A geographic information system fiscal analysis of development patterns in Bozeman, Montana
by B Stewart Mitchell, Jr

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
Rapid population growth in and around Bozeman, Montana is creating sprawl. The community is struggling to manage the rising cost associated with sprawl and preserve the traditional quality of life. This thesis addresses the question of whether it is possible to accommodate the growth in a less costly manner and preserve the qualities that make the Gallatin Valley a desirable to place to live. Current planning practices' and zoning regulations permit only sprawl style development. However, new urbanism development patterns offer cost savings over sprawl. This thesis uses a geographic information system and a fiscal model to compare and contrast a sprawl development and a new urbanist development in Bozeman, Montana. The results demonstrate the new urbanist development generates more tax revenue and has a lower cost of services than the sprawl development.

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B. Stewart Mitchell, Jr.

A thesis submitted in partial fulfillment
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of

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in

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APPROVAL

of a thesis submitted by

Barton Stewart Mitchell, Jr.

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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TABLE OF CONTENTS

Page

LIST OF TABLES.. vii

LIST OF FIGURES.. viii

ABSTRACT... x

PREAMBLE.. xi

INTRODUCTION... xii
Definitions.. xiii

1. GENERAL CONTEXT OF THE THESIS.............................. 1
Population Growth.. 1
Land Use Conversion... 3
Planning... 6
The Development Patterns to be Compared........................ 11
Local Landscape.. 13
Other Research... 16
The Plan... 16

2. THE MODEL.. 18

3. DATA... 26
Development Patterns.. 26
Spatial Data... 31
Cost of Services.. 37
Tax Revenue and Land Use Types................................. 39

4. METHODS.. 47

5. RESULTS.. 53
Valley Unit Subdivision... 53
Sprawl Development.. 55
New Urbanist Development.. 55

6. DISCUSSION... 57

Page

Cost of Services: Sprawl vs. New Urbanist.............................. 57
Tax Revenue... 63
Spatial Differences in the Sprawl and New
Urbanist Development.. 64
Future Land Use Conversion, Cost of Services
and Tax Revenue.. 65

7. CONCLUSION.. 67

REFERENCES CITED.. 68

APPENDICES... 72
Appendix A- Cost of Services.. 73
Appendix B- Montana Power Company
Gas and Electric Costs.. 75

LIST OF TABLES

Table Page

1. General Characteristics of Residential Sprawl and New Urbanist Developments xv
2. General Conditions of Urban Sprawl and Smart Growth 12
3. Spatial Data Creation Sources for Valley Unit Subdivision 32
4. Tax Revenue Generated by Land Use Types 41
5. Results 54
6. Future Land Use Conversion, Cost of Services, and Tax Revenue 66

LIST OF FIGURES

Figure Page

1. Map of Water Well Density by Date.................................... 7
2. Proposal for a New Urbanist Style Development in Bozeman, MT.. 10
3. Study Area and Valley Unit Subdivision................................ 19
4. SmartPlaces® Interface with Radix, Scenario Builder and Report Card in ArcView® 21
5. Example of a SmartPlaces® Radix.. 23
6. Example of Attribute Table with Cost Data............................. 25
7. General Layout and Land Use Types in the Valley Unit Subdivision.. 28
8. General Layout and Land Use Types in the Sprawl Development... 29
9. General Layout and Land Use Types in the New Urbanist Development... 30
10. Data Flow Chart... 36
11. Location of Properties Used for Tax Data Quantification........... 42
12. Amount of 1999 Annual Property Taxes................................43
13. SmartPlaces® Report Card for Radix Evaluation of the New Urbanist Development................................... 52
14. Comparison of Road Features in Sprawl and New Urbanist Development... 59

LIST OF FIGURES CONTINUED

Page

15. Comparison of Land Use Patterns and Types in the Sprawl and New Urbanist Development.................................. 60

16. Comparison of Water Features in Sprawl and New Urbanist Development.. 61

17. Comparison of Sewer Features in the Sprawl and New Urbanist Development.. 62

ABSTRACT

Rapid population growth in and around Bozeman, Montana is creating sprawl. The community is struggling to manage the rising cost associated with sprawl and preserve the traditional quality of life. This thesis addresses the question of whether it is possible to accommodate the growth in a less costly manner and preserve the qualities that make the Gallatin Valley a desirable to place to live. Current planning practices and zoning regulations permit only sprawl style development. However, new urbanism development patterns offer cost savings over sprawl. This thesis uses a geographic information system and a fiscal model to compare and contrast a sprawl development and a new urbanist development in Bozeman, Montana. The results demonstrate the new urbanist development generates more tax revenue and has a lower cost of services than the sprawl development.

Preamble

It was a warm spring day and I was riding in my father's car with my 10 year old eyes. I watched the endless rows of houses and stores scroll through the frame of my window. I asked my father, "How big is our town?" my father replied, "Its getting bigger every day. When I was a boy this whole area was nothing but farms and fields." I always enjoyed watching the "landscape movie" play through a car window. Every time I return to my childhood home and travel a familiar route, I am treated to a sequel, and just like a Hollywood sequel, it gets worse with every repetition. The forests and fields I loved as a child are now covered with subdivisions and mini malls. I have often wondered, if this never ending consumption is the best use of our land resources.

INTRODUCTION

The dominant pattern of land use that spreads out from most American population centers, converting farms and fields to homes and malls, is known as urban sprawl. Sprawl is low density, unplanned, inefficient, auto dependent growth (Burchell, 1997). Sprawl is the landscape signature of the American dream.

Until recently, such low density development was unquestionably accepted as progress in this country. Now, in the post modern era, some are beginning to question the merits of this type of expansion and realize this type of low density development has produced unanticipated consequences.

The drivers and consequences of sprawl represent a complex web of connections between socioeconomic factors and the landscape. The drivers of sprawl include population growth, land use conversion and zoning. Large scale land use conversion at low densities resulting from urban sprawl has been associated with low quality of life, rising tax burdens and increasing pollution (Gordon and Richardson, 1997). Moreover the sense of place is lost when the landscape becomes so homogenized, that one place becomes undistinguishable from another (Kunstler, 1993). These consequences are compounded in regions with little planning and rapid population growth. One of the most significant problems associated with urban sprawl is the cost of providing and maintaining municipal services to new low density development.

In the last ten years, there has been a growing wave of "Smart Growth" initiatives across the country (Morris, Feb. 1999). The main goal of these initiatives is to create a landscape that is less costly to the public and individuals from an economic and lifestyle perspective. Smart growth achieves these goals by encouraging or mandating land use development in a more efficient and compact pattern.

This study will quantify the costs of providing municipal services to a sprawl style development and contrast these results to the financial costs related to an alternative land use pattern known as new urbanism. New urbanism is associated with Smart Growth. The comparison of these development patterns will be conducted through the use of a Geographic Information System (GIS) model. The model results will test the hypothesis that higher density development with mixed zoning has economic benefits over low density sprawl development.

Urban sprawl, new urbanism, smart growth and land use are terms that have varying definitions in public and academic contexts. For clarity, the following definitions will be used in this thesis.

Definitions

Land use refers to how humans interact with, change and use the natural landscape of a region for various economic functions (Platt, 1996). **Land use** types are used by the United Stated Geological Survey (USGS) to distinguish specific types and subsets of specific land uses such as, agricultural, commercial, urban or residential. **Subdivision** refers to the division of a tract or parcel of land into two or more lots or parcels (Kelly and Becker, 2000). **Urban sprawl** or simply **sprawl** is the unlimited outward expansion from population centers of low density, segregated, auto dependent, commercial and residential land uses (Jackson, 1987). This type of land use usually follows a path of least resistance along existing roads (Lewis, 1999). **Leap Frog development** is a term used to describe sprawl development that occurs beyond the edge of existing developed land uses (Vermont Forum on Sprawl, 1999).

Smart growth is an all encompassing term that is frequently used to describe a type of land use development that seeks to decrease the negative impacts of commercial and residential land use development through higher densities, less dependence on the automobile and mixed zoning types (O'Neil, 1998). **New urbanism** is depicted as an area where homes are closer together and closer to the street, walking is made easy by attractive pathways connecting homes to shopping and community services, street systems are interconnected to reduce traffic congestion, forms and scales are comfortable and comparable and open spaces of many kinds are readily accessible (Porter, 1997).

Table 1: General characteristics of residential sprawl and new urbanist developments.

Sprawl	New Urbanist
Based on a Grid	Based on a Grid
Single type of residential land use	Mixed types of residential and commercial
Low dwelling units per acre	High dwelling units per acre

The first chapter will set the general context for the local and national landscape from the perspective of land use issues and will introduce the development patterns that will be compared by the model. The second chapter provides a detailed explanation of the software used to model the differences between the development patterns. Chapter 3 outlines the data compilation methods for the project. Chapter 4 explains the methodology used in the study. Chapter 5 will present the results of model. Chapter 6 discusses all findings and suggests areas for further research. The conclusion will be stated in the final chapter.

