

THE RELATIONSHIP OF THE COST
OF PUBLIC UTILITIES
TO THE SUBDIVISION PATTERN

By

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Professor Frederick J. Adams
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Dear Professor Adams:

I herewith respectfully submit this thesis entitled "The Relationship of the Cost of Public Utilities to the Subdivision Pattern", in partial fulfillment of the requirements for the degree of Master in City Planning.

Respectfully,

Alan M. Voorhees

DEDICATION

I wish to dedicate this to the eighty Senators who introduced the G. I. Bill of Rights, for without its financial support this thesis would have been impossible!

A.M.V.

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For the purpose of this thesis, we have limited ourselves to the study of the relationship in a subdivision between the original and maintenance costs of public utilities and the pattern of streets, as well as costs which affect the location of parks, public buildings and open spaces. We feel that in the very near future these relationships will play an even more important part in the design of a community, especially with the advent of large scale housing programs and the abundant use of prefabricated homes.

As an underlying belief, we felt that such an investigation should prove very valuable to the community and the future home owners. Both could be beneficiaries of many more amenities if economies were used to their full advantage. Likewise, the developer could profit by making a more pleasant neighborhood in which he would build and sell his homes.

Furthermore, we hoped that this thesis might be helpful as a guide to the agency in the community approving plats for land subdivision. These economic findings might help this agency in "winning a point" with a subdivider.

Fortunately, these cost relationships are not new to the planning field. They have been studied for many years, particularly in the early 1930's as the idea of garden cities became very popular. Messrs. Whitten and Adams were the great pioneers in America in this field. Their study entitled Neighborhoods of Small Homes¹, published in 1931, was the beginning of a series which tried to investigate the economic advantages of a garden development. The primary effort of this book was directed into an analysis of the current approach to subdivision. There were also some very interesting facts concerning blocks revealed in this publication. This book was later followed up by a more detailed study by Adams in which he investigated most of the cost variables of subdivision.² He made several theoretical studies of house arrangements in relation to the street, but these were all based on rather geometric patterns.

During the same period, President Hoover appointed a committee to study existing problems of home building and

¹ Robert Whitten and Thomas Adams, Neighborhoods of Small Homes (Cambridge, 1931)

² Thomas Adams, The Design of Residential Areas (Cambridge 1934)

home ownership. One of the basic studies made by this Presidential committee was the establishment of standards, goals and economies in residential areas.¹ Different schemes of house arrangements were also analyzed, much as Professor Adams had done.

It is not the purpose of this thesis to probe into what has been done in the past, but rather to proceed from where these planners left off, that is to say, to study the effects of the street pattern and how it affects the economic cost of public services. The onrush of publications in the 1930's had already brought forth many studies that indicated the economic efficiencies of various house to street relationships.

A further purpose of the present study was to supplement what had already been undertaken. We were of the opinion that most of these studies fell short of their purpose in that they failed to consider fully the variations due to topography, type of soil, geographical location factors, and, most important, maintenance and costs of operation. Likewise, their design was so stiff and geometric

¹ Report of the President's Conference on Home Building and Home Ownership, Planning for Residential Districts (Washington, D.C., 1932)

that one would have little opportunity to apply the results in the field. The primary goal of this thesis was that its results be applicable to the many conditions which might be encountered in the field.

In the creation of new subdivisions, complex elements must be weighed and given their proper value. The requirements of the street pattern, standards of recreation, the relationship of the house to the street, topography, governmental restrictions, the density and size of subdivision, the difference in geographical location, connections with various forms of transportation, and the resulting cost of development must all be taken into consideration in order to provide the promise of lasting value and beauty.

Certain general principles covering these factors are to be discussed very briefly in introducing the main analysis. First of all, we shall discuss some of the more basic elements of subdivision, namely, the street system and the relationship of the house to the street. We shall then attempt to familiarize ourselves with accepted standards of subdivision.

STREET SYSTEM

The principle functions of the streets in the subdivision are to provide access to the building sites, and a reservation for public utilities, such as water lines, sewers, gas lines, etc. The character and value of streets in the subdivision pattern are largely dependent upon the elimination of non-local traffic with its attendant noise and hazards. If this is accomplished, surfacing of local streets can be made of less expensive material. Likewise, a more efficient and logical program of maintenance can be carried out with a segregation of traffic uses.

The minor streets should follow the topography to secure an attractive and more pleasant development. In general, these minor streets should permit convenient access and egress, and a general direction of flow toward the place of work or the heart of the business area. There should be as few intersections with major streets as possible in order to eliminate hazards and to expedite thoroughfare movement. Minor streets should run parallel to major streets and connect at points in the subdivision closest to the point of access for the area. Intersections of

streets should be as nearly at right angles to each other as possible in order to decrease traffic hazards, to permit a more efficient layout of corner lots, and to save residential area.

The gridiron plan, which has been so universally adopted in many of our cities, has several disadvantages when applied to residential areas. In the first place, it creates waste by providing greater paved area than is necessary to serve residential communities adequately. Secondly, it causes the installation of more expensive types of paving by dispersing the traffic equally throughout the area, which, in turn, creates an increased traffic hazard. In addition to these disadvantages, the gridiron plan creates a monotonous, uninteresting architectural effect and fails to create a neighborhood feeling.

Nevertheless, there are advantages to the gridiron system, particularly the benefit of a systematic arrangement, which permits ease of orientation and simplicity of adapting such a scheme to the boundaries, constructional methods and surveying techniques.

A few years ago, many cities were laying out complete systems of alleys running through residential

blocks. In general, alleys are not economical because they require additional land and must be paved, repaired and, if possible, lighted. The savings in construction cost of garage driveways and sometimes in lot width do not compensate for the expense of providing alleys. Moreover, it is possible to place telephone and lighting wires and other utilities in easements along the rear lot lines, thus achieving one of the advantages of the alley without incurring its costs.¹

In more recent years, the trend has been toward irregular layouts which feature curved streets. Fundamentally, the curvilinear pattern is more attractive than the gridiron plan because it overcomes monotony by giving each street a special character of its own. By skilfully locating these curved streets on hilly or rolling ground, street grades can be reduced and the volume of cut and fill will be decreased. However, adjustment of the street system to the contour of the land can be carried to excess. Care must be taken to avoid very oblique intersections and uneconomical lot sizes and shapes. Furthermore,

¹ Land Subdivision, American Society of Civil Engineers, (New York, 1939), page 41.

these contour streets may cause certain house foundations to be below the usual grade of utilities. This would result in having sewers abnormally deep in order to take waste from the cellars of such houses. Thus, the saving in cut and fill must be balanced against the possible increase in expense for sewer excavation.

Sometimes loop streets and culs-de-sac are considered an integral part of a curvilinear system, but often they are associated with the super block, which is really a particular kind of curvilinear pattern. In the latter case, they are used to assure privacy and freedom from traffic. This type of street permits families to be served by a non-thoroughfare and, at the same time, orients the houses upon a park area rather than a traffic artery. Under such conditions, the road may be narrower and the utilities of small size. Radburn, New Jersey, is the foremost example of the super block system.

There are several undesirable qualities in super blocks to which attention must be drawn. The service streets should be a related part of the whole street design, and they must be designed to adhere to the maintenance policy of the community. These service streets should not lessen the

convenience of the access between different parts of the neighborhood.

A word should be said about cross access streets, which have been used very infrequently.¹ Under this scheme, the house fronts on a narrow "cross access street" which runs through a wide block instead of a main street. Like the cul-de-sac, the arrangement adds to privacy. It would seem that such a layout would appear quite choppy, broken up and rather unpleasant to the eye.

¹ Adams, op. cit., p. 187.

THE RELATIONSHIP OF THE HOUSE TO THE STREET

Planners of the past have discussed this problem at length, but all their ideas can be grouped into the following classes:

- Single building line
- Double and triple building line
- Culs-de-sac
- Cross access streets
- Loops
- Service bays

Without going into the various merits of these different layouts, we can take them as units and correlate their efficiency with the various street patterns. Thus, we can establish the economies that can be obtained from combining the particular advantages of these various schemes with the economies of various street patterns.

In the briefest way possible, we shall try to outline the background and approach to many of the standards which are generally accepted in the field of subdivision. The purpose of this is not to make any new revelations but rather to clarify our viewpoints in preparation for the economic study which is to follow. These standards which we have considered are:

- Community facilities
- Block size
- Lots
- Streets
- Utilities

COMMUNITY FACILITIES

In the field of recreation, trends have been toward the separation of small children's playgrounds and larger recreational centers which include athletic fields and swimming pools for older age groups. Likewise, there is a trend toward incorporating these facilities with school buildings (which can be used during off-school periods), thus avoiding the duplication of indoor facilities, such as toilets, showers and gymnasiums. Therefore, it was adopted that schools and recreation facilities be contiguous and used cooperatively and that supervision be provided.

Usable recreational areas should be within not more than fifteen minutes' walking distance without crossing major traffic arteries unless adequate safety precautions were taken. Small areas for pre-school children should be provided, such as tot lots.

Should these recreational areas be located within the block as is done at Radburn, or should the parks be of larger area and located on street frontage? As has already been pointed out by such studies as that of Henry Wright, the internal recreational area has a much lower initial cost since it is not served by streets, but the debatable issue

is whether the maintenance costs are much higher on such a system. We have tried to answer this by an analysis made later on in this thesis. As to the various amount of land required by these active and passive recreational facilities, we have adopted those standards set forth in Planning the Neighborhood.¹ These can be found in the appendix. As for the proper location and areas for other community facilities, the standards and specifications as set forth in Planning the Neighborhood were once again embodied in this study.

¹ Planning the Neighborhood, American Public Health Association Committee on the Hygiene of Housing, (1948), p. 53

BLOCK SIZES

Unfortunately, the local customs and regulations will often have as much influence on the size and shape of blocks as does any physical characteristic of the site. For this study, we have dismissed many of these regulations in lieu of more desirable standards. Some site planners believe that a desirable plan should permit blocks up to 1800 feet long and, under proper conditions, up to 2000 feet in length.¹ In general, long blocks should lie in the direction of the main traffic flow and should not cause long detours in reaching major objectives, such as schools and shopping centers. Crosswalks can overcome many of the present objections. However, such walks must not become a nuisance to abutting property owners, and they must be used only when functionally required.

Much has already been said about the so-called super block plan consisting of large deep blocks penetrated by a series of cul-de-sac service drives and with sidewalks

¹ The Community Builders' Handbook, Community Builders' Council of the Urban Land Institute, (Washington, D.C. 1947), p. 48.

located in a semi-common interior area. Radburn again presents a particularly fine example of such a system.

LOTS

The primary purpose of any land subdivision is to provide good building sites. Ideally, a good site should be found on every lot. When all lots within the same development tend to approximate each other in size, it produces a rather homogeneous development which might be considered questionable from the social viewpoint. Thus, we felt that it was more important to study areas for residential development rather than a given number of lots.

The particular sizes of lots are regulated by many outside functions, namely, 1) the remoteness from the center of the community, 2) the price of raw land, 3) the character of land improvements, 4) the character of the land, 5) the desires of the people, and 6) the type and character of houses.¹ With these varying influential stipulations, it is almost impossible to set up a normal size lot, and here again the logical approach to this situation seems to be to study it from the residential area developed rather than from the number of lots developed.

¹ Adams, op cit. p. 68.

STREETS

Earlier we have discussed the function of the street and we shall now try to cover some of the accepted standards. First of all, we are of the opinion that minor street rights-of-way in residential neighborhoods of detached houses should be fifty feet wide, with a roadway twenty-six feet from face of curb to face of curb. This provides for two lanes of parallel curb parking and one lane for moving traffic, which usually is adequate for local circulation. On major residential streets which must act as collector streets for traffic originating in the neighborhood, on streets adjacent to the community or commercial facilities, and where serving apartments, developments should have a right-of-way of sixty feet and pavement of thirty-four feet. This provides for two moving lanes.

Culs-de-sac are dead end streets which have turning space at the end. We believe that they should not be more than 500 feet long and should have a turn-around of not less than forty feet radius from center of circle to outside curb with a small grass space in the center. The use of "Y" or "T" types instead of these turnabouts was not considered in this study.

Federal Housing Administration standards for the wearing surface in a development of one-family detached houses require a pavement equal to a one-inch bituminous road mix top or a double bituminous surface treatment constructed on a base designed to carry the contemplated traffic load. This is considerably below the quality we have found out in the field. Farrington, as well as Levitt, was using a five-inch shell concrete pavement with macadem or cement topping. In fact, such pavement is very close to Federal Housing Administration standards for developments of apartments or row houses. For the purpose of this thesis, however, we shall accept the Federal Housing Administration regulations for detached houses as the minimum. These can be found in Street Improvements, Land Planning Bulletin Number 2.¹ Other standards for gutters, curbs and the like have been based on data sheets of this publication.

¹ Land Planning Bulletin Number 2, Federal Housing Administration, Washington, D.C., Data Sheet No. SA 101 and SA 201

UTILITIES

The authority on desirable standards for various utilities is Planning for Residential Districts,¹ the first report of President Hoover's conference on Home Building and Home Ownership. The principles concerning storm and sanitary sewers, water mains, with their connections, etc. have been adopted for this report as our guide, but the more detailed regulations have followed the data sheets of the Federal Housing Administration and are discussed in connection with the cost analysis made later in this thesis.

¹ Planning for Residential Districts, op. cit.

OUT IN THE FIELD

To form a background for this thesis, we were fortunate enough to be able to spend some time visiting and studying various subdivisions of this "house hungry" America. Such enterprises as the Byrne Organization and Levitt and Sons were visited personally, while correspondence was carried on with the Kaiser Community Homes in Los Angeles, William G. Farrington Company in Houston, and Place and Company in South Bend, Indiana. All these organizations are of large size. They are taking raw land, clearing it, perhaps leaving a few trees, and then locating the utilities and streets in a pattern which they think to be most beneficial in selling the property.

Both Byrne and Levitt used many of the basic methods of mass production and their outlook was very progressive. We often wonder why their methods of construction differ so greatly when they both have the same goal of economy. However, after talking with Mr. Kline, the economist of the Byrne Organization, we can readily realize just why there can be so many approaches to the basic idea of building cheap homes. He stated that few of the major elements of cost have been considered from the economic viewpoint. As Mr. Kline stated,

"The old man feels that this is the proper way to do it, and that's all there is to it." Of course, it is true that Mr. Byrne is not a new man in this field and that his judgments are not made without a considerable amount of experience, but we wonder why there should be such a lack of scientific analysis of various cost problems. Due to this attitude in the field, we have been faced with many difficulties which further complicate our study.

The first and foremost of these difficulties was getting statistical data on cost. Engineers were not interested in breakdown of costs to the fine detail into which we must go for a true analysis. It may be that they were aware of the various increments that made up costs but that they were not particularly eager to establish these cost variables. They approached the problem by the rule of thumb. They had the background and knowledge to do this, but unfortunately, there are many planners who cannot do likewise. We are left with the alternative of studying these cost situations in detail and perhaps developing some of our own rules.

Just as Mr. Kline thought one of the basic needs in the Byrne Organization was the study of the economics of the steel frame, so we have felt that the economic framework

of a subdivision must be studied. Five particular items should be analyzed, namely, the spotting of parks and other community facilities within the area, the arrangement of the houses in relationship to the street, the pattern of the streets, the cost of maintenance, and the economic variables of the utilities and streets.

SITE PLAN EFFICIENCY

Upon first considering the problem of the relationship of these various items of the economic framework, we were led to the conclusion that the efficiency of any site plan was the relationship between the area served and the street length. Most of the engineers and planners whom we met in the field agreed with this conclusion. This was based on the reasoning that subdivisions under various similar standards would have the same unit cost for development of their utilities. The Federal Housing Administration has published a very interesting table which is based on this fundamental assumption that unit cost for lot improvements is related to the unit cost of streets and utilities.¹

With this basic assumption in mind, we proceeded to study various existing projects in which cost analysis was available so that we might check this hypothesis. As in most theoretical studies, practical application fell far short of our original theory. There was one alternative to follow, that is, to check why unit costs of utilities and streets varied.

¹ Land Planning Bulletin No. 2, op cit., Data Sheet No. SA 401. (See appendix.)

Unfortunately, such an investigation could not be made unless we took into consideration three major items: current prices, standards in communities, and natural variations, such as soil conditions.

PRICES

Prices, as usual, prove to be the trouble maker. We are first faced with the spiraling of prices and the usual variations caused by difference in the quality of workmanship. Likewise, the common practice of unbalanced bids almost prohibited the use of costs found in various contracts. Our first attempt was to find what large contractors were being paid for the laying of utilities. Such organizations as Kaiser Community Homes, William G. Farrington and Company, Place and Company, the Byrne Organization and Levitt and Sons were consulted. Satisfactory information was obtained from all these companies with the exception of Levitt and Sons. In conjunction with these price standards, data obtained from the Federal Housing Administration was used. This consisted of average improvement costs for five sections of the country and had been brought up-to-date to June 1948 by the Urban Land Institute.

This comparison of standard costs was further improved by the analysis of costs found in various contracts of the Boston Metropolitan Water Commission and Metcalf and Eddy. Of especially valuable assistance in weighing these

costs was the information given us by Mr. Rice of Metcalf and Eddy. Most of this information concerning cost variables in excavation is based on his understanding of the subject.

In general, we limited ourselves to prices which would most likely be found in the Northeastern states and would result from a project that would consist of at least 100 units. The following outline of prices gives a general idea of what we considered to be the unit prices in this study. A more detailed analysis can be found in the appendix along with comparable costs in various sections of the United States.

Rough grading of land in preparation for roads or housing sites was taken at \$1.00 per cubic yard. Paving costs, which include very high grade bituminous wearing surface of about two to three inches and a stone base of about six inches in depth, were considered to be \$2.00 per square yard. Curbs and gutters, usually considered as being made of concrete rolled or straight faced, usually cost \$1.50 per linear foot.

In considering the sewer systems, we were limited by two controlling factors, namely, the depth at which sewers

would be located and the minimum size of pipe. The latter we established as eight inches, but the former we considered as an integral part of the standard cost of sewers, that is, from Federal Housing Administration figures, the standard cost of the sewers is reported as \$3.00 per running foot. This took into consideration variations in depth and similar variation in size of pipe but was based on a high standard of soil conditions.

The storm sewers were considered in like manner. The minimum size was limited to fifteen inches and the other factors resulted in a standard cost of \$1.18 per linear foot of street.

The water system, since it is not a gravity controlled system, need not vary in depth from that required by frost action and, furthermore, most subdivisions can be supplied by the minimum six-inch main. This means that the Federal Housing Administration average for the Northeastern states took in very few variables and that the \$3.00 cost per linear foot would be quite accurate in most subdivisions.

Probably the most irregular items of expense in utility costs are those contributed by the utility connections, manholes, fireplugs and catchbasins. In studying the findings

of these large contractors, we found over 100 per cent variation in some of these items, particularly in manholes and catchbasins. This is undoubtedly due to the great variation in costs that is contributed by labor in different sections of the nation.

Another important item affecting these costs seemed to be the quantity in which they were built. Apparently, great savings resulted in having teams especially assigned to constructing any of these connections. In this report, standard costs for manholes are considered at \$160., fireplugs at \$150., catchbasins at \$100., and cleanouts, which are usually used in connection with culs-de-sac, at \$50.

LOCAL STANDARDS

These basic prices are all entangled with various local standards. Such standards as those found in New England towns which permit only granite curbing or require storm sewers to be constructed below frost action are very costly to the subdivider.

At the present time, Mr. Ralph Wilson, of the Federal Housing Administration in New York City, is making a study which should enlighten us as to just how much these local regulations mean in affecting costs. He is proceeding in his analysis by visiting various towns and determining their standards for streets and utilities. With those standards, he approaches contractors in the area and consults them on cost estimates. Compiling this information from town to town, he will have a rather interesting picture of how these costs are affected by local standards even though they do not take into consideration variations due to standards of different contractors. At the moment, indications from his studies seem to hint that a variation of twenty-five per cent can be contributed by local regulations.

NATURAL CONDITIONS

The last of these controlling factors is the effect of natural conditions on streets and utilities. This proved to us to be far more important than we had imagined. Soil conditions might raise construction costs some 128 per cent, whereas we had anticipated only about a 50 per cent increase. We have considered variations in soil conditions which would affect the excavation cost for streets and utilities. This includes such extreme conditions as excavation in rock ledges and in peat. These conditions will be discussed in detail in the various studies made for the different items of expense. However, with regard to this, several general comments can be made. 1) Trench excavation in peat and rock ledges increases digging costs about an equal amount, that is, some 300 per cent to 400 per cent. 2) The soil condition which occurs in trench excavation affects costs appreciably only when trenching required sheeting or when excavation is hindered by rock ledges. 3) A great deal of attention must be given to the subsoil condition for the streets. 4) In general, street costs will be increased at least 85 per cent if the streets are built on swampy land, such as peat.

PROCEDURE FOR ANALYSIS

In outlining the procedure for this analysis, we must indicate some of the objectives of the research problem. First of all, we wanted something applicable in the field and at the same time results which could be absorbed and comprehended by a rather inexperienced crew of technicians. To meet this first goal, we have worked around actual designs rather than theoretical designs, that is, we have taken as our standard costs those encountered in the field. Depths of sewer mains, storm sewers and water mains were determined by field studies. The number of catchbasins, manholes and fireplugs were derived from actual subdivisions.

We could have undertaken this analysis in two ways; first, we could have taken the averages of these various items to establish an average condition which might act as a standard but which would give little indication of how much items could vary from it. In the second way, we could take a statistical average of these various factors and thus establish limits within which we could expect a good design to be found.

To give a concrete example of this by taking five or six plans of good subdivisions, we could make a study of

the number of manholes vs. the length of streets. From these five or six studies, we could determine the statistical average, let us say, one manhole for every 350 feet of street. Likewise, we could establish the possible range that could be expected under a normal distribution with a 95 per cent confidence. Further enlarging upon our example, this would mean that in 95 per cent of good designs, we would find that one manhole would be constructed for between the range of every 300 to 400 feet of street. This was the basic procedure for the majority of the work found in Tables I through VI. They indicate the possible range of variation which might be found in a subdivision that could be attributed either to the design or to natural causes. The distinction between these two causes is quite important.

The cost variables due to the design of the subdivision are controlled by two general factors: 1) the basic scheme of streets and 2) how this scheme of streets is adapted to the topography of the land. The basic scheme of streets affects the number of manholes, catchbasins, number of intersections and various other items. In the detailed breakdown of the various variables found in Tables IV through VI, these design variables are designated by (D). The natural conditions are indicated by (N), which shows what variables are caused by natural conditions of the subdivision, mainly those con-

nected with soil conditions and depth of water table. These were determined by relative cost studies based on various contract costs or average costs.

Furthermore, the tables are supplemented by a figure called here a "conceivable high". This high is based on such conditions that would be very seldom met in the field, such as very steep topography or very swampy land, in which cases these figures give a guide as to what may be expected. Throughout these tables, variations have been considered from two bases, one which we call "standard cost" and the other "total standard cost". Total standard cost is the total cost per foot of street, which was established by adding up various standard costs for particular items of expense. The standard cost is the cost of various particular items of expense per foot of street which would result from constructing a subdivision under average conditions based on a good design. Therefore, anything found under columns entitled "Variation in Standard Cost" is based on that particular standard cost of the item being considered. Any percentages found under "Variation from the Total Standard Cost" are related to the statistical range varying from the total standard cost of \$19.79.

THE SUMMATION OF ALL COST VARIABLES COMMITTED TO A SUBDIVISION

	Standard Cost \$/ft. of street	Possible Percentage Variation from Standard Cost			Percentage of Total Standard Cost	Possible Percentage Variation from Total Standard Cost		
		Below	Above	Conceivable High		Below	Above	Conceivable High
Street (total)	\$ 9.418	11.0	105.0	119.0	47.5	5.2	49.8	52.6
(1) Intersections	(-) 0.322	40.0	130.0	(-) 60.0	(-) 1.7	0.6	2.2	(-) 1.1
(2) Grading	0.960	25.0	180.0	238.0	4.8	1.2	8.6	11.4
(3) Paving	5.780	12.0	130.0	140.0	29.2	3.5	38.0	40.8
(4) Curb and Gutters	3.000	0.0	7.0	10.0	15.1	0.0	1.0	1.5
* "T" Intersections	(-) 0.393	40.0	70.0	(-) 30.0	(-) 2.0	0.8	1.4	0.6
* Turnabout - Cul-de-sac	1.328	20.0	70.0	70.0	6.7	1.3	4.7	4.7
Underground Utilities (total)	7.670	28.2	230.0	320.0	38.7	11.0	89.0	123.8
(1) Sanitary Sewers	3.270	35.0	245.0	349.0	16.5	5.8	40.4	57.4
(2) Storm Sewers	1.250	49.0	231.0	356.0	6.3	3.1	14.6	22.4
(3) Water Mains	3.150	13.0	208.0	277.0	15.9	2.1	34.0	44.0
Connections (total)	1.289	34.0	44.2	49.5	6.5	2.3	2.9	3.2
(1) Manholes	0.688	43.0	53.0	56.0	3.5	1.5	1.9	1.9
(2) Fireplugs	0.340	9.0	19.0	23.5	1.7	0.2	0.3	0.4
(3) Catchbasins	0.261	44.0	54.0	65.0	1.3	0.6	0.7	0.9
* Cleanout - Cul-de-sac	0.257	54.0	64.0	72.0	1.3	0.7	0.8	0.9
Planting and Seeding	0.580	0.0	50.0	50.0	3.0	0.0	1.5	1.5
Engineering and Overhead	0.833	0.0	50.0	50.0	4.3	0.0	2.1	2.1
Total Standard Cost	\$ 19.790				100.0%	18.5%	145.3%	183.2%
(Dollar/ft. of street)								
For improvements which do not serve residential area (20%)	3.960							
Land in Right-of-way	0.720							
Total	\$ 24.470							

* - Not considered in totals.

We have introduced negative values in this Table since in establishing the procedure for measuring streets, we measured the center line of streets. This meant a duplication of intersections.

