in this chapter describing the pattern of energy consumption in the metropolitan Washington area is based on a combination of the two approaches, drawing on the 1973 energy balance for the Washington area developed by the Council of Governments and other sources.

Information for these energy balance accounts was obtained from various sources, including utility output data, air quality and transportation data, and per-unit consumption data for process uses (air conditioning and water heating, for example). It should be pointed out that an adjustment to the metropolitan energy balance was made that is not reflected in the tables summarizing areawide sources and uses which follow. Because of the manner in which utilities maintain their information, multi-family residential structures are generally included in the commercial sector, so that in the energy balance residential energy use is understated and the commercial/industrial/institutional total is overstated. The notes on each table document the necessary adjustment made for these sectors. The adjustment was performed by calculating the portion of commercial consumption that is represented by multi-family housing, subtracting it from commercial consumption and adding it to residential. Of course, the metropolitan area total does not change.

a. <u>Sources of Energy</u>

The sources of energy consumed in the metropolitan Washington area are reported in Table 3-1. The transportation sector is

Table 3-1

Energy Consumption By Source
In the Metropolitan Washington
Area, 1973
(in 10^{12} Btu/yr.)

	Direct				Generated Electricity		
	Oil	Natural Gas	Gasoline	Other	Used	Wasted	Total
Residential	39.1	65.5	2.0	0.7	27.5	56.7	191.5
Commercial Industrial/Institutional	49.6	53.4	4.0	9.0	43.9	90.5	250.4
Transportation	--	--	127.9	55.5	--	--	183.4
Total	88.7	118.9	133.9	65.2	71.4	147.2	625.3
Percent of Total By Source	14.2	19.0	21.4	10.4	11.4	23.5	100.0

Note: The totals for residential and commercial/industrial/institutional uses are adjusted to 265.3 and 176.6, in 10^{12} Btu, respectively to reflect the shift of multi-family housing into residential: This adjustment of 73.8 X 10^{12} Btu is carried forward through all subsequent analysis.

Source: MWCOG

almost entirely dependent on gasoline, while the residential and commercial/industrial/institutional sectors require substantial amounts of natural gas, oil, and electricity. It must be noted that electricity is of two types--useable and wasted. Because of the inherent inefficiencies in electricity generation and transmission, there is considerable waste heat loss, so that for every Btu equivalent of energy supplied to the power plant--assuming use of fossil-fuel sources--only about one-third is available at the point of use. When wasted energy is included, electricity accounts for about 35 percent of the region's total energy needs.

b. Uses of Energy

The factors that determine the level of energy consumption may be organized according to the following framework:

(1) Availability of supply. If adequate supplies of fuel are not available--either reflected in higher prices or mandatory allocations of supplies by rationing--then, of course, the pattern of consumption will be altered.

(2) Demand elasticity. Depending on the relationship between changes in price and changes in the quantity of fuel or electricity consumed, overall consumption levels will vary. If consumers do not reduce their demand in direct proportion to price increases, then the level of consumption is relatively unresponsive or inelastic to demand.

(3) Operating characteristics. The manner in which energy-utilizing systems are operated has considerable effect upon energy consumption. If residents turn off lights, turn down thermostats, and use appliances less, energy savings will result. If drivers use other available forms of transportation or combine and shorten trips, consumption levels may decrease; and if offices reduce the amount of lighting used, reduce air conditioning, or turn off equipment when not in use, energy use decreases.

Much consumption is determined by personal habits, lifestyles, and administrative or maintenance procedures that may prove energy-inefficient.

(4) Structural characteristics. How buildings are constructed and infrastructure networks designed will also affect the level of energy consumption, both in the use of materials which require energy in their production, and in the characteristics of the building or network itself.

(5) Institutional factors. The manner in which systems combine influences the level of consumption. If legal requirements, financial and real estate institutions, governmental regulations, or other factors interrelate in such a way as to prevent or reinforce certain actions, then there is potential leverage for altering levels of consumption.

(6) Technological options. Use of available or developing technologies will have a large impact on levels of consumption, from both the supply and demand sides. If additional sources of energy become available through new technologies, then consumption will be altered in turn. If more efficient technologies are found for residential, transportation, or commercial/industrial/institutional end uses, then consumption will be reduced.

The pattern of consumption by end-use sector in metropolitan Washington is summarized in Table 3-2, below. The largest single use of energy is for space heating, with almost 30 percent of total energy consumed when residential and commercial/industrial/institutional sectors are combined. The second most important end use is passenger transportation, which includes both private automobiles and public transit systems. It is noteworthy to compare the breakdown of energy use by sector between national statistics and the metropolitan Washington area. On a nationwide basis, residential uses consume approximately 15 percent of total energy; industrial and commercial uses consume 60 percent; and transportation consumes about 25 percent. The major difference

Table 3-2
Energy Consumption by End Use Sector
In Metropolitan Washington, 1973
(in 10^{12} Btu/yr.)

	10^{12} Btu	Percent
Residential		
Space Heating	83.2	13.3
Water Heating	43.7	7.0
Air Conditioning	29.5	4.7
Process (Lighting, Appliances)	35.1	5.6
Sub-Total, Residential	191.5*	30.6*
Commercial/Industrial/Institutional		
Space Heating	101.0	16.1
Water Heating	13.7	2.2
Air Conditioning	8.7	1.4
Process (Lighting, Refrigeration, Industrial Uses, Appliances)	127.0	20.3
Sub-Total, C/I/I	250.4*	40.0*
Transportation		
Ground-Passenger	114.3	18.3
Ground-Freight	20.5	3.3
Air-Total	48.6	7.8
Sub-Total, Transportation	183.4	29.4
Total	625.3	100.0

Source: Metropolitan Washington Council of Governments

*Note: The totals for residential and commercial/industrial/institutional uses are adjusted to 265.3 and 176.6 (in 10^{12} Btu) respectively to reflect the shift of multi-family housing into residential; this adjustment of 73.8 X 10^{12} Btu is carried forward through all subsequent analysis.

If the adjusted end use totals are used, the residential sector consumes about 42 percent of total energy and the commercial/industrial/institutional sector around 28 percent; the proportion used in the transportation sector is unchanged.

lies in the absence of a heavy industrial or manufacturing base for the metropolitan economy. Because this heavily energy-consuming sector is not found in metropolitan Washington to any significant extent, the proportions for the other sectors are increased. If the proportions are examined after the necessary adjustment for the shift of multi-family housing from commercial to residential, the residential sector consumes almost 42 percent of total energy, while the commercial sector drops to roughly 28 percent. In either case, the comparison with national averages demonstrates what was stated in the previous chapter about the dominance of governmental, service, and institutional sectors of employment, and, hence, in areawide energy consumption patterns.

Regional totals of energy consumption are useful for understanding present relationships, but are too gross for use in projecting future energy consumption. Per-unit consumption estimates will prove more useful, because such factors allow aggregation that is more sensitive to likely variations. Such factors are also useful in themselves, for they illustrate the magnitudes and types of differences that exist among sectors. The per-unit factors that are used in this paper are presented in Table 3-3, below. Their underlying assumptions and the manner in which they were derived are described in Appendix A.

Table 3-3

Per Unit Factors Of
Energy Consumption

	Annual Consumption (in Btu)
Residential (Per Dwelling Unit)	
Single Family Detached	288.6×10^6
Single Family Attached	236.3×10^6
Walkup or Garden Apartment	172.4×10^6
High Rise Apartment	140.0×10^6
Commercial/Industrial/Institutional (Per Employee)	
Office, Including Governmental, Institutional, and Services	57.0×10^6
Retail Trade-Wholesale Trade	71.0×10^6
Industrial (Manufacturing, Construction)	288.0×10^6
Transportation (Per Vehicle Mile Traveled)	
Automobile	9,480
Public Transit	45,000

Source: Real Estate Research Corporation. See Appendix A for derivation and sources.

CHAPTER 4

PROJECTION OF PLANNING AND DEVELOPMENT CONTEXT: ALTERNATIVE DEVELOPMENT SCENARIOS

In viewing metropolitan Washington's land use and energy future, this analysis begins with the assumption that activities that occur in the future can be controlled and provided for in advance. Thus, if the current energy shortage is to be overcome and if long-term energy balances are to be achieved with the simultaneous objectives of maintaining the quality of life, economic growth, and environmental protection, then it is necessary to think through the effects of alternative development patterns. If alternative futures can be analyzed--futures which define the boundaries or reasonable extremes of arrangements of future activities--for likely impacts, important information is obtained. Through this means, it is possible to discover the longer-term consequences of current development policies and to consider variations from them in a systematic fashion, focusing on land use in isolation. This is the technique used in this paper for the following purposes:

- To measure in rough fashion the energy consumption associated with various development scenarios, so that energy-efficient forms of development might be described.
- To identify further issues that arise from relating energy and development policies.
- To weigh the energy-efficient development forms against these issues to determine the likelihood of conserving energy by means of land use and growth management approaches.
- To explore how the process of growth management might be conducted to obtain some optimum level of

energy conservation in conjunction with other objectives; in particular, to define what policies might prove useful in undertaking and guiding that process.

The method that was used in creating the various scenarios of future growth and development was partially determined by the availability of data, by the compatibility of this task with the work program of the Council of Governments, and by its usefulness in displaying possible variations in energy consumption.

The bulk of the design of the scenarios was undertaken by Council of Governments staff, including the specification of the particular growth policy characteristics that were varied for analysis. It was initially assumed that the forecast year for the development scenarios would be 1992, and would deal with not only the total levels of activity at that time, but with the increment of growth occurring between 1976 and 1992. The years "1976" and "1992" are used in a hypothetical sense only. The levels of activities reported for given years in this report are more appropriately referred to as "base year" and "forecast year," whether projected activity levels are actually realized in 1976, 1992 or in some other year, if ever. They do not constitute official projections of COG or any of its member jurisdictions. The reader is cautioned that in undertaking the analysis of alternative scenarios, the purpose is to derive gross levels of magnitudes of difference, not to develop or propose future allocations of activities, either on a metropolitan, or jurisdictional, or small-area basis. Following are listed the critical assumptions maintained throughout the analysis:

- Total population, total number of households, and total employment do not vary by scenario.
- Existing development in the base year remains in place, so that base level numbers and types of activities are carried forward to the forecast year (see Figs. 4-1 and 4-2 for analysis areas used in this study).
- Incremental development between the base year and the forecast year, however, is re-arranged. Locations, densities, and dwelling unit mixes are allocated differently, and, similarly, employment locations also vary--but the mix of total employment does not vary.
- With regard to highway transportation, it is assumed that the existing highway network is maintained with no significant additions of freeways or arterials (see Fig. 4-3). There is no assessment of how capacity in the system is utilized, but it is assumed to be adequate.
- For the forecast year the full planned 98-mile METRO rapid rail system is assumed for all alternatives; this means that the planned levels of rail, feeder bus, and route-oriented bus will be available for all scenarios (see Fig. 4-4).

The general characteristics of the scenarios are summarized on the following table, and the detailed characteristics of each are reported in Appendix A. The alternatives may be described as follows:

A. "Local Interpretation of 'Wedges and Corridors' Development," reflecting prevailing local policies and plans as determined by local jurisdictions. These are often referred to in planning parlance as "6.2 modified" projections, having been formulated in 1972 by COG in coordination with local governments.

B. "Dense Center," reflecting a higher density, more concentrated configuration with emphasis on the metropolitan center.

