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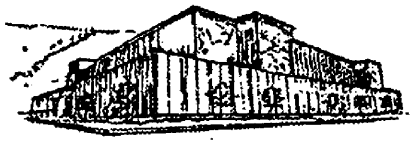

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APPLICATION OF 3D VISUALIZATION SOFTWARE TO THE PROPOSED HIGHWAY 93 EXPANSION CORRIDOR BETWEEN POLSON AND EVARO IN LAKE COUNTY, MONTANA

by

William A. Veteto

B.S. University of Memphis, 1989

Presented in partial fulfillment of the requirements

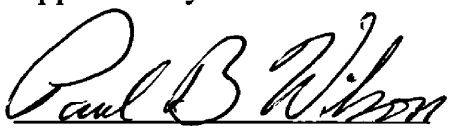
For the degree of

Master of Arts

The University of Montana

May 2006

Approved by:



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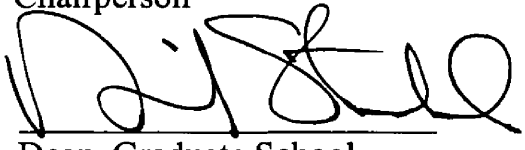

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Veteto, William A. M.A., May 2006 Geography

Application of 3D Visualization Software to the Proposed Highway 93 Expansion Corridor between Polson and Evaro in Lake County, Montana

Chairperson: Paul Wilson PW

Most Geographical Information Systems (GIS) software platforms now offer the capability of modeling landscapes in 3D, yet 3D models are generally underutilized in the planning process. This research seeks to facilitate the planning process by building two 3D land use models for a pilot study area within the Highway 93 expansion corridor between Polson and Evaro in Lake County, Montana. One of the 3D visualizations shows a land use development scenario based on the Highway 93 Corridor Plan written by the University of Montana Law School, and the other 3D visualization shows a land use development scenario based on the Density Map created by the Lake County Planning Department. The two completed 3D visualizations were evaluated by professionals in the planning and GIS fields, and a series of questions were asked to identify the strengths, weaknesses, and ideal planning applications of the 3D models.

The interviews with land use professionals indicated that the 3D models do achieve sufficient realism to be a valuable part of the planning process, and that they generally work well to show different build-out densities and to compare individual requirements of a land use plan. However, the perceived realism of the 3D scene varied depending on the angle of view and the elements present in the view. The highest degree of realism was achieved when mountain backdrops were included in the 3D view.

To Jeanne, Katie, and Luke.

ACKNOWLEDGEMENTS

I wish to thank my family for their support and encouragement. I would also like to thank Dr. Paul Wilson for providing advice and guidance during the course of this project, and also thank my other committee members, Dr. Sarah Halvorson and Dr. Tom Roy. Also, I am grateful to Janet Camel, Dr. Anna Klene, Dr. David Shively, and John Horwich, J.D., for participating in the interview process. I am also appreciative of the assistance and data provided by the GIS personnel at the following agencies and departments: the Confederated Salish and Kootenai Tribes, the Land Use Clinic at the University of Montana School of Law, the Lake County Planning Department, the Montana Department of Transportation, and the Natural Resource Conservation Service. Also, I would like to thank John Horwich, J.D. for his assistance during this research, and Dave Degrandpre for initially suggesting this research topic. Lastly, I would like to thank the following GIS and planning personnel, as their advice was very helpful in the completion of this research: Pete Gillard, Neil Svendsen, Shane Stack, Steve Barton, and Ken Wahl.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design and Drafting
CIF	Commercial Industrial Floating District
CGA	Community Growth Area
CSKT	Confederated Salish and Kootenai Tribes
DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
FAR	Floor to Area Ratio
FHWA	Federal Highway Administration
GIS	Geographic Information System
INTU-VAL	Intuition and Evaluation
MDR	Medium Density Residential
MDT	Montana Department of Transportation
MOA	Memorandum of Agreement
MUAGGAT	MapUnit Aggregated Attribute Table
NAIP	National Agricultural Imaging Program
NASA	National Aeronautics and Space Administration
NRIS	Natural Resources Information System
RAR	Rural Agricultural Residential
RR	Rural Residential
TIN	Triangulated Irregular Network
UTM	Universal Transverse Mercator

CHAPTER 1

INTRODUCTION

The Use of 3D Visualization in Planning

Planners have long had a difficult time finding adequate means to portray the impact of land use plans to the public. The complex nature of the subject material makes it difficult to convey using conventional medium such as 2D maps, prospective drawings, charts, and tables. In the early 1970's, researchers began experimenting with 3D computer visualizations as a new way of presenting information. However, technological limitations and prohibitive costs prevented researchers from incorporating computerized 3D visualization in the planning process. In the 1990's, the new power of desktop computing made 3D visualizations an attainable—if expensive and labor intensive—goal. Numerous projects incorporated 3D visualizations by combining the power of GIS with visualization software, but the technology was still complicated and expensive, and much time and effort had to be spent creating the details of a 3D landscape.

Most Geographical Information Systems (GIS) software platforms now offer the capability of modeling landscapes in 3D, yet 3D visualizations are generally underutilized in the planning process. This research seeks to facilitate the planning process by building two 3D land use models for a pilot study area within the Highway 93

expansion corridor between Polson and Evaro in Montana. One 3D visualization will show a land use development scenario based on the Highway 93 Corridor Plan written by the University of Montana Law School, and the other 3D visualization will show a land use development scenario based on the Density Map created by the Lake County Planning Department. The two completed 3D visualizations will then be evaluated by professionals in the planning and GIS fields, and a series of questions will be asked to identify the strengths, weaknesses, and ideal planning applications of the 3D models. These responses will then be incorporated into the findings of the research.

The Highway 93 Expansion Corridor

U.S. highway 93, which extends from Canada to Southern Arizona, is the primary north-south thoroughfare for travel in Western Montana (Figure 1.1). The section of the road that passes through the Flathead Indian Reservation is a two and three-lane design that is inadequate to deal with current and projected traffic volume.[1] However, planned highway expansions and improvements have aroused controversy and their implementation has been delayed for over a decade.[2] Primarily, this is because the Confederated Salish and Kootenai Tribes (CSKT)—who own the majority of the land within the Flathead Indian Reservation—were concerned about the impacts that an expanded highway would have upon their land and their way of life.

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[1] 105th Congress, *Senate Rpt.105-249 - Department of Transportation and Related Agencies Appropriations Bill, 1999*(1999, accessed 6 June 2004); available from http://www.congress.gov/cgi-bin/cpquery/?&dbname=cp105&&r_n=sr249.105&sel=TOC_361042&.

[2] University of Montana Land Use Planning Clinic, *Highway 93 Project* (Missoula: University of Montana, unknown).

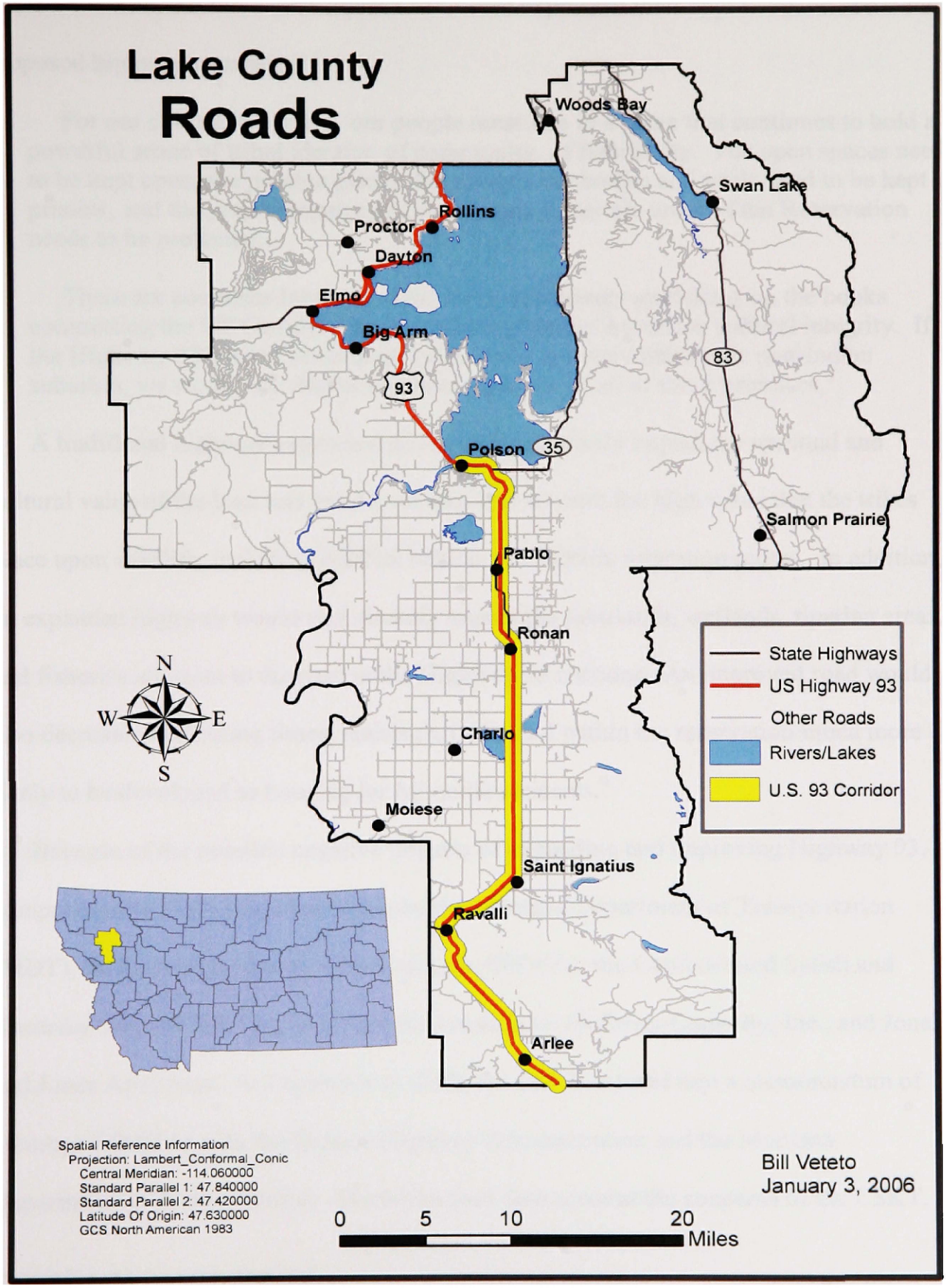

Figure 1.1. Lake County Roads with Highway 93 Expansion Corridor

In June of 1992, the Flathead Culture Committee expressed their apprehension about the proposed highway expansion:

> For our culture to survive, our people must live in a place that continues to hold a powerful sense of tribal identity, of community, of familiarity. The open spaces need to be kept open, the pristine places that nurture our bodies and souls need to be kept pristine, and the preponderance of tribal people in certain areas of the Reservation needs to be protected...
>
> There are countless laws and regulations and agency guidelines on the books committing the US Government to protecting Native American cultural integrity. If the Highway 93 project turns these valleys into an overwhelmingly non-Indian suburbia, we would see that as a serious violation of all of those promises.[3]

A traditional highway expansion plan would negatively impact the spiritual and cultural value of the land and would not take into account the high value that the tribes place upon wildlife, including wildlife habitat and wildlife migration routes. In addition, an expanded highway would significantly impact the farmlands, wetlands, riparian areas, and fisheries adjacent to the road in the Highway 93 corridor. An improved road would also decrease commuting times, making private land within the reservation much more likely to be developed as housing for Missoula residents.[4]

Because of the possible negative impacts of expanding and improving Highway 93, a comprehensive study was undertaken by the Montana Department of Transportation (MDT), the Federal Highway Administration (FHWA), the Confederated Salish and Kootenai Tribes (CSKT), and the private consultants Skillings-Connolly, Inc., and Jones and Jones Architects. In December of 2000, the CSKT entered into a memorandum of agreement (MOA) with the Federal Highway Administration and the Montana Department of Transportation. The MOA took into account the concerns of the CSKT,

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[3] Dale Becker, et al, *Flathead Reservation Comprehensive Resources Plan* (Confederated Salish and Kootenai Tribes, 1994), 7:15.

[4] John Horwich, interviewed by author, Missoula, Mt., 17 April 2004.

and spelled out in detail suggested highway improvements, including lane configurations, design characteristics, and mitigation features for the 41.4 miles of the 56.3 highway miles between Evaro and Polson.[5] While the MOA provided for intelligent highway expansion and construction, the authors of the document also acknowledged that an improved highway would lead to land use problems in Lake County and the Reservation:

> Improvement and expansion of U.S. 93 will induce population growth, parcel subdivision, and development and construction in the U.S. 93 corridor. These activities will cause habitat fragmentation, environmental impact, and significant changes to the Reservation landscape. In response, MDT, FHWA and the Tribes commit to diligently explore and apply methods for limiting and directing highway induced growth and development.[6]

History of Planning in Lake County

One of the primary goals of Lake county officials and planning personnel over the past few decades has been to preserve the rural nature of the county. To achieve that goal, the general policy of Lake County has been to follow a twenty-acre housing density for new subdivisions in unincorporated rural areas. This policy allowed only one residential structure per twenty acres of land in residential subdivisions. This policy was never put into writing, and density in rural areas was determined on a case-by-case basis. Other than the twenty-acre density policy, Lake County has historically had no regulations governing land use except in the areas of sanitation and water permitting issues.[7]

Lake County General Land Use Plan: The Lake County Planning Office developed the Lake County General Land Use plan in 1988 in response to rapid

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[5]Montana Department of Transportation, *Memorandum of Agreement: Us 93, Evaro to Polson* (2000), 1:1.
[6] Ibid, 3:31.
[7] Sue Shannon of Lake County Planning Department, interview by author, 3 December 2004.

population growth over the preceding decade. The land use plan was updated in 2003 and renamed a growth policy, as mandated by Montana code. The growth policy had no enforcement mechanism. Instead, it was simply meant to provide guidelines to avoid the negative aspects of development.[8] As stated in 76-1-605 Montana Code Annotated 2:

> (a) A growth policy is not a regulatory document and does not confer any authority to regulate that is not otherwise specifically authorized by law or regulations adopted pursuant to the law. (b) A governing body may not withhold, deny, or impose conditions on any land use approval or other authority to act based solely on compliance with a growth policy adopted pursuant to this chapter.[9]

Several lawsuits against the county called into question the legality of the county's undocumented twenty-acre density policy. In order to formalize the county's long-term goal of regulating density, new land use regulations were needed.

Two New Land Use Plans for Lake County

Highway 93 Corridor Land Use Plan: In late 2001, the CSKT, Lake County, and Missoula County requested that the University of Montana's School of Law Land Use Clinic assist them in drafting a land use management plan for the Highway 93 corridor (Figure 1.1). Because the MOA was very specific about preserving the visual and ecological qualities of the landscape and allowing for traditional animal migration patterns, the goal for the land use management plan was to incorporate the design elements and objectives of the MOA into land use planning zones that would extend one-half mile on each side of the highway.[10] In addition, the management plan would draw

---

[8] Lake County, *Lake County Growth Policy*(Lake County, 2003, accessed 3 December 2004); available from http://www.lakecounty-mt.org/planning/growthpolicy.html.
[9] State of Montana, *Montana Code Annotated 2003*(Montana Legislative Services, 2003, accessed 3 December 2004); available from http://data.opi.state.mt.us/bills/mca/76/1/76-1-605.htm.
[10] Clinic.

heavily upon relevant land use planning done in the past by Lake County, Missoula County, and CSKT. A rough draft of the Highway 93 Corridor Plan was completed in June of 2004, and a copy was supplied to the author for the purpose of visualizing part of the Highway 93 corridor in order to facilitate the implementation of the plan. In consultation with the Law Land Use Clinic, a study area was chosen immediately north of St. Ignatius.

The Highway 93 Corridor Plan has the following objectives: (1) to encourage development to occur in a manner that will promote the public health and general welfare of CSKT and Lake County, (2) to protect and maintain the high quality of the rural and scenic character of the Highway 93 Corridor, (3) to preserve and enhance the environmental qualities of the surrounding landscape, and (4) to provide developers and landowners clear and consistent regulatory guidelines and an efficient review process.[11] The Corridor Plan uses a traditional zoning approach in its restrictions on land use. Zones are classified as residential, commercial, or agricultural districts (or a combination of land use types). There are regulations for many aspects of development, including the following: density, location, height, number of stories, size of buildings and other structures, open spaces, land use and site development standards, penalties for violating the plan, and the establishment of a Board of Adjustment.[12]

The Lake County Density Map: At the same time that the Highway 93 Corridor Plan was being drawn up, a Density Map was being developed by Lake County planning personnel. The Lake County Density Map and Regulations were adopted into use by the Lake County Commissioners in October of 2005.

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[11] University of Montana Land Use Planning Clinic, "Draft Highway 93 Corridor Land Use Plan," (Missoula, Montana: University of Montana School of Law, 2004), 1.
[12] Ibid.

The Density Map (Figure 1.2) is significantly different from the Highway 93 Corridor Plan in both its scope and approach. The Density Map applies to all of Lake County, as opposed to just the Highway 93 corridor. Secondly, the Density Map regulates only one zoning factor: housing density. It does this by limiting the size of future subdividable lots in rural areas.[13] The goal of the Density Map is to guide more intensive future development into areas that are close to existing cities and towns and to encourage sparser development in areas far from urban areas.[14] In guiding more intensive growth into areas near urban centers, the Density Map aims to achieve several objectives: (1) to reduce public expenditures on infrastructure such as road construction and fire and police protection, (2) to preserve the rural character of agricultural and timber production areas, (3) to protect natural resources and wildlife habitat within the county, and (4) to give clear guidelines about the development potential of specific regions in Lake County.[15]

Comparison of the Two Land Use Plans Using 3D Visualizations

A 3-D GIS visualization has the potential to show the public the impacts of the two land management plans on future development, and to compare the differences between the plans. However, a 3D visualization for the entire length of the 41.4 mile Highway 93 expansion corridor was beyond the scope of this study. Instead, a small representative study area was chosen for visualization purposes.

