The Fiscal Impacts of Alternative Single Family Housing Densities: *Infrastructure Costs*

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Acknowledgements

Aligning the behavior of township officials, developers, realtors, homeowners and others involved in land development decision making toward smart growth principles is an important objective of land use policy reform advocates in Michigan. This goal was embraced by the Michigan Land Use Leadership Council (MLULC), empanelled by Governor Jennifer Granholm, and the subsequent report of the Council in 2003. The report calls for greater understanding of the benefits of smart growth and the encouragement of such practices. One of the critical issue areas where more information is needed is the benefits associated with denser development patterns. More precisely, the long-term infrastructure and other public costs of large lot development patterns are not well understood. This report focuses on the implications of denser single family home development patterns for infrastructure costs.

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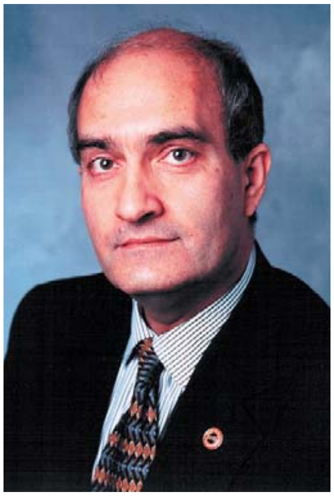
About the Authors

Mohammad Najafi



Dr. Mohammad Najafi, P.E., is Director of the Center for Underground Infrastructure Research and Education (CUIRE) at Michigan State University. He has completed his Doctoral education in Civil Engineering from Louisiana Tech University and M.S. and B.S. both in Civil Engineering from Purdue University and Texas Tech University respectively. From 1976 to 1987, for more than 12 years, he worked with several construction companies on multi-million dollar projects in positions of project engineer and project manager. From 1990 to 1993, he was Program Manager of the Trenchless Technology Center (TTC) at Louisiana Tech University, on numerous research and consulting assignments. From 1993 to 2001, he was Assistant and Associate Professor with tenure of Construction Engineering Technology at Missouri Western State University, St. Joseph, Missouri. From 2001 to 2002, he was Visiting Associate Professor at the Department of Civil and Environmental Engineering at the University of Missouri – Columbia and Director of the Trenchless Research and Development Center (TRDC). Currently he is area editor for pipelines for the American Society of Civil Engineers (ASCE) *Journal of Transportation Engineering.* His interest area is in infrastructure asset management and innovative technologies for underground infrastructure construction and renewal. He is active with ASCE in developing several manual of practices and guidelines specifications.

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William Rustem

Mr. Bill Rustem is the President and CEO of Public Sector Consultants, Inc. (PSC) and Co-Principal Investigator of the People and Land Cluster of the W.K. Kellogg Foundation. Mr. Rustem has a Bachelor of Science degree in Social Science and a Master of Science degree in Resource Development from MSU. He was Governor William G. Milliken's Chief Staff Advisor on environmental matters and Interim Director of the Toxic Substances Control Commission. Following his service with the State of Michigan, Mr. Rustem became the first Executive Director of the newly established Center for the Great Lakes in Chicago and then joined the Michigan United Conservation Clubs as Director of Development. He co-chaired the 1980 campaign to shift education funding from the property tax to other sources and coordinated the 1984 statewide campaign for the constitutional amendment creating a Michigan Natural Resources Trust Fund. Since joining Public Sector Consultants, he has directed studies on the status of Michigan cities, wastewater treatment needs, recycling, and land use. Mr. Rustem holds special expertise in public policy relating to land use, urban development, and water policy. He is an adjunct professor in three colleges at Michigan State University, and has chaired or been the principal staff for statewide task forces on Department of Natural Resources organization, the MSU Museum, wetland protection, and the Michigan Land Use Leadership Council.

The Fiscal Impacts of Alternative Single family Housing Densities: Infrastructure Costs

Executive Summary

In the realm of land use issues, "density" is a loaded term. It has a negative connotation for those people who do not want to live too closely together. It is seen in a positive light by people who are concerned about the provision of municipal services, traffic congestion, and walkability of their neighborhoods. Density means different things to different people. Trying to achieve high density without regard to design and impact on a community could be problematic. However, high density does have its benefits.

This report analyzes one aspect of density and its relationship to the way we live. It investigates how high and low density single family housing development influences the cost of providing services to residents, particularly water, sewer, and transportation services. The construction, operation, and maintenance costs of these valuable infrastructures are taken into account in this analysis, providing a comprehensive look at life cycle costs of service provision. It should be noted that this analysis is limited to those subdivisions that are within local government public service boundaries and to the three public services listed above (e.g. storm water infrastructure was not included in this analysis). Eight case studies across Michigan, including both a high and low density development in each community, provide a real comparison of these specific costs. While the developments are real, standard infrastructure measurements and materials are used to isolate the differences that density causes.

The analysis shows that the length of the infrastructure for roads, sewer and water provided to each unit increases with lot size. Subsequently, the *cost* of building these types of infrastructure increases with lot size. It should be noted that the cost of constructing public service infrastructure is not always borne by the local government, but sometimes by the developer, and thus homeowners. The net present value of life cycle costs (including construction, operation, and maintenance up until replacement age) also increases with the lot size of each unit. Finally, the study shows that, while annual life cycle costs for provision of sewer and water increase as lot size increases, the annual user fees for sewer and water actually *decrease* for the case study communities. Although there is no physical or economic reason why it should be so, owners of large lots appear to pay lower user fees for public services than owners of small lots. User fees are not solely based on the infrastructure, or the density requiring different lengths of infrastructure; other factors are often considered in the setting of user fees. In communities where this pattern of pricing exists, it suggests that large lots are less fiscally sustainable than small lots on revenue grounds, as well as on cost grounds.

In a preliminary examination of Meridian Township, Michigan, results suggested that higher property values were statistically correlated with smaller lots, holding other factors constant. This relationship suggests the potential for smaller lots, or higher density, to pay off for local units of government, since property tax revenues are based on property values. To the extent that the provision of non-infrastructure services (e.g. police and fire protection) realize this inverse relationship between lot size and taxable value, municipalities can also benefit from higher density development on the revenue side. Further analysis of the impact of density on non-infrastructure costs and revenues is needed.

Due to the positive relationship between smaller lots and fiscal health, both from a cost and revenue perspective, this report recommends that consideration be given to density in the drafting of Master Plans and the approval of neighborhood developments. Additional benefits of high density development (e.g. alleviation of traffic congestion, availability of walking opportunities), as well as disadvantages, must also be analyzed and considered in development decisions. Finally, design is a major factor in ensuring that high density development meets the needs and desires of residents.

Another main issue to emerge from this study is the degree to which local jurisdictions in Michigan lack asset management systems. The degree to which data were not available on either the physical extent of infrastructure or the costs for maintaining and replacing these infrastructures makes it difficult to understand the relationship between public service provision, public revenues and residential density. With this in mind, future research is recommended to increase the capacity for local jurisdictions to perform detailed fiscal impact analysis by investing time and thought into appropriate asset management systems.

Other important areas of research were made apparent through this analysis. In addition to infrastructure costs, there are a host of fiscal impact multipliers associated with density that are required to fully analyze the effects of local development policy. Among these multipliers are the number of jobs created per investment dollar, new treatment plant requirements, school expenditures, etc. Updating these multipliers and making them specific to Michigan is of critical importance. These multipliers can be used to develop a methodology for jurisdictions to perform comprehensive fiscal impact analysis.

In addition, a fiscal impact analysis of the different impacts of residential property versus commercial, industrial, farmland, and open space on local government costs and revenues is needed to determine whether certain types of land use “subsidize” others. Finally, it is important to note that the results of this study are not applicable to houses that have septic tanks, wells, and private roads. Further analysis with the inclusion of these types of residential development, as well as larger lot sizes, would be valuable to local governments, particularly in the suburban and rural areas of Michigan.

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1.0 Introduction

Throughout Michigan, new residential developments are emerging every day, many in towns and communities that do not have sufficient infrastructure in place to accommodate the needs of new businesses and residences. To support each new development, developers and local governments have to construct new roads, expand sewer and water lines, and provide other infrastructure and public services to new residents. However, financing the construction and maintenance of new infrastructure has become a contentious issue due to the various demands placed on local government budgets. Thus, there have been calls on local governments to ensure that new developments generate sufficient tax revenues to cover the costs of the new services that they require.

1.1 Background

The fiscal impacts of new developments on local governments depend on the type of development. For instance, costs relative to revenue for single family homes have been shown to be higher than that of different housing categories, such as townhouses, apartments, or assisted living facilities, as well as industrial and commercial facilities. Further, with the category of single family homes, the density of development can affect the costs of road construction and sewer and water lines, and the economies of scale for providing services such as police, fire protection, libraries, and recreational park services. However, information on the additional financial burden placed on the community to support single family residential development is lacking. This report is a preliminary step toward filling this gap in knowledge in Michigan. In particular, this report attempts to understand the fiscal implications of building single family homes at alternative densities within public service boundaries.

1.2 Project Objective

The objective of this study is to ascertain how the costs of certain infrastructure improvements vary with the density of single family residential development. Specifically, this study examines how capital and life-cycle costs of roads and sewer and water lines vary with density, or lot size. The report examines only on-site costs, that is, the costs for infrastructure located within subdivisions. It should be noted that this analysis is limited to those subdivisions that are within the local government public service boundary (i.e. on public sewer, water and road lines). In addition, the report takes an initial look at how density might impact the revenues that accrue to the community through public service user fees and property tax revenues.

This report begins with a look at existing literature and previous studies that have analyzed the relationship between residential density and public service provision. Next, an analysis of eight communities in Michigan, or sixteen subdivisions, compares costs and revenues between high and low density developments. Following this analysis is a preliminary study of the relationship between lot size and the taxable value of a home and its associated property (i.e. public revenue). The conclusion provides a summary of the project findings, recommendations for state and local governments and suggestions for further research.

2.0 Literature Review

The costs associated with low density and discontinuous development have attracted extensive research, particularly with regard to the costs of infrastructure. Among the early studies, Isard and Coughlin (1957) found that costs per lot for sewer lines and roads increase with average lot size. Similar results have been reported by Downing et al. (1969; 1974). Archer (1973) found that leapfrogging development in Lexington, Kentucky, increased costs to the public compared with other types of developments. Similarly, the Real Estate Research Corporation (RERC, 1974) found that compact and continuous development reduced the costs of providing utility services. Kelly (1993) and Ewing (1994) reported that using existing infrastructure reduced costs and increased efficiency. Others who have noted higher costs associated with additional low density development infrastructure include Dougharty et al. (1975), Frank (1989), and Speir and Stephenson (2002).

Some researchers believe that what is called sprawl (low density development) is an efficient outcome of market forces at work (Richardson & Gordon, 1993). Others criticize the studies that show that sprawl results in additional costs. Windsor (1979), for instance, believes that the cost savings discovered in the RERC (1974) study are a result of incorrect assumptions about the type of housing, construction standards, and the socioeconomic status of residents in urban neighborhoods. Peiser (1984) found that there is not much difference in costs between communities with "planned" and "unplanned" growth, though he did not investigate the effect that lot size might have had on his results. Ladd (1992) showed that costs could actually increase with higher density.

Much of the literature has tended to combine on- and off-site costs when analyzing the costs of sprawl. This practice most likely reflects the fact that on-site infrastructure eventually becomes the property of local governments that are then responsible for maintenance, repair, and replacement; thus, it is reasonable to combine these costs with off-site costs (Nelson and Duncan, 1995). This practice was reinforced by the fact that after the 1980s, local governments were forced to take on more responsibility for the provision and maintenance of infrastructure because the federal government scaled back its subsidies (Nelson and Duncan, 1995). Grouping on- and off-site costs would therefore appear to be a reasonable approach for researchers attempting to understand how the costs of sprawl affect local government finances.

However, such an approach masks the effects of lot size on on-site infrastructure costs because many of the fixed costs included in such analyses might not be as sensitive to density in on-site infrastructure costs. This report aims to specifically understand how on-site costs for certain infrastructures vary with density. It updates previous studies, such as by Isard and Coughlin (1957), and improves on those studies by using actual construction information and by determining life-cycle costs. This report also lays the groundwork for future studies on determining how a community may "subsidize" the supply and maintenance of infrastructure for single family residential developments.

3.0 Data and Methodology

This report employs a case study approach to understand how the costs of roads and sewer and water lines vary with density. Because of logistical and financial constraints, the study is limited to eight communities across six regions (southeast, southwest, central, northeast, northwest, and Upper Peninsula) in Michigan. Within each community, two developments of different densities were examined.

3.1 Selection criteria for Communities and Subdivisions

Identifying communities and subdivisions for analysis was challenging. Many communities do not collect, maintain, or have access to the information necessary to perform the analysis. Thus, the final list of communities and subdivisions selected for study was partially determined by the availability of data. Nonetheless, two criteria were borne in mind when selecting communities and subdivisions within them for analysis:

- The community is experiencing growth or is an important urban center or suburb.
- The community contains a pair of subdivisions such that one could be considered low and the other considered high density. Furthermore, the two subdivisions in each community should:
    - Be approximately of the same size in terms of the number of lots.
    - Be approximately of the same socio-economic status.
    - Contain approximately the same number of single family homes.
    - Be of approximately the same age.
    - Be serviced by public sewer and water.

Subdivisions were designated low or high density based on lot sizes related to the other subdivision selected in the community. Whether a subdivision was considered low or high density, however, is not important for the analysis. In the results to be presented, lot size is treated as a continuous variable that ranges from small to large.

Using these criteria, and working within the constraints of data availability, the following eight communities were selected:

1. Alpena Township, Alpena County.
2. Canton Township, Wayne County.
3. City of Kentwood, Kent County.
4. City of Marquette, Marquette County.
5. City of Troy, Oakland County.
6. Garfield Township, Grand Traverse County.
7. Lincoln Township, Berrien County.
8. Meridian Township, Ingham County.

The subdivisions selected from these communities for further study are shown in Table 3.1 along with basic data on each.

Table 3.1: Basic Data on Selected Communities and Subdivisions

Region*	County	Jurisdiction	Subdivision	No. of Units	Average Density (Acres/Lot)	Density
NW	Grand Traverse	Garfield	Silver Lake Farms #2	44	0.50	Low
			Stone Ridge #2	47	0.35	High
NE	Alpena	Alpena	Wyndham Gardens	25	0.85	Low
			Forest Hills	21	0.33	High
CL	Ingham	Meridian	Ember Oaks	34	0.79	Low
			Whispering Oaks	36	0.30	High
SW	Berrien	Lincoln	Hidden Pines	40	0.44	Low
			Alabaster 2 and 3	43	0.30	High
SE	Wayne	Canton	Kimberly Meadows	126	0.49	Low
			Lexington Square	77	0.19	High
SE	Oakland	Troy	Somerset North	61	0.38	Low
			Long Lake Meadows #2	44	0.25	High
SW	Kent	Kentwood	Princeton Estates #14	33	0.27	Low
			Bailey's Grove #22	25	0.17	High
UP	Marquette	Marquette	Premeau's Peak*	17	0.91	Low
			Granite Pointe*	53	0.44	High

*NW—Northwest; NE—Northeast; SE—Southeast; SW—Southwest; CL—Central; UP—Upper Peninsula

3.2 Type of Information Collected

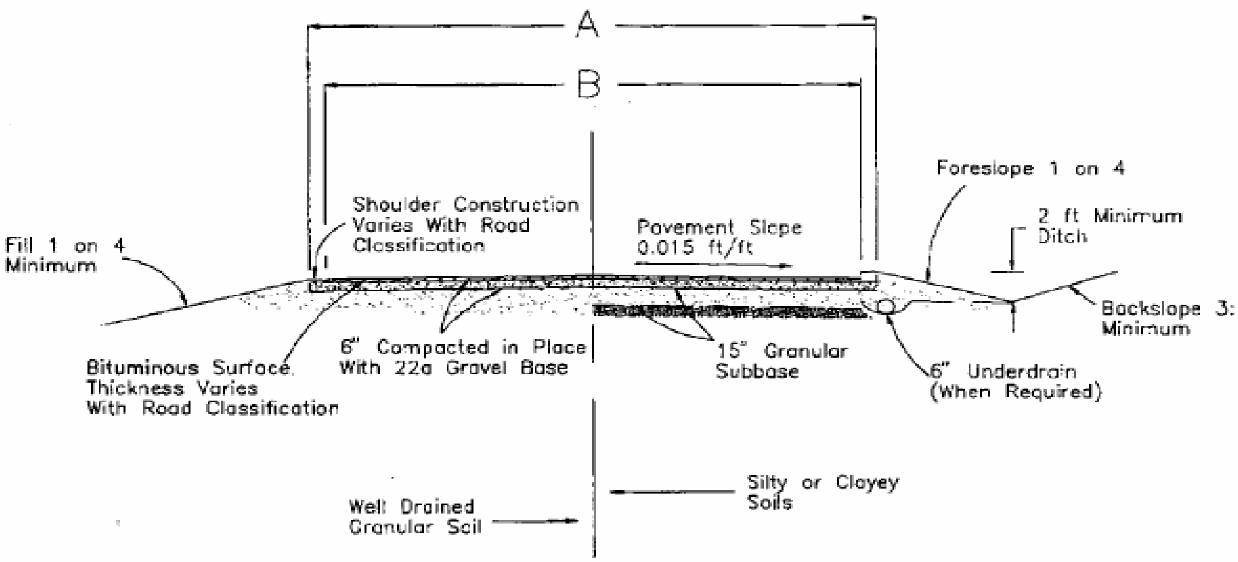
Information was collected on the physical dimensions and structural characteristics of roads and sewer and water lines within each subdivision that was examined. With regard to sewer and water lines, only information on the main lines was collected, that is, lateral extensions from the main lines to each house are not included in this analysis.[1] The following information was obtained for each subdivision:

1. Total length of roads.
2. Right-of-way of roads (different roads and streets may have specific requirements for right-of-ways).
3. Structural characteristics of roads.
4. Total length of pipes used for sewer and water lines.
5. Diameter of pipes used for sewer and water lines.
6. Structural characteristics of pipes used for sewer and water lines.