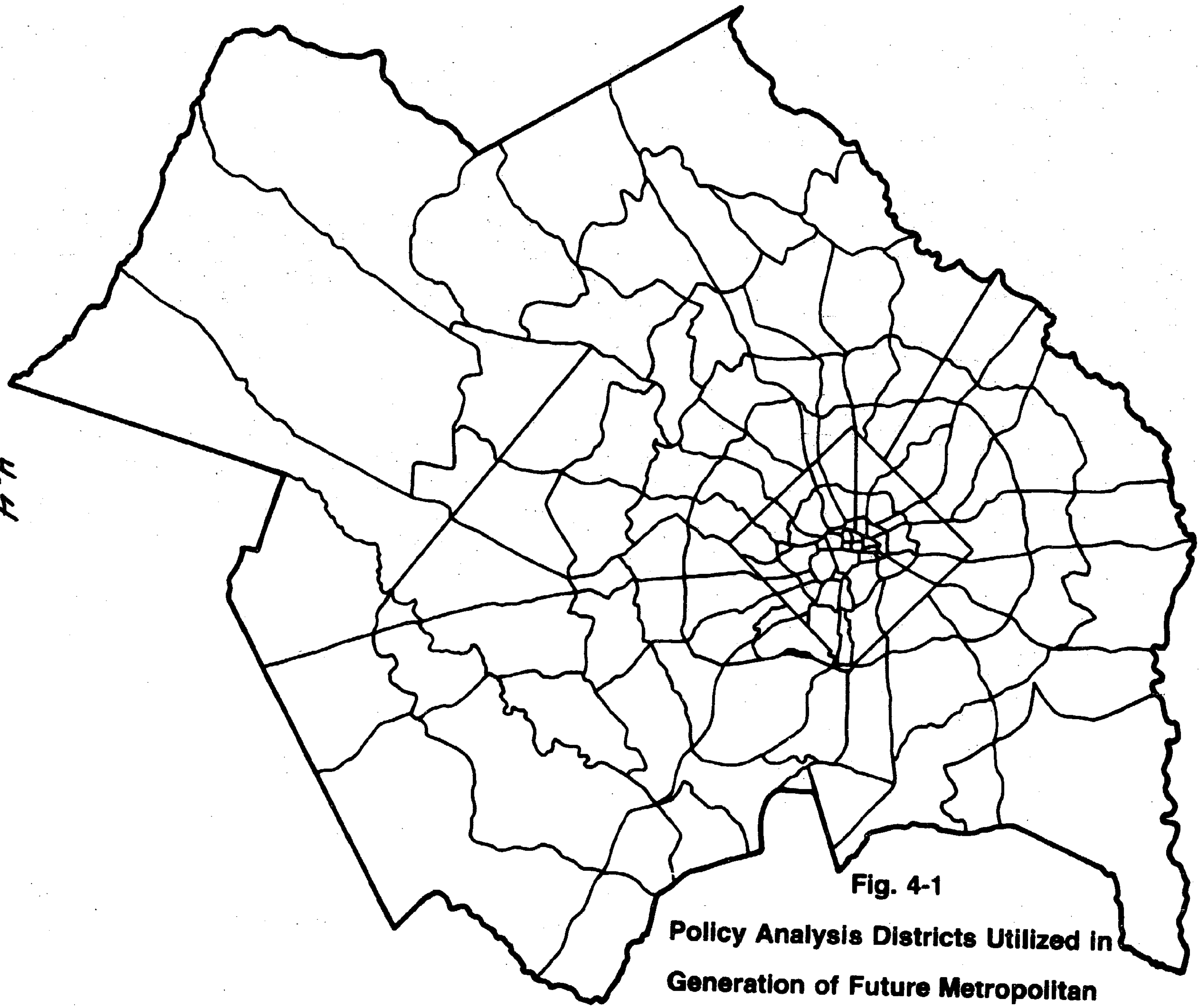

Fig. 4-1

Policy Analysis Districts Utilized in Generation of Future Metropolitan

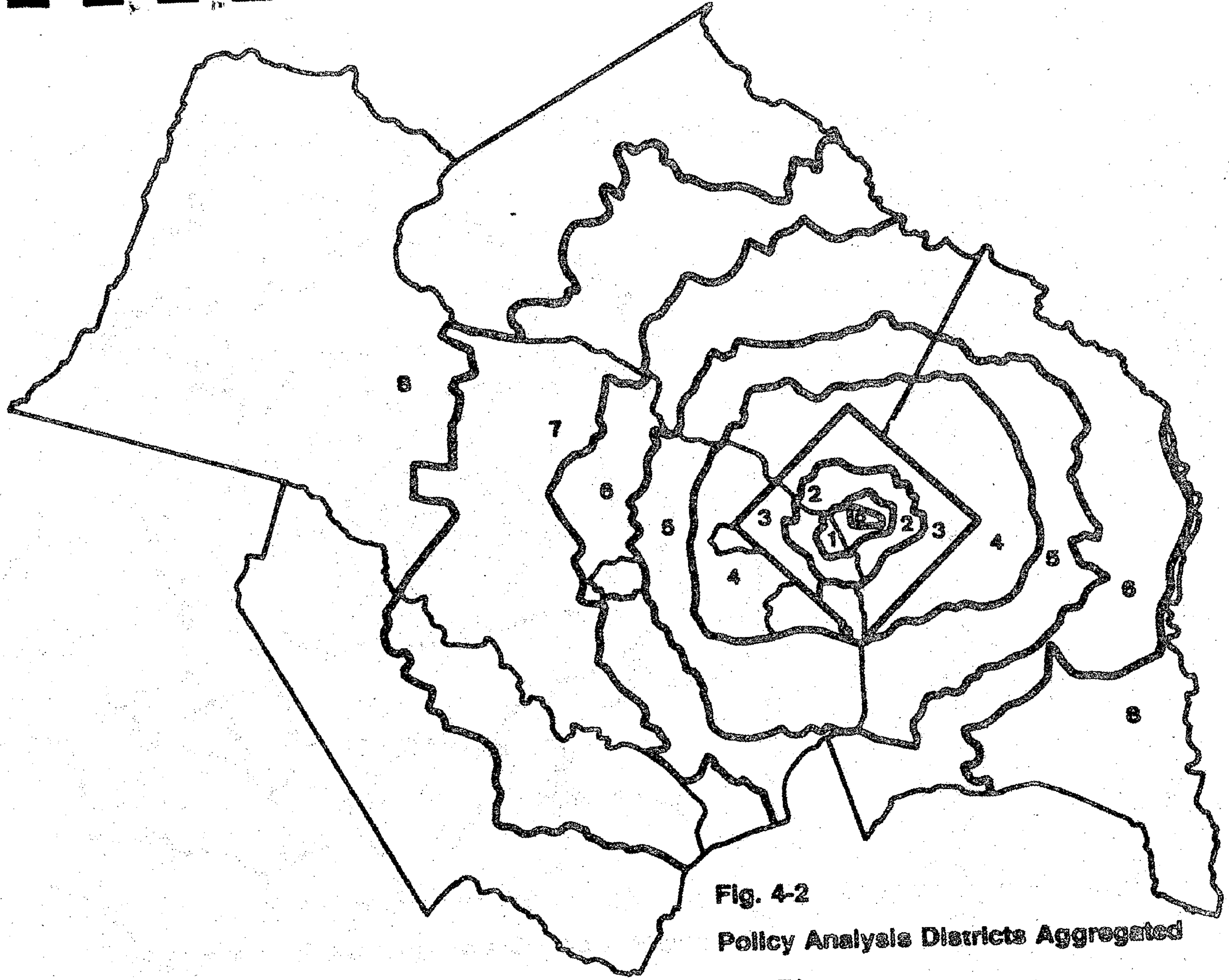

Fig. 4-2

Policy Analysis Districts Aggregated Into Rings

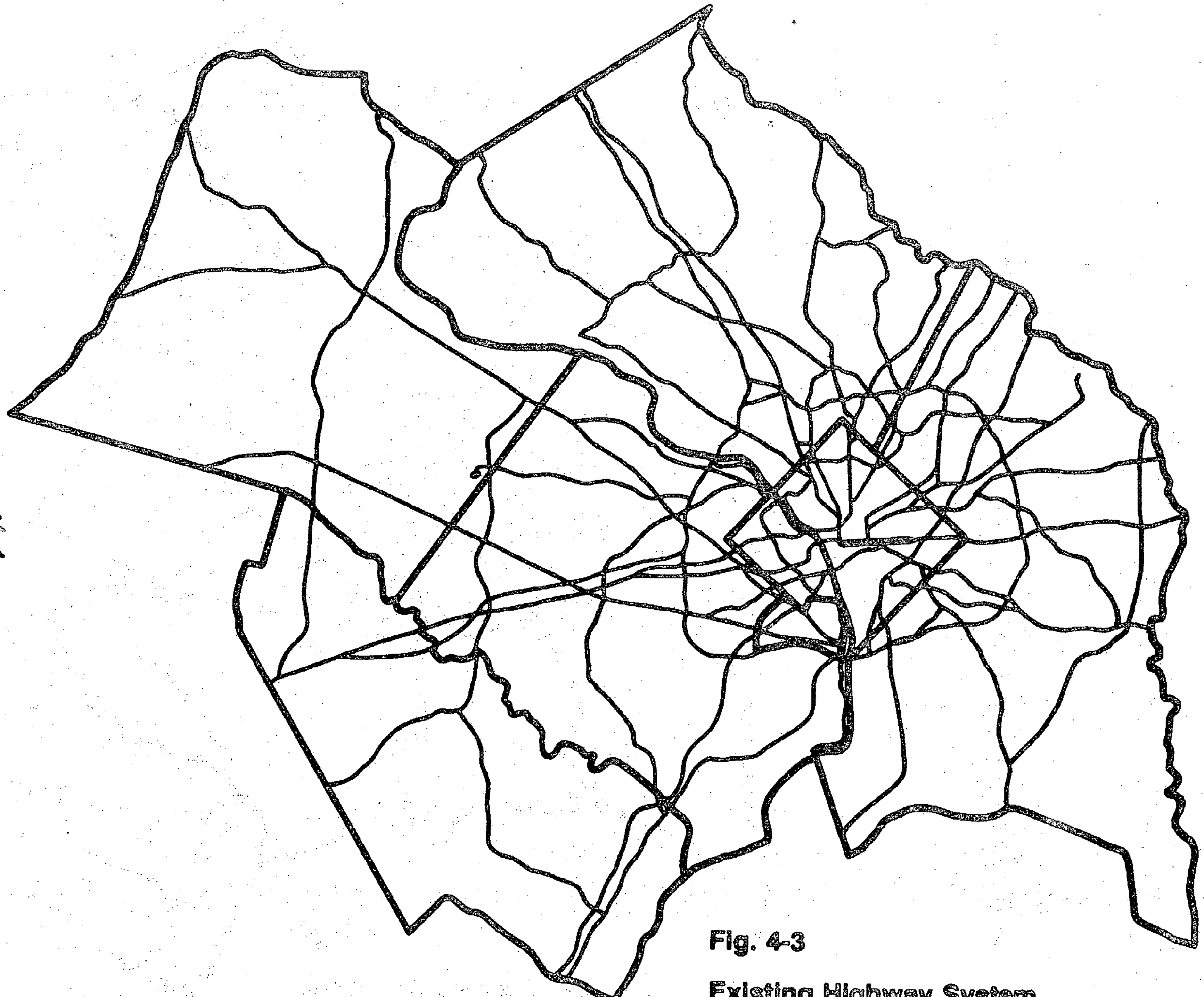

Fig. 4-3

Existing Highway System

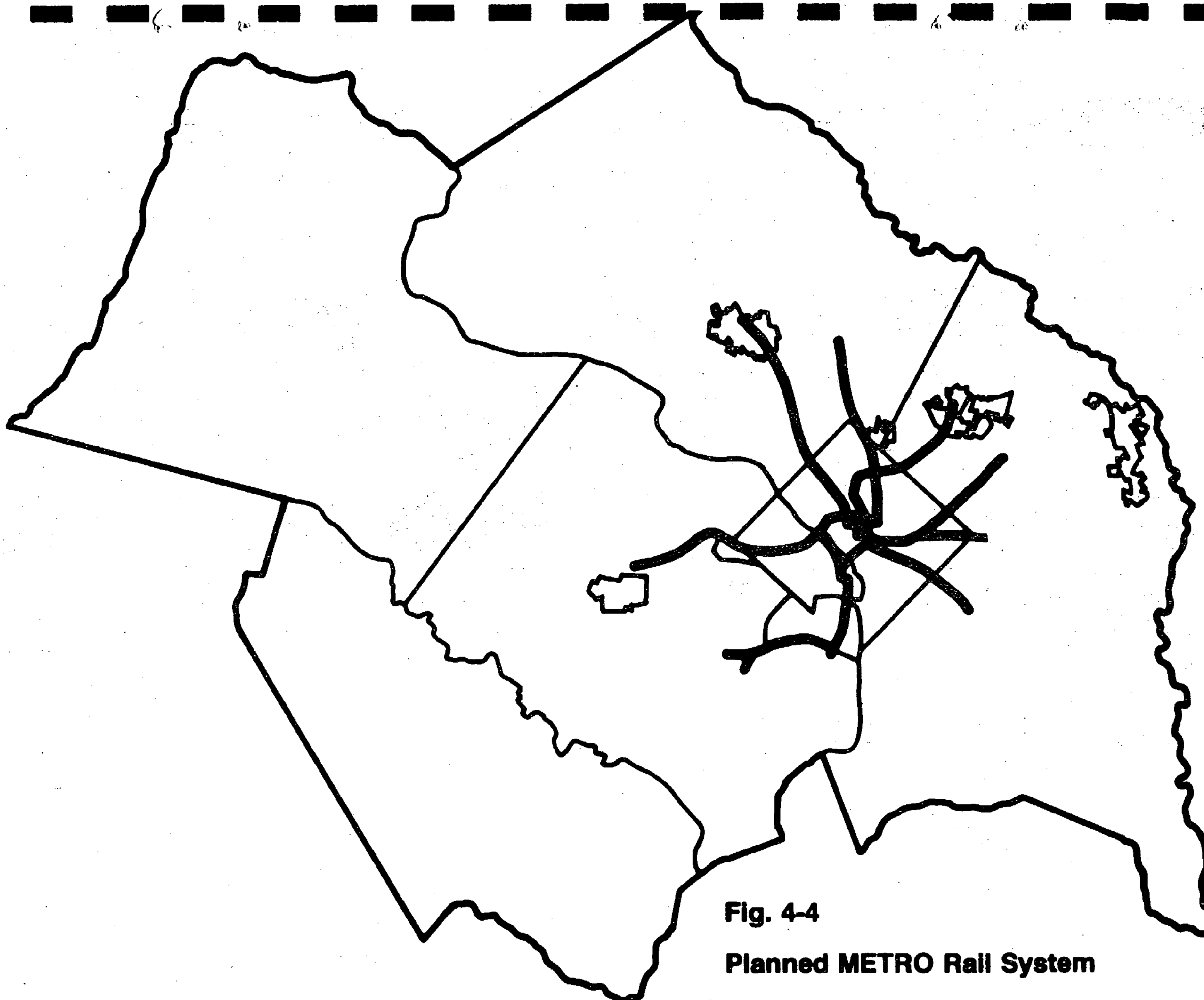

Fig. 4-4

Planned METRO Rail System

(Adopted 98-Mile Regional System)

C. "Balanced Communities in Corridors Oriented to METRO Station Impact Areas," where new households and new jobs are located in a radial configuration along transit routes concentrated in districts where transit stations are planned.

D. "Local Interpretation of 'Wedges and Corridors,' With Income Balance," where differences in median household income by district are reduced, but household and employment allocations derived in scenario "A" are maintained. This alternative was tested to determine the effects upon VMT (Vehicle Miles of Travel) when household income for all policy analysis districts falls within the middle two quartiles of the metropolitan household income distribution, since VMT is sensitive to the longer, more frequent auto trips generated by upper income households.

E. "Sprawl," where considerable development occurs on the urban fringe at low densities, with noncontinguous residential configurations, New employment on the other hand is more concentrated in the metropolitan center, while new retail activity is located around the Beltway.

F. "Concentrated Development Around the Beltway," with all new development occuring on vacant land immediately inside and outside the Capital Beltway.

The variations among these development scenarios are best illustrated by relating activities--households and employment--to area, so that density differences among the scenarios are revealed. In the following series of figures (4-5 through 4-16) average household density and the average intensity of employment per acre at the level of the planning analysis district are displayed. Differences among these alternative scenarios reported numerically may be found in Appendix A.

With each figure, there is also associated a density gradient (see Figures 4-17 and 4-18), which shows average density by ring for total households or employment for the forecast year. Since the wide ranges used on the maps obscure some of the differences in density, this second set of measures is also useful.

In the household density comparisons, three alternatives look very much the same: "Wedges and Corridors," "Wedges and Corridors with Income Balance," and "Sprawl." Alternative F, "Beltway-Oriented," is similar to these, except for a bulge at Rings 4 and 5. The other two are very different: the "Dense Center" alternative shows an increase in density from the metropolitan center, and then a sharp decline. The "Transit-Oriented" alternative shows consistently high density from the Core to the Beltway, then drops sharply. This pattern reflects the assumption that new households are allocated according to the number of transit stops in the policy analysis district. Since there are more transit stops in the inner rings, there are more new households allocated and, therefore, higher densities as a consequence.

The gradients of employment intensity among alternatives are similar, with some slight shifts in slope. These differences directly reflect the underlying assumptions; the only important observation to be gained from them is the difference in upper density. In both the "Sprawl" and "Dense Center" alternatives, the employment intensity in the central ring is significantly higher than the others, reflecting the assumption that the major fraction of incremental employment in both cases would be allocated to the metropolitan core.

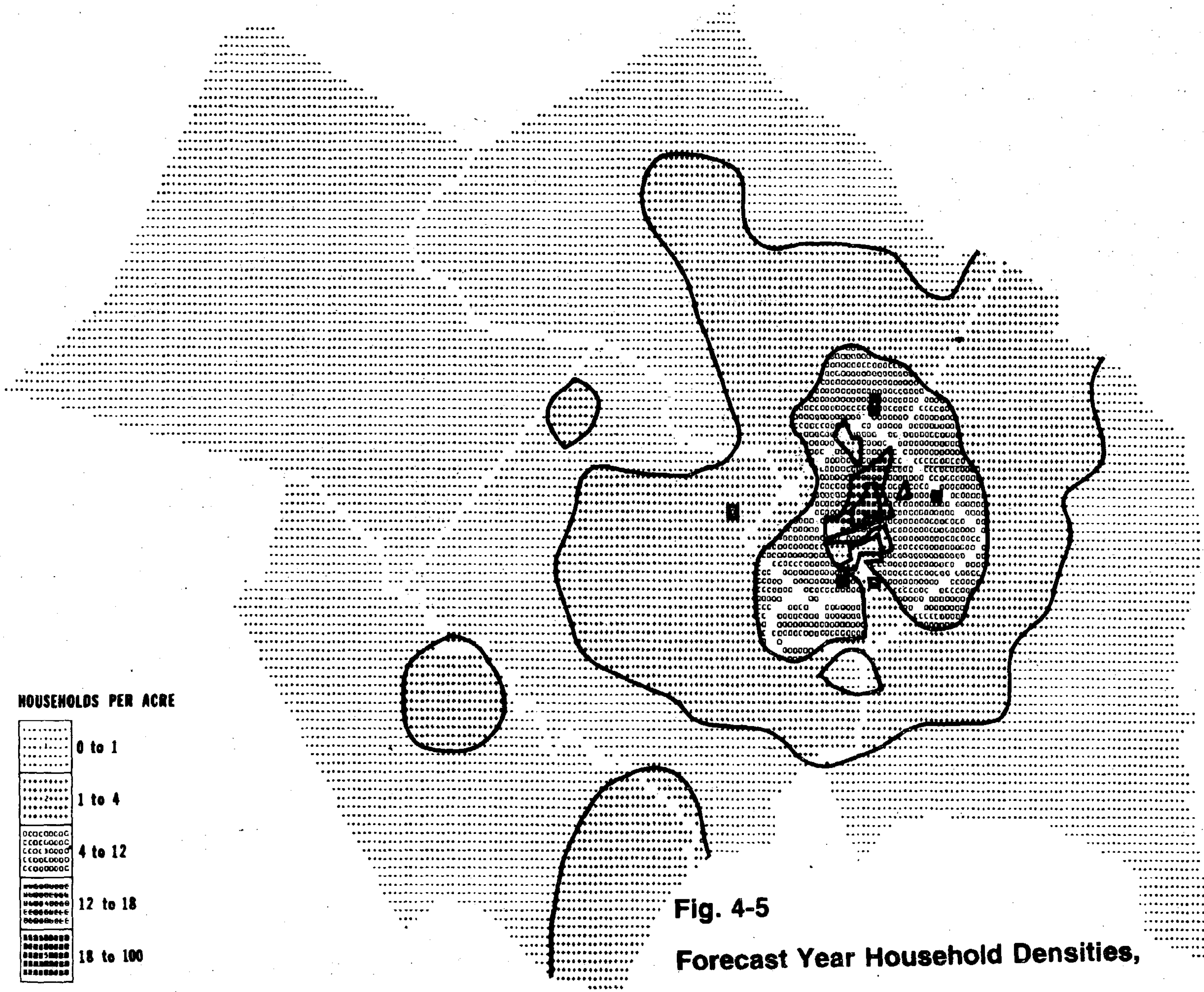

Fig. 4-5

Forecast Year Household Densities, "Wedges and Corridors," Scenario A

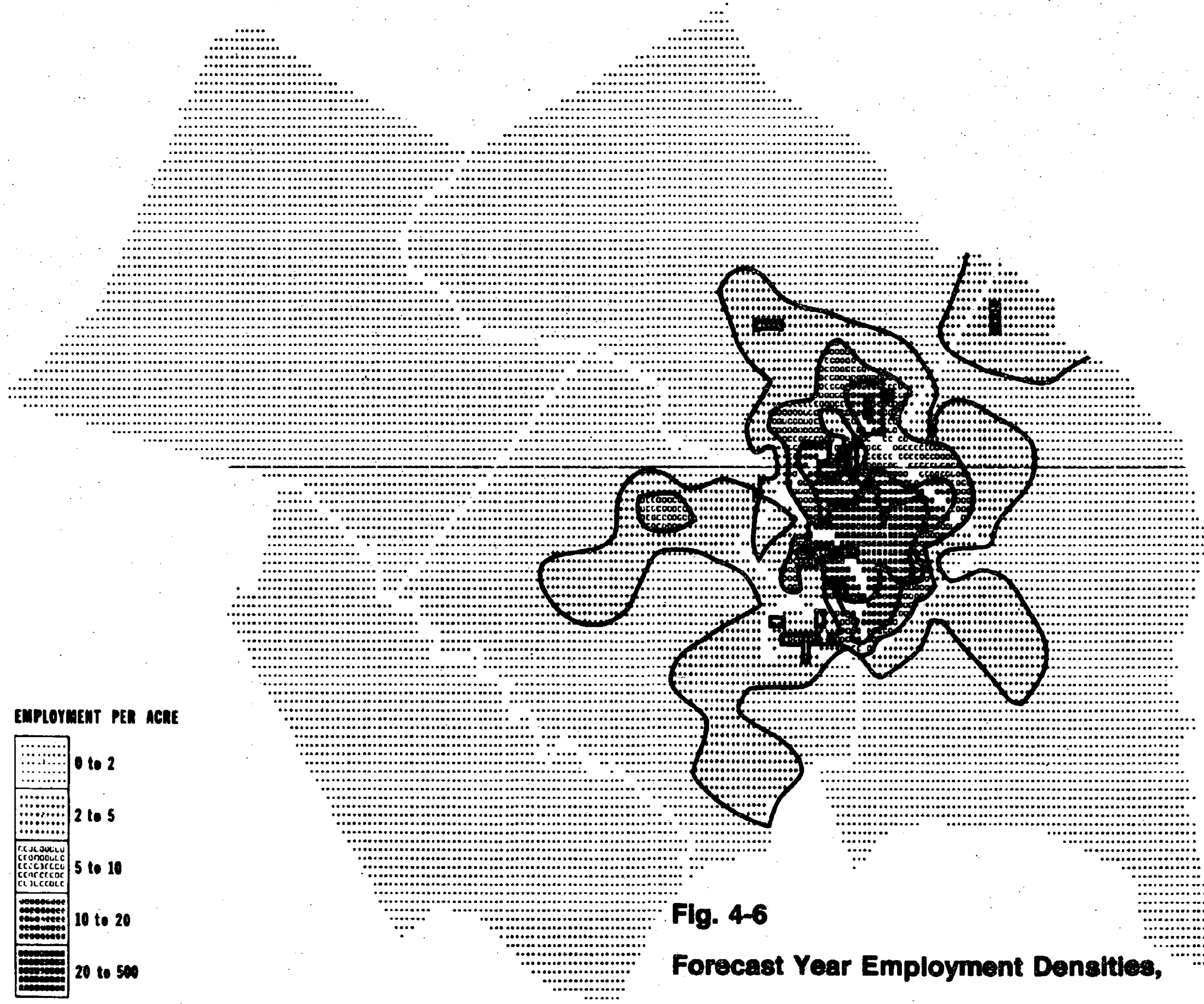

Fig. 4-6

Forecast Year Employment Densities,

"Wedges and Corridors,"