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[13] John Stromnes, *Lawsuit Stalls Regulations on Density*(The Missoulian, 2004, accessed January 01 2006); available from http://www.missoulian.com/articles/2004/12/10/news/mtregional/znews07.txt.
[14] Lake County, *The Lake County Density Map and Regulations* [Electronic document] (Lake County, 2005, accessed 1 January 2005); available from http://www.lakecounty-mt.org/planning/pdf/DensityMapRegulations_draft11.pdf.
[15] Ibid.(accessed).

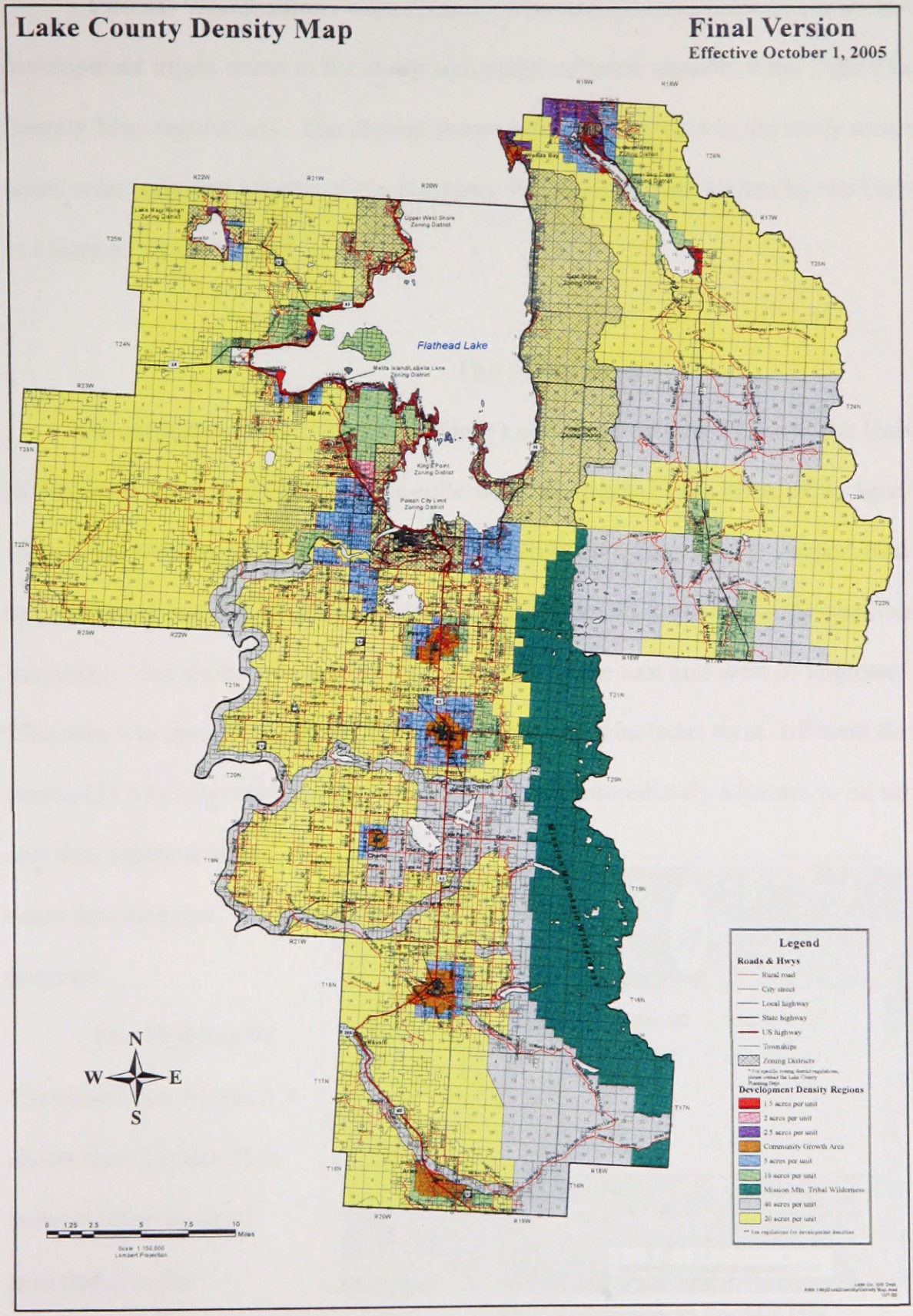

Figure 1.2. Lake County Density Map

Source: Lake County Planning Departmente

Two 3D visualizations were created. The first 3D visualization shows how development might occur in the study area under selected aspects of the Lake County Density Map regulations. The second shows how development in the study area might occur under selected aspects of the Highway 93 Corridor Plan written by the University of Montana's Law School.

The Study Area

In consultation with the Law School Land Use Planning Clinic at the University of Montana, a two-mile long by one-mile wide study area to the north of St. Ignatius was chosen to be the location for the 3D GIS visualizations (Figure 1.3). Airport Road marks the southern boundary of the study area, and Pinsoneault Road marks the northern boundary. The study area extends one-half mile to the east and west of Highway 93. This area was chosen for the following reasons: (1) it includes three different density zones, (2) it is relatively undeveloped, and (3) it is immediately adjacent to an urban area, and thus stands to bear more development pressure.

The Highway 93 Corridor Plan: Figure 1.4 shows the Corridor Plan zones within the study area and also the minimum lot sizes from

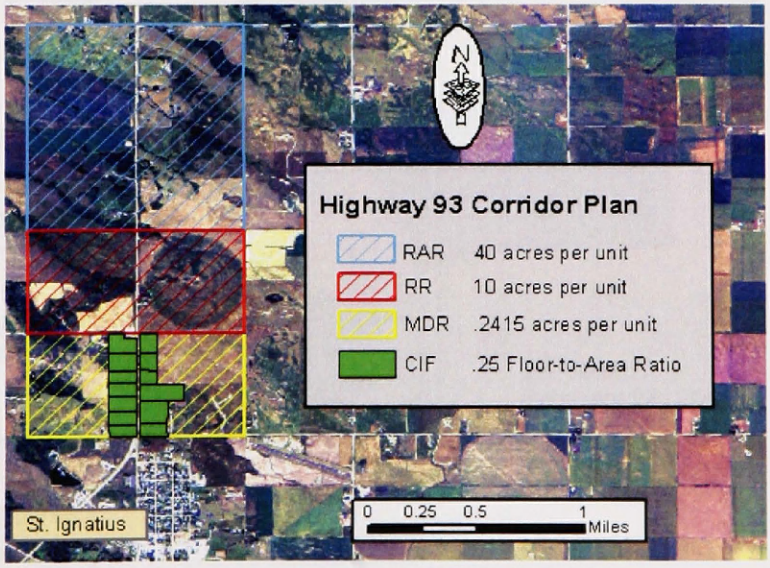

Figure 1.4. Zones in the Highway 93 Corridor Plan

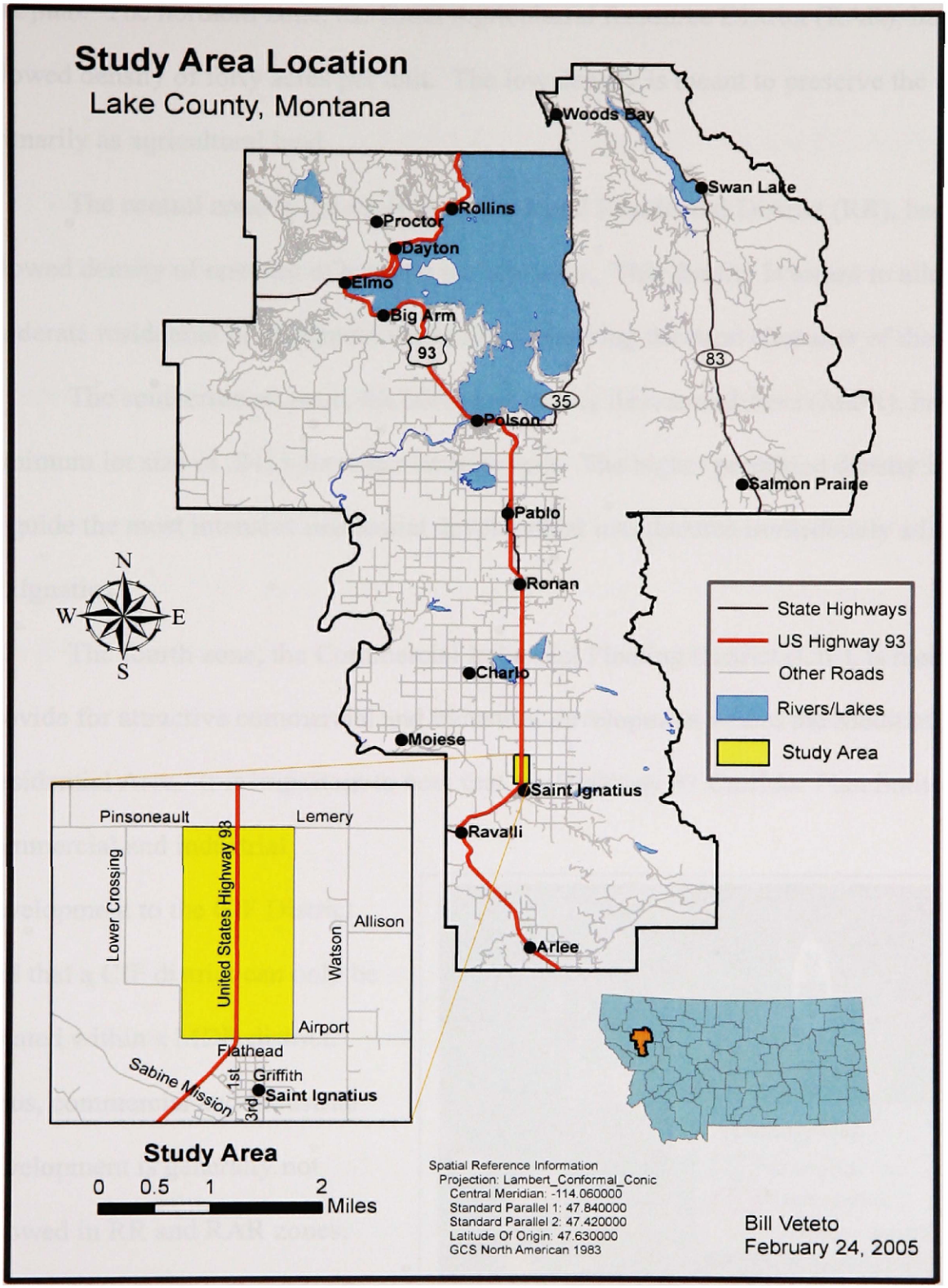

Figure 1.3. Location of the Study Area

that plan. The northern zone, the Rural Agricultural Resource District (RAR), has an allowed density of forty acres per unit. The low density is meant to preserve the zone primarily as agricultural land.

The central zone in the study area, the Rural Residential District (RR), has an allowed density of one unit of housing per ten acres. This density is meant to allow moderate residential development while also preserving the rural character of the area.

The southernmost zone, the Medium Density Residential Area (MDR), has a minimum lot size of .2415 acres per housing unit. The higher permitted density is meant to guide the most intensive residential development into the area immediately adjacent to St. Ignatius.

The fourth zone, the Commercial Industrial Floating District (CIF), is meant to provide for attractive commercial and industrial development within the Medium Density Residential Area. It is important to note that the Highway 93 Corridor Plan limits commercial and industrial development to the CIF District, and that a CIF district can only be located within a MDR district. Thus, commercial and industrial development is generally not allowed in RR and RAR zones.

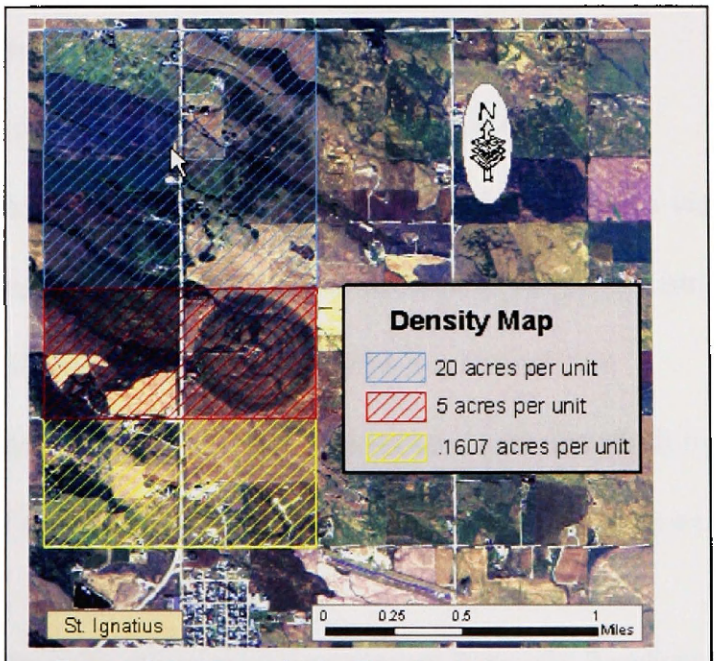

Figure 1.5. Zones in the Density Map

Lake County Density Map: The Lake County Density Map divides the study area into three

zones (Figure 1.5). The boundaries of these three zones are identical to the boundaries of the three largest zones in the Highway 93 Corridor Plan (the RAR, RR, and MDR Districts). This is because the boundaries of the Highway 93 Corridor Plan were based upon those of the Density Map.

In the northernmost zone of the study area (marked in blue in Figure 1.5), the allowable density is twenty acres per housing unit. In the central zone of the study area, the allowable density is five acres per housing unit. In the southernmost zone of the study area, the Community Growth Area (CGA), the Density Map allows twelve units per acre unless the area is annexed into a municipality. However, a density of one housing unit per .1607 acres (7000 square feet per housing unit) was chosen after consultation with Lake County planning staff. This allows the CGA area to be modeled with single-family residential housing and a comparison made with the MDR area from the Highway 93 Corridor Plan.

Literature Review

Three-dimensional computer visualizations involving GIS have enormous potential in the planning field, because they can reduce complex planning topics to visual displays that almost anyone can understand. The general public finds it very difficult to convert 2D maps into corresponding 3D mental images.[16] Tufte has shown that information presented in a visual format is more efficiently processed and absorbed by the human brain than information that is in a textual, numerical, diagrammatic format.[17]

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[16] Katy Appleton, and Andrew Lovett, "Gis-Based Visualisation of Development Proposals: Reactions from Planning and Related Professionals.," *Landscape and Urban Planning* 29 (2005), 328.
[17] E.R. Tufte, *The Visual Display of Quantitative Information* (Cheshire, Connecticut: Graphics Press, 1992).

Langendort argues that to understand nearly any subject of consequence in our complex world it is necessary to examine it from a variety of viewpoints, and that the understanding of this complex information is made much easier if visualized.[18] Ware makes the point that visualization helps us to comprehend huge amounts of data, helps us to understand large and small-scale features of the data, and helps us to facilitate hypothesis formation.[19] Pullar and Tidey argue that land use planning decisions have a long-lasting effect, and therefore it is essential to view proposed modifications of the built environment through visualizations and assess their impact before such modifications are cast in concrete.[20] Wang states that "the importance of computer visualization for planning practice lies in its potential for improving the quality of decision-making."[21]

GIS and 3D visualization each have their own advantages.[22] GIS allows the user to examine the spatial relationship among entities, and 3D visualization enables the representation of data in a way that may reveal patterns and possibilities that are hard to detect in a two-dimensional approach or with non-visual approaches such as text and tables. The integration of GIS and visualization can benefit both fields. GIS gains a more dynamic graphical output, and visualization becomes more connected to its base geographic attributes.[23]

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[18] Richard Langendorf, *Computer-Aided Visualization: Possibilities for Urban Design, Planning, and Management*, ed. Richard K. and Richard E. Klosterman Brail, Planning Support Systems (Redlands, California: ESRI Press, 2001), 309.
[19] Colin Ware, *Information Visualization: Perception for Design* (United States of America: Academic Press, 2000), 4.
[20] David V and Margo E. Tidey Pullar, "Coupling 3d Visualization to Qualitative Assessment of Built Environment Designs.," *Landscape and Urban Planning* 55 (2001), 1.
[21] Xinhao Wang, "Integrating Gis, Simulation Models, and Visualization in Traffic Impact Analysis," *Computers, Environment and Urban Systems* In Press, Corrected Proof (2004), 472.
[22] Ibid, 474.
[23] Ibid.