Basic information for the roads was obtained from the typical road cross section drawings from each of the case study communities. Three examples of these drawings are provided in Figures 3.1 through 3.3).

Figure 3.1: Typical Cross Section of the Grand Traverse County Road

Typical Road Cross Section



ROAD CLASSIFICATIONS	A	B
Alleys	20'(6m)	18'(5.5m)
Residential	32'(10m)	30'(9m)
Local Access (1)	34'(11m)	32'(10m)
Commercial	36'(11m)	34'(11m)
Industrial	42'(13m)	40'(12m)
Secondary Collector	42'(13m)	40'(12m)
Principal Collector	56'(17m)	54'(16m)
Local Arterial	71'(22m)	69'(21m)

(1) = Pavement widths of local access roadways with less than 5% grades may be 22 feet with a 25 foot transition required for paved shoulders. (Except in Subdivisions)

Figure No. 1

GRAND TRAVERSE COUNTY ROAD COMMISSION
3949 SILVER LAKE ROAD
TRAVERSE CITY, MI. 49684

ev. 3/97

Figure 3.2: Cross Section of the Silver Lake Farms No. 2 Road

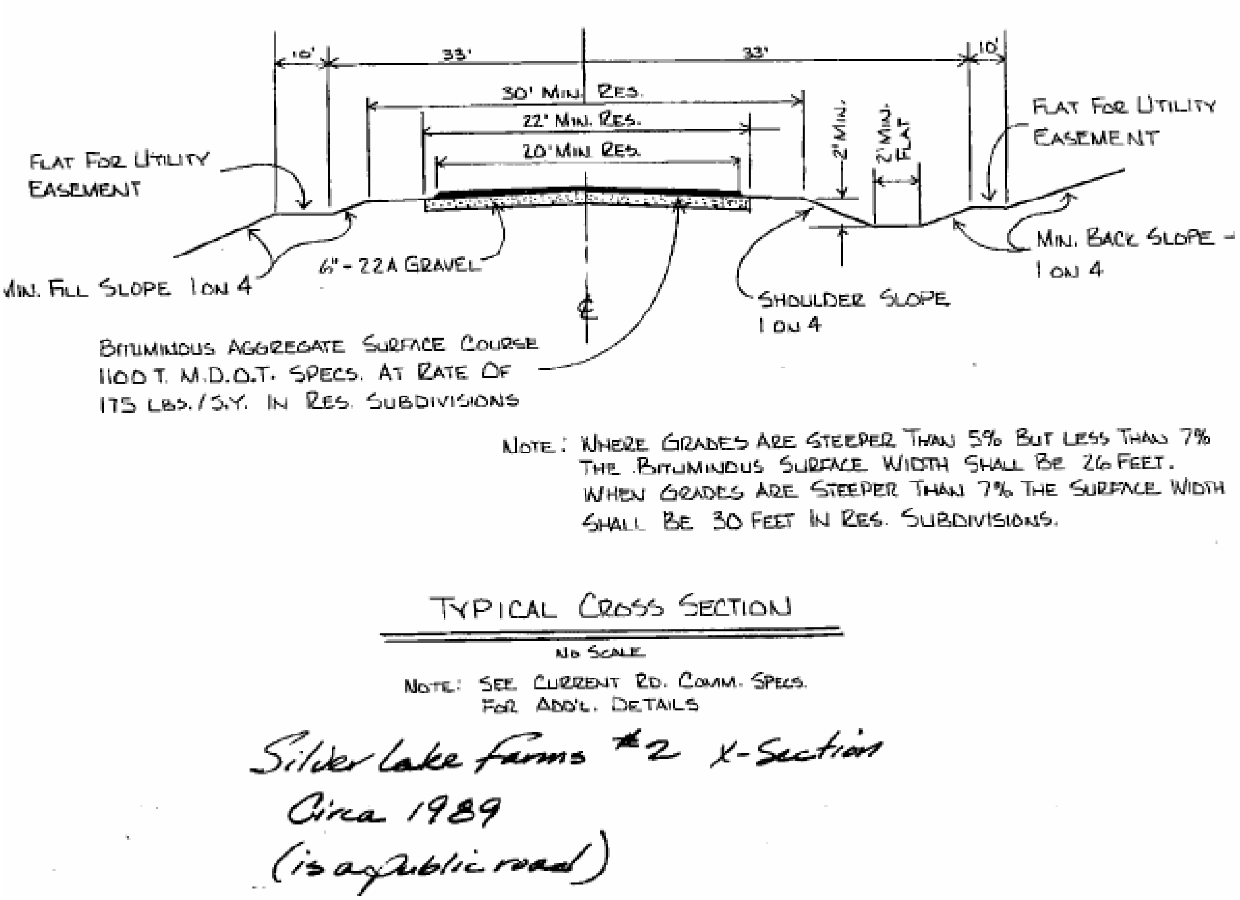
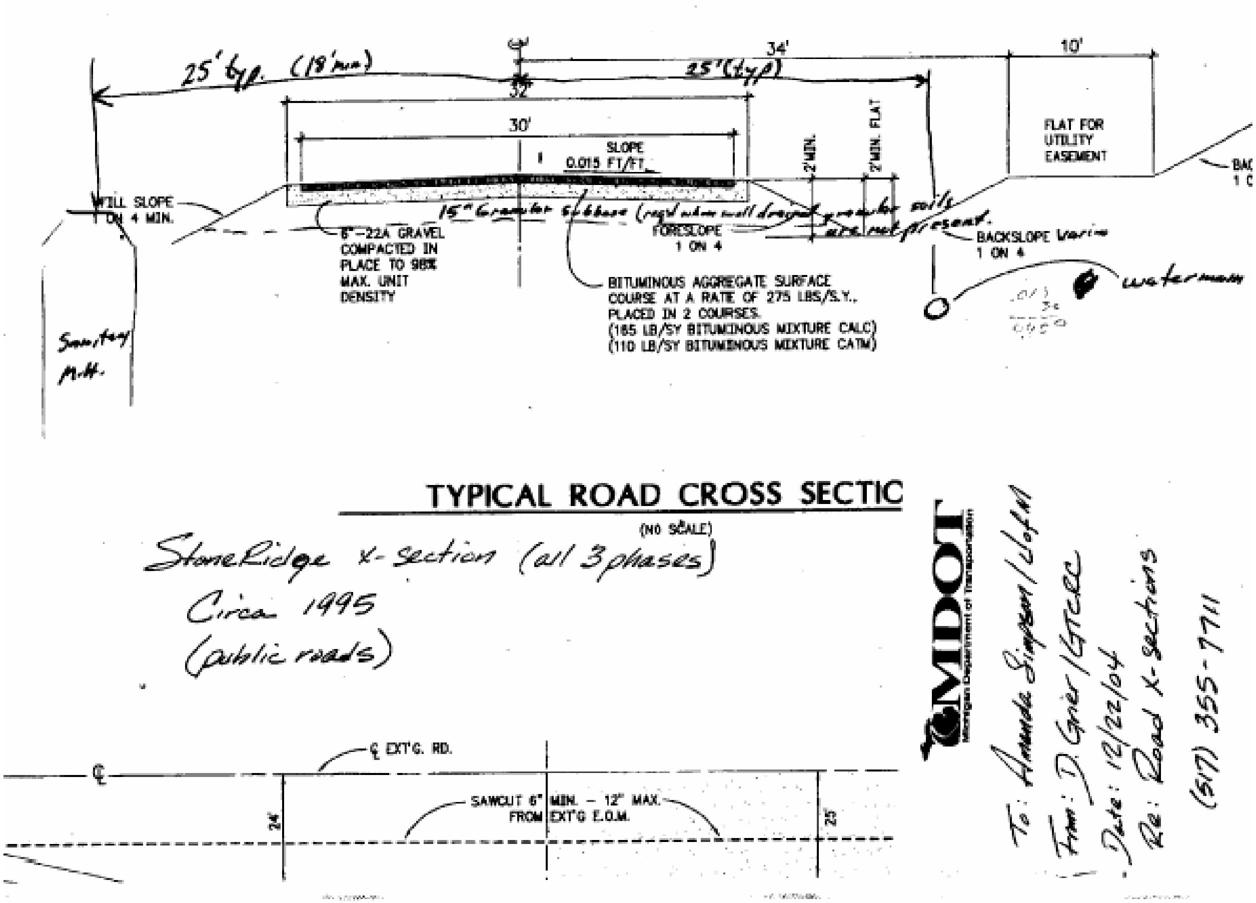


Figure 3.3: Cross Section of the Stone Ridge Road



3.3 Sources of Information

A variety of local government and private sources were contacted to provide the relevant information. At the local government level, Planning, Public Works, and Engineering Departments were contacted. In many instances, these departments were not able to provide the required data. In cases where data on sewer and water lines were not available, the information was obtained from developers or subdivision plat maps and maps of sewer and water infrastructure. In instances where plat maps were not available from local government agencies, the maps were obtained from the following two State of Michigan government agency websites: the Center for Geographic Information (Michigan CGI, 2005) and the Department of Labor and Economic Growth (Michigan DLEG, 2005).

For incorporated jurisdictions, data on roads were usually available from Public Works or Engineering Departments. Outside of incorporated jurisdictions, data on roads were collected from County Road Commissions. In some instances, structural data were provided by developers. Subdivisions plat maps (Figures 3.4-3.7) and other engineering drawings were also used to obtain information that could not be obtained from local government departments or developers.