Scenario A

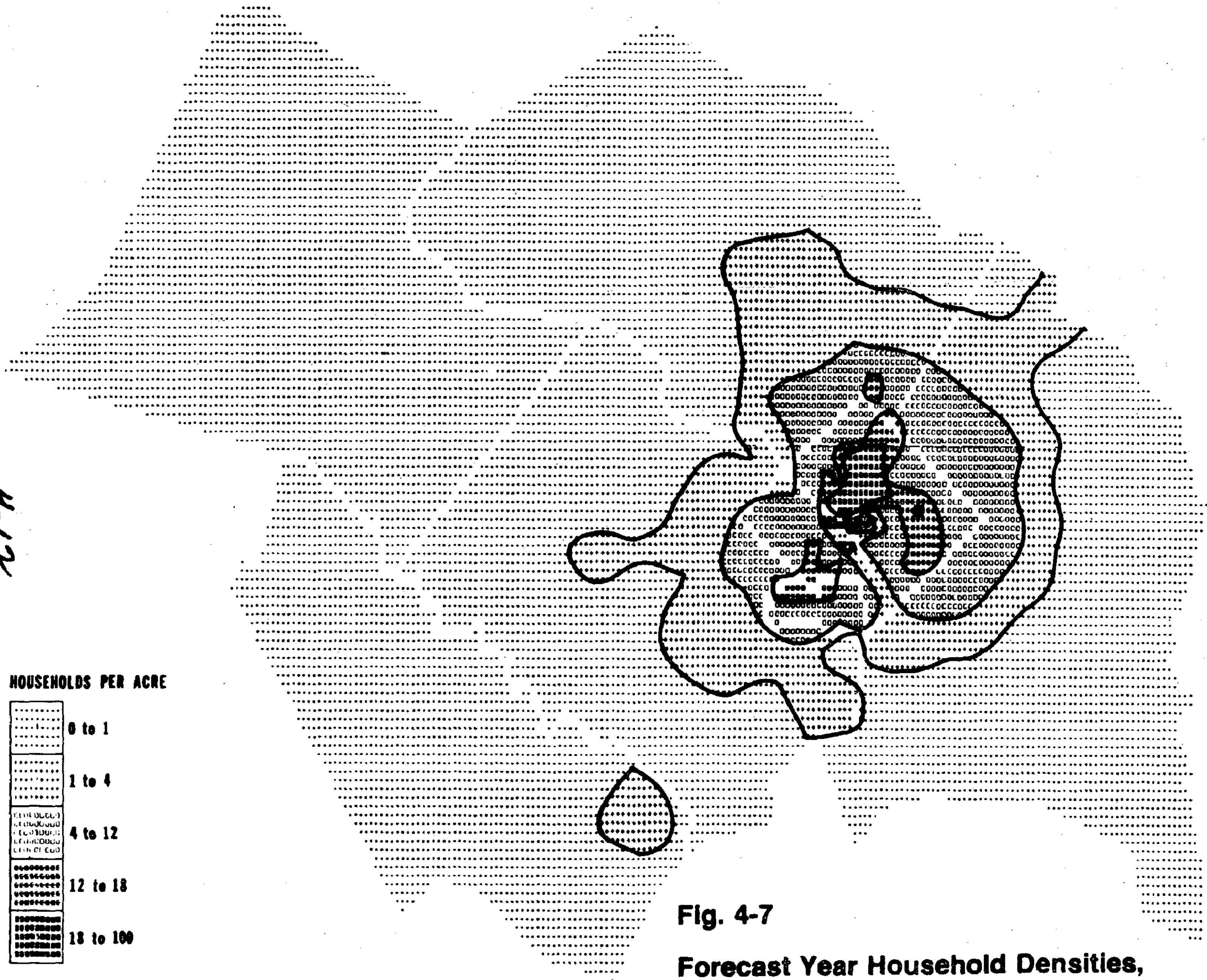

Fig. 4-7

Forecast Year Household Densities,

"Dense Center," Scenario B

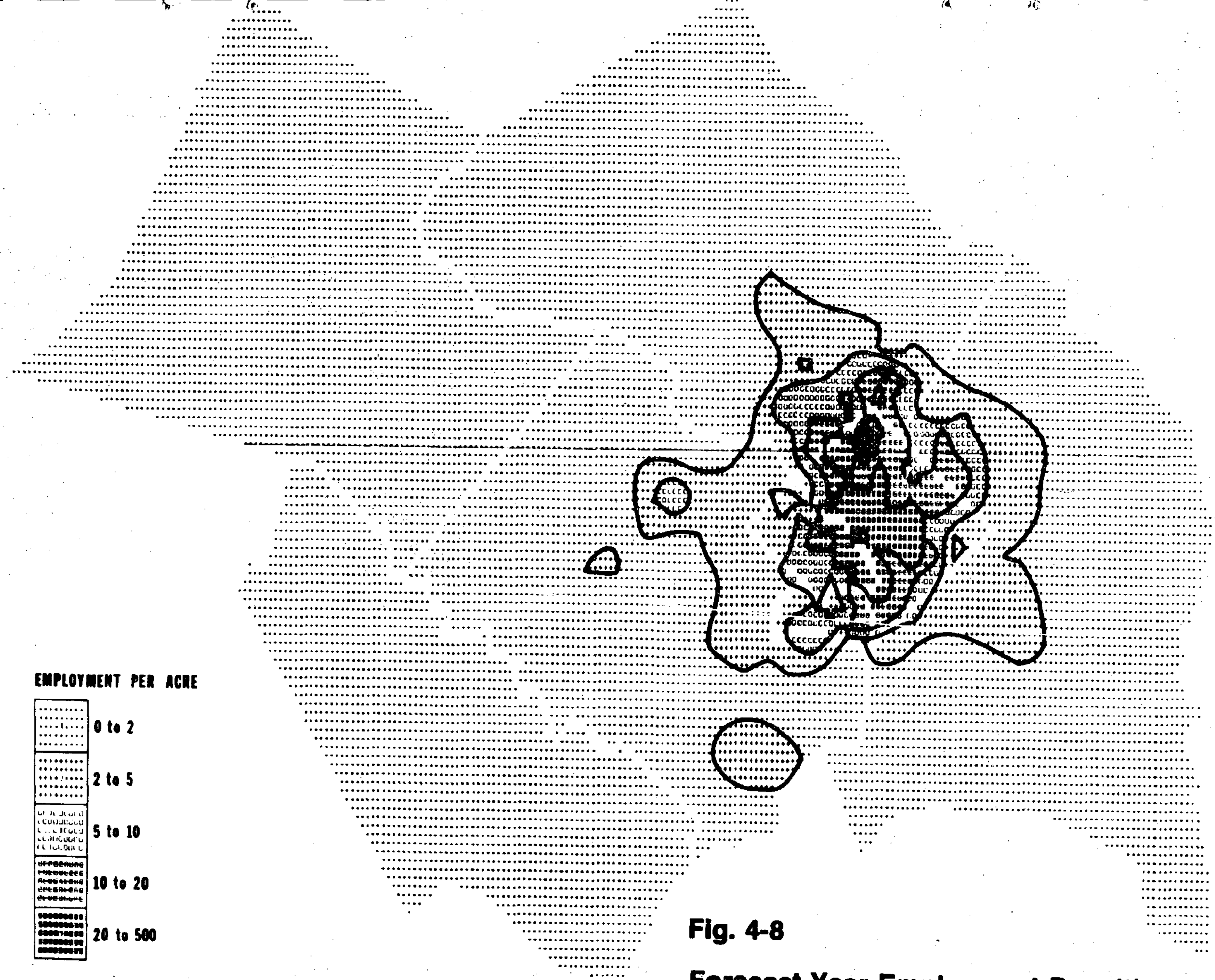

Fig. 4-8

Forecast Year Employment Densities, "Dense Center," Scenario B

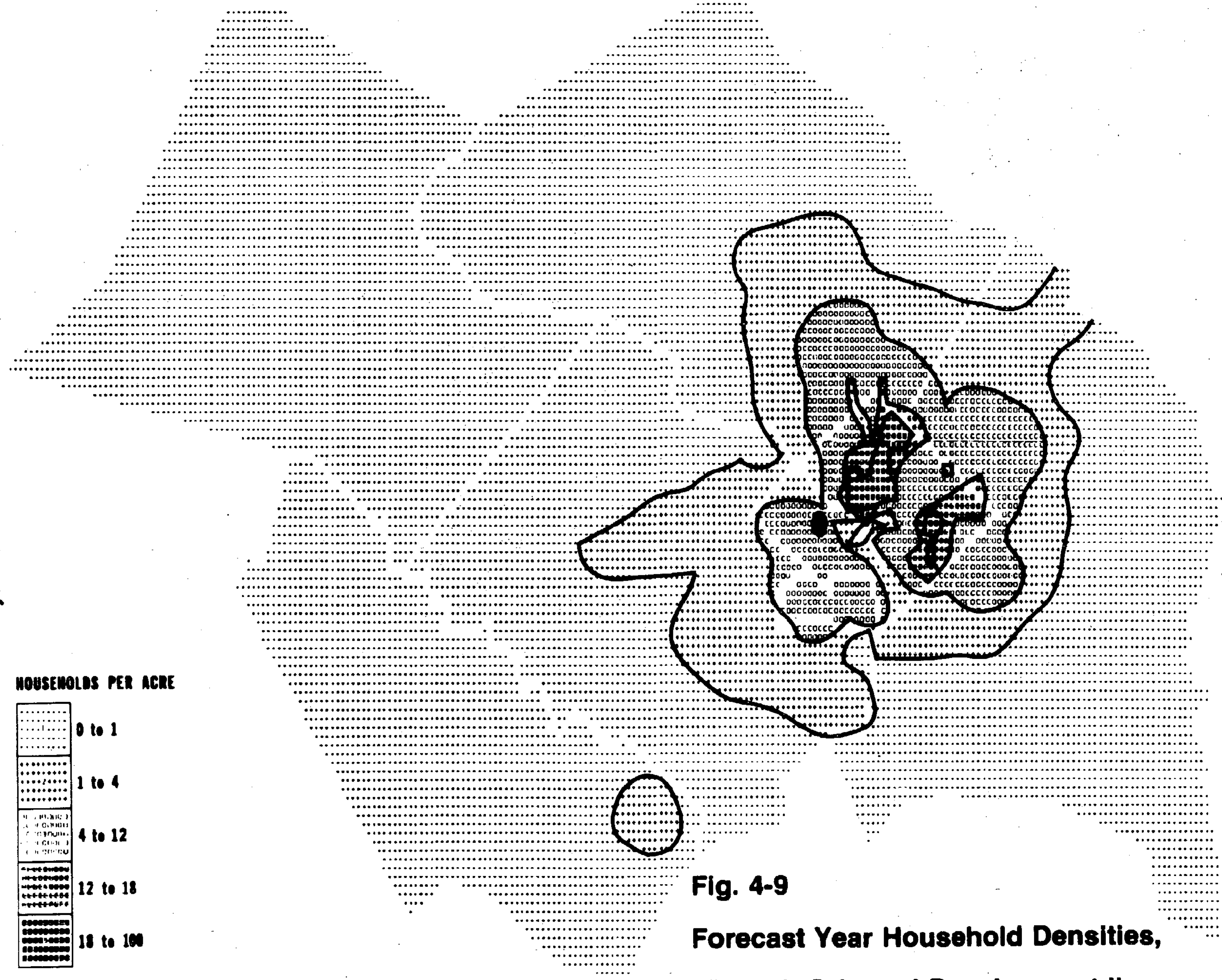

Fig. 4-9

Forecast Year Household Densities,

"Transit-Oriented Development,"

Scenario C

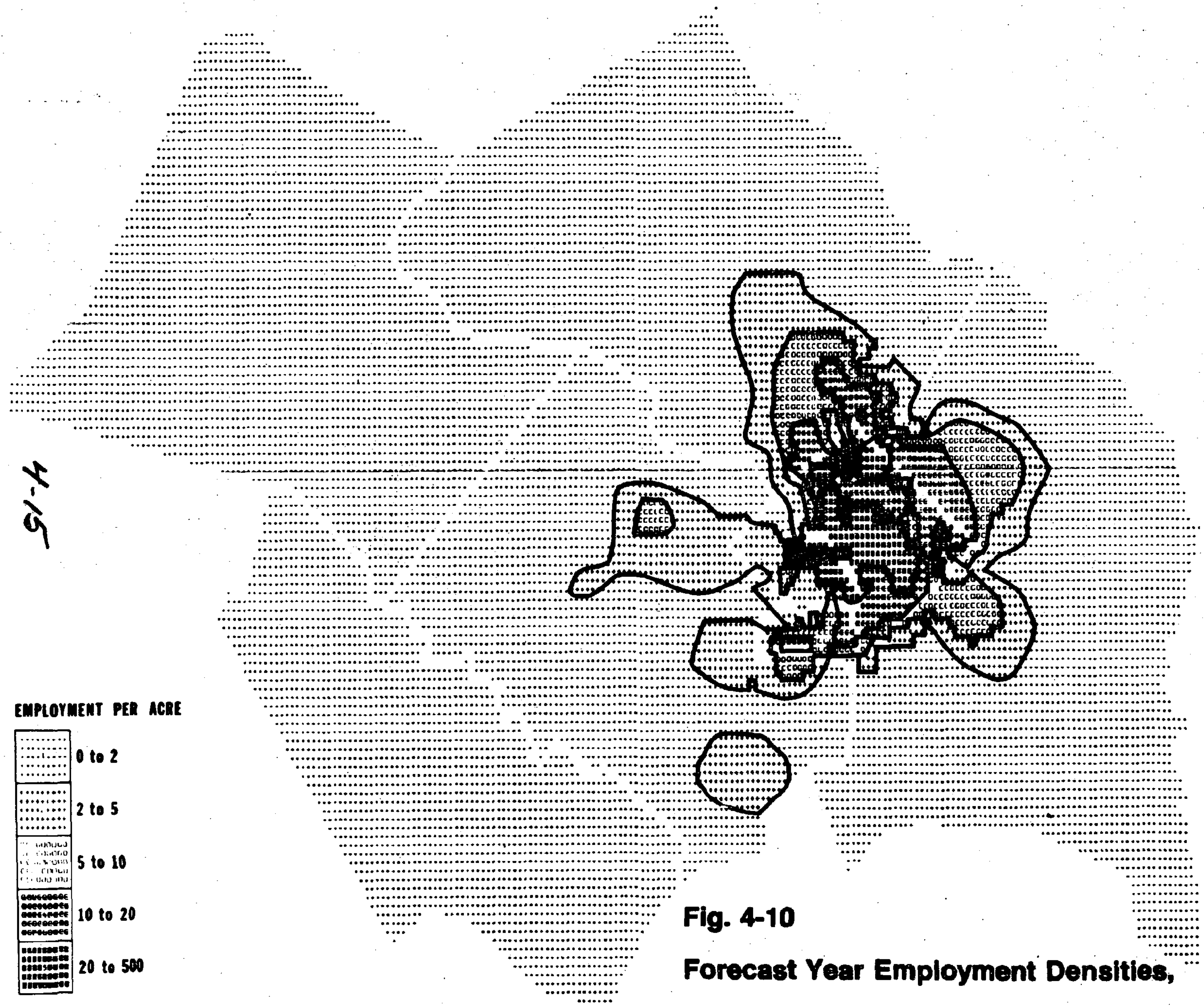

Fig. 4-10

Forecast Year Employment Densities, Transit-Oriented Development," Scenario C

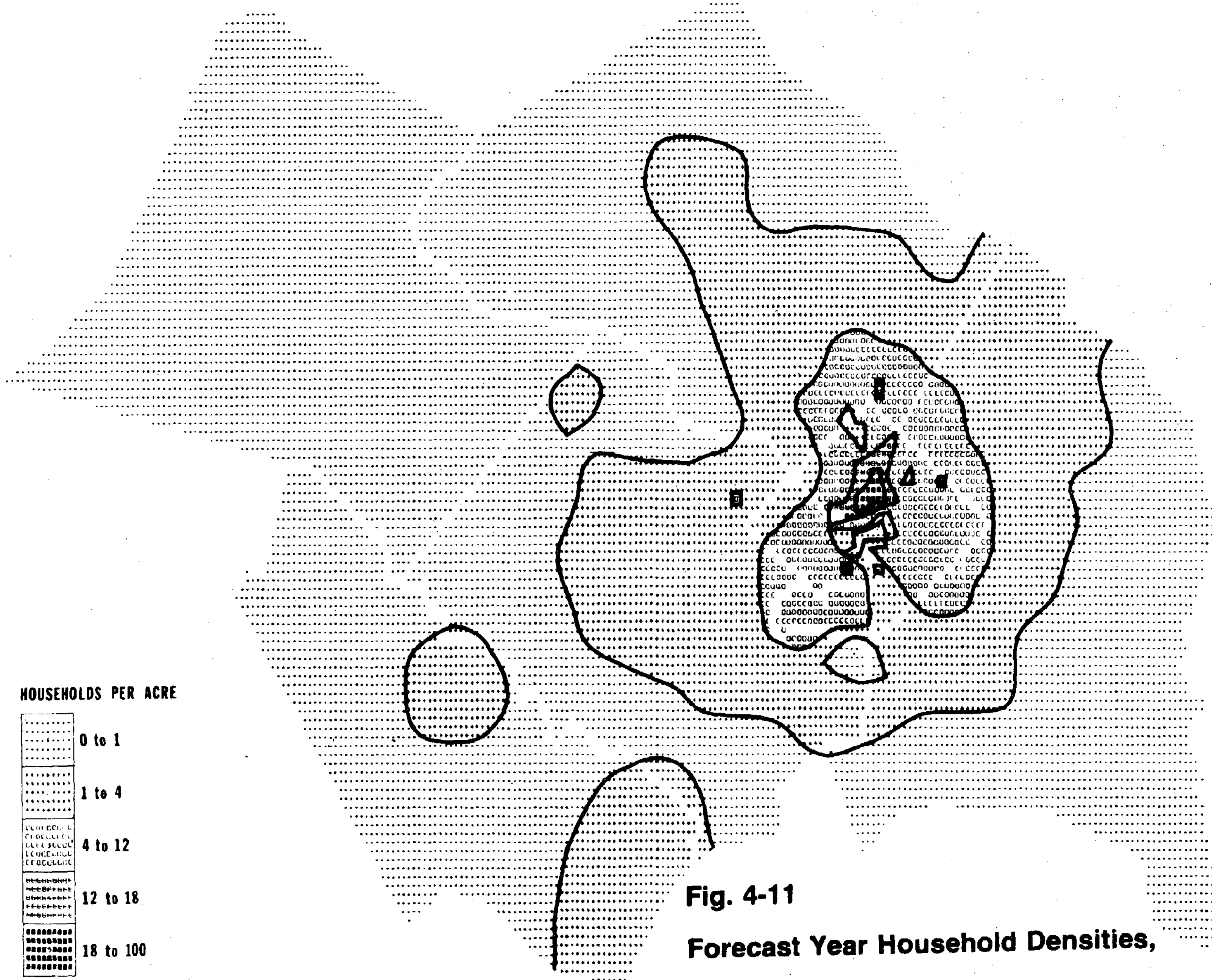

Fig. 4-11

Forecast Year Household Densities,

"Wedges and Corridors with Income Balance,"