There are many recent studies demonstrating that 3D visualizations linked to a GIS can be integrated into the planning process. Lange demonstrated that three-dimensional representations were effective in portraying the real world to a wide audience.[24] Pullar and Tidey used 3D visualization to aid in the assessment of different environment designs.[25] Wang integrated GIS with simulation models and 3D visualization in order to support planning-related decision making.[26] Al-Kodmany used a GIS-based visualization to incorporate suggestions from the general public during the planning process.[27] Bishop, Wherrett, and Miller employed a detailed 3D model of various proposed pathways to demonstrate that people make choices in the virtual environment that match their stated preferences.[28] Richland County, South Carolina, used a GIS system loosely linked to visualization software to create a forty-square-block 3D model of downtown Columbia, South Carolina.[29]

There are obstacles that have hindered widespread use of visualizations in planning. Visualizations have often been considered an expensive supplement in selling a plan to the public.[30] Specialized hardware and software is needed, which makes a 3D visualization an expensive proposition. Also, large datasets are needed within GIS-based visualizations, and these datasets usually slow down processing time.[31] Lastly, adding built objects and vegetation to a 3D scene is time consuming. Perhaps due to these

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[24] Eckart Lange, "The Limits of Realism: Perceptions of Virtual Landscapes," *Landscape and Urban Planning* 54, no. 1-4 (2001), 163-182.
[25] David V. Pullar and Margo E. Tidey, "Coupling 3d Visualisation to Qualitative Assessment of Built Environment Designs," *Landscape and Urban Planning* 55, no. 1 (2001), 29-40.
[26] Wang, 471-496.
[27] K. Al-Kodmany, "Using Visualization Techniques for Enhancing Public Participation in Planning and Design: Process, Implementation, and Evaluation," *Landscape and Urban Planning* 45, no. 1 (1999), 37.
[28] Ian D. Bishop, JoAnna R. Wherrett, and David R. Miller, "Assessment of Path Choices on a Country Walk Using a Virtual Environment," *Landscape and Urban Planning* 52, no. 4 (2001), 225-237.
[29] Brian Fitzgerald, "Feasibility of Modeling Urban Environments in 3d," *Geospatial Solutions* 2004, no. July 2002 (2001), 28-35.
[30] Lange, 180.
[31] Ibid.

factors, the great majority of presentations to decision-makers and the public are still done the old-fashioned way, with two-dimensional (2D) maps and static images.[32]

Statement of Purpose

When using conventional communication media, there is difficulty describing to the public the effect that zoning (and, conversely, a lack of zoning) would have upon impacted lands. Three-dimensional visualizations have the potential to present large amounts of complex information. However, 3D GIS visualizations are under-utilized in the planning community, despite the fact that most of the major GIS software platforms include the capability of 3D modeling.

The purpose of this research is to gauge the effectiveness of using the Communityviz 3D visualization software as a means to facilitate the implementation of land use plans. Two 3D scenarios will be created, and these scenarios will be shown to professionals in the planning field in order to evaluate the effectiveness and the degree of realism of the 3D visualizations.

Significance of the Study

This study will determine the feasibility of using a desktop 3D GIS visualization scheme to portray the impact of land use plans. If the visualizations are successful, then the 3D images could be a valuable contribution towards helping the public choose the most appropriate land use plan. If the visualizations are not helpful in presenting alternative futures, then the outcome will be to point out areas where 3D GIS software requires improvement in order to be effective in the planning field.

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[32] Wang, 472.

Organization

The research will be presented in five chapters. The first chapter gives an introduction to the problem, background on the study area, and the approach used in the research. The second chapter gives a brief history of computer 3D visualizations and the current methods used in 3D GIS visualizations. The third chapter discusses the methodology and the software used. The fourth chapter details the analysis of the 3D models created for the study area, including a recap of notable points. The fifth chapter presents a summary of the findings, conclusions, and also suggests future avenues of research related to this study.

CHAPTER 2

3D VISUALIZATIONS

History of 3D Visualization in Landscape Modeling

Digital landscape modeling is less than fifty years old.[33] Ivan Sutherland from MIT developed the first graphical user interface in 1963, and pioneered many of the central concepts of computer graphics today.[34] In the late 60's and early 70's, GIS was developed in several places around the world. Professor Carl Steinitz's work at the Harvard University Graduate School of Design was the most notable, where a series of project he oversaw in computer aided landscape and design led to much of what we see today in GIS software and capabilities.[35] In the early 1970's, researchers at the Graduate School of Architecture and Urban Planning at the University of California proposed the creation of an urban laboratory. Using what was then state-of-the-art computer graphics technology, they aimed to bring together researchers, decision makers, and community representatives to get reactions to simulated alternative futures. The idea was that those involved would be active participants in the planning process, modifying alternatives

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[33] Stephen M. Ervin, and Hope H. Hasbrouck, *Landscape Modeling : Digital Techniques for Landscape Visualization* (United States of America: McGraw-Hill, 2001), 33.
[34] Marcia Riley, *Ivan E. Sutherland*(unknown, accessed 24 August 2004); available from http://www.cc.gatech.edu/classes/cs6751_97_fall/projects/say-cheese/marcia/.
[35] Ervin, 34.

interactively to suit their needs.[36] In order to show the viability of this type of planning process, two pilot projects were developed: INTU-VAL (Intuition and Evaluation), an on-line computer graphics program used for evaluating and iteratively designing projects; and CITYSCAPE, an urban flight simulator built jointly with the General Electric Corporation and using NASA simulation facilities. While neither project became fully operational due to costs of the technology and technological limitations, the projects did demonstrate the feasibility of simulated environments.[37] The director of the project, Professor Peter Kamnitzer, was prescient in his views on how 3D visualizations should operate:

> This [simulator] will permit an observer-participant to insert himself into a dynamic, visual model of an urban environment by means of a visual simulation system employing on-line generation of color projections onto large screens with as much as 360 degrees of vision. By means of controls which direct his speed and the direct, as well as the movement of his eye, the viewer will be able to "walk," "drive" or "fly" through sequences of existing, modified or totally new urban environments. Such simulated environments would be initiated either by the researcher or by representatives of government and citizen groups participating jointly in urban planning and design activities. Simulations of sound and atmospheric conditions could be added to heighten the sensory experience of the participants.[38]

In the following decades, the field of computer technology saw rapid advances, with ever increasing processing speed and power. Mainframe computers were largely replaced by compact, powerful, and easy to use personal computers. Spectacular advances were seen in computer-aided design and drafting (CAD), GIS, and computer

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[36] William H. Jepson, Robin S. Liggett, and Scott Friedman, "An Integrated Environment for Urban Simulation," in *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools*, ed. Richard K. and Richard E. Klosterman Brail (United States of America: ESRI, 2001), 388.

[37] Ibid.

[38] Kamnitzer, P. Computers and the Problems of Society, ed. H. Sackman and H. Borko. Reston, VA: AFIPS Press, 1972, quoted in Jepson, William H., Robin S. Liggett, and Scott Friedman. "An Integrated Environment for Urban Simulation." In Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools, ed. Richard K. and Richard E. Klosterman Brail. United States of America: ESRI, 2001, 388.

visualization as a result of high resolution full-color displays and other output devices.[39] By the 1990's, 3D visualization was possible with desktop computers, but the software was expensive and performance was lacking. Also, there was a low level of integration between the GIS systems used to store information and the software that was actually used to create the 3D visualization.[40] Today, however, there are several applications that have a high level of integration between the GIS and the visualization software, and these programs are making 3D visualizations a realistic option for professional planners. Many of Peter Kamnitzer's visions for the future of 3D visualization have become reality.

Levels of Integration between GIS and 3D Visualization: Traditionally, GIS and 3D visualization were separate technologies. The need for more closely integrating these systems was recognized but was a challenge because of the different nature of GIS and 3D systems.[41] GIS has traditionally focused on the spatial attributes of the data and their relationships to other features, and is used to store, edit, query, and analyze data. In contrast, 3D visualization has been more closely tied to CAD systems, with a focus towards generating a single viewing perspective, often involving extremely complex shapes and surfaces. The earliest attempts to link the two technologies involved using GIS to generate designs, then outputting them to a CAD system for viewing. This arrangement did not allow interactive exploration and analysis of the 3D models.[42] In

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[39] Richard E. Klosterman, *Planning Support Systems: A New Perspective on Computer-Aided Planning*, ed. Richard K. and Richard E. Klosterman Brail (United States of America: ESRI, 2001), 3.
[40] Ibid.
[41] Pullar, "Coupling 3d Visualization to Qualitative Assessment of Built Environment Designs," 30.
[42] Ibid.

defining this linkage, there are usually three broad categories that describe joining or coupling a GIS to an analytical model:[43]

1. Tightly Coupled: The GIS and the model have a common user interface and the model is embedded within the code for the GIS software.
2. Closely Coupled: This type is much more common than tightly coupled systems. The model and the GIS share a common interface, but the model is a separate program created in the GIS scripting language.
3. Loosely Coupled: The GIS and the model do not share a common user interface, and the model is a separate program outside of the GIS.

In the past few years, GIS and visualization software have become more closely integrated. The visualization software used for this research, Community Viz, is a closely coupled system. While Community Viz has a separate viewer for its 3D visualization, the software shares an interface with the GIS (ESRI's ArcGIS program), and data can be sent and updated from the 2D interface.

Degree of Realism: Degree of realism refers to how realistic a 3D visualization appears to the user. It might seem logical that 3D visualizations should be modeled in minute detail in order to be the most effective. However, one drawback to highly detailed 3D models is that the large number of objects (trees, houses, cars, utility poles, etc.) that are added to the built environment can dramatically slow the rendering speed for the 3D scene. In addition, the widespread assumption that "more realistic is better" may not always be true.[44] If the level of detail is too high, the audience may find the minor details distracting, or they may focus on trivial aspects of the visualization that are

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[43] Ohio EPA, *Learn Gis: An Introduction to Geographic Information Systems*(The State of Ohio, 17 October 2000, accessed 19 July 2004); available from http://www.epa.state.oh.us/dsw/gis/learngis/5model/model2.html.

[44] J. Dykes, "An Approach to Virual Environments for Visualization Using Geo-Referenced Panoramic Imagery," *Computers, Environment and Urban Systems* 22 (2000), 130.

not the main objective of the 3D visualization.[45] Lastly, no matter how detailed the final visualization is, it will always be generalized and thus will never reach the level of detail of reality.[46]

Current Method for Visualization in Most GIS Systems

Creation of a Landscape "base" for the 3D Scene: In most 3D GIS systems (including the CommunityViz software used for this research), a 3D landscape is created by draping a digital orthophoto over an elevation layer. The foundation of the 3D scene is a digital "base terrain" from a digital elevation model. Remote sensing images (aerial or satellite photos) are draped onto the base terrain. Point, line, and polygon shapefiles[47] or feature classes[48] can then be represented in the 3D scene with a variety of 3D textures or pre-built 3D models.

Symbolizing Point, Line, and Polygon Features in 3D: Point features are commonly replaced with 3D models, with texture applied to the sides of the sides of the 3D models to give added realism. There are often a wide range of 3D models available to users, including trees, houses, shrubs, commercial businesses, and signs. The size of the 3D model can be controlled by inserting a size attribute in the shapefile table, and the orientation can be adjusted with an attribute in the shapefile table. Figure 2.1 shows four 3D models that can be substituted for a point in the Sitebuilder 3D program in Communityviz.

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[45] Katy Appleton, and Andrew Lovett, "Gis-Based Visualisation of Rural Landscapes: Defining 'Sufficient' Realism for Environmental Decision-Making," *Landscape and Urban Planning* 2003, no. 65 (2003), 330.
[46] S. Nicholson-Cole, "Representing Climate Change Futures: A Critique on the Use of Images for Visual Communication," *Computers, Environment and Urban Systems* 29, no. 3 (2005), 261.
[47] Shapefiles are a group of files containing a set of points, arcs, or polygons that store tabular data and spatial information.
[48] A feature class is a group of geographic features represented by exactly the same type of geometry (point, line, or polygon).

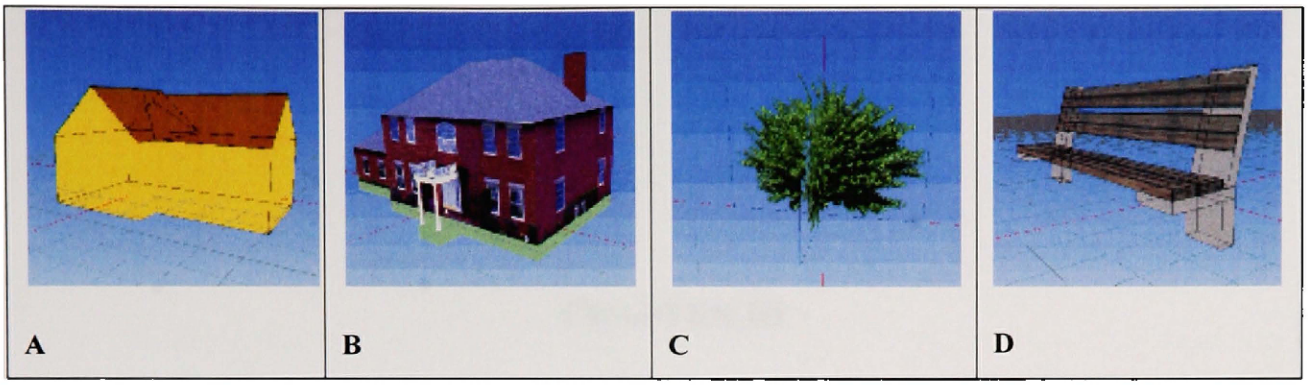

Figure 2.1. 3D Models from the CommunityViz Library. **A.** Simple volume. **B.** Volume with custom texture. **C.** Tree. **D.** Park Bench.

Line features such as roads, sidewalks, and fences can be extruded to a given height or width, and colors and textures can be applied to the sides of the extruded feature. The base of the line feature conforms to the surface of the base terrain. Polygon features can be extruded using a variety of methods, and texture and color can be applied to the sides and tops of the polygons to give a real-world appearance. Again, the base of the polygon features conforms to the base terrain.

CHAPTER III

METHODOLOGY

Introduction

In recent years, 3D visualization software has become available that is closely tied to GIS systems. When researchers want to judge the effect of these 3D GIS visualizations, one method commonly used is to present the 3D visualizations to an audience and to ask questions to determine the impact of the visualizations. Depending on the aims of the research, the audience can either be professionals from planning and related fields, or the audience can be laypersons. Examples of this audience methodology in the 3D GIS visualization field can be found in studies done by Appleton and Lovett[49], Pullar and Tidey[50], and Lange.[51] The audience survey methodology was used to assess the effectiveness of the visualizations for the St. Ignatius study area. Professionals in the geography and planning fields were used as interview subjects because they had the necessary knowledge and skills to make judgments about the value of the visualizations. The bulleted points below show the sequence of steps that were necessary to develop

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[49] Appleton, "Gis-Based Visualisation of Development Proposals: Reactions from Planning and Related Professionals," 322.
[50] Pullar, "Coupling 3d Visualization to Qualitative Assessment of Built Environment Designs," 34.
[51] Lange, 169.

each of the two 3D GIS visualizations and to present the visualizations to a professional audience:

- Gather the necessary data for the study area
- Develop a "constraints to development" layer for the study area
- Perform two spatial build-out analyses for the study area (one for each land use plan)
- Perform two visual build-outs using Sitebuilder 3D visualization software (one for each land use plan)
- In an interview process, show professionals the 3D visualizations and ask questions to identify the strengths and weaknesses of the 3D visualizations

BASIC CONCEPTS FOR APPLYING THE METHOD

Developing a "Constraints" Layer

Constraints refer to features that would limit or prohibit future development. These include flood zones, wetlands, parcel boundaries, existing structures, rights-of-way, easements, and roads. A constraints layer can be used in a GIS as a "region of exclusion" when placing building points upon the landscape in the build-out portion of the land use scenario. For instance, a flood zone layer can be brought in a GIS, and then when a maximum capacity build-out is performed the flood layer can be designated as a zone in which no building points can be placed.

Spatial Build-out

Before building a 3D development scenario for a given area, a spatial build-out analysis must be first done to estimate the amount and placement of development within the study area. The basic build-out process is well-established in the planning field, and has been adapted for use in the GIS realm. A build-out analysis calculates the development potential of the land based on assumptions for density, physical and environmental constraints to development, and existing or proposed land use regulations.[52] The first step in the build-out analysis is the compilation of all relevant digital data layers for the study area, including proposed and existing land use restrictions, possible constraints to development (such as existing structures, roads, rights of way, parcel boundaries, flood boundaries, etc), digital orthophotos, and digital elevation models. Once a constraint layer has been developed, a conventional build-out analysis determines the development potential of the remaining land using two separate steps: (1) a numeric build-out that estimates the maximum number of building points that can be placed on the landscape, and (2) a spatial build-out that attempts to place the projected points on the landscapes and in the process revise the number of points based upon the geometry of the land, irregularities of parcel boundaries, placement of roads, etc.

3D Visual Build-out

In addition to the two traditional steps used in a build-out, a third step—a visual build-out—will be used in this study to show the results of the spatial build-out in 3D. In

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[52] The Orton Family Foundation, *Working with the Build-out Wizard* [pdf software documentation] (The Orton Family Foundation, 2004, accessed 11 December 2005).

this step, the individual building points from the spatial build-out are assigned appropriate 3D symbols or textures. A textured draping layer is developed as a landscape backdrop for the 3D buildings. The draping layer is creating using orthophotos and digital elevation models. Additional point, line, and poygon feature classes representing trees, sidewalks, roads, and other objects can be digitized in 2D, and then represented in the 3D scenario using appropriate 3D symbols and textures.

Focus Points in the 3D Visual Build-Outs

Because it would have been very difficult to model every aspect of the two land use plans, three focus areas were chosen for 3D modeling purposes:

1) **Requirement for screening vegetation in commercial areas:** One aim of this study is to determine if individual components of a land use plan can be adequately modeled in a 3D visualization. The Highway 93 Corridor Plan requires that screening vegetation be used around commercial businesses in the CIF area. The Density Map has no such requirement.