CHAPTER 1

GENERAL CONTEXT OF THE THESIS

The objective of this thesis is to compare the cost of providing specific municipal services and to determine the amount of tax revenue generated by two distinct land use development patterns using a GIS model. The model will compare a sprawl and new urbanist development with an equal spatial footprint. The specific aspects of these developments to be compared by the model include: the cost of municipal services, tax revenue generated, spatial properties and amount of projected future land use conversion with each development pattern.

The comparison of land use development patterns on the landscape presents a very complex task. Various large scale elements of land use must be introduced for the small scale analysis of different development patterns to be understood. The large scale elements affecting land use include population growth, specific types of land use conversion, planning and socio-economic conditions.

Population Growth

In the United States there are 3148 counties of which 838 experienced a population growth rate between 14% - 156% percent between 1990 through 1999 (ArcView® /Census, 1999). Two hundred and eleven of these counties are located in the Rocky Mountain states: Arizona, Colorado, Idaho, Montana, New Mexico, Utah and Wyoming (ArcView® /Census, 1999). The average population growth rate of these 211 counties was 26 percent. In Montana, 17 counties grew by 14 % or more during the same period.

The population of Gallatin County expanded by 26% between 1990 and 1999 (Montana Department of Commerce, 2000). The latest wave of growth is the result of a uniquely motivated surge of immigration from other national regions (Jobes, et. al., 1992). Significantly, this migration was not motivated by economic opportunity, the historical norm in previous waves of western settlement (Jobes, et. al., 1992). Rather. the primary motivation of these new migrants was the perceived quality of life, sense of community and access to resource amenities that provide a wide array of recreational opportunities (Jobes, et. al., 1992).

From the late 1940s through the 1980s, Bozeman, the largest town in Gallatin County, grew at a relatively constant rate and retained a compact development pattern. The town's main socio-economic structure was based largely on agriculture, the retail sectors and government entities (Rasker, et.al., 1991).

Population growth in Gallatin county provides a driving factor creating shifts in land use conversion and increasing demand for public services.

Land Use Conversion

According to a recent study only 2.7% of the total area of the continental United States is urban (Imhoff, et. al. 1999). This figure suggests that a benign amount of land has been converted to urban land use. However, this study and others have found that residential, commercial, and industrial land use development has occurred on the most productive agricultural lands (Imhoff, et. al. 1999). This phenomenon is largely a result of America's agrarian heritage. Population centers historically developed in rich agricultural areas. Consequently, increasingly large tracks of land are being converted from agriculture to commercial and residential uses as urban areas continue to grow at low densities. This process is known as sprawl. The Rocky Mountain region is experiencing a new wave of land development driven by the expansion in the service, recreational, and information sectors. (Riebsame, et.a.l., 1996). As the population of Gallatin Country grows the amount of land converted from agricultural to commercial and residential land use steadily increases.

Sprawl is becoming an increasingly prevalent topic across the country. The loss of open spaces and climbing costs associated with such development have brought this issue to the forefront of public policy debate (Morris, Feb. 1999). The geographic area affected by urban sprawl can be identified as most areas surrounding established population clusters that have been, or are currently experiencing increases in land use development (American Farmland Trust, 1995).

Between 1970 and 1990, there was a 6% - 12% increase in land consumption for every 1% gain in population in metropolitan areas (American Farmland Trust, 1999). In Chicago, in the same period, the population grew by 4% while the land area devoted to urban uses increased by 46% (American Farmland Trust, 1999). These numbers support the observation that land use conversion is occurring at relatively low residential and commercial densities. In Gallatin County and western Montana more people are moving to rural areas than to incorporated areas such as cities (Johnson 1998).

Basic economic forces also encourage this type of land use conversion. Land sold for commercial and residential development has a higher value than equivalent parcels designated for agricultural use (Platt, 1996). Limiting the amount of land for this development conversion eliminates the potential for capital gain by individuals (Platt, 1996). Low density development assists in the perpetuation of land use conversion by ensuring the demand for commercial land development is higher than if land use development is done at higher densities (Platt, 1996).

Another factor driving the shift in land use patterns since WWII is the automobile (Platt, 1996). The post WWII development patterns are characterized by the improvement and extension of roads, setting stores further back from roads to allow for store front parking and homogeneous development occurring along connecting road corridors (Platt, 1996). The Highway Act of 1956 increased the spread of low density development by making previously distant land accessible to large population centers (Audriac et al, 1990).

For the last 50 years, the automobile has been an undisputed feature of American life, however many are beginning to question its real benefits (1000 Friends of Oregon, 1996). There are more automobiles on American roads than ever before and people are spending more time in their automobiles (Davis and Seskin, 1997). Although the automobile can be a great convenience and has made significant contributions to the development of our culture, it is now apparent that this contribution has come with hidden costs. These costs include pollution, cost of constructing and maintaining roadways, and individual operating costs (Bartholomew, 1993). The automobile has also been accused of decreasing the quality of life experienced by many Americans (Davis and Seskin, 1997). The time spent in an automobile reaching frequently needed services is lost to more productive uses. From 1970-1990, the U.S. Population grew by 22.5% and the number of vehicle miles traveled grew 98% (American Farmland Trust, 1999). The proliferation of the automobile has increased the amount of land use development and significantly reduced its overall density (Handy, 1992). Prior to large scale use of the automobile, population centers were designed around the distance one could walk, rather than drive.

It is important to note that an array of other factors have also contributed to the contemporary landscape. Low cost mortgage programs created under the Federal Housing Act made home ownership possible to many who could not otherwise afford to buy a home (Gerckens, 1994).

Montana and other rural areas in the Rocky Mountain region have not experienced the same high levels of low density land use conversion that occurred in the rest of the country since the 1950s due to the region's long distances to major metropolitan centers. Much of the low density land use development in this region has occurred in the last 15 years. An isoline map of well density by date in the Gallatin Valley shows developments have sprung up far from existing population clusters in the greater Bozeman area in the last 13 years (Figure 1). Low transportation costs afforded by the automobile make this type of development possible. The map depicts densities of well permits for residential use in ten year increments from 1977 through 1997. On the map there are several residential developments that appeared in the last decade in areas with little or no previous residential development.

Planning

A major influence on land use patterns that has functioned in concert with the automobile is single land use zoning (Canter, 1985). It is also known as Euclidean zoning from the precedent setting case of *Euclid vs. Amber Realty* in 1926 that upheld the validity of New York's Zoning Ordinance of 1916 (Woodruff, 1980). Euclidean zoning was introduced in the first half of this century in most large

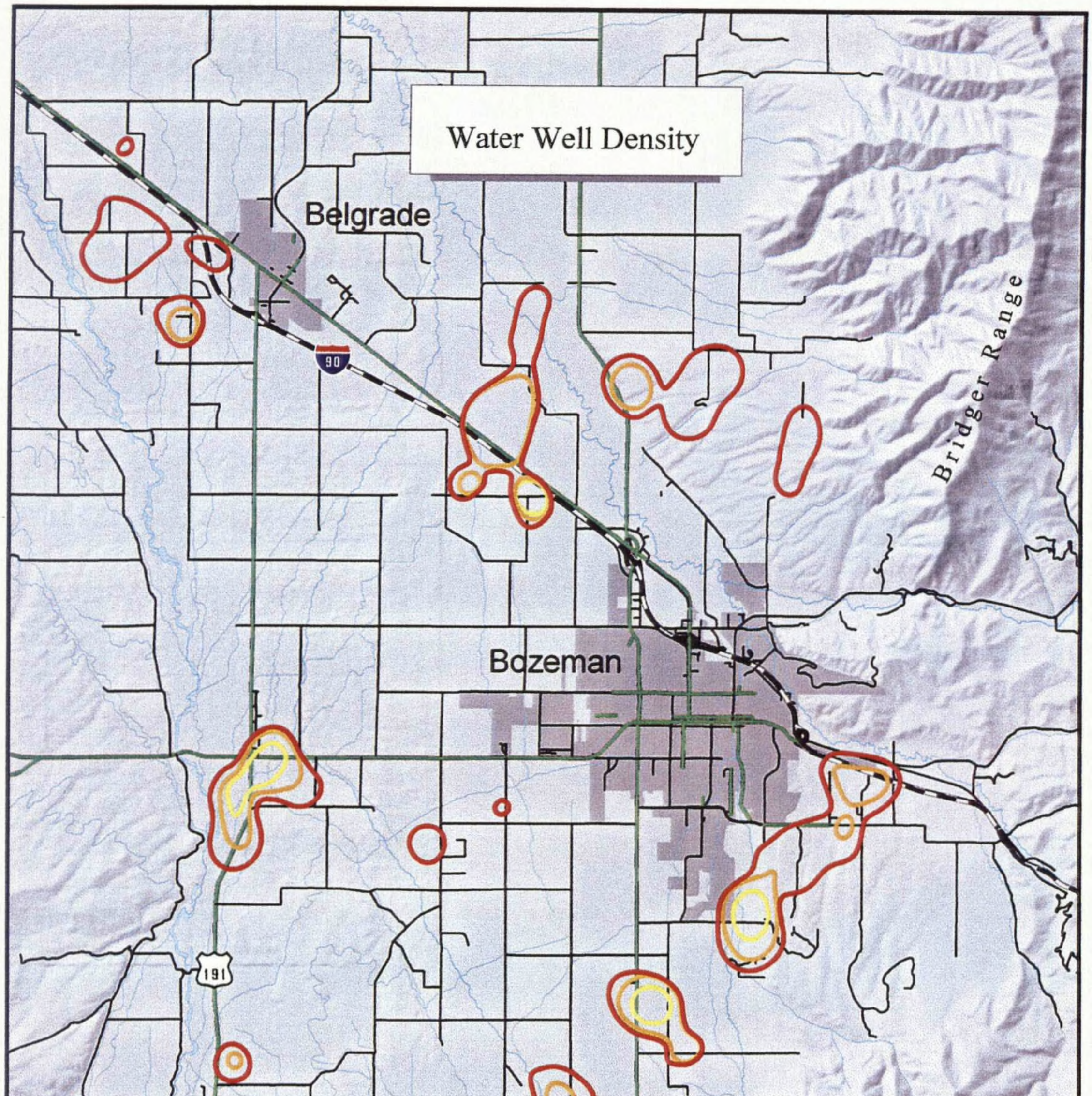


Figure 1: Map of water well density by date.