Figure 3.4: Silver Lakes Farms No.2 Plat Map

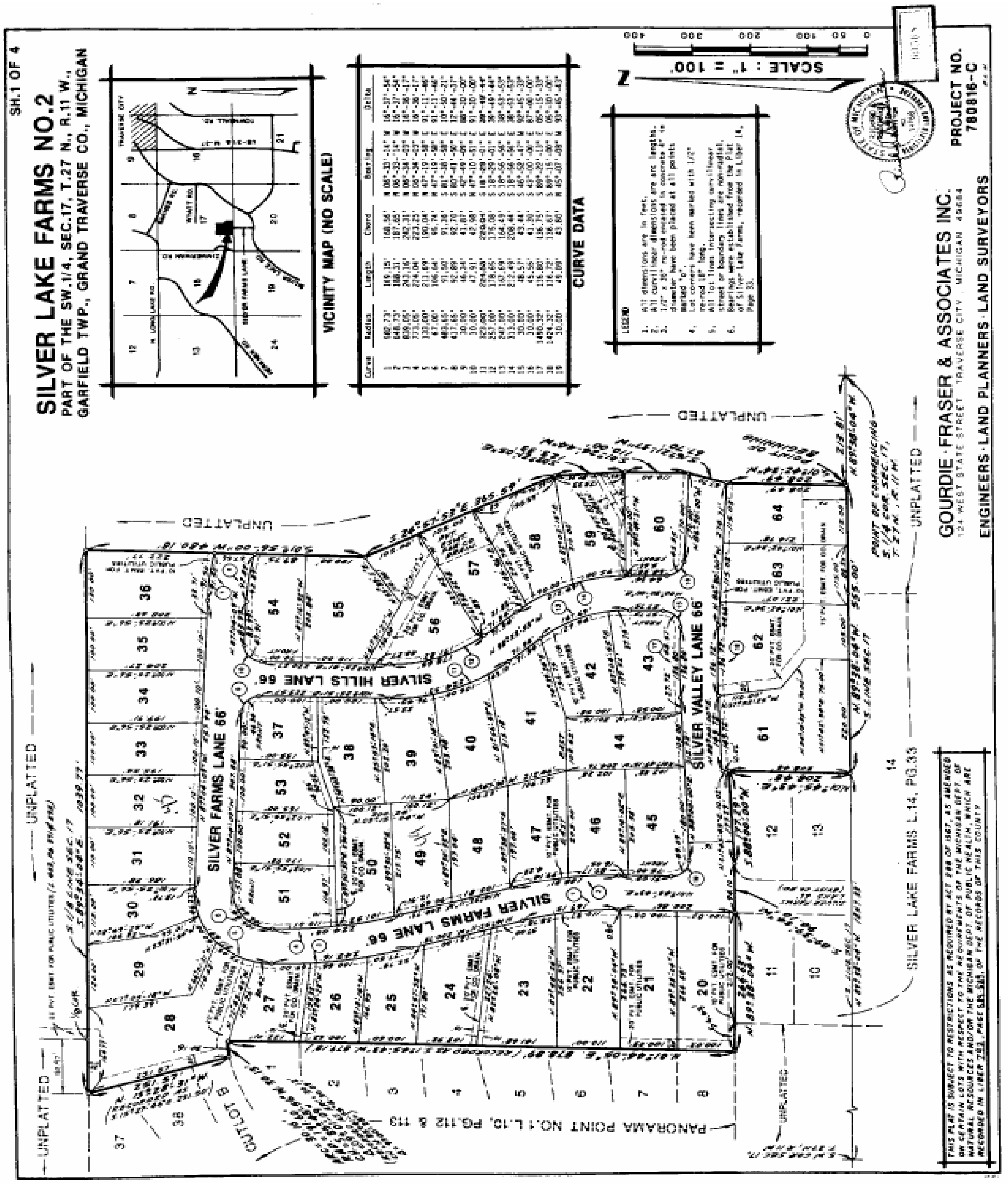


Figure 3.5: Stone Ridge II Plat Map

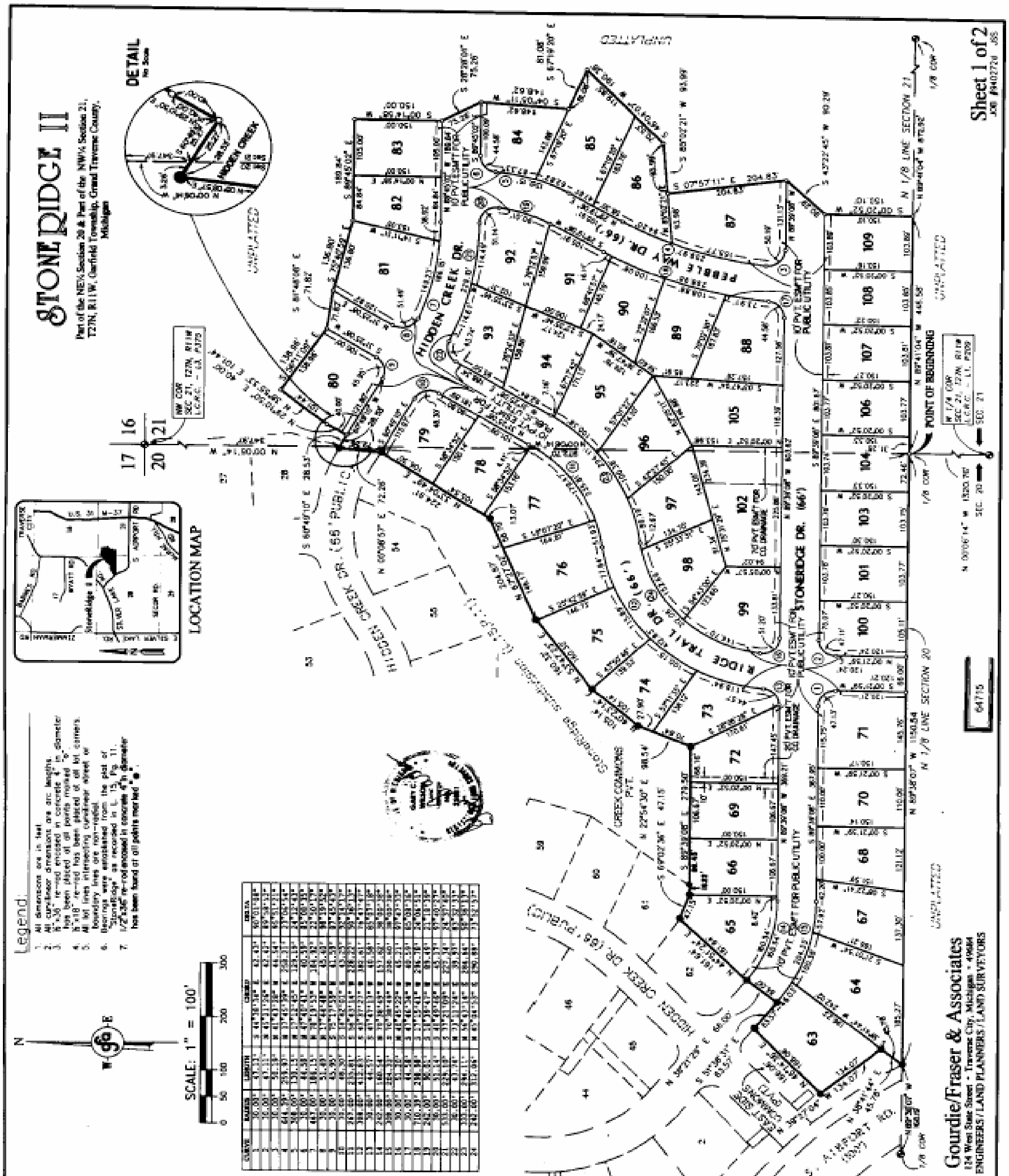


Figure 3.6: Bailey's Grove No.22 Plat Map

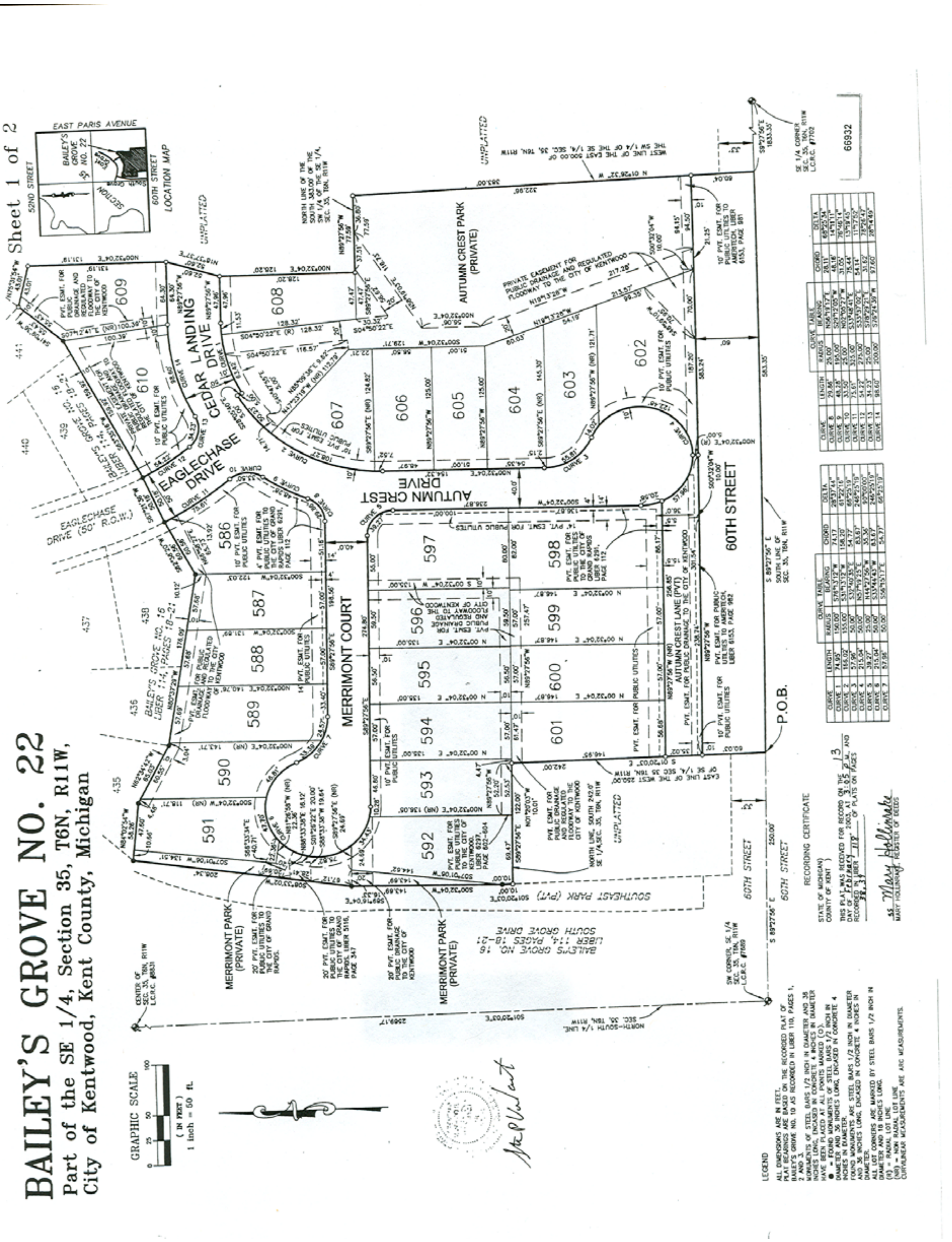
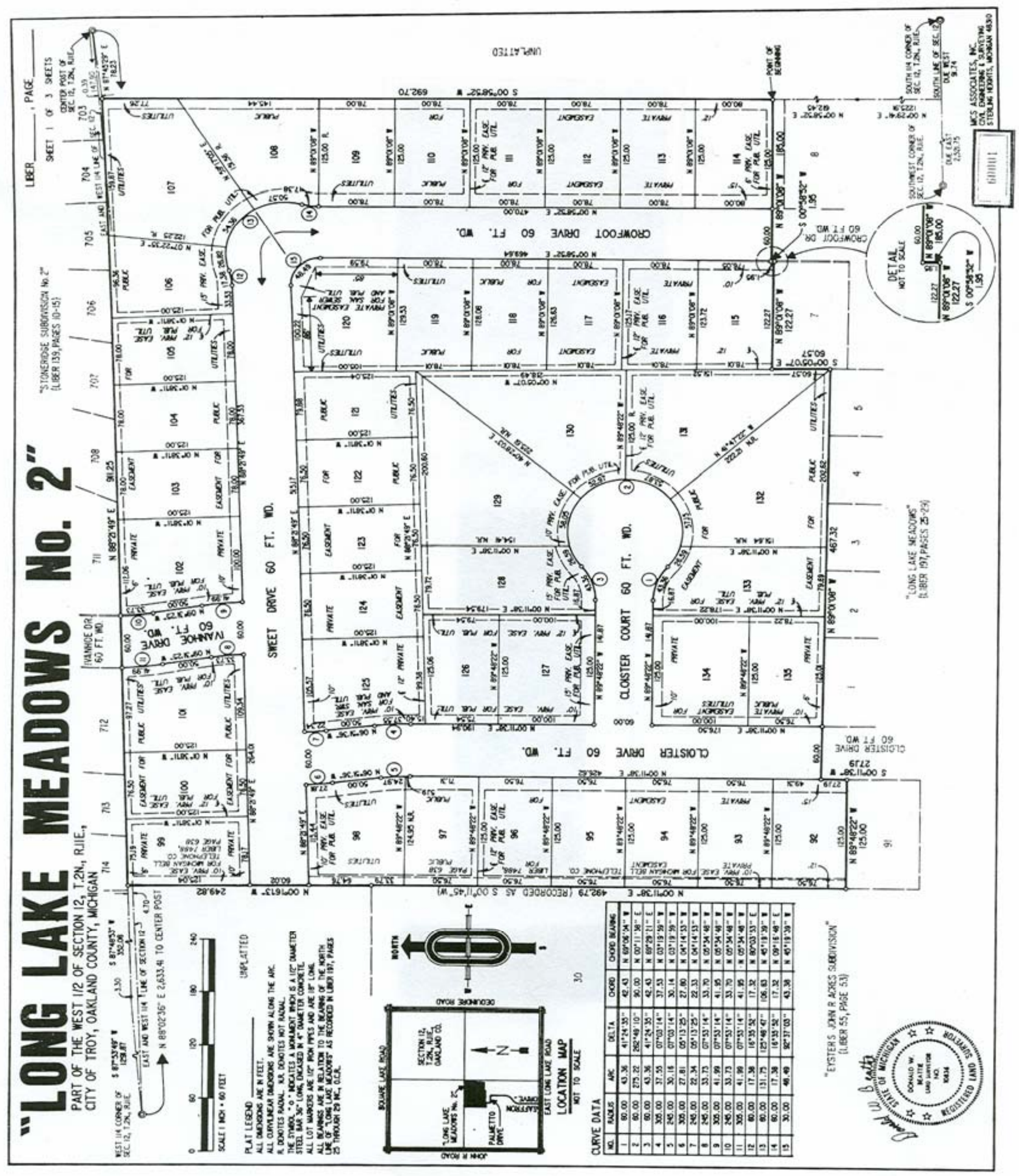


Figure 3.7: Long Lake Meadows No.2 Plat Map



3.4 Methodology

Using the data described above on the physical extent and structural characteristics of roads and sewer and water lines in each subdivision, three types of costs were analyzed to see how they vary with density. First, the capital costs of constructing roads and sewer and water lines were ascertained. Capital costs were determined by applying standard cost multipliers, obtained from *R. S. Means*, to the known physical extent and structural characteristics of these infrastructures. Second, again using information from *R. S. Means*, standard annual maintenance costs were determined.

The capital and maintenance costs were inflation adjusted (using inflation rates provided by *R. S. Means*) to project replacement and maintenance costs over the typical life of these infrastructures. Using standard discounting techniques, the replacement and maintenance costs were then aggregated to determine the third cost, that is, the life cycle costs for roads and sewer and water lines.

Simple graphs were constructed, as appropriate, to show how the different costs vary with density. Where applicable, regression analyses that assume different functional forms are reported to ascertain the best relationship to describe how costs vary with density. It should be noted that differences in road costs are due to length of infrastructure based on lot size and are not the result of differences in road design, which is standard across most cases.

4.0 Data Preparation for Cost Calculations

With information on the physical extent and structural characteristics of roads and sewer and water lines, the costs of these infrastructures could be easily established through the use of cost multipliers that are expressed in terms of costs per foot of infrastructure.

4.1 Estimation of Cost Multipliers for Capital Investments

Choosing cost multipliers to apply to roads and sewer and water lines is complicated by the fact that the structural characteristics of these infrastructures vary from one subdivision to the other. Thus, assumptions had to be made about the most appropriate multiplier to employ such that results would be consistent and robust across a range of densities. The multipliers cover the full costs of installation.

4.1.1 Cost Multipliers for Roads

The unit costs for roads depend on a number of factors, including expected traffic (which affects the required right-of-way and other structural features of the road), soil conditions, topography, climate, etc. As such, there is no universal cost multiplier for all subdivision roads. Indeed, for the 11 subdivisions for which data were available, the records show that the structural characteristics of the roads in these subdivisions varied. These variations translated into costs that range from $33 per ft to $55 per ft for bituminous roads and from $143 per ft to $158 per ft for concrete roads.

This large variability in costs is primarily related to the type of materials used. Expensive concrete roads tend to be found in upscale subdivisions or in areas where soil conditions dictate stronger pavements. However, the majority of subdivisions were found to contain bituminous roads. Thus, bituminous roads are assumed as the standard.

Table 4.1 reports the structural characteristics of each subdivision included in the analysis.

A common cross section of 12” sub-base, 6” base and 3” coating, with a paved road width of 30 ft., yields a cost of $47 per ft. This figure was converted into 2004 dollars,[2] yielding an estimate of $47.36 per ft. This inflation-adjusted figure was used in the calculations of capital costs for road infrastructure in the next chapter. This figure is close to the one reported by the Ingham County Road Commission of $39/ft for local roads.

Table 4.1: Road Cross Sections and Costs

Subdivision	Coating (in)	Base (in)	Sub-base (in)	Paved Rd (ft)	Cost ($/ft)
Bitumen					
Ember Oaks	3.0	6.0	8.0	30.0	43.7
Alabaster	3.0	8.0	12.0	30.0	50.8
Bailey Grove	3.0	8.0	12.0	28.0	47.4
Silver Lake	3.0	6.0	12.0	22.0	33.2
Stone Ridge	3.0	6.0	15.0	32.0	51.8
Princeton Estates	2.0	7.0	8.4	30.0	54.5
Granite Point	3.0	8.0	18.0	24.0	44.9
Premeau's Peak	3.0	6.0	17.0	30.0	41.3
Average	2.9	6.9	12.8	28.3	45.9
Median	3.0	6.5	12.0	30.0	46.1
Concrete					
Long Lake Meadows	7.0			30.0	142.8
Somerset North	7.0			30.0	142.8
Lexington Square	7.0	6.0		30.0	158.2
Kimberly Meadows	7.0	6.0		30.0	158.2
Average	7.0	6.0		30.0	150.5

4.1.2 Cost Multipliers for Sewer and Water

As in the case of roads, different sewer and water pipes were used in different subdivisions. From the data collected, sewer lines were found to range from 8 to 12 inches in diameter and to be made of PVC. Water lines were found to range in diameter from 6 to 10 inches, and were mostly made of ductile iron pipe (DIP). The most common size for both infrastructures was 8 inch diameter pipes. Thus, the study team adopted an 8 inch PVC pipe as the standard for the sewer lines and an 8 inch DIP as the standard for water lines.

The type of pipes used dictates specifications on the type of trenching and bedding, the mechanism for joining pipes, and the mobilization method. According to the data from *R. S. Means*, pipe diameters of 6 to 12 inches require 2 ft wide beddings, and therefore require trenching of 2 ft. The analysis assumes a 4 ft depth for water and an 8 ft depth for sewer. This study adopted a trench excavation slope of 0.5/1.

Similar to roads, the cost multipliers for these activities were also determined. Capital cost multipliers for trenching, bedding, pipe laying, mobilization and demobilization are included in Table 4.2.

Table 4.2: Capital Cost Multipliers for Sewer and Water

Infrastructure	Trenching ($/ft)	Bedding ($/ft)	Pipe (Including Installation - $/ft)	Mobilization and Demobilization (Lump Sum - $)	Capital Cost Multiplier ($)
Sewer pipe: 8 in. PVC pipe laid 8 ft. deep	16.24	2.68	9.05	584	27.97 per ft. plus 584
Water pipe: 8 in. class 50 DIP laid 4 ft. deep	7.28	2.68	32	584	41.96 per ft. plus 584

4.3 Estimation of Multipliers for Operation and Maintenance Costs

4.2.1 Roads

Residential road operation and maintenance (O&M) costs include the costs of street lighting, street sweeping and cleaning, snow removal, and resurfacing as needed. No published data could be obtained on residential road maintenance costs. Most available O&M data is for highways, the cost of which is far higher than for local residential roads. The study team therefore relied on information from counties that had such data and the Southeast Michigan Council of Governments (SEMCOG, 2005). These two sources provided the lower and upper limits of O&M costs.