2) **Density in residential areas:** In both of the 3D models, the zone closest to St. Ignatius has the highest allowed density. The Highway 93 Corridor Plan has a minimum lot size of .2415 acre, while the Density Map has a maximum density of .1607 acre per housing unit. One major aim of the 3D models is to determine if 3D GIS modeling is an appropriate way to present differences in density between plans.

3) **Degree of Realism:** Another major aim of this research is to determine if the models display a sufficient degree of realism—both in the rural and residential areas—to show the differences between two land-use plans.

Identifying Strengths and Weakness of the 3D Visualizations

The two completed 3D models were shown to professionals in the planning and GIS fields, and a series of questions were asked to identify the strengths, weaknesses, and ideal planning applications of the 3D models. The questions in the survey focused upon the points mentioned in the section above. These responses were then incorporated into the findings of the research.

THE SOFTWARE USED

ArcGIS

ArcGIS 9.1: ArcGIS 9.1 is an integrated package of desktop GIS programs. The ArcView 9.1 version of ArcGIS was used as the GIS interface for this project. Within ArcGIS 9.1, the ArcMap, ArcCatalog, and ArcToolbox components were used for data management tasks.

Communityviz 2.1

Communityviz is a suite of analysis and 3D Visualization tools that gives planners advanced ways to look at and visualize land development options and scenarios. Communityviz consists of two components: Scenario 360 and Sitebuilder 3D.

Scenario 360: This software, which is an extension for ArcGIS, uses quantitative analysis and 2D visualization within the ArcMap environment to support land use decision-making.[53] Scenario 360 takes the various land use restrictions entered by the user, such as building setbacks, density, height restrictions, etc., and calculates the maximum allowable structures allowed within the different zoning categories. In addition, Scenario 360 allows the user to create multiple land use scenarios for a given geographic extent.

Sitebuilder 3D: This extension for ArcGIS uses a separate viewer to take 2D data from ArcMap and display it in 3D. Various 3D models and textures can be chosen for each data layer, and Sitebuilder 3D also allows the manipulation of scene elements such as lighting, clouds, time of day, fog, and shadows. Users can walk, drive, or fly through the 3D landscapes to explore land use scenarios created in Scenario 360.

Feature Analyst 3.5

Feature Analyst 3.5.02, an extension for ArcGIS, uses machine learning algorithms to classify geographical features in digital imagery. The user provides digitized "training examples" of geographic features, and the software "learns" from those examples and classifies similar geographical features across an entire digital image (or multiple images). The user can then provide feedback to the Feature Analyst software about the accuracy of the classification, and corresponding changes are made in the image classification by the software. Feature Analyst was used in this study to develop a

[53] CommunityViz, *Communityviz Products*(Placeways, 2006, accessed 4 February 2006); available from http://www.communityviz.com/index.asp?circuit=7&fuse=resource.

land-use classification for the study area. This classification was then assigned textures in the 3D viewer to create more realistic ground texture for the study area.

APPLICATION OF THE METHOD IN THE STUDY AREA

Gathering Data

Vector shapefiles: Vector data in the form of shapefiles was collected from several on-line sources. A large data bundle was downloaded for Lake County using the automated function at the Natural Resources Information System (NRIS) web site.[54] The downloaded layers included streams, slope, soils, mines, abandoned mines, landfills, fault lines, wetlands, forest boundaries, lakes, dams, schools, and airports. Cadastral data for Lake County was downloaded from the Montana Cadastral Mapping website.[55] Additional higher accuracy shapefiles for stream locations were acquired from the CSKT GIS department.

Orthophotos: Orthophotos were the primary reference for digitizing development within the boundaries of the St. Ignatius study area. Orthophotos are orthographic photographs, which means that the scale, tilt, and relief distortions that characterize normal aerial photographs have been removed. The result is essentially a photomap in which true distances, angles, and areas may be directly measured. These characteristics make orthophotos excellent base maps for digitizing and compiling data for a GIS.[56]

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[54] http://nris.state.mt.us/gis/default.htm

[55] State of Montana, *Montana Cadastral Mapping Program*(State of Montana, unknown 2004, accessed 19 March 2004); available from http://gis.doa.state.mt.us/.

[56] Thomas S. Lillesand and Ralph W. Kiefer, *Remote Sensing and Image Interpretation* (United States: John Wiley and Sons, Inc., 1999), 170.

Within a 3D visualization, orthophotos have another valuable purpose besides being the base layer for digitizing: orthophotos can be "draped" over a digital elevation model in order to give a 3D scene a texture. While it is possible to use a panchromatic image as a draping layer, a color image provides a more realistic drape.

In general, high resolution (one meter or less) color orthophotos of relatively recent vintage are the best choice for digitizing purposes and also for 3D display. In the case of the St. Ignatius study area, the only one-meter orthoimagery that was available was panchromatic imagery from 1991. This imagery was not ideal for this study for two reasons: (1) it would not show the development that had occurred in the area from 1991 to the present, and (2) the panchromatic image would not provide a true color "drape" for the 3D scenario. A two-meter color digital mosaic for Lake County was acquired from the Natural Resource Conservation Service in Missoula. The digital mosaic was created in 2004 by the National Agricultural Imaging Program, or NAIP.[57] While the NAIP image had fairly low resolution and was not orthorectified, it was still useful for identifying development and as a draping layer in the 3D visualizations.

Aerial Photographs: To partially remedy the problem of not being able to discern the level of development in the 2004 NAIP images, a series of hard copy panchromatic aerial photos from 1999 were obtained from the Montana Department of Transportation.[58] These images, which were taken with a high-precision mapping camera, cover an area 1800 feet to the east and west of the Highway 93 centerline. While these photos did not cover the complete extent of the study area, they did include a

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[57] United States Department of Agriculture, *National Agriculture Imagery Program*(Aerial Photography Field Office, 2004, accessed 10 April 2005); available from http://www.apfo.usda.gov/NAIP.html.
[58] Montana Department of Transportation, "Airphotos of Highway 93 Corridor," (Montana: Montana Department of Transportation, 2001).

substantial portion of the most developed portions of the study area. The aerial photographs were taken at a 1:4800 scale, and the high resolution of these photos made it relatively easy to see the number and type of structures present on the landscape. While the photos were six years old, they at least partially bridged the gap between the 1991 orthophotos and the 2004 NAIP images. The aerial photographs were used whenever the 1991 NRIS orthophotos or the 2004 NAIP images proved insufficient for determining the actual level of development.

Digital Elevation Models and TINs: A digital elevation model (DEM) is a grid of evenly spaced elevation values that are referenced horizontally either to a Universal Transverse Mercator (UTM) projection or to a geographic coordinate system.[59] DEMs are useful for the construction of a 3D scene because they provide the base elevation values for the scene. Other raster layers—such as orthophotos—that do not have elevation values can be matched pixel-for-pixel with the DEM elevation values and effectively draped over the DEM. However, a dense elevation grid with many elevation points slows down processing times when a 3D scene is rendered. For relatively flat areas, a TIN (Triangulated Irregular Network) often works just as well as a grid as a base for the 3D display, and it can greatly speed up the rendering of the 3D scene. A TIN can be generated from a DEM using tools in ArcGIS or other software platforms.

Two digital elevation models (DEM) quadrangles for the study area were downloaded from NRIS.[60] Several steps were necessary to make the DEMs usable within the ArcGIS environment. First, the DEMs had to be converted to ESRI grid format using

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[59] United States Geological Survey, *Us Geodata Digital Elevation Models*(USGS, 1998, accessed 29 May 2005); available from http://www.usgsquads.com/downloads/factsheets/usgs_dem.pdf.
[60] Montana State Library, *Natural Resource Information System*(Montana State Library, 2005, accessed 12 March 2005); available from http://nris.state.mt.us/.

the "DEM to grid" tool in ArcToolbox. Next, the two grids were mosaicked together using the ArcToolbox tool "Mosaic to New Raster," and then the mosaic was clipped to suitable dimensions using the Spatial Analyst extension in ArcMap.

Slope Raster: A raster with slope information for Lake County was acquired from the CSKT GIS department.[61] This raster layer had a higher degree of accuracy than the slope shapefile that was available from the NRIS website. The slope raster was used to identify areas that could not be developed due to excessive slope.

Creating a Geodatabase

ArcCatalog was used to create a geodatabase to hold the various project layers. The geodatabase was organized into four feature datasets, as shown in Figure 3.1:

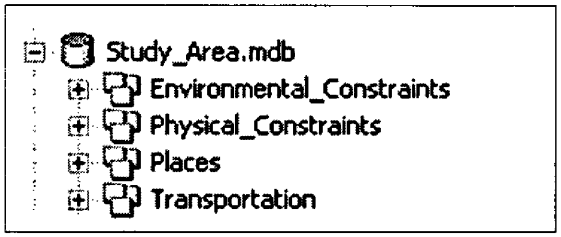

Figure 3.1. Geodatabase for the Study Area

Identifying Possible Constraints to Development

To portray a realistic 3D build-out scenario, one must first identify constraints to development. For the purposes of this discussion, there are two types of constraints: physical and environmental. Physical constraints are man-made obstacles to development such as existing homes and businesses, parcel boundaries, highway right-of-ways, and land use zoning. Environmental constraints are natural obstacles to development such as flood zones, areas of high slope, earthquake faults, riparian areas,

[61] Confederated Salish and Kootenai Tribe, "Slope, Stream, and Flooding Layers," (Montana: Confederated Salish and Kootenai Tribe, 2005).

and wildlife corridors. For the Highway 93 study area, all of the physical and environmental constraints had to be identified and brought together into one layer.

Digitizing the Study Area: The boundaries of the study area were digitized in ArcMap using the panchromatic 1991 orthophoto and the Lake County cadastral layer. A field was added to the attribute table and unique values assigned to each of the three zones that were common to both land use plans.

Digitizing Existing Building Locations: All of the existing houses and commercial structures within the study area were digitized as points in order to provide the build-out wizard in Communityviz with information about parcels that had been partially or fully developed. Without this information, the build-out wizard would have overpopulated the study area when projecting the number of possible structures allowed under the land use regulations. Points representing the building centroids were digitized while referencing the 1991 panchromatic orthophoto, the 2004 color NAIP image, and hard copy aerial photos from the Montana Department of Transportation. Later in the 3D scenario, these centroids would be replaced with OpenFlight 3D symbols from the Sitebuilder 3D library.

Identifying Relevant GIS Data for the Constraint Layer: The individual NRIS shapefile layers were overlaid on the study area shapefile in ArcMap to determine which NRIS layers actually had features present within the study area. Out of all the layers that were acquired from the NRIS website and the CSKT GIS department, only four layers actually had features located within the study area: streams, slopes greater than 15%, ownership parcels, and frequent flooding zones.

Stream Buffers: The streams layer mentioned above was clipped to the boundaries of the study area. Based on information from the CSKT about the ideal setback of underground septic tanks from surface water,[62] a 100-foot buffer was created on each side of the stream features. This buffer was created using the buffer wizard in ArcMap. Figure 3.2 shows the stream buffer layer.

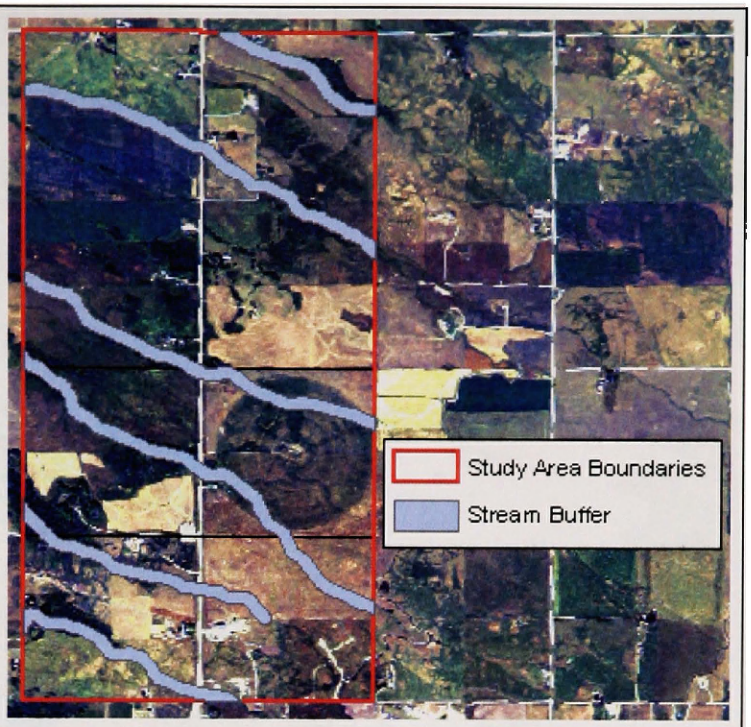

Figure 3.2. Stream Buffer Feature Class for the St. Ignatius Study Area

Slopes Greater than 15 Percent: The slope layer that was provided by the CSKT GIS department was clipped to the boundaries of the study area. The "select by attributes" function was used to select only those pixels that had a slope value of 15 percent or greater. The selected pixels were then exported to a new feature class (as a vector layer) using the "Export Data" option. It was found that only one very small region within the study area had a slope greater than 15 percent. This region happened to be covered by one of the parcels owned by a government agency, so there was no need to include the slope layer in the final constraints layer.

[62] Janet Camel of Confederated Salish and Kootenai Tribes, interview by author, 25 February 2005.

Flood Zones: There was no official flood layer available for the study area. An alternative suggested by CSKT planner Janet Camel[63] was to use an NRIS 1:24,000 "frequent flooding" soils layer. This layer was loaded into ArcMap, and then a table join was performed to join the "muaggatt" table to the shapefile.[64] The join was then made permanent by exporting the data to a shapefile. The Analysis>>Extract>>Clip" tool in ArcToolbox was then used to clip the soils layer to the size of the study area. Next, a new feature class was created in the environmental constraints dataset.

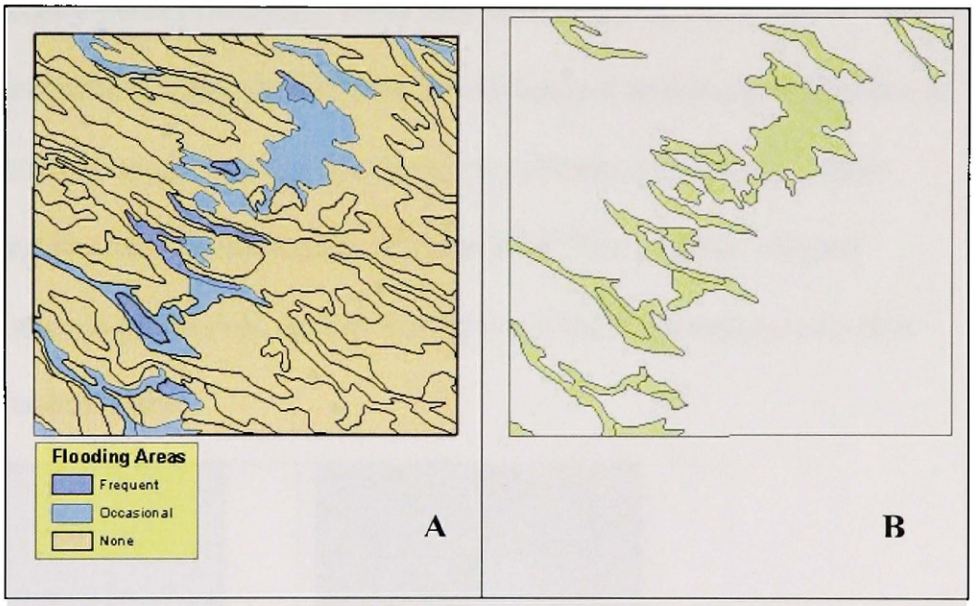

Figure 3.3. Flooding Areas. **A.** Clipped parcel boundaries from cadastral layer. **B.** Exported parcel feature class belonging to state, federal, or tribal governments.

Lastly, the "select by attributes" option in ArcMap was used to select the areas in the "frequent" or "occasional" flooding categories. After these selected areas were exported to a new feature class in the project geodatabase, the "Data Management>>Generalization>>Dissolve" tool in ArcToolbox was used to dissolve the boundaries between the "frequent" and "occasional" flooding polygons. Figure 3.3 shows the clipped soils layer on the left and the exported "frequent and occasional flooding areas" on the right.

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[63] Janet Camel, planner for CSKT, interview by author, 15 March 2005.
[64] "Muaggatt" refers to the "map unit aggregated attribute" table generated by the Natural Resources Conservation Service.

Unbuildable Parcels: The cadastral parcel layer was used to identify parcels that were owned by the state of Montana, the United States government, or the CSKT. It was assumed for the purposes of this study that these parcels were unbuildable; that is, no development would take place on those parcels in the foreseeable future.

The first step in creating an unbuildable parcels layer was to clip the study area parcels from the larger county parcel boundary layer that was obtained from NRIS. Once this was done, the attribute table for the clipped parcel was opened and the government or tribally owned parcels were selected by using the "select by attributes" option. These parcels were then exported to a new feature class (Figure 3.4). The original clipped parcel boundary layer is shown on the left, and to the right are the exported parcels that were identified as being unbuildable.