Scenario D

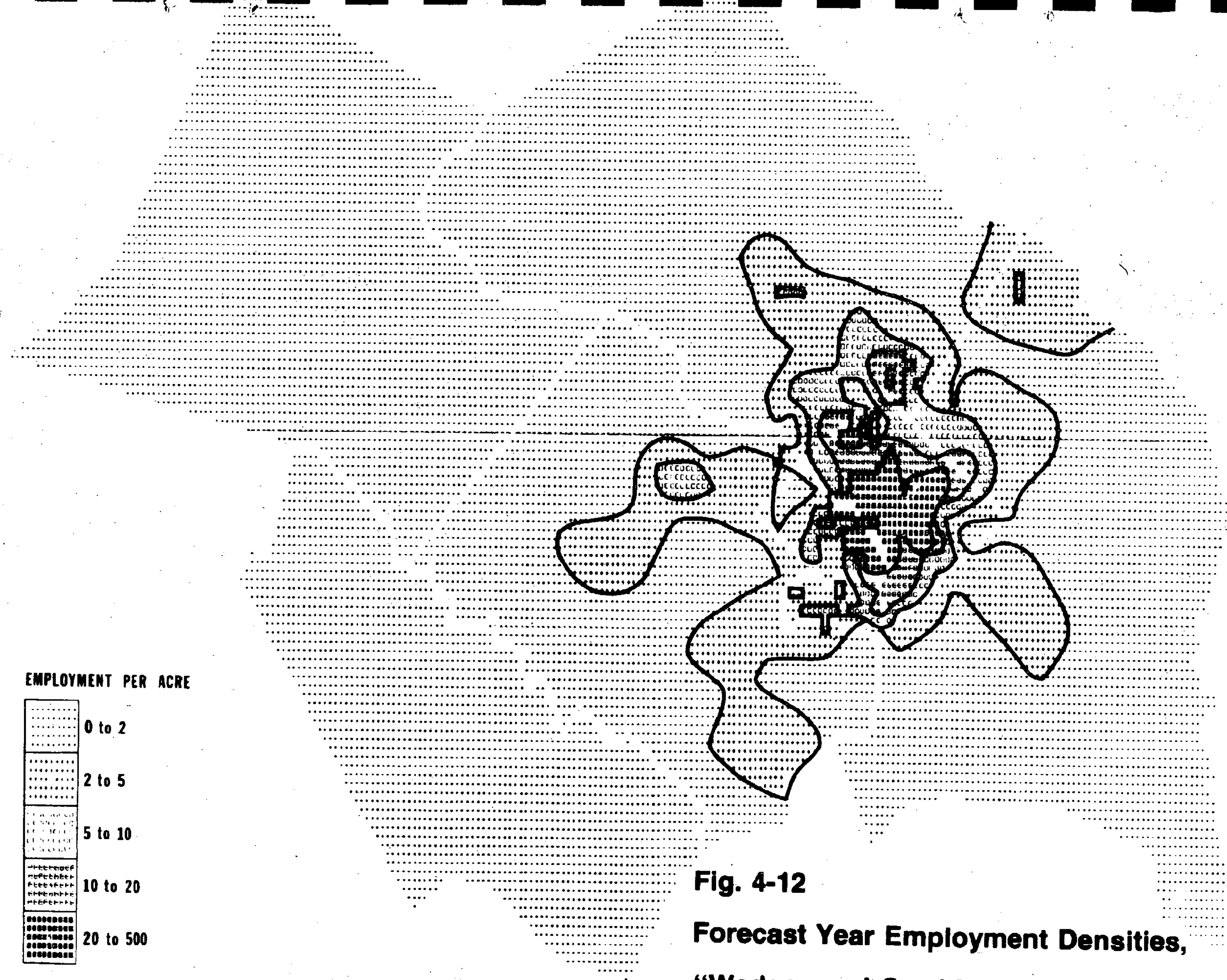

Fig. 4-12

Forecast Year Employment Densities, "Wedges and Corridors with Income Balance," Scenario D

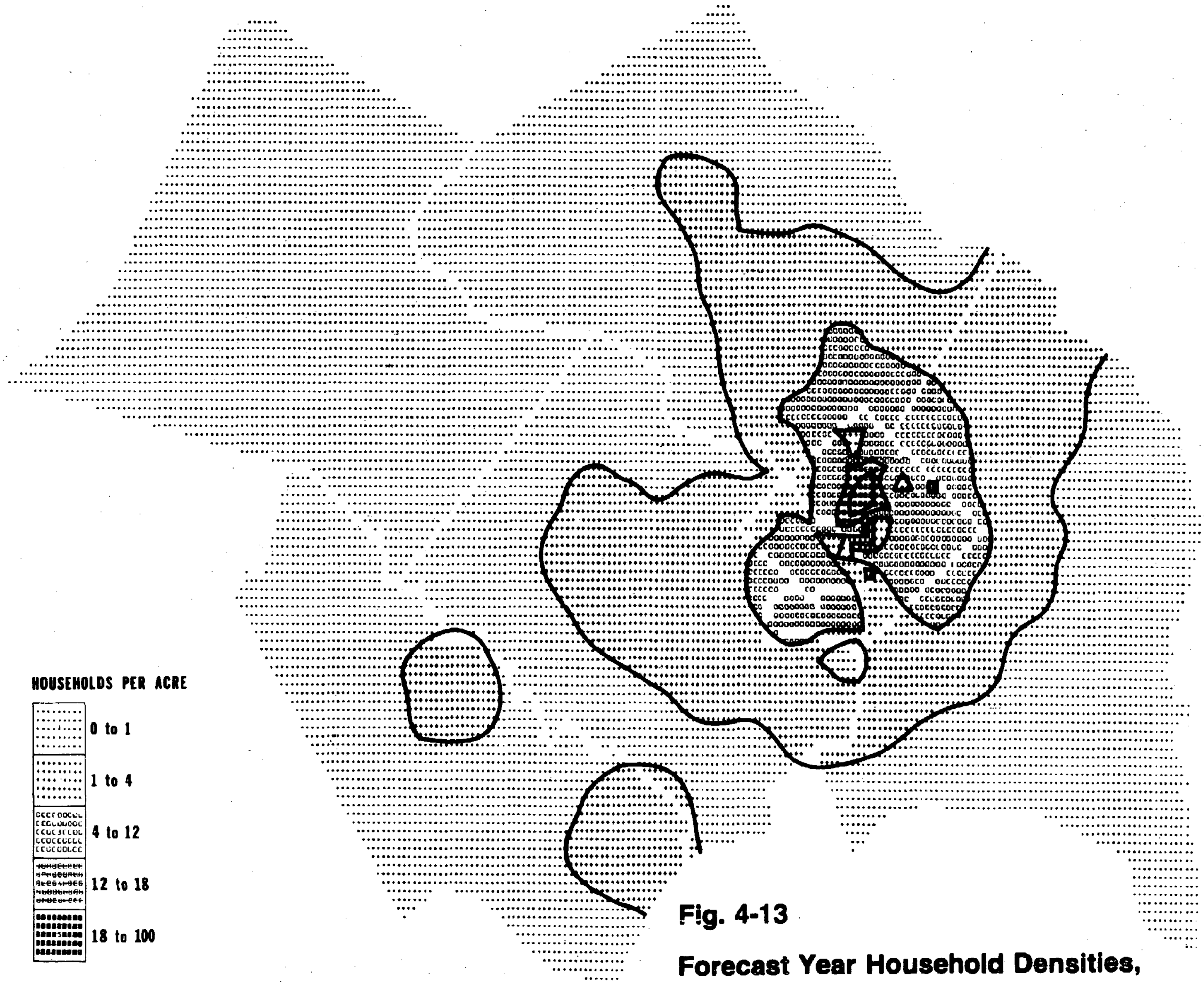

Fig. 4-13

Forecast Year Household Densities, "Sprawl," Scenario E

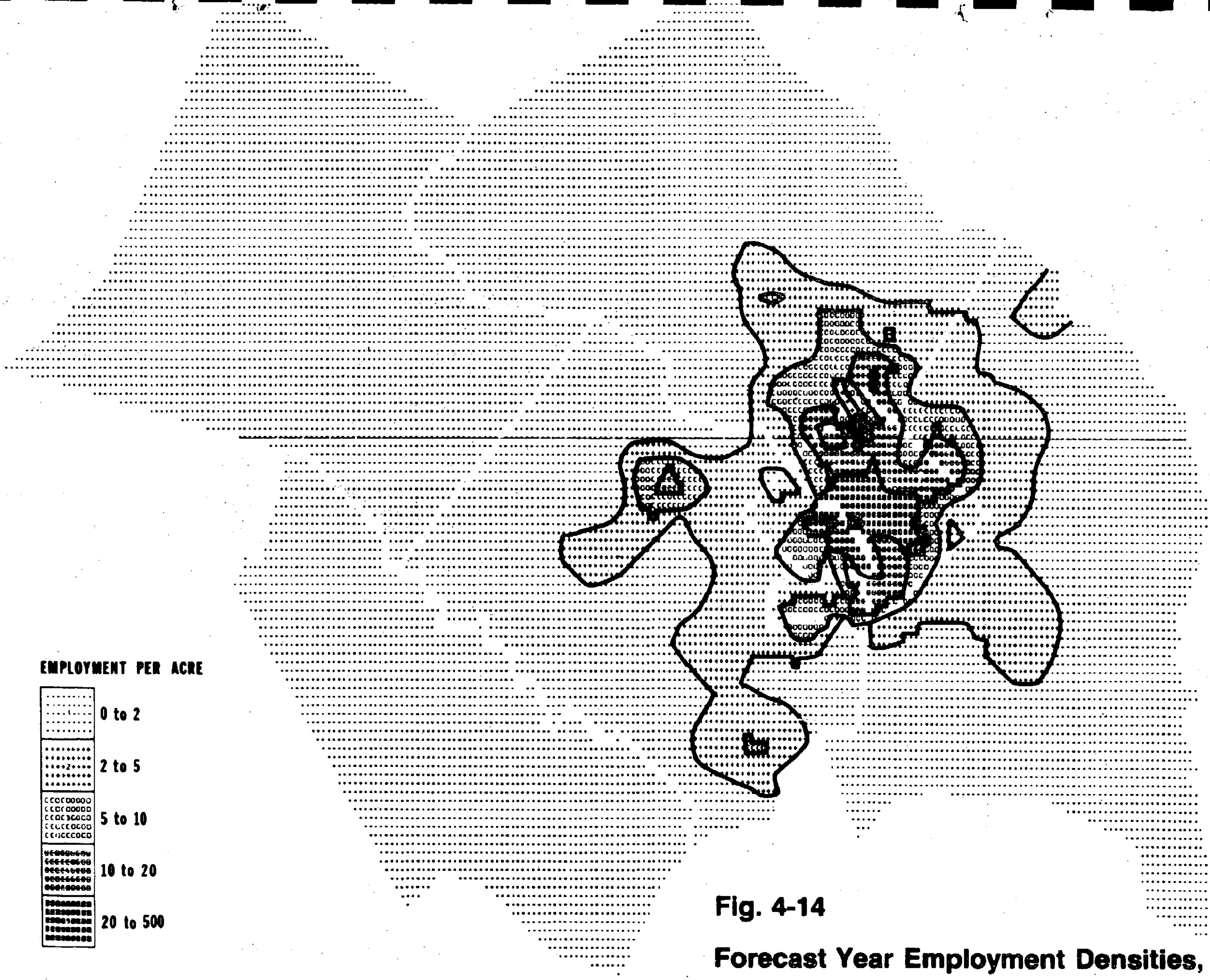

Fig. 4-14

Forecast Year Employment Densities, "Sprawl," Scenario E

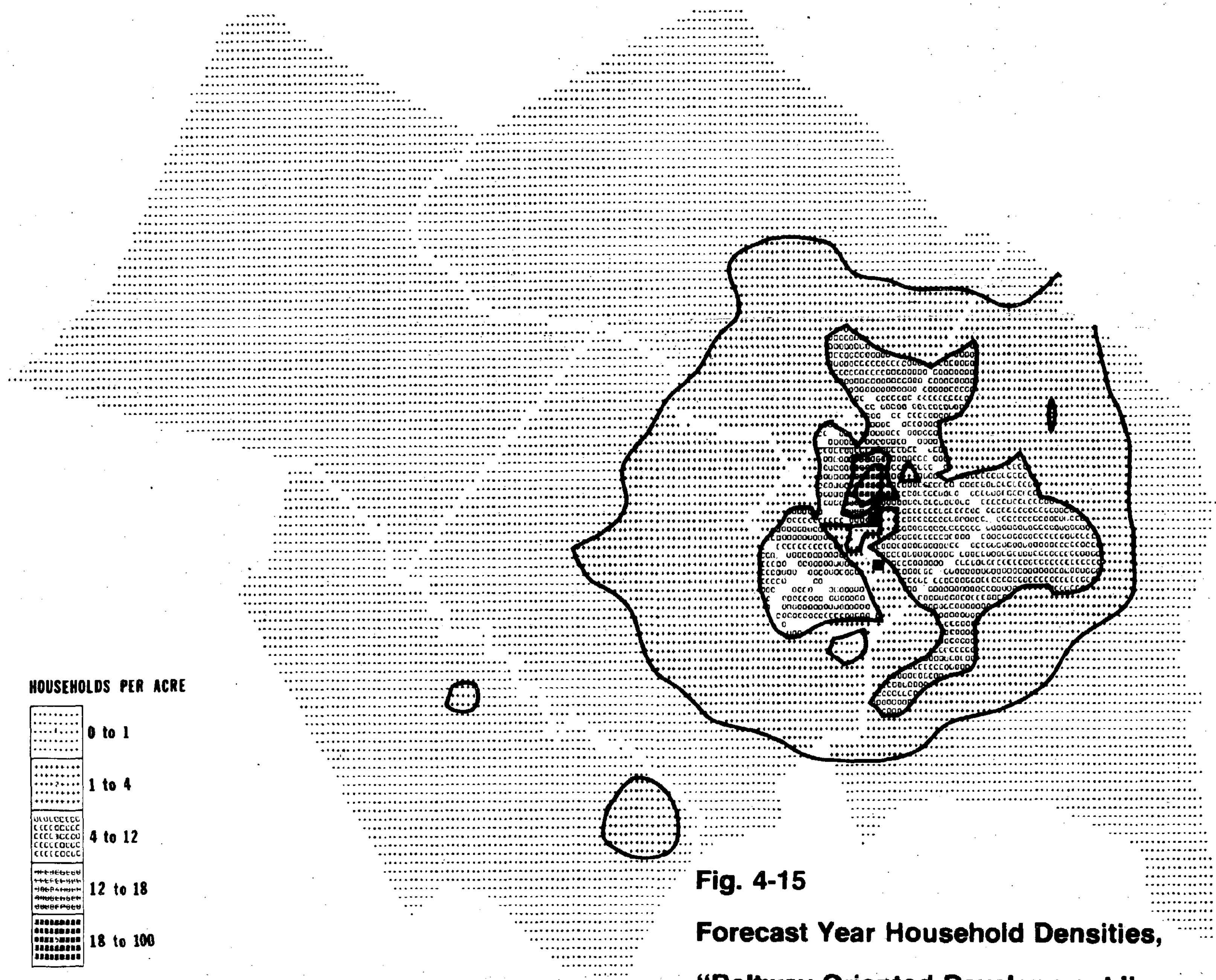

Fig. 4-15

Forecast Year Household Densities, "Beltway-Oriented Development," Scenario F

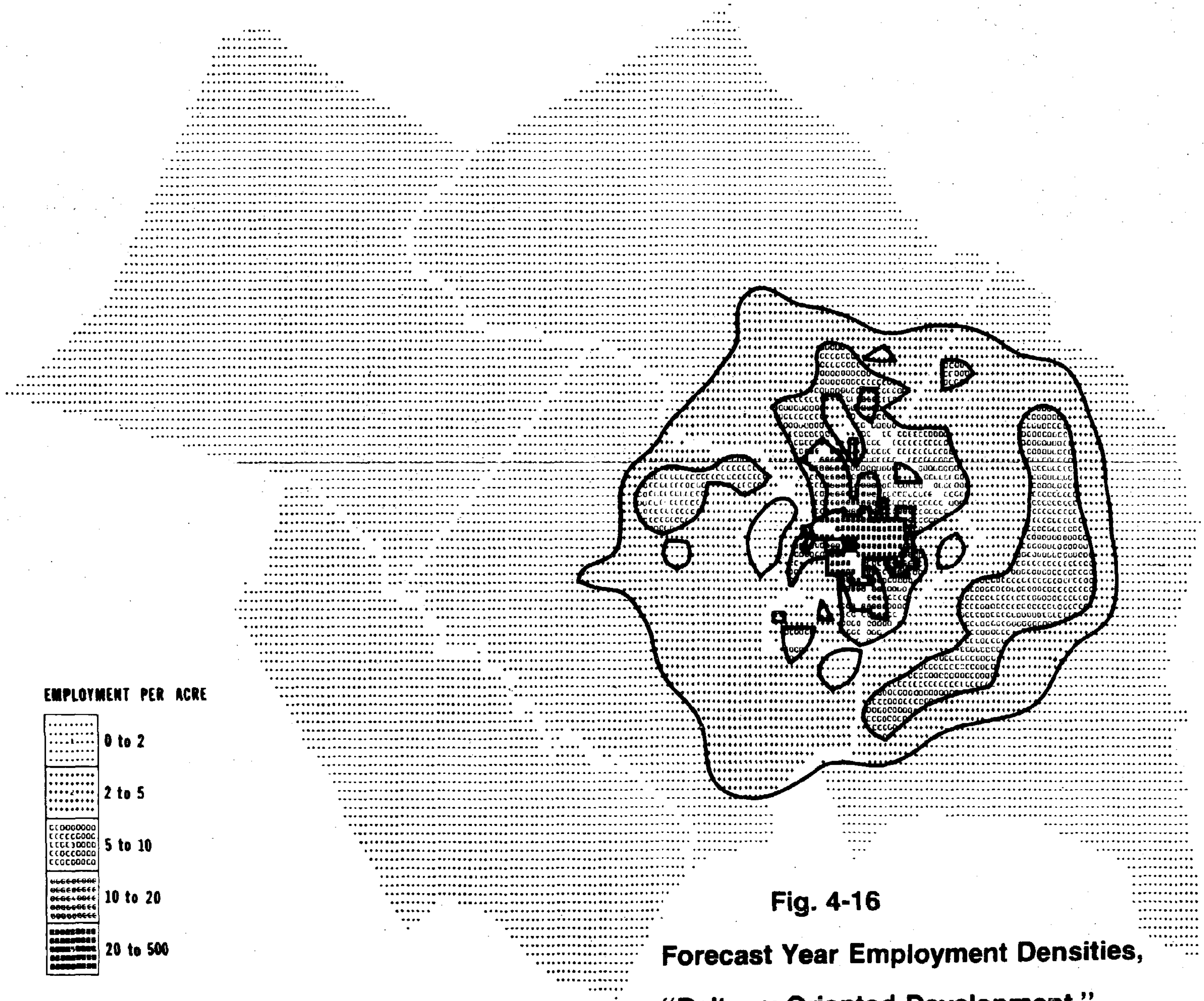

Fig. 4-16

Forecast Year Employment Densities,

"Beltway Oriented Development,"