THE SUMMATION OF ALL COST VARIABLES COMMITTED TO A SUBDIVISION

	Standard Cost \$/ft. of street	Possible Percentage Variation from Standard Cost			Percentage of Total Standard Cost	Possible Percentage Variation from Total Standard Cost		
		Below	Above	Conceivable High		Below	Above	Conceivable High
Street (total)	\$ 9.418	11.0	105.0	119.0	47.5	5.2	49.8	52.6
(1) Intersections	(-) 0.322	40.0	130.0	(-) 60.0	(-) 1.7	0.6	2.2	(-) 1.1
(2) Grading	0.960	25.0	180.0	238.0	4.8	1.2	8.6	11.4
(3) Paving	5.780	12.0	130.0	140.0	29.2	3.5	38.0	40.8
(4) Curb and Gutters	3.000	0.0	7.0	10.0	15.1	0.0	1.0	1.5
* "T" Intersections	(-) 0.393	40.0	70.0	(-) 30.0	(-) 2.0	0.8	1.4	0.6
* Turnabout - Cul-de-sac	1.328	20.0	70.0	70.0	6.7	1.3	4.7	4.7
Underground Utilities (total)	7.670	28.2	230.0	320.0	38.7	11.0	89.0	123.8
(1) Sanitary Sewers	3.270	35.0	245.0	349.0	16.5	5.8	40.4	57.4
(2) Storm Sewers	1.250	49.0	231.0	356.0	6.3	3.1	14.6	22.4
(3) Water Mains	3.150	13.0	208.0	277.0	15.9	2.1	34.0	44.0
Connections (total)	1.289	34.0	44.2	49.5	6.5	2.3	2.9	3.2
(1) Manholes	0.688	43.0	53.0	56.0	3.5	1.5	1.9	1.9
(2) Fireplugs	0.340	9.0	19.0	23.5	1.7	0.2	0.3	0.4
(3) Catchbasins	0.261	44.0	54.0	65.0	1.3	0.6	0.7	0.9
* Cleanout - Cul-de-sac	0.257	54.0	64.0	72.0	1.3	0.7	0.8	0.9
Planting and Seeding	0.580	0.0	50.0	50.0	3.0	0.0	1.5	1.5
Engineering and Overhead	0.833	0.0	50.0	50.0	4.3	0.0	2.1	2.1
Total Standard Cost	\$ 19.790				100.0%	18.5%	145.3%	183.2%
(Dollar/ft. of street)								
For improvements which do not serve residential area (20%)	3.960							
Land in Right-of-way	0.720							
Total	\$ 24.470							

* - Not considered in totals.

We have introduced negative values in this Table since in establishing the procedure for measuring streets, we measured the center line of streets. This meant a duplication of intersections.

TABLE II

SUMMATION OF COST VARIABLES DUE TO THE DESIGN OF A SUBDIVISION

	Standard Cost \$/ft. of street	Possible Percentage Variation from Standard Cost			Percentage of Total Stand- ard Cost	Possible Percentage Varia- tion from Total Standard Cost-Conceivable		
		<u>Below</u>	<u>Above</u>	<u>Conceivable High</u>		<u>Below</u>	<u>Above</u>	<u>High</u>
Street (total)	\$ 9.418	11.0%	28.3%	31.4%	47.5%	5.2%	13.3%	14.7%
(1) Intersections	(-) 0.322	40.0	20.0	(-)60.0	(-) 1.7	0.6	0.3	(-) 1.1
(2) Grading	0.960	25.0	150.0	208.0	4.8	1.2	7.2	10.0
(3) Paving	5.780	12.0	20.0	20.0	29.2	3.5	5.8	5.8
(4) Curb and Gutters	3.000	0.0	0.0	0.0	15.1	0.0	0.0	0.0
* "T" Intersections	(-) 0.393	40.0	20.0	(-)20.0	(-) 2.0	0.8	0.4	(-) 0.4
* Turnabout - Cul- de-sac	1.328	20.0	20.0	20.0	6.7	1.3	1.4	1.4
Underground Utilities (total)	7.670	28.2	38.0	60.0	38.7	11.0	14.8	25.2
(1) Sanitary Sewers	3.270	35.0	45.0	82.0	16.5	5.8	7.4	13.5
(2) Storm Sewers	1.250	49.0	59.0	128.0	6.3	3.1	3.7	8.0
(3) Water Mains	3.150	13.0	23.0	23.0	15.9	2.1	3.7	3.7
Connections (total)	1.289	34.2	34.2	36.5	6.5	2.3	2.3	2.4
(1) Manholes	0.688	43.0	43.0	46.0	3.5	1.5	1.5	1.5
(2) Fireplugs	0.340	9.0	9.0	9.0	1.7	0.2	0.2	0.2
(3) Catchbasins	0.261	44.0	44.0	50.0	1.3	0.6	0.6	0.7
* Cleanout - Cul-de-sac	0.257	54.0	54.0	60.0	1.3	0.7	0.7	0.8
Planting and Seeding	0.580	0.0	0.0	0.0	3.0	0.0	0.0	0.0
Engineering and Overhead	0.833				43.0	0.0	1.5	1.5
<u>Total Standard Cost</u> (Dollars/ft. of street)	\$ 19.790				100.0%	18.5%	31.9%	43.8%

* - Not considered in totals.

TABLE III

SUMMATION OF COST VARIABLES DUE TO NATURAL CONDITIONS FOUND IN SUBDIVISIONS

	Standard Cost \$/ft. of street	Possible Percentage Variation from Standard Cost			Percentage of Total Stand- ard Cost	Possible Percentage Varia- tion from Total Standard Cost		
		<u>Below</u>	<u>Above</u>	<u>Conceivable High</u>		<u>Below</u>	<u>Above</u>	<u>Conceivable High</u>
Street (total)	\$ 9.418	0.0%	76.7%	87.6%	47.5%	0.0%	36.5%	37.9%
(1) Intersections	(-)0.322	0.0	110.0	0.0	(-)1.7	0.0	1.9	0.0
(2) Grading	0.960	0.0	30.0	30.0	4.8	0.0	1.4	1.4
(3) Paving	5.780	0.0	110.0	120.0	29.2	0.0	32.2	35.0
(4) Curb and Gutters	3.000	0.0	7.0	10.0	15.1	0.0	1.0	1.5
* "T" Intersections	(-)0.393	0.0	50.0	(-)10.0	2.0	0.0	1.0	(-) 0.2
* Turnabout - Cul- de-sac	1.328	0.0	50.0	50.0	8.7	0.0	3.3	3.3
Underground Utilities (total)	7.670	0.0	192.0	260.0	38.7	0.0	74.2	98.6
(1) Sanitary Sewers	3.270	0.0	200.0	267.0	16.5	0.0	33.0	43.9
(2) Storm Sewers	1.250	0.0	172.0	229.0	6.3	0.0	10.9	14.4
(3) Water Mains	3.150	0.0	185.0	254.0	5.9	0.0	30.3	40.3
Connections (total)	1.289	0.0	10.0	13.0	6.5	0.0	0.6	0.8
(1) Manholes	0.688	0.0	10.0	10.0	3.5	0.0	0.4	0.4
(2) Fireplugs	0.340	0.0	10.0	14.5	1.7	0.0	0.1	0.3
(3) Catchbasins	0.261	0.0	10.0	15.0	1.3	0.0	0.1	0.2
* Cleanout - Cul-de-sac	0.257	0.0	10.0	12.0	1.3	0.0	0.1	0.1
Planting and Seeding	0.580				3.0	0.0	1.5	1.5
Engineering and Overhead	0.833				4.3	0.0	0.6	0.6
<u>Total Standard Cost</u> (Dollars/ft. of street)	\$ 19.317				100.0%	0.0%	113.4%	139.4%

We shall proceed to investigate why unit cost of utilities and streets vary; first, the variation caused by laying the streets; second, the deviation from the standard cost caused by the underground utilities; and third, the variation in connections (manholes, catchbasins and fireplugs). In the following pages, we will discuss in detail the causes behind these variations and relate these to total standard cost as well as to standard cost.

STREETS

The factors of deviation that we applied to the street fall into the following categories as found in Table IV: Intersections, Grading, Paving and Curbs and Gutters. As indicated by the table, "Paving" (including the wearing surface and base) and the "Curbs and Gutters" were the major items of expense.

The standard cost of paving (\$5.780) was affected by the chosen width of the street and the condition of the subsoil (including the elevation of the water table). In making this study, we found that the unit cost of the pavement alone was increased or decreased by almost four per cent for every foot that it varied from the standard width of 26 feet. But, on the other hand, if the curbs and gutters and the remainder of the cost of a street were considered, there was a variation of

2.5 per cent which would be attributed to each foot that it varied from the standard. In turn, this meant a change of 1.1 per cent in the total standard cost. This variation had a simple relationship since the materials and labor were in direct proportion to the width of the streets.

As the texture of the subsoil became poorer, construction methods were needed to improve the base. This usually called for the removal of the undesirable subsoil to allow fill that would act as a good base or the use of various types of mechanical treatment of the soil, such as the use of sheeps-foot rollers. If extra fill is required, which will necessitate extra grading or excavation, the unit cost of the pavement will increase by 22 per cent for every six inches of bank gravel that is needed as fill. However, if we consider the total unit cost of the streets, there would be a variation of 12 per cent which could be assigned to each six inches of fill required. This results in a change of 6.5 per cent in the total standard cost. The amount of fill can be determined approximately from the tables included in the appendix. Soil classified as A-4, which is soil susceptible to frost action, may require a thirty-inch fill. This would mean 110 per cent increase in the cost of pavement, or a 32.5% increase in total standard cost. Under extreme conditions of

very peaty soil, the increase might be as high as 35 per cent of the total standard cost. On the other hand, rock ledges as usually encountered would raise the total standard cost about five to six per cent. In the process of design, the extreme high cost resulting from building roads or streets on swampy land should be noted particularly.

Curbs and gutters, which were the second major item of expense, had few variables. Allowances for driveways was not considered as a variable since the curbs were of the rolled type. The only important variable was the subsoil which affected the standard cost by about 1.6 per cent under the worst conditions. This variation was determined in the same manner as above.

Among the minor items of expense, the variables applied to grading had the most profound effect. It was possible that the grading cost might increase some 238 per cent over the average cost which was based on a one-foot cut. This meant an increase of 11.8 per cent in the total standard cost due to natural and design variables. These high costs for grading can be reduced by running roads perpendicular to the contours or by locating them on ridges or in valleys if poor soil conditions can be avoided.

In establishing the procedure for measuring street length, we decided to measure the center line of streets since it was most convenient. This meant that at intersections there was a duplication. Therefore, to correct this, we have introduced negative values in Table ⁵IV. The duplicated construction cost for an intersection was calculated to be \$388. This figure takes into account the reduction in the amount of paving and curbing which would be required at intersections if compared with ordinary streets. Two interesting results can be noticed in Table IV; first, the angle of intersection as it varies from the right angle can affect the construction cost of intersections up to 20 per cent and, second, the ratio of the number of intersections to the street length (one intersection to 1050 feet of street) does not vary too greatly in the design considered (about 20 per cent). This second result is far below the possibility of a theoretical ratio based on our original assumption of a 2000 foot block. In an extremely large subdivision with blocks 2000' x 200', the above ratio would have been one intersection to ^{2,000}2000 feet of street. Thus we might say that the plans studied had only a 48 per cent "block efficiency".

Although not included under "Intersections" in Table

IV, there are additional expenses that might be assigned to this category, such as the extra grading caused by the variation in the gutters and street grades, the necessity of more catchbasins, and additional cost due to the intervention of continuous construction methods. However, these items are considered under various other headings, such as Grading, Pavements, and Catchbasins.

Far more important than these small increments is the extra cost incurred by the loss of residential area at intersections. At least 10,000 square feet of land is lost by the passage of an additional street through the residential area. This is greatly increased if the lot depths are greater than 100 feet. In cost, this means that every intersection increases the cost of streets and utilities at least \$1000. If the intersection is made at other than a right angle, the cost will increase as the secant of the angle varies from the perpendicular. With an angle variation of 45 per cent, the cost would grow to \$1400.

On the other hand, if it is considered that the "intersecting" street cannot serve new residential areas in the vicinity of the intersection (100 feet either side of the right-of-way), the cost of an intersection is still higher. This would mean that an intersection really increases costs

of utilities and streets approximately \$6000. In turn, this is increased by the secant of the angle that the intersection varies from a right angle. Thus a 45 degree angle of intersection increases the cost of an intersecting road by about \$8500.

Further consideration was given to "T" intersections and turnabouts for culs-de-sac. These were not introduced into the total standard cost since they had only a limited use in subdivisions. However, similar cost analyses were made in each of the above cases and can be found in Table IV. The important aspect of "T" intersections and turnabouts is the resultant effect they have on the area served. By using "T" intersections, one loses about 5000 square feet of residential area, which means an additional expense of about \$500. (under a system with lot depth of 100 feet.) However, if we consider the "T" intersection as we did the regular intersection, we should attribute an additional expense to the improvement cost of \$3000. for every "T" intersection used in a plan. This would be affected in like manner by the secant of the angle that it varies from the right angle.

On the other hand, the use of culs-de-sac increases the area served by some 22,000 square feet. This resulted

in the reduction of improvement costs in a subdivision to about \$2200. (with the usual lot setup). By combining the results of the "T" intersection and the turn abouts, we find that each cul-de-sac will increase the total improvement cost about \$450.

Engineering costs might very easily be considered under "Streets". This expense should contribute to many savings, such as the proper choice of road surfaces and the right materials. Engineering costs for large subdividers run about four per cent of the total standard cost in the usual subdivision. This is an increase of about 100 per cent over the cost of layout in a gridiron system. Likewise, the extra cost which must be allotted to the construction methods required in the building of curved roads was considered to be in the neighborhood of five per cent of the standard cost. This, in effect, means that the cost of departing from the standard gridiron system due to extra construction costs and engineering costs would amount to 3.5 per cent of the total standard cost. This, we consider, is a small factor when considering the numerous aesthetic advantages offered by the curvilinear street pattern.

In summing up the variations which can be attributed

to the construction of the streets, we can say that one may expect, under extreme conditions, a variation of 119 per cent from the standard cost of streets. This means that a deviation of 52.6 per cent is possible under extreme conditions in the total standard cost. This deviation in the total standard cost was affected about 75 per cent by the natural conditions, thus indicating the importance of locating roads on good grounds. Variation in the variables controlled by the design of the plans we studied indicated that a conceivable high of approximately fifteen per cent above the standard cost might be anticipated.

TABLE IV

DETAILED ANALYSIS OF THE VARIABLES COMMITTED TO STREETS

	Average or Standards for Variables	Standard Cost - Dollars per foot of street length	Possible Percentage Variation from Standard Cost		Variation in Standard Cost in Dollars		Conceivable High
			Below	Above	Below	Above	
Intersections (total)	(-) \$ 388.	(-) \$ 0.322	40.0%	130.0%	\$0.130	\$0.504	(-) \$0.192
(1) No. of units/ft. of street (D)	0.00955	-	20.0	20.0%	0.065	0.065	-
(2) Angle of intersection (D)	Right Angle	-	20.0	0.0	0.065	0.0	-
(3) Soil Condition (N)	A-1	-	0.0	110.0%		0.427	-
Grading (total)	\$1.00/cu.yd.	0.960	25.0	180.0	0.240	1.728	2.288
(1) Volume (D)	1 ft. cut	-	25.0	150.0	0.240	1.446	2.000
(2) Soil Condition (N)	A-1	-	0.0	30.0	0.000	0.288	0.288
Paving (total)	\$2.00/sq.yd.	5.780	12.0	130.0	0.694	7.455	8.012
(1) Width (D)	26 ft.	-	12.0	20.0	0.694	1.155	1.155
(2) Soil Condition (N)	A-1	-	0.0	110.0	0.000	6.300	6.857
Curbs and Gutters (N)	\$1.50/ft.	3.000	0.0	7.0	0.0	0.210	0.300
* "T" intersections (same variable as intersections)	(-) \$236.	(-) 0.393	40.0	70.0			
* Turnabout - Cul-de-sac	\$796.	1.328	20.0	70.0	0.268	0.930	0.930
<u>Total</u>		<u>\$ 9.418</u>			<u>\$ 1.064</u>	<u>\$ 9.897</u>	<u>\$ 10.408</u>

* - Not considered in total.

UNDERGROUND UTILITIES

For reasons of clarity, the underground utilities have been studied separately. The first in the group, as found in Table V, is the sanitary sewerage system. The factors of deviation as set forth in this table are: the ratio of the length of the sewerage system to length of streets, the size of the depth of the line, and soil conditions.

The statistical results of this first factor proved to be quite unexpected. They indicate that in most systems the pipeline is longer than the center line of the streets. This is the result of the line not following the center of the street and the extra connections which are necessary at an intersection, thus indicating another expense which should be allocated to the intersection. This, among other things, leads us to believe that there can be great savings from not following the right-of-way of streets. Of course, this is only possible when undetached housing units are used. This technique was used very successfully at Greenbelt, Maryland, but, unfortunately, these costs are out of line with present values and could not be used in this study.

In comparing the length of sewer lines used by the

existing system at Greenbelt with the length which would have been required had the sewer been laid in the right-of-way of the street, we found that a reduction of about twenty per cent in length of line might be expected by using the Greenbelt scheme. But it is not justifiable to say that such a procedure would reduce construction costs by the same amount since the two systems are not comparable (the existing system at Greenbelt does not have laterals). The lack of these laterals would cause a variation in the pipe size in the two systems.

Before we start to deliberate on the variables attributed to the soil condition, we shall first make some decision as to the standards for excavation in connection with methods of trenching and contractual procedure. We have assumed that, if possible, trenching machines would be used. In general, there are two kinds of trenching machines, the wheel trencher, which may be used for trenches about one to two feet wide and up to about seven to eight feet deep, and the ladder type trencher, which will dig trenches from three to six feet wide and as deep as twenty feet. Since the wheel type is so limited in range and is not too often used, we have only considered excavation as accomplished by the ladder type.

This means that the trench will have a minimum width of three feet and, disregarding the soil condition, the excavation and backfill cost of pipe sizes, eight to fifteen inches (permissible size in three-foot trench), will be a function of the depth times a constant. This is also based on the fact that most contracts are determined on the cubic yard content removed (which we have adopted as standard for this thesis). We also accept the common practice of most contractors of increasing the cost per cubic yard as the depth increases. In applying these assumptions, the aforementioned constants (based on cost in dollars and depth in feet) were established as follows as the trench varied in depth: from 0-9 feet: \$0.24 per cubic yard; from 9-12 feet: \$0.26; from 12-15 feet: \$0.31; and over 15 feet: \$0.51. These are based on the fact that excavation and backfill account for about 67 per cent of the average per foot cost for sanitary sewers.

If we take into consideration soil condition, we find a very interesting fact. The above constants are very minutely affected by soil conditions until a need for sheeting or a rock ledge is encountered, in which case the above constants are increased some 300 to 400 per cent. This affects the total standard cost about 44 per cent. In most cases the sheeting expenses are slightly higher than rock

excavation, assuming that the rock excavation is based on a three-foot wide trench. Thus it is advisable for planners to avoid sheeting and rock excavation wherever possible.

When is sheeting required? This is a very difficult question to answer since it depends on many local conditions, but, in general, a very deep trench, wet ground or loose soil, such as sand and gravel, will require sheeting of some type. There are also some other important elements such as the length of time the trench is open and the presence of vibrations which affect the requirements for sheeting.

The variables affecting the size and depth of pipes are quite involved and rather complex. Analyses should have been made of these variables (compaction factor, distribution of the population, topography, and local and national regulations) in order to establish a standard cost. Since this information was impossible to obtain, we considered these factors as grouped together. We then searched for average costs which would take these variables into consideration. We finally arrived at an average cost of \$3. per foot as based on Federal Housing Administration figures for the Northeastern area. (The minimum pipe size permissible was eight inches.) From this average cost, we determined the

standard cost by correcting for ratio of sewer length to street length. The statistical range for depth and pipe size was computed using figures which were available. Although these averages were made independent of the data used in determining the average cost, we assumed that there would be a natural coordination between the two.

The average invert depth for the sanitary sewerage system was determined, as mentioned above, as 8.2 feet. This was really controlled by the depth of the basement in the plans studied, since the cellars must be drained by the sewer mains. On the other hand, if these lines were laid for cellarless homes, such as Byrne's and Levitt's, we might have found an average depth of between three or four feet. This would have meant a saving in the total standard cost of nearly two per cent.

The furnishing and laying of the sanitary sewer mains accounted for 33 per cent of the standard cost. It was discovered that at Harundale, Maryland (Byrne) which is composed of 1200 single-family homes, the average pipe size determined by a cost analysis was equivalent to a ten-inch pipe and there was a very small footage larger than fifteen inches. This means that the minimum width of three feet for a trench would take care of most subdivisions' sanitary sewerage systems.

A point which should be brought out at this time is that great savings can result from having the bitter end of a line on rather a steep grade. This is due to the requirement that a lower portion of a line cannot be smaller in size than the upper portion of the line even if hydraulic conditions permit such an arrangement. Ideally, it would be best to have all sewer lines decrease in grade as they become lower in elevation. In summing up the topic of sanitary sewers, the main point of emphasis is that sheeting should be avoided.

In proceeding to our next category, that of storm sewers, we find almost identical variables. The only item which differs appreciably from the sanitary system is the ratio between the length of storm sewers and the length of street. The statistical average of this ratio proved to be about one to three (1 foot of storm sewer to 2.83 feet of street). We are faced with the same relationships as found in the excavation and backfill cost of the sanitary sewer system except that the storm sewers may require trench widths in excess of the minimum three feet sufficient in the sanitary sewers. However, the effect of the variables will be less appreciable in the total standard cost because the ratio of the length of storm sewers to length of street is smaller. (Based on the fact that excavation costs account for 57 per cent of the standard cost

for storm sewers, the necessity for sheeting will increase the total standard cost about ten per cent.)

Since the trenching machine can remain stationary while widening the trench, there would be about a 25 per cent saving in excavation and back fill cost for the extra excavation needed to widen the trench. The aforementioned constants which were based on average excavation cost per foot would increase 12.5 per cent for every six inches that the trench is widened to permit the usage of pipe larger than fifteen inches. This cost increment for widening affected the total standard cost about one per cent.

Once again we used a standard cost based on Federal Housing Administration average per foot costs of storm sewers (\$3.50) for the Northeastern area. (The minimum pipe size permissible was fifteen inches.) After we had calculated the standard cost by correcting for the ratio of the length of storm sewer to length of street, the statistical range for depth and pipe size was computed with figures which were available. This was based on the same assumption made in connection with the sanitary sewers.

According to Federal Housing Administration Data Sheet Number SH 101, "pipe lines shall be placed at a sufficient depth below the surface of the street to avoid dangerous

gravity controlled and, therefore, the size of pipe is not affected by the topography of the land. Most subdivisions up to 1000 housing units can be supplied by an ordinary six-inch main because the controlling requirements are determined by fire protective measures as outlined by the Board of National Fire Underwriters.

The average invert depth (5.0 - 5.5 feet) is controlled by the frost action, which penetrates considerably deeper in New England than the minimum depth required by compaction factors in the storm system. The type of soil controls the depth to which frost can penetrate. Variation due to this condition may cause additional expense, perhaps 5 per cent of the standard cost. If the depth of water main were controlled by compaction factors (as in the South), we could expect a savings of about two per cent in total standard cost.

The average cost per foot of water main, which includes the cost of installing valves, was taken from Federal Housing Administration figures as \$300. In converting the average cost into standard cost, it was affected in a lesser degree than the sanitary sewers by the ratio of the length of water line to the length of streets. (1.05 to 1). We found again that the Greenbelt scheme was able to save about fifteen per cent of the

length of water main by not installing the lines in the right-of-way of streets. This seems to indicate that such a procedure should be recommended for row housing or garden apartment developments.

Since pipe size and depth of water mains may practically be considered as constants, the most profound effect on the water system cost is found in the encountering of soil conditions that require sheeting. This increases excavation costs some 300 to 400 per cent. Figures studied seemed to indicate that excavation costs for water mains amount to about 44 per cent of the standard cost of such a system. This would result in a variation of almost 34 per cent of the total standard cost.

In summarizing the variations which can be attributed to the installation of the underground utilities, one may expect, under extreme conditions, a variation of 320 per cent from the standard cost of utilities, which means that a deviation of 123.8 per cent is possible under extreme conditions in the total standard cost. This deviation in the total standard cost was affected largely by the natural conditions (98.6%).

TABLE V

DETAILED ANALYSIS OF THE VARIABLES COMMITTED TO UNDERGROUND UTILITIES

Average or Standards for Variables	Standard Cost - Dollars per foot of street length	Possible Percentage Variation from Standard Cost		Variation in Standard Cost in Dollars		Conceivable High	
		Below	Above	Below	Above		
Sanitary Sewers	---	\$ 3.27	35%	245%	\$1.14	\$8.01	\$11.41
(1) Length of S.S./Length of street (D)	1.09	---	9	9	0.29	0.29	0.29
(2) Size (D)	8" min.	---	15	25	0.49	0.82	1.64
(3) Depth (D)	8.2 ft.	---	11	11	0.36	0.36	0.75
(4) Soil Condition (N)	A-1	---	0	200	0.0	6.54	8.73
Storm Sewers		1.25	49	231	0.61	2.89	4.45
(1) Length of S.S./Length of street (D)	0.353	---	16	16	0.20	0.20	0.20
(2) Size (D)	15" min.	---	20	30	0.25	0.38	0.90
(3) Depth (D)	5.2 ft.	---	13	13	0.16	0.16	0.50
(4) Soil Condition (N)	A-1	---	0	172	0.0	2.15	2.85
Water Mains		3.15	13	208	0.41	0.74	8.72
(1) Length of W.M./Length of street (D)	1.05	---	13	13	0.41	0.41	0.41
(2) Size (D)	6"	---	0	10	0.0	0.31	0.31
(3) Soil Condition (N)	A-1	---	0	185	0.0	0.02	8.00
<u>Total</u>		\$ 7.67			\$ 2.16	\$ 17.64	\$ 24.58

CONNECTIONS

In this last category, which includes manholes, catchbasins, fireplugs and clean outs, we found simpler relationships. All standard costs for connections were affected by two items - the ratio of the number of units to the length of street and the soil conditions. In all but the fireplugs, depth was also considered as a variable. The number of connections varied in some degree according to the number of intersections, layout of streets (sharpness and number of curves) and local and national regulations. All these variables had very little effect on the total standard cost as indicated on Table I. However, we believe that a reduction in the number of these connections has a very close relationship to the efficiency with which the topography has been used in placing the underground utilities. For instance, the number of manholes may indicate the number of times the grade lines have been changed, which is often the result if the topography is not followed as closely as possible. The averages which may serve as a guide in the installation of underground utilities are: one manhole (sanitary) for every 309 feet of street; one manhole (storm) for every 720 feet of street; one catchbasin for every 383 feet of street; and one fireplug for every 440 feet of street.

The standard cost of clean outs was included in the study of connections on Table VI but was not used in computing the total standard cost since they have a limited use in subdivision plans.

TABLE VI

DETAILED ANALYSIS OF THE VARIABLES COMMITTED TO UTILITY CONNECTIONS

Variables	Average or Standard Standards for	Standard Cost- Dollars per foot of street length	Possible Percentage Vari- ation from Standard Cost		Variation in Standard Cost in Dollars		Conceivable High
			Below	Above	Below	Above	
Manholes (storm & sanitary)	\$160.00	<u>\$0.688</u>	43%	53%	<u>\$0.296</u>	<u>\$0.365</u>	<u>\$0.385</u>
(1) No. units/ft. of street(D)	0.0430		32	32	0.220	0.220	0.230
(2) Depth (D)	6.6 ft.		11	11	0.076	0.076	0.080
(3) Soil Condition (N)	A-1		0	10	0.0	0.069	0.075
Fireplugs (total)	\$150.	<u>0.340</u>	9	19	0.030	0.064	0.080
(1) No. units/ft. of street(D)	0.0227		9	9	0.030	0.030	0.030
(2) Soil Condition (N)	A-1		0	10	0.0	0.034	0.050
Catchbasins (total)	\$100.	<u>0.261</u>	44	54	0.115	0.141	0.171
(1) No. units/ft. of street(D)	0.0261		31	31	0.081	0.081	0.081
(2) Depth	5.2 ft.		13	13	0.034	0.034	0.050
(3) Soil Conditions (N)	A-1		0	10	0.0	0.026	0.040
*Cleanout (total)	\$50.	0.257	54	64	0.139	0.165	0.185
(1) No. units/ft. of street(D)	0.0515		45	45	0.115	0.115	0.125
(2) Depth (D)	5.4 ft.		9	9	0.024	0.024	0.030
(3) Soil Condition (N)	A-1		0	10	0.0	0.026	0.030
<u>Total</u>		<u>\$ 1.289</u>			<u>0.441</u>	<u>0.570</u>	<u>0.636</u>

* - Not considered in total.