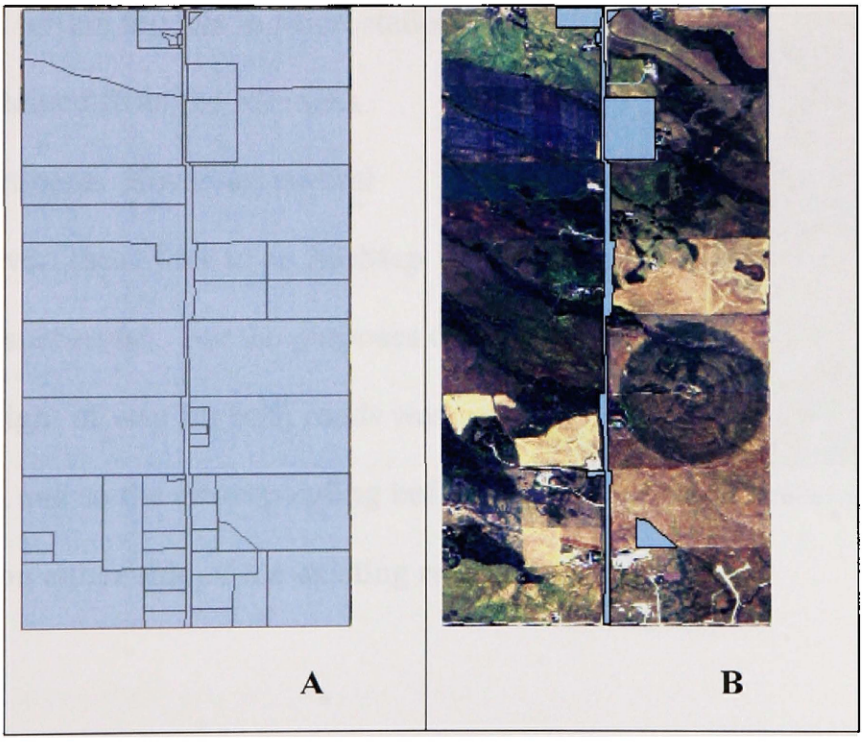

Figure 3.4 Unbuildable Parcels. **A.** Clipped parcel boundaries from cadastral layer. **B.** Exported parcel feature class showing parcels belonging to state, federal, or tribal governments.

Road Right-of-way Constraints: The term "right of way" refers to land set aside for use as a highway or road corridor. A right of way is purchased before the construction of a new road, and usually sufficient extra land is purchased for building sound walls, retaining walls, and other mitigation features.[65]

The study area had two types of rights of way: highway rights of way and county road rights of way. According to the Montana Department of Transportation, the right of way for county roads is sixty feet (thirty feet on each side of the road).[66] The Highway 93 right of way varies in width. In an attempt to obtain detailed rights of way for the Highway 93 corridor, digital terrain models in Microstation format were obtained from the Montana Highway Department. However, several attempts to convert these files to an ArcMap format were unsuccessful. For the purposes of this study, the right of way for both roads was set at sixty feet, and so the corresponding buffer was thirty feet on either side of the existing road (Figure 3.5).

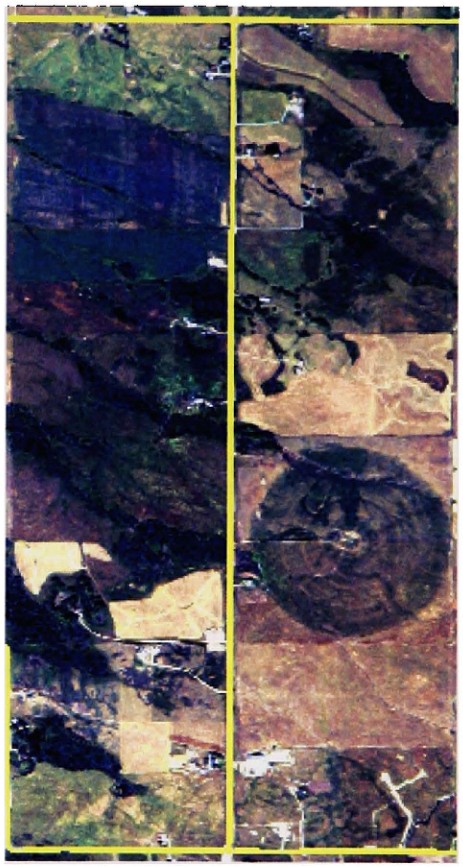

Figure 3.5. Road buffers for St. Ignatius

[65] Interstate-Guide.com, *Interstate-Guide Glossary*(Interstate-Guide.com, 5 October 2003 2005, accessed 1 June 2005); available from http://www.interstate-guide.com/glossary.html.
[66] Shane Shack of Montana Department of Transportation, interview by author, 15 March 2005.

Assembling the Final Constraint Layer: Once all the constraints were identified and brought into one data frame, they were combined into one layer using the "Union" tool in ArcCatalog, and then the internal boundaries were dissolved with the " Dissolve" tool. As can be seen in Figure 3.6, the final constraint layer (in solid yellow) affects all three of the major zones in the study area.

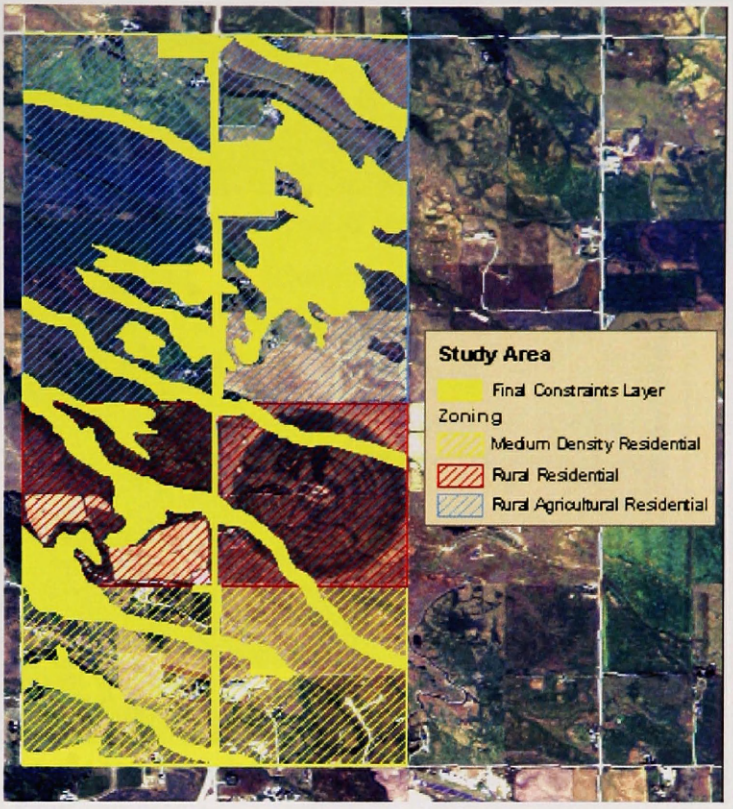

Figure 3.6 .Final Constraint Layer.

Spatial Build-out of Highway 93 Corridor Plan

Numerical Build-Out: As mentioned earlier, the numerical build-out procedure calculates the maximum development given the land use regulations and the availability of buildable land. Scenario 360's numerical build-out wizard makes these calculations for the user. Three data layers were loaded into the ArcMap data frame to perform the numerical build-out within the study area. These were the following:

- clipped Cadastral Layer
- clipped constraint layer
- layer showing digitized existing buildings in study area

A new field was created in the Lake County Cadastral Layer, and an attribute value was assigned to each parcel based on its location in the Highway 93 Corridor Land Use Plan. These zones are shown in Figure 3.7.

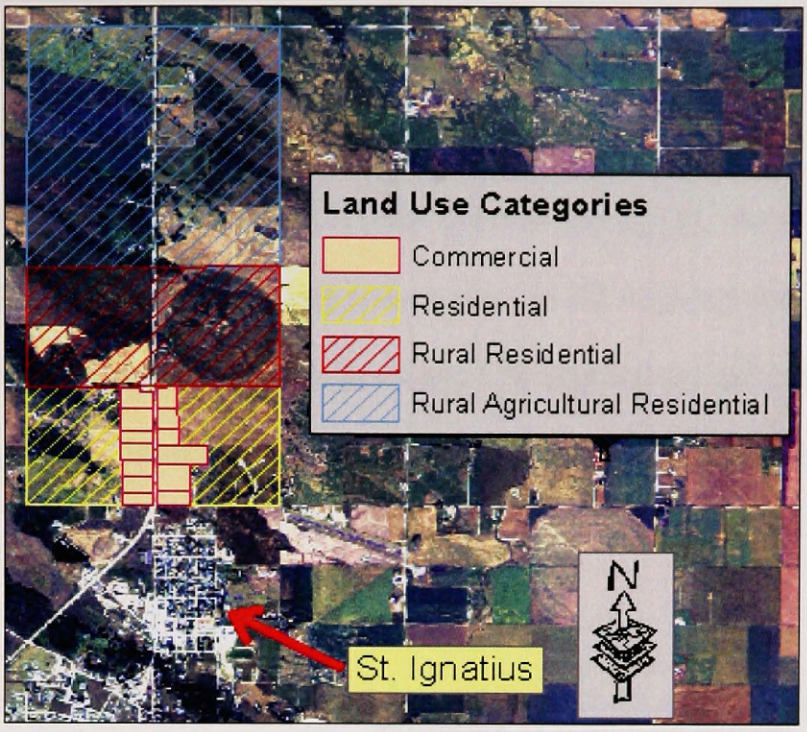

Figure 3.7. Land Use Categories for the Law School's Land Use Plan.

The next step in the numerical buildout was to gather information about density restrictions (in the form of minimum lot sizes) from the Highway 93 Corridor Land Use Plan. These restrictions are listed in Table 1.

Table 1 .Allowed Densities for the zones in the Highway 93 Corridor Land Use Plan.

Highway 93 Corridor Land Use Plan: Allowed Densities	
Medium Density Residential	10,600 square feet
Rural Residential	10 Acres
Rural Agricultural Residential	40 Acres

This information was then entered into the relevant fields in the wizard. The constraints layer was then specified as was the existing buildings layer. Based on the land use restrictions and the constraints layer, the software calculated the maximum number of buildings (both commercial and residential) that could be placed into each of the four

zones in the study area. Next, in the spatial build-out step, additional information was entered into the appropriate fields of the wizard, including minimum separation distance between buildings and the set-back distance from roads. The spatial buildout wizard then took into account the actual geometry of the land and refined the building count. As a final step, the spatial buildout wizard inserted building points into the 2D ArcMap data frame. The spatial build-out for the Highway 93 Corridor Land Use regulations produced 551 building points in the study area. These building points are broken down by zone in Table 2.

Table 2. Build-out results from Highway 93 Corridor Plan.

Zone	Number of Building Points
Commercial (.25 FAR –Floor to Area Ratio)	13
Medium Density Residential (.2433 units per acre)	513
Rural Residential (10 acres per unit)	20
Rural Agricultural Residential (40 acres per unit)	5
Total Building Points	**551**

The spatial build-out points are shown in the ArcMap environment in Figure 3.8.

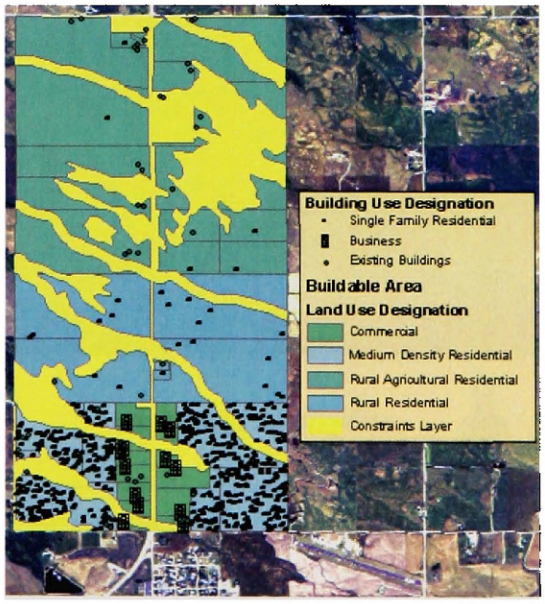

Figure 3.8. Allowed Densities for the zones in the Land Use Plan.

The Visual Build-out of the Highway Corridor Plan Results in 3D

A visual build-out takes the 2D spatial build-out data and converts it into visual form. For the study area, the first step in this process was to acquire elevation data for the study area and to create a 3D landscape (a terrain and a draping texture) using the Sitebuild 3D interface. Point, line, and polygon features were then digitized in the 2D interface and added to the 3D landscape and 3D symbols and textures assigned using the Sitebuilder 3D toolbar. Next, with the data for the same region being shown in both the ArcMap and the Sitebuilder 3D interface, edits were made in the ArcMap window. The 3D landscape was then updated with the added or changed 2D data using the Sitebuilder 3D toolbar. By repeatedly adding or editing 2D data and then visualizing it in the 3D viewer, a 3D scene was slowly created in which the 3D elements had the proper size and spatial orientation. The sections below discuss these steps in more detail.

Formatting and Clipping the NAIP Image: The Sitebuilder 3D program does not accept compressed image formats such as MrSid, so the original NAIP photo had to be converted into a TIFF. This was accomplished by using the "Raster to New Format" tool in ArcToolbox. The TIFF image was then clipped with a shapefile using the Spatial Analyst extension of ArcGIS

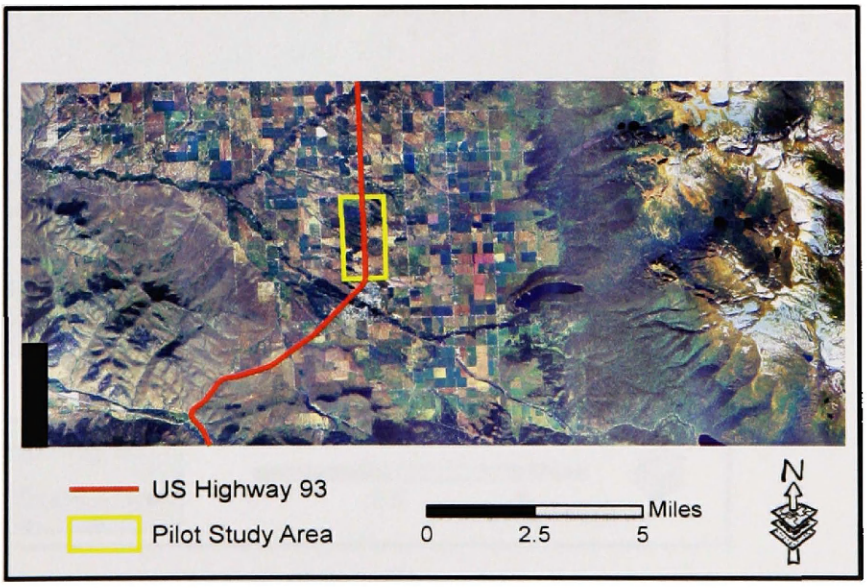

Figure 3.9. Clipped NAIP image with Study Area

9.1. The image was clipped so as to include a large portion of the Mission Range as a backdrop for the 3D scene. Figure 3.9 shows the clipped portion of the NAIP image.

Creating Terrain: An elevation layer was needed as a base "terrain." Two 10-meter resolution DEMs were downloaded from the NRIS web site for this purpose, and were converted to ESRI grids using the "Dem to Raster" tool in the conversion section of ArcToolbox. The grids were then mosaicked together using the "Mosaic to New Raster" tool in the "Data Management>>Raster" section of Arctoolbox. Next, the DEM mosaic was clipped so that it was slightly larger than the Tiff image. The original intention was to bring the clipped elevation grids directly into SiteBuilder 3D; however, for unknown reasons Sitebuilder 3D was unable to create a 3D terrain using the elevation grids. As an alternative, the "raster to TIN" tool in ArcGIS's 3D Analyst was used to create a TIN (Figure 3.10). Sitebuilder 3D was then used to create a terrain from the TIN.

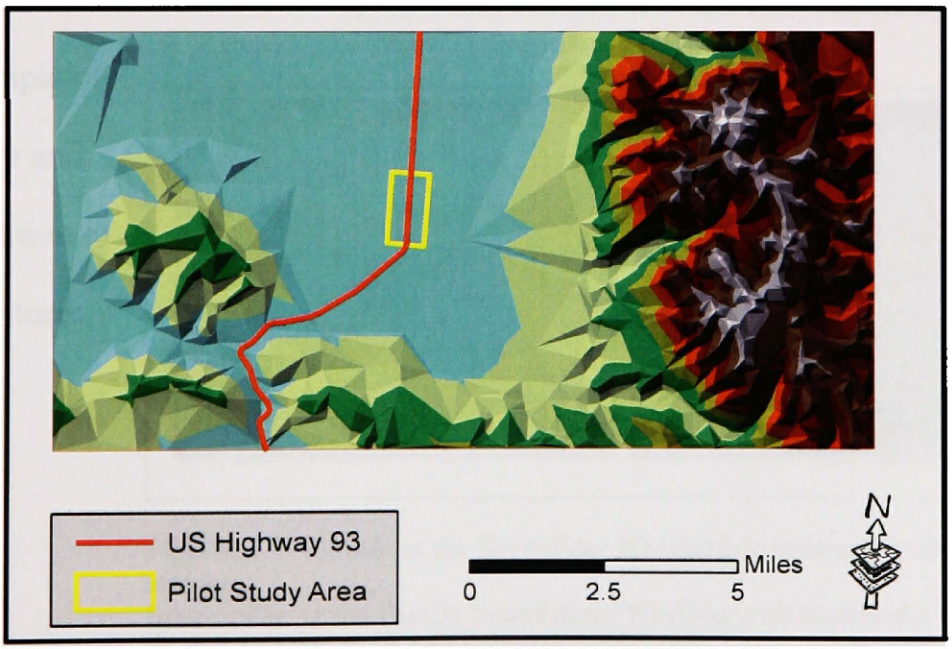

Figure 3.10. Clip showing TIN in relation to Study area

Draping the NAIP Image onto the Terrain: Image draping refers to overlaying a 2D digital raster—such as an orthophoto, aerial photo, or satellite image—onto a digital

elevation model (DEM) or Triangulated Irregular Network (TIN). The raster is matched to the DEM or TIN so that the raster follows the topographic surface of the elevation layer.[67] The main advantage of image draping is that it represents the landscape with a minimal amount of information, which increases the speed of rendering and enables the user to navigate through the landscape relatively quickly and smoothly (depending on the software and the type of computer used).[68]

Two options were available for creating the draping texture: (1) using the actual resolution of the NAIP layer, and (2) using the screen resolution of the NAIP image. Using the actual resolution of the NAIP image would have increased the resolution of the drape but would have dramatically slowed down the rendering of the scene. In contrast, creating a draping texture from the ArcMap display of the NAIP image created a file that was much smaller (256 megabytes) that could be rendered more quickly in 3D. For this reason, the "Drape Texture from Display" option was chosen. Figure 3.11 shows a general example of terrain before and after the addition of a draping texture.