The SEMCOG data provided information on collector, but not local, roads. In addition, the data concentrates on the resurfacing of roads. These data indicated that annual O&M costs for roads were $1.26 per ft. This figure is used as a benchmark against which figures obtained from other sources can be examined.

Local road O&M figures were obtained from the following six counties and local governments:

- Berrien County $1.48/ft/year (includes local and primary roads)
- City of Kentwood $0.17/ft/year (includes local and primary roads)
- Grand Traverse County $1.13/ft/year
- Ingham County $0.90/ft/year
- Marquette County $2.73/ft/year
- Wayne County $1.80/ft/year

For Berrien County and the City of Kentwood, road maintenance costs are applicable to both local and primary roads. The average O&M costs with and without these two communities are $1.37 and $1.64 per ft per year, respectively. The lower average is adopted as it is closer to the figure reported by SEMCOG.

4.2.2 Sewer and Water

Data on the O&M costs of sewer and water are not maintained by the jurisdictions studied. Thus, this analysis relies on a study conducted by the American Society of Civil Engineers (ASCE, 1999) on O&M costs for the minimum acceptable performance of wastewater collection systems.

It was found that a minimum of $0.53 and a maximum of $1.90 per foot per year were required to meet minimum performance standards. A mid-range estimate of $1.25 is adopted. This figure is consistent with responses to a survey conducted by SEMCOG in 2001 (SEMCOG, 2001). The SEMCOG estimate was chosen and adjusted to 2004 dollars using MEANS historical indices.

No similar costs were found for water lines. However, O&M requirements for water lines are not much different from those for sewer lines. The figure adopted for sewer lines is therefore also appropriate to use for water lines. The total O&M cost (adjusted to 2004 dollars) is $1.33/ft/year.

5.0 Results

5.1 Lengths of Infrastructure and Density

This section reports the general findings of the analysis and potential explanations. Table 5.1 summarizes the study findings on the lengths of roads and sewer and water lines in the 16 subdivisions that were examined. Table 5.2 presents the results in terms of length of infrastructure per lot. Figures 5.1 to 5.3 show how the lengths of roads and sewer and water lines per lot, respectively, vary with average lot size. It does appear that the length for each infrastructure increases with average lot size, though the relationship is not unambiguous.

Table 5.1: Total Length of Infrastructure in Different Subdivisions (2004)

Subdivision	Road Length (ft)	Sewer Length (ft)	Water Length (ft)	Density
Silver Lake Farms #2	1,523	2,874	2,600	Low
Stone Ridge #2	1,658	4,800	4,750	High
Wyndham Gardens	2,155	4,000	4,000	Low
Forest Hills	1,447	3,450	3,450	High
Ember Oaks	3,940	3,187	2,840	Low
Whispering Oaks	2,849	1,909	1,718	High
Hidden Pines	2,356	4,395	2,699	Low
Alabaster 2 and 3	1,967	2,700	3,130	High
Kimberly Meadows	3,720	4,495	3,566	Low
Lexington Square	5,190	5,290	4,880	High
Somerset North	3,625	3,400	3,525	Low
Long Lake Meadows #2	2,250	1,831	2,294	High
Princeton Estates #14	1,510	1,387	890	Low
Bailey's Grove #22	1,450	1,300	1,359	High
Granite Pointe	3,295	3,821	3,206	Low
Premeau's Peak	920	1,048	1,170	High

Table 5.2: Infrastructure Length per Lot in Different Subdivisions

Subdivision	Road Width (ft)	Sewer Length (ft)	Water Length (ft)	Density
Silver Lake Farms #2	35	65	59	Low
Stone Ridge #2	35	102	101	High
Wyndham Gardens	86	160	160	Low
Forest Hills	69	164	164	High
Ember Oaks	116	94	84	Low
Whispering Oaks	79	53	48	High
Hidden Pines	59	110	67	Low
Alabaster 2 and 3	46	63	73	High
Kimberly Meadows	48	58	46	Low
Lexington Square	41	42	39	High
Somerset North	59	56	58	Low
Long Lake Meadows #2	51	42	52	High
Princeton Estates #14	46	42	27	Low
Bailey's Grove #22	58	52	54	High
Granite Pointe	62	72	60	Low
Premeau's Peak	54	62	69	High

Figure 5.1: Road Length per Lot and Average Lot Size

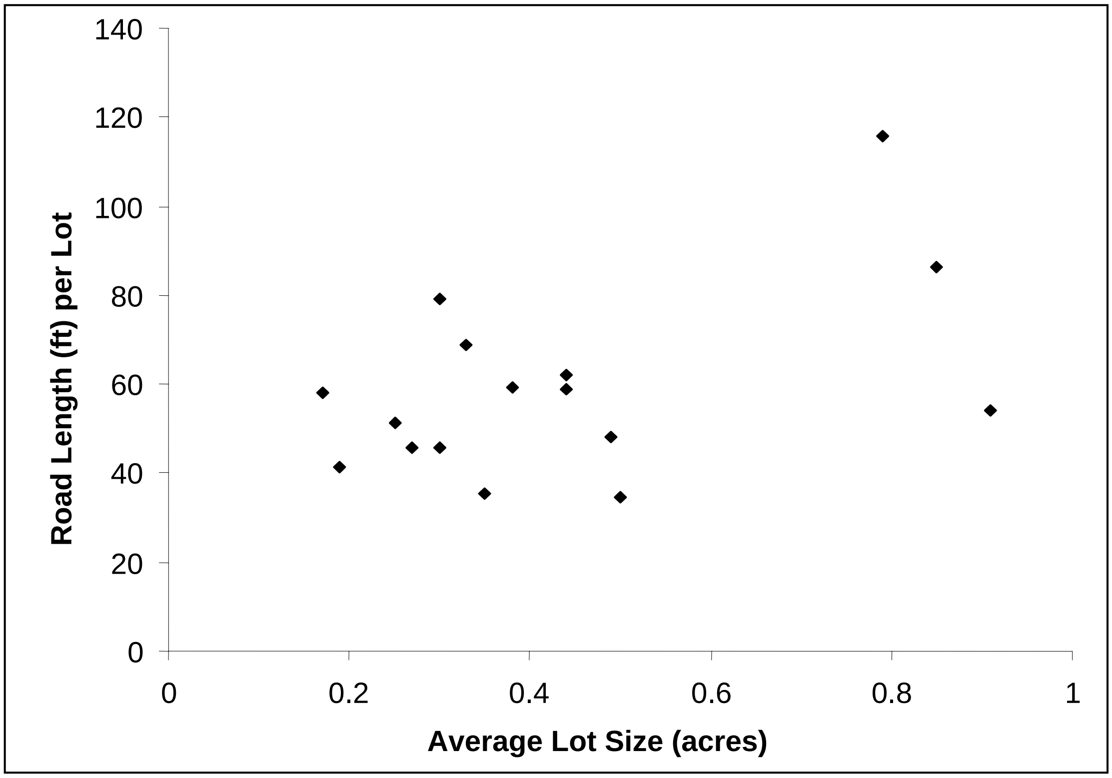


Figure 5.2: Length of Sewer Pipe per Lot and Average Lot Size

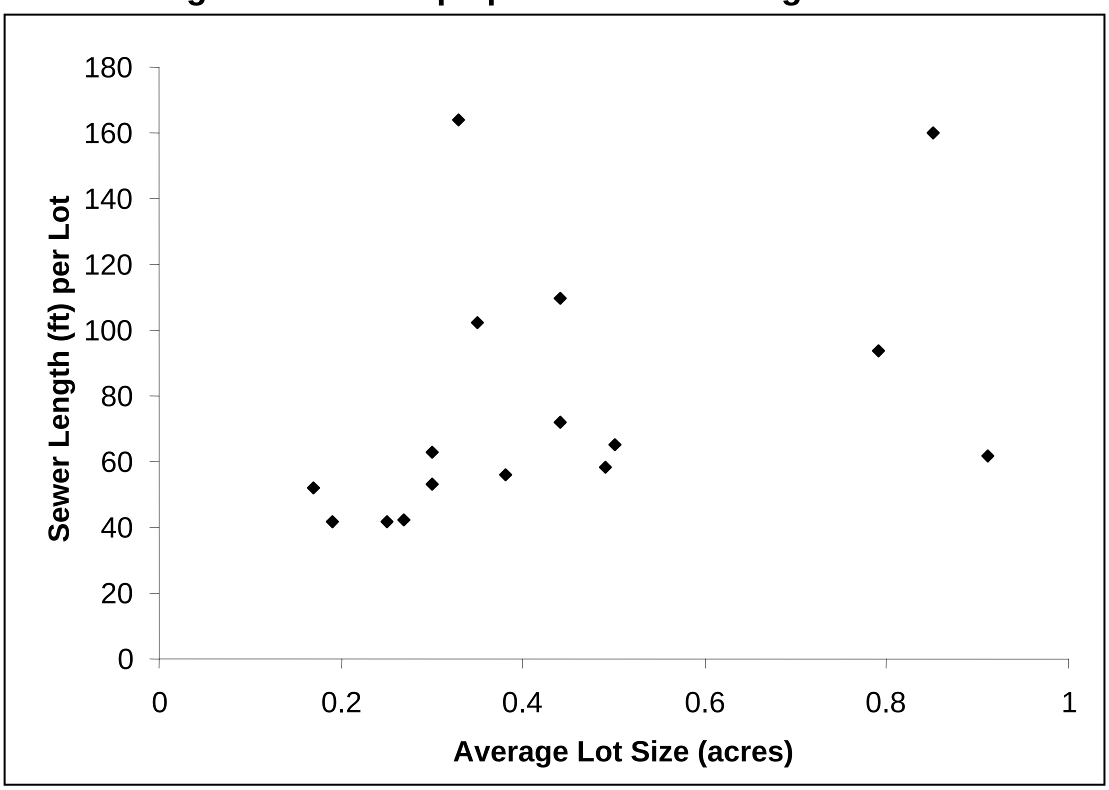
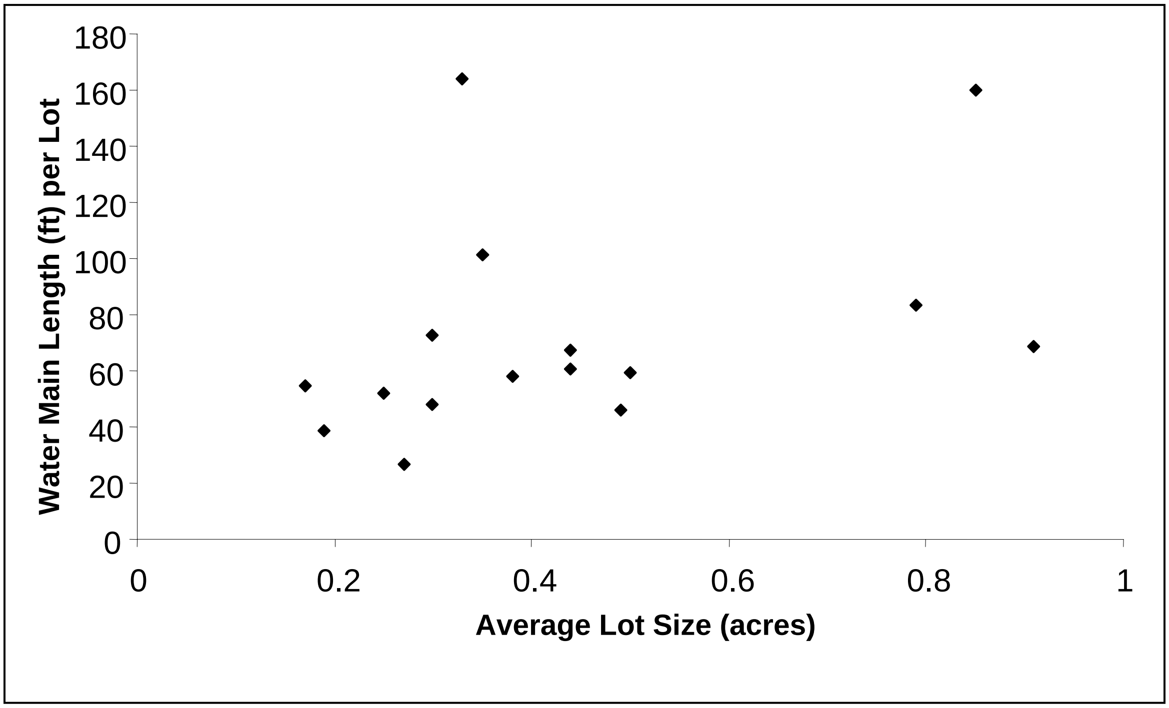


Figure 5.3: Length of Water Pipe per Lot and Average Lot Size



Because the strength of the relationship between the length of infrastructure and average lot size is not readily apparent from Figures 5.1 to 5.3, simple regression analyses were employed to shed additional light on the data. The regression analyses utilized different functional forms to ascertain which would result in the best fit of the data, as measured by R^2, and to reveal any underlying trends in the data. The dependent variable in the regression analyses is the length of infrastructure per lot and the independent variable is average lot size.

Table 5.3 contains the parameter estimates obtained from regressions using six different functional forms. This table shows that resulting R^2 values for all regressions are relatively low. With the exception of the power specification, the regressions have stronger explanatory power in predicting length of roads than in predicting length of sewer and water lines.

Table 5.3: R^2 Values of Regressions Using Alternate Functional Forms[1]

Regression	Road	Sewer	Water	Average
Linear	0.245	0.164	0.155	0.188
Log	0.205	0.194	0.157	0.185
Polynomial 2	0.250	0.199	0.155	0.201
Polynomial 3	0.201	0.199	0.162	0.187
Power	0.165	0.269	0.215	0.216
Exponential	0.250	0.164	0.203	0.206

[1] Length of infrastructure R^2 results demonstrate that average lot size alone does not predict length of infrastructure with strong explanatory power.

The linear, exponential, and power regression relationships are shown in Figures 5.4 to 5.6. In all of the regressions, it is clear that the length of infrastructure increases with lot size. The exponential specification shows a relationship where the length of roads per lot increases at a decreasing rate with lot size. In the case of sewer and water, however, the exponential specification shows that the length of pipes per lot increases at an increasing rate as average lot size increases. In the case of sewer and water, the power relationship shows that the length of pipes per lot increases at a declining rate as average lot size increases. In summary, nonlinear regressions do not result in a consistent relationship between the length of infrastructure per lot and average lot size. Because the linear regressions produce consistent results that are generally in agreement with expectations, linear regressions are taken to be acceptable representations of the data.