1
58
1

MAINTENANCE

Maintenance costs have been compiled on Table VII for various items of upkeep. Figures are given from Cambridge and Brookline, Massachusetts and New Brunswick and Highland Park, New Jersey. The weighted average is what we believed would result if these figures were based on maintenance costs of a large subdivision. We considered the size, density, population and efficiency in local government in determining the weighted average. The total of these average annual maintenance charges was \$3300. per mile of street, which amounts to about half the cost of amortizing (at two and one-half per cent interest over twenty years) the cost of a mile of street and utilities.

The expenditure for maintenance was in direct proportion to the length of street for the following items: road repair (greatly affected by the subsoil condition), street cleaning, street lighting and snow removal. However, the expense of the sewer and water system was proportional to the density and length of the system. If the values for the various cities we studied are any indication, we would expect a great saving in these items of expenditure as the density increases. For example, with a density of five families per acre, (Highland Park), a saving of fifty per cent may be anticipated in this

maintenance charge if the density is doubled. This means a saving of about \$100. per mile of street as the density is doubled along the street. Of course, this would only be true in rather low density (five to twenty families per acre).

A special study was made in connection with refuse and garbage collection, since they constituted about one third of the maintenance cost. In this case, we assumed that the cost of these collections was based on the following relationships - cost of maintenance equals the density of families times a constant plus the length of route (serving the families) times a constant. This is based on the assumption that the garbage collectors walk from pick up to pick up. (They do this in densities as low as three families per acre.)

Having determined these constants by solving several quadratic equations and having taken the average of the constant, the resulting equation was developed: $8.5 F$ (number of families per mile of route) plus $250 M$ (miles of route) equals the total annual operation cost in dollars. We found that as the density of families doubled, collection costs increased only 75 to 80 per cent. This meant a saving of about 25 per cent or \$275. per mile of route. Again, this would be true only in rather low density areas (five to twenty families per acre.)

One comment we should like to make is that maintenance costs run higher on culs-de-sac. First of all, snow removal

is more costly since ploughing cannot be done by a continuous operation. This is an important factor in New England where this amounts to about one-fourth of the annual maintenance costs. Secondly, garbage collection is more difficult on such streets, but this should not increase collection costs more than ten per cent. The last point is more intangible. Most macadem roads need a certain amount of movement in them to keep them "alive" and thus save repair costs. This might double repair costs in an area composed largely of culs-de-sac, which would mean an increase of six per cent in maintenance charges.

TABLE VII

MAINTENANCE COSTS IN DOLLARS FOR ROADS AND UTILITIES AS FOUND IN VARIOUS CITIES

Item of Maintenance	Weighted Average	Cambridge, Mass. ¹ (Pop: 110,879)	Brookline, Mass. ¹ (Pop: 49,786)	New Brunswick, N.J. (Pop: 33,180) ¹	Highland Park, N.J. (Pop: 9,002) ¹
Road Repair (per mile)	\$ 200.00	\$ 55.00	\$ 230.00	\$ 280.00	\$ 210.00
Sewer System					
Per Mile	200.00	155.00	153.00	320.00	410.00
Per Family		0.82	1.18	1.92	2.28
Water System					
Per Mile	200.00	(2)	(2)	240.00	180.00
Per Family				1.40	1.00
Street Lights (per mile)	600.00	560.00	1100.00	580.00	420.00
Refuse Collection					
Per Mile	600.00	700.00	970.00	1000.00	530.00
Per Family		2.60	7.45	6.00	2.95
Garbage Collection					
Per Mile	500.00	520.00	470.00	830.00	470.00
Per Family		1.95	3.62	5.00	2.61
Street Cleaning (per mile)	200.00	390.00	640.00	290.00	146.00
Snow Removal (per mile)	800.00	1560.00	800.00	210.00	250.00
<u>Total</u>	<u>\$ 3300.00</u>				

¹ 1940 Census
(2) Not Available

STREET PATTERNS

In opposition to what has been done before in setting up theoretical patterns of rather geometric shapes, we have studied various street systems which are in existence today or have been planned for particular sites. We have also added some theoretical plans to try to determine the relationship of the efficiency of the theoretical plan to actual plans. These street systems have been enclosed within this study for the reader's observation. They have been arranged in order of what we call "site plan efficiency", that is to say, the ratio between the area served and the length of streets expressed in percentage of a theoretically perfect plan. This theoretically perfect plan is based on a plan which is served by a continuous street without intersections of any type. It might be added that such a theoretical plan would have the same efficiency as any plan based on a single enclosed geometric figure. In determining street length we measured only culs-de-sac which were independent of a super block arrangement such as Radburn. The cost of such culs-de-sac and other service streets found in super block plans will be considered as part of the cost of improving the area served. This topic will be covered under "House Arrangements".

The particular advantage of this plan is that one is

not limited to any particular arrangement of houses in relation to the street. The study thus indicates that whatever plan is used within the block will have the same efficiency of utilities lying within the right-of-way of the street with the exception of the sewer system.

Corrections should be made for various requirements which are attributed to the change in density for various arrangements of houses. We have assumed that as the density doubles, installation cost of sanitary sewers will increase 50 per cent. (This is the same increase as we developed for maintenance.) We feel this is fairly satisfactory until a more detailed study of cost vs. density of population can be made. Likewise, we have assumed that as the density increases, the standard street, 26 feet, will be adequate to serve the area. This, of course, is not wholly true, especially as the density becomes quite high. We have felt that this problem of designing residential streets for particular widths and surface qualities depending upon their functional requirement was much needed in planning. It seems that a process for determining these values could be developed along the lines of that used in designing sanitary sewers. This could be possible only after a study of the number of cars emanating from a certain section at a given time had been completed.

The interesting fact revealed in preparation for this study is that the area served proved to be a function of the number of lots, that is, for example, if in a certain subdivision a standard lot size were adopted (60' x 100'), the area served would be that territory lying between the right-of-way of the street. Regardless of the irregularity in the shape of lots, there was a constant relationship between the number of lots equivalent to 60' x 100' and the area served as previously defined. (See the appendix for an illustration of this.) This is in contrast to popular belief that a system of curvilinear streets loses lots for a subdivider. This belief is only true if the curvilinear street pattern used does not adjust itself to the boundaries of the property.

We can sum up our deductions for the efficiency of a subdivision as determined by the aforementioned procedure for the plans enclosed in this text into three general categories; 1) the resulting average or medians; 2) the economies of various patterns; 3) the cost effect in changing the site plan efficiency.

The resulting medians of the site plan efficiency of the 24 plans studied was 84 (or 16 per cent of the possible area served is absorbed by intersections) which corresponds very

closely to the rule of thumb used in the field. This is that about 15 per cent of street length is lost for residential purposes by the requirement of land for intersections. Unfortunately our study is rather out of balance because of the many theoretical plans which have found their way to the top of the site plan efficiency list. If we deduce these theoretical plans, we find that our median site plan efficiency is about 83. This still probably is high for the ordinary site planning of curvilinear streets since most of the high site plan efficiency value plans are based on long culs-de-sac. In considering the average subdivision of detached homes using a curvilinear system of streets without a predominance of culs-de-sac, we should expect a site plan efficiency of 80. This would indicate that the rule of thumb (15 per cent) is a bit low, which we firmly believe.

This site plan efficiency of 80 would mean that there would be an intersection for every 1500 feet of street, or in an infinitely large subdivision the blocks would be 1250' x 250'. This is not a discrepancy in the value of 1050 feet of street per intersection, as we used in Tables I through IV since this was based on a system of streets not using culs-de-sac. In addition, this was a statistical average, not a median.

In general, we found that the efficiency of different

street patterns can be listed in the following descending order: 1) tree shape patterns using long culs-de-sac; 2) super blocks with a regular street pattern; 3) large blocks with irregular pattern of streets; 4) blocks with regular pattern of streets fundamentally based on rectangular blocks; 5) blocks with regular pattern of streets but with the streets radiating out from the center; 6) blocks with irregular pattern of streets; and 7) street patterns which employ a great deal of grass strips in separating traffic lanes for the purpose of producing a boulevard effect.

The tree shape patterns are quite theoretical and we should like to dismiss them immediately since they do not offer good circulation of vehicles. However, they do quite often provide for excellent pedestrian access to the community center, etc. Frequently the culs-de-sac are designed for more than the accepted length of 600 feet. These are illustrated by Design Numbers 1, 2, and 3.

The super block with a regular street pattern, such as exemplified by Greenbelt and Radburn, is very efficient (S.P.E. about 93). We think very highly of these schemes, especially that used in Greenbelt, in which the circulation is quite good for such high site plan efficiency. On the other hand, as the street pattern becomes more irregular, the site

plan efficiency drops considerably (86) as indicated by the Norris plan. Likewise, we feel that the circulation suffers from this irregularity.

As the block became small, the site plan efficiency of course dropped, but we noticed that regular patterns had the highest efficiency, particularly those based on rectangular blocks, such as illustrated by Harundale, Maryland. We believe that such a plan is quite adequate for vehicular transportation.

Next in line of site plan efficiency is the pattern based on radiating streets. Here we felt that a site planner had to be very particular in how he handled the streets in order not to impede good circulation. A fair example of this is Maplewood, Louisiana.

Levittown, Long Island, was a fine example of an irregular pattern of streets producing a low site plan efficiency, as well as an area exposed to poor vehicular access or egress. Likewise, Westover (S.P.E. 47.8) is a perfect example of the efficiency of a "grassed boulevard" system.

In general, it might be stated that where there is a great deal of cheap land, the site plan efficiency can be raised by increasing the block to include open area. Also, there is

more freedom in placing the street pattern so as to reduce the standard cost of the utilities. This should be considered at all times.

The site plan efficiency as such will never affect the total standard cost, but as the site plan efficiency is increased there will be additional saving in total improvement costs. This saving is directly proportional to the increase in the site plan efficiency. Thus, if a plan is improved by raising the site plan efficiency one percent, one per cent will be saved on the total improvement cost of the subdivision. We believe that many plans could be improved by five per cent very easily by reducing the number of intersections, since the number of intersections actually determines the site plan efficiency for a given amount of street. This is brought out in Table VIII.

TABLE VIII

HOW THE NUMBER OF INTERSECTIONS AND CULS-DE-SAC AFFECT SITE PLANNING EFFICIENCY

Design No.	S.P.E.	Road Length in ft.	Road Length not Serving Residential, in ft.	Possible Resident Area - in acres	Number of Intersections	Number of "T" Intersections	Number of Culs-de-sac	Area Lost by Culs-de-sac and Intersections - in areas	% of Possible Residential Area Lost
1 (T)	96.7	83,000	22,800	273.0	6	34	38	12.1	3.3
2 (T)	96.0	20,000	5,500	65.0	0	14	12	3.6	4.0
3 (T)	94.7	30,500	4,450	116.8	4	20	29	7.4	5.3
4	94.7	22,700	5,000	80.5	1	14	11	7.6	5.3
5	94.1	66,500	18,000	214.0	6	7	0	12.9	5.9
6	92.8	21,500	3,500	77.2	7	9	4	14.0	7.2
7 (T)	92.5	34,800	3,500	142.3	16	3	33	12.0	7.5
8 (T)	90.6	32,800	12,500	89.0	5	27	36	14.0	9.4
9	86.2	37,000	* 5,560	146.0	5	46	11	36.6	13.8
10	85.8	32,000	9,600	114.5	2	27	0	20.6	14.2
11	85.0	34,000	5,600	131.0	14	6	0	22.6	15.0
12	84.7	144,000	26,500	535.0	56	52	17	106.0	15.3
13	83.2	22,800	4,000	85.5	3	11	3	8.8	16.8
14	83.0	68,000	7,000	278.0	13	57	8	53.9	17.0
15	82.9	19,850	3,000	63.2	5	13	1	15.5	17.1
16	82.0	30,000	4,900	114.6	6	32	10	25.1	18.0
17	82.0	86,000	11,000	342.0	20	67	5	72.0	18.0
18	81.9	28,500	2,800	120.0	5	26	2	24.0	18.1
19	80.7	25,400	8,000	79.5	12	11	3	22.8	19.3
20	79.9	44,500	* 6,670	177.0	23	13	0	39.3	20.1
21	78.6	24,000	4,250	90.0	10	15	1	22.8	21.4
22	77.6	110,000	6,400	472.0	20	125	137	115.5	22.4
23	73.2	84,000	6,840	325.0	52	46	0	105.0	26.8
24	47.8	48,600	9,500	132.0	16	130	0	122.0	52.2

* Assumed to be 15% of street length
 (T) Theoretical plans

TABLE IX

COST COMPARISON OF VARIOUS DESIGNS

Design No.	Resident Area in acres	Road Length in ft.	S.P.E.	Original Cost in \$1000.	Cost of Utilities for 100' x 100' lot	Maintenance Cost in dollars	Maintenance Cost for 100' x 100' lot	Circulation
1 (T)	264.0	83,000	96.7	\$1,640	\$1,430	\$52,000	\$ 45.60	Poor
2 (T)	62.5	20,000	96.0	396	1,475	12,500	46.60	Poor
3 (T)	110.5	30,500	94.7	604	1,268	19,100	40.30	Poor
4	76.2	22,700	94.7	449	1,371	14,200	43.30	Poor
5	201.0	66,500	94.1	1,315	1,520	41,600	48.10	Good
6	71.7	21,500	92.8	426	1,396	13,450	43.50	Good
7 (T)	131.9	34,800	92.5	689	1,218	21,800	38.60	Poor
8 (T)	80.6	32,000	90.6	634	1,825	20,000	57.70	Poor
9	126.0	37,000	86.2	732	1,350	23,200	36.80	Fair
10	98.3	32,000	85.8	634	1,505	20,000	47.20	Good
11	111.2	34,000	85.0	673	1,400	21,300	44.50	Fair
12	453.0	144,000	84.7	2,850	1,428	90,000	46.20	Fair
13	71.0	22,800	83.2	452	1,440	14,280	46.80	Good
14	231.5	68,000	83.0	1,345	1,355	42,600	42.60	Good
15	52.5	19,850	82.9	393	1,750	12,420	55.00	Good
16	94.0	30,000	82.0	594	1,470	18,780	46.40	Fair
17	280.5	86,000	82.0	1,700	1,410	53,800	44.50	Good
18	98.5	28,500	81.9	554	1,310	17,800	42.00	Fair
19	64.2	25,400	80.7	503	1,820	15,900	57.70	Good
20	141.5	44,500	79.9	881	1,445	28,900	47.50	Good
21	70.5	24,000	78.6	475	1,465	15,000	49.50	Fair
22	366.0	110,000	77.6	2,180	1,390	68,700	43.70	Fair
23	238.0	84,000	73.2	1,663	1,625	52,500	51.30	Fair
24	63.2	48,600	47.8	960	3,540	30,400	112.00	Fair

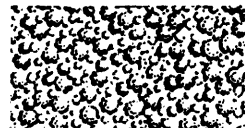
(T) Theoretical plans

The following street patterns were studied to determine the site plan efficiency. We made analyses of street systems which are in existence today or which have been planned for particular sites. We have also added some theoretical plans to try to determine the relationship of the efficiency of the theoretical plan to actual plans.

Residential Areas
any and all types of
dwelling units



Open Areas
parks and recreation
areas



Schools



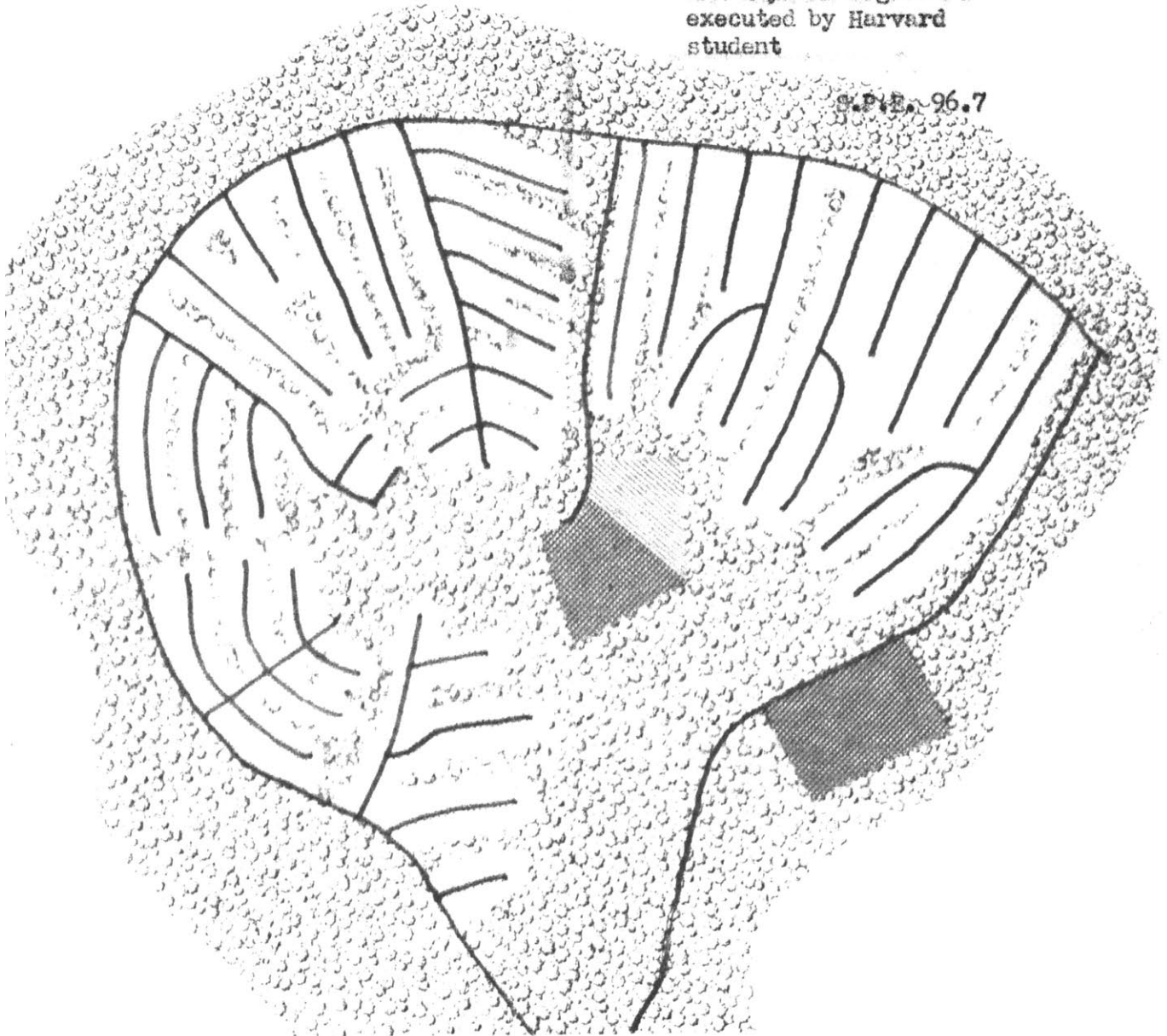
Commercial and industrial
areas



Design Number 1

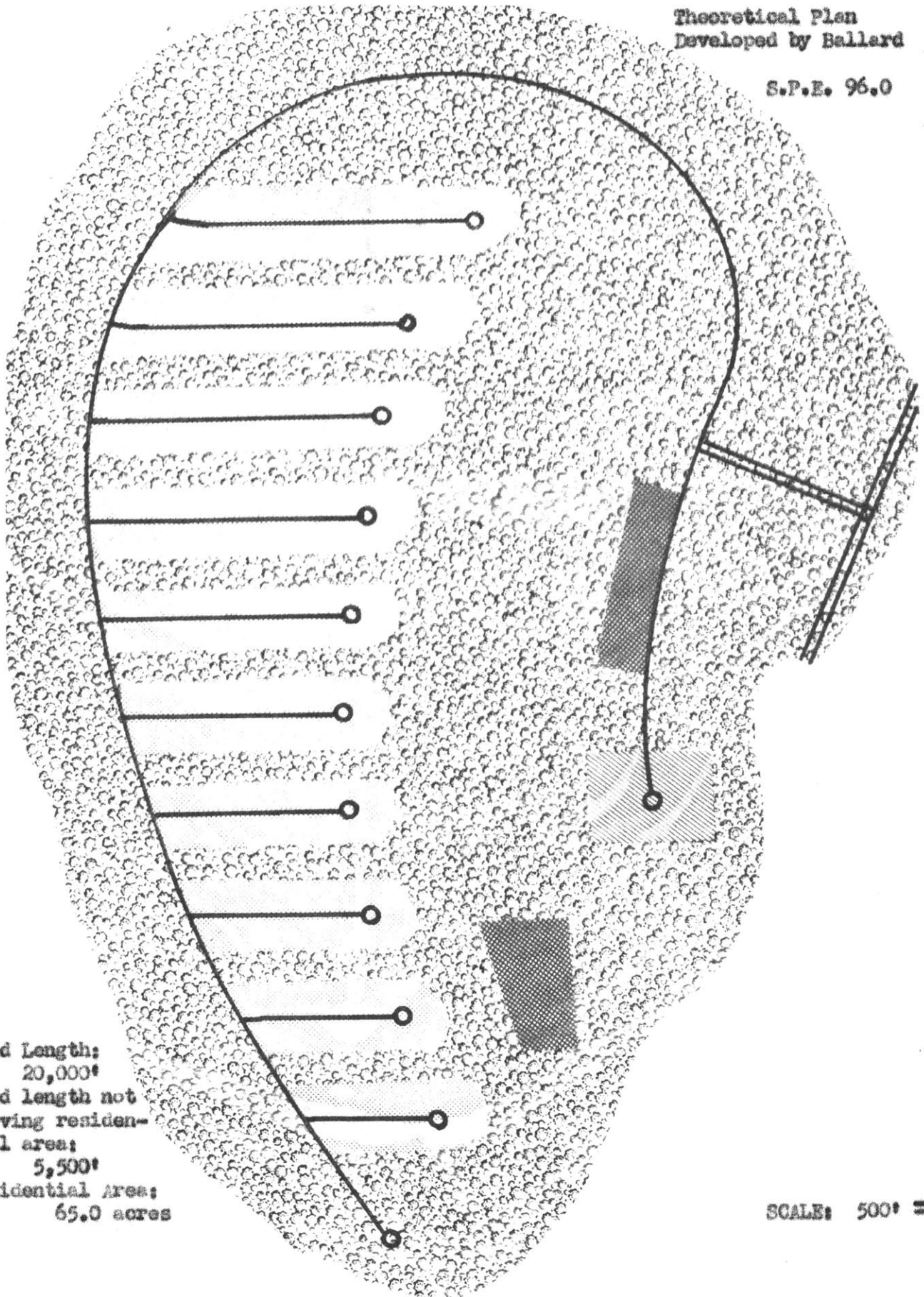
Proposed town in Weston
and Wayland region as
executed by Harvard
student

S.P.E. 96.7



Road Length: 83,000'
Road length not serving
residential area: 22,800'
Residential area: 273 acres

SCALE: 1" = 1300'



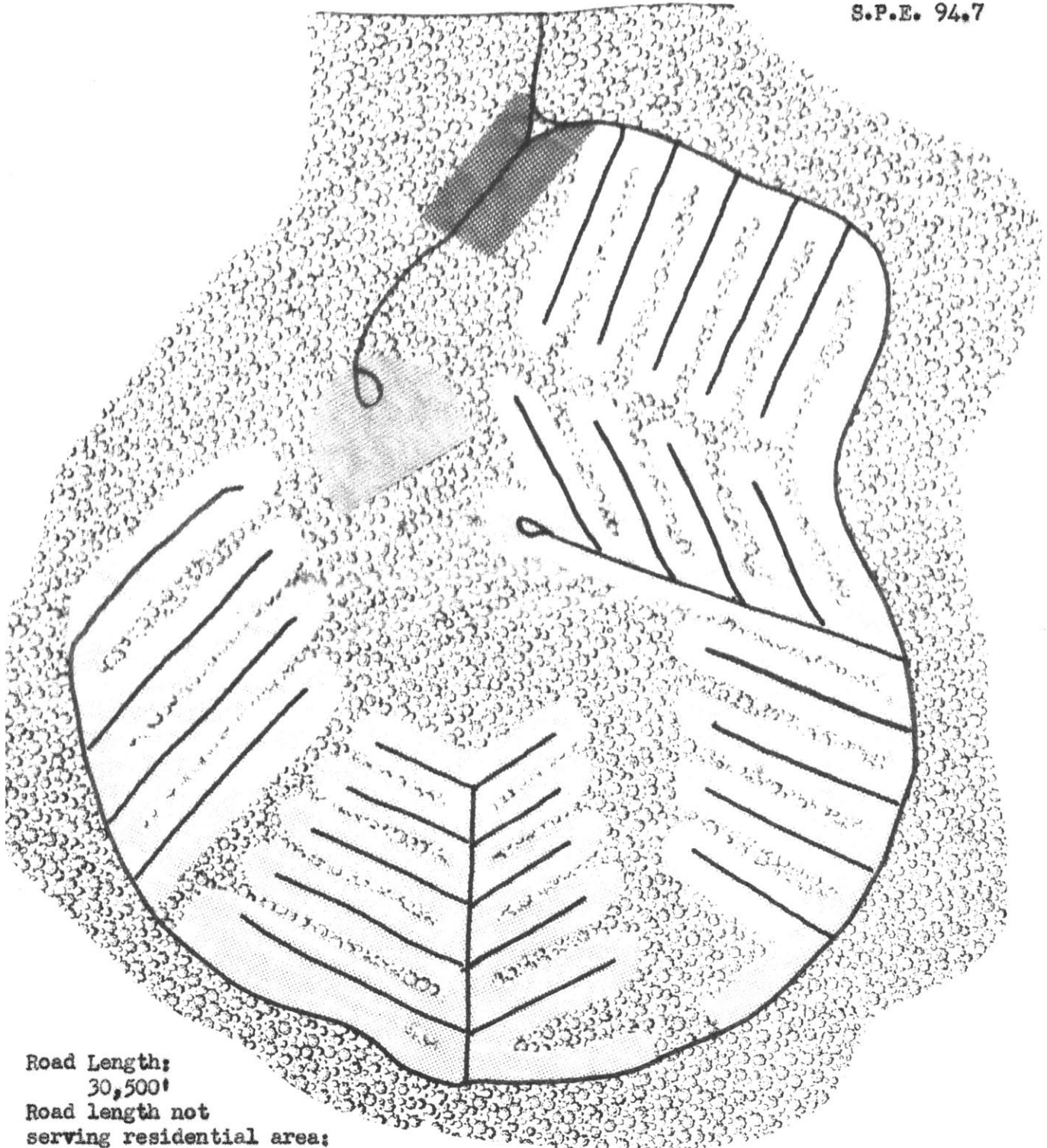
Road Length:
20,000'
Road length not
serving residen-
tial area;
5,500'
Residential Area:
65.0 acres