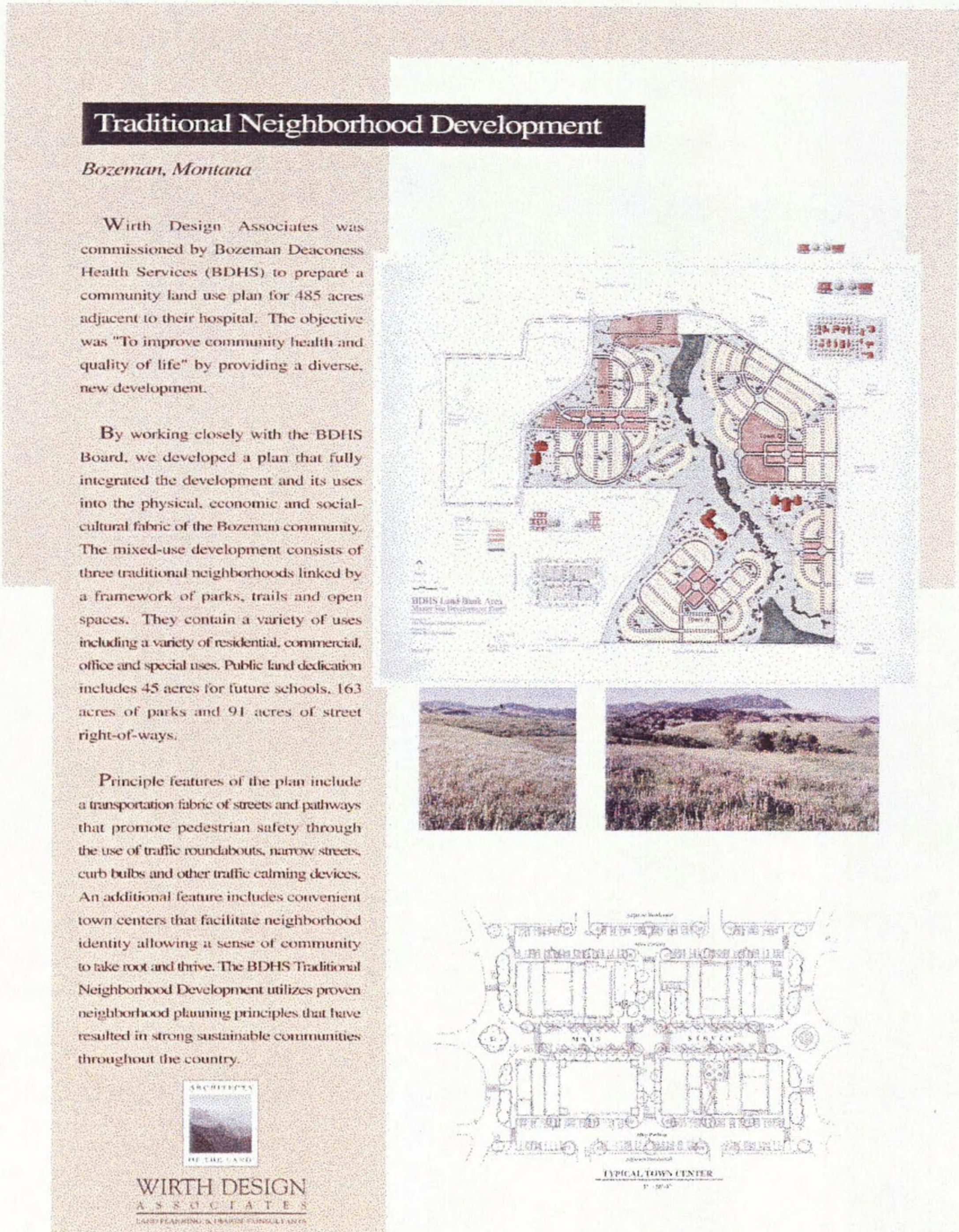
metropolitan areas (Gerckens 1994). Planning agencies embraced the concept as a rational and effective method of harmonizing different and often conflicting land uses such as industrial and residential (Platt, 1996). It also became a tool for municipalities to further subdivide residential land uses. Minimum lot sizes and housing square footage facilitated the grouping of different socio-economic classes (Lapping, 1980). Although Euclidean zoning was seemingly well intentioned at the time, only now are its unintended consequences becoming apparent.

Dividing a landscape into of homogenous land use patches is inefficient in that it increases distances between service providers and users (Davis and Seskin, 1997). The degree of inefficiency is a function of total population. As the population of an area with segregated land use grows, so does the distance individuals must travel to different types of service providers. Although Euclidean zoning exists almost everywhere in the United States, a small town with a relatively small total population will not have such great distances between residences and various services as exist in large metropolitan areas. This land use pattern contributes to the concept of small towns providing a high quality of life to its residents.

As the population grows in the rocky mountain region the demand for effective planning practices also grows. As Euclidean zoning is virtually the only paradigm in use, its reaction to rapid population growth has resulted in vast landscapes of sprawl. The debate about the causes and effects of growth planning and land use conversion has only heightened rage as powerful development interests seek to protect capital interests and local governments struggle to react to rapid growth.

As in much of the region, growth is a growing public concern in Bozeman, but there is little consensus on the drivers and impacts of growth. In fact there is a large portion of the community that believes that the management of land use conversion is best left to the free market. This sentiment seems to be the dominant political view as evidenced by the relative lack of planning in the region. Moreover, the planning that does exist is completely based on the principles of Euclidean zoning. The absence of effective local planning can compound the negative effects of rapid growth (Forman, 1995). In reality, the true land use planners are the private land owners and free market forces that derive different values for specific land-use types (Davis and Seskin, 1997). Municipal planning boards are in this situation reactive organizations. Until the rapid growth of the last decade there were few obvious land use problems in the Bozeman area. Today the local municipal planning infrastructure has been overwhelmed.

New urbanist developments have been proposed in Bozeman (Figure 2). However, they currently require special permits due to existing zoning conflicts. This special status allows any opposition to easily prevent local authorities from granting the special permitting as happened with the Wirth Designs proposal (Miller, 1998).



Traditional Neighborhood Development

Bozeman, Montana

Wirth Design Associates was commissioned by Bozeman Deaconess Health Services (BDHS) to prepare a community land use plan for 485 acres adjacent to their hospital. The objective was "To improve community health and quality of life" by providing a diverse, new development.

By working closely with the BDHS Board, we developed a plan that fully integrated the development and its uses into the physical, economic and social-cultural fabric of the Bozeman community. The mixed-use development consists of three traditional neighborhoods linked by a framework of parks, trails and open spaces. They contain a variety of uses including a variety of residential, commercial, office and special uses. Public land dedication includes 45 acres for future schools, 163 acres of parks and 91 acres of street right-of-ways.

Principle features of the plan include a transportation fabric of streets and pathways that promote pedestrian safety through the use of traffic roundabouts, narrow streets, curb bulbs and other traffic calming devices. An additional feature includes convenient town centers that facilitate neighborhood identity allowing a sense of community to take root and thrive. The BDHS Traditional Neighborhood Development utilizes proven neighborhood planning principles that have resulted in strong sustainable communities throughout the country.

ARCHITECTS OF THE LAND

WIRTH DESIGN
ASSOCIATES

Figure 2: Proposal for a New urbanist style development in Bozeman MT.

The Development Patterns to be Compared

Robert Burchell, a leading researcher with the Center for Urban Policy at Rutgers University, defines ten elements of large scale sprawl as follows (Morris, 1999 and Downs, 1998).

1) Low density residential development.
2) Unlimited outward expansion of development.
3) Segregation of different types of zoning.
4) Leapfrog development.
5) No centralized ownership of land or planning.
6) Transportation dominated by privately owned motor vehicles.
7) Fragmented governance of land use between different local governments.
8) Varying fiscal capacity of local governments (revenue-raising capability strongly tied to property values and economic activity within municipal boarders).
9) Widespread commercial strip development along major roadways.
10) Reliance on the trickle-down process to provide housing for low income households.