Fig. 4-17 Forecast Year Household Density Gradients by Ring, Scenarios A-F

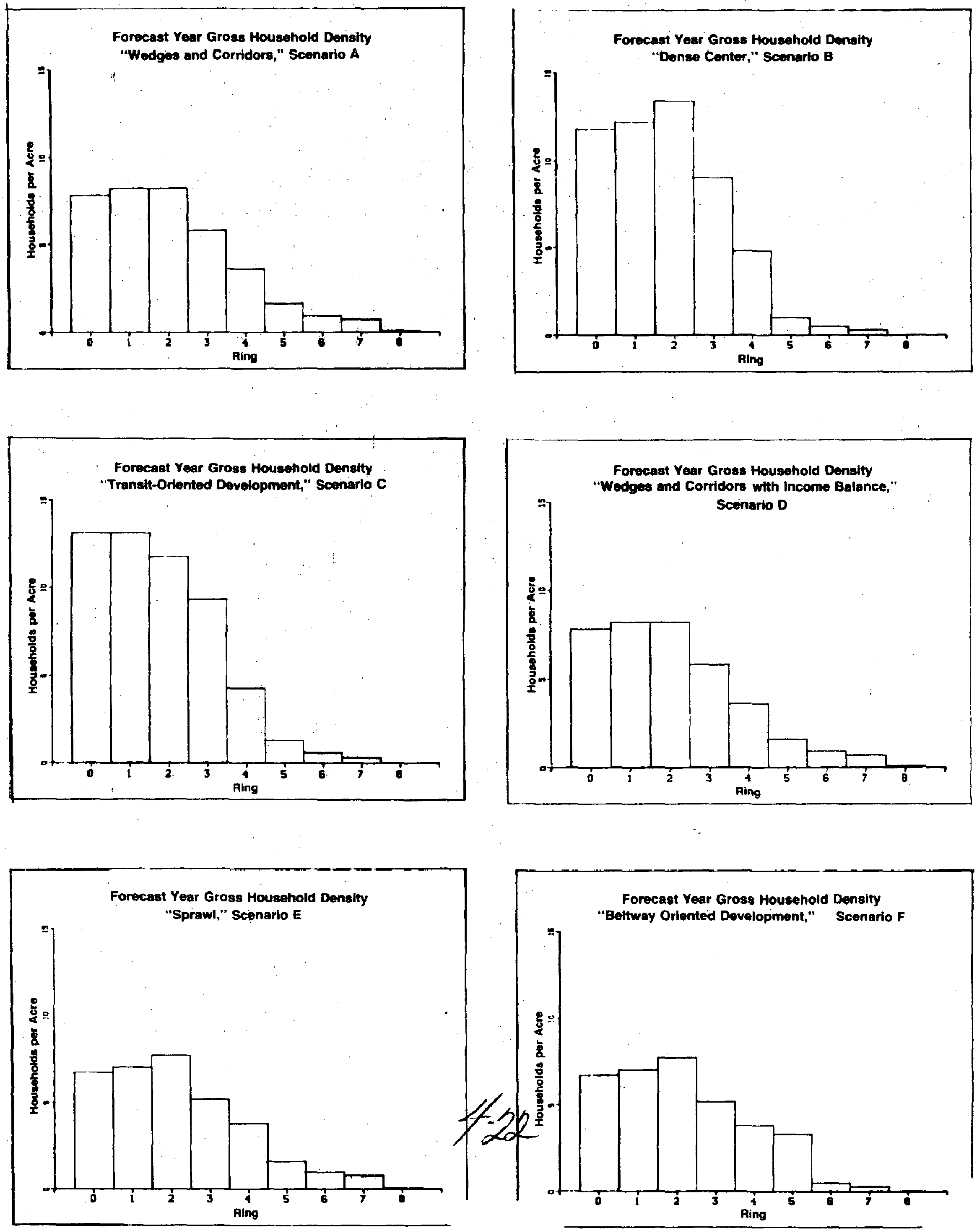

Fig. 4-18 Forecast Year Employment Density Gradients by Ring, Scenarios A-F

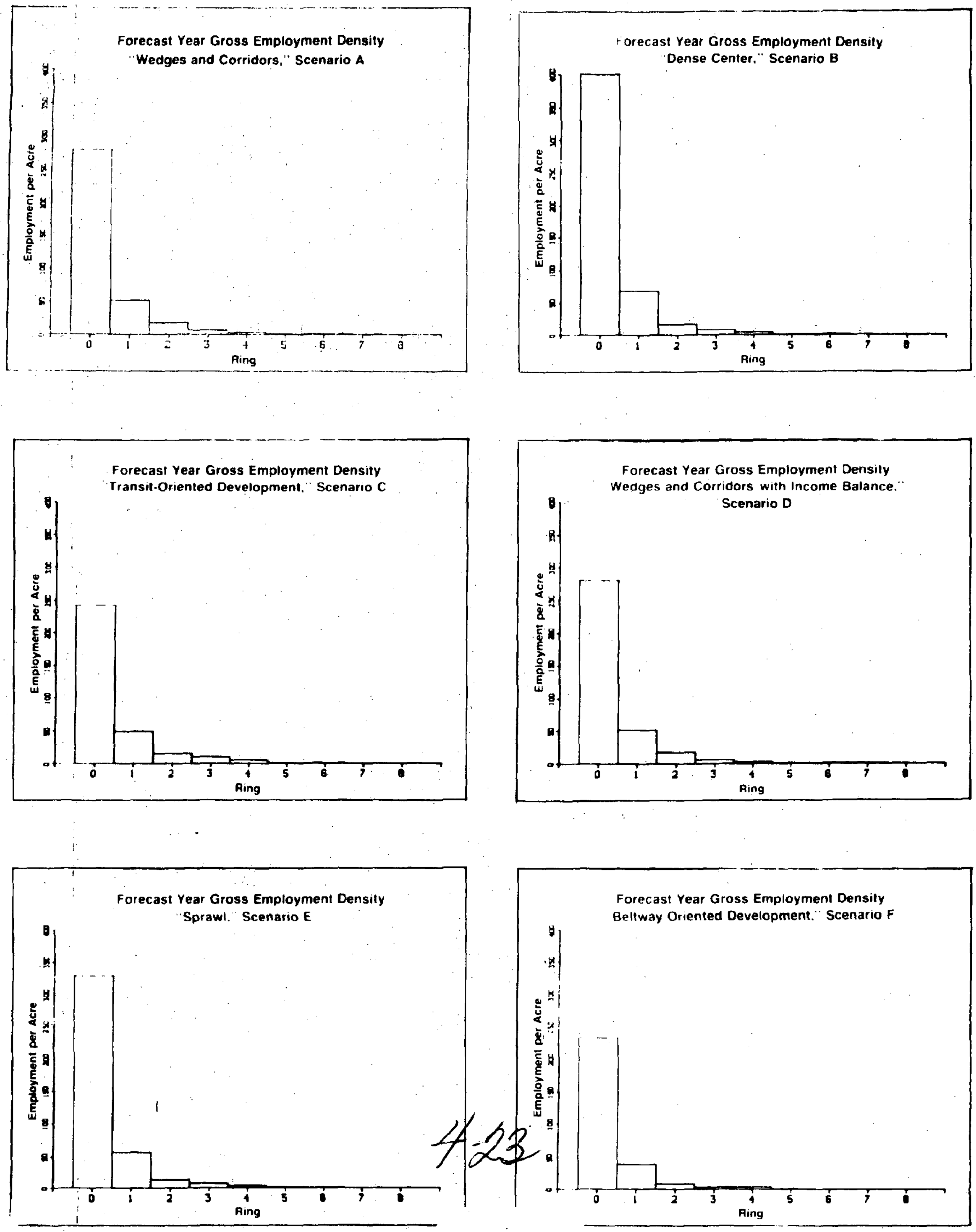

Table 4-1

Summary of Characteristics of Alternative Development Scenarios

A. General Characteristics (do not vary by scenario):

	Base	Increment	Total
Population:	3,307,000	1,199,800	4,506,800
Households:	1,090,300	499,600	1,589,900
Employment:	1,496,000	782,800	2,278,800

B. Characteristics of Incremental Household and Employment (Varv bv scenario)

Scenario	New Households	New Employment
"Local Expression of Wedges and Corridors" (Scenario A)	Allocated according to "6.2 modified" projections provided by local jurisdictions.	Allocated according to "6.2 modified" projections provided by local jurisdictions.
"Dense Center" (Scenario B)	All new households allocated inside Beltway in proportion to base year households.	All new employment allocated inside Beltway in proportion to base year employment levels.
"Transit-Oriented" (Scenario C)	New households allocated to districts with METRO transit stations, weighted by the number of stations within districts.	New employment in retail and commercial sectors allocated to districts with METRO transit stations; new employment in industrial and "other" allocated to rings 3, 4, 5, 6 only, according to base year levels of activity.

Table 4-1 (continued)

Scenario	New Households	New Employment
Wedges and Corridors, With Income Balance" Scenario D)	Allocated according to "6.2 modified" projections but median household income for all policy analysis districts is assumed to be in the middle two quartiles of the metropolitan household income distribution.	Allocated according to "6.2 modified" projections.
"Sprawl" (Scenario E)	200,000 new households (single-family) allocated to districts outside Beltway according proportion of vacant land; balance of incremental households allocated outside ten-mile square.	Incremental retail employment allocated between beltway and ten-mile square; all other employment allocated in proportion to base year employment levels within policy analysis districts.
"Beltway-Oriented" (Scenario F)	Incremental households allocated to rings 4 and 5 according to base year proportion of vacant land.	Incremental employment allocated to rings 4 and 5 according to base year proportion of vacant land.

C. Housing Mix

Percent of New Housing by Type Assumed for Scenarios

	Single Family Detached	Single Family Attached	Garden or Walkup Apts.	High-Rise Apts.
A. "Wedges & Corridors"	30	30	20	20
B. "Dense Center"	10	20	25	45
C. "Transit-Oriented"	10	30	25	35
D. "Wedges & Corridors with Income Balance"	30	30	20	20
E. "Sprawl"	45	35	15	5
F. "Beltway-Oriented"	30	35	20	15

CHAPTER 5

PROJECTION OF ENERGY CONSUMPTION AND FUTURE ENERGY BALANCES

a. Alternative Development Scenarios: Methodology

In calculating metropolitan energy consumption for each alternative scenario, several steps were required. The calculations are summarized according to sectors:

(1) Residential: The number of dwellings of each type (single family detached, attached, garden apartment, and high-rise) was multiplied by the per dwelling unit energy consumption factor appropriate to that type of unit, then totaled for the alternative.

(2) Employment: In similar fashion, the number of employees by sector was multiplied by the appropriate per-unit factor, and summed.

(3) Transportation: This sector was both an input and an output. Transportation demand was determined by the level and location of employment and household activities for the forecast year. Daily and annual vehicle miles traveled (VMT) for automobiles were then calculated utilizing the Council of Governments' Transportation Integrated Modelling System (TRIMS). In addition, energy consumption of the METRO transit system was obtained from the Washington Metropolitan Transit Authority and added directly to the transportation sector. Vehicle miles of travel (VMT) were converted to energy consumption using average fuel consumption factors.

b. Alternative Development Scenarios: Findings

Energy consumption according to development scenario is summarized in Table 5-1. The results present interesting variations, both in the magnitude and direction of energy use. In the residential sector, the greatest variation is between the "Sprawl" alternative and the "Dense Center" alternative; the difference amounts to nine percent of total residential energy consumption for the forecast year. The percentage difference between the

Table 5-1

Energy Consumption by
Alternative Development Scenarios

(In 10^{12} Btu/Yr.)

Consumption by Sector	Base	A Wedges and Corridors"	B "Dense Center"	C "Transit-Oriented"	D "Wedges & Corridors with Income Balance"	E "Sprawl"	F "Beltway-Oriented"
Residential	265.3						
Increment		109.9	91.0	95.8	109.9	122.6	112.4
Total, Forecast Year		375.2	356.3	361.1	375.2	387.9	377.7
Commercial/Industrial Institutional	176.6						
Increment		78.9	78.9	78.9	78.9	78.9	78.9
Total, Forecast Year		255.5	255.5	255.5	255.5	255.5	255.5
Transportation, Automobile	117.9						
Increment		59.5	35.1	33.1	46.8	70.6	52.2
Total, Forecast Year		177.4	153.0	151.0	164.7	188.5	170.1
Transportation, METRO	2.5						
Increment		12.4	12.4	12.4	12.4	12.4	12.4
Total, Forecast		14.9	14.9	14.9	14.9	14.9	14.9
Total	562.3						
Increment		260.7	217.4	220.2	248.0	284.5	255.9
Total, Forecast Year		823.0	779.7	782.5	810.3	846.8	818.2
Variation Index (Percent of 6.2 modified)		100.0	94.8	95.1	98.5	102.8	99.5

Source: Real Estate Research Corporation increments of the two extremes over the base year is about 26 percent. This means that for the housing units that will be added in the metropolitan area between the base year and the forecast year, energy consumption can be reduced by a little over one quarter through higher densities.

In the commercial sector, the analysis shows no differences in either total or incremental consumption by scenario. Since it was found that energy use in the commercial, industrial, and institutional sectors--assuming the relative homogeneity of those sectors in the metropolitan Washington area--does not appear to vary with density and location, it was decided to hold energy use attributable to these employment activities constant. It is recognized that this is not a completely satisfactory approach, but it was necessitated by the lack of data in this area. The full rationale and computation of per-unit employment consumption factors is documented in Appendix A. Since the commercial/industrial/institutional sector is such a large consumer of energy, it was included in the analysis for bookkeeping purposes so that a more realistic set of metropolitan totals might be obtained, and so that the degree of variation among the alternatives might be realistically dampened. It should be noted that the consumption levels in the base year reflect the readjustment required to remove multi-family residential from the commercial sector, as was discussed previously.

Transportation, on the other hand, shows interesting variations in consumption. METRO energy consumption is included, again for bookeeping reasons, since it does not vary by scenario, but, more importantly, to show the magnitude or difference between public transit consumption and automobile consumption. Automobile use of energy is eleven times greater (Btu equivalent basis) than the use of the METRO bus and subway system. For automobile travel in the forecast year, the maximum degree of variation in total distance traveled and, therefore, energy consumed is 25 percent; the largest difference in the increment of energy consumption is around 113 percent. The extreme cases are "Sprawl" and "Transit-Oriented" development scenarios. Stated another way, automobile energy consumption increases by 60 percent between the base and fore cast years with "Sprawl" development, while with "Transit-Oriented" development, consumption is increased by only about 28 percent. The difference is attributable to three factors: shorter trip lengths, fewer trips, and a higher level of ridership on transit.

For total energy consumption for the metropolitan area in the forecast year, the extent of difference is nine percent; the difference among the increments alone is 31 percent. The extremes are represented by Alternative C, "Transit-Oriented," and Alternative E, "Sprawl." It is significant that such a large amount of variation is implied by varying land use patterns.

These conclusions, however, are only a rough measure of the differences. As was noted, there will be variations in the employment sector, but it was not possible to incorporate such variations in this analysis. In addition, there are some forms of ground transportation that are not included. The major consuming sub-sector that was omitted is truck use, since the TRIMS model could not be used to generate truck vehicle miles in the time available for this analysis. Likewise, inter-regional transportation uses such as airline travel, air freight, truck freight, and pipeline shipments are not included. School bus travel is also excluded, as are motorcycles. With respect to total travel, however, other ground transportation energy uses are small and would not significantly alter the basic variations. The net result of these omissions is to understate the differences in the total ground transportation sector among the scenarios tested.

c. Other Options

The analysis thus far has operated under an important basic assumption: that present sources and uses of energy apply to all scenarios, and that there are no changes except for systematic variations in land use, dwelling unit mix, and transportation volumes in the patterns of energy consumption for the forecast year. That is, it was assumed that present energy availability is continued into the future, that all future energy sources are found in the same proportion as at present, and that no other attempts at conservation are initiated. This assumption was useful in holding the changes between the base case and the six scenarios constant, so that the effects of alternative development patterns could be determined in isolation. In fact, changes in both sources and uses will occur over the time period. The next section relaxes this assumption.

The following discussion explores how future energy balances might be achieved, assuming changes in both supplies and demands. When future demands are met by supply, any shifts among the sources of energy supply will merely accomplish a redistribution of resources. If, given the same level of consumption, one source becomes scarce, another must be expanded to meet the demand. Total energy consumption is not reduced, but the proportions of supplies are reallocated. In the event supplies are not fixed but are reduced, then current levels of demand cannot be met and consumption must be cut back as well. The case where both supplies and demands are altered is what will likely occur. Therefore, future energy balances will likely result from shifts in energy forms and corresponding reductions in demands.

1. Alternative Sources:

Since the focus of this paper is on energy end uses and their relationship to land use and growth, only limited attention is devoted to altering supplies of energy. It seems clear, however, that shifts in sources will occur over time, although the overall pattern of supply will likely remain largely the same:

- The use of natural gas will decline--partially because of price rises that might be anticipated to make up for under-pricing at present, but, more importantly, because of scarcer supplies.
- The use of coal may increase, but there will be dislocations and adjustments required to use it.
- The use of petroleum products from new technologies such as coal gasification or oil shale development will not provide much additional fuel. There will continue to be reliance on both foreign and domestic sources for petroleum products, although efforts to reduce the proportion of foreign-supplied oil will accelerate.

- Use of geothermal and wind sources appears limited over the near term although there may be some activity in this area by 1992. A basic question exists as to the suitability of this metropolitan area for use of geothermal energy at any time; the same may also be said for wind-provided power generation on a large scale.

- Increased use of nuclear power appears likely over the period to 1992, but the extent of this source in electricity generation will not outweigh use of conventional sources.

- Since electrical power is derived from other fuel sources, there may be an increase in the proportion of electricity out of total energy. It is very likely that electrical energy use will grow, regardless of the sources of fuel for its generation.

- One source that has potential impact on supply is solar energy. It is believed that a major portion of home heating and water heating in new residences can be furnished from solar sources, and that by 1992 traditional power sources could be supplemented by use of solar energy. It must be cautioned, though, that the potential is limited in the short-run by the amount of suitable homes in the existing housing stock and the rate of new housing construction, unless some means of retrofitting existing homes for solar energy on a wide scale is found.

- Another possible source of power is from combustion of solid waste materials produced in the metropolitan area. Although there may be some problems in implementing this form as an energy source due to collection requirements and emissions from combustion, this may become a small, but significant, future source.

2. Conserving Options:

The basic conclusion from the supply side is that some changes will occur by 1992, but they will not radically alter the pattern of energy supplies. This forces attention to the demand side, and necessitates consideration of conservation efforts. Conservation has a dual dimension with respect to energy use--in altering the present pattern of consumption so that more efficient use of energy can be made, and in limiting the rate of growth of demand. Both will help in achieving long-term energy balances.

There are two ways to describe conserving options. The first is to organize by time-frame, i.e., whether the option can be implemented immediately, in the near-term, or in the longer-term. The second is by manner of application, i.e., changes in operational characteristics, structural and/or institutional characteristics, and technological changes. Changes in habits or lifestyles may conserve energy in the operational sense; structural or design changes may result in better utilization of energy; and, as has been discussed, application of new technologies has potential for reducing consumption.

In the residential sector conservation may be achieved by operational measures, such as turning down thermostats during winter months or turning off lights when not in use. In addition, changes in building design and specifications emphasizing use of thermal glass, storm doors and windows, and adequate insulation can help.

A technological possibility that exists for larger, multi-family complexes is the "total energy" system, which is an on-site fossil fuel-powered electricity generating plant that provides space heat requirements by capturing waste heat from combustion. A possibility for smaller structures is use of waste heat from furnaces without the associated electricity generating capacity. The conserving options that will be evaluated in the residential sector include:

- Upgrading insulation in all new homes.
- Upgrading insulation in all existing homes.
- Refitting homes with storm windows and doors.
- Lowering thermostats 2° in winter months.
- Using waste heat from furnaces.
- Using total energy systems in new multi-family structures.