SCALE: 500' = 1"

Design Number 3

Theoretical Plan
based on Plan by
Frederick Coolidge

S.P.E. 94.7



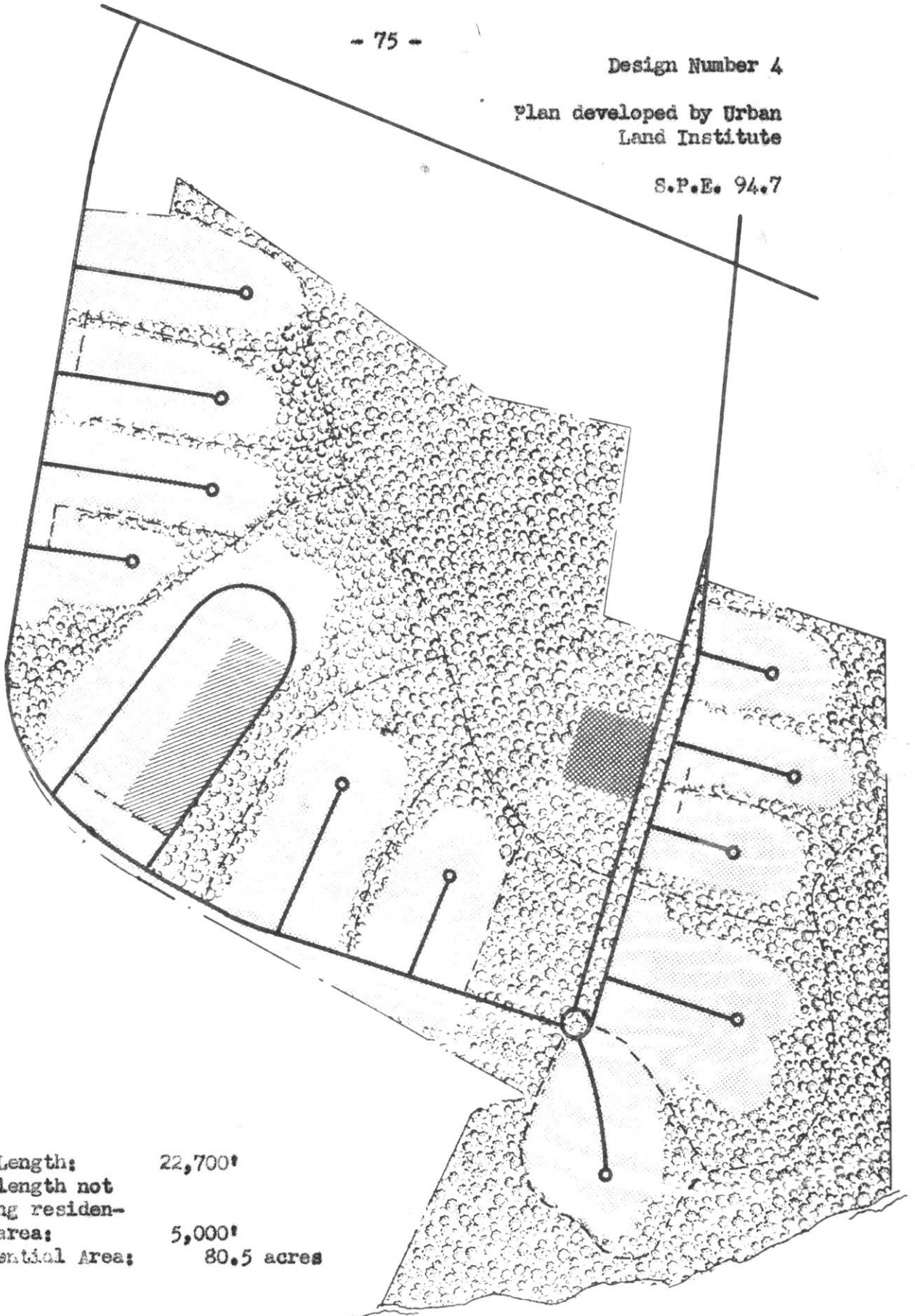
Road Length;
30,500'
Road length not
serving residential area;
4,450'
Residential Area;
116.8 acres

SCALE: 500' = 1"

Design Number 4

Plan developed by Urban
Land Institute

S.P.E. 94.7



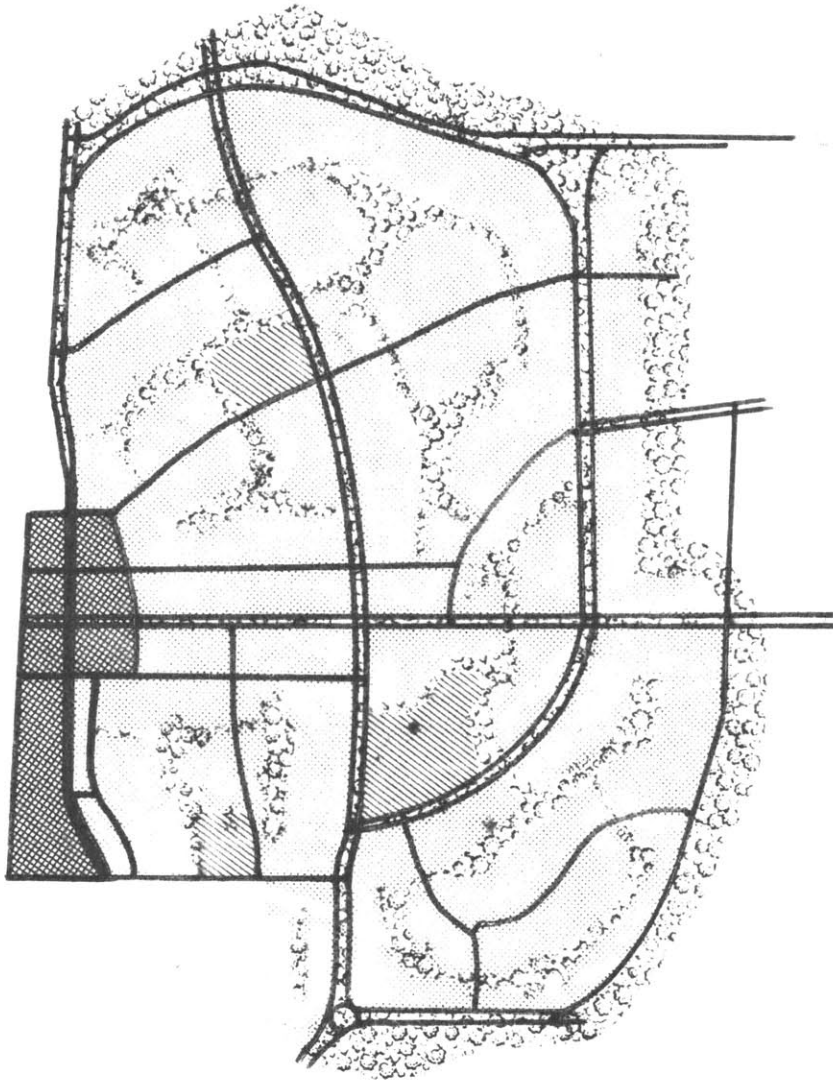
Road Length;	22,700'
Road length not serving residen- tial area;	5,000'
Residential Area;	80.5 acres

SCALE: 500' = 1"

Design Number 5

Radburn, New Jersey

S.P.E. 94.1



Road Length: 66,500'
Road length not serving
residential area: 18,000'
Residential area:

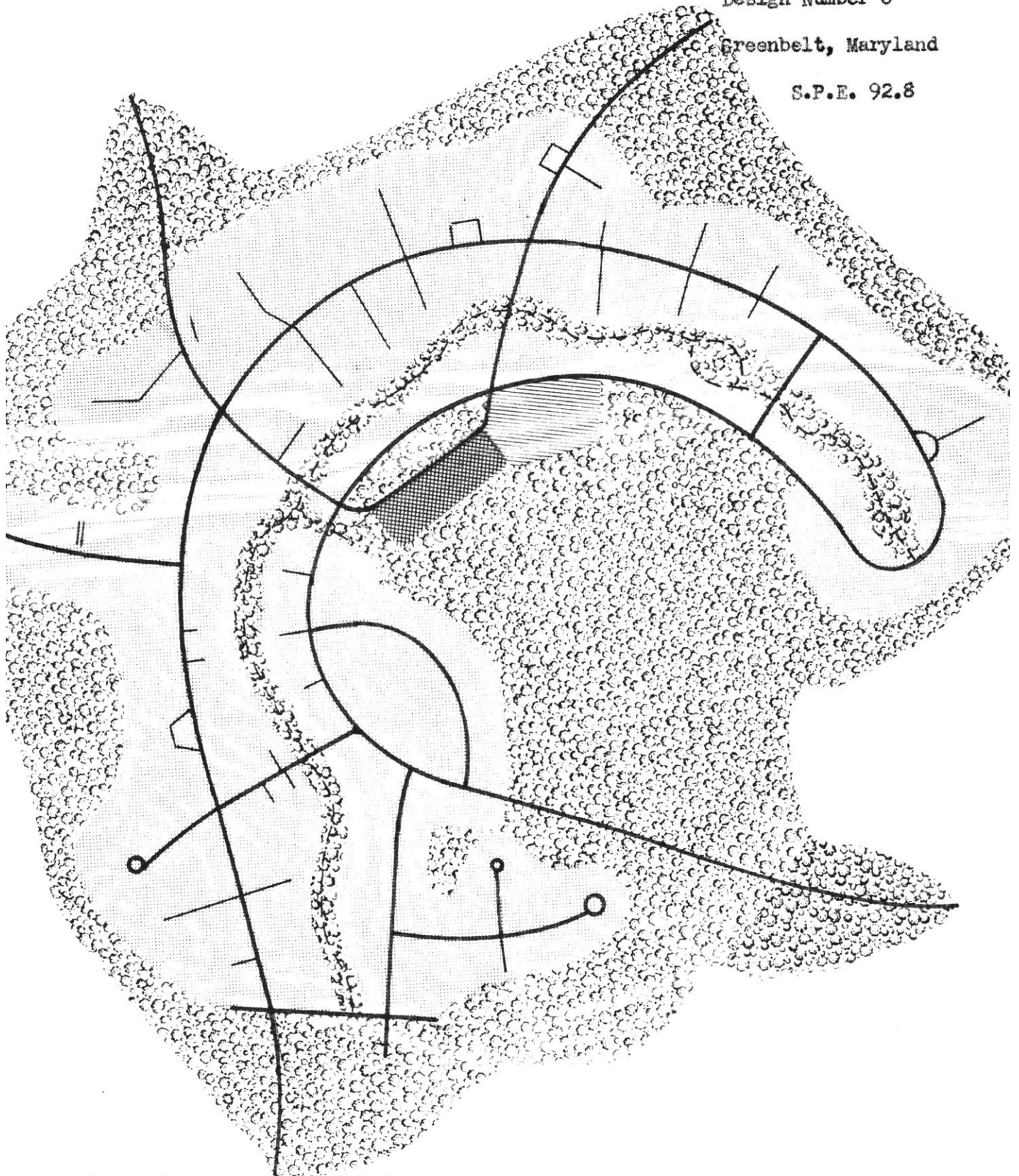
214 acres

SCALE: 1" = 1800'

Design Number 6

Greenbelt, Maryland

S.P.E. 92.8



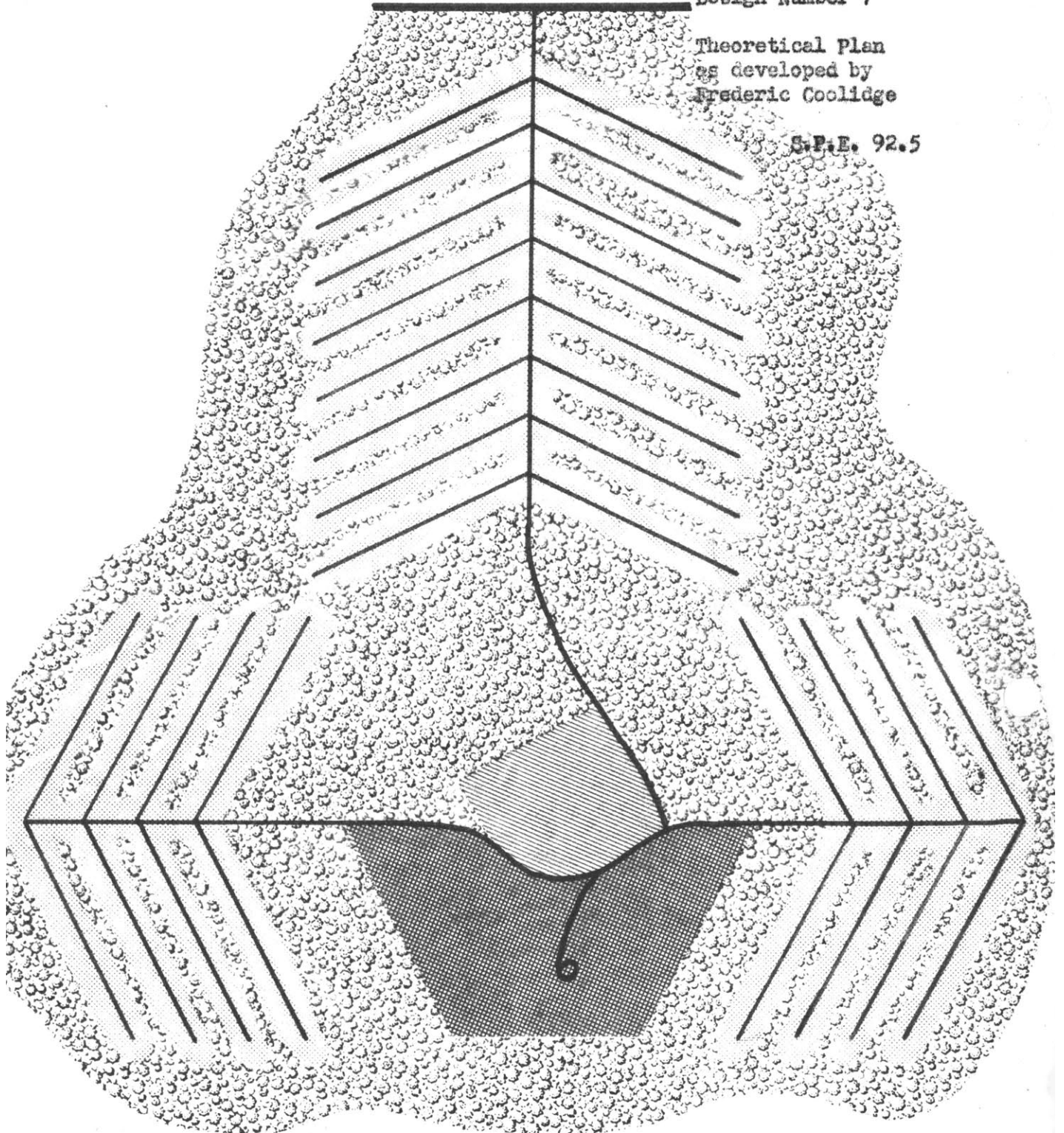
Road Length: 2,500'
Road length not serving residential area: 3,500'
Residential area: 77.2 acres

SCALE: 500' = 1"

Design Number 7

Theoretical Plan
as developed by
Frederic Coolidge

S.P.E. 92.5

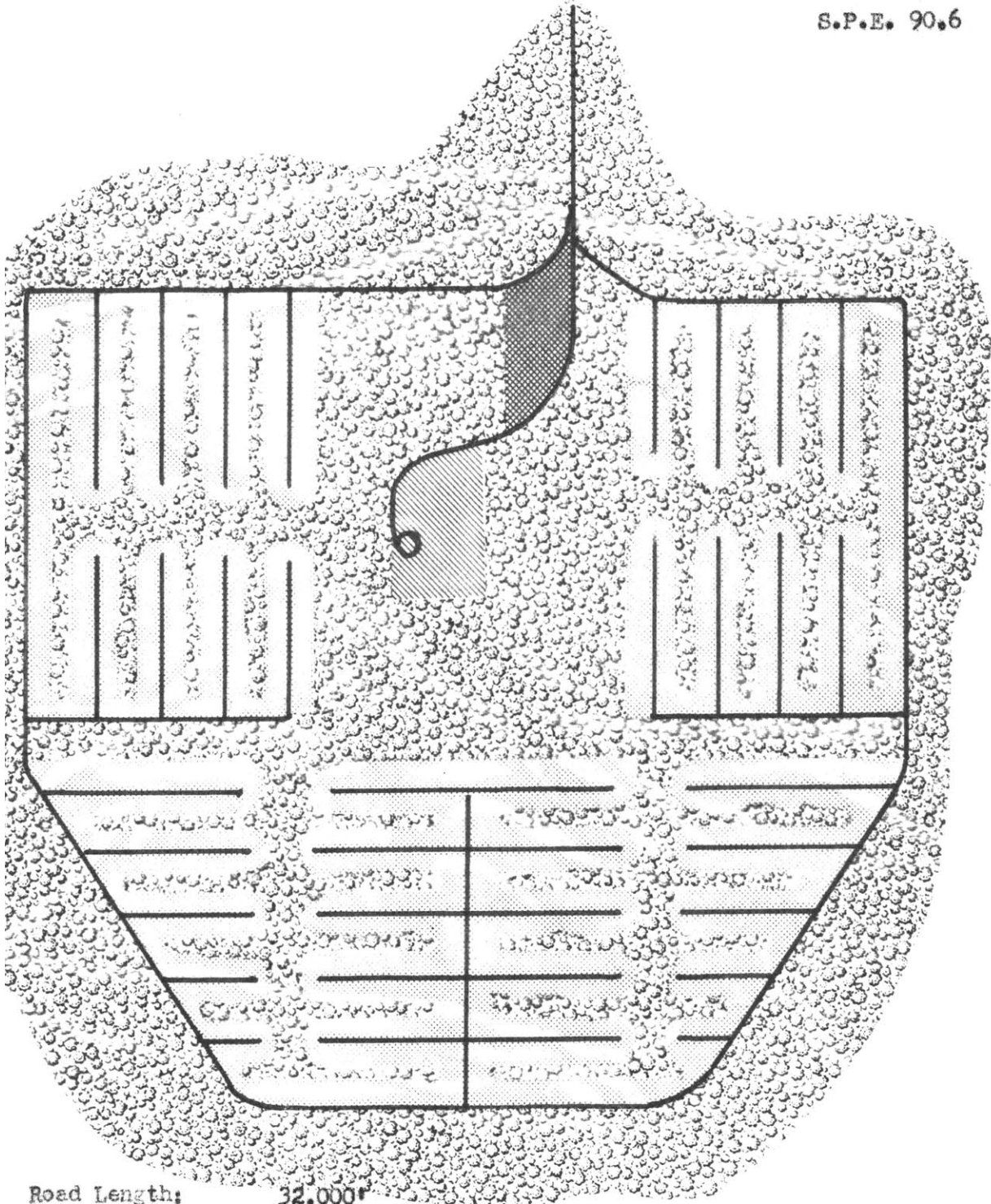


Road Length: 34,200'
Road length not serving
residential area: 3,500'
Residential area: 142.3 acres

SCALE: 500' = 1"

Theoretical Plan as Developed
by Frederic Coolidge

S.P.E. 90.6



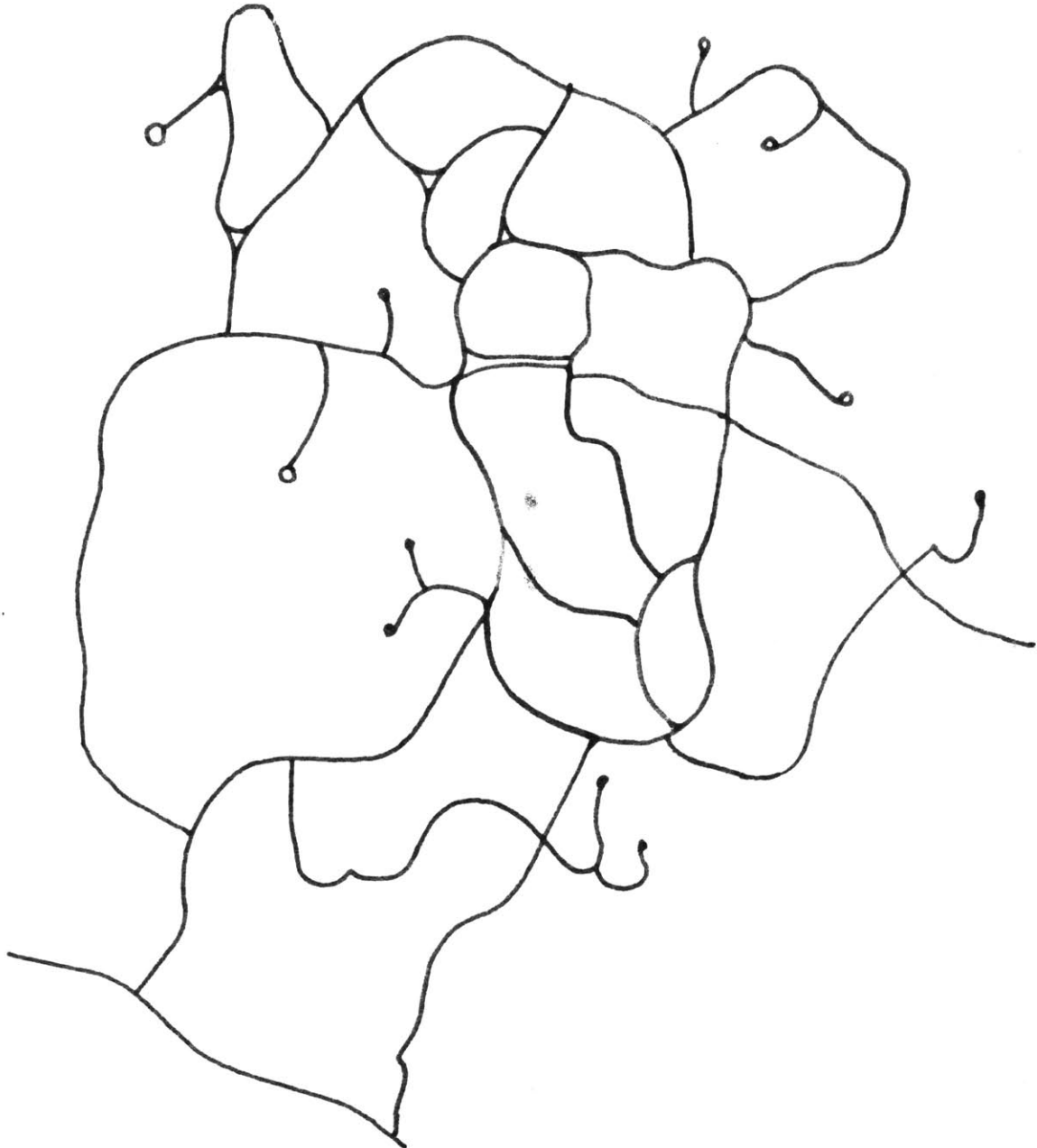
Road Length; 32,000'
Road length not
serving residen-
tial area; 12,500'
Residential Area; 89.0 acres

SCALE: 500' = 1"

Design Number 9

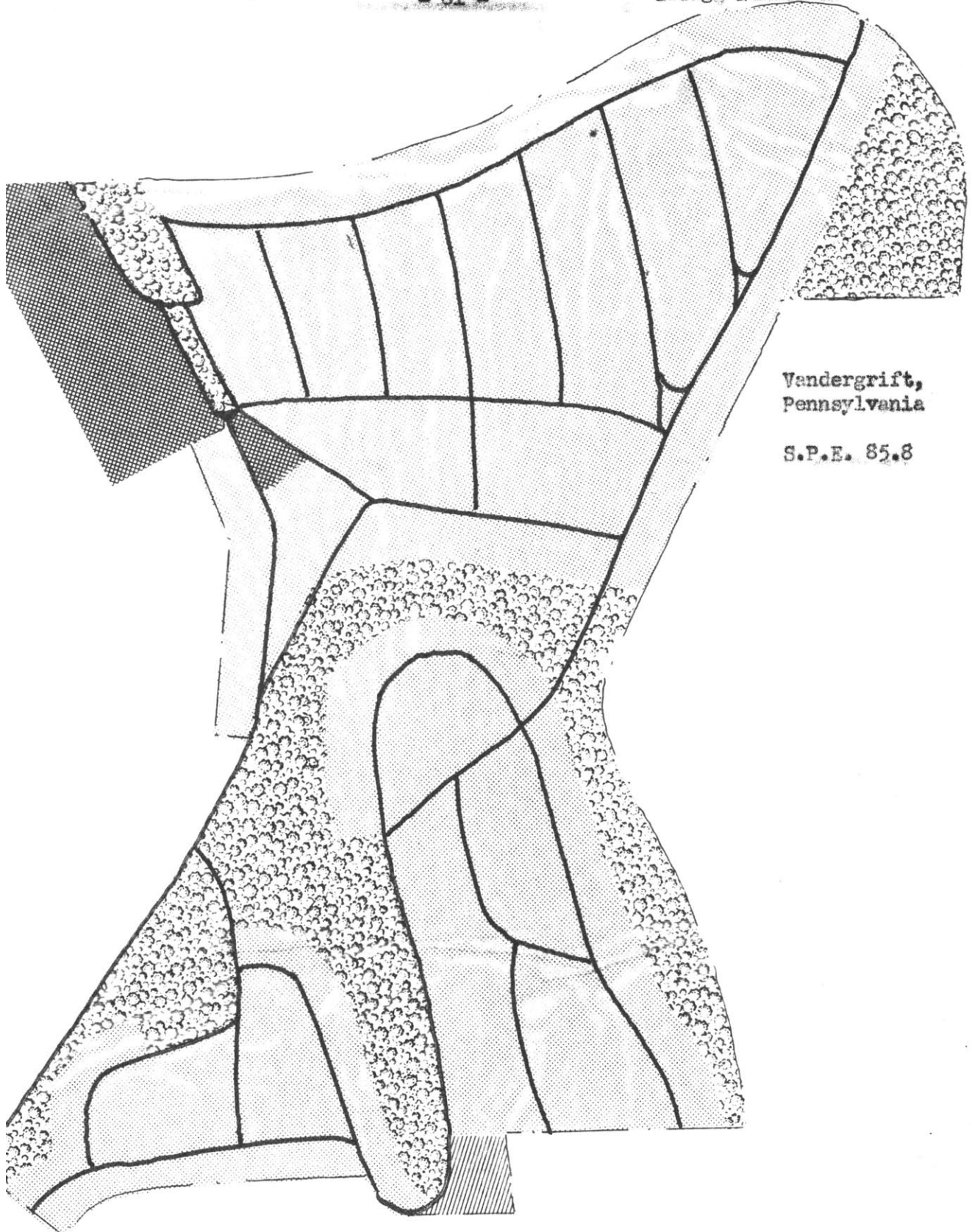
Town of Norris, Tennessee

S.P.E. 86.2



Road Length: 57,000'

SCALE: 500' = 1"