It is clear that all of these elements exist and are dominating development patterns in the City of Bozeman and Gallatin Valley.

The other type of development pattern that will be analyzed is currently referred to as New Urbanist or New Urbanism. It features a combination of land use types and zoning designations including light commercial and mixed residential types, laid out in a grid with significant amounts of public open space (James Duncan and Assoc., 1999). New urbanist developments have a much higher density than is usually found in sprawl style developments. Although such developments and smart growth principles are becoming more popular in local communities, the legal, political and economic conditions that have contributed to sprawl also work against the application of smart growth principles that would allow new urbanist developments (Katz, 1993). In order for new urbanist developments to be built the opposite conditions of sprawl must exist (Burchell, 1997)(Table 2).

Table 2: General conditions of urban sprawl and smart growth.

	Conditions of Urban Sprawl	Conditions of Smart Growth
1	Weak non-centralized planning	Centralized planning authority
2	Unlimited outward expansion	Growth boundaries
3	Homogenous Zoning pattern	Mixed Zoning
4	Leapfrog Development	Infill development
5	Mostly Auto travel	Public and pedestrian travel

All conditions of smart growth as listed above need not exist in every development. A survey of recent new urbanist developments and smart growth policies reveals varying degrees of success with none possessing all the opposite conditions of sprawl (Urban Land, 1999). The two hypothetical developments that will be compared in this study are a small scale residential sprawl and new urbanist development.

Local Landscape

Although many can describe the favorable attributes associated with a local community, few understand how land use patterns and total population contribute to these attributes. The current geographic situation in Bozeman and its high quality of life are largely due to its small total population, isolation from large metropolitan areas, and its relatively mixed and compact development patterns. This type of land use pattern makes small towns desirable places to live (Johnson and Rasker, 1995). These conditions exist due to Bozeman's exclusion from the major socio-economic shifts and resulting land use changes that were so prevalent in the rest of the country since WWII. Until about 1990, Bozeman did not experience large amount of sprawl development.

In small booming communities like Bozeman in the 1990s the building industry wields considerable economic, social, and political power as it generally represents one of the largest sectors of the local economy. The capital interests within this sector are naturally reluctant to change a currently profitable paradigm. With the dominant land use development model of sprawl the risk of development creating large physical distances between services and consumers also grows. Observation of the landscape anywhere in the Gallatin Valley demonstrates that the growth of the last decade has produced large amounts of relatively unplanned, inefficient, low density and low quality development. This development starkly contrasts the land use pattern experienced by many Montana communities from the time of the original Anglo settlement until the mid 1980s. This compact land use pattern can still be seen in many rural Montana towns that have not experienced a recent population boom. A good example would be Three Forks, which is located on the western edge on the Gallatin Valley. The land use development pattern of town centers with mixed use surrounded first by residential land use and then a sea of agricultural or forested areas is more European than late 20^{th} century American (Diamond and Noonan, 1996).

Unfortunately, the idea that clustered compact land use patterns and the lack of sprawl make small communities desirable places to live has not been realized by many within the local Bozeman community. Until the mid 1980s, the greater Bozeman area possessed elements of small compact mixed land use patterns. Unfortunately, as this region increasingly experiences unplanned sprawling growth, its desirable land use patterns and sense of place are being lost.

A recent study in the Bozeman area suggests that existing residential land use does not generate sufficient tax revenue to pay for the services it requires (Haggerty, 1996). The high cost of services and the impact of recent development has become a very contentious issue. Impact fees on area builders have been instituted by referendum but the measure is being challenged in court by the Southwest Montana Building Industry Association (Miller, 1999).

There is a strong correlation between the current health of the local economy and the role of the county's population growth (Johnson and Rasker, 1995). It is widely accepted that, if future growth is not managed in a manner that prevents the destruction of the traditional landscape, there could be future negative implications for the local economy (Johnson and Rasker, 1995). If Bozeman loses its traditional mixed use land use and compact development patterns, the wave of immigrants and resulting economic prosperity could be significantly diminished. Although some interests would surely relish in the decline of migration to the Gallatin Valley, the remaining residents could be left with a very expensive municipal landscape to service.

The typical model of large scale urban sprawl development throughout most of the United States relies on retail sales taxes to pay for the increasing cost of providing municipal services to low density inefficient development (Burchell, 1992). In Montana there is no sales tax to compensate for a growing deficit in public funds. As inefficient development continues to spread across the landscape, so does the demand on the tax base, and the threat of a major fiscal crisis grows.

The complex web of different human constructs and topics involved in land use conversion has been briefly introduced. Although it is beyond the scope of this project to consider all of these topics in detail, it is important to remember the scope and complexity of the issues involved in land use development. The many connections between different elements of society and the natural landscape make this a significant topic that is best examined from a geographic perspective.

Other Research

There is a significant amount of research in quantifying the costs of services and the costs of sprawl across the country by a variety of different interest groups which considered many potential areas of impact (Morris, Feb.1999). The majority of previous research has generated the similar conclusions and research difficulties (Morris, Feb. 1999). Urban sprawl is a costly and inefficient development pattern that is occurring at an alarming rate across the country (Burchel, 1994). Smart growth, new urbanism, clustered, and mixed use zoning land use provide a better quality of life while generating the necessary tax revenue to sustain the development (SEMCOG, 1997). The studies reviewed by Morris describe difficulty of quantifying costs associated with growth and land development in a consistently accurate manner. However, the majority of these studies have reached the same conclusions by so wide a margin that they exceed any realistic margin of error in quantifying costs (Morris, Mar. 1999).

The Plan

Given the current trends in Bozeman and what has occurred elsewhere in the country, it is important to quantify the specific costs associated with growth patterns and the amount of tax revenue they generate. Although this type of study has been completed in other locations it is vital to conduct a local area study to add relevance to the results. Equally important is the comparison of current development patterns with alternative development patterns that may have more overall benefits. It is hoped that this project will provide local stakeholders with valuable information and a method of inquiry which can be used in directing future land use policy.

This thesis is designed to reduce quantification uncertainties of previous large scale impact analysis by reducing its scale and incorporating the actual costs of specific features within a GIS. The results will provide actual numbers as opposed to statistical interpretations. The calculations will reveal differences in the cost of services, tax revenue generated, spatial properties and the amount of future land use conversion associated with two distinct land use development patterns. The general development patterns analyzed exist in the real world and provide the context for understanding the fiscal differences. A third "real world" development that exists on the ground will be included as a reference for the model and the results it generates.

CHAPTER 2

THE MODEL

Urban sprawl is recognized as being a less than economically optimal land use (Diamond and Noonan, 1996), but what does this mean? What are the financial benefits of possible alternatives? Most land use models are framed in an urban economic or industrial context (Frank, 1989). These types of land use conversion models rely on statistical analysis of many variables (Frank, 1989). These models take years to construct and their hard to quantify methodologies are complex, making interpretation by the public difficult. This model will accurately define the economic characteristics of two different types of small scale developments and an actual subdivision.

This thesis focuses on quantifying the financial costs of supplying municipal services and the amount of tax revenue generated by a sprawl development and a new urbanist development in the City of Bozeman. Valley Unit, a 229 acre subdivision on the western edge of Bozeman will be used as a reference for the two hypothetical subdivisions. An actual 385 acre piece of ground currently slated for development will be used as the footprint for the two hypothetical developments, this area is shaded in yellow directly west of Valley Unit which is shaded in blue on the study area map (Figure 3).