Figure 5.4: Length of Roads per Lot Regressed Against Average Lot Size

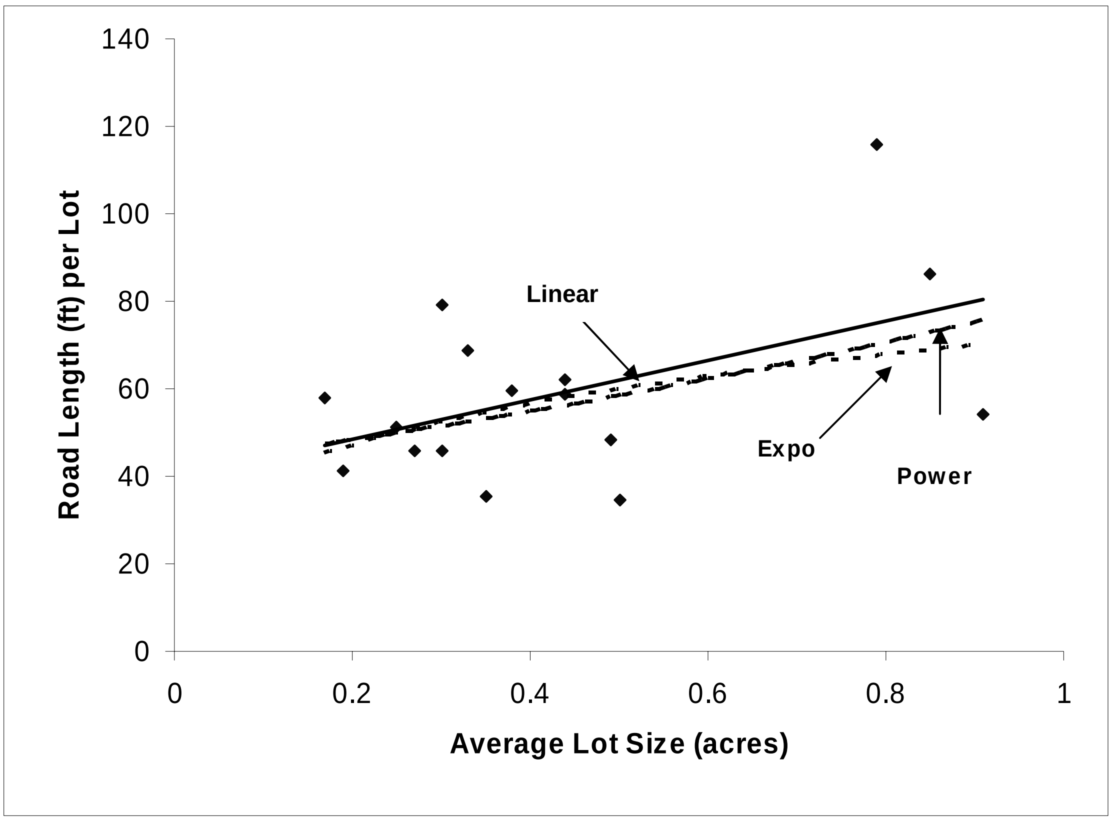


Figure 5.5: Sewer Pipe Length per Lot Regressed Against Average Lot Size

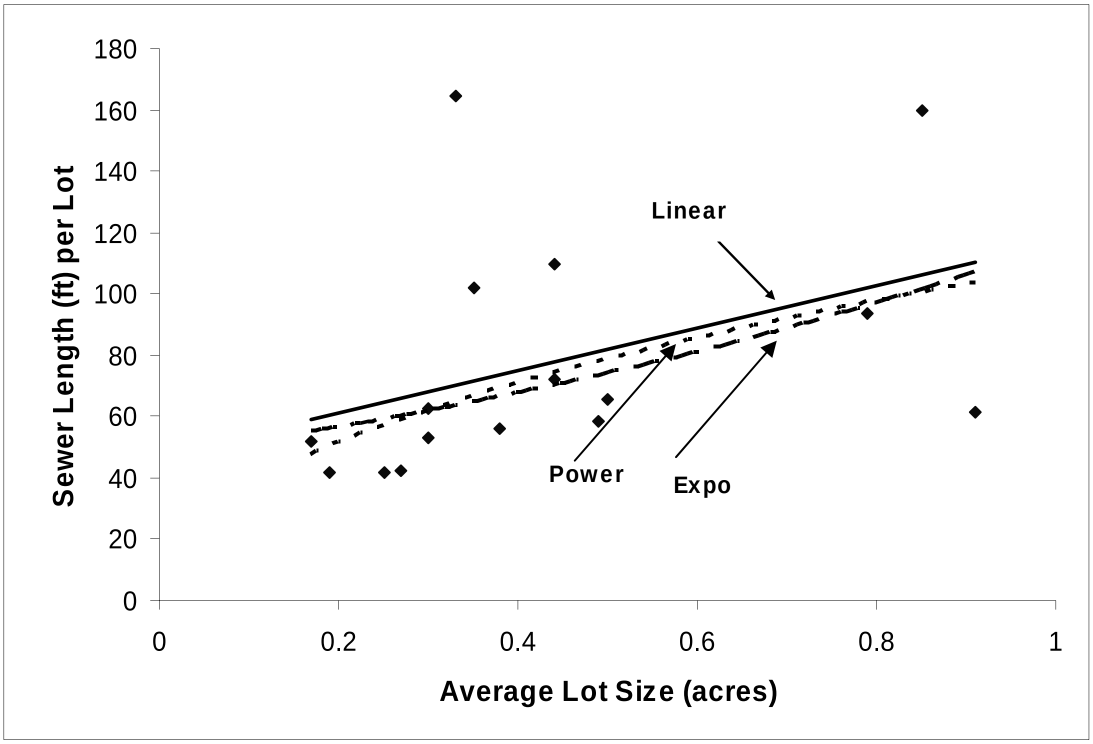


Figure 5.6: Unit Water Pipe Length Regression

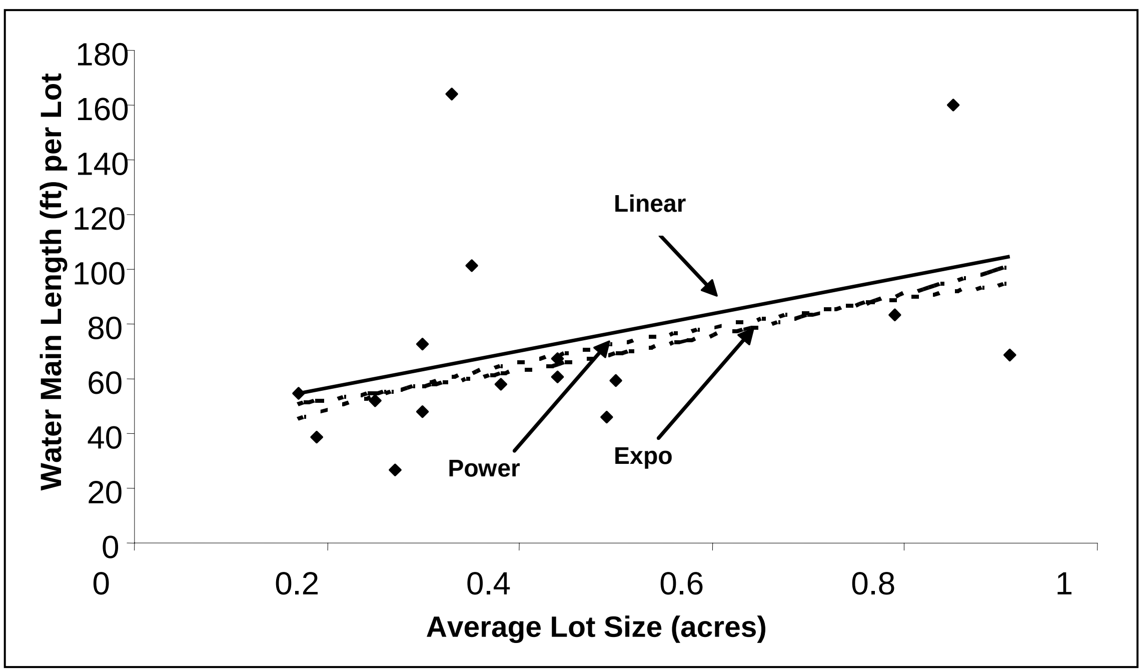


Table 5.4 reports intercepts and parameter estimates for linear regressions of average lot size (the independent variable) against length of infrastructure (the dependent variable) for each type of infrastructure investigated. The road length required for a one unit increase in average lot size is

39 feet. The sewer and water pipe lengths required for a one unit increase in average lot size are slightly larger at 47 and 43 feet, respectively.

Table 5.4: Results of Simple Linear Regressions for Infrastructure Length

Type of Infrastructure	Intercept	Parameter Estimate for Average Lot Size (Acres)
Roads length	45	39
Sewer pipe length	69	47
Water pipe length	67	43

The magnitude of the intercept term suggests that there is some fixed infrastructure required in subdivision development. Moreover, the fixed investments for sewer and water are greater than those required for roads. In the case of sewer and water, close to 70 feet of pipes per lot is required before each lot is serviced. The equivalent number for roads is somewhat less, with 45 feet of road per lot required before roads are built for each lot.

5.2 Costs of Infrastructure and Density

This section combines the cost multipliers discussed earlier with known lengths of infrastructure to ascertain how costs vary with lot size. The resulting costs for roads and sewer and water lines are shown in Table 5.5.

Table 5.5: Per Unit Infrastructure Cost

Subdivision	Average Lot Size (Acres)	Road Cost[1]	Sewer Cost[2]	Water Cost[3]	Total Cost	Density
Silver Lake Farms #2	0.50	1,639	1,840	2,493	5,972	Low
Stone Ridge #2	0.35	1,671	2,504	4,253	8,428	High
Wyndham Gardens	0.85	4,082	4,499	6,737	15,318	Low
Forest Hills	0.33	3,263	4,623	6,921	14,807	High
Ember Oaks	0.79	5,488	2,639	3,522	11,649	Low
Whispering Oaks	0.30	3,748	1,499	2,019	7,266	High
Hidden Pines	0.44	2,789	3,088	2,846	8,723	Low
Alabaster 2 and 3	0.30	2,167	1,770	3,068	7,005	High
Kimberly Meadows	0.49	2,288	1,640	1,951	5,879	Low
Lexington Square	0.19	1,951	1,179	1,630	4,759	High
Somerset North	0.38	2,814	1,569	2,434	6,817	Low
Long Lake Meadows #2	0.25	2,422	1,177	2,201	5,800	High
Princeton Estates #14	0.27	2,167	1,193	1,149	4,510	Low
Bailey's Grove #22	0.17	2,747	1,478	2,304	6,529	High
Granite Pointe	0.44	2,944	2,027	2,549	7,521	Low
Premeau's Peak	0.91	2,563	1,759	2,922	7,244	High

[1] Based on $47.36/ft; [2] Based on $27.97/ft plus $584/subdivision; [3] Based on $41.96/ft plus $584/subdivision

As was the case with the lengths of infrastructure, the average lot size is plotted against costs per lot, and simple regressions were estimated with the former as the independent variable and the latter as dependent variables. Because the previous analysis showed that nonlinear regression specifications did not consistently perform better than linear regressions, only linear regressions were performed at this stage of the analysis.

The best linear approximations of costs for roads and sewer and water lines per lot versus average lot size are shown in Figures 5.7 to 5.9. Although the resulting R^2 values are relatively low, there is a clear increasing relationship between the costs of infrastructure and lot size.

Figure 5.7: Road Cost per Lot

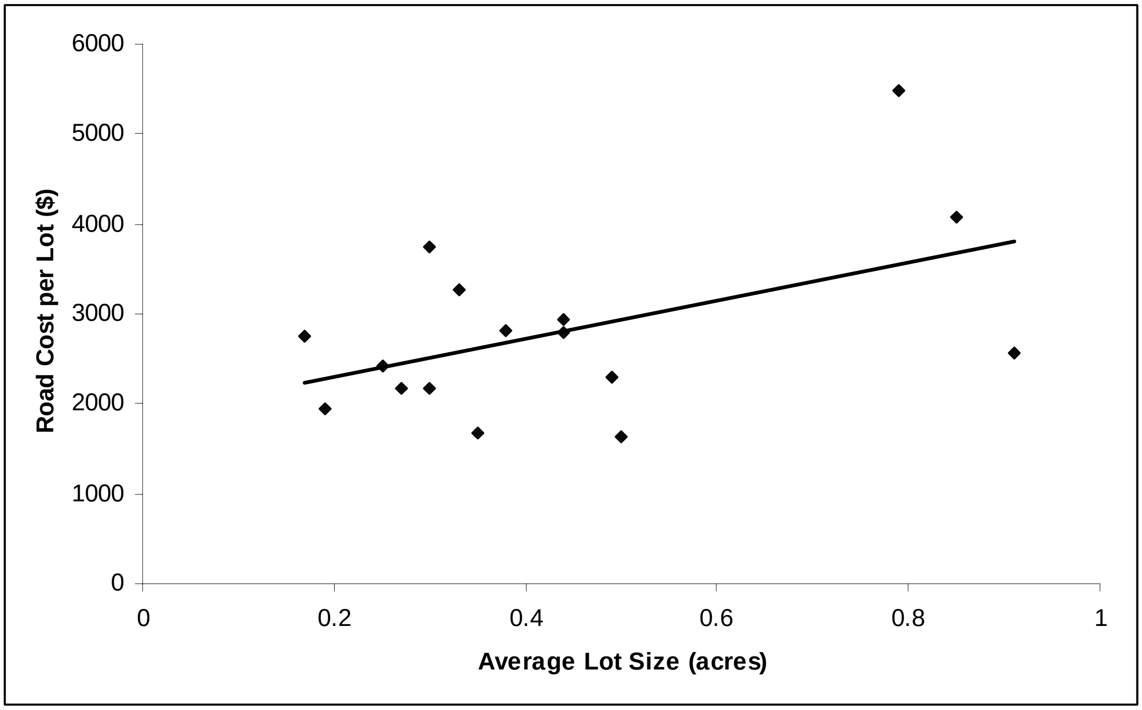


Figure 5.8: Sewer Pipe Cost per Lot

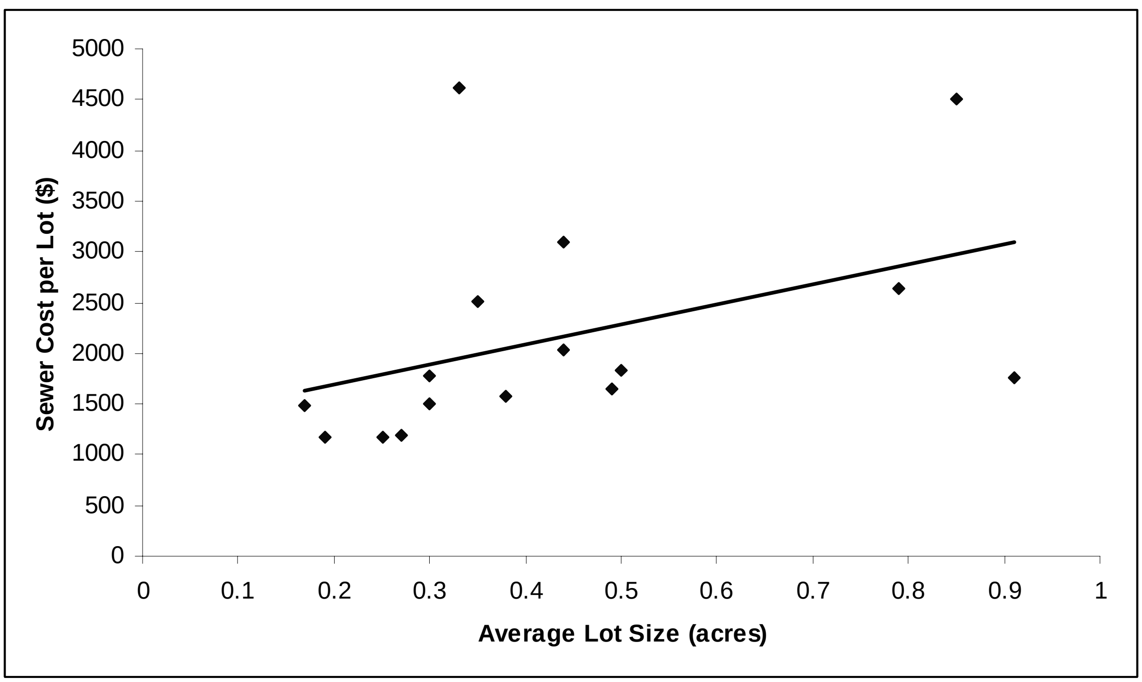


Figure 5.9: Water Pipe Cost per Lot

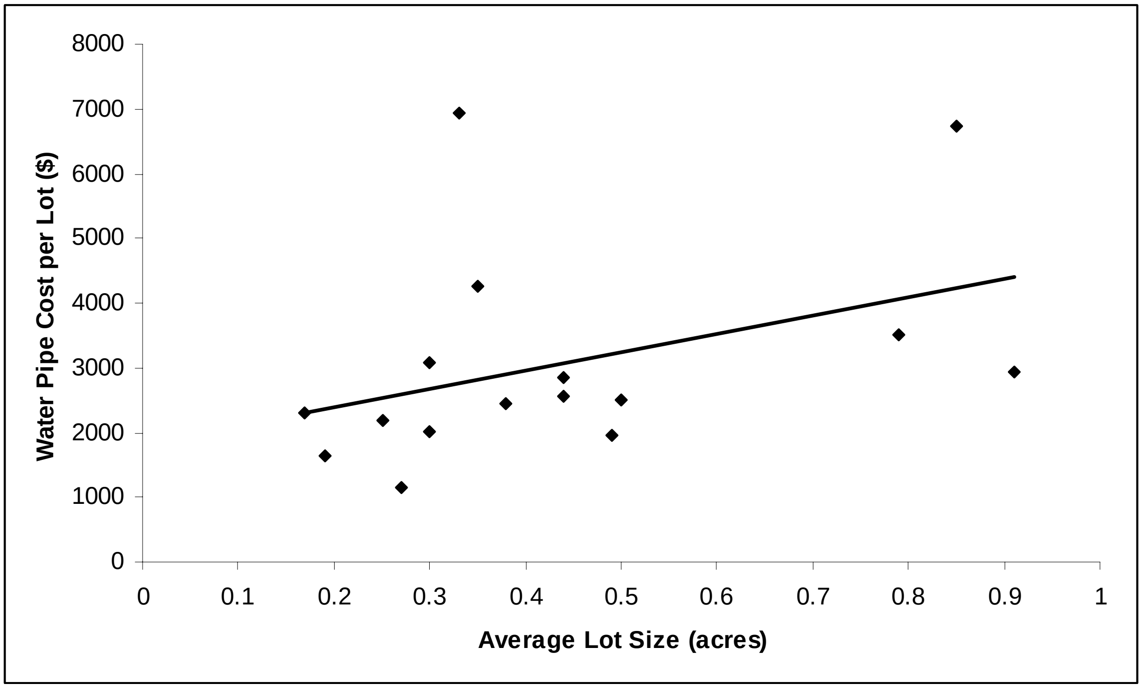


Table 5.6 summarizes the linear regression results. As in the case of lengths of infrastructure, the results for sewer and water in response to a unit increase in lot size were similar, and in this case the results for *roads* and water costs are similar. For roads and water pipes, a unit increase in average lot size results in cost increases of $1,865 and $1,828, respectively. The unit increase cost for sewer pipes is considerably less: $1,290.