Vandergrift,
Pennsylvania

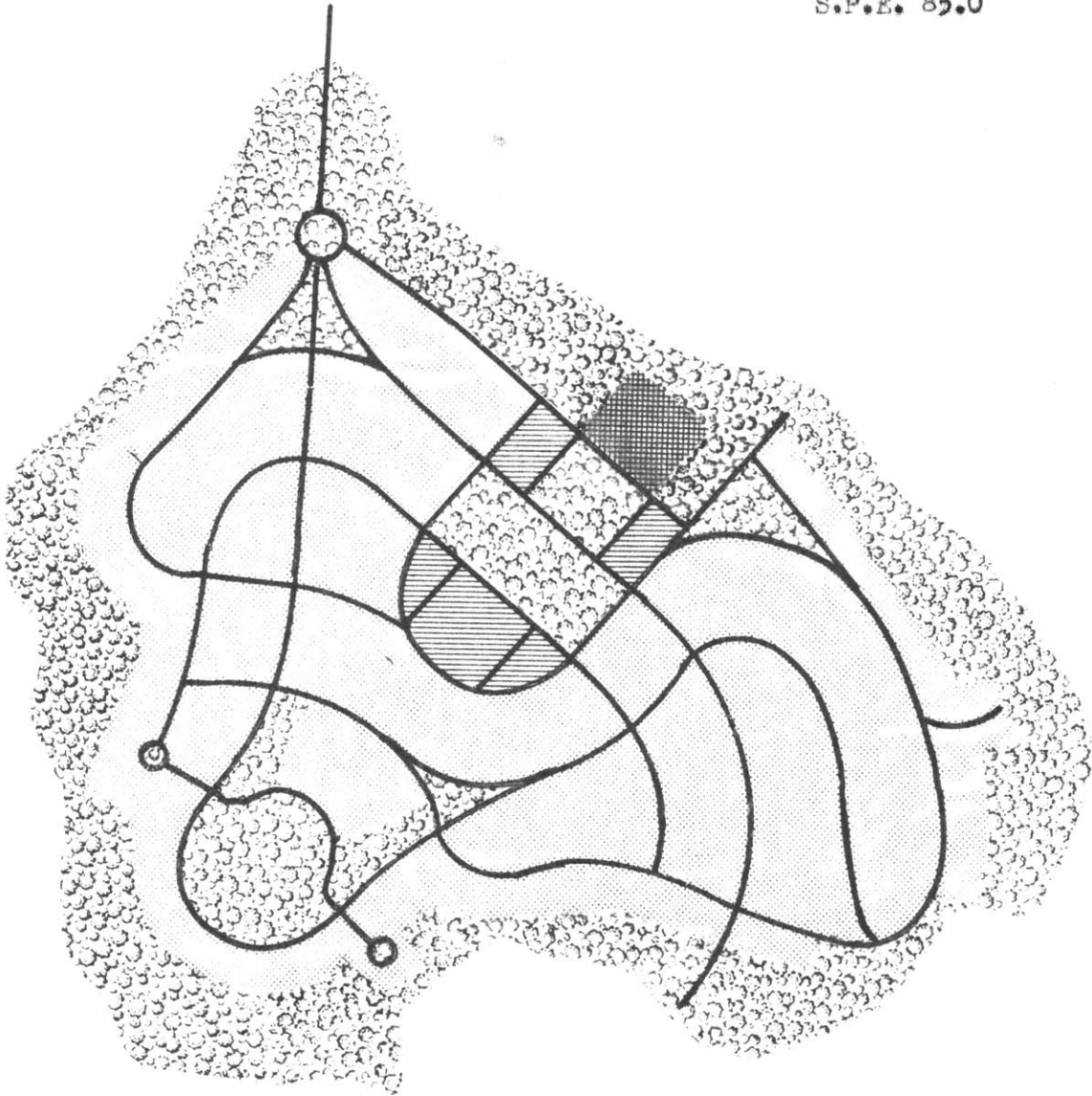
S.P.E. 85.8

Road Length;	32,000'
Road length not serving residential area;	6,600'
Residential Area;	114.5 acres

SCALE: 1000' = 1"

Design Number 11
Sheffield, Alabama
(U.S. Nitrate Plant)

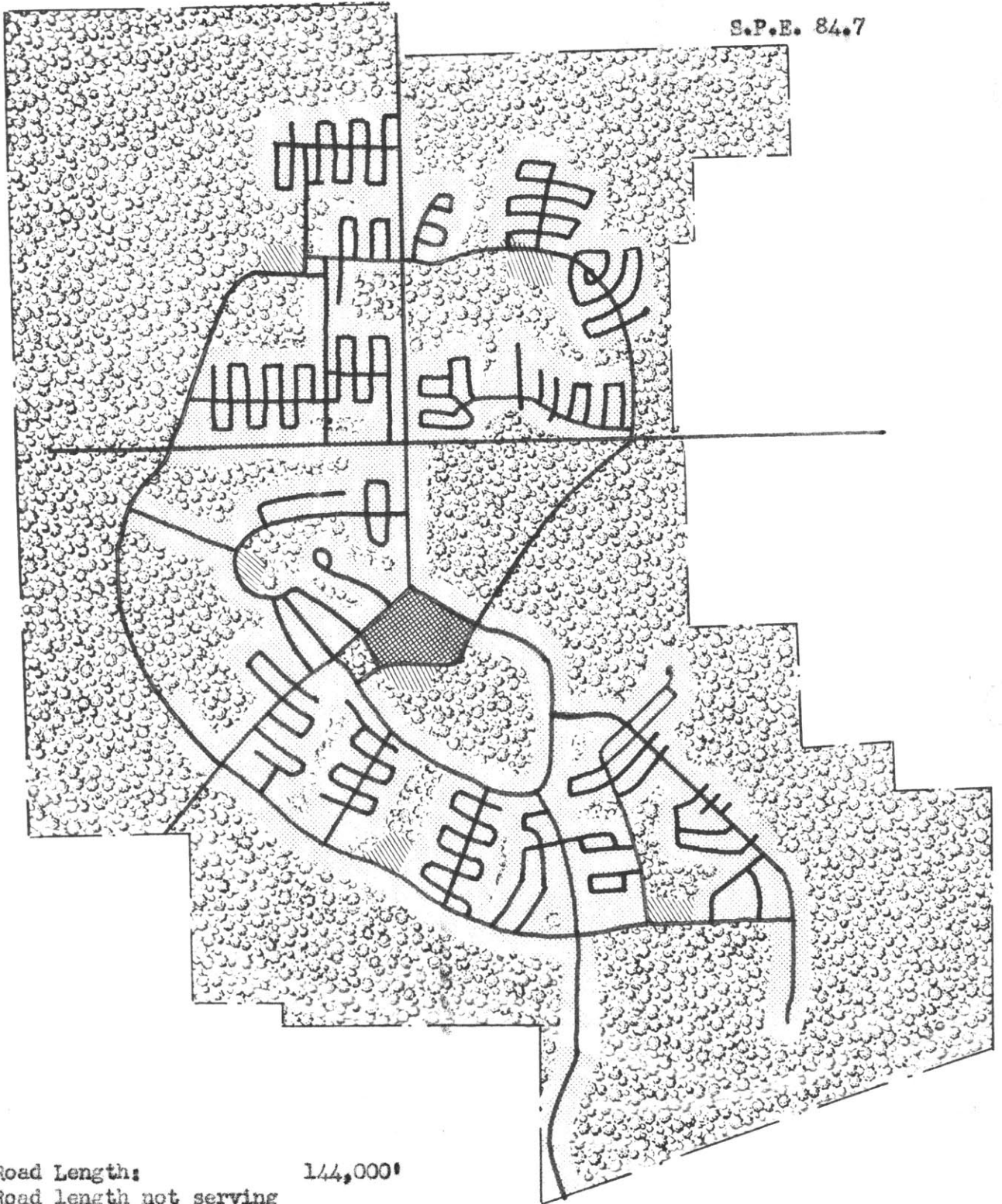
S.P.E. 85.0



Road Length:	34,000'
Road length not serving residential area:	5,600'
Residential Area:	131.0 acres

SCALE: 1" = 1800'

S.P.E. 84.7

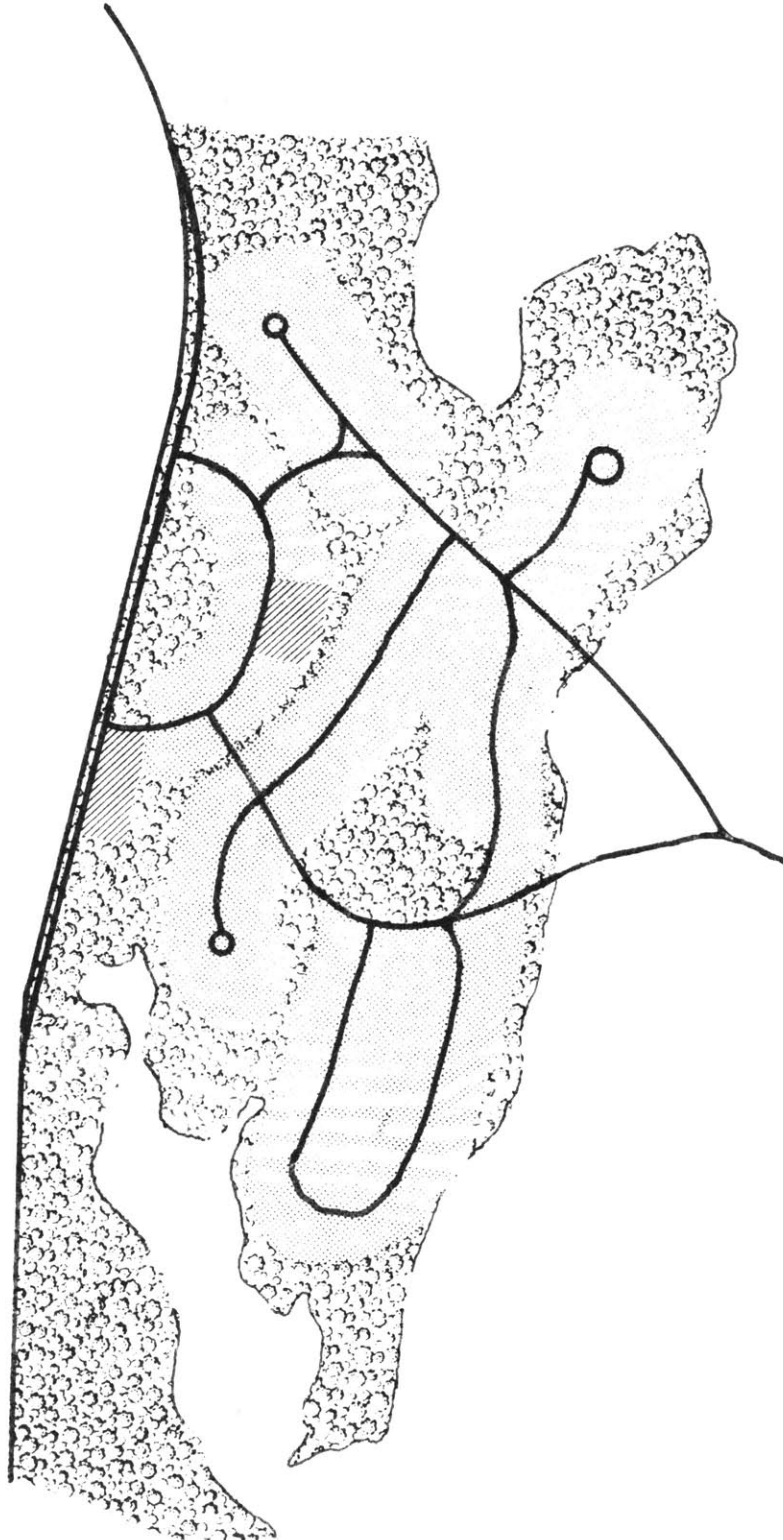


Road Length:	144,000'
Road length not serving residential area:	29,500'
Residential area:	535 acres

SCALE: 500' = 1"

The Village of
Hill, New Hampshire

S.P.E. 83,2

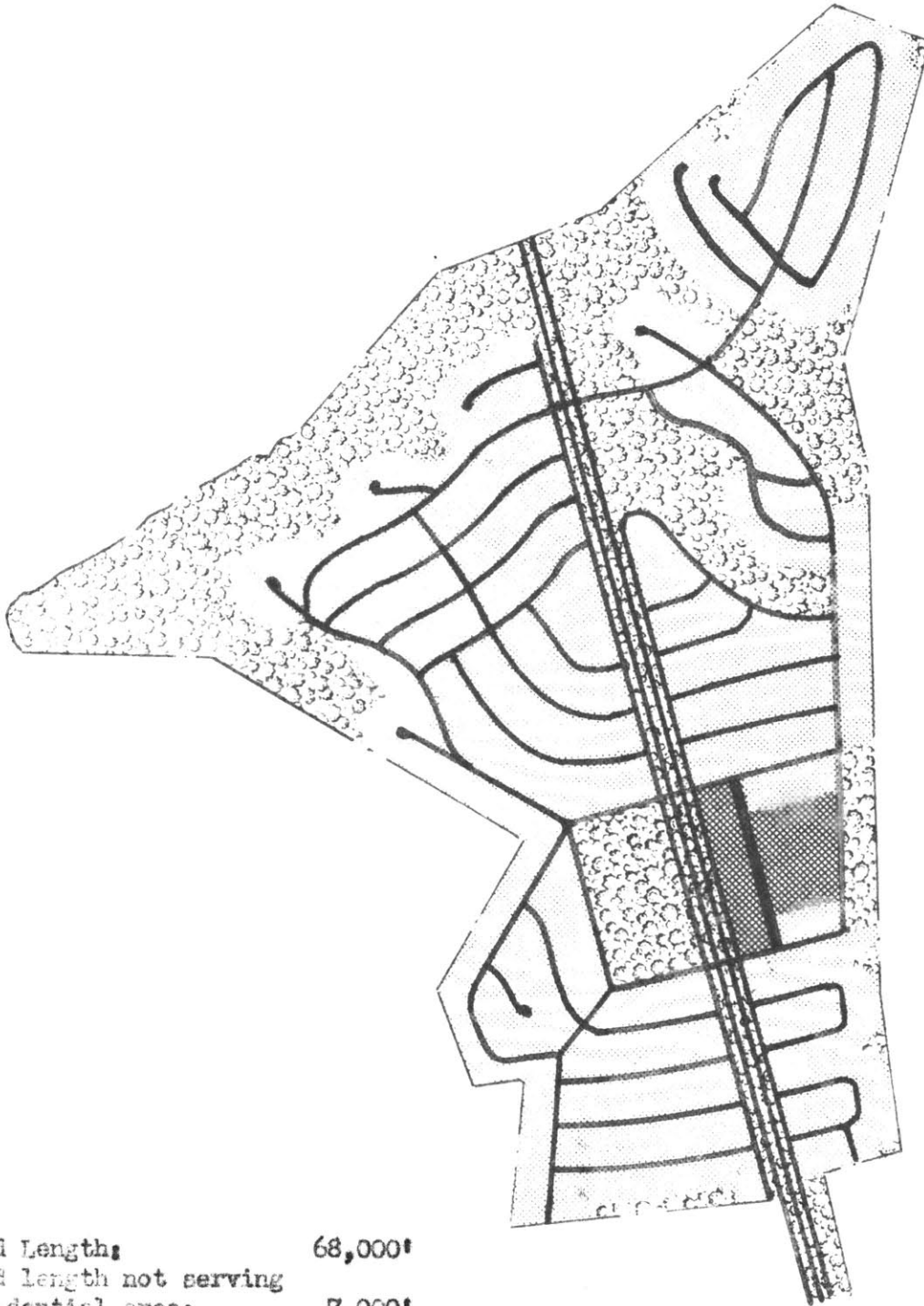


Road Length;
22,800'
Road length not
serving residen-
tial area;
4,000'
Residential area;
85.5 acres

SCALE: 500' = 1"

Harundale, Maryland
(Byrne Organization)

S.P.E. 83.0



Road Length;	68,000'
Road length not serving residential area;	7,000'
Residential area;	278. acres

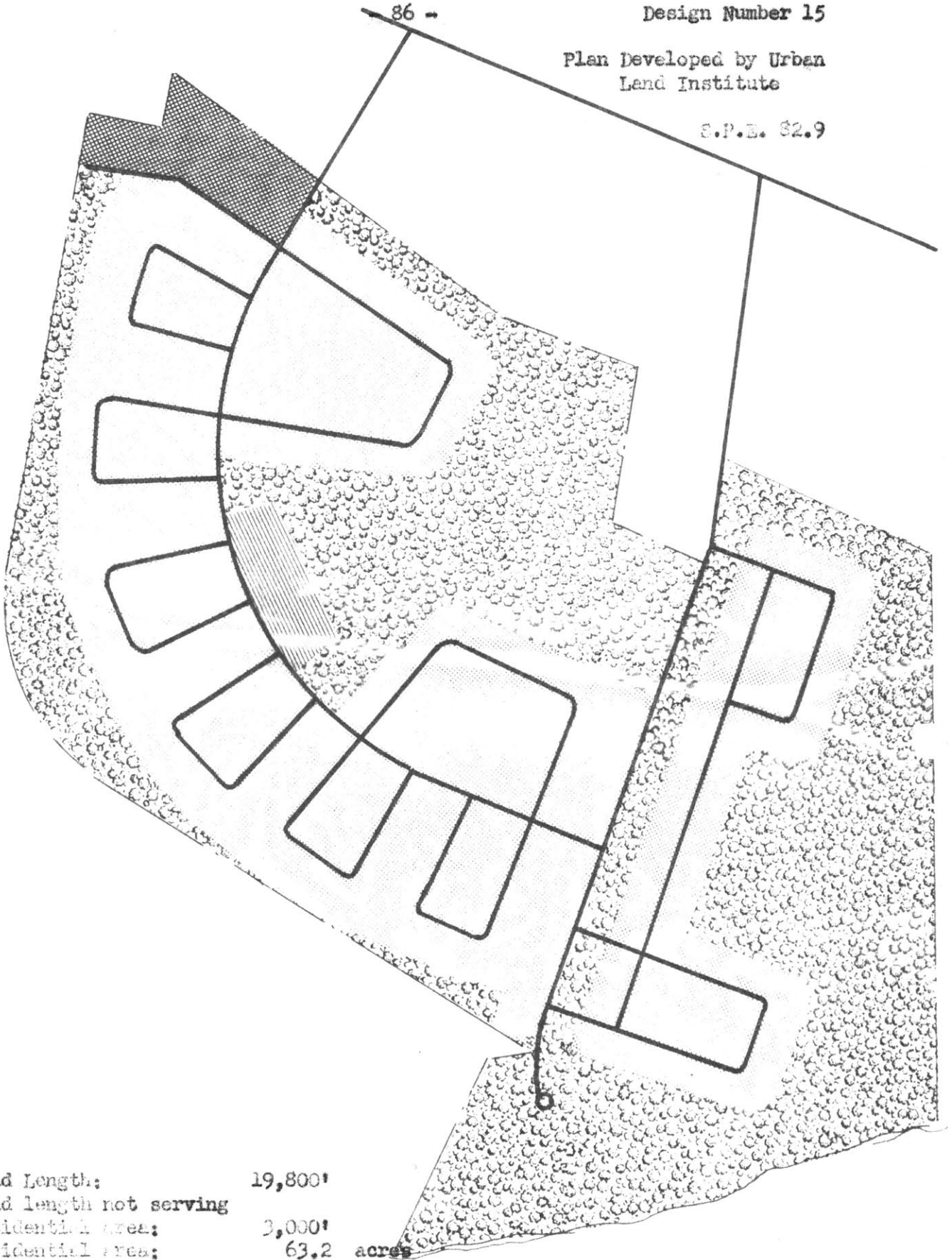
SCALE: 500' = 1"

86 -

Design Number 15

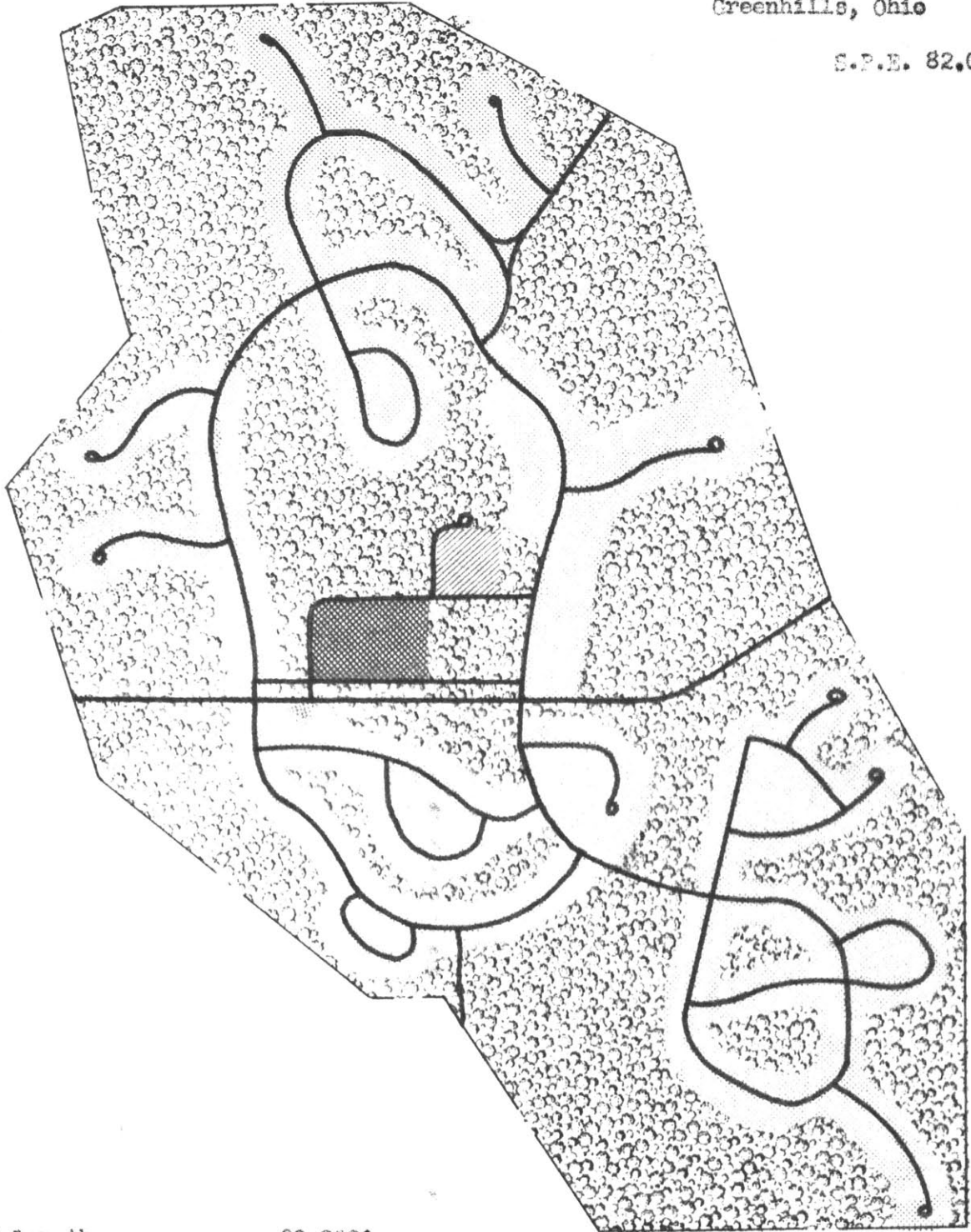
Plan Developed by Urban
Land Institute

S.P.E. 82.9



Road Length: 19,800'
Road length not serving
Residential area: 3,000'
Residential area: 63.2 acres

SCALE: 500' = 1"



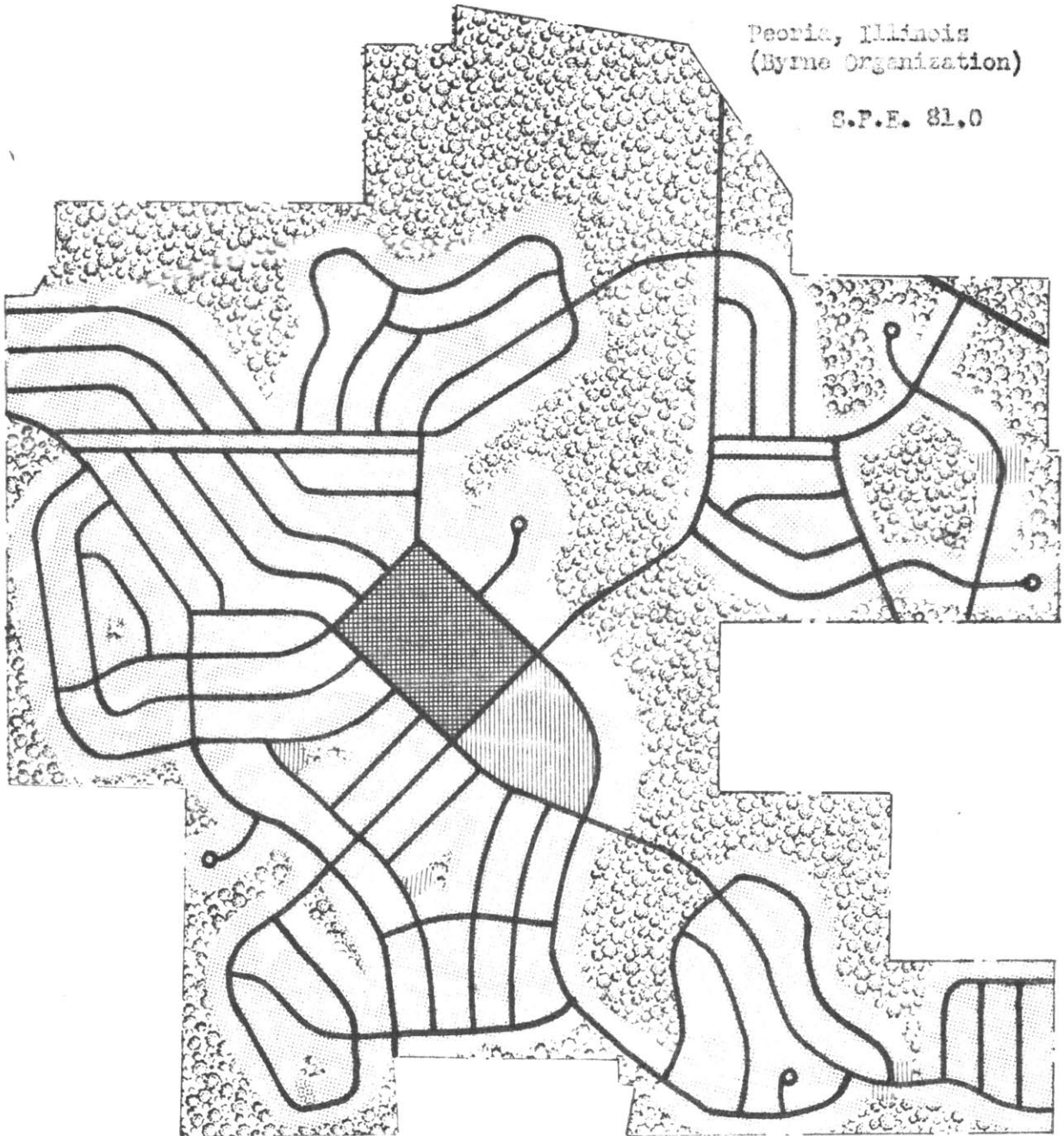
Road Length; 30,000'
Road length not serving residential area; 4,900'
Residential area; 114.6 acres