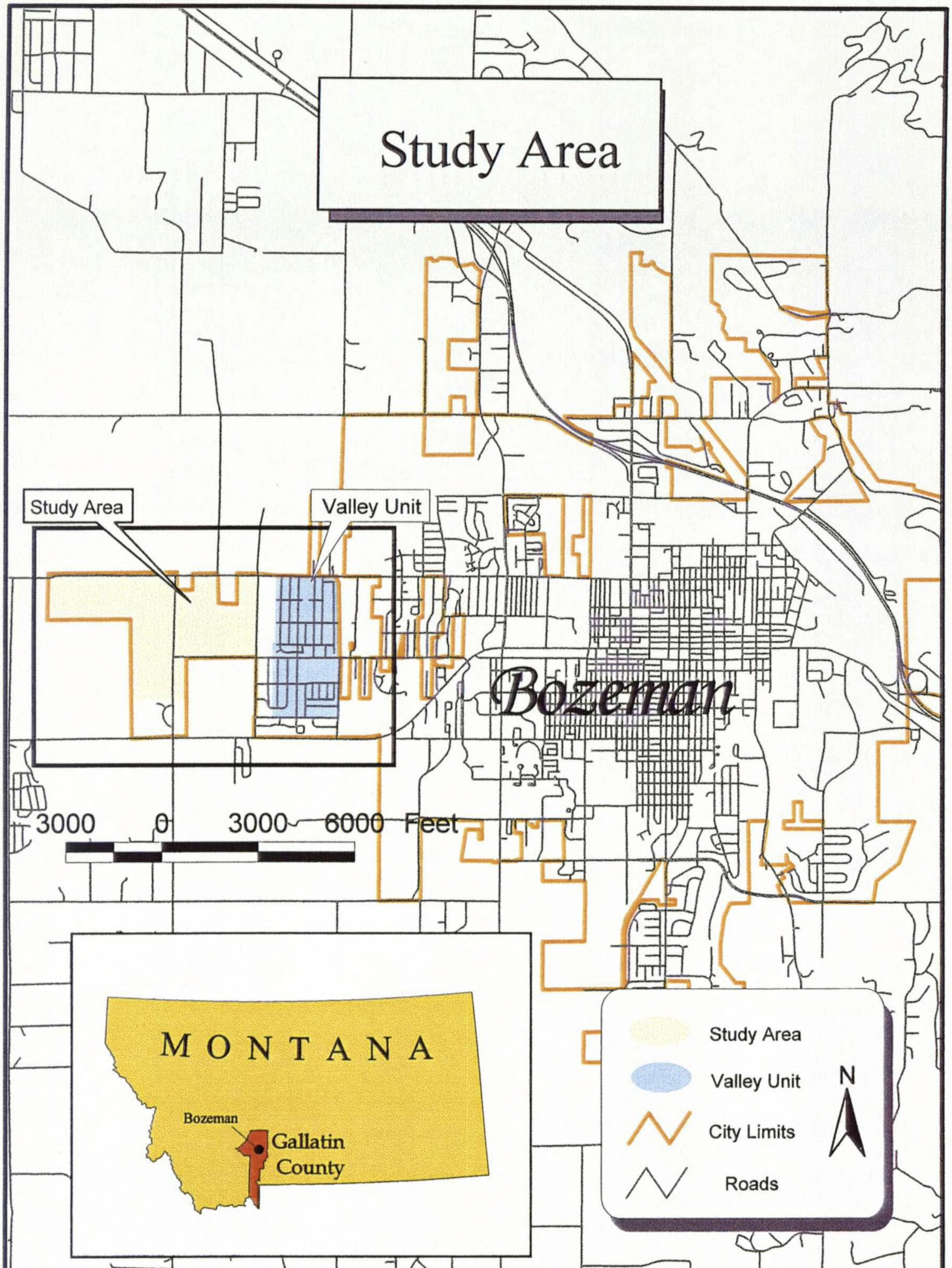


Figure 3: Study area and Valley Unit subdivision.

The GIS model has two main components. The first in ArcView®, in its standard configuration. The second component is an extension for ArcView®, SmartPlaces®. SmartPlaces® is a GIS based decision support system that employs a unique graphical interface enabling simple integration, calculation and modification of attribute data within GIS coverages. SmartPlaces® was designed to make quantification and analysis of large geographic data sets easily understood by non-geographers (Electric Power Research Institute, 1998).

The interpretation of the modeling process by non-GIS users is achieved by displaying its functions and results in a graphical manner. SmartPlaces® will be used to determine the cost of services, the amount of tax revenue generated and the spatial properties of the two hypothetical developments and Valley Unit subdivision, Valley Unit. Although ArcView® is capable of these functions it does not have a graphical interface that links several functions into one command, and the ability to perform simultaneous calculations on several different themes without adding a custom application in ArcView's® programming language Avenue®. SmartPlaces® will be employed as a spatial spreadsheet for determining the fiscal characteristics of the three developments.

SmartPlaces® has two main components: a scenario and a radix (Figure 4). The scenario contains the themes to be evaluated by the radix. The radix can calculate any tabular or spatial data within the Scenario. The scenario is fully compatible with all the functions of ArcView®.

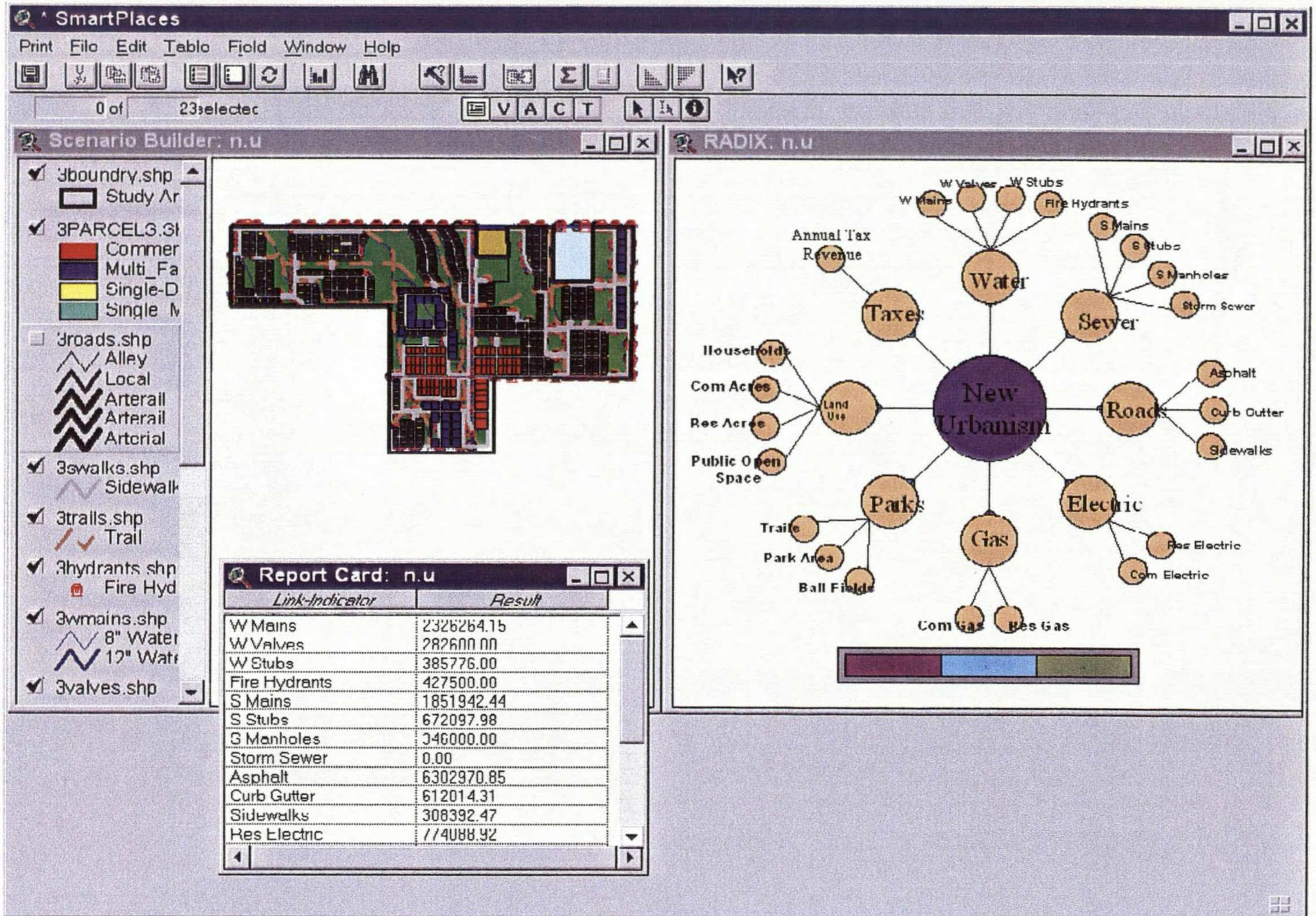


Figure 4: SmartPlaces interface with radix, scenario builder and report card in ArcView.

All of the ArcView® themes representing the Valley Unit subdivision, sprawl and new urbanist developments were loaded into an individual SmartPlaces® scenario.

The radix has many possible functions and can be best described as a graphical interface with a GIS's functionality. It allows individual, or groups of calculations to be made on the values in ArcView's attribute tables. The calculations are user defined and can be conducted on any field included in the attribute table. The radix is the interface to the functions responsible for processing user defined calculations. In this thesis, SmartPlaces® provides a graphical organization for cost, tax and spatial calculations.

The radix has three concentric rings of circles representing the core, features and indicators respectively (Figure 5). The core represents the scenario to which the radix is linked. For example, the core of the radix for the new urbanist development is labeled new urbanist and is linked to the new urbanist scenario. The next outward set of circles attached to the core represent the feature classes that will be measured. One example of a feature class is "water." The next set of outward circles represent the feature indicators that represent the specific elements of the feature class. An example of a water feature indicator is "water mains." Each indicator can be programmed to perform any one of several statistical analyses on values contained in one or several fields in a scenario themes attribute table.