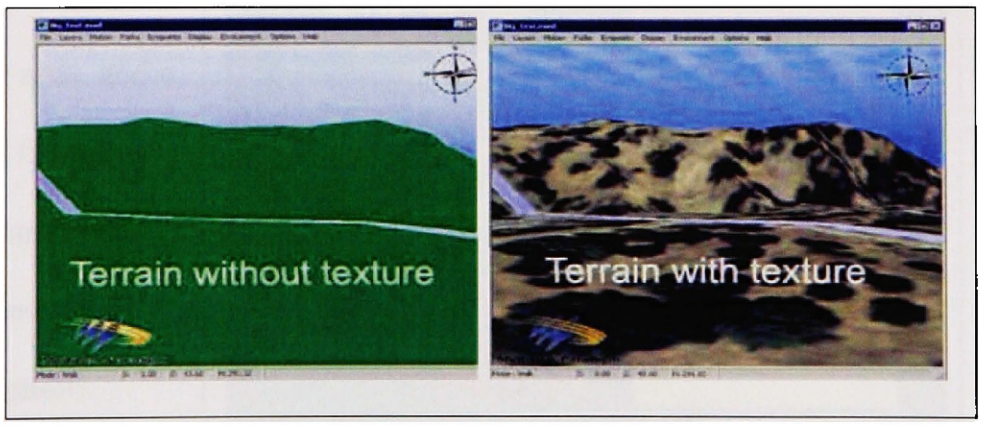

Figure 3.11. Terrain in the Sitebuilder 3D interface before and after the addition of texture.
Source: The Orton Family Foundation, Working with Sitebuilder 3D [pdf software documentation] (The Orton Family Foundation, 2004, accessed 11 December 2005).

[67] Katy Appleton, Andrew Lovett, Gilla Sunnenberg, Trudie Dockerty, "Rural Landscape Visualisation from Gis Databases: A Comparison of Approaches, Options and Problems," *Computers, Environment and Urban Systems* 26, no. 2-3 (2002), 148.
[68] Ibid.

Creating a Land Classification Using Feature Analyst 3.5: When the two-meter NAIP orthophoto was draped onto the TIN, the resulting texture appeared fairly realistic at long range (the Mission Mountains in the backdrop, for example) but less so at close range. To give the groundcover of the 3D scene a more realistic appearance at close range, a land use classification was needed for the study area. The polygons from such a land use classification could then be assigned 3D textures using 3D Sitebuilder.

To create such a land use classification by hand would have been a major undertaking. As a more time-efficient alternative to hand digitizing the land classification, the automated feature extraction software "Feature Analyst" was used. The 2004 NAIP photo was chosen to be the basis for the land use classification. This was mainly because the NAIP photo was the only color option available for the study area, and a land use classification from this photo would more naturally fit into the surrounding texture drape from the NAIP photo.

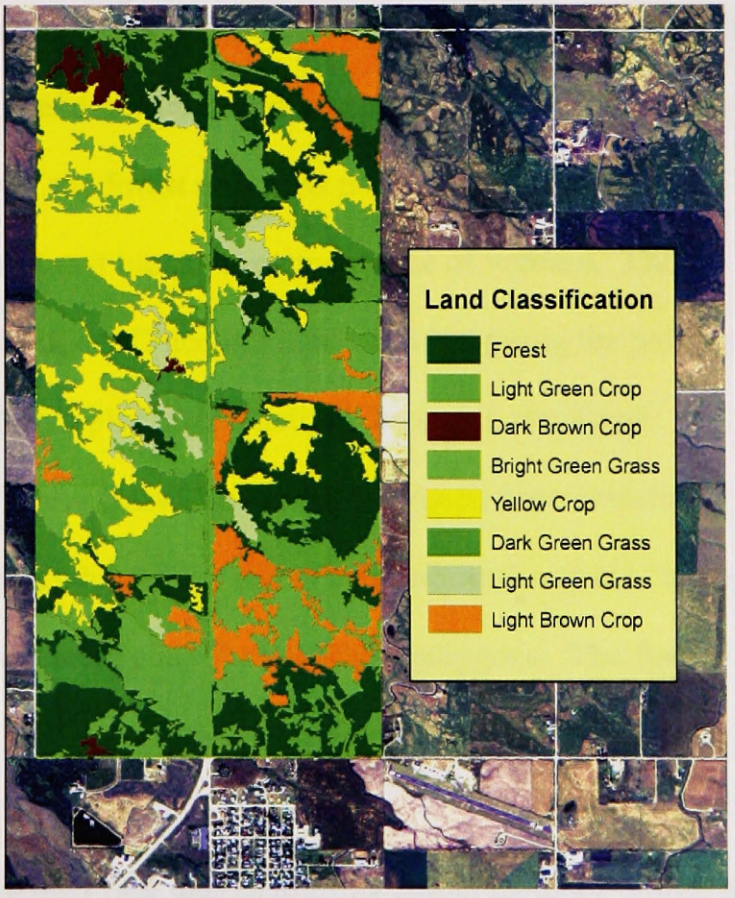

Figure 3.12. Final land classification layer for the study area.

Eight broad categories were created for the land use classification based on the color patterns present in the NAIP

photo (Figure 3.12). These categories were: light green crop, dark brown crop, bright green grass, yellow crop, dark green grass, forest, light green grass, and light brown crop. Shapefiles were created for each category and then training sets were digitized for each shapefile. These shapefile training sets were then combined using Feature Analyst's "create Multiclass input" command. Next, settings were chosen for the extraction using the "set-up learning" section of Feature Analyst, and then several iterations of the land cover classification were run, with the training sets modified between each iteration to produce more accurate results.

A new dataset was created in the project geodatabase, and the land use classification shapefile was imported into a feature class. Seven of the eight land use categories were to be visualized using the "Top" placement method. This method uses a surface conforming polygon with a top and no sides, and is appropriate for something such as a relatively flat field. However, the forest polygons needed to a different placement method in order to give the forest blocks the appearance of volume. The "Box" placement method within Sitebuilder 3D accomplishes this by giving the polygons a top *and* sides. In order to use a different placement method, however, the forest polygons needed to be in a separate feature class. The forest polygons were selected within the land classification attribution table using "select by attributes" and the "export data" option was used to create a new feature class for the forest polygons. The forest polygons were then reselected in the land use classification layer and these polygons were deleted.

Creating a road network: The next task was to digitize a road network within the Medium Density Residential area. This road network would allow building points to be

placed in a logical and consistent manner given the existing and projected development in the study area. The grid-type residential development within the urban area of St. Ignatius was chosen as the model for developing a road grid. A small frame of 10,600 square feet (the minimum size allowed in the Corridor Plan) was first created using the St. Ignatius urban area as a backdrop. Copies of this frame were created and grouped together, leaving room in between the houses for a service road (image A in Figure 3.13). This grid was then moved to the study area and rotated using the rotate tool on the drawing toolbar. This allowed the house placement frame to align with existing roads in the study area (image B in Figure 3.13). Copies of the frame were then made and pasted into ArcMap so that the road grid could be created across a larger portion of the MDR area.

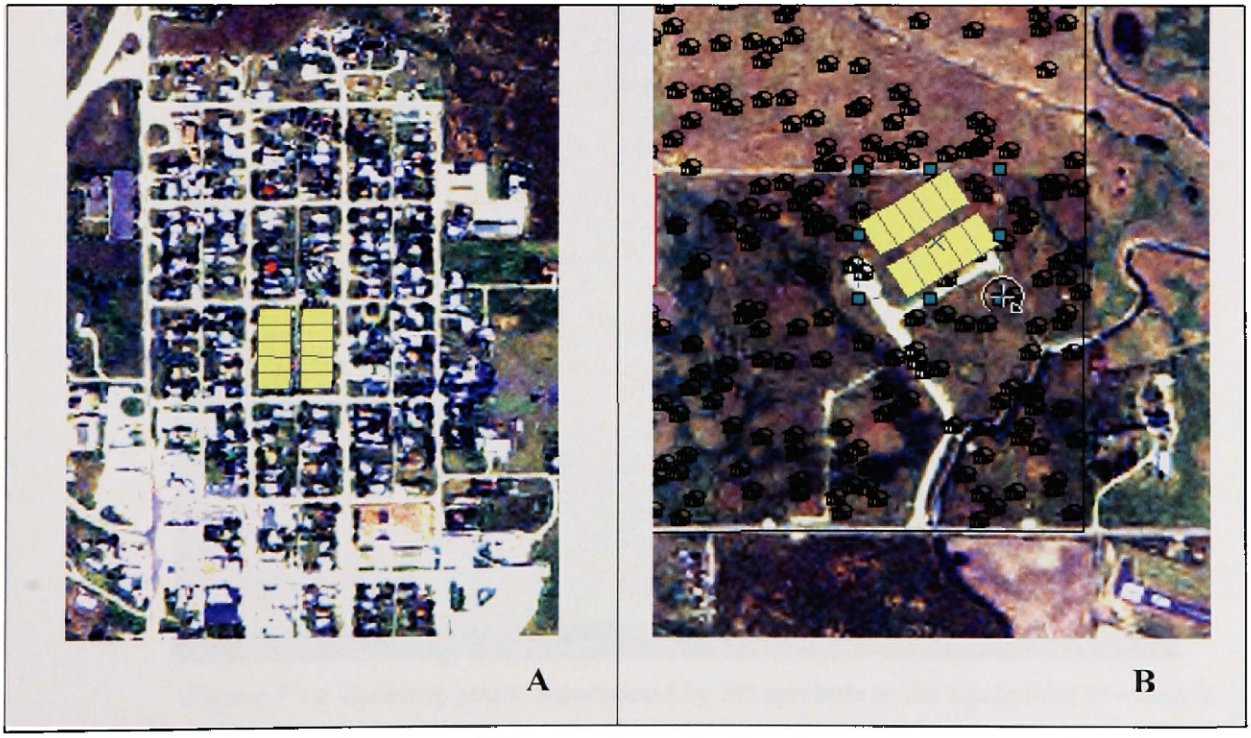

Figure 3.13. Steps in Creating Road Network **A.** Frame (in yellow) created with ArcMap drawing tools in its original location in St. Ignatius urban area. **B.** Frame after being positioned in study area and rotated into position for use in drawing a road grid and relocating building points.

Existing gravel and blacktop roads in the study area were incorporated into the new road grid in an attempt to make the proposed road network as realistic as possible. The road grid was based on the St. Ignatius road network, with service roads separating the back yards of houses. All of the road layers were snapped to each other to avoid gaps and dangles in the line shapefile.

Relocating building points and displaying the points in 3D: The road layer was used in combination with the house placement frame to relocate building points in the MDR area. These points were then symbolized in the Sitebuilder 3D viewer using appropriate 3D symbols, and the houses' orientation was modified so that the houses were facing the nearest road. Figure 3.14 shows an early phase in the Highway 93 Corridor 3D scene.

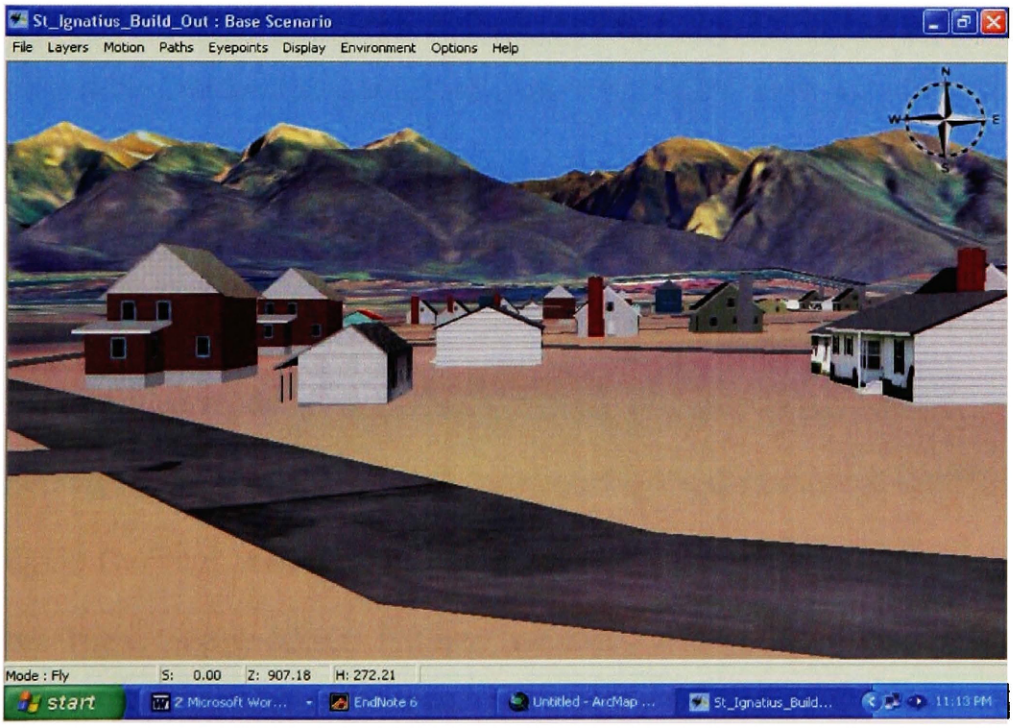

Figure 3.14. Building points represented by 3D symbols in the Sitebuilder 3D viewer.

Because there was not enough room in the final MDR road grid for all of the house points, some of the points were deleted. The number of remaining buildings in the

MDR area was 420, down from the original 513 building points produced in the original spatial build-out estimate. A section of the completed MDR grid development can be seen in 2D view in Figure 3.15.

Figure 3.15. House points placed within road grid for study area.

For the other residential/agricultural zones within the study area (the Rural Residential and Rural Agricultural Residential zones), the relative scarcity of building points made it unnecessary to develop a road grid. Instead, the existing roads were simply extended into new undeveloped areas and the spatial build-out house points were moved alongside the extended roads.

Digitizing Additional Features: Additional feature classes were needed for all of the Highway 93 Corridor zones in order to convey a greater sense of reality in the 3D visualization. These feature classes fell into two categories: (1) existing features that could be directly digitized from the NAIP image (individual trees, roads, etc), and (2) features that would likely be present in the future urban landscape (sidewalks, driveways, trees, etc). A complete list of the digitized features for each category is shown in Table 3.

Table 3. Layers Used in 3D Scenario for Highway 93 Corridor Plan

MDR District	Type of Feature Class	Placement Method
Commercial_Shrubs	Point	Point
Livestock_fence	Line	Line
Commercial_trees	Point	Point
Commerical_walls	Line	Ribbon
Commercial_berms	Polygon	Top
Commercial_parking_lot	Polygon	Top
Churches	Point	Point
Schools	Point	Point
School Parking Lots	Polygon	Top
Trees_suburbs	Point	Point
Suburban Trees	Point	Point
Telephone_poles	Point	Point
Driveways3	Line	Ribbon
Sidewalks	Line	Ribbon
Subdivision_roads1	Line	Ribbon
Lawns	Polygon	Top
Fences_houses	Line	Fence
Alleyways	Line	Ribbon
Shrubs	Point	Point
Shrubs_rural_area	Point	Point
Trees_rural_area	Point	Point
Rural Grass	Polygon	Top
Highway93_digitized	Line	Ribbon
Gravel_roads	Line	Ribbon
FA_digitized_paved_roads	Line	Ribbon
Existing_Buildings	Point	Point
Existing_blgs_gravel_lots	Polygons	Top
Existing_blgs_yards	Polygon	Top
New_final_clip_multiclass	Polygon	Top
Forest_polygons	Polygon	Top
Commercial_buildings	Point	Point
Residential_buildings	Point	Point

Inserting Feature Classes into the Sitebuilder 3D Viewer: After the features were digitized in the 2D ArcMap interface, they were placed into the Sitebuilder 3D viewer. Appropriate 3D symbology and textures were chosen using the Sitebuilder 3D placement interface. If elements needed to be added or moved, this was done by editing the 2D source data in ArcMap. The 3D view was then updated with the latest data. Thus, the 3D scene was built slowly in an iterative fashion, with modifications made along the way to

the 2D data so that it matched other elements of the 3D scene in spatial orientation and size.

Symbolizing Feature Classes in 3D: The Sitebuilder 3D interface offers several different ways to symbolize data in the 3D view, depending on whether the data is in point, line, or polygon form. Point features are symbolized with OpenFlight files, an open standard 3D format developed by Multigen-Paridigm. Various 3D models can be selected for the different points in a shapefile layer. This is done by creating an attribute field with the desired range of numbers and then assigning a particular Openflight model to each number. Similarly, the size and the orientation of each 3D symbol can be assigned through the use of an attribute field. Line and polygon features can be placed using a variety of methods, and can be assigned colors or photo-realistic textures.