SCALE: 500' = 1"

Design Number 17

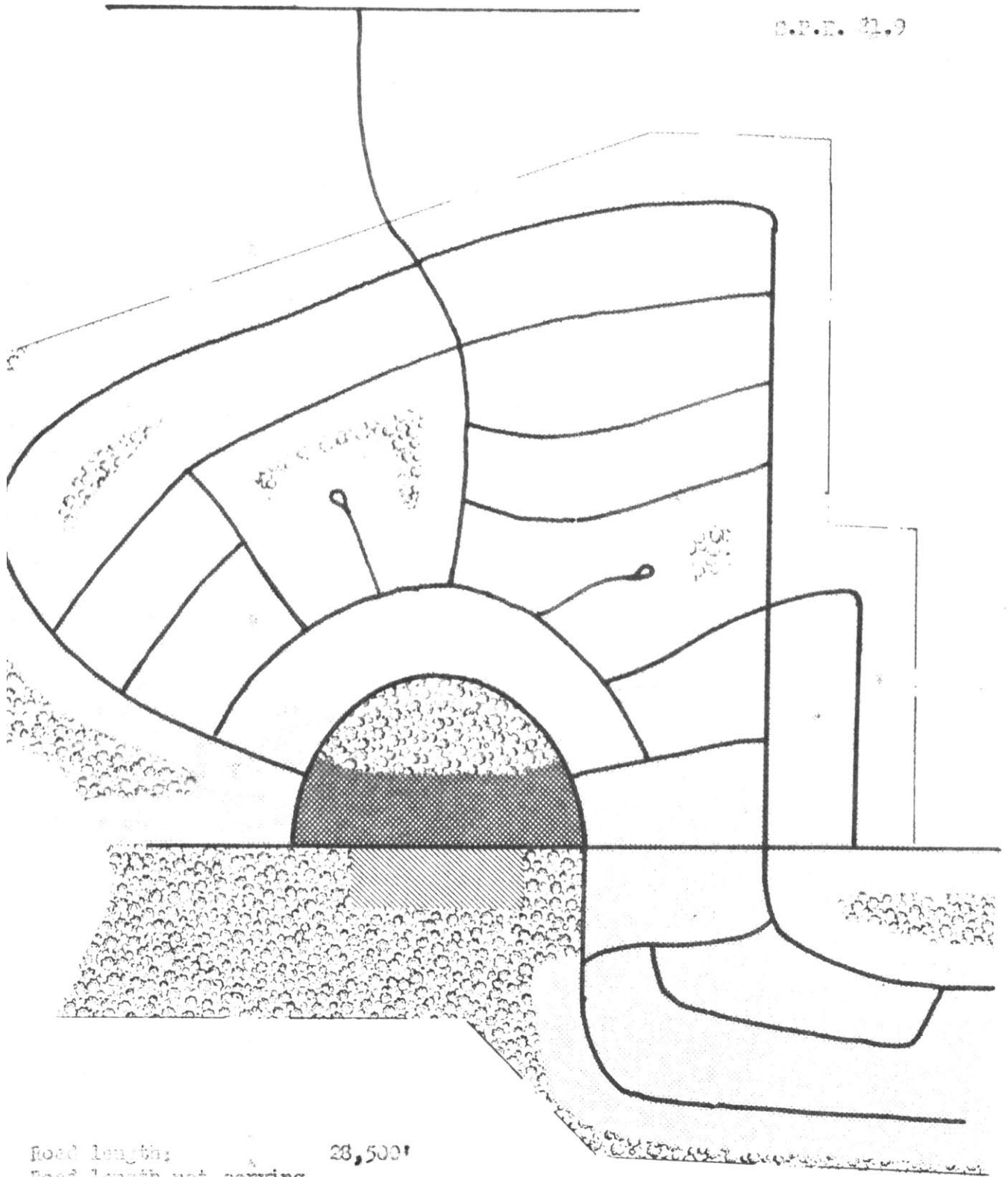
Peoria, Illinois
(Byrne Organization)

S.P.E. 81.0



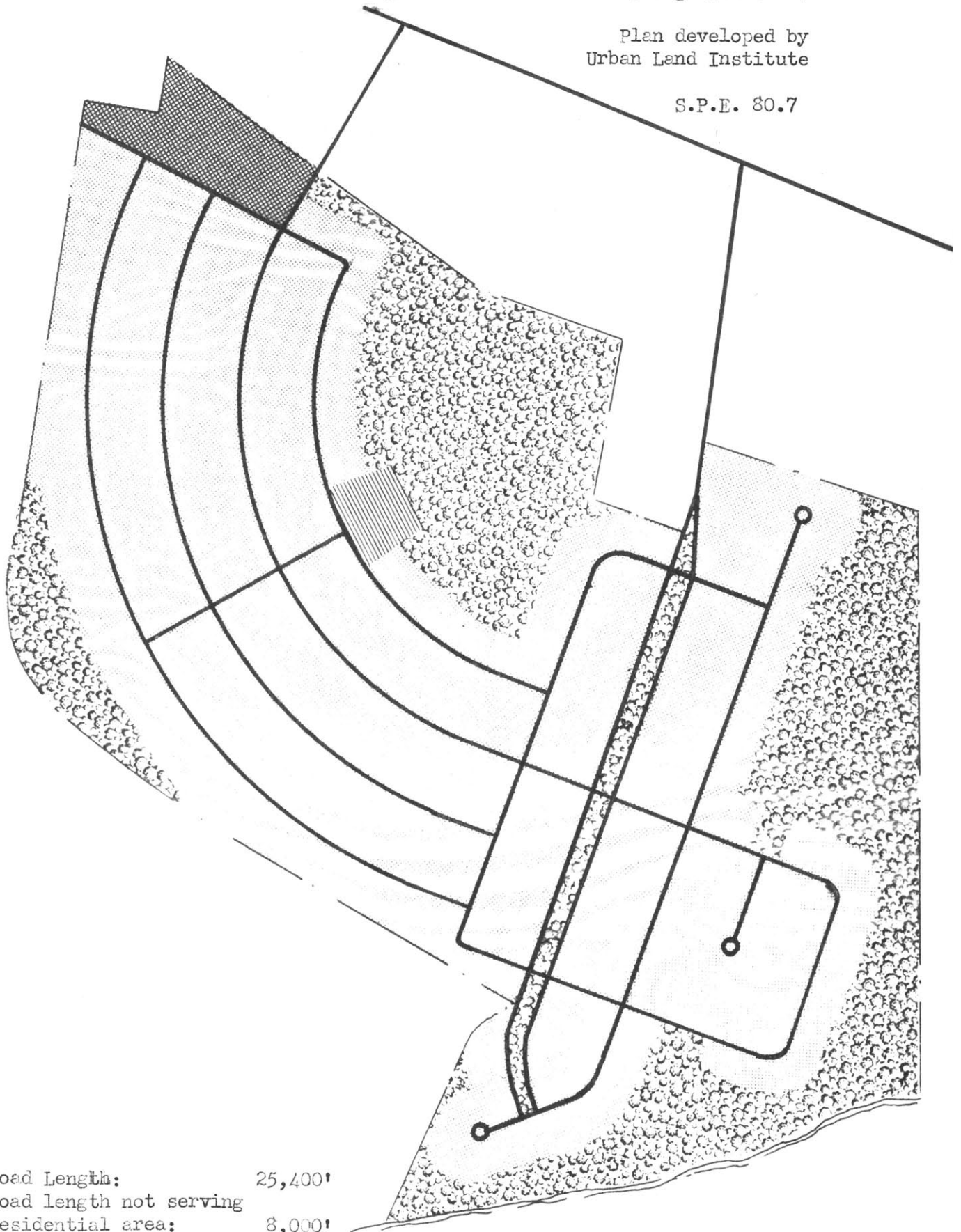
Road Length: 86,000'
Road length not serving
Residential area; 13,000'
Residential area; 342. acres

SCALE: 500' = 1"



Road length: 28,500'
Road length not serving Residential area: 2,800'
Residential area: 120. acres

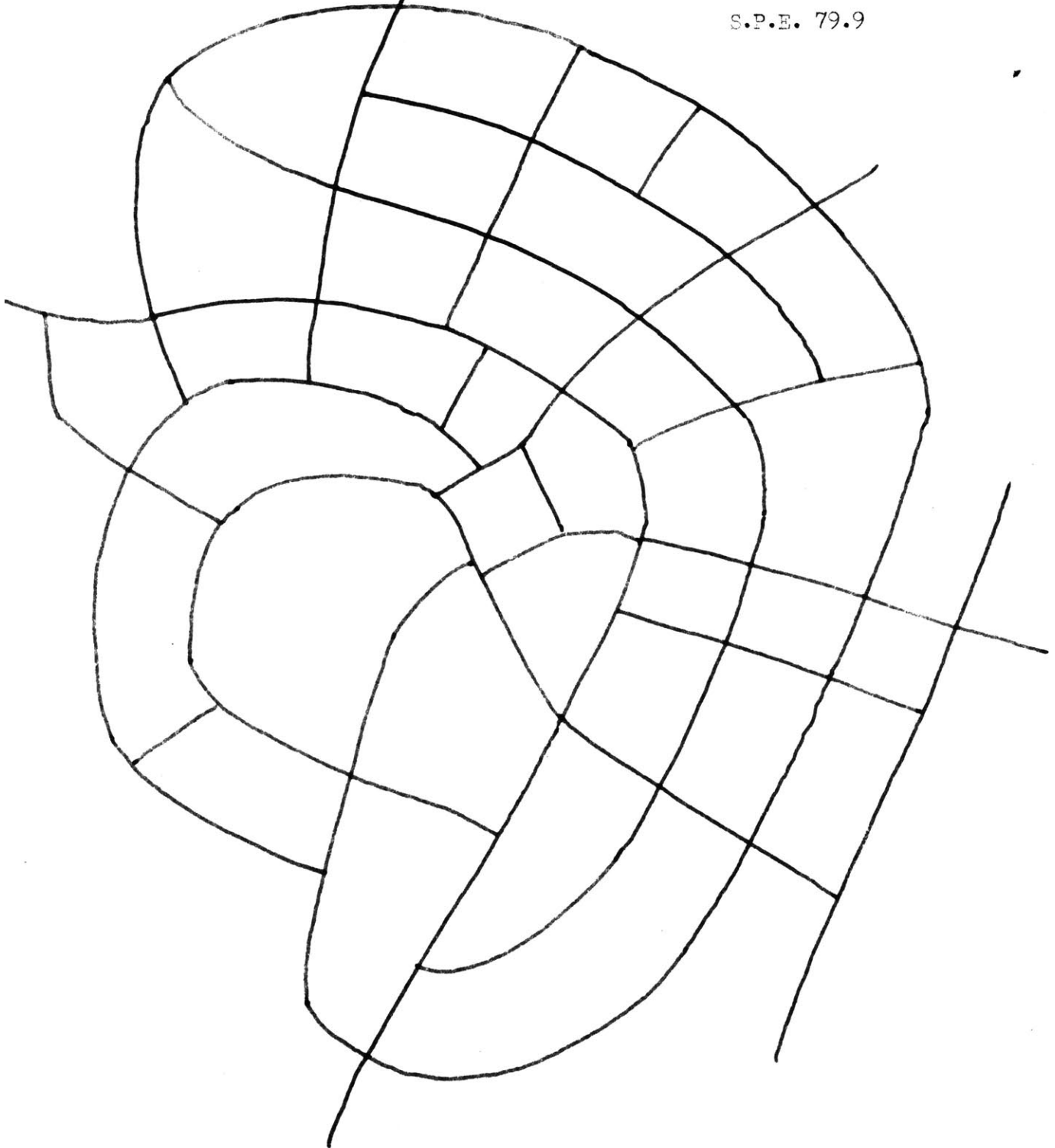
SCALE: 500' = 1"



Road Length: 25,400'
Road length not serving
residential area: 8,000'
Residential area: 79.5 acres

SCALE: 500' = 1"

Design Number 20
Greenbrook, New Jersey
S.P.E. 79.9



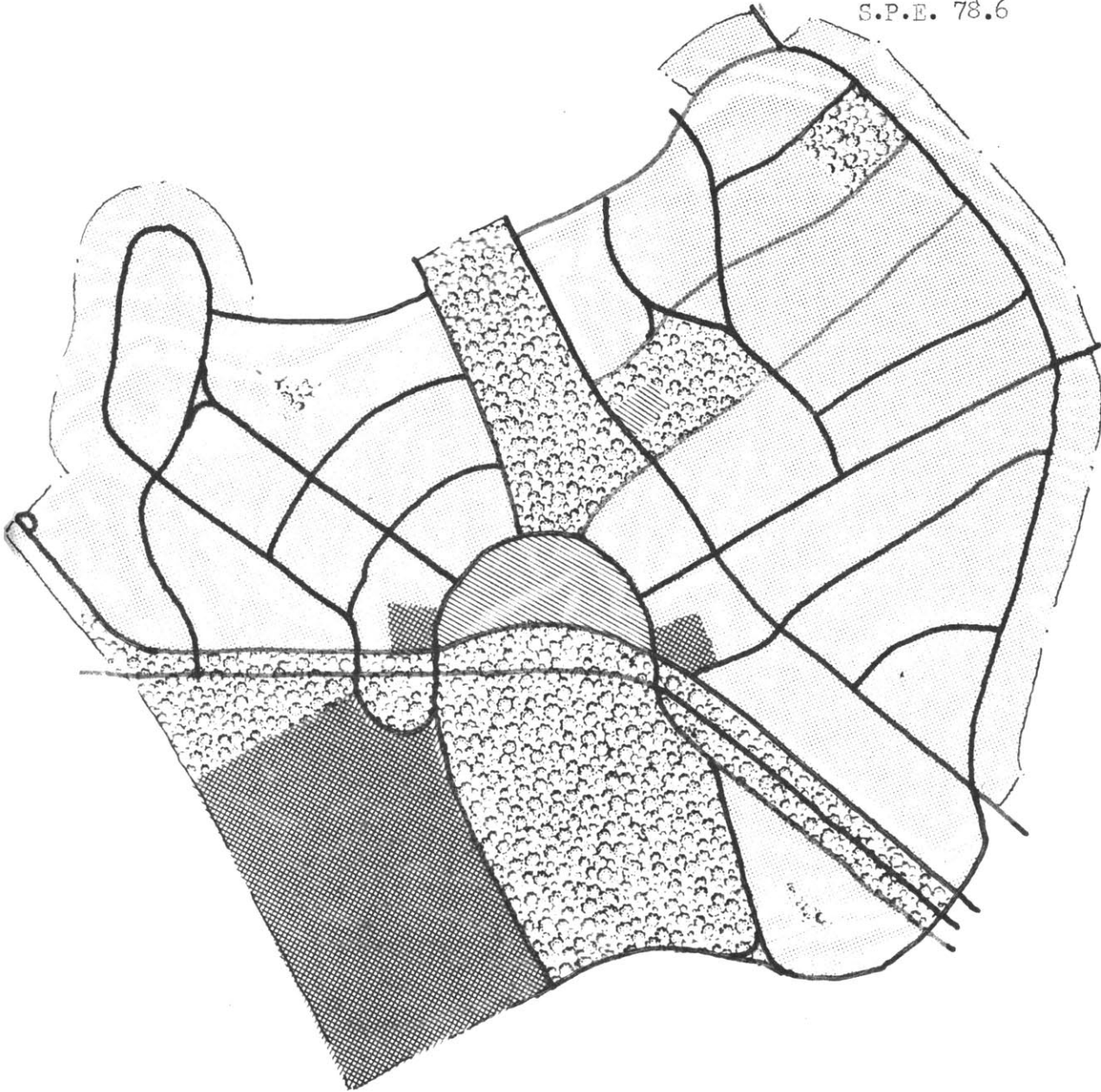
Road length: 44,500'

SCALE: 250' = 1"

Design Number 21

Chicopee, Georgia
(Johnsen & Johnsen)

S.P.E. 78.6



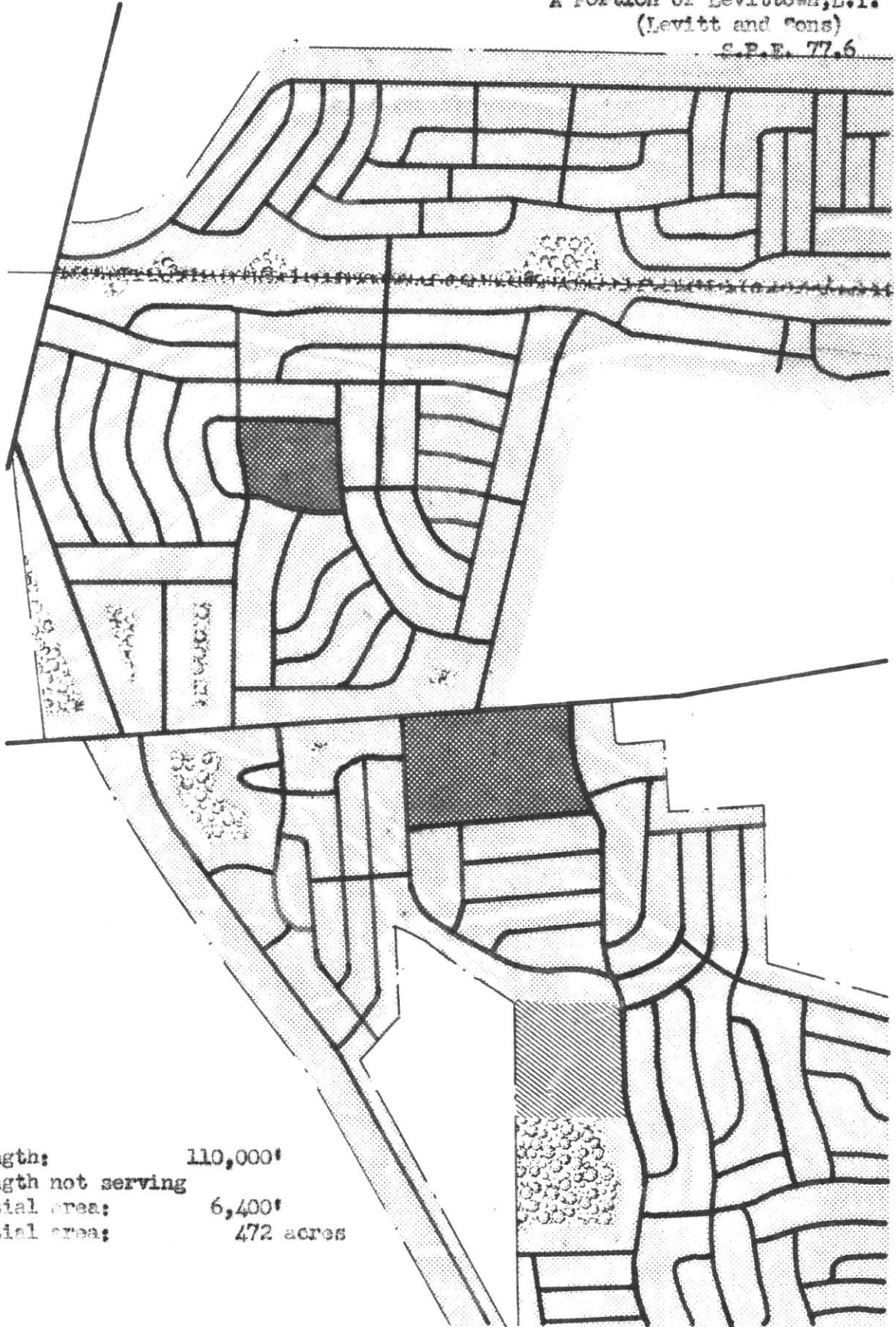
Road length: 24,000'

Road length not serving
residential area: 4,250'

Residential area:
90.0 acres

SCALE 1/4" = 1"

A Portion of Levittown, L.I.
(Levitt and Sons)
S.P.E. 77.6



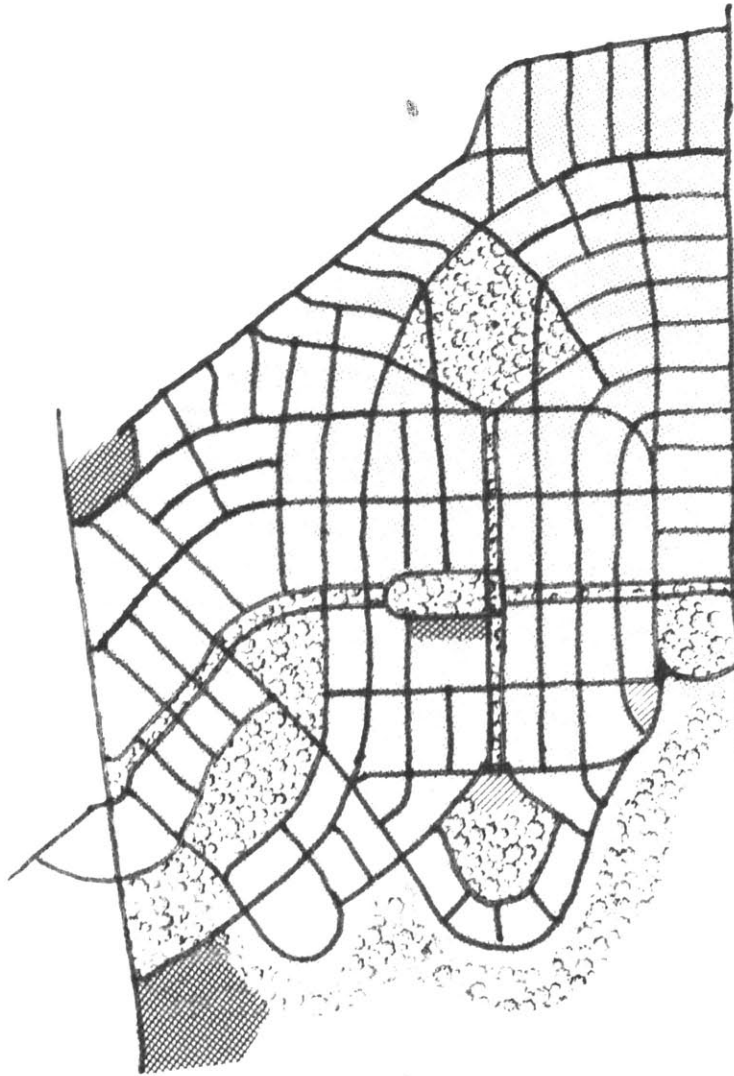
road Length: 110,000'
road length not serving residential area: 6,400'
residential area: 472 acres

SCALE: 500' = 1"

Design Number 23

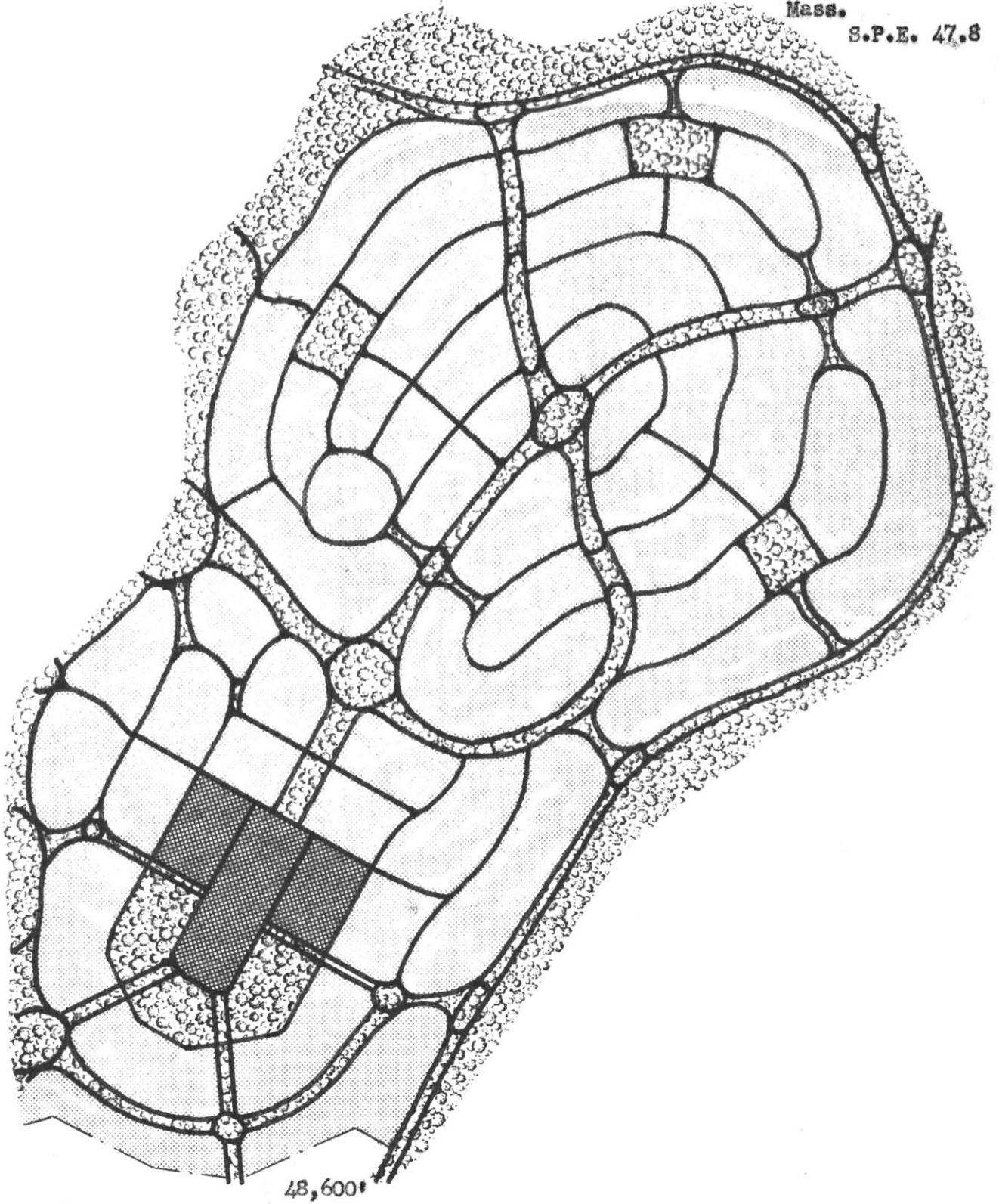
Cradock
Norfolk, Virginia

S.P.E. 73.2



Road Length: 84,000'
Road length not serving
residential area: 6,840'
Residential area: 325. acres

SCALE: 1000' = 1"



48,600'

Road Length;
Road length not serving 19,500'
Residential area; 132 acres
Residential area;

SCALE: 500' = 1"

HOUSE ARRANGEMENT

In the arrangement of the house to the street, we are faced with many old and fundamental issues: How close should a house be to its service street? Should this house face service streets? What functional relationship should there be among the houses? How should the areas for drying clothes be arranged? Where can the baby boy play? How close can people live together? These questions have been left to the individual site planner. To permit a study upon which flexible arrangements of houses could be based, we have set upon the course of considering area served rather than lots developed.