After the radix has been programmed it serves two purposes. 1) The radix performs the programmed analysis and generates the output in the form of an on-screen table called a report card. 2) It allows the selection of individual, a

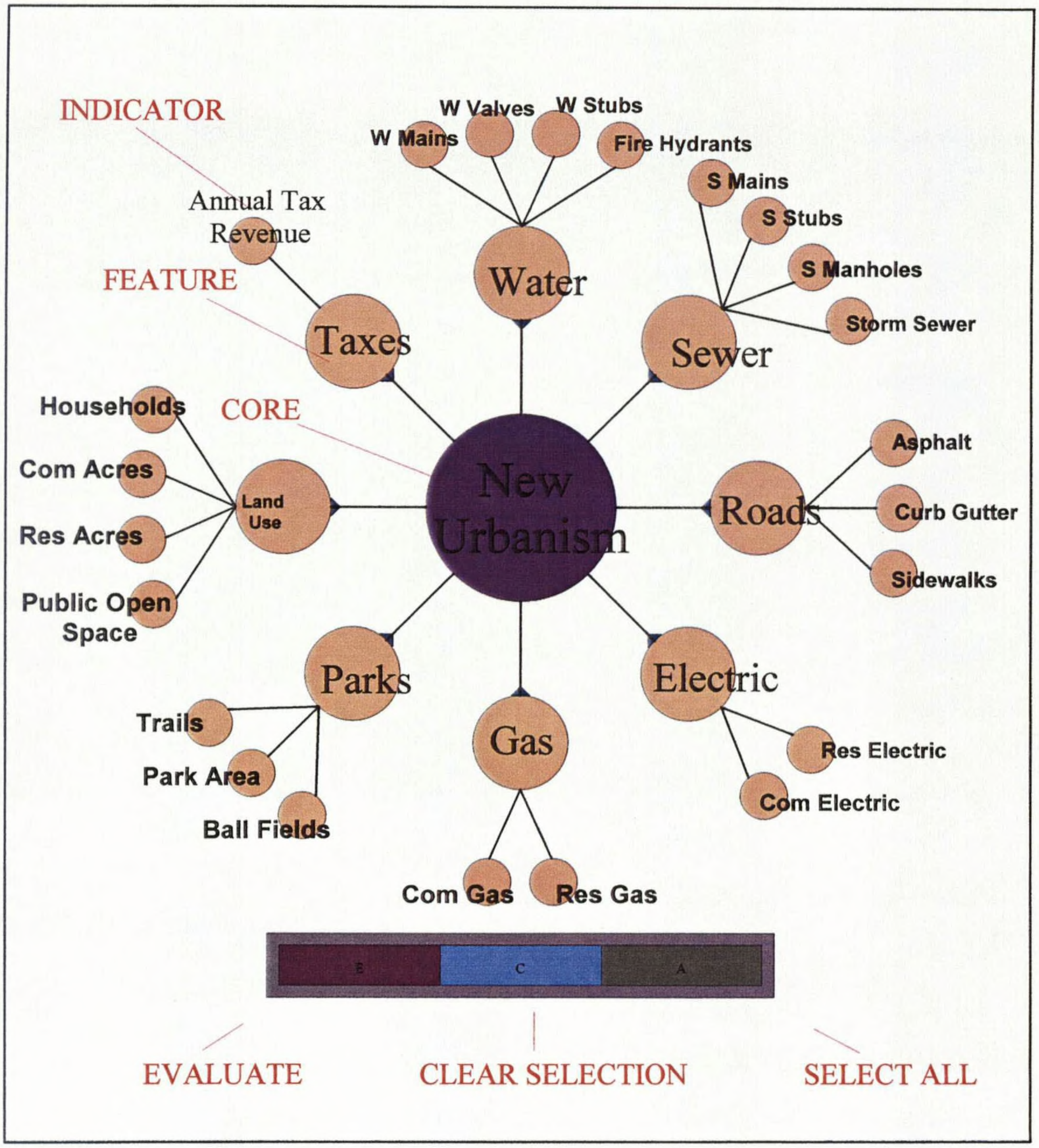


Figure 5: Example of a Smart Places Radix.

group, or all indicators to be evaluated. The radix can also be programmed to produce charts of all analysis.

In this study, SmartPlaces® is employed to sum the cost, tax and area fields for individual themes contained within each respective scenario. For example, the attribute table of the water main theme in all three scenarios contains a length field for each section of water main pipes. This table also contains a cost per length field and a cost field (Figure 6). SmartPlaces® will determine the total cost of water mains in each scenario by summing the cost field using an indicator within the given radix. This indicator is linked to the water main theme in the respective scenario.

A radix and a scenario are constructed for the two hypothetical developments and the Valley Unit subdivision. The output or report cards will be combined to create one table. This table will display the results of the spatial and fiscal comparison.

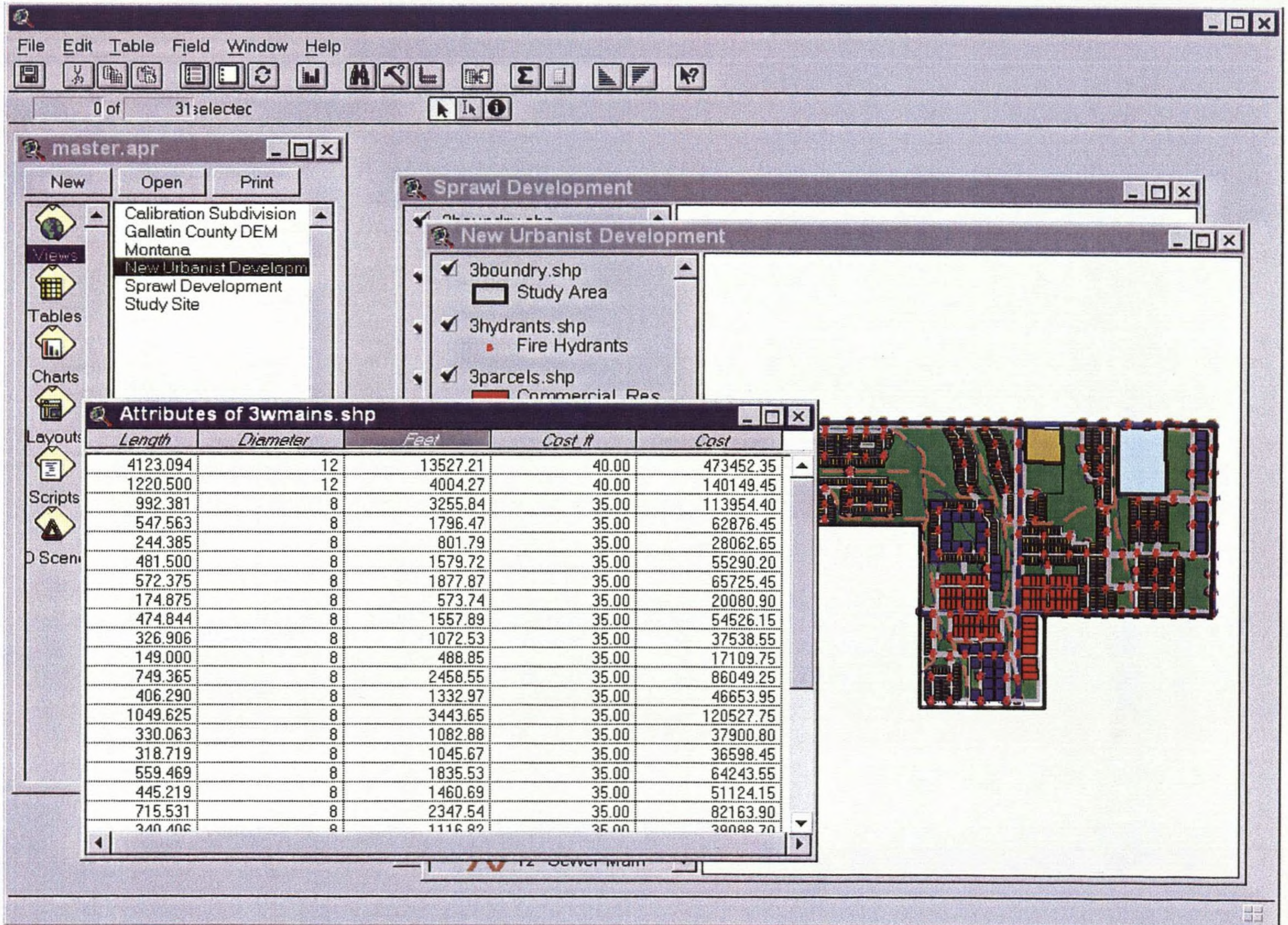


Figure 6: Example of attribute table with cost data.

CHAPTER 3

DATA

This project required a large variety of data to accurately quantify the various features associated with the different development patterns and the amount of tax revenue they generate. The Valley Unit subdivision and the two hypothetical developments represent the three basic sets of data that were required for the GIS to model spatial, cost and tax revenue differences.