The higher marginal cost of water lines as compared to sewer lines is a somewhat surprising result. Regulations that require water pipes to be looped for public health reasons require installation of additional pipes for water systems, and may therefore contribute to higher water line costs. The dependence of engineered sewer systems on gravity flow, as compared to water supply that requires less precision in installation, does not appear to compensate for the costs of additional pipes required for water lines in subdivision development.

The fixed costs for water are also considerably larger than the fixed costs of sewer. This again is surprising, but it could also be explained by the requirement to loop water lines.

Table 5.6: Results of Simple Linear Regressions for Costs of Infrastructure[1]

Variable	Intercept	Parameter Estimate for Average Lot Size
Roads Cost	$2,141	$1,865
Sewer Cost	$1,990	$1,290
Water Cost	$2,838	$1,828

[1] For example, the equation *$2,141 + $1,865 * Lot Size* yields road costs.

5.3 Life Cycle Costs

The results presented thus far represent the costs that developers can expect to bear for installing roads and sewer and water lines within subdivisions. However, although often developers bear the initial costs of installation, these infrastructures eventually become the property of local governments. For local governments, therefore, the fiscal management of infrastructure requires an understanding of the costs for maintenance and replacement of infrastructure, i.e. life cycle costs. This section turns toward examining this issue. For this report, the net present value of future maintenance and replacement costs was used to determine the life cycle costs of infrastructure. This study employed the following assumptions:

- Results obtained from linear regressions were used to predict capital replacement and maintenance costs for roads and sewer and water lines for each subdivision.
- The capital replacement and maintenance costs were inflated from current values at a rate of 2.1 percent per year to reflect current inflation trends for infrastructure.
- Since many infrastructure improvements are financed with government-backed municipal bonds, the going bond rate for local governments in Michigan was utilized as the discount rate. The rate is currently around 4 percent.
- Initial capital investment costs were ignored because these investments were assumed to have been made by developers.
- Roads have a life of 25 years and sewer and water pipes have a life of 50 years. The analyses of net present values were determined over a 50-year period, meaning that roads will be replaced twice (in year 25 and again in year 50), and that sewer and water pipes will be replaced once (in year 50).
- R.S. Means' cost data were used to come up with annual maintenance costs.

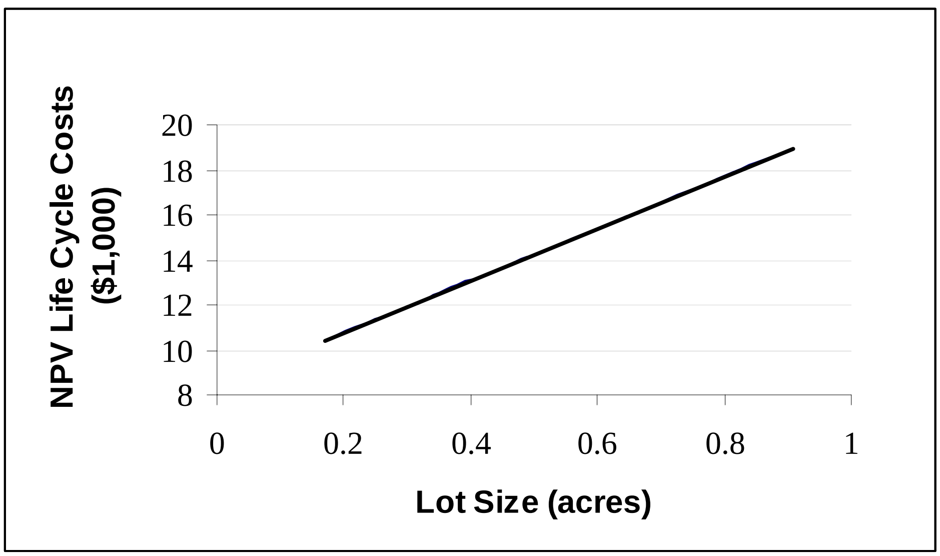
Table 5.7 reports life cycle costs (in terms of net present values) for maintenance and replacement of roads and sewer and water pipes over a 50-year period. Because the ultimate concern is how life cycle costs vary with density, these results are presented in order of increasing lot size. (Two subdivisions are 0.30 acres each and another two are 0.44 acres each. Thus, Table 5.7 contains data for 14 subdivisions, rather than 16.)

Table 5.7: Life Cycle Costs (Net Present Value for the Maintenance and Replacement) of Roads, Sewer and Water Infrastructure

Lot Size (acres)	Life Cycle Costs per Lot in Terms of Net Present Value ($1,000 per household)			
	Roads	Sewer Pipes	Water Pipes	Total
0.17	4.17	3.08	3.17	10.42
0.19	4.25	3.16	3.25	10.65
0.25	4.49	3.38	3.48	11.34
0.27	4.57	3.45	3.56	11.57
0.3	4.69	3.56	3.67	11.92
0.33	4.81	3.67	3.79	12.27
0.35	4.89	3.74	3.87	12.50
0.38	5.01	3.85	3.99	12.85
0.44	5.25	4.07	4.22	13.54
0.49	5.45	4.25	4.42	14.12
0.50	5.49	4.29	4.46	14.23
0.79	6.65	5.35	5.59	17.59
0.85	6.89	5.57	5.82	18.28
0.91	7.13	5.79	6.06	18.98

Figure 5.10 presents the information graphically. Together, Table 5.7 and Figure 5.10 show that life cycle costs for roads and sewer and water lines, when expressed in terms of the net present values, are almost as twice as high for a 1-acre lot as for a 0.2-acre lot.

Figure 5.10: Net Present Value Cycle Costs for Roads, Sewer & Water Lines



6.0 Revenue Considerations

Although local governments clearly face increasing life cycle infrastructure costs as lot sizes increase, one finding of interest to policy makers is whether larger lots result in higher user fees and taxes to cover these costs. This issue is addressed in the following section.

6.1 User Fees

Just as it is across much of the United States, there are no user fees specifically collected for local roads in Michigan. The maintenance and replacement of local roads are generally funded from general revenues in the budget. User fees are usually collected for sewer and water.

It is important to note that user fees vary widely between jurisdictions for several reasons, including the age of the system, water quality, soil composition, etc. An understanding of how capital costs are incorporated into user fees is also important; for instance, some sewer and water infrastructure in Michigan was built using federal subsidies, and some jurisdictions charge upfront connection fees to cover the cost of extending services. The reduction in public expenditures to cover construction costs can mean lower user fees for residents.

User fees may also vary due to economies of scale (i.e. providing these services to larger developments with more users may result in lower bills) and the provision of these services by private companies (as opposed to the local government). Finally, to achieve efficiency, rates should be set such that growth will “pay for itself” (i.e. users are charged connection fees and bills in line with maintenance and replacement costs); however, deliberate, well-informed rate-setting is not widely practiced (Beecher, 2006).

Understanding these caveats with respect to the variance in user fees for sewer and water provision, the next section provides an analysis of the user fees charged in the eight case study communities. The assumption used here is that user fees are set in an efficient manner to cover the costs of services associated with these two types of infrastructure. Further research is needed to isolate the effect of rate-setting inefficiencies and other factors from the effect of residential density.

6.1.2 User Fees for Sewer and Water

User fees for sewer and water were found to vary significantly in structure and magnitude from one community to another. Table 6.1 shows the rate structure for sewer and water for the different jurisdictions studied.

To employ these rates in determining user fees per household, an assumption about the daily consumption of water per household had to be made. The study used a rate of 183 gallons per day per capita, a figure estimated by the EPA (1995). This figure was adjusted to account for average household sizes in the jurisdictions that were studied. Table 6.2 contains average household sizes for each of these jurisdictions.

Table 6.1: Water and Sewer User Rates[1]

Jurisdiction	Water User Fee	Sewer User Fee
Garfield	$24.15/quarter up to 10,367 gallons; over that $1.65/748 gallons	$51.00/quarter/house
Alpena	$3.77/1,000 gallons	$3.77/1,000 gallons
Meridian	$2.47/7,480 gallons	$2.46/1,000gallons
Lincoln	$1.82/748 gallons	0-6732 gallons: flat fee of $35.10; over 6732 gallons: $1.08/ cubic feet
Canton[1]	$5.41/1,000 gallons	
City of Troy[1]	$27.90/7,480 gallons	
City of Kentwood	$1.45/748 gallons	$2.18/748 gallons
City of Marquette	$2.73/748 gallons	

[1] User fees for Canton, Troy and Marquette are for both sewer and water combined.

Table 6.2: Average Household Size

Jurisdiction	Average Household Size
Garfield Township	2.28
Alpena Township	2.39
Meridian Township	2.36
Lincoln Township	2.52
Canton Township	2.77
City of Troy	2.69
City of Kentwood	2.43
City of Marquette	2.13

The overall average household size in the jurisdictions studied is approximately 2.45 persons. This results in an average daily consumption of about 448 gallons of water per day, 40,316 gallons of water per quarter, and 161,406 gallons of water per year. Using these figures, Table 6.3 shows the corresponding sewer and water user fees per household.

There are two important caveats to these results. First, no data on how these user fees are spent was available. In particular, there is no data on whether these fees are used to fund the maintenance of sewer and water lines, or whether they are used to fund capital improvements. Second, this analysis assumes that sewer and water consumption do not vary with housing density. There is reason to believe that lower density housing uses more water because of the

[1] In terms of gallons or cubic feet as originally used in the jurisdiction.

need for more lawn maintenance. However, this study does not present data to confirm such a hypothesis. Thus, as can be seen in Table 6.3, water user fees do not vary with density between subdivisions within a community.

6.2 Property Tax Revenue

Another source of revenue that is used to maintain infrastructure is property tax. The project team collected tax rates from the offices of tax assessors for the different jurisdictions studied and applied these rates to each house in each subdivision to determine the total property taxes that are generated by each subdivision. The average property taxes for each house in each subdivision were extrapolated from this data. The resulting property tax per household is shown in Table 6.3. As in the case with user fees, there is no data on how property tax revenues are used for the maintenance and replacement of infrastructure.

Table 6.3: Annual User Fees for Sewer and Water and Annual Total Revenues per Household

Subdivision	User Fees for 2004 ($ per Household)	Property Taxes for 2004 ($ per Household)	Annual Revenues for 2004 ($ per Household)	Density
Silver Lake Farms #2	565	2,838	3,403	Low
Stone Ridge #2	565	3,199	3,764	High
Wyndham Gardens	609	3,115	3,724	Low
Forest Hills	609	1,898	2,507	High
Ember Oaks	796	14,725	15,521	Low
Whispering Oaks	796	6,382	7,178	High
Hidden Pines	651	4,165	4,816	Low
Alabaster 2 and 3	651	3,152	3,803	High
Kimberly Meadows	873	3,914	4,787	Low
Lexington Square	873	3,201	4,074	High
Somerset North	602	10,202	10,804	Low
Long Lake Meadows #2	602	5,576	6,178	High
Princeton Estates #14	783	3,528	4,311	Low
Bailey's Grove #22	783	2,703	3,486	High
Granite Pointe	589	3,985	4,574	Low
Premeau's Peak	589	4,490	5,079	High

7.0 Expenditures and Revenues

Revenues are used for a variety of purposes, and the maintenance and replacement of infrastructure is usually low on the list of priorities. Without data on how revenues are allocated to the maintenance and replacement of infrastructure, it cannot be determined with any degree of certainty that revenues cover the costs of infrastructure on larger lots.

However, this analysis can provide some preliminary findings about whether user fees cover the life cycle costs of infrastructure, and about the relationship between total revenues, life cycle costs of infrastructure, and density. This analysis was done in two stages. The first step was a comparison between user fees for sewer and water with life cycle costs for sewer and water. Roads are excluded from this comparison because user fees are applicable to sewer and water only. Further, since user fees are annual amounts (in 2004 dollars); life cycle costs are now expressed in terms of annual equivalents. The resulting figures are shown in Table 7.1. (The figures are presented in terms of increasing lot size to increase ease of interpretation.)

Table 7.1: Annual Life Cycle Costs, User Fees and Total Revenues

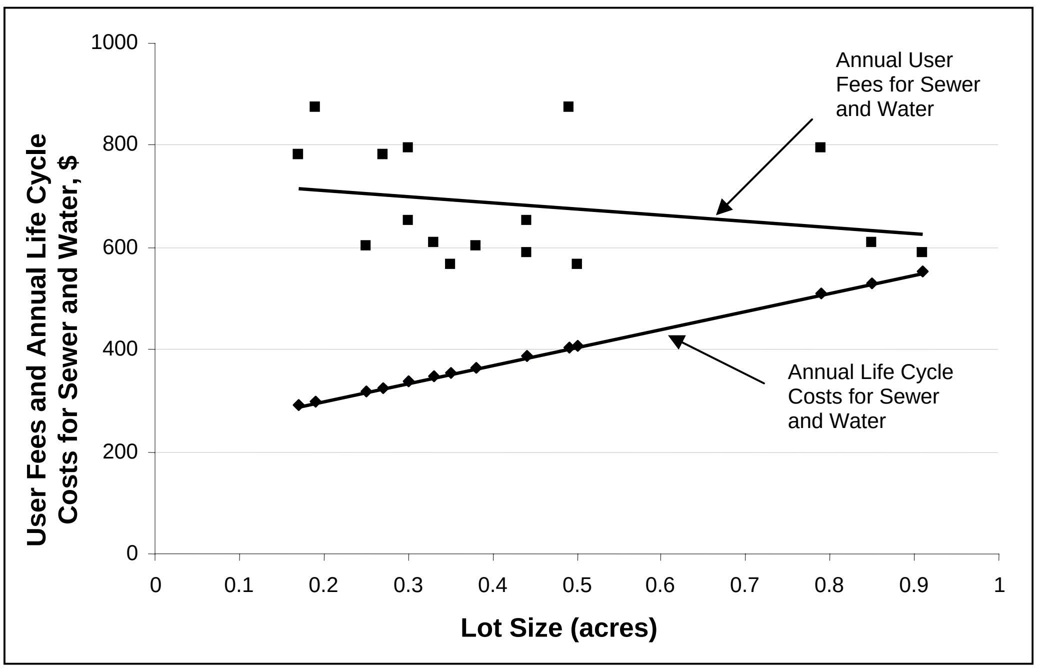
Lot Size (Acres)	Annual Life Cycle Costs for Sewer and Water ($ per household)	Annual Sewer and Water User Fees for 2004 ($ per Household)	Total Annual Life Cycle as a Percentage of Total Annual Revenue[1] (2004)
0.17	291	783	8.3
0.19	298	873	7.3
0.25	319	602	5.2
0.27	326	783	7.6
0.3	337	796	4.7
0.3	337	651	17.1
0.33	348	609	13.9
0.35	355	565	9.4
0.38	365	602	3.4
0.44	386	651	8.0
0.44	386	589	12.9
0.49	404	873	8.4
0.50	408	565	12.0
0.79	510	796	3.4
0.85	531	609	14.2
0.91	552	589	10.9

[1] Total Annual Revenue data is reported in the fourth column of Table 6.3.