As we have stated before, this study is to supplement what has been done in the past. With this in mind, we have taken as a unit all studies made by Whitten and Adams for various arrangements of houses in relation to the street. Their cost analyses were corrected with present day values and extra items of expense were added so that we might be able to carry out our procedure as outlined above. All this information has been compiled in Tables X and XII and gives a fair estimate of what to expect.

COST OF IMPROVEMENTS ON THE LOT

SCHEME NUMBER	Indirect Costs						TOTAL
	Walks 3' Wide 4" Thick @ .60 per lin. ft.	Garage Drive 8' Wide @ 2.00 per lin. ft.	Housing Connections @ 2.75 per lin. ft.	Grading Loaming Seeding @ .50 per sq. ft.	Roads for Either Cul-de-sac Loops Alleys	Utilities Connection to Street for Scheme No. 3, 4, 5	
Single Building Line							
1-A Feet	120.0	25.0	22.5	2715			
Dollars	72.00	50.00	61.80	135.50			\$319.80
Double Building Line							
1-B Feet	95.0	35.0	37.5	2710			
Dollars	57.00	70.00	103.00	135.00			365.00
1-C Feet	80.0	29.4	19.4	2700			
Dollars	48.00	58.8	53.40	135.00			294.40
Triple Building Line							
2-A Feet	77.0	28.0	21.7	2820			
Dollars	46.20	56.00	57.00	141.00			300.20
2-B Feet	75.0	32.1	18.7	2793			
Dollars	45.00	64.20	51.50	139.50			297.2
Cul-de-sacs (18 feet wide)							
3-A Feet	99.5	23.2	24.0	2791	12.2	12.2	
Dollars	59.70	46.40	66.00	139.50	88.75*	78.50	478.85
3-B Feet	66.7	22.3	20.2	2896	10.8	10.8	
Dollars	40.20	44.6	55.50	144.56	77.90*	69.50	432.20
Loops (18 feet wide)							
4-A Feet	65.3	23.3	18.3	2893	18.3	18.3	
Dollars	39.20	46.60	50.30	144.50	119.00	117.50	523.10
4-B Feet	61.5	20.0	17.0	2931	19.0	19.0	
Dollars	36.90	40.00	46.70	146.50	123.00	122.00	515.10
Cross Access Streets (18 feet wide)							
5 Feet	80.0	25.0	20.0	2835	17.9	17.9	
Dollars	48.00	50.00	55.00	142.00	116.00	115.00	526.00

* Includes Cost Turnarounds

PARKS

As has been discussed before, there are two general arrangements of parks, the intra-block park, such as found at Radburn, and the ordinary city park. There has been a dispute among planners regarding which of these plans is more efficiently maintained. We believe we were able to make enough studies on the subject to arrive at an answer which we feel to be reliable.

In our first study, we obtained information from the Brookline Massachusetts Park Commission. This information was based on the cost of maintaining squares and triangles throughout the town and the maintenance costs of the usual city park. It was felt that these squares and triangles gave a very clear picture of maintenance problems which are found in the interior park of the Radburn scheme, while the city parks were representative of the block park. We believe that the advantages of being located on a street had little effect on the maintenance costs, since cost of delivered materials amounted to less than twenty per cent of the maintenance costs. In studying the cost analyses of these two types of parks, it was determined that the square or triangle type cost about 65 per cent more to maintain.

In another study that was made by compiling data for maintenance of grounds at Rutgers University, similar results were obtained. In this case, the closely knitted campus was used in comparison with the Radburn park, and the open expanse located around the stadium area was associated with the city park.

The result of the Rutgers comparison indicates that the intra-block park costs about 80 per cent more to maintain. This, we feel, is a little high since the stadium area is not exactly comparable with the city park. Therefore, we have adopted the Brookline study as a satisfactory comparison. The Brookline results were used in Table XI where we made a further study of the annual cost of intra-block park vs. the city park. This included original cost and maintenance cost of streets which serve the park. This study indicates that a city park of 25 acres which is served by streets on one-fourth of its perimeter is just as economical as the intra-block park. We have felt that under either of these schemes, many savings could result with regular patterns of trees and shrubs and still not be unpleasant to the eye.

TABLE XI

HOW DIFFERENT TYPES OF PARKS ARE AFFECTED BY MAINTENANCE COSTS

Type and Size of Park	Maintenance Cost per Year per Area			Total Main- tenance per Acre - includ- ing Park Upkeep \$/acre	Annual Cost of Amor- tizing Roads and Utilities over		Annual Charge per Acre Amortized over	
	<u>Road and Utilities</u>	<u>Snow Removal</u>	<u>Street Cleaning</u>		<u>20 years at 2½%</u>	<u>40 years at 2½%</u>	<u>20 years at 2½%</u>	<u>40 years at 2½%</u>
	\$/mile	\$/mile	\$/mile		\$/mile	\$/mile	\$/acre	\$/acre
<u>Small Park (1 acre)</u> Perimeter served by following length of street (Upkeep cost - \$462. per acre)	\$1200.	\$800.	\$200.					
0 - Radburn scheme	0.00	0.00	0.00	462.00	0.00	0.00	462.00	462.00
1/4	47.50	31.80	8.00	549.30	260.00	175.00	809.30	724.30
1/2	95.00	63.60	16.00	636.60	520.00	350.00	1156.60	986.60
3/4	142.50	95.40	24.00	723.90	780.00	525.00	1503.90	1248.90
All	190.00	127.20	32.00	810.20	1040.00	700.00	1850.20	1510.20
<u>Larger Park (25 acres)</u> Perimeter served by following length of street (Upkeep cost - \$278. per acre)								
0	0.00	0.00	0.00	278.00	0.00	0.00	0.00	278.00
1/4	95.00	63.30	15.80	452.10	52.00	35.00	504.10	487.10
1/2	190.00	126.60	31.60	626.20	104.00	70.00	730.20	696.20
3/4	285.00	189.90	47.40	800.30	156.00	105.00	956.30	905.30
All	380.00	253.20	63.20	974.40	208.00	140.00	1182.40	1114.40

COMBINING THE RESULTS

Since all the previous studies were based on either the street system or lot improvement cost, we can make a direct comparison with any combination of street patterns and house arrangement in relationship to the street. The site planner is not limited to arrangement and layout as found in this text. He may make separate studies of various designs which will functionally carry out his ideas. However, if he follows the procedure of this thesis, he could be guided and assisted by much of the data enclosed herewith.

In making an analysis of different arrangements of housing units, the site planner should first determine the cost of improving the lots. This includes direct and indirect cost as indicated on Table X. To this should be added the cost of the utilities and the street that are attributed to each dwelling unit. The cost of the sewerage system should be corrected for the various densities in the different schemes. Then these items of expense can be totalled to establish the true cost relationship between the different schemes. This has been done for a few arrangements in Table XII.

TABLE XII

COMBINED EFFECTS OF HOUSE ARRANGEMENT AND STREET PATTERN
(Cost in Dollars per Dwelling Unit)

Design No.	Single B-L *3-A	Double B-L 3-C	Triple B-L 4-B	Culs-de-sac 5-B	Loops 6-B	Cross Access Streets - 7
1 (t)	\$ 869.	\$ 620.	\$ 623.	\$ 589.	\$ 765.	\$ 708.
2 (t)	898.	630.	633.	594.	773.	714.
3 (t)	818.	583.	591.	571.	737.	690.
4	848.	607.	610.	583.	755.	701.
5	905.	640.	643.	599.	781.	720.
6	858.	612.	615.	585.	759.	702.
7 (t)	789.	572.	575.	566.	729.	682.
8 (t)	1024.	710.	713.	633.	834.	759.
9	840.	602.	605.	581.	752.	698.
10	900.	638.	641.	598.	778.	718.
11	860.	613.	613.	586.	760.	703.
12	870.	620.	623.	589.	794.	708.
13	875.	623.	626.	590.	767.	710.
14	842.	603.	606.	581.	752.	699.
15	995.	693.	696.	624.	821.	749.
16	886.	629.	632.	594.	772.	711.
17	864.	616.	619.	587.	762.	706.
18	825.	593.	596.	576.	744.	693.
19	1020.	709.	712.	632.	833.	758.
20	876.	624.	627.	591.	768.	711.
21	885.	628.	631.	593.	771.	713.
22	855.	611.	614.	585.	758.	703.
23	946.	665.	668.	611.	799.	733.
24	1683.	1100.	1103.	822.	1135.	978.

* See appendix for details of house arrangements.
(t) Theoretical plan

RESULTS

Thus far in this thesis, we have discussed many variables found in subdivisions and how these are affected by various conditioning factors. Many of the results of the investigations have been expressed in cost ranges that may be anticipated. These deductions were expressed as limits within which most variables for a good design will be situated. The findings are very much like the limits for urban land uses as set forth in Bartholomew's studies made at Harvard.¹ These deductions are not arbitrary but are limits which are controlled by many regulating influences. Bartholomew found that a certain number of people can support a given amount of commercial area since the people have limits to their spending power. Likewise, we found that there were limits for variables in subdivisions. The limits were influenced by such things as local regulations, natural conditions, boundaries, maintenance procedure and the ability of the designer to carry out his plan. These deductions can be placed into four categories, 1) limits that should be attributed to the detailing ability of the designer, 2) limits assigned to the street pattern, 3) limits due to the area in which the subdivision is to be planned, and 4) limits that are not controlled by the original cost.

¹ Harland Bartholomew, Urban Land Use, (Cambridge, Mass., Harvard University Press, 1933)

The first two limits are almost solely controlled by the site planner, who makes the final decision on street layout as well as the integral details of the plan. The details include such things as the radii of street curves, how the catchbasins should be arranged and the angle of intersections. All such details affect in some way the cost of installing the utilities which means variations in the total standard cost, while the choice of street layout influences the site planning efficiency.

However, as we have pointed out before, the efficiency with which these details are carried out indicates greater reduction in cost than one usually imagines. That is, for example, if the number of manholes can be reduced, the total savings are not solely expressed by the cost increment due to the reduction in the number of manholes. This reduction in the number of manholes is usually accompanied by other savings which owe their existence to this reduction. The usage of fewer manholes might mean that the average pipe size could be reduced with accompanying savings. Thus, the site planners should keep in mind the statistical average with its assigned limits for the following items: one manhole (sanitary) for every 309 feet of street with a computed range of 32 per cent; one manhole (storm) for every 720 feet of street with a computed range of ten per cent; one catchbasin for every 383 feet of street with a computed range of 31 percent and one fireplug for every 440 feet of street with a computed range of nine per cent. It might be added

that the above averages should give a more realistic indication as the number of short utility lines are reduced, ⁵ Since in short utility lines, the number of connections is almost arbitrarily established by the length of line.

Likewise, a site planner should be well aware of the details that affect the standard costs of utilities as presented in Tables I through VI, and particularly so with the method and contractual procedure of excavation. The requirement for road base under various soil conditions shown in Table III points out that soil condition can increase paving cost up to 120 per cent. Furthermore, the necessity of sheeting or the encountering of rock ledge in excavation can increase cost of underground utilities some 260 per cent. All these factors are extremely important in making cost estimates.

The other limits in which the site planner plays an important part is in the street pattern. By laying out the streets properly, he can reduce the number of intersections and thus increase the site planning efficiency. This, as we have indicated, can best be accomplished by adopting some regularity in the street system and by the usage of large blocks. This does not mean that the street arrangement must be formal or rigid. We have also found that the rectangular block system is quite efficient, especially in comparison with the scheme of using radial streets. A system which begins at the center with the gridiron and then introduces many variations in the block system is efficient. The Harundale plan of the Byrne Organization

is a good example of this type.

We have noticed that there are a great deal more possibilities for street patterns as the land for subdivision is increased and as the cost is reduced. The site planning efficiency can very often be increased by making larger blocks which may contain some open spaces within themselves. The standard costs can be reduced by choosing the proper location of roads and utilities.

As for the limits due to the area in which the subdivision is to be located, we are first faced with the usual numerous local regulations. These must be studied in detail to develop savings, and at the same time to present a more pleasant subdivision. Next, the physical boundaries of the property must be studied and analyzed so as to determine the most efficient street system. Sometimes a site planner's hands are tied by regulations that require the continuance of unnecessary streets. This makes the street plan much more regulated which is very unfortunate. The site planner is also limited by the natural conditions found within the area.

The limits that are not controlled by the original cost are those usually associated with maintenance. We found that annual cost of maintenance of utilities and streets amounts to about one-half the cost of amortizing the original cost over a period of twenty years at two and one-half per cent interest.

Further studies which we made seemed to indicate that the city park served by one-quarter of its perimeter was just as efficient as the small intra-block park, such as those found at Radburn. There are also many engineering problems for which consultation should be held, especially in regard to annual cost of different types of pavement, etc. A site planner should be well aware that these conditions exist. Besides being of value in developing savings by carrying out certain details, we hope that the cost analyses will assist a planner in making cost estimates.

Naturally, it can be said by using the ranges of variation, one could determine a better cost estimate for a project. This could be done by taking such a factor as the subsoil conditions whereby one could establish the variation due to this item alone. Thus, all the variations in the variable could be determined and by summing up these variations, a more accurate estimate could be obtained. At the same time, this estimate should point to many cost savings to be sought after in the subdivision plan.

Since the main purpose of this thesis was to contribute something which would be applicable in the field, how can we use the information we have gathered? We believe if a subdivider follows the outline given below, a great deal of economy will result.

A. Principles to be followed in making the first preliminary plan.

- 1) Make the layout as simple and direct as possible.
 - a. Make the pattern quite regular.
 - b. If possible, use large rectangular blocks.
- 2) Reduce the number of intersections to a minimum.
 - a. This saves space for residential areas.
 - b. This reduces extra cost due to extra catchbasins, etc.
- 3) Increase the use of culs-de-sac when they will not hamper the circulation.
 - a. This increases the residential area.
 - b. This saves on utility costs.
- 4) Make use of topography.
 - a. Roads should follow the topography to reduce grading costs.
 - b. The number of catchbasins and manholes should be reduced by considering the topography (particularly at intersections).
 - c. Curves and slopes should follow the topography but be as gentle as possible to prevent additional costs in utilities.

B. After a more detailed plan has been worked out, check the standard costs for roads to see if they are within the statistical limits for good design.

- 1) Determine what additional costs are represented by the variation in soil conditions from the statistical average.
- 2) Determine if savings could result by locating road on better subsoil in subdivision.

C. Check the standard cost for the underground utilities which result from using this detailed plan.

- 1) Do the established grades cause a variation in average cost?
- 2) How does the average depth for excavation compare with standards?
- 3) Check the standards for fireplugs, catchbasins and manholes and see how they affect the standard cost.

With the outline and the method of analysis for the economies of utilities and streets developed in this thesis, the planner should have some guiding facts in assisting him to reduce costs of subdivision. We firmly believe that if this method of determining "average" value had been developed further by including a breakdown of different types of sites, the results would have been even more applicable. In particular, there should have been "averages" developed for various types of topography, such as gentle rolling land, fairly hilly land and quite hilly areas. With such "averages" and the accompanying limits assigned to different types of sites, the planner could very easily determine if the subdivision he were working on was within the range of a "good design". This thesis has pointed out that there is a rather limited range within which most good design lies, even though this study is based on average sites.

Such an analysis would not be weakened by the fact that land, material and labor costs fluctuate from month to month and vary widely between different cities.

We feel that this investigation should prove very valuable to the community and the future home owners, for, as we stated, both could be beneficiaries of many more amenities which could be paid for by the saving resulting from information derived from this thesis. Furthermore, we hope that this study might prove to be helpful as a guide to the agency in the community which will approve plats for subdivision.

APPENDIX

SOIL CLASSIFICATION

As Described in WARTIME ROAD PROBLEMS

Number 8

Thickness of Flexible Pavements for
Highway Loads

- A-1 These soils are well graded, predominantly granular materials, seldom occurring as such in natural deposits. They are ordinarily produced by combining gravel or sand or both with suitable quantities of fine material to create stable mixtures.
- A-2 These soils are essentially granular soils containing a higher percentage of materials passing the Number 200 sieve than A-1 materials. They have high supporting value when dry, but because of their greater capillarity, less supporting value when wet than the A-1 materials.
- A-3 These soils are gravel or sand containing little or no silt or clay. These materials are highly permeable and cohesionless. When thoroughly compacted, they can fail only in shear, in which case the granular material adjacent to the loaded area must expand. To prevent such expansion, a base course is required to exert a confining influence. Because of their high permeability, these materials drain well.
- A-4 These soils are relatively cohesionless, silty soils susceptible to frost action, which indicates a need for drainage.
- A-5 These soils are similar to A-4 materials but are susceptible to elastic rebound due to the presence of mica or diatoms.
- A-6 These soils are highly plastic colloidal clay soils subject to detrimental volume changes and softening due to moisture penetration.
- A-7 These are plastic clay soils with low permeability, not likely to be adversely affected by frost but subject to softening and volume change due to moisture fluctuations.
- A-8 Peat, or muck, with very low supporting value should be given special study.

For further description of these soil groups, see Public Roads, February 1942.

II

TABLE A

RANGE IN PAVEMENT

Thickness (Wearing Course and Base)
in Inches

<u>State</u>	<u>Soil Groups</u>						
	A-1	A-2	A-3	A-4	A-5	A-6	A-7
Alabama	0-8	8	8	8	8	8	8
Arizona	0-6	0-12	0-6	6-12	0-12	12-18	9-18
Arkansas		6	6	6-8		8-12	8-12
Florida	6	6-8					
Idaho	2-4	2-4	2-4	6-12	8-12		8-12
Illinois	7	7	7	7-12	7-12	7	7
Maryland	4	4	4	6	6	6	6
Minnesota	2-3	6	2-3	6-12		6-9	6-9
Mississippi		0-8	0-6	4-8		8	8
Nevada	6-12	6-18	6-12	12-18	15-21	15-21	15-21
North Dakota	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Ohio		6	6	6			6
Oregon	6-9	6-9	6-9	12-18	9-12	9-12	12-18
Texas	3-6	3-8	3-8		6-18	6-18	
Washington	3-6	3-6	3-6	3-6	3-6	3-6	3-6
Wisconsin	3-6	3-6	3-6	6-9	9	6-9	9
Wyoming	0-5	0-6	0-6	4-7	6-9	6-9	7-9

From WARTIME ROADS PROBLEMS

These are recommended or required thicknesses for the wearing courses and bases which are used in the above states.

III

TABLE B

RANGE IN ROAD FOUNDATION

Thickness (Sub-base Course) in Inches

<u>State</u>	<u>Soil Groups</u>						
	<u>A-1</u>	<u>A-2</u>	<u>A-3</u>	<u>A-4</u>	<u>A-5</u>	<u>A-6</u>	<u>A-7</u>
Alabama				0-4	0-10	0-10	0-10
Florida	0-6	0-6	0-6	0-6	12	12	12
Idaho				0-8	4-12	6-12	8-18
Illinois						12-24	12-24
Iowa				12-24		12	18-24
Maryland				6-12	12-24	12-24	12-24
Mississippi		12		12-18	18	15-21	21
New Hampshire		7-13	3	13-31		19	
North Dakota				2 1/2-12	2 1/2-12	2 1/2-12	5-21
Ohio				12-18	18		
Oregon	4-8	4-8	4-8	4-12	6-12	6-12	6-12
South Carolina				6	6-12		6-12
Tennessee					6-8	6-10	0-12
Texas						0-10	0-10
Washington	3-6	3-6	3-6	6-12	9-24	9-24	9-24
Wisconsin					0-15		0-15

From WARTIME ROAD PROBLEMS

These are recommended or required thicknesses of the sub base courses which are used in the above states.

IV

TABLE CVARIATION IN DEPTH OF BASE FOR FLEXIBLE WEARING SURFACES

	<u>Soil Groups</u>						
	A-1	A-2	A-3	A-4	A-5	A-6	A-7
Average range in Wearing Course and Base Thickness in Inches.	3.3-6.0	4.3-7.6	3.8-6.5	6.6-10.0	6.5-10.2	6.0-10.8	8.0-10.4
Min. - Max.	0-12	0-18	0-12	3-18	3-21	3-21	3-21
Average range in Sub-base Thickness in Inches.	0	5.2-9.0	0	8.2-13.6	7.8-14.9	8.6-15.5	3.2-16.4
Min.-Max.	0	0-13	0	0-31	0-24	0-24	0-24

From WARTIME ROADS PROBLEMS

This Table was determined from data appearing in Tables A and B.

	Northeastern States		Southeastern States		North Central States		Southwestern States	
	Unit Cost	Front Foot Cost	Unit Cost	Front Foot Cost	Unit Cost	Front Foot Cost	Unit Cost	Front Foot Cost
ing verage 12" Cut	1.00 cu.yd.	.50	.80 cu.yd.	.40	1.00 cu.yd.	.50	.90 cu.yd.	.45
ing se - Sand, Clay, ravel or equal aring Surface ouble Surface reatment	.90 sq.yd.	1.15	.80 sq.yd.	1.02	1.50 sq.yd.	1.92	.75 sq.yd.	.96
	.60 sq.yd.	.77	.50 sq.yd.	.64	.55 sq.yd.	.70	.60 sq.yd.	.77
and Gutter ment concrete, lled or straight iced	1.50 ln.ft.	1.50	1.35 ln.ft.	1.35	1.60 ln.ft.	1.60	1.40 ln.ft.	1.40
walks - Cement ncrete 4' x 4"	.32 sq.ft.	1.28	.30 sq.ft.	1.20	.40 sq.ft.	1.60	.30 sq.ft.	1.20
tary Sewer	3.00 ln.ft.	1.50	2.50 ln.ft.	1.25	3.00 ln.ft.	1.50	2.50 ln.ft.	1.25
m Sewer	3.50 ln.ft.	0.59	3.00 ln.ft.	.50	3.50 ln.ft.	.59	3.00 ln.ft.	.50
r	3.00 ln.ft.	1.50	2.50 ln.ft.	1.25	3.25 ln.ft.	1.63	2.50 ln.ft.	1.25
ting and Seeding		.35		.35		.35		.35
Subtotal		<u>9.14</u>		<u>7.96</u>		<u>10.39</u>		<u>8.13</u>
		1.37		1.19		1.56		1.22
		0.63		.59		.72		.56
Total		<u>11.14</u>		<u>9.70</u>		<u>12.67</u>		<u>9.91</u>

UNIT COST OF UTILITIESAs Reported by Kaiser Community HomesPANORAMA CITY, CALIFORNIAUnit Cost

Grading, excavation and compaction	0.35	cu. yd.
Streets (30' to 76' wide)		
Base (4" disintegrated granite)	0.36	sq. yd.
Wearing Surface (3" R. and O.)	0.90	sq. yd.
Curb and Gutters (concrete, 1' gutter)	1.25	ln. ft.
Sidewalk (4' x 3")	0.20	sq. ft.
Sanitary Sewer (8" vitrified clay)	1.40	ln. ft.
(6" vitrified clay)	1.30	ln. ft.
Manholes	175.00	each
Storm Sewer (It doesn't rain in California!)		
Water Mains (6" cast iron)	1.60	ln. ft.*
Service including meter	18.00	each
Fireplug	240.00	each
Landscaping (street trees)	3.00	each
Cost of unimproved land	3200.00	acre

Relationship of the lot improvement cost

to the total cost of the house and lot. 6%

* City installs mains for \$0.80 per front foot. This is considerably less than actual cost.

VII

UNIT COST OF UTILITIES

As Reported by William G. Farrington

HOUSTON, TEXAS

	<u>Unit Cost</u>
Grading	0.40 cu. yd.
Streets (27' and 36' wide)	2.35 sq. yd.
Base (5" cone - reinforced at expandable joints)	
Wearing Surface*	
Curb and Gutters (monolithic with street)	0.50 ln. ft.
Sidewalk (4' - 4")	0.60 sq. ft.
Sanitary Sewer (10" vitrified clay)	1.80 ln. ft.
8" vitrified clay	1.60 ln. ft.
6" vitrified clay)	1.40 ln. ft.
Manholes	145.00 each
Storm Sewer	
36"	7.95 ln. ft.
30"	6.25 ln. ft.
24"	4.70 ln. ft.
18"	3.45 ln. ft.
15"	2.70 ln. ft.
Manholes	160.00 each
Catchbasin	90.00 each
Water Mains	
12"	4.50 ln. ft.
8"	3.90 ln. ft.
6"	3.30 ln. ft.
Fireplug	150.00 each
Landscaping	
Cost of unimproved land	2000.00 to 2500.00 acre
Relationship of the lot improvement cost to the total cost of the house	<u>12%</u>

* Typical paving used in residential areas here is 5" shell concrete with 1/4" monolithic wearing surface of cement topping. Curb and gutters are poured monolithic with street and finished with cement topping.

VIII

UNIT COST OF UTILITIES

As Reported by the Byrne Organization

HARUNDALE, MARYLAND

		<u>Unit Cost</u>
Grading		\$ 0.75 cu. yd.
Street (26' - 36' wide)		1.75 sq. yd.
Base (stone)		
Wearing Surface (3" macadem)		
Curb and Gutters (concrete)		1.25 ln. ft.
Sidewalk (3' x 4")		0.50 sq. ft.
Sanitary Sewer	15" vitrified clay	2.90 ln. ft.
	12" vitrified clay	2.40 ln. ft.
	10" vitrified clay	2.10 ln. ft.
	8" vitrified clay	1.80 ln. ft.
Manholes		160.00 each
Storm Sewers	30"	7.35 ln. ft.
	24"	5.40 ln. ft.
	18"	3.95 ln. ft.
	15"	3.25 ln. ft.
Manholes		175.00 each
Catchbasin		100.00 each
Water Mains	8"	3.40 ln. ft.
	6"	3.00 ln. ft.
Fireplugs		125.00 each
Landscaping		25.00 per lot
Cost of unimproved land	2000.00 to 3000.00	per lot
Relationship of the lot improvement cost to the total cost of the house		<u>8 %</u>

UNIT COST OF UTILITIESAs Reported by Place and CompanySOUTH BEND, INDIANA

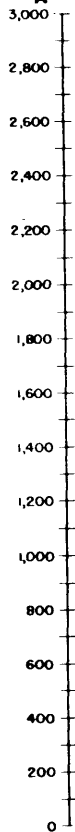
		<u>Unit Cost</u>
Grading		\$ 0.90 cu. yd
Street (28' wide)		0.50 sq. yd.
Base (6" stone)		
Wearing Surface (macadem)		1.10 sq. yd.
Curb and gutters (concrete)		1.00 ln. ft.
Sidewalk (4' x 4")		0.40 sq. ft.
Sanitary Sewer	12" vitrified clay	2.70 ln. ft.
	10" vitrified clay	2.30 ln. ft.
	8" vitrified clay	2.10 ln. ft.
Manholes		175.00 each
Storm Sewer	24"	6.20 ln. ft.
	18"	4.30 ln. ft.
	15"	3.50 ln. ft.
Manholes		175.00 each
Catchbasin		100.00 each
Water Mains	8"	3.30 ln. ft.
	6"	2.90 ln. ft.
Fireplug		150.00 each
Landscaping (street trees)		5.00 each
Cost of unimproved land		2500.00 acre
Relationship of the lot improvement cost to the total cost of the house		Not Available

COMPUTING CHART

TO FIND THE TOTAL COST OF AN IMPROVED LOT (RAW LAND AND STREET IMPROVEMENTS)

**COST OF
RAW LAND
DOLLARS PER ACRE**

**SCALE
A**



— INSTRUCTIONS —

LAY STRAIGHT EDGE ACROSS SCALES "A", "B", "C", "D" AND "E" SO THAT IT CROSSES SCALE "A" AT THE POINT REPRESENTING THE COST OF RAW LAND PER ACRE, AND CROSSES SCALE "B" AT THE POINT REPRESENTING THE COST OF STREET IMPROVEMENTS PER FRONT FOOT. THE READING AT THE POINT WHERE THE STRAIGHT EDGE CROSSES SCALE "C" INDICATES THE TOTAL COST OF AN IMPROVED 50 FT BY 100 FT LOT; WHERE THE STRAIGHT EDGE CROSSES SCALE "D", INDICATES THE TOTAL COST OF AN IMPROVED 60 FT BY 120 FT LOT; WHERE THE STRAIGHT EDGE CROSSES SCALE "E", INDICATES THE TOTAL COST OF AN IMPROVED 70 FT BY 140 FT LOT.