Development Patterns

Two of the three developments to be compared are hypothetical in the sense that they do not actually exist on the landscape. The Valley Unit subdivision does exist on the west edge of Bozeman (Figure 7). The area immediately to the west of the Valley Unit subdivision development was used as the footprint for the hypothetical sprawl and new urbanist developments (Figures 8 and 9). The footprint is a recent annexation to the city and is currently under plans for development. The location of the study area was chosen because of its proximity to and inclusion in the City of Bozeman and the availability of AutoCAD Drawings for existing services in Valley Unit Subdivision. A GIS roads coverage for the Valley Unit subdivision and surrounding area also existed. The physical layout for the two hypothetical subdivisions, or scenarios was created to represent contrast between a single zoned low density residential sprawl development and a higher density multi zoned, new urbanist development. The layouts were created in collaboration with the City of Bozeman Planning Department. Although these layouts do not actually exist, there are similar developments in the Bozeman area. Downtown Bozeman provides an example of what a new urbanist development would look like. Valley Center northwest of Bozeman provides an example of what the sprawl development would look like.

Three main types of data were required for each of the three developments, 1) spatial, 2) cost of services and 3) tax data.

The first data type collected was the spatial data of the features to be measured. These data were entered into the GIS. The second data type is the monetary cost values for each feature measured by the model. These data were attached to its respective GIS data in ArcView® . The third type was the amount of annual tax revenue generated by each specific type of land use in the two hypothetical developments and the Valley Unit subdivision. The tax data was generated by the Gallatin County Assessor's office.

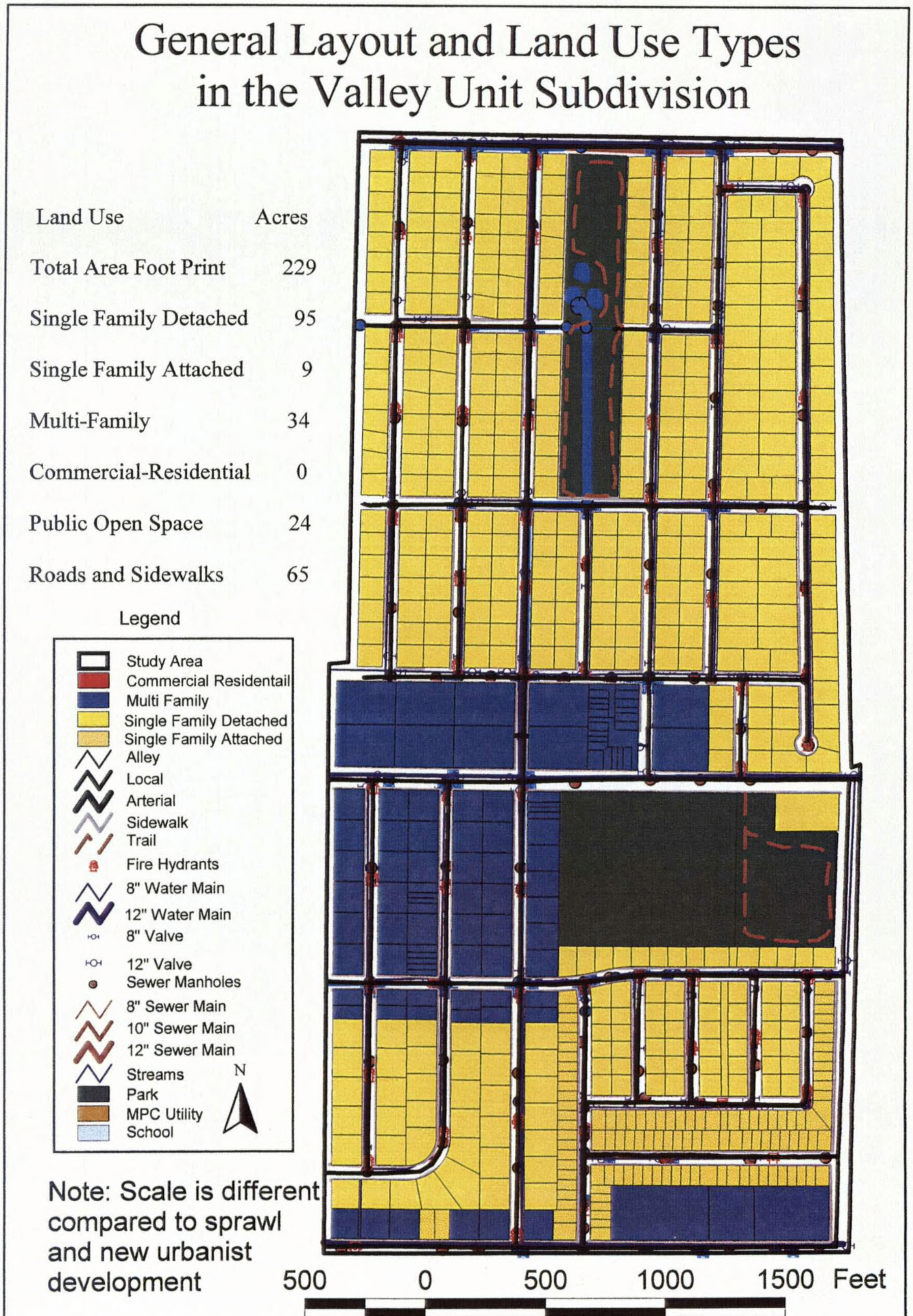


Figure 7. General layout and land use types in Valley Unit subdivision

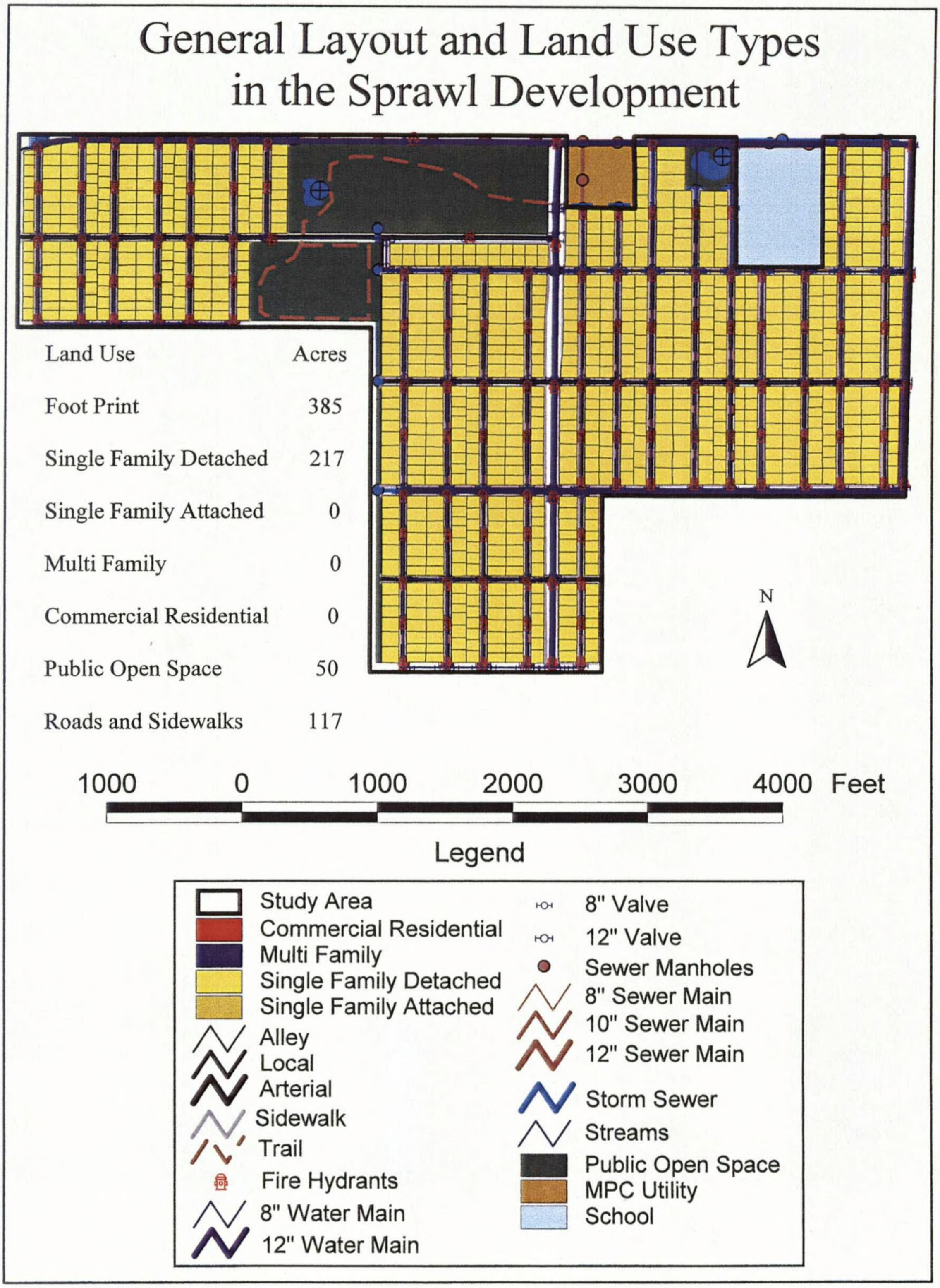


Figure 8. General layout and land use types in the sprawl development.