Figure 7.1 shows how annual life cycle costs and user fees vary with density for sewer and water. It shows that, in general, annual user fees for sewer and water are greater than annual life cycle costs for sewer and water. However, this statement is only valid for the range of lot sizes examined in this report. It is clear that as lot size increases, the difference between user fees and annual life cycle costs becomes smaller. This statement is based more on the upward slope of the line that shows life cycle costs than on the downward slope of the line that shows annual user fees. (See later discussion for why the slope of the line for annual user fees may not be applicable beyond the case studies.) At a lot size of approximately one acre, user fees will not be sufficient to cover the maintenance and replacement costs of sewer and water lines within subdivisions.

It must again be noted that annual life cycle costs for sewer and water lines do not include any allowances for capital, operating, and maintenance costs associated with sewer and water trunk lines and treatment facilities; the life cycle costs considered here are applicable only to the maintenance and replacement of pipes within a given subdivision. Given the generally close proximity between the two lines shown in Figure 7.1, if costs for trunk lines and treatment facilities are included in the calculated life cycle costs, then these costs will in all likelihood exceed user fees.

Figure 7.1: User Fees and Annual Life Cycle Costs for Sewer and Water vs. Lot Size

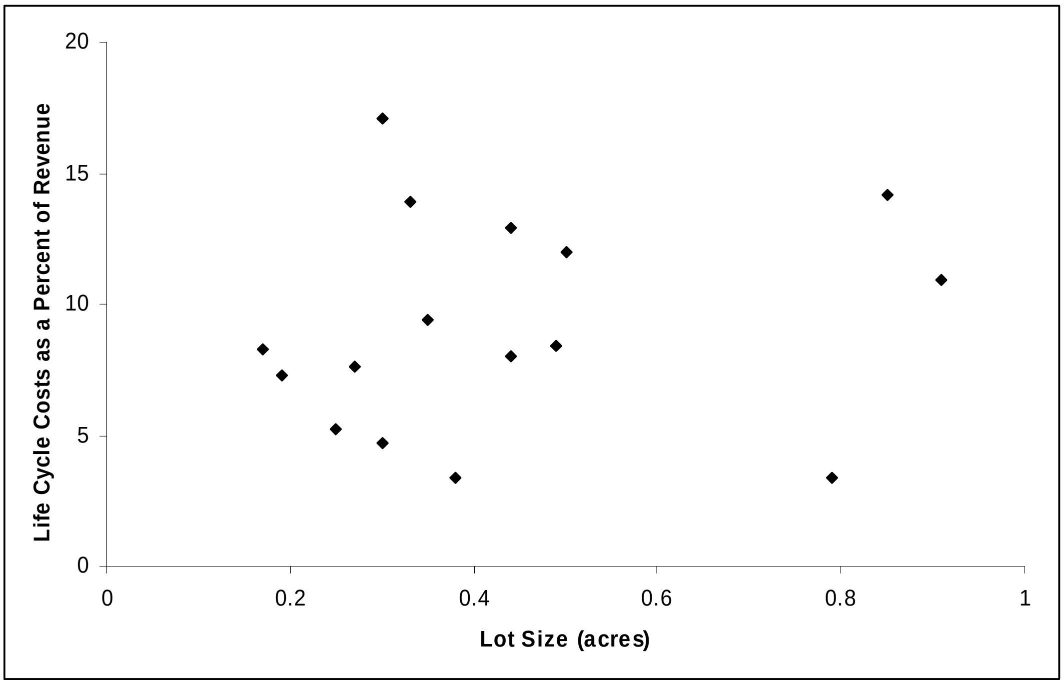


A further point is warranted about the slope of the line for annual user fees for sewer and water. The downward slope of the line could primarily be a unique result for the jurisdictions that were studied rather than a true, typical relationship. As can be seen in Table 6.1, user fees for sewer and water are not at all related to lot size, but rather are arbitrary figures determined at the local level.

As stated earlier, because there are no data on how total revenues (property taxes and user fees for sewer and water) are allocated to the maintenance and replacement of subdivision infrastructure, it is difficult to make direct comparisons between revenues and life cycle costs. One measure that provides some insights is a measure of how annual life cycle costs as a percentage of revenues vary with density. This measure perhaps provides the most interesting insights into whether revenue is related to life cycle costs and density. Table 7.1 reports the appropriate data in the final column, and Figure 7.2 displays the data.

The data shows that there is no relationship between how life cycle costs for roads and sewer and water lines as a percent of revenues vary with lot size. (A simple regression between the two variables produced an R^2 of 0.06). At a lot size of 0.79 acres (Ember Oaks), life cycle costs as a percent of revenues are approximately 3.4 percent, but for a slightly larger lot, 0.85 acres (Wyndham Gardens), the same figure is approximately 14.2 percent. The same discrepancy is observed when the lot size is 0.38 acres (Somerset North – 3.4 percent) versus when it is 0.33 acres (Forest Hills – 13.9 percent).

Figure 7.2: Life Cycle Costs as Percent of Revenue versus Average Lot Size



It should be repeated that the fact that life cycle costs for roads and sewer and water lines are a fraction of revenues does not imply sound fiscal management of these infrastructures; it is not understood what fraction of revenues is actually spent on infrastructure management.

8.0 Beyond Infrastructure Costs

The sections above provide a comparative analysis of the relationship between the densities of residential development and infrastructure costs. By concentrating on the basic infrastructure aspects of the residential developments, namely roads, sewer and water pipes, this study addresses an important issue that is often raised about optimal housing density from the standpoint of communities. Conceivably, density also impacts non-infrastructure costs, such as those costs associated with municipal services (e.g. fire, police, schools, parks, libraries and recreational facilities). Without an assessment of the effects of housing density on these other aspects of public costs, this analysis is incomplete.

In an attempt to explore some of the non-infrastructure cost issues, this section of the report focuses on the relationship between housing density, property values and the total tax revenues of a pilot municipality, Meridian Township in Michigan. The optimal lot size range that maximizes revenue per house for the municipality is identified.

8.1 Approach

The approach followed in this portion of the report required the collection of data on recent real estate sales in Meridian Township, Ingham County. For the year 2005, the residential parcel count for the township was 12,308, commercial parcel count was 663, industrial parcel count was 47, and agricultural parcel count was 5. The total assessed value of residential property was $1,274,286,150, which is approximately 72.26% of the total real value of properties in the county. The analysis focused on all real estate transactions from October 2004 through March 2005 for which actual sales had occurred. Michigan law provides a cap on property tax increases as long as property ownership remains the same. Hence the sale of property triggers an adjustment of taxable value and therefore tax liability. By focusing on multiple listing data, one avoids the problem of discrepancies between assessed and actual revenue.

The data consisted of 137 observations (single family houses). For each house sold, information was available on the following housing characteristics (variable names in parentheses):

1. Sale price of the house and property (Sold_price).
2. List price of the house and property (Listprice).
3. Taxable value of the house and property (Taxval).
4. Age of the house (Age).
5. Presence of a basement (D_bsmt).
6. Number of car places in garage (No_of_garage).
7. Presence of garage (D_attch_gar).
8. The total square footage of the house above the ground (Sqft_above).
9. Availability of sewage facility (D_sewer).
10. The number of bedrooms in the house (Bedrooms).
11. The number of non-bedrooms in the house (Non_bedrooms).
12. The number of full bathrooms (Full_bath).
13. The number of half bathrooms (Half_bath).
14. The total lot size of the house (Tot_lot_size).
15. The number of stories of the house (Type).

16. The number of days the house has been on the market (DOM).

Two primary approaches were used in the analysis:
1. Analysis of correlation between lot size and property value per acre.
2. Hedonic regression analysis of impact of lot size on total property value.

The approaches and results are presented below.

8.2 Analysis of Correlation between Lot Size and Property Value

Figure 8.1 presents the lot size and the taxable value per acre of each house in order to evaluate the relationship between lot size and the taxable value of a house. An application of the tax rate to property value illustrates the tax revenue impact of each lot size. As shown in Figure 8.1, which plots lot size on the horizontal axis and taxable value per acre on the vertical axis, greater property valuation per acre seems to be correlated with smaller lots. Plotting the lot size classes (with increments of 0.1 acre) against property value per acre shows this relationship more distinctly (see Figure 8.2).

Figure 8.1: Taxable Value versus Lot sizes of Recently Sold Houses in Meridian Township, MI (October 2004 - March 2005)

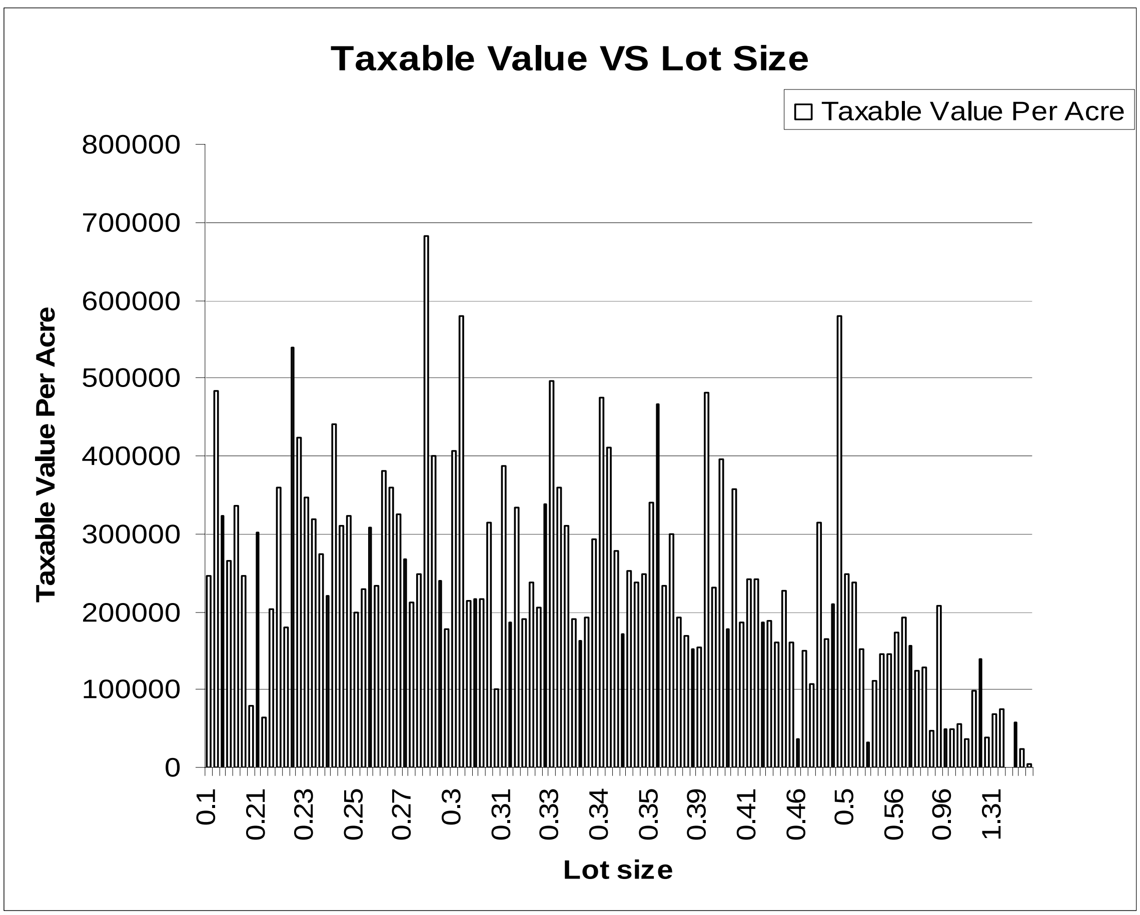


Figure 8.2: Taxable Value per Acre by Range of Lot Size

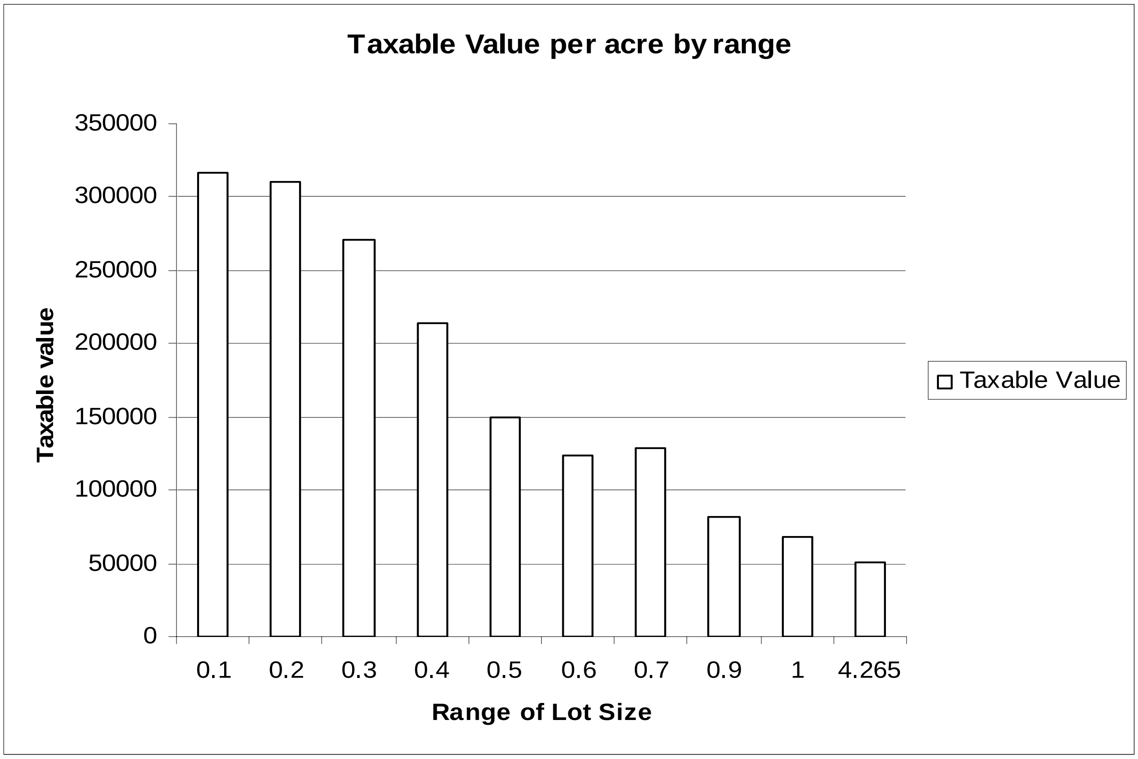


Figure 8.2 suggests that an inverse relationship exists between lot size and taxable value per acre. This implies that the yield to a community in terms of revenue per acre is higher for densely packed housing. This relation is consistent in the sense that taxable value progressively decreases, except for the lot size of 0.6 to 0.7 acres. In other words, there is a saddle point at 0.6 to 0.7 acres, but the most beneficial size class is 0.0 to 0.2 acres. It is important to note that this is a preliminary analysis focused on one township.

8.3 Regression Analysis

The plot shown above is merely analogous to correlation analysis. Therefore, it does not provide sufficient evidence for causality. Regression analysis is therefore used to decompose taxable value into its determinants. This method allows us to isolate the effect of each determinant on the property value and taxable value, using the hedonic pricing approach. The approach is in line with a similar analysis in Michael, Boyle and Bouchard (Land Economics, 2000).

The basic hedonic price approach is to regress property value (sale price of a house and its corresponding property) against housing attributes (housing, property and neighborhood characteristics). If a linear model is used, the coefficient of an attribute will represent the effect on the dependent variable (property value) of a one unit increase in the value of the attribute. In the case of a log-linear model, the coefficient would represent the percentage change in valuation for every 1-unit change in the attribute. For the purpose of this study, linear and log-linear models were used.

The structural hedonic valuation function approach used in this study involved the regression of sold-price against property attributes. Sold price translates directly into tax revenue through the application of appropriate tax rates to assessed value, or taxable value. Some of the variables needed to be transformed because they were not continuous variables or because of the need to test some group effects. The variables that were transformed are as follows:

Age: Broken down into dummy variables for the age of the house

i. *D_age_0to10* = 1 if property age is between 0 to 10 years
ii. *D_age_10to20* = 1 if property age is between 10 to 20 years
iii. *D_age_20to30* = 1 if property age is between 20 to 30 years
iv. *D_age_greater30* = 1 if property age is greater than 30 years

Basement: The dummy variable *D_bsmt* equals 1 if the house has a basement, and otherwise equals 0.