Creating a Sharable Scene: Once the 3D build-out was complete for the Highway 93 Corridor plan, the 3D scene needed to be put into a format that could be shared with members of the planning community so that they could evaluate the 3D build-outs. The Sitebuilder 3D software can create "Sharable 3D Scenes" that are complete copies of the 3D scene, including a 3D viewer. This option is portable, which means it can be viewed on other computers that do not have CommunityViz, Sitebuilder 3D, or any specialized GIS software. The 3D scene can be viewed in its entirety, and users can maneuver through the scene and can manipulate the scene elements. For example, 3D layers can be turned on and off, and the user can choose to walk, drive, or fly through the 3D terrain using keyboard commands.

Spatial Build-out of the Density Map Using Communityviz

Numerical Buildout: The same build-out procedures that were used for the Law School scenario were repeated in order to create a 3D build-out for the Lake County Density Map. The clipped Cadastral Layer, the clipped constraint layer, and the layer showing existing buildings were loaded into a new data frame in ArcMap. The boundaries for the different zones were the same as in the Law School build-out, but the density values were different in all of the zones. The most significant difference was in the Community Growth Area (CGA) of the study area, which is the same geographic region as the Medium Density Residential (MDR) Area of the Law School's Land Use Plan. In the Lake County Density Map, the CGA allows developers up to twelve single-family residences on one acre. This density would only change if the property were annexed into a municipality.[69] It seemed unreasonable to use the twelve residences per acre, as that would have meant using lot sizes of only 3,630 square feet. After consultation with the Lake County Planning Office, a more reasonable (but still relatively small) lot size of 7,000 square feet (.1607 acres) was used.[70] Table 4 shows the minimum lot sizes used for the Lake County Density Map build-out:

Table 4. Allowed Density in Lake County Density Map zones.

Lake County Density Map: Allowed Densities for Study Area	
Community Growth Area	.1607 acres (7000 square feet)
Rural Residential	5 acres per unit
Rural Agricultural Residential	20 acres per unit

[69] Pam Repnak, (Lake County Planning Department: 2005).
[70] Ibid.

The allowed densities for the Density Map are shown below in Figure 3.17:

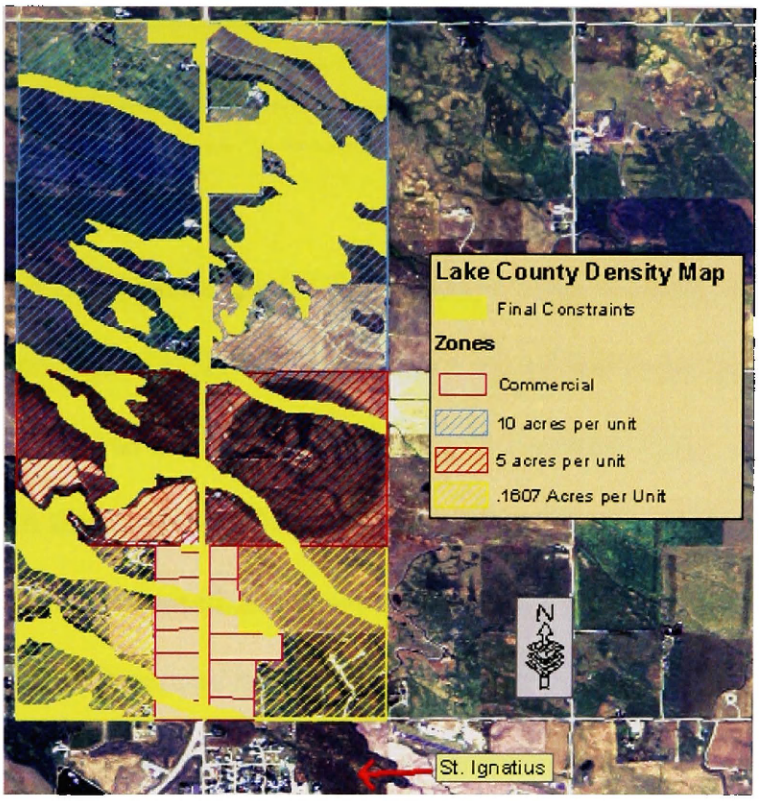

Figure 3.16. Density Zones from Lake County Density Map.

There is no official "commercial zone" in the Density Map, but for the sake of consistency the same commercial zone used in the Law School's Land Use was also used in the Density Map build-out. This would allow a comparison to be made between the screening vegetation requirement in the Highway 93 Corridor Plan versus the Density Map, which has no such screening vegetation requirement.

The numerical build-out for the Density Map regulations produced 840 building points in the study area. These building points are broken down by zone in Table 5.

Table 5. Build-out results from the Lake County's Density Map regulations.

Zone	Number of Building Points
Commercial (.25 FAR – Floor to Area Ratio)	13
Community Growth Area (.1607 units per acre)	776
5 acres per unit	44
20 acres per unit	7
Total Building Points	**840**

The Visual Build-out of the Density Map Results in 3D

Converting the spatial build-out results to a visual build-out followed the same procedures that were used to convert the Highway 93 Corridor Plan. Many of the layers that were produced in the earlier build-out, such as the TIN, the clipped NAIP image, and the land classification were reused in the visual build-out for the Density Map. There were only a few minor differences in the placement of the building points and the digitization of new features, and those are discussed below.

Creating a Road Network: The road network for the Community Growth Area involved a grid design similar to that used for the MDR area of the Law School's Land Use Plan, but one major difference was that the CGA residential road grid did not have alleys. This was mainly because there were many more houses that needed to be placed in the CGA zone. Even without the alleyways, some of the housing points in the CGA zone had to be eliminated. After housing points were placed in relation to the road network, the final count for houses in this zone was 750. This was down from 776 in the original spatial build-out.

There was ample room in the five acre and ten acre per unit zones for the housing units, so none of those housing points were deleted. The rural road network from the

Highway 93 Corridor Plan was extended and the additional houses placed along the new road sections.

Digitizing Additional Features: Many of the digitized features from the Highway 93 Corridor build-out were re-used for the Density Map 3D visualization, but in other cases new feature classes were created and were populated with point, line, and polygon features. A list of the feature classes used in the Density Map 3D scene are shown in Table 6.

Table 6. Layers used in Density Map 3D scenario

MDR District	Type of Feature Class	Placement Method
Park_lot_lines_rural	Line	Fence
Businesses_rural	Point	Point
Park_lots_rural	Polygon	Top
Strip_objects	Point	Point
Commercial_shrubs	Point	Point
Livestock_fence	Line	Fence
Commerical_trees	Point	Point
Commercial_walls	Line	Wall
Commercial_berms	Polygon	Top
Commercial_parking_lots	Polygon	Top
Churches	Point	Point
Schools	Point	Point
Trees_CGA	Point	Point
Telephone_poles	Pint	Point
Driveways_CGA	Line	Ribbon
Sidewalks_CGA	Line	Ribbon
Subdivision_roads1	Line	Ribbon
Lawns	Polygon	Top
Shrubs_rural_area	Point	Point
Trees_rural_area	Point	Point
Rural-grass	Polygon	Top
Highway93_digitized	Line	Ribbon
Gravel_roads	Line	Ribbon
FA_digitized_paved_roads	Line	Ribbon
Existing_buildings	Point	Point
Existing_bldgs_trees	Point	Point
Existing_bldgs_gravel_lots	Polygon	Top
Existing_bldgs_yards	Polygon	Top
New_final_clip_multiclass	Polygon	Top
Forest_polygons	Polygon	Box
Comm._bldg	Point	Point
Buildings	Point	Point

Conclusions about the 3D Visualization Process

One of the goals in this study was to identify possible reasons why 3D visualizations are generally underutilized in the planning field. During the course of preparing the two 3D visualizations for the St. Ignatius study area, several issues became apparent that could be reasons for this underutilization of 3D visualizations.

Time-intensive preparatory steps: Much time was needed to complete the preparatory steps for the 3D visualizations. These steps included gathering data (aerial photos, digital elevation models, cadastral data, etc.), digitizing development in the study area, learning the Scenario 360 and Sitebuilder 3D interfaces of the CommunityViz software, and performing spatial buildouts with Scenario 360.

Placing elements in the 3D scene is labor-intensive: The 3D visualizations were time-consuming to create with the Sitebuilder 3D interface of the CommunityViz software. This was due to the following factors:

- The need to use two different interfaces to create the 3D scenes. The ArcMap interface was used to manage and edit data, while the Sitebuilder 3D interface was used to place the data into 3D form and to view the data in 3D. If problems were noted between scene elements in the 3D view, then the data was edited in the ArcMap interface and then re-visualized in the Sitebuilder 3D interface. Often several iterations of this procedure had to be done for individual trees or sidewalks in the scene.
- All of the buildings in the 3D scene need an "orientation" value. This involved adding an attribute field to the shapefile or feature class and then populating the field with an appropriate orientation value (from 0 to 360 degrees) so that

buildings faced the nearest street. Adding this value for several hundred houses was time-consuming because it sometimes involved several iterations of editing and then rebuilding the 3D layers to determine the correct orientation value for each house.

- Lack of adequate documentation in the Communityviz software. The documentation in the CommunityViz software did not mention two important points: (1) null values were not allowed in the attribute fields of feature classes or shapefiles, and (2) the "add data" button in CommunityViz and the "add data" button in ArcMap were visually identical, but the CommunityViz button should have been the exclusive choice when adding data in a CommunityViz project. Problems related to this lack of documentation eventually required the author to rebuild both development scenarios in ArcMap and recreate the 3D visualizations in Sitebuilder 3D.
- Inconsistent sizing of objects within the 3D viewer. Several of the "small business" models in the Sitebuilder 3D model library were much larger in the 3D view than other similar "small business" 3D models from the library. A similar problem was noted with tree and shrub models from the 3D library. This reduced the number of models available for the 3D visualization, and made it difficult to vary the tree and shrub sizes in the 3D visualizations.
- Instability of the CommunityViz software. Crashes of the software were not infrequent, and the data within a CommunityViz project sometimes became corrupted after simply closing and reopening a project.

Software and hardware no longer a major obstacle to 3D visualization: In the past, 3D GIS visualization often required the latest software and hardware to create and view 3D scenes. In contrast, the 3D visualizations created for this study were done on a 3.5 year-old Dell desktop computer equipped with a 1.8 gigahertz processor and 512 MB of RAM. Compared to new computers, which typically have 3.0 gigahertz processors and 1 GB of RAM, this computer is outdated, yet it functioned very well for 3D scene creation and viewing.

Automation of Land Classification: The Feature Analyst 3.5 software was used to quickly develop a land classification for the study area. This type of automation holds much promise in speeding up the production of 3D visualizations. There are other steps in the 3D visualization process that could be automated; for example, the attribute field for house orientation could be populated by software that determines the direction of the nearest road segment and puts that value in the attribute field.

Use the smallest study area possible: The amount of time needed to model a 3D scene is surprising large. Keeping the 3D visualization as small as possible would allow more time to be devoted to important components of the scene. For example, if a smaller area had been used in this study, existing buildings could have been modeled in more detail by taking pictures of those structures and pasting clipped portions of the photographs onto extruded buildings in the 3D scene.

CHAPTER IV

ANALYSIS OF 3D MODELS

Introduction

Three-dimensional visualizations would seem to have great potential in the planning field, yet there is limited information in the scientific literature about the effect of 3D visualizations on the planning process. Also, 3D visualizations are underutilized in the planning process compared to static images and 2D maps.[71] In order to study these issues, two 3D visualizations for the St. Ignatius study area were created. The completed 3D visualizations were shown to a small number of geography and land use professionals, and a series of questions was asked to determine the effectiveness of the 3D visualizations.

The Interview Participants: The complexity of the information contained in the 3D visualizations meant that it would be difficult for a layperson to see how useful the visualizations would be for the planning field. In order to gain meaningful feedback about the value of the 3D visualizations, it was necessary to interview professionals from the geography and the planning fields. A group of four professionals were selected, each of whom was an expert in a different aspect of land use planning or geographical

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[71] Wang, 473.

information systems. Two of the group had helped develop the Highway 93 Corridor Plan, and thus were ideal candidates to evaluate the visualization of that plan. Notes were taken during the interview and the interviews were also recorded for later reference. However, a technical problem rendered two of the tapings unusable. The four professionals who participated in the study were:

- Janet Camel, Resource Planning Coordinator, CSKT Lands Department, Pablo, Montana
- Dr. Anna Klene, Professor of Remote Sensing, Department of Geography, University of Montana, Missoula, Montana
- Dr. John Horwich, Director of the Land Use Planning Clinic at the University of Montana School of Law, Missoula, Montana
- Dr. David Shively, Planning Professor, Department of Geography, University of Montana

Developing the Interview Procedure

Two practice interviews were conducted with other students and staff to develop a list of questions and a consistent interview procedure. Each practice participant was interviewed separately, and after each interview modifications were made to the presentation process and the interview questions. The final presentation format is listed below:

1. Give the participant an introductory document (see Appendix 1) that provides background information on the study area and details about the land use plans being visualized.
2. While the participant is reading the introductory document, the "sharable scene" for the Highway 93 Corridor Plan 3D visualization is copied to the participant's desktop computer and the 3D visualization is started up.
3. The introductory material is briefly reviewed with the participant and an overview of the study area is given.
4. A medium-height flythrough of the 3D visualization is done to orient the person to St. Ignatius and also show them the four zones in the Corridor Plan. The house and commercial structures in the MDR zone and in the CIF zone are turned on and off so that the interview subjects can see what structures have been added to the landscape.

5. A low-level drive-through is done along Highway 93 to show the participant the structures and land surface textures along the highway. Frequent stops are made and a pan view is shown so that participants can see the entire scene.
6. A low-altitude flythrough of Medium Density Residential district is done to show the houses in each zone, stopping to pan around occasionally.
7. A flythrough of the Rural Residential (RR) and Rural Agricultural Residential (RAR) districts is done to display the structures and textures in these districts.
8. The service station at the southern edge of the commercial industrial floating zone (CIF) district is displayed in the Sitebuilder 3D viewer, and the screening vegetation for that business is turned on and off to demonstrate the screening vegetation requirement in the Corridor Plan for the CIF zone.
9. Screenshots of the Density Map's Community Growth Area (CGA) are shown while also occasionally toggling back to the MDR area of the Corridor Plan. This allows the participant to compare the density of the MDR and CGA areas.
10. Show one of the ".avi" movie files so that participants can see an alternative method for presenting the 3D visualizations.
11. Turn on tape recorder. Ask the list of interview questions. Note the answers on an answer form.

The List of Interview Questions: The questions focused on three specific aspects of the 3D visualizations: (1) the requirement for screening vegetation in CIF zone of the Highway 93 Corridor Plan, (2) the perceived density in the MDR and CGA zones in the two visualizations, and (3) the degree of realism of the 3D visualizations.

The interview questions are listed below:

1. On a scale of 1 to 5, with 1 being the least realistic and 5 being the most realistic, how would you rate the degree of realism of the high-density residential areas in the 3D models?

2. Do you think the degree of realism in the high-density residential areas is sufficient for use in showing differences in the plans to a general audience?

3. Do you think that the area surrounding the study area needs to be modeled in order to present a more realistic scenario?

4. On a scale of 1 to 5, with 1 being the least realistic and 5 being the most realistic, how would you rate the degree of realism of the rural areas of the 3D models?

5. Do you think the degree of realism in the rural areas is sufficient to for use in showing differences in the plans to a general audience?

6. (a) When looking at the housing density in the residential areas of the two 3D scenarios (the MDR and CGA areas), is there a noticeable difference in housing density between the two scenarios? (b) Do you think that a 3D scenario is an effective way to visualize differences in residential density? (c) IF YES, how would you rate the effectiveness of the contrast on a scale of 1 to 5?

7. (a) Do you think that the 3D scenarios are adequate to model the difference between the screening vegetation requirement in the commercial section of the Highway 93 Corridor 3D scenario? (b) Does the 3D scenario present compelling evidence that a screening vegetation requirement should be used? (c) IF YES, on a scale of 1 to 5, how would you rate the effectiveness of the screening presentation?

8. In which of the land use zones in the Highway 93 Corridor 3D model did you think the 3D modeling appeared to be the most realistic? (a) Medium Density Residential area (b) Rural Residential district (c) Rural Agricultural Resource district (d) Commercial Industrial Floating zone.

9. (a) Three different means of showing the 3D presentations to audiences are listed below. Please rank the presentation methods in the order that you think they would be most effective: (i) a forum setting with a moderator navigating through the 3D scenarios and narrating for the audience, (ii) an Internet setting where users could access the 3D models at their convenience, but would have to navigate for themselves, or (iii) as a prerecorded flythrough on a web site or on a DVD that would show one or more flightpaths through the 3D scenes. (b) Explain the reasons for your choice.

10. It took approximately two hundred man-hours to create these 3D scenarios. Do you think that—in this case—the benefits of the 3D scenarios in the general planning process would justify the time and expense in creating them?

11. Choose the price range that you think would be tolerable to justify the expense to create these two 3D visualizations:

    a. <$1000
    b. $1,000 to $2,000
    c. $2,000 to $3,000
    d. >$3,000

Discussion of Interview Responses

The responses to the interview questions are shown below in tabular form:

Table 7. Responses from Interviews

	Dave Shively	Janet Camel	Anna Klene	John Horwich
Question 1	3	3	4	4
Question 2	Yes	Not sure	Yes	Yes
Question 3	No	Yes – the town and mid-distance	Yes - the town	No
Question 4	4	Not sure	5	3
Question 5	Yes	No	Yes	Yes
Question 6	a. yes b.yes c. 5	a. no b.no c. n/a	a. yes b. yes c. 4	a. yes b. yes c. 4
Question 7	a. yes b. yes c. 5	a. yes b. yes c. 5	a. yes b. yes c. 4	a. yes b. yes c. 4.5
Question 8	COM	RAR	RAR	MDR, COM
Question 9	1. movie 2. forum 3. self-guided	1. forum 2. movie 3. self-guided	1. movie 2. forum 3. self-guided	1. forum 2. movie 3. self-guided
Question 10	Not sure	Not sure	Yes	Yes
Question 11	> $3,000	> $,3000	$1,000-$2,000	>$3,000

Each question will be listed below, and will be followed by a brief discussion of the responses from the participants.