In the commercial sector, wide disparities in the amount of energy consumed are found and are attributable to a number of factors. Perhaps the largest potential source of reduction is in building operation and maintenance practices. It has been demonstrated that the amount of energy consumed can be halved by using a number of conserving measures: adjusting air conditioning loads, reducing temperatures, rearranging cleaning schedules, shutting off or reducing unnecessary lighting, reducing hot water temperatures in lavatories, to name a few. Structural improvements will also result in reduced energy consumption. Attention to such matters as increased insulation, proper siting and orientation to the sun, analysis of lighting, heating, and cooling needs in relation to the work being performed, and reduction in window areas are all possibilities.

The use of the total energy system suggested for multi-family structures is also possible with office buildings, and the recovery of waste heat from furnaces and refrigeration units may provide savings. The options that will be evaluated in the commercial sector include:

- Reduction of glass area by 25 percent.
- Use of thermal glass.

- Reduction of lighting levels by 50 percent.
- Use of waste heat from refrigeration units and furnaces.

Different types of conservation options exist in the transportation sector. In general, the potential for reducing energy use is found in improving automobile mileage, improving traffic flow, and shifting to more energy efficient modes of transportation. Measures that will result in improved vehicle mileage come from technological changes--with better engine and car design, or from shifts in the composition of the automobile fleet. If smaller cars displace larger, heavier ones, fleet efficiency will increase.

Automobiles and other vehicles operate more efficiently under cruising conditions rather than during acceleration or deceleration. To that extent, analysis of traffic systems and networks to promote smooth flows is useful. Although public transit vehicles consume more energy per mile than automobiles, relative efficiencies of public transit systems emerge when passenger-miles rather than vehicle-miles are used as the measure of consumption. Therefore, any conserving option that will increase the level of transit ridership or that will make riding the bus or subway competitive with automobile driving will conserve energy. A fourth way of reducing energy consumption in the transportation sector--reducing vehicle miles travelled--is discussed in the following chapter.

As may be seen in Table 5-2, some of the options with the greatest potential for energy reduction are in the transportation sector, although the percentage savings calculations are not fully comparable with the residential and commercial options.

Table 5-2

Evaluation of Conserving Options

Conserving Option	Conservation Potential (Percent of Total Sector Energy Consumption)	Feasibility	Implementation
Residential			
°Upgrade insulation in all new homes.	6%	Added costs recovered in two years; technically feasible; implementation requires overcoming resistance to higher costs.	Immediate
°Upgrade insulation in existing homes.	3%	Costs and technology feasible, but implementation is a problem.	Possbile immediately, but would require time to complete
°Refit homes with storm windows and doors.	1%	Savings of energy consumption in new homes estimated at 9% annually; will have added costs, but recovered in short period: technically feasible.	Same as above
°Lower thermostat 2° in winter.	3%	Feasibility is no problem.	Immediate

Table 5-2
(Cont'd.)
Evaluation of Conserving Options

Conserving Option	Conservation Potential (Percent of Total Sector Energy Consumption)	Feasibility	Implementation
Residential			
°Use waste heat from furnace.	2%	Improves efficiency of furnace from 75% to 90%; may require substantial alternations to older homes. Consumers not aware of this option.	Near-term to long-term
°Use total energy systems in new multi-family structures.	3%	Improves efficiency of electrical generation from about 38% to 70%; initial costs absorbed in some instances within five years; consumers not aware of this option.	Near-term to long-term
Commercial/Institutional			
°Reduction of glass area by 25%.	7% for heating 4% for cooling	Depends on building, owner, and design preferences; other options may carry more importance.	Immediate to near-term
•Use of thermal glass.	20%	Added expense soon offset by savings in energy cost; technically no problem.	Near-term

Table 5-2
(Cont'd.)
Evaluation of Conserving Options

Conserving Option	Conservation Potential (Percent of Total Sector Energy Consumption)	Feasibility	Implementation
°Reduction in lighting levels by 50%.	15%	Feasibility is no problem but requires analysis of lighting needs; hallways, reception areas can be reduced greatly, work areas somewhat more, but less than what is now common.	Immediate
°Use of waste heat from refrigeration units and furnaces.	6-7%	Feasibility limited only by acceptance in building and design industries; not widely applied at present.	Near-term
Transportation*			
°Increase automobile commuter trip occupancy rate by one (carpooling).	14%	Present occupancy on journey to work is 1.2 persons per vehicle; would not only conserve energy, but also reduce emissions and relieve congestion; carpooling cooperation may limit desirability; requires incentive for implementation.	Immediate to near-term
°Check automobiles every 5,000 miles, with tune-ups as necessary.	5%	Requires public action since voluntary compliance is unlikely; probably feasible as part of state vehicle inspections.	Near-term

* Includes intraregional passenger travel only.

Table 5-2
(Cont'd.)
Evaluation of Conserving Options

Conserving Option	Conservation Potential (Percent of Total Sector Energy Consumption)	Feasibility	Implementation
°Increase public transit ridership to 50 percent on journey to work.	18%	Requires adequate service and convenience to compete with auto.	Near-term to long-term
°Improve automobile mileage.	27%	Anticipated shift in size of automobiles will allow average of 17.4 MPG in 1992, rather than current 13.5 MPG.	Long-term

Source: Real Estate Research Corporation

The potential savings are based on reductions in total automobile travel and commuting by public transit, and are not based on the total transportation sector. This represents about 60 percent of all travel. The savings, therefore, are overstated, but are comparable with the levels of consumption reported for the alternative scenarios, and might be applied to them. It should be noted that, in combination, the potential reductions may be greater or lesser than for single elements alone.

In the commercial sector, relatively straightforward or simple options can have considerable impact. For instance, use of thermal glass can conserve 20 percent of the energy used in buildings, and changes in levels of lighting, 15 percent. The impacts that are possible in the residential sector are not as large, but it must be recalled that a small percentage gain in a very large sector of consumption may result in considerable savings in absolute amounts.

It should be emphasized that these estimates are not firm and fixed quantities, and direct application to scenarios or other measures of consumption is difficult. They are, however, useful in indicating an order of magnitude of savings that might result, and to demonstrate that energy consumption levels can be significantly altered by conservation practices.

CHAPTER 6

ENERGY AND LAND USE

In Chapter 2, land use was defined as the process of growth and development over time, in various locations and densities, and in unique spatial arrangements. Energy may be seen as the prime mover for activities and facilities organized by the land use pattern. If predicted shortages or shifts in sources of supply occur, energy has a potentially large impact on growth, development, and how land uses are organized.

The preceding chapter discussed the differences in energy consumption among alternative development scenarios, and various conservation options suggested ways in which future energy balances might be achieved. This chapter will discuss a further set of conserving options that are related to or afforded by development patterns.

a. Alternative Scenarios: A Closer Look

The variations of energy consumption in the residential sector are attributable to the dwelling unit mix assumptions made for each scenario. Dwelling unit mix does not necessarily relate to density, for it is possible to have a very large residential structure with a large number of energy conserving dwelling units occupying a very large site, or that is located in an area with very few total dwelling units. In this case, the density of the area would be relatively low, and energy consumption attributable to smaller dwelling units would be low as well. There is, however, a very strong relationship between dwelling unit mix and density. Smaller units are found at higher densities and the existence of smaller dwelling units at lower densities would be the exception, not the norm. The conclusion that energy use is less at higher densities seems sustainable on the basis of dwelling unit mix itself.

There are further aspects of higher densities, however, that have a bearing on energy consumption. Many of these are discussed in the following section on land use arrangements. These arrangements can be expected to yield overall higher densities and associated energy savings. Another relationship between energy use and density is stated in the third section of this chapter: densities afford the use of technologies that will reduce energy consumption.

A closer look at the findings from Chapter 5 in the transportation sector yield further relationships between energy and land use. In the more dense and compact configurations,less energy was required because of shorter trip distances and higher levels of ridership on public transportation. These differences are noted in Table 6-1, below.

The differences in average trip length may seem to be small, but when extrapolated to total trips and converted to an annual basis, small variations contribute to substantial differences in in vehicle miles of travel (VMT). Trip lengths vary in expected ways: shorter trips are found in the transit-oriented alternative because of the availability and use of public transportation, and because of the location of employment and housing within transit corridors. Similarly, orientation to the Beltway in Scenario F

6-3

Table 6-1

Transportation Characteristics of Alternative Development Scenarios

	Base	Alternative Scenarios A "Wedges and Corridors"	B "Dense Center"	C "Transit-Oriented"	D "Wedges and Corridors with Income Balance	E "Sprawl"	F "Beltway-Oriented"
Average Work Trip Length (miles)	—	7.6	7.2	6.9	7.6	8.0	7.0
Transit Use: Percent Trips by Transit							
a. Home-Based Work Trips	21.5	25.6	33.6	28.9	28.7	26.4	21.8
b. Home-Based Work Trips To Core	44.9	54.5	58.1	56.6	61.3	53.2	55.1

Source: MWCOG/RERC

result, in shorter trips, since many of the services required by households are located there. At the opposite extreme, "Sprawl" development requires not only longer trips to work, but trips from outlying areas to the Beltway corridor for shopping purposes as well.

The use of public transportation also presents interesting variations. Use of transit for work trips varies from almost 34 percent in the concentrated high density central core-oriented scenario to 22 percent for the "Beltway-Oriented" development alternative. This means that ridership in the "Dense Center" alternative is about 50 percent higher than when all new household and employment activities are placed around the Beltway. It is interesting to note that the level of ridership that could be expected with the "Beltway-Oriented" alternative is only slightly higher than the level found in the base period; there is no significant increase in transit use.

Transit work trips to the central core in every instance show some improvement in ridership over the base period. For trips to the central area, the smallest improvement over base levels of ridership occurs with "Sprawl", but it is closely grouped with "Wedges and Corridors" and "Beltway-Oriented" development. These findings reflect more difficult access to transit or better access to freeways associated with those alternatives, and less propensity to use public transit. The highest level of public transit use, interestingly, is with the "Income Balance" alternative, where over 60 percent of commuting trips to the Core occur by public transit. Having a balance of income mix throughout the metropolitan area will reduce auto VMT because high income households generate more and longer trips under the more typical pattern of household income distribution.

In terms of total energy consumed for transportation purposes, the lowest level of energy consumption is found in Alternative C, "Transit-Oriented," where increased use of METRO is combined with shorter trips because of the location of residences and employment close to METRO stations. In that form of development, the proximity of shopping and employment centers--or accessibility by public transit--results in a lower level of transportation-related energy consumption. The "Dense Center" configuration shows lower levels of consumption for largely the same reasons. At the opposite extreme is "Sprawl," where longer trips and larger numbers of trips, coupled with lower use of public transit, result in the highest level of energy consumption in the transportation sector. An intermediate case occurs with the "Income Balance" alternative where the high level of public transit use is accompanied by relatively long auto trip lengths.

These findings indicate that, with respect to the increment of development, for METRO and auto consumption there exists a potential for at least 45 percent reduction in added energy requirements because of spatial configuration; in terms of total (increment + base) development, the degree of difference is 20 percent. The potential for energy savings, therefore, is considerable, but it is not without a price.

There may be a greater level of congestion found in the higher density alte natives, although no direct measure of congestion was applied to these scenarios.

b. Energy Consumption and Urban Form

A number of possibilities exist in the arrangement of land uses for energy consumption savings:

- The physical arrangement of facilities or the lengths of networks in general may relate to energy savings in three ways: (1) in reducing the amounts of materials and energy consumed in the construction of urban systems; (2) in arranging activities so that less travel is required in carrying them out; and (3) in the relationships among uses so that activities may not only be carried out over less distance, but with more efficiency as well.

- For example, it has been demonstrated that more compact and contiguous development results in less resource expenditure for sewer and water lines, highways, and other investments. The energy embodied in the creation or manufacture of materials used in constructing these facilities would then be less. Similarly, as less material is required with more compact development, the energy required for construction and installation will be less as well.

- With respect to the operating aspects of contiguous development forms, there are also potential energy savings. If school bus routes or police and fire patrol areas are more compact, the energy required for such activities are likewise reduced. Maintenance of streets and roads, and solid waste pick-up should also prove more energy-efficient.

- There are a number of land use alternatives that may encourage energy conservation. Such development patterns are usually considered innovative, but are becoming more common. Cluster housing with smaller lots and common open space embodies potential energy savings; likewise, industrial parks can be shown to reduce energy consumption. Large-scale multi-use complexes should also be energy-efficient, since multiple activities can be accomplished in a single trip. If employment, retail, and recreational uses are coupled with residential uses, for example, savings could result.

- Two examples of land use configurations that have energy saving potential are the planned unit development and the planned new community. With either of these, a number of techniques mentioned previously might be combined--including cluster housing and multi-use complexes. The potential for savings is, however, dependent upon the location of the development. If the project is far from an urban center and considerable travel is involved outside the planned development, then the savings internally will be substantially offset. If the project is closer to other activities, then the savings potential is much greater. A new-town-in-town, therefore, would have excellent prospects for contributing to energy conservation.

- Some questions of urban form become relevant. The configuration of shopping facilities--whether center or strip--may add to or subtract from potential energy savings. The differences in energy consumption associated with the two forms are not clear, for although there are a larger number of stops at lower speeds required for strip shopping, center shopping may be located at greater distances from home and require longer trip lengths.

- If greater orientation to public transportation is achieved, then several other questions of urban form must be considered. Concentrating development around transit systems implies that development will occur only within the immediate vicinity of the transit network itself. It might be suggested that the true area of influence would be the area covered by feeder systems--whether private automobiles or buses.

- If this pattern should become prevalent, its potential might be enhanced by the location of major employment, retail, and industrial uses at the junctions of transit corridors. This pattern also implies that relatively less development will occur between the corridors and the potential will exist for preserving such areas for open space or low-density uses.

- There are clear implications for land values and changes in development activities with alternative urban forms. There would certainly be in-filling of passed-over lands closer to transportation systems and nearer major employment and retail centers. There would also be less intense pressure on farther-removed areas--unless lower land costs outweigh potentially higher energy costs. It has been suggested that the redevelopment of inner core areas might result from energy shortages, but this is difficult to predict, since a number of other factors impinge upon this possibility. Clearly there would be greater pressure on underutilized areas close to transportation facilities.

c. Energy Conservation Opportunities

There is another class of energy savings resulting from the relationship between energy and land use. When certain densities or combinations of density and location occur, opportunities for energy conservation may be found that would otherwise not be possible. Most of these opportunities take advantage of available conservation technologies that would not be possible at today's relatively low densities. Following are some opportunities that could arise from the interaction of density and configuration:

- The use of solar energy may be aided or hindered by higher densities. There seems to be a maximum size of structure that can utilize solar energy, because as a building increases in volume and, therefore, has greater heating or cooling requirements, the available surface area is less in proportion to the volume. With surface-to-size ratios limiting the amount of energy that can be produced, above certain densities solar energy has limited possibilities. On the other hand, if land surrounding the facility is available, then solar collectors might be placed on the ground rather than on the structure and more energy could be captured.

- The same arguments might be raised with regard to wind power. Fairly large installations are required to produce adequate amounts of power, which would apparently preclude the widespread use of such devices at higher densities. A commonly discussed approach to this problem is to create windmill "farms" with a full network used to distribute energy to users. Since this would entail converting mechanical energy into electrical energy, the efficiencies of the process might not be particularly worthwhile.

- There are technologies that rely directly on higher densities. The most immediate example is improved public transportation, for without household and employment activities in adequate concentrations, the level of ridership might not warrant such service.

- Another example of how higher densities open up opportunities for energy savings is the use of "total energy" systems. In many applications of this concept, the electricity generating plant with waste heat recovery capacity is located within the complex or development itself. This means that unless a certain size is obtained, the potential for such systems may not be realized. Furthermore, if total energy systems are used with multi-use complexes, the peak loads for energy from the uses will be smoothed and the plant may operate more efficiently.

- The relationship of the total energy system to density is strengthened when the total energy system is coupled with combustion of solid waste derived fuel from the complex as a fuel source. The relationship to density occurs because such systems are not linked to existing power generating stations, but may operate independently and at a smaller scale; however, it is necessary to have a certain threshold size before it becomes feasible, and, therefore, a requisite density.

- It is possible to extend the total energy system application a step further by combining an "integrated utility system" in which a total energy system with solid waste combustion is combined with waste-water treatment. If the integrated utility system is used on a modular basis, then economies arise from locating it at certain densities.

- A final possibility is a variation of the previous opportunities. Not all solid waste is combustible and a portion may be recycled for use, providing a suitable user is found and costs of delivering the useable material are not prohibitive. If the potential users of recycled materials--aluminum, glass, ferrous metals--are located near the recycling plant, then transportation costs are low. In order to take advantage of this possibility, the locational arrangements must be grouped. Perhaps the greatest potential exists in industrial parks, where internally generated wastes are used by various manufacturers within the complex.

d. Energy Efficient Development Patterns

It is now necessary to define energy efficient land use patterns. Given the same level of activities or facilities on land, the most efficient arrangement from an energy resources management point of view would be that arrangement that results in the least aggregate consumption of energy.

(1) Residential

Residential energy efficiency is directly related to the type of dwelling unit; variations in per dwelling consumption will be reflected in the mixes of dwelling units. Further, energy efficiency will be enhanced by the opportunity to use energy-conserving technologies. In both cases, it appears that energy efficiency is related to higher densities.

(2) Commercial/Industrial/Institutional

In terms of structure characteristics, it is difficult at this time to state how energy use varies with the size and type of building. Therefore, the relationship to density and spatial arrangement is not particularly apparent, except as part of overall land use interrelationships, as discussed below.

(3) Transportation

Energy consumption by automobiles is directly related to the amount of travel (VMT). Since the amount of travel, in part, is related to distances among destinations or links among land uses, urban form substantially affects the amount of energy consumed in the transportation sector. Similarly, energy consumption is related to density, for unless higher densities are available, some modes as alternatives to the private automobile are not possible. The relationship between transportation uses and energy efficiency, therefore, depends on both density and spatial arrangements.

(4) Land Use Patterns

Energy efficiency operates here in several ways. With contiguous development or more compact development, less material is consumed in construction; likewise, with shorter distances, less energy need be used for distributing goods and services. With clustered land uses, fewer trips may be generated. Again, the conclusion regarding land use efficiency for energy is inclined toward higher-density, contiguous development--where the interrelationships of uses tend to reinforce one another.

If the scenarios are re-examined once again, energy efficiency seems to require extensive use of public transportation, combining land uses into clusters and complexes, and locating activities so that less energy is expended to complete them. In conclusion, it must be stated that what constitutes an energy-efficient land use pattern may not, in fact, be a desirable pattern except from the energy perspective. There are a number of additional issues that are associated with energy-efficient development patterns in relation to land use and growth management, and these are the subject of the next chapter, where trade-offs between energy conservation and other factors are identified.

CHAPTER 7

STATEMENT OF ISSUES

The previous chapters developed baseline information from alternative development scenarios in order to measure relative differences in energy consumption attributable to land use patterns. It is now necessary to determine how that information is useful in the context of metropolitan growth and development management. As was indicated in Chapter 6, energy conservation by land use means may not be a clear choice, nor is consensus guaranteed, for this resource management mechanism requires substantial changes in how growth and development occur.

The following list of issues is not fully comprehensive. It is intended to provoke discussion, as is the intent of this paper. It is hoped that this list will help clarify the choices necessary in planning for future levels of energy consumption.