Garage: The dummy variable *D_attch_gar* equals 1 if the house has an attached garage, and otherwise equals 0.

Sewer: The dummy variable *D_sewer* equals 1 if the house has access to a municipal sewage treatment facility, and otherwise equals 0.

Type: The dummy variable *D_type* equals 1 if the house is a 'Ranch' (one story building), and otherwise equals 0.

After a detailed and careful analysis, a basic linear model was chosen, with some quadratic terms:

$$Sold\_price_i = \beta_0 + \beta_1 controls + v_i$$

Where the control variables consist of the following variables:

Taxval_listprice, D_age_10to20, D_age_20to30, D_age_greater30, D_bsmt, no_of_garage, D_attch_gar, Sqft_above, Bedrooms, Full_bath, Half_bath, Tot_lot_size, Tot_lot_sizesqr, Tot_lot_sizecube, D_type, and *DOM*.

The variable v_i is the error term that is assumed to be independently and normally distributed. Note that *Tot_lot_sizesqr* and *Tot_lot_sizecube* represent squared and cubed terms of *Tot_lot_size*. Table 8.1 reports regression results for variations of the model.

Table 8.1: Effects of Attributes on Property Values, Meridian Twp, Michigan

Variable Name	$ Impact on Sold Price (Hedonic Model)			% Impact on Sold Price (Log dependent Variable)		
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Taxval_listprice	-2,467.173***	-2,475.002***	-2,459.178***	-.0049655***	-.004947***	-.0042909***
D_age_10to20	-69,818.13***	-69,317.23***	-69,441.54***	-.1682026***	-.1692877 ***	-.1750481***
D_age_20to30	-104,886.8***	-105,135.6***	-105,557***	-.3182749***	-.3176896 ***	-.3358984***
D_age_greater30	-107,566.1***	-108,903.9***	-109,027.9***	-.3491419***	-.3461423 ***	-.3514195***
D_bsmt	35,184.74	34,970.79	34,928.14	.3464804***	.3469487***	.3452923***
No_of_garage	38,091.2***	38,054.25***	37,907.31***	.1102928***	.1103334***	.1046777***
D_attch_gar	-23,387.33	-23,589.48	-23,615.42	.0006508	.0010789	.0003132
Sqft_above	61.34866***	59.22853***	59.41019***	.0002474***	.0002521***	.0002601***
Bedrooms	-7,740.034	-7,686.436	-7,803.537	.0108277	.0107389	.0053631
Full_bath	36,719.13***	37,170.28***	37,066.38***	.0906232***	.0896539 ***	.0846998***
Half_bath	12,595.03	13,660.36	13,728.28	.0206092	.0181949	.0214334
Tot_lot_size	6,557.253 *	12,403.29	14,930.06	.0219703**	.0088423	.1161865*
Tot_lot_sizesqr	-	-422.1631	-1,005.847	-	.0009482	-.0237903*
Tot_lot_sizecube	-	-	28.76551	-	-	.0012177 **
Dummy_type	-3,435.485	-3,317.755	-3,540.738	-.002648	-.0029494	-.0118854
DOM	51.40723	54.83476	54.25461	-.000452**	-.0004595**	-.0004861**
Cons	137,000.2***	138,010.9***	137,433.2***	11.45438***	11.45206***	11.42844 ***
R^2	0.8700	0.8702	0.8702	0.9021	0.9022	0.9062
Adjusted R^2	0.8532	0.8520	0.8506	0.8893	0.8884	0.8919

***, **, and *** represent significance at the 10, 5 and 1% levels, respectively.**

Models 1 through 3 represent the regression analysis of the linear model estimated using OLS. In Model 1, the statistical significance of *Tot_lot_size* at the 10% level, and the relatively high R^2 value of 0.87 suggest a good model fit.

The estimated hedonic average price of a house is about $137,000, as shown by the coefficient of the constant in the hedonic model. This coefficient is statistically significant at the 1% level. Before evaluating the relationship between lot size and the sold price of a house, it is important to state the relationship of the other independent variables to assess the validity of the model. The regression yielded results that were in line with expectations and results achieved in similar hedonic studies.

The estimated coefficient on *Taxval_listprice* indicates that for every one unit increase in the taxable value ratio, the sold price of the house decreases by approximately $2,467. Estimated coefficients for dummy variables representing home age indicate that the sold price of a 10 to 20 year old home, a 20 to 30 year old home, and an over 30 year old home is less than homes under 10 years old by amounts of $69,818; $104,887; and $107,566 respectively.

Other estimated coefficients yield the following interpretations. For each additional car space in the house's garage, the sold price of the house increases by about $38,091. For every one unit increase in the square footage of the house, its sold price increases by approximately $61. For each additional full bath, the sold price increases by around $36,719. These variables are statistically significant at the 1% level.

The effect of total lot size on home values is of particular interest in this analysis. The estimated coefficient on this variable suggests that, for every one unit (acre) increase in the total lot size of the house, its sold price *increases* by $6,557. This coefficient is statistically significant at the 10% level.

The effects of housing characteristics on sold price using a log-linear model were also estimated. The log-linear model is chosen for three reasons:

(1) Using natural log forms produces coefficients with easily understandable interpretations so that one can disregard the units of measurement of variables appearing in logarithmic form because the slope coefficients are invariant to rescaling.
(2) Taking logs usually narrows the range of the variable, in some cases by a considerable amount. This method makes estimates less sensitive to outlying observations on the dependent or independent variables.
(3) The coefficients become percentage changes in the dependent variable, which can be applied to determine actual changes, where desirable.

In Table 8.1, models 4, 5 and 6 represent the regression analysis of the log-linear model. Of these three models, Model 6 demonstrates the strongest explanatory power because of the high statistical significance of *Tot_lot_size, Tot_lot_sizesqr* and *Tot_lot_sizecube*, and because of the relatively high R^2 value of 0.91, which indicates that approximately 91% of the variation in the dependent variable *Sold_price* can be explained by the above mentioned independent variables.

The subsequent interpretation of estimated coefficients, therefore, uses reported results from Model 6.

For every one unit *increase* in the taxable value ratio, the sold price *decreases* by roughly 0.43 percent. Sold price of a home 10 to 20 years old, 20 to 30 years old, and over 30 years old is lower that that of a newer home by approximately 17.5, 33.6, and 35 percent, respectively. If the house has a basement, the sold price is generally 34.5 percent higher than a house without a basement. For each additional car space in the garage, the sold price of the house increases by 10.5 percent. For every one unit increase in the square foot of the house, its sold price increases by roughly 0.03 percent. For every additional full bath, the sold price of the house increases by about 8.5 percent. These variables are statistically significant at the 1% level.

For every additional day a house is on the market, the sold price decreases by 0.04861 percent. This variable is statistically significant at the 5% level.

For every one unit (acre) increase in the total lot size of the house, its sold price increases by roughly 11.6 percent. For every one unit increase in the square of total lot size of the house, the sold price decreases by 2.4 percent. These variables are statistically significant at 10% level. The For every one unit increase in the cube of total lot size of the house, the sold price increases by 0.12 percent. This coefficient is statistically significant at the 5% level. The quadratic form of the model suggests that the relationship between lot size and sold price is not exactly linear.

The results suggest a positive coefficient of lot size but a negative coefficient of the squared lot size indicating the presence of diminishing value as lot size increases. In order to obtain the optimal lot size, both sides of the log-linear model are differentiated with respect to total lot size and equated to zero.

1. $\delta \log (\text{Sold Price}_i) / \delta (\text{Total Lot Size}_i) = 0$
2. (0.1161865 - 0.0475806 * Total Lot Size) + 0.0036531 (Total Lot Size $)^2$ = 0
3. Total Lot Size = (0.0475806 +-.02379) / 0.232373
4. Total Lot Size = (0.0713706, 0.0237906) / 0.232373
5. Total Lot Size = 0.30714, 0.10238

The second order condition reveals that the sold price is maximized for both values of optimal lot size, i.e. for 0.30714 and 0.10238 acres, resulting in a bimodal distribution. This result is in accordance with the result obtained in the dual approach.

8.4 Summary

The results from the regression analysis are consistent with the findings from the infrastructure analysis. The results suggest that, at a given point, increasing the size of a lot has negative implications for sale price, taxable value, and thus tax revenue accrued from a house, ceteris paribus. In other words, between approximately 0.3 and 1.5 acres, there are diminishing marginal returns to increasing lot size. The benefit of using real market data is that the gap between market value and taxable value is known. Thus with recent data, the effects of lot size on the taxable value of the houses can be isolated.

This analysis is based upon a comparatively small sample size, i.e. 137 sample points from a population of 12,308 points. Moreover, the analysis is restricted to Meridian Township data. It is only a preliminary analysis that opens up opportunities for analyzing other townships and counties. Further assessments of the impact of lot size on non-infrastructure costs and revenues are needed.

9.0 Conclusions

Two broad issues emerge from this study. The first is the relationship between life cycle costs of infrastructure and density. The second is related to systems that local governments should put in place to manage their investments.

With regard to the life cycle costs for roads and sewer and water lines, it is clear from Figure 5.10 that these costs increase as lot sizes increase (or as density decreases), within the local government service boundary (i.e. for single family homes on public roads, sewer and water infrastructure). However, whether revenues from user fees and property taxes are sufficient to cover these costs is unclear. While user fees for sewer and water appear to be sufficient to cover life cycle costs for these infrastructures, the cost calculations presented here center only on the infrastructure contained within subdivisions. If the costs for trunk lines and treatment facilities were included, there is little doubt that user fees for sewer and water would be insufficient. In addition, preliminary results from the Meridian Township study suggest that property tax revenues tend to decrease as lot size increases from 0.3 to 1.5 acres.

This report provides valuable insights to inform local government decisions about sewer, water and road construction, maintenance and replacement, and zoning regulations within public service boundaries. Information that is specific to particular subdivisions studied here can not be directly applied to the experiences of other areas. However, the trend that the data shows suggests that local governments should reconsider their zoning regulations associated with the density of single family subdivisions, perhaps during the process of updating the community Master Plan. Local assessment might encourage decision makers to allow for higher density (smaller lots) to keep public service costs low enough to be offset by public revenues. Another recommendation suggested by these findings is for local governments to revisit the setting of user fees for public infrastructure to ensure that they are efficient and appropriate.

The other main issue to emerge from this study is the degree to which local jurisdictions in Michigan, with the exception of the City of Troy, lack asset management systems. The degree to which data were not available on either the physical extent of infrastructure or the costs for maintaining and replacing these infrastructures makes fiscal impact analysis difficult to perform. With this in mind, future research is recommended to increase the capacity for local jurisdictions to perform detailed fiscal impact analysis.

Five areas of research are apparent. First, research on appropriate asset management systems for local governments in Michigan is recommended. Note that this research would not be intended to establish asset management systems for each jurisdiction across the state, but to create a methodology for local governments in Michigan to set up such a system. However, as part of such research, the implementation of pilot programs for asset management across a sample of local governments would be useful. The jurisdictions studied in this report, with the exception of Troy, could serve as test cases. Indeed, Troy’s program could be used as a prototype upon which to base other programs. Pilot programs are important because they represent an education and Extension avenue for transferring knowledge from universities to communities, which is part of the mission of Michigan State University. Asset management systems would help local governments to track infrastructure life cycle costs and charge appropriate user fees to cover those costs.

The second area of research relates to multipliers used for fiscal impact analysis. As is clear from this report, there are no standard multipliers for infrastructure costs established for Michigan. However, infrastructure multipliers comprise just one class of multipliers used for fiscal impact analysis. In addition to these, there are a host of fiscal impact multipliers that are required to analyze the effects of local land and economic development policy. Among these multipliers are the number of jobs created per investment dollar, new treatment plant requirements, school expenditures, etc. Across the nation, it is not uncommon for fiscal impact analysis of economic policy to rely on multipliers constructed since 1978 by Burchell et al. (1978; 1985; 2002). Updating these multipliers and making them specific to Michigan is of critical importance.

The third area of research is to use the multipliers established above and, like the asset management program of the first recommendation, to develop a methodology for jurisdictions to perform comprehensive fiscal impact analysis. As in the first recommendation, pilot programs are also recommended as an avenue toward implementing this recommendation.

The fourth area of recommended study deals with evaluating the costs and revenues associated with non-infrastructure services provided by the local government. As noted above, the preliminary analysis of Meridian Township, Michigan, does not provide results that are readily applicable to other communities in Michigan. This same analysis can be conducted on a statewide level to determine the relationship between lot size and taxable value at a broader scale. Also, in order to determine the impact of lot size on individual government services, such as police protection, fire safety, and parks and recreation, it would be necessary to develop a regression analysis for each service, including all other variables that influence the service cost. A fiscal impact analysis of the different impacts of residential property versus commercial, industrial, farmland, and open space on local government costs and revenues is needed to determine whether certain types of land use "subsidize" others.

Finally, this study focused on the infrastructure cost differentials between single family houses that rely on public service provision of water, sewer, and roads. It is important to note that the results are not applicable to houses that have septic tanks, wells, and private roads. It would be very difficult to compare the infrastructure life cycle costs between a house within the public service boundary and one outside of it because the latter are hard to quantify (i.e. the costs borne by the individual landowner to build and maintain his/her septic system, well, and roads). Other costs, such as police and fire protection, may be quantifiable if the information is collected in an accessible format. In addition, this study was limited to relatively small lot sizes (less than one acre); further analysis with larger lot sizes is needed. One other consideration that must be noted is the cost of transferring homes currently on personal infrastructure to public infrastructure and services, which would require the decommissioning of old systems and construction of new systems. A fifth area of research, including developments that are not on public services, would be valuable to local governments, particularly in the suburban and rural areas of Michigan.

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End Notes

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[1] Lateral extensions are usually the responsibility of the homeowner and not the municipality. For this reason, they are not included in this analysis.
[2] Specifically, the cost indices for 2004 and 2003 are 133 and 132, respectively, resulting in an inflation rate of 1.01 between the two years.

Glossary

Easement - A limited right to make use of a property owned by another, for example, a right-of-way across the property.

Land use - The way land is developed and used in terms of the kinds of anthropogenic activities that occur (e.g. agriculture, residential areas, and industrial areas).

Life Cycle Costs: The cost of an asset from its inception to demolition including cost of planning, design, construction, operation and maintenance, and disposal.

Road Maintenance: In general, the preservation (scheduled and corrective) of a highway or transit line. It includes the preservation of the surface, shoulders, roadsides, and structures, including right-of-way (ROW) maintenance; and such traffic-control devices as are necessary for safe, secure, and efficient use of a highway/transit line.

Open Space: An area of land that is valued for natural processes and wildlife, for agricultural and sylvan production, for active and passive recreation, and providing other public benefits.

Right-of-Way: The land used for maintenance of roads, streets or railroad tracks belonging to the appropriate authority (highway department, county, municipality, railroad, etc.).

Sanitary Sewers: Underground pipes that carry off only domestic or industrial waste, not storm water.

Septic System: An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of tank that receives waste from a residence or business and a system of tile lines or a pit for disposal of the liquid effluent (sludge) that remains after decomposition of the solids by bacteria in the tank and must be pumped out periodically.

Septic Tank: An underground storage tank for wastes from homes not connected to a sewer line. Waste goes directly from the home to the tank.

Sewage: The waste and wastewater produced by residential and commercial sources and discharged into sewers.

Sewer: A channel or conduit that carries wastewater and storm-water runoff from the source to a treatment plant or receiving stream. "Sanitary" sewers carry household, industrial, and commercial waste. "Storm" sewers carry runoff from rain or snow. "Combined" sewers handle both.

Sewerage: The entire system of sewage collection, treatment, and disposal.

Spoil: Dirt or rock removed from its original location--destroying the composition of the soil in the process--as in strip-mining, dredging, or construction.

Sprawl: The spread of development across the landscape that far outpaces population growth" (Ewing et al., 1994).

Storm Sewer: A system of pipes (separate from sanitary sewers) that carries water runoff from buildings and land surfaces.

Trench Slope: Slope of trench excavation walls which is dependent on the soil type to prevent trench cave ins as required by OSHA.

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