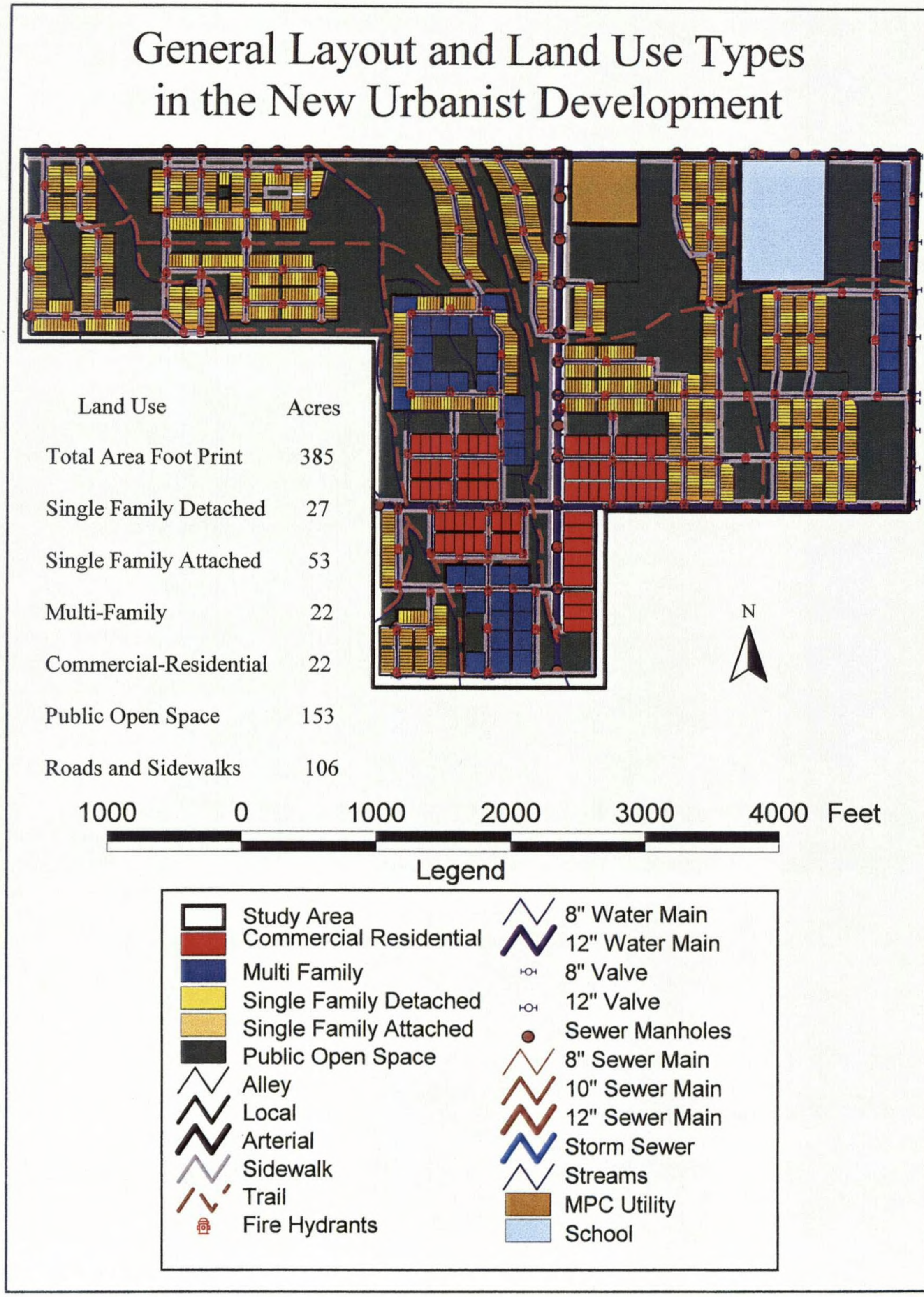


Figure 9. General layout and land use types in the new urbanist development.

Spatial Data

The first step in creating data coverages in the GIS representing the three different developments to be compared by the GIS model is to create or convert the spatial data layers into a digital form that can be imported into the GIS and given a common projection.

County roads were the only existing GIS layer for the study area. The road layer was acquired from the Gallatin County GIS Department and was in the UTM, Zone 12, NAD83 projection. All other layers were converted to this format and projection; the road layer was used as the base layer for the entire project. The roads data were collected in the 1996 Global Positioning System (GPS) road survey conducted by the Geographic Information and Analysis Center at Montana State University and represents an accurate base/reference data set.

For the Valley Unit subdivision digital layers in AutoCAD .DWG format for water, sewer and storm sewer were available from the City of Bozeman Engineering Department. These files were originally created by the engineering and construction firms which designed or installed water, sewer or roads and other services in the City of Bozeman (Table 3).

Table 3: Spatial data creation sources for Valley Unit subdivision.

Valley Unit	GIS/Shapefile	AutoCAD	Digitized	Created
Boundary				X
Fire Hydrants			X	
Parcels		X		
Public open spaces				X
Roads	X			
Sewer Mains		X		
Sewer Manholes		X		
Sidewalks				X
Storm Sewer Detention Ponds				X
Storm Sewer Inlets		X		
Storm Sewer Laterals		X		
Storm Sewer Mains		X		
Storm Sewer Manholes		X		
Storm Sewer Outlets		X		
Trails				X
Water Mains		X		
Water Valves		X		

A plat of parcels for the Valley Unit subdivision was also available in AutoCAD format from the City of Bozeman Engineering Department. Other spatial data were in the form of blue prints and this data was digitized in ArcView. Spatial layers that did not exist in any form were created as graphics using existing data as a reference in ArcView. These graphic layers were then converted into a GIS coverage.

The process of converting AutoCAD data into a GIS format proved to be problematic. All layers of data in a GIS must have a spatial reference to an actual point on the earth's surface. Although the drawings in AutoCAD were to scale, they had no geo-reference. AutoCAD files with no geo-reference are referred to as being in "paper space". Several steps were required to convert .DWG AutoCAD files within paper space into geo-referenced GIS coverages. First AutoCAD was employed to covert the files from .DWG to .DXF for import into ArcView® . Then after being converted into a shapefile in ArcView® , the layers were converted into an ArcInfo® coverage. However, the coverages would not project in ArcInfo® even after a projection had been defined. ArcInfo® had no basis for defining a projection for a paper space layer created in AutoCAD due to the lack of a geo-reference.

A workaround was created to give the original .DXF files a geo-reference prior to initial conversion to shapefile. The original .DXF file was displayed in ArcView® and a world file was created. A world file is a spatial reference from a point in a GIS layer that is attached to the corresponding point in the AutoCAD layer. In this case a point on the road layer was used to match a corresponding point on a given AutoCAD layer. This allowed the AutoCAD layer to be displayed in its general position over the road coverage. Then with the world file on, the theme was converted to a shapefile. This gave the AutoCAD layer, now a shapefile, an actual geo-reference within the GIS environment. The shapefile was then converted into an ArcInfo® coverage. The UTM projection was defined as the projection and the layer were displayed over the road coverage. The AutoCAD coverages, now an ArcInfo® coverage still did not properly align with the base road coverage. This was due to drawing errors in the AutoCAD layers. ArcEdit in ArcInfo®, and edits tools in ArcView® , were used to move features to their appropriate locations using the road coverage as the base layer.

It is important to note that absolute positional accuracy is not a crucial factor in data development for this study. The model will measure lengths and areas of features, but does not depend on an absolute geographic position on the earth's surface to accurately measure the spatial attributes of individual features. Allowing positional accuracy to be within 10 meters made the hand editing an acceptable element in the creation of data layers and significantly reduced the time and cost of data compilation. Therefore the accuracy of spatial measurements will be plus or minus 10 meters. The parcel layer for each of the developments and the Valley Unit subdivision were overlaid on digital ortho photographs. The distance between the edge of an individual feature and a known ground feature, such as a road, was measured Using ArcView®. The distance was generally found to be off by less than five meters.

All of the existing digital layers for the Valley Unit subdivision were incomplete to some degree and required updating. This was done with onscreen digitizing. As-built blue prints from the City Engineering Department were compared to the older original AutoCAD data sources, after they were imported to the GIS. Again using the edit capabilities of ArcView®, features in each layer were added, deleted or adjusted as necessary. After these edits were completed, these coverages were transferred back to ArcInfo® to have their topology and feature attributes reconstructed. This was done using standard commands in ArcInfo®. Each coverage was then imported back to ArcView® and converted to a shapefile. The attribute tables in the shapefiles now contained the necessary spatial attributes for each individual feature to allow for cost calculations based on spatial measurements.

All of the layers for the low density and high density development layout were created from design graphics. This was achieved by converting ArcView® graphics to a shapefile and then building their topology in ArcInfo®. All of the layers for each of the hypothetical subdivisions were created in this manner in ArcView®. Then the layers were converted into GIS coverages using ArcInfo®. The process of using ArcInfo® to build topology and feature attributes was employed. After the physical edits to the GIS coverages were complete, cost data was added to the attribute table of each shapefile and the shapefiles were moved into the appropriate scenario in SmartPlaces® (Figure 10).