- <u>Changes in the quality of life</u>:

  One of the clear effects of changes in energy supplies and adaptation of new consumption levels will be in the quality of life. It may not yet be fully predicted how changes will occur and it is not a foregone conclusion that the future quality of life will diminish. It may be speculated that if energy-conserving measures are adopted so that higher densities prevail, there may be less privacy and more time consumed for some purposes--including the journey to work--and perhaps a perceived limitation to choices or opportunities available in the future.

- <u>Changes in personal preferences</u>:

  One aspect of the change in quality of life is personal preference and lifestyle. The desire of households for the convenience and mobility of the private automobile, and the prevailing dream of a single-family home on its own land are persistent and will only be given up with difficulty. If such preferred amenities are sacrificed for energy considerations, then suitable substitutes must be found.

- Changes in lifestyles:

  Changes in energy supplies and demands alone, and in combination with changes in land use, may also dictate changes in lifestyles. It is possible that shorter workweeks and longer weekends might result from the need to reduce work-related travel. It is possible that shopping habits may change, with more reliance on communications and pre-planning to reduce travel and fuel consumption. Desire for some types of recreation experiences may change, with more emphasis on local activities rather than those requiring additional travel.

- Changes in density and mobility:

  Many of the effects of shortages and shifts in energy supplies resulting in lifestyle changes will be the consequence of changes in density and mobility. For example, if future development is more compact, energy may be saved, but at the expense of greater congestion and reduced open space. If higher densities result, then the lack of privacy will exact a price in human satisfaction as well. Energy-conserving community development may not necessarily be desirable or feasible in view of other community goals.

- Optimality and conflicting objectives:

  If the goals of growth and development are to simultaneously achieve community balance, enhance economic growth and increase productivity, maintain the environment, and enhance overall quality of life, then the weight of energy considerations is unclear. Energy conservation may, in fact, rate rather low among competing objectives, so that sub-optimal energy conservation becomes a more realistic possibility.

- Individual rights versus community rights:

  One of the fundamental problems of land use and development management is the reconciliation of individual rights with community rights. The public interest or welfare could be defined very narrowly to provide benefits for a small group, or more widely to provide benefits for a larger group. The adjustments required for energy shortages suggest that the wider public interest may prevail in many instances.

- Equity considerations:

  The need to reconcile differences in the public interest takes on a special form with respect to groups that generally fare less well in the use of resources and in the negotiations that determine the allocation of those resources. Lower-income groups bear a heavier burden relative to their income for a number of costs, and energy shortages will affect them disproportionately. Elderly individuals on fixed incomes cannot adapt readily to changes that might result from changes in energy supplies, and thus may suffer more.

- <u>Role of government and effective leverage</u>:

  The question may be raised as to whether it is the proper role of government to be concerned with energy limitations and their potential impacts. It seems certain that governments will be involved, but the extent or consequences of that involvement are not known. For example, it is not known where the greatest opportunity for conservation exists. It may be that greater leverage can be exerted by fiscal and other economic measures by providing incentives or disincentives for energy conservation or consumption. Or it may be that working through market mechanisms is less effective than direct intervention by way of regulation and mandatory action. In other instances the use of administrative review may be most useful. In all likelihood, a combination of tactics will be developed for use by governmental units.

- <u>Relationship to growth management</u>:

  In the coordination and process of negotiation that are implied by growth management, the precise weight of energy constraints has not been determined. It has been stated that energy limits can reinforce or contradict efforts to manage future growth and development. How energy considerations can be introduced into growth management depends on the magnitude of future energy dislocations and the shifts in consumption that will take place. For example, if higher levels of mass transit use become practical for energy conservation purposes, the implications for location and housing unit mix, for transportation systems, and the delivery of governmental services and facilities must be addressed through the process of growth management.

It is possible to define more specific impacts or effects that result from the consideration of energy as a factor in metropolitan development. Such impacts include:

- Size of the increment of growth:

  It was assumed that about one-half million households would be added to the metropolitan area in developing the alternative development scenarios of Chapter 4. A significant question is whether that increment is large enough to provide sufficient leverage to markedly influence future total energy consumption. Since the increase over present levels of population and households is about 50 percent, the answer to that question appears to be in the affirmative. On the other hand, if only the increment of development is targeted in policies and conservation measures, then only one-third of the total consuming sector will be affected. Therefore, it makes sense to concentrate not only on the increment of growth, but also existing development. This may require two sets of strategies or techniques for reducing energy consumption.

- Spatial arrangements:

  The relationships among land uses would certainly be altered if energy-conserving measures were implemented, and such changes would probably have positive or negative side-effects. For example, if regional shopping centers no longer predominate, and there is a resurgence of neighborhood retailing, then the economic consequences and the travel characteristics of regional centers would change. Likewise, if strip commercial development is proved to be more energy-consuming, then some means must be found for providing the same goods and services in other than the traffic-oriented, linear arrangement often found at present. Furthermore, the developmental consequences of fully integrated land use and transportation systems have not been addressed. For instance, planned unit developments have usually required a substantial amount of land located on the fringe and somewhat apart from existing development. If there is greater orientation to public transit, then the potential number of sites for such development might be limited, or the size of such sites may be reduced due to the competition for available land.

- Fringe development versus center redevelopment:

  It is unclear as to how shifts in energy supplies will impact various geographic areas. Whether close-in sites will increase in attractiveness because of shorter distances and higher densities to such a degree as to offset the problems now associated with their redevelopment and preservation is a relevant question. On the other hand, the impact of energy shortages on development in the exurban fringe, characterized by considerable distances from the center and fewer locations for employment and retail activities, may be to reduce the pace of development. The question, then, is whether energy considerations will reverse the present trend of development or simply slow it.

- Development in undeveloped or mature areas:

  Because energy impacts will affect the course of development, there is a question of whether new development will differ greatly from already developed areas. It may be that along transit routes, for instance, the areas that have already been developed will act to restrict any further development that might be more energy-conserving, while in areas of vacant land availability the opportunity will exist for more energy-conserving development. The reversal of present trends or patterns of development is then possible.

- Capital facilities planning:

  As part of the general relationship between growth and development, there may be a problem in providing adequate capacity in public facilities--so that capacity is available in schools, sewer lines and treatment plants, water treatment and distribution systems, and road and street networks at the time population demands arise. Efficient sizing and phasing of facilities may be complicated or rendered impossible because of distortions due to energy shortages. On the other hand, if there is more emphasis on presently developed areas rather than developing areas, the investment in capital facilities might prove more efficient, since such facilities can be used to capacity.

- Jurisdictional conflicts:

  If individual communities or jurisdictions take independent measures toward conservation, the displacement of activities that results could have unwanted side effects. For instance, if one area adopts more stringent, conservation-oriented building codes, then development might be displaced to other areas with less stringent regulations. A related question is which level of government is appropriate to undertake energy conservation measures. It is probably the case that conservation will require efforts by multiple units of government.

- Fiscal impacts:

  A number of issues relate to the potential for energy savings by use of fiscal incentives or disincentives. The changes in both costs and revenues can also have hidden consequences. For example, if a tax intended for conservation purposes is levied at one level, there may be repercussions from others. If a tax is levied by a local jurisdiction according to the number of automobiles owned or miles driven, and if this results in a substantial reduction in vehicle travel, then less revenue from motor fuel taxes will become available to the state, which, in turn, may reduce the amount available for distribution to local jurisdictions. These interrelationships are complicated by the existing arrangements among levels of government for allocating funds. While suburban Maryland and Northern Virginia jurisdictions receive less than they generate in state revenues, this is not the case in the District of Columbia. Such interworkings of the tax structures may complicate energy-conserving measures in the Washington region and result in unforeseen impacts.

Another question with regard to fiscal impacts is the policy toward differential taxation of existing versus new residents. If the potential leverage for conservation lies with control over new construction and development, then the benefits of energy conservation may not match the burdens, and it might be argued that either existing or new residents should share the additional burden.

Another question relates to large expenditures for capital equipment that may be made obsolete by a shortage of fuel or the creation of reasonably priced alternative sources. The assumption of long-term municipal debt for such facilities may be unwarranted and even wasteful.

- Economic impacts: employment shifts:

In many cases, there must be some decision as to whether energy conservation gains outweigh the disruptive effects that such measures entail. If an economic activity proves especially dependent on or directly involved with heavy consumption of energy, and if energy supplies become scarce, those activities may cease--ending jobs in the short-run and forcing employment shifts in the long-run.

- Economic impacts: pricing effects:

Another important issue is the potential leverage that can be found in the pricing of energy sources. Depending on the consumption pattern and on the requirements for energy, the potential adjustment to energy supply changes or to policies to decrease demands for energy may be limited. That is, if the price of fuel rises significantly, many consumers will be unable to adjust readily. Home heating systems dependent on supplies of natural gas or oil cannot be converted to another source very quickly, and price increases must be absorbed. Similarly, unless substitute transportation is available, those households dependent on the automobile will not be able to cut back consumption in proportion to the increase in price. There may be some adjustment possible by economizing in numbers or lengths of trips. The sensitivity to price under a variety of circumstances is an uncertain phenomenon and must be considered as an issue, for it bears upon potential impact that any conserving measure might have.

- Environmental impacts:

  There are numerous ways in which environmental impacts might relate to energy use. If development occurs at higher densities, some reductions in air pollution on a regional scale might be achieved, although there would probably be increases in pollution within the higher density developments. Water quality may decline if sewage and water treatment facilities are overburdened. Similarly, the effects of erosion and amounts of run-off contributing to flooding are greater at higher overall densities but may be reduced through the the design of strategic combinations of high and low density. This is complicated by "downstream" effects, when the full impact of environmental degradation does not fall only upon the source but upon neighboring areas, too.

  Another environmental problem arises from the location of power plants. If smaller, self-contained utility plants--as with the total energy systems--are widely used, pollutants would be more dispersed than they would be from relatively few large generating plants relying on fossil fuels. They would be more concentrated than the emissions from heating plants in individual homes or offices. This is offset by the greater efficiency in fuel use associated with on-site generation, contrasted with conventional electricity generation at remote plants.

  A third environmental problem is the trade-off between environmental concerns and energy consumption. Tertiary sewage treatment requires considerably more energy for process use, but results in much higher quality effluent. Preservation of unique and/or historical sites might be helped by reducing the need for or developing new sources.

- <u>Socio-economic impacts</u>

The fact that the burden of energy costs--either in the present or in the future--is not necessarily borne in proportion to the size of the group has been indicated. It is known that upper income families tend to consume more energy *per capita* than lower income families. It is also known that lower income groups tend to pay more as a portion of income for energy than upper or middle income groups. But many of the measures that have been proposed to limit energy use have a regressive effect in requiring lower income groups to bear a relatively greater burden than other groups. If a flat-rate increase in tax on gasoline consumption is levied, for example, the burden will fall more heavily on lower income groups because they pay a higher proportion of income for energy, despite the fact that consumption by upper income families is greater. The issue, then, is how such unequal impacts can be minimized, so that lower income groups and the elderly on fixed incomes do not suffer undue burdens.

CHAPTER 8

IMPLICATIONS FOR METROPOLITAN GROWTH AND DEVELOPMENT

a. Energy and Metropolitan Growth

The following economic, demographic, market, and housing factors are significant for the future of the metropolitan Washington area:

- There will be continued economic growth, but at a more moderate rate. The Federal government will continue to dominate the employment sector--both directly and through those organizations dependent upon or oriented toward it. The metropolitan economy will be relatively insulated from the severe impacts observed in other metropolitan areas. If birth rates continue to decline, the population level may reach some stable equilibrium. Moderate growth is likely to continue, however.

- One significant trend is the continuing decline in household size. Whether average household size continues to decline, levels off, or reverses and begins to increase, this factor will have great impact on virtually every aspect of growth and development. If average household size continues to fall, there will be changes in the types of housing required, changes in lifestyles and consumption patterns, and changes in urban form and land use. Smaller dwelling units closer to central locations could become more attractive, for example. If, however, the decline in average household size is only a temporary phenomenon and part of a long cycle of family formation, or if changes in family patterns are attributable to deferring children in order to combine incomes, or because better opportunities exist for second job-holders in the family, then the trend could be reversed. If it is reversed, an entirely different set of circumstances will prevail. Instead of a baby bust or a baby boom there may be only a temporary "baby barricade." Speculation in this area is difficult, but it does not seem unreasonable to expect that a permanent change has occurred. It is likely to result eventually, however, in a levelling off of the rate of decline of household sizes.

- If population is levelling off and if there is net outmigration, then housing demand originates largely from two factors--a backup of demand that has persisted for several years, and increase in the number of households of smaller size. If, in a number of years, housing supply catches up with demand, then housing demand pressures--like population growth at present--may also reach a plateau.

- Several strong factors operating in the housing market must be taken into account. The price of undeveloped land has become a critical component in the price and type of dwelling unit that developers can afford to build. All other costs, except labor to some extent, are to a large degree beyond their control. Therefore, the attraction of land on the fringe is very strong in order to keep prices down to meet a wider segment of the potential market. Another factor seems to be the prevailing distaste for higher density living among many home-buyers. This has been overcome in some instances by careful design and provision of amenities.

- A final factor that has had much to do with housing choices and location is accessibility. The desire for mobility and choice of place of employment and residence has had much to do with the prevailing pattern of development. So long as access could be taken for granted, residents have tended to make their home purchase decisions on other grounds, such as schools, type of community, and housing characteristics. Accessibility plays a role, of course, but it has weighed less heavily than other factors.

Energy relates to these trends and development factors in a number of ways, some reinforcing or accelerating the trends, and others seemingly in contradiction.

- Clear energy implications arise from shifts in sizes of households. It has been demonstrated that there are energy savings related to the size of housing unit. If the trend toward smaller household size continues, then lower energy costs in smaller units will result in energy savings compared to previous prevailing development patterns.

- The impacts of higher energy costs are already being felt in the housing market. Because of substantially higher costs for natural gas and electricity which cannot be passed on because of rent controls, rental properties are becoming less profitable, and the move to condominium construction is being reinforced. A second effect is that there is a change from master-metering apartments to installing individual meters, thereby placing utility costs directly upon consumers. A third possible effect is that mortgages may be more difficult to obtain if utility costs are so high as to reduce the amount of money available in family incomes to meet mortgage payments. In addition, the costs of maintaining common areas in condominiums are rising faster than revenues, which may put pressure upon association budgets.

- Another housing factor is that, at a rate of two percent increase in number of dwelling units each year, by 1990 over 45 percent of all dwelling units will have been built after 1974. This means that energy conserving measures incorporated into building codes could have permeated almost half the existing housing stock by that time.

- It will take considerably higher energy prices, however, to offset (1) the difference in land costs between central and fringe locations, and (2) the desire for accessibility and mobility by automobile. The costs of producing lower density homes closer to the core area may prove prohibitive, so that the builder of single family homes cannot afford to build at desired locations in transit corridors. The expected rise in energy costs will not be enough to prohibit the developer from building in now undeveloped areas. Secondly, there seems to be relative price inelasticity of demand for gasoline, at least in the near term. Consumers seem willing to pay increased prices in order to preserve the convenience of the automobile. Indeed, in many fringe areas there simply is no alternative form of transportation. Shifts in car size and reductions in the amount of travel might be expected, but the status of the automobile is not yet in jeopardy. If, however, there are severe shortages of gasoline, then accessibility by auto will become the basic determinant in residential location. The freedom and mobility afforded by the automobile would be compromised.

- In terms of employment, shifts in energy use and shortages of supplies may result in temporary dislocations of employment, but given the caliber and types of skills represented in the metropolitan area's labor forces, as well as the mobility in and out of the area for employment purposes, such changes can be accommodated. It might even be expected that changes in energy supplies would create more jobs.

- The trend toward decentralization of jobs and the shift of employment from the central core may, in the long run, prove more energy efficient. If employment is located along transit routes, there would be a two-way flow on the system at rush hours, assuming that job opportunities in outlying centers were filled by centrally located residents.

- If there occurs a greater shift to public transit, there can be a comensurate shift away from public spending on highways and automobile-related functions. Less expenditure in the long run could be devoted to freeways, streets, and parking facilities. It could also be argued that with such networks, greater costs will be incurred because of the necessity to maintain highways as well as public transit, unless rights-of-way are abandoned.

b. Energy and Metropolitan Growth Management

Since growth management refers to a process of monitoring and guiding growth, the impacts of growth management are largely unknown at this point and will emerge from the working through of the process. To the extent that energy availability serves as a constraint on development, energy conservation seems to be one of a number of concerns which should be included in growth management.

A second type of relationship between energy use and growth management derives from the fact that growth management implies a process of negotiation of trade-offs among competing objectives. Since energy conservation may require substantial changes in urban design and facility operation, it is clear that choices will have to be made, and that negotiations of trade-offs will be necessary. The mechanism for such choices can be supplied by growth management efforts serving as a forum of negotiation among conflicting objectives or purposes.

If growth management serves to aid in implementing and reconciling conflicts in energy conservation, energy use can also serve the purposes of metropolitan growth policy. That is, if metropolitan growth policy encourages local jurisdictions to negotiate their interests in a metropolitan context, then areas presently at a disadvantage will better compete by virtue of their involvement in the process. Since many elements of energy conservation relate differentially to portions of the metropolitan area, energy awareness could reinforce this aspect of growth policy. If it can be demonstrated that inner city areas are more energy-conserving because of higher densities and greater use of public transportation, and that strengthening inner city functions will serve energy conservation, then a metropolitan growth policy that will allow the central area to share in the benefits of growth is reinforced by energy conservation. And to the extent that growth and development occur in the central area rather than on the suburban fringe, then there will be a reduction in overall energy demands.

It is essential, therefore, from the standpoint of energy conservation that growth policy be developed at the metropolitan level, for it is only on an areawide basis that transportation systems and other major region-serving facilities can be planned. Incentives and disincentives in the housing market and regulations in the commercial sector may be best developed on a cooperative, areawide basis as well. If a single jurisdiction tries to implement certain conserving options independently of other jurisdictions, it may create a price or cost differential that will work to that jurisdiction's disadvantage in comparison to competing areas.

c. <u>Energy and Land Use</u>

The analysis of alternative development patterns indicates the impact of various densities and spatial arrangements on energy consumption. The earlier discussion of energy and land use also identified energy-conserving options that were largely dependent on land use patterns in order to be implemented. The point seems unmistakable that the arrangement and intensities of activities and facilities can have a substantial impact on the amount of energy consumed. It is now necessary to speculate upon what future forms development might take, weighing energy conservation against other factors of development.

- In the near-term, present patterns and trends will largely prevail. Public preference in this metropolitan area is to the automobile and the single-family home. At present, the sentiment for detached dwelling units has become dormant since a number of potential home owners have been crowded out of the market by high prices. In this case, energy considerations are enhanced by and reinforce a strong market current.

- As the METRO system is completed, there will be a relative decrease in dependence on the automobile, but it is expected that transit ridership levels would average around 30 percent of total trips. It might be expected that within reasonable proximity to transit routes there would be some increase in densities. In the mature and developed areas, it is unlikely that land uses would change unless land is under-utilized and the value so low as to warrant replacement of the existing use with a more intense use. It is conceivable that in some areas dwelling units of low value might be replaced by higher density units or even shopping or office facilities, but only in the immediate vicinity of transit stops. In undeveloped areas, there is potential for higher density uses, but such development will depend on available zoning, site assembly, and availability of other public services. Again, market forces would reinforce energy-conserving land use.