EXAMPLE WHERE THE COST OF RAW LAND IS \$900 PER ACRE, AND THE REQUIRED IMPROVEMENTS COST \$7 PER FRONT FOOT — PLACE THE STRAIGHT EDGE ON SCALE "A" AT \$900 AND SCALE "B" AT \$7.

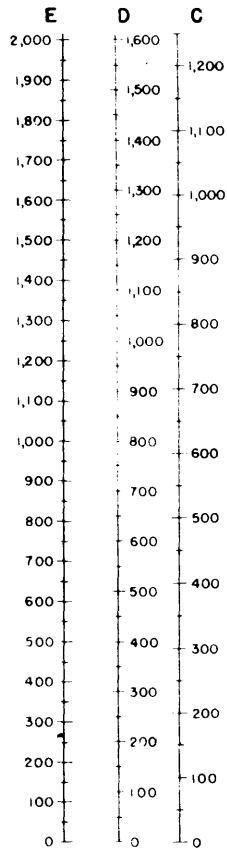
FOR 6 LOTS PER ACRE - 50'X100' - , READ ON SCALE "C" \$500, THE COST OF AN IMPROVED LOT

FOR 4.2 LOTS PER ACRE - 60'X120' - , READ ON SCALE "D" \$630, THE COST OF AN IMPROVED LOT.

FOR 3.1 LOTS PER ACRE - 70'X140' - , READ ON SCALE "E" \$780, THE COST OF AN IMPROVED LOT.

**TOTAL COST - DOLLARS PER LOT
INCLUDING RAW LAND & STREET IMPROVEMENTS
70'X140' 60'X120' 50'X100'**

**SCALE SCALE SCALE
E D C**



— NOTE —

IN THIS CHART APPROXIMATELY 25% OF THE GROSS ACREAGE IS ALLOWED FOR PUBLICLY DEDICATED LAND.

LOT SIZE	NET LOTS PER ACRE
50' X 100'	= 6.0
60' X 120'	= 4.2
70' X 140'	= 3.1

IN ARRIVING AT THE TOTAL COST OF EACH IMPROVED LOT AN ALLOWANCE MUST BE ADDED TO THE FRONT FOOT COST FOR THE INSTALLATION OF IMPROVEMENTS IN THE CROSS STREETS ON WHICH NO LOTS FACE. THIS ALLOWANCE WILL VARY FROM 12% TO 40% DEPENDING ON THE LENGTH AND WIDTH OF BLOCKS.

AN ADDITIONAL ALLOWANCE FOR RAW LAND COST SHOULD BE MADE WHERE LARGE PARK AREAS ARE DEDICATED.

**COST OF
STREET IMPROVEMENTS
DOLLARS PER FRONT FOOT**

**SCALE
B**

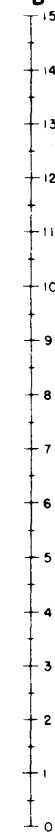


TABLE 11. LAND AREA OF ALL NEIGHBORHOOD COMMUNITY FACILITIES
Component Uses and Aggregate Area, by Type of Development and Population of Neighborhood^a

TYPE OF DEVELOPMENT	NEIGHBORHOOD POPULATION				
	1,000 persons 275 families	2,000 persons 550 families	3,000 persons 825 families	4,000 persons 1,100 families	5,000 persons 1,375 families
ONE- OR TWO-FAMILY DEVELOPMENT^b					
<i>Area in Component Uses</i>					
1) Acres in school site.....	1.20	1.20	1.50	1.80	2.20
2) Acres in playground.....	2.75	3.25	4.00	5.00	6.00
3) Acres in park.....	1.50	2.00	2.50	3.00	3.50
4) Acres in shopping center.....	.80	1.20	2.20	2.60	3.00
5) Acres in general community facilities ^c.....	.38	.76	1.20	1.50	1.90
<i>Aggregate Area</i>					
6) Acres: total.....	6.63	8.41	11.40	13.90	16.60
7) Acres per 1,000 persons.....	6.63	4.20	3.80	3.47	3.32
8) Square feet per family.....	1,050	670	600	550	530
MULTI-FAMILY DEVELOPMENT^d					
<i>Area in Component Uses</i>					
1) Acres in school site.....	1.20	1.20	1.50	1.80	2.20
2) Acres in playground.....	2.75	3.25	4.00	5.00	6.00
3) Acres in park.....	2.00	3.00	4.00	5.00	6.00
4) Acres in shopping center.....	.80	1.20	2.20	2.60	3.00
5) Acres in general community facilities ^c.....	.38	.76	1.20	1.50	1.90
<i>Aggregate Area</i>					
6) Acres: total.....	7.13	9.41	12.90	15.90	19.10
7) Acres per 1,000 persons.....	7.13	4.70	4.30	3.97	3.82
8) Square feet per family.....	1,130	745	680	630	610

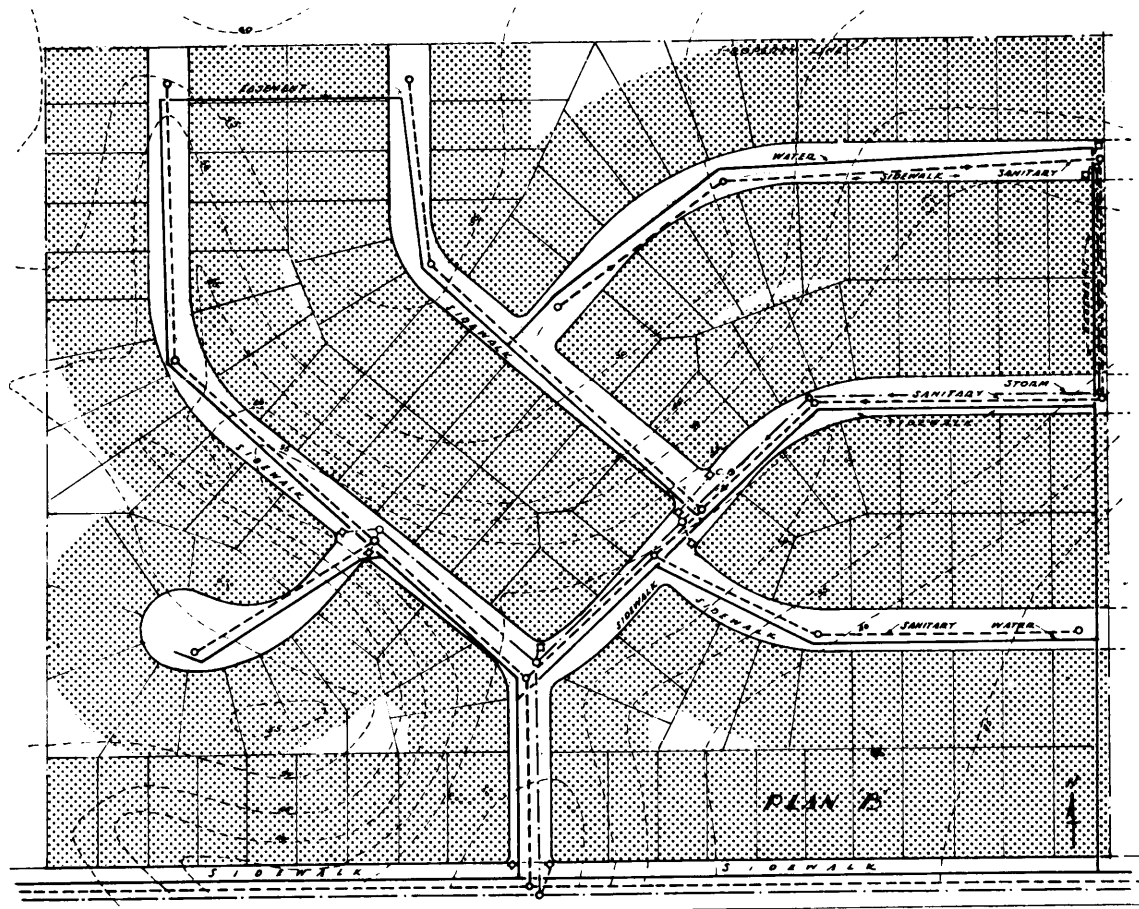
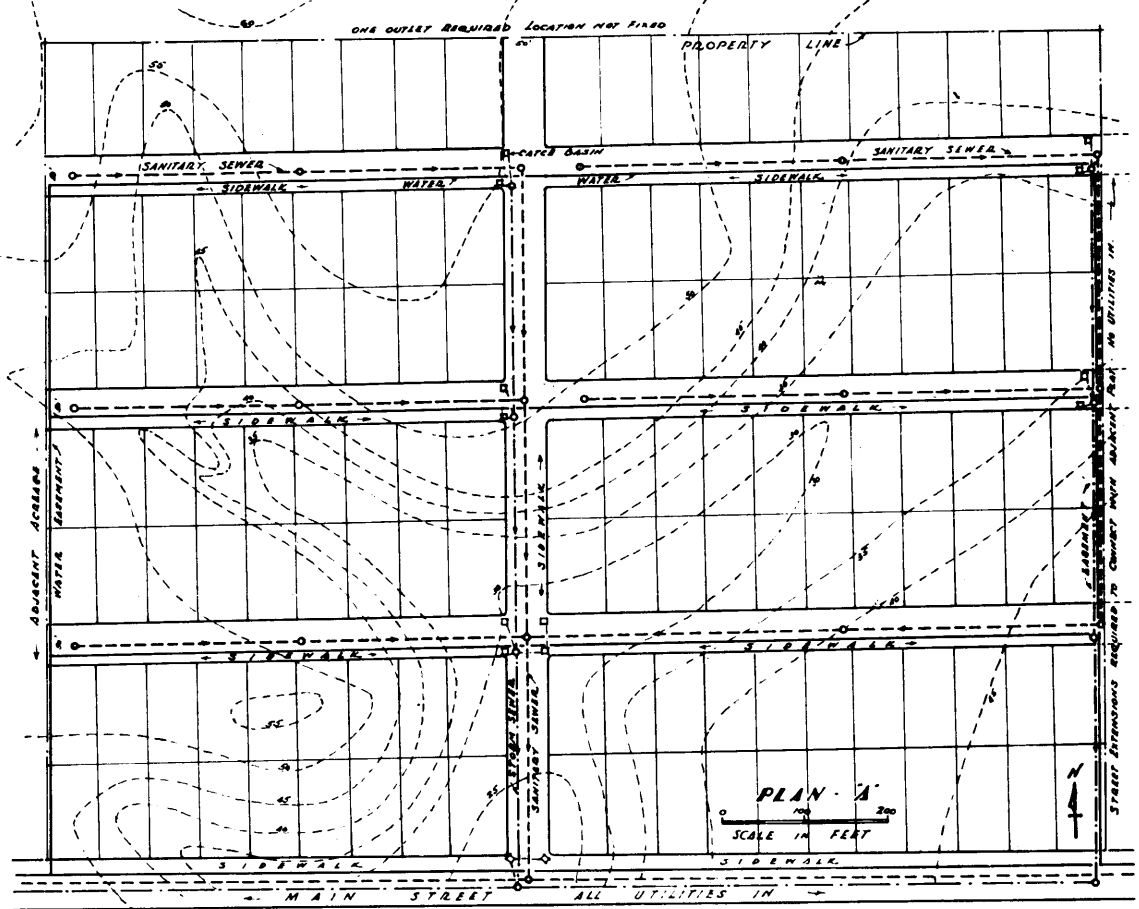
^a This table combines the recommended or assumed values of Tables 7-10.

^b With private lot area of less than ¼ acre per family (for private lots of ¼ acre or more, park area may be omitted).

^c Allowance for indoor social and cultural facilities discussed in Section 22 (church, assembly hall, etc.) or separate health center, nursery school, etc., unallocated above. Need will vary locally.

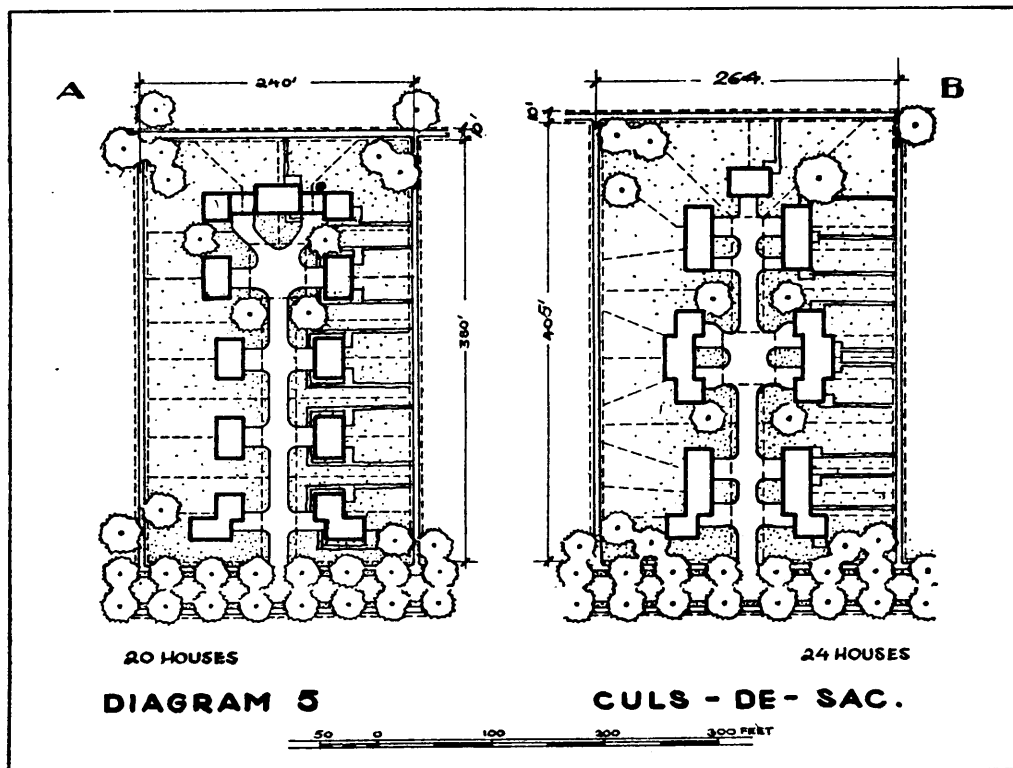
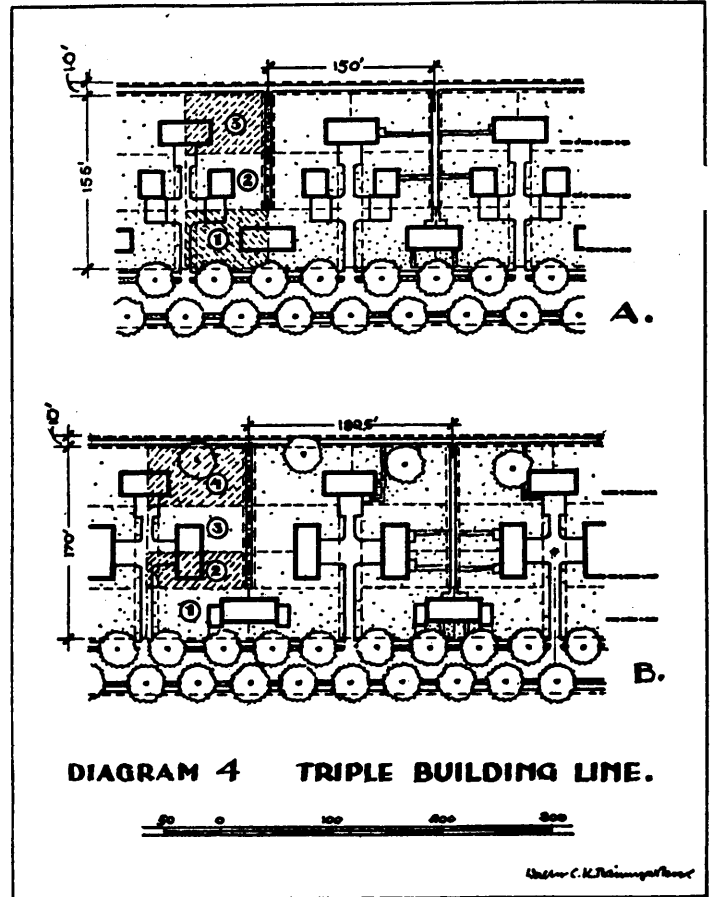
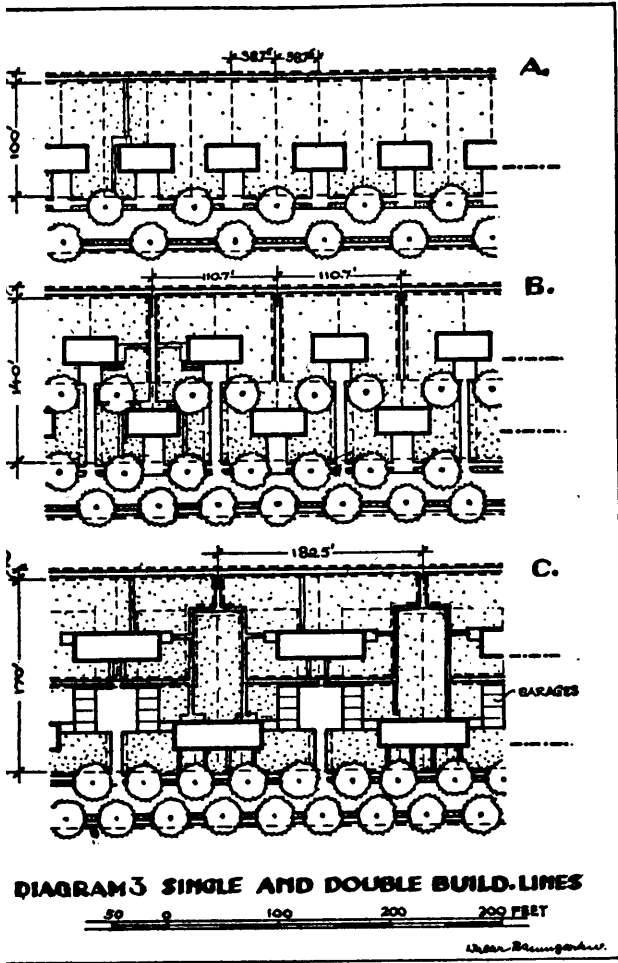
^d Or other development predominantly without private yards.

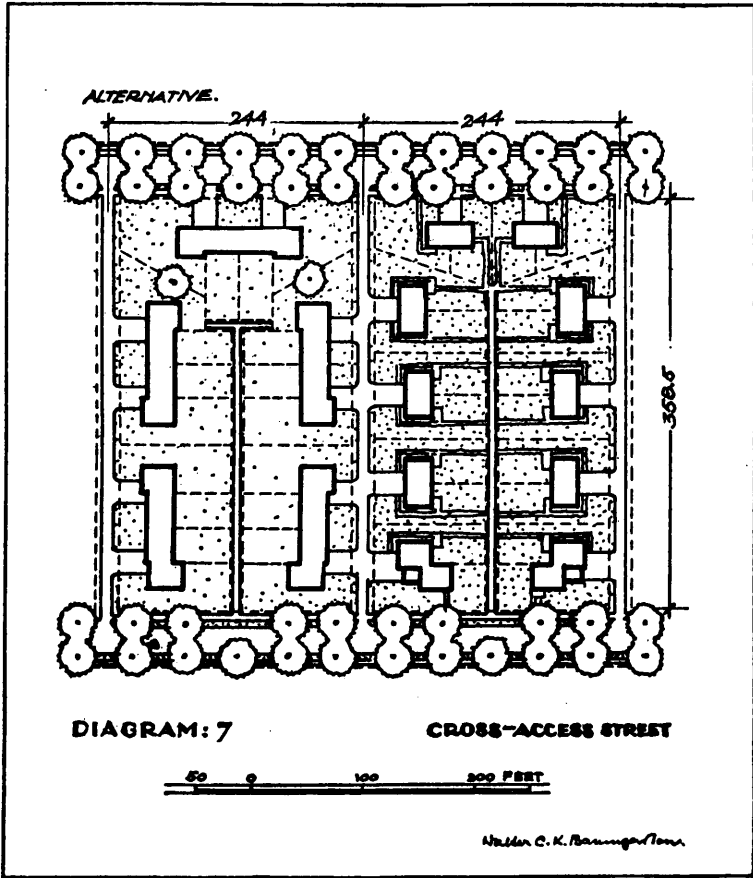
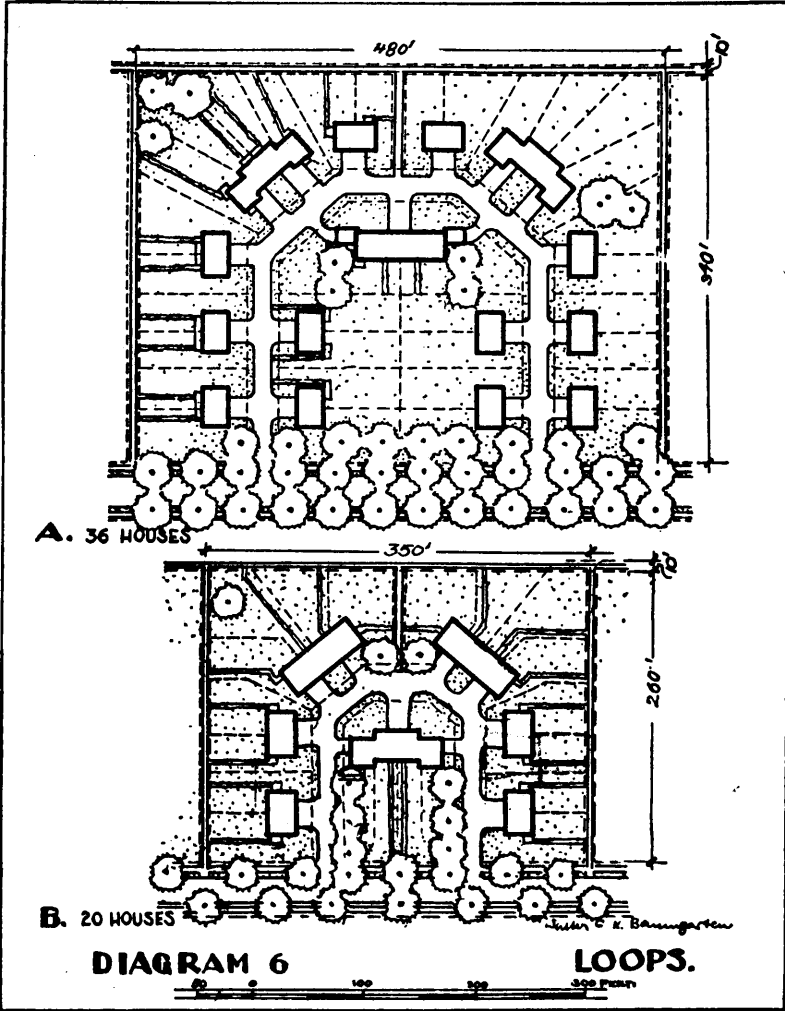
THE RELATIONSHIP BETWEEN AREA SERVED AND NUMBER OF LOTS



Shaded area is the area served.
From IRRAN LAND

HOUSE ARRANGEMENT IN RELATIONSHIP TO THE STREET





BIBLIOGRAPHY

- Adams, Thomas, The Design of Residential Areas, Cambridge, Harvard University Press, 1931.
- American Public Health Association Committee on the Hygiene of Housing, Planning the Neighborhood, 1948
- American Road Builders' Association, Report of the Committee on Concrete Pavement Design, Subgrade Soil Practices, Washington, 1947.
- American Society of Civil Engineers, Committee on Land Subdivision Manual, New York, The Society, 1939.
- Bell, J. Franklin, "A City Block, How Long, How Wide?", American City, May 1929.
- Boyd, John Taylor, Jr., "How Intensively Must We Use the Land?", American City, November 1927.
- Bruce, Arthur G., Highway Design and Construction, Scranton, International Textbook Company, 1934.
- Clark, Charles D., "Federal Housing Administration Standards for Land Subdivision", Planners' Journal, September-October 1938.
- Community Builders' Council of the Urban Land Institute, The Community Builders' Handbook, Washington, 1947.
- Farm Security Administration, Architectural Forum, January 1941.
- "Greenbelt Towns", Architectural Record, September 1936.
- Hardenbergh, W. A., Water Supply and Purification, Scranton, International Textbook Company, 1938.
- --- ---, Sewerage and Sewage Treatment, Scranton, International Textbook Company, 1942.
- Highway Research Board, Wartime Road Problems - Number 8 - "Thickness of Flexible Pavements for Highway Roads", Washington, 1943

BIBLIOGRAPHY
(Continued)

- Hill, Hoover, Heckler, Kohankie, "Planning War Housing",
Architectural Forum, May 1942
- Hubbard, Henry V., "The Influence of Topography on the Layout
of Land Subdivision", Landscape Architecture,
April 1928.
- Klaber, Eugene H., "Land Planning Methods Compared", American
City, December 1941.
- Mayer, Albert, "A technique for Planning Complete Communities",
Architectural Forum, January 1937.
- Peets, Elbert, "Site Planning for Livability", American City,
October 1941.
- Pulver, H. E., Construction Estimates and Costs, Hill Book
Company, New York, 1940.
- President's Conference on Home Building and Home Ownership,
Report of, Planning for Residential Districts,
Washington, 1932.
- Rosenauer, Michael, "Site Plan Considerations in Public Housing
Projects", Landscape Architecture, October 1941.
- U.S. Federal Housing Administration, Land Planning Bulletin No.
2, Washington.
- U.S. Federal Housing Administration, Title II of the National
Housing Act, Washington, Government Printing Office,
1939.
- U.S. Federal Housing Administration, Successful Subdivisions
Planned As Neighborhoods for Profitable Investment
and Appeal to Home Owners, Washington, Government
Printing Office, 1941.
- U.S. Federal Housing Administration, Better Subdivisions Mean
Better Homes, Insured Mortgage Portfolio, First
Quarter 1941.
- Walker, Hale J., "Some Major Technical Problems Encountered in
the Planning of Greenbelt, Maryland", Planners'
Journal, March-April 1936.

BIBLIOGRAPHY
(Continued)

Whitten, Robert, and Adams, Thomas, Neighborhoods of Small Homes, Cambridge, Harvard University Press, 1931.

Wright, Henry, "Wanted: A Substitute for the Gridiron Street System", American City, March 1930.