- Energy shortages or changes in supply will have diverse impacts on areas, regardless of METRO locations or availability. For example, it might be expected that central core areas in mature suburbs would have some potential for redevelopment with multi-family housing. This change in land use would depend on the particular community, but overall it is a possible impact. Within the District of Columbia, there is potential for either restoration or preservation, and the possibilities exist for major redevelopment that can encompass and create its own living environment. Such change will not in all likelihood, however, alter the prospects for sub-marginal areas, and a renaissance of development cannot be attributed to changes in energy supplies alone; other factors dominate the possibilities for redevelopment in those areas.

- In the longer-term, more extensive changes in land use might be foreseen. There will probably be added emphasis on transit-oriented development. For the extent of the METRO system as it is now planned, it is doubtful if additional open space between the corridors will be preserved since those areas are largely developed; that opportunity does exist if METRO is extended beyond its present limits, but in order to preserve such areas, efforts must begin now. At transit stops, higher density development, with large multi-use complexes combining offices, schools, retail areas, and residential uses are likely. Lower density residences will also be present, if only by the fact of the present pattern of development.

- An interesting aspect of future land uses under energy constraints lies in the role of transit systems. Just as the direction, sizing and staging of capital facilities--principally sewer and water lines--are now being used to control growth, and as Interstate highways and other urban freeways contributed to growth in previous decades, rail transit routes have the same potential for guiding growth.

- As was mentioned previously, different land uses afford the possibilities of utilizing energy-conserving technologies. Clustering of uses and development at higher intensities might be expected both as a function of costs in land markets and in order to conserve energy.

- Perhaps the more significant changes that result from land use changes--and that are implicit in energy conservation--are alterations to present lifestyles and patterns of energy use. It seems apparent that technology will provide part of the solution to energy shortages, but it is also certainly clear that changes in personal habits are necessary, if energy balances in the long-term are to be realized.

- Possible changes that might occur include: restrictions on mobility and more limited use of private vehicles; adjustments to higher density living; shorter workweeks and longer weekends; perhaps use of gasoline powered automobiles for weekend trips where higher occupancies and more efficient engine performance are possible. This shift from a consuming ethic to a conservation ethic will not be easy, but in order to adapt to land uses that are more efficient, as well as to reduce the accustomed levels of energy consumption, it will perhaps be necessary.

CHAPTER 9

POLICIES AND IMPLEMENTATION STRATEGIES

The many problems associated with energy, land use, and growth management also present many opportunities for local governments. This chapter suggests how local jurisdictions might use their powers or resources to reduce energy consumption. This is not an exhaustive catalogue of policies and strategies, but a listing which will indicate the types of activities--some of which are already found in metropolitan Washington--that might be undertaken.

A. Residential

- Policy: To improve the energy efficiency of new and existing structures.

  1. Allow credit on property taxes for improvements to homes that reduce energy consumption, so that the costs of retrofitting insulation, storm windows and doors are subtracted from tax bills.

  2. Allow deferral of the reassessment of such improvements, so that energy-conserving expenditures in the home do not immediately add to property taxes.

  3. Create loan guarantee programs, perhaps with revolving funds, to assist homeowners in borrowing the necessary money to undertake energy-conserving home improvements.

  4. In new residences, require certification as to the energy-efficiency of the structure.

  5. Require developers to build according to energy performance specifications.

  6. Modify zoning regulations and building codes to reduce impediments to the construction of more energy-efficient structures.

° Policy: <u>To encourage the application of energy-conserving technologies.</u>

1. Allow tax credits for investment in solar energy, waste heat recovery, or other systems in individual homes.

2. Modify building codes and zoning regulations to allow or mandate the application of new technologies.

3. Initiate demonstration projects to show use of technologies, with initial costs either guaranteed or subsidized by local governments and with repayment, if the building is to be used by a private owner.

B. <u>Commercial/Institutional/Industrial</u>

° Policy: <u>To improve energy efficiency of new and existing buildings.</u>

1. Provide tax incentives--perhaps as a one-time property tax rebate, or in deferral of future tax burdens--for applications of new technologies.

2. Reduce barriers of zoning, building codes and planning reviews required for approval of uses or activities that are non-conforming to community regulations, but that are conserving of energy.

3. Analyze and publicize studies of applications of technologies, so that the feasibility and steps required for implementing such changes are known; establish and publicize administrative procedures for projects which will demonstrate the potential for technological changes.

C. <u>Transportation</u>

° Policy: <u>To improve the operational efficiency of automobiles and other vehicles.</u>

1. Improve the flow of traffic, so that vehicles can operate more smoothly with less stop-and-go driving; measures to accomplish this would include revised timing of traffic signals, creation of one-way streets, establishing reversible lanes for peak hour flows, and imposing limits upon on-street parking.

2. Require periodic automobile maintenance checks and tune-ups through state vehicle inspection procedures.

3. Improve bus operation by allowing expanded use of limited access express lanes on freeways.

4. Initiate appropriate regulatory actions to reduce the amount of time spent by public and private vehicles (especially delivery vehicles) in the motor-idling mode.

- Policy: To discourage use of the automobile and reduce vehicle miles of travel.

1. Increase taxes on parking; if parking is provided by public authority, increase rates.*

2. Limit the number of parking spaces in central business districts.

3. Levy taxes according to weight of vehicle, number of vehicles owned, or number of miles driven.

- Policy: To encourage use of modes other than the automobile

1. Operate buses on priority lanes at rush hours; allow higher occupancy automobiles to use such lanes to provide an incentive for carpooling.

2. Improve public transit so that it is more competitive with the automobile--by fare reductions, park-riding facilities, improvements in service, including route and schedule modifications.

3. Where appropriate, encourage use of bicycles by constructing bikeway systems; such systems should be designed to encourage substitution for automobile trips.

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*A tax levied only in peak periods would discourage travel by commuters, but would not discourage downtown shoppers.

- Policy: <u>To make urban goods delivery more efficient.</u>

  1. Take appropriate regulatory actions to reduce the amount of travel required for delivery of goods and services in urban areas by modifying routes and schedules.

  2. Encourage use of delivery vehicles sent out from stores; encourage shopping by phone and delivery by van.

  3. Encourage clustering of pickup and delivery services.

D. <u>Land Use-Related</u>

- Policy: <u>To reduce distances of travel and inefficiencies in land use plans or existing patterns.</u>

  1. Analyze general plans and zoning maps for energy inefficiencies in transportation systems, sewer and water systems, and other networks.

  2. Relate land uses to one another, combining uses so that fewer and shorter trips are required.

  3. Encourage use of such development techniques as new communities, planned unit developments, industrial parks, and multi-use complexes where both densities and reduced distances will reduce necessity for travel and capital investment.

  4. Discourage non-contiguous development.

  5. Discourage construction of public facilities with excessive capacity.

  6. Require energy impact analysis as part of development review; data could be provided as an element of the entire impact assessment package, including analysis of alternatives.

- Policy: <u>To enhance the application of energy-conserving technologies</u>

  1. Analyze feasibility of recycling solid wastes, for materials recovery and for recovery of the combustible fraction as a supplementary fuel source.

2. Examine use of integrated utility systems to determine necessary densities for operation, economics of installation and use, and possible barriers due to building codes or zoning regulations.

3. In general, provide incentives through lower and differential taxes for experimentation with new techniques of conservation.

- Policy: <u>To relate land uses to efficient forms of transportation.</u>

  1. As part of the planning process, coordinate public transit needs with employment, shopping and residential uses.

  2. Supplement fixed-rail systems with adequate feeder bus systems.

  3. Provide public transit in a circumferential as well as a radial pattern, to improve service across the metropolitan area.

  4. Review zoning, comprehensive plans, and other land use mechanisms to reflect service levels provided by existing and future transportation systems.

  5. Curtail automobile-oriented transportation facility construction, and concentrate on public transit expenditures.

There are other areas where governmental action seems particularly useful. One such area is in the operating methods and purchasing decisions of local governments themselves. Since governments are major employers and consumers, they can exert leverage over how energy is consumed. For example, if local route-oriented services--library bookmobiles, school buses, solid waste collection, police and fire patrols--are reviewed from the standpoint of energy conservation, energy savings might result. Likewise, for the application of new technologies or innovative management techniques, governments can try demonstration projects or require an energy conservation orientation from its suppliers or contractors.

Many of these suggestions rely on direct economic or fiscal leverage in order to be implemented; others require changes in the administration of regulatory powers; and still others require a demonstration of guidance or leadership by undertaking energy conservation where other sectors might be more reluctant.

Finally, energy considerations should be incorporated into land use decisions by means of the growth management mechanism. In this prospect lies the possibility of achieving future energy balances while simultaneously balancing economic growth, environmental preservation, balanced community and other community development goals.

APPENDIX A

ALTERNATIVE DEVELOPMENT SCENARIOS AND PER UNIT FACTORS OF ENERGY CONSUMPTION

This appendix consists of two parts: documentation and derivation of per unit factors of energy consumption, and detailed characteristics of the alternative development scenarios used in this report.

1. Per Unit Factors of Energy Consumption

a. Residential:

The source used for per dwelling unit energy consumption factors was Hittman Associates, Inc., Residential Energy Consumption: Volume III--Multi-Family Housing, Columbia, Maryland, 1974, prepared for the Office of Policy Development and Research, Department of Housing and Urban Development.

This report analyzes the energy consumption characteristics of prototypical residential structures in the Baltimore-Washington area; it provides reliable and useful estimates appropriate to this area.

b. Commercial/Industrial/Institutional:

The per employee factors were derived by Real Estate Research Corporation, according to the following assumptions:

It was assumed that, from an energy perspective, institutional uses are similar to office uses, since a large portion of institutional employees are located in office space.

It was assumed that the commercial sector is predominantly characterized by office employees, except for the retail sector.

It was assumed that industrial and manufacturing employment is small in the metropolitan area, and that even a substantial portion of employees in this subsector would occupy offices (about one-half in fact are office workers; the balance are production workers).

The per employee energy factors were derived as follows:

(1) Office/Institutional/Other was derived by multiplying 285,000 Btu/square foot times 200 square feet/employee to get 57 million Btu/employee (or 57.0 X 10^6)/year. Energy consumption was adjusted to account for waste heat loss at the plant and in transmission of electricity.

Source: The number of Btu's per square foot was derived from the Preliminary Analysis of the Metropolitan Washington Board of Trade's Energy Use Survey, using average data for 1974. This analysis was performed by the Metropolitan Washington Council of Governments.

Source: The number of square feet per employee was based on interviews with the Building and Office Managers Association and the American Institute of Architects Research Corporation.

(2) Retail/Wholesale Trade was derived by multiplying 169,000 Btu/square foot times 420 square feet/employee to get 71 million Btu/employee (or 71.0 X 10^6)/year. Energy consumption was adjusted to account for energy consumed at the power plant.

Source: The number of Btu's per square foot was derived from Arthur D. Little, Inc., Residential and Commercial Energy Use Patterns, Cambridge, Mass., 1974, prepared for the Federal Energy Administration and the Council on Environmental Quality.

Source: The number of square feet per employee was derived from the Metropolitan Washington Council of Governments' 1975 Metropolitan Parcel File.

(3) Industrial energy consumption was derived using analyzed data obtained in a study of energy use in the New York region to get 288 million Btu/employee (or 288.0 X 10^6)/year. Energy consumption is adjusted to account for energy consumed at the power plant.

Source: Resources for the Future and Regional Plan Association., Inc., Regional Energy Consumption: Second Interim Report, New York, New York, 1974.

This approach to commercial/industrial/institutional energy consumption was used for several reasons:

- It was found that energy consumption did not vary necessarily with size of building, but rather age of structure, type of activity, and operating procedures of tenants.

- It was also found that within sectors or sub-sectors there was wide variation in the amount of energy consumed. Furthermore, depending on when measures of energy use were taken, there could also be wide variations.

- There are very little data that relate energy consumption to numbers of employees. There are data relating energy to size to building, and these were converted to the per employee basis. It was necessary to use per employee consumption in order to utilize the data base maintained by the Council of Governments.

c. Transportation:

The per vehicle mile traveled energy-consumption factors were derived according to the following assumptions:

(1) Energy consumption in miles per gallon for an average automobile in 1975 is assumed to be 13.5; at 128,000 Btu/gallon of gasoline, this converts to 9,481 Btu/vehicle mile traveled for automobiles.

(2) Energy consumption in miles per gallon for buses is assumed to be 3.1; at 139,000 Btu/gallon of diesel fuel, this converts to approximately 45,000 Btu/vehicle mile traveled for buses.

Source: Metropolitan Washington Council of Governments.

2. <u>Detailed Summary of Characteristics of Alternative Development Scenarios, Table A-1</u>

Table A-1, below, summarizes the land use activity characteristics developed in testing alternative growth scenarios for energy consumption. For a description of these scenarios, see Chapter 4.

Table A-1

DETAILED SUMMARY OF CHARACTERISTICS
OF ALTERNATIVE DEVELOPMENT SCENARIOS

Characteristic	Base	A "Wedges & Corridors"	B "Dense Center"	C "Transit-Oriented"	D "Wedges & Corridors" (Income Balance)	E "Sprawl"	F "Beltway-Oriented"
POPULATION							
Total	3,306,985	4,506,760	4,506,760	4,506,760	4,506,760	4,506,760	4,506,760
Increment	--	1,199,775	1,199,775	1,199,775	1,199,775	1,199,775	1,199,775
HOUSEHOLDS							
Total	1,090,330	1,589,930	1,589,930	1,589,930	1,589,930	1,589,930	1,589,930
Increment	--	499,600	499,600	499,600	499,600	499,600	499,600
a. Percent Increment Households in Ring No.							
0	--	0	1	1	0	0	0
1	--	1	6	7	1	0	0
2	--	2	22	15	2	0	0
3	--	5	27	30	5	0	0
4	--	19	44	34	19	24	23
5	--	21	0	10	21	19	77
6	--	20	0	3	20	23	0
7	--	20	0	0	20	22	0
8	--	12	0	0	12	12	0
b. Percent Total Households in Ring No.							
0	1	0	1	1	0	1	1
1	3	3	4	5	3	2	2
2	13	9	16	14	9	9	9
3	17	13	20	21	13	11	11
4	27	25	33	29	25	26	26
5	16	17	11	14	17	16	35
6	12	15	8	9	15	16	8
7	8	12	5	5	12	13	6
8	3	6	2	2	6	6	2

Table A-1 (Cont.)

DETAILED SUMMARY OF CHARACTERISTICS OF ALTERNATIVE DEVELOPMENT SCENARIOS

Characteristic	Base	A "Wedges & Corridors"	B "Dense Center"	C "Transit-Oriented"	D "Wedges & Corridors" (Income Balance)	E "Sprawl"	F "Beltway-Oriented"
c. Percent Increment Housing Mix							
Single Family, Detached	--	30	10	10	30	45	30
Single Family, Attached	--	30	20	30	30	35	35
Walkup/Garden Apartment	--	20	25	25	20	15	20
High Rise Apartment	--	20	45	35	20	5	15
EMPLOYMENT							
Total	1,496,005	2,278,820	2,278,820	2,278,820	2,278,820	2,278,820	2,278,820
Increment	--	782,815	782,815	782,815	782,815	782,815	782,815
a. Percent Increment Employment Ring No.							
0	--	7	26	1	7	15	0
1	--	8	19	7	8	12	0
2	--	18	16	15	18	10	0
3	--	7	13	30	7	12	0
4	--	11	26	34	11	23	23
5	--	10	0	10	10	14	77
6	--	20	0	3	20	9	0
7	--	12	0	0	12	4	0
8	--	7	0	0	7	1	0

Table A-1 (Cont.)

DETAILED SUMMARY OF CHARACTERISTICS
OF ALTERNATIVE DEVELOPMENT SCENARIOS

Characteristic	Base	A "Wedges & Corridors"	B "Dense Center"	C "Transit-Oriented"	D "Wedges & Corridors" (Income Balance)	E "Sprawl"	F "Beltway-Oriented"
b. Percent Total Employment in Ring No.							
0	18	15	21	13	15	17	12
1	14	12	15	11	12	13	9
2	12	14	13	13	14	11	8
3	9	9	11	17	9	10	6
4	19	16	22	24	16	20	20
5	11	11	7	11	11	13	34
6	10	12	6	7	13	9	7
7	5	7	3	3	7	5	3
8	2	3	1	1	3	2	1
TRANSPORTATION Automobile:							
Avg. Workday VMT (Million Miles)	37.0	55.7	48.0	47.4	51.7	59.2	53.4
Total Annual VMT (Million Miles)	12,432.0	18,715.2	16,128.0	15,926.4	17,371.2	19,891.2	17,942.4
Increment Annual VMT (Million Miles)	--	6,283.2	3,696.0	3,494.4	4,939.2	7,459.2	5,510.4
Public Transit (METRO):							
Bus-Annual VMT (Million Miles)	56.8	58.6	58.6	58.6	58.6	58.6	58.6

Table A-1 (Cont.)

DETAILED SUMMARY OF CHARACTERISTICS
OF ALTERNATIVE DEVELOPMENT SCENARIOS

Characteristic	Base	A "Wedges & Corridors"	B "Dense Center"	C "Transit-Oriented"	D "Wedges & Corridors" (Income Balance)	E "Sprawl"	F "Beltway-Oriented"
Home-Based Work Trips (Thousands)							
Total Trips (all modes)	2,161.6	3,154.9	3,097.6	3,100.0	3,147.0	3,164.2	3,164.0
Transit Trips	464.7	807.3	1,040.8	896.5	908.8	836.8	690.3
Modal Split (% Transit)	21.5	25.6	33.6	28.9	28.7	26.4	21.8
Home-Based Work Trips to Core (Thousands)							
Total Trips (all modes)	597.1	738.2	948.6	630.3	736.4	807.4	561.5
Transit Trips	268.4	402.0	550.9	356.9	451.7	429.6	309.5
Modal Split (% Transit)	45.0	54.5	58.1	56.6	61.3	53.2	55.1
Average Trip Length (Miles, All Purposes)	--	7.6	7.2	6.9	7.6	8.0	7.0
Auto Driver Trips: No. of Daily Trips (Thousands)*							
Home-Based Work	1,412.6	1,977.0	1,765.3	1,919.5	1,873.6	1,950.0	2,183.0
Home-Based Shopping	974.6	1,519.5	1,399.2	1,394.8	1,309.0	1,533.7	1,621.6
Home-Based Other	1,552.9	2,365.3	2,263.9	2,276.9	2,151.3	2,390.9	2,503.8
Non-Home Based	962.7	1,466.9	1,443.0	1,493.5	1,466.9	1,508.2	1,592.2
TOTAL	4,902.8	7,328.7	6,871.4	7,084.7	6,800.8	7,382.8	7,900.6

*Not adjusted for ring 8; excludes trip origins and destinations outside cordon line (ring 7).
Note: Totals may not add to 100% due to rounding.

Source: COG/RERC

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