Question 1: On a scale of 1 to 5, with 1 being the least realistic and 5 being the most realistic, how would you rate the degree of realism of the high-density residential area in the 3D model?

Two participants gave a rating of 3 to the high-density residential area of the 3D scenario, while the two other participants rated it a 4. Several reasons were mentioned for not giving a higher rating, including the following:

- lack of the human element (for example, people, cars, and urban blight)
- the expectation of a "photo-realistic" 3D scenario was not met
- the 3D scene is generally too "green" and too "Disney"
- not enough realism at a ground level view

Two of the respondents noted that the degree of realism varied depending on which elements of the 3D scene were included in the view. One consistent theme noted was that the mountain backdrop added realism to the scene whenever it was visible to the audience.

Question 2: Do you think the degree of realism in the high-density residential areas is sufficient for use in showing differences in the plans to a general audience?

Three "yes" responses and one "not sure" response were received. One person mentioned that while most people would find the 3D scenes realistic enough, younger people might not because they are accustomed to a higher degree of realism when playing video games. One person mentioned that if more built objects such as cars and people were added in to the scene, it might distract the audience from the density issue. The one "not sure" respondent mentioned that a photorealistic backdrop would greatly add to the realism of the 3D scene.

Question 3: Do you think that the area surrounding the study area needs to be modeled in order to present a more realistic scenario?

The participants were evenly split on this question, with two wanting the surrounding area modeled and two thinking it unnecessary. From the "no" point of view, one person mentioned that adding more human elements to the study area (adding cars, for example) might detract from the realism, because the mountain backdrop gives the scene much of its realism and the additional objects in the foreground of the scene might

lower that sense of realism. The two "yes" respondents mentioned in particular that the town of St. Ignatius should be modeled so that the audience can see familiar landmarks when they are viewing the southern end of the study area and so that the audience will be able to see a transition from the St. Ignatius housing density to the study area density.

Question 4: On a scale of 1 to 5, with 1 being the least realistic and 5 being the most realistic, how would you rate the degree of realism of the rural areas of the 3D models?

Reponses to this question ranged from 3 to 5. One respondent was not able to give a rating because the presence or absence of the mountain backdrop in the scene greatly affected the perceived realism of the 3D model. One person mentioned they found the rural areas less realistic because of the poor quality of the house models used in the rural areas, and because there were not enough agricultural outbuildings in the area. Another mentioned that the high perceived realism of the rural scene might have simply been because there were fewer of the poor quality 3D house models present as compared to the higher-density residential areas.

A consistent theme noted was that the participants found that the degree of realism varied depending on the particular scene elements shown on the screen.

Question 5: Do you think the degree of realism in the rural areas is sufficient for use in showing differences in the plans to a general audience?

Three of the participants answered "yes" to this question. The "no" respondent indicated that the absence of 3D trees and structures in the area surrounding the study area resulted in a lack of landmarks that could orient the audience, and there was a corresponding decrease in the perceived realism of the scene. The same person also

noted that utility poles are a common feature along Highway 93, and that the 3D scenes omitted these utility poles. Interestingly, this person lives in the area and therefore is much more familiar with the study area and the surrounding landscape. This could indicate that a local audience would be more sensitive to missing elements in the 3D scenes.

Question 6: (a) When looking at the housing density in the residential areas of the two 3D scenarios (the MDR and CGA areas), is there a noticeable difference in housing density between the two scenarios? (b) Do you think that a 3D scenario is an effective way to visualize differences in residential density? (c) IF YES, how would you rate the effectiveness of the contrast on a scale of 1 to 5?

Three of the participants answered "yes" to part A and part B of this question, while one person answered "no" to both A and B. The "no" respondent thought that there was not a significant enough difference between the MDR and CGA area for a lay person to tell differentiate them and that a 3D presentation would only be useful when there was a drastic difference in the density, such as between a rural area and an urban area. One of the "yes" respondents mentioned that that the 3D scenario was "much more effective than dots on a map or footprints on a map."

On the C portion of the question, which asks the participants to rate the degree of realism of the scene, there were two scores of 4 and one 5.

Question 7: (a) Do you think that the 3D scenarios are adequate to model the difference between the screening vegetation requirement in the commercial section of the Highway 93 Corridor 3D scenario? (b) Does the 3D scenario present compelling

evidence that a screening vegetation requirement should be used? (c) IF YES, on a scale of 1 to 5, how would you rate the effectiveness of the screening presentation?

All of the participants answered "yes" to parts a and b of this question. Also, when participants were asked to access the effectiveness of the screening vegetation, all responded with ratings of 4 to 5. One participant mentioned "otherwise you would have static images, architectural images, and I think this is much more dynamic." Another person mentioned, "the ability to turn on and off the variables that you are building into the ordinances ... is an incredibly powerful tool."

Question 8: In which of the land use zones in the Highway 93 Corridor 3D model did you think the 3D modeling appeared to be the most realistic? (a) Medium Density Residential area (b) Rural Residential district (c) Rural Agricultural Resource district (d) Commercial Industrial Floating zone.

Two of the participants found the 3D modeling in the RAR (one housing unit per forty acres) to be the most realistic. One found the 3D modeling of the commercial section to be the most realistic. The remaining participant thought that the commercial and the medium density residential areas were both more realistic than the rural areas, but noted that this perception might have been because not as much time was spent in the rural areas and because the angle of view during the 3D demonstration was not high enough to show the rural area in its best light.

One participant mentioned that his preference in general was for density to be either low or high, and that this preference probably skewed his perception of which area he found to be the most realistic in the 3D visualization. Two participants mentioned that the forest blocks (as opposed to individual trees) were particularly unrealistic, and that

the forest blocks greatly detracted from the realism when they were included in close-up 3D views.

Question 9: (a) Three different means of showing the 3D presentations to audiences are listed below. Please rank the presentation methods in the order that you think they would be most effective: (i) a forum setting with a moderator navigating through the 3D scenarios and narrating for the audience, (ii) an Internet setting where users could access the 3D models at their convenience, but would have to navigate for themselves, or (iii) as a prerecorded flythrough on a web site or on a DVD that would show one or more flightpaths through the 3D scenes. (b) Explain the reasons for your choice.

The pre-recorded movie was the first choice for two of the participants, while the forum setting was the first choice for the other two participants. The self-guided option was a unanimous choice for last place. Reasons for preferring the forum setting included the following:

- The flexibility to focus on certain areas.
- The ability to respond to the audience's questions or requests.

Some of the reasons given by the participants for preferring the movie format are listed below:

- The pre-recorded movie format would allow multiple viewings of the scene by the audience to get comfortable with the scene.
- The movie format would avoid problems with group dynamics that are inherent with a large audience
- The movie format is the most effective for a lay audience.

The "self-guided" option was ranked last by all the participants. Some of the reasons mentioned for this last-place ranking were:

- The audience would be distracted by the novelty of flying around, and would be tend to play around with the flight options.
- The user interface is too complicated to learn easily.

Question 10: It took approximately two hundred man-hours to create these 3D scenarios. Do you think that—in this case—the benefits of the 3D scenarios in the general planning process would justify the time and expense in creating them?

Two of the participants responded with a "yes" on this question, while two of the participants were not sure. One of the "yes" respondents mentioned that these types of visualizations should be more commonplace in the planning field because they help a lay audience visualize various components of land use plans.

Of the "not sure" responses, one person indicated that a greater degree of realism would be needed to justify the time and expense of creating these visualizations; specifically, more landmarks were needed in the scene, and a better "before and after" visualization comparison should be made in which the existing landscape would be shown first and then proposed development would be added in gradually. The other "not sure" respondent mentioned that it would be more likely that the costs of developing 3D visualizations would be more likely paid by developers rather than local government.

Question 11: Choose the price range that you think would be tolerable to justify the expense to create these two 3D visualizations.

Three of the participants chose the "greater than $3,000" category, while one person chose the $1,000 to $2,000 range. One person who chose the "greater than

$3,000" range mentioned that this type of visualization is "priceless" because the general public often has a difficult time visualizing differences in density, such as showing cluster versus non-cluster development. For example, a cluster development that has 10 units per acre in certain areas to preserve open space could be compared to a non-cluster development that uses a density of 2.9 units per acre but that has no open space. The open space in the cluster development could be demonstrated to the audience by taking them on a virtual tour of the parks that would be available.

Recap of Notable Interview Points

The majority of the interview responses indicated that the 3D visualizations were valuable in presenting the two land use plans to the public. Most of those interviewed thought that the degree of realism was sufficient for the intended purposes, and that the visualizations were an effective way to portray differences in housing density to the public. Interview participants also thought that the 3D visualizations were especially effective in presenting individual ordinances such as the screening vegetation requirement in the Highway 93 Corridor Plan.

During the interview process, participants brought up several noteworthy points about the 3D visualizations. These observations are summarized below:

- The angle of view was important when navigating the 3D scene. Rural areas needed a higher viewing angle (i.e., a higher flythrough elevation) than did the residential areas.
- Participants found some portions of the 3D scenes more realistic than other portions of the 3D scenes.
- In general, the 3D building models (both residential and commercial) from the Communityviz library were not rated as being highly realistic.

- The mountain backdrop added greatly to the realism of the visualizations
- Landmarks might be more important to local residents than they would to non-locals.
- The St. Ignatius area perhaps should be modeled to some degree in order to show the transition to the residential area of the study area and to give the audience better landmarks for orientation purposes.
- Private developers are more likely to use 3D visualizations than are government agencies.

CHAPTER V

SUMMARY AND CONCLUSIONS

Introduction

The goal of this study was to facilitate the implementation of a land use plan by using 3D GIS visualizations. The methodology involved building two 3D visualizations for a study area based on two land use plans and then showing the 3D visualizations to a professional audience in order to gauge the effectiveness of the models. The two 3D visualizations were successfully created using the Communityviz extension for ArcGIS 9.1. However, several general issues regarding 3D GIS visualizations were noted during the 3D creation process that might be factors in why 3D GIS visualizations are under-utilized in the planning field.

The completed 3D visualizations were shown to four professionals from the planning and geography fields. While the two 3D models were generally judged to be an effective way to present the land use plans to the public, the interview participants had mixed responses to some aspects of the 3D visualizations.

Findings related to the 3D scene creation process

There were several issues noted during the 3D scene creation process that might have some bearing on why 3D GIS visualizations are under-utilized in the planning field. These issues are discussed in more detail below.

First, there was a lack of raster and vector data available for the study area. Specifically, up-to-date orthophotos of the study area were not available from public or private Internet data sources. As a workaround to this problem, a variety of digital and hard copy photographs were located and acquired. These photographs were used to identify and digitize existing development in the study area, and were also used as a draping layer in the 3D visualizations. Regarding vector data, there were no building location layers or building footprint layers available. This lack of easily available and up-to-date data is not uncommon for rural areas, especially in the less-populated American West, but it does point out one obstacle that might be a factor in the under-utilization of 3D GIS visualizations.

Secondly, the CommunityViz software had a fairly steep learning curve, and was prone to crashes and corruption of data. The learning curve was compounded by the lack of adequate documentation in the software tutorials about potential trouble areas in creating the 3D scenes. This lack of adequate documentation was to greatly lengthen the time it took to build the 3D visualizations, because both scenes had to be completely rebuilt to eliminate an easily identifiable error.

Third, the 3D creation process was time-consuming and labor intensive. This was mainly due to the following: the relatively large study area, the need to digitize many different data layers, the use of two software interfaces—one to edit the data and one to

visualize the data, the iterative process required to place and move objects in the 3D view, and the inconsistent sizing of objects in the Communityviz library.

Taken together, the points mentioned above could constitute a significant obstacle to the use of 3D visualizations in the planning field, mainly due to the time and costs of creating the 3D visualizations.

Findings Related to the Interview Process

One finding was that the perceived realism of the 3D scenes varied depending on which elements of the scene were present in the 3D viewing window. Similar findings have been noted in earlier studies, including Appleton[72] and Lange.[73] Participants generally felt that the "draped" mountain backdrop was the most realistic element present in the 3D visualizations, and the presence or absence of the mountains in the background determined the overall degree of realism of the scene. Participants also felt that the mountain backdrop was important as a landmark to orient the audience within the scene. The one interview participant who was a local resident of the study area was much more sensitive to the absence or presence of prominent landmarks local features. The interviewees generally were not impressed with the Communityviz models that were used to represent houses and commercial structures. Some participants mentioned that they would have preferred photo-realistic models for the existing structures in the study area. Even though the 3D visualizations as a whole did not receive the highest realism ratings from the participants, the level of realism was judged sufficient for the intended purposes.

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[72] Appleton, "Gis-Based Visualisation of Development Proposals: Reactions from Planning and Related Professionals," 330.
[73] Lange, 180.

Interviewees judged the screening vegetation component of the visualizations to be the most realistic. This portion of the 3D presentation showed just one commercial structure and involved turning on and off the screening vegetation layer that surrounded the business in order to demonstrate the effects of a screening vegetation ordinance. This result indicates that 3D visualizations can perhaps achieve the highest levels of realism when they focus upon specific themes within a land use plan and when they tightly control the elements that the audience can see in the foreground and background.

The majority of the interviewees thought that the 3D visualizations were effective in showing differences in density between two land use plans. Participants indicated that density is an especially difficult concept to express to a lay audience with static displays such as photographs, and that the two 3D visualizations were effective in expressing density differences between the high-density areas of the two visualizations. However, one of the participants doubted that a lay audience would be able to discern density differences except when comparing vastly different densities, such as comparing a rural area with a high-density residential area.

The interviewees preferred either the pre-recorded movie format or the moderator-guided format as the means to present the 3D visualizations to an audience. The self-guided tour of the 3D visualization was rated as the least preferred option by all of the interview participants.

When participants were told that the 3D visualizations took approximately 200 hours to produce, two of the four persons responded with a "yes" when asked if the benefits would justify the time and expense involved in creating them. The other two persons were not sure. Of the people who were not sure, one person indicated that a

greater degree of realism would be necessary to justify the time and expense, while the other person indicated that the answer to this question would depend upon the amount of money available for the planning process.

Conclusion

Two 3D visualizations were successfully created for the St. Ignatius study area using 3D GIS software, and these visualizations were generally judged by a group of planning and geography professionals to be effective in facilitating the planning process. However, the varying degrees of perceived realism in the 3D scenes combined with the time and expense involved in creating the 3D visualizations made some interview participants question whether or not local governments would choose to use 3D visualizations in the general planning process.

Suggestions for Future Study

The 3D visualizations produced in this study used ArcGIS 9.1 as the GIS system and the Communityviz extension as the 3D visualization software. There are several other 3D GIS visualization software packages available, and it would be useful to create a similar study in these other 3D GIS programs in order to gauge whether or not the findings in this study are representative for the 3D visualization process in general. In particular, it would be useful to know if a greater degree of realism can be obtained with other programs with less of a time investment.

Ethical issues involved in 3D scene creation were not addressed in this study, but is another area in which research would be helpful. Three-dimensional visualizations are

a powerful tool in conveying images of a future landscape. Because of the potential for misuse, it would be useful to identify a list of ethical rules governing the creation of 3D scenes.

In this study, experts in the GIS and planning field were interviewed regarding the effectiveness of the 3D visualizations. However, there are many other audiences that could be interviewed, including members of the general public, local residents, and specific cultural groups. These population groups might have completely different impressions of the 3D visualizations compared to the interview group in this study.

Automated feature extraction and generation is another area in which additional research would be helpful with regards to 3D visualizations. The need to manually digitize and to manually populate attribute fields is time consuming. In this study, the Feature Analyst 3.5 automated feature extraction software was used to quickly produce a land use classification. This land use classification was then assigned textures (based on attribute values) to create a ground cover layer that was much more detailed in close-up views than was the draped digital photo. Automating other portions of the 3D visualization could substantially lower the amount of time and energy required to produce 3D visualizations.

Lastly, it would be interesting to conduct interviews with two groups of experts, one familiar with the area and one not, in order to determine whether or not landmarks are more valuable for a local audience than for a non-local audience.

APPENDIX 1

QUESTIONNAIRE

Application of 3D Visualization Software to the U.S. Highway 93 Expansion Corridor

Purpose: Most GIS software platforms offer the capability of modeling landscapes in 3D, and this visualization capability is of potential benefit in the planning process. However, 3D models are generally underutilized in the planning process. In addition, there is a gap in the literature regarding the effect that 3D models might have in planning decisions. This research seeks to address these issues by building two 3D land use models for one study area, with each model showing the outcome of a particular land use plan. The two completed 3D models will be shown to professionals in the planning and GIS field, and a series of questions will be asked to identify the strengths, weaknesses, and ideal planning applications of the 3D models. These responses will then be incorporated into the findings of the research.

Location of the Study Area: The study area is a portion of the U.S. Highway 93 corridor immediately north of St. Ignatius Montana (see Figure 1 below), with Airport Road

marking the southern boundary and Pinsoneault/Lemery road marking the northern boundary. The study area extends one-half mile to the east and west of U.S. Highway 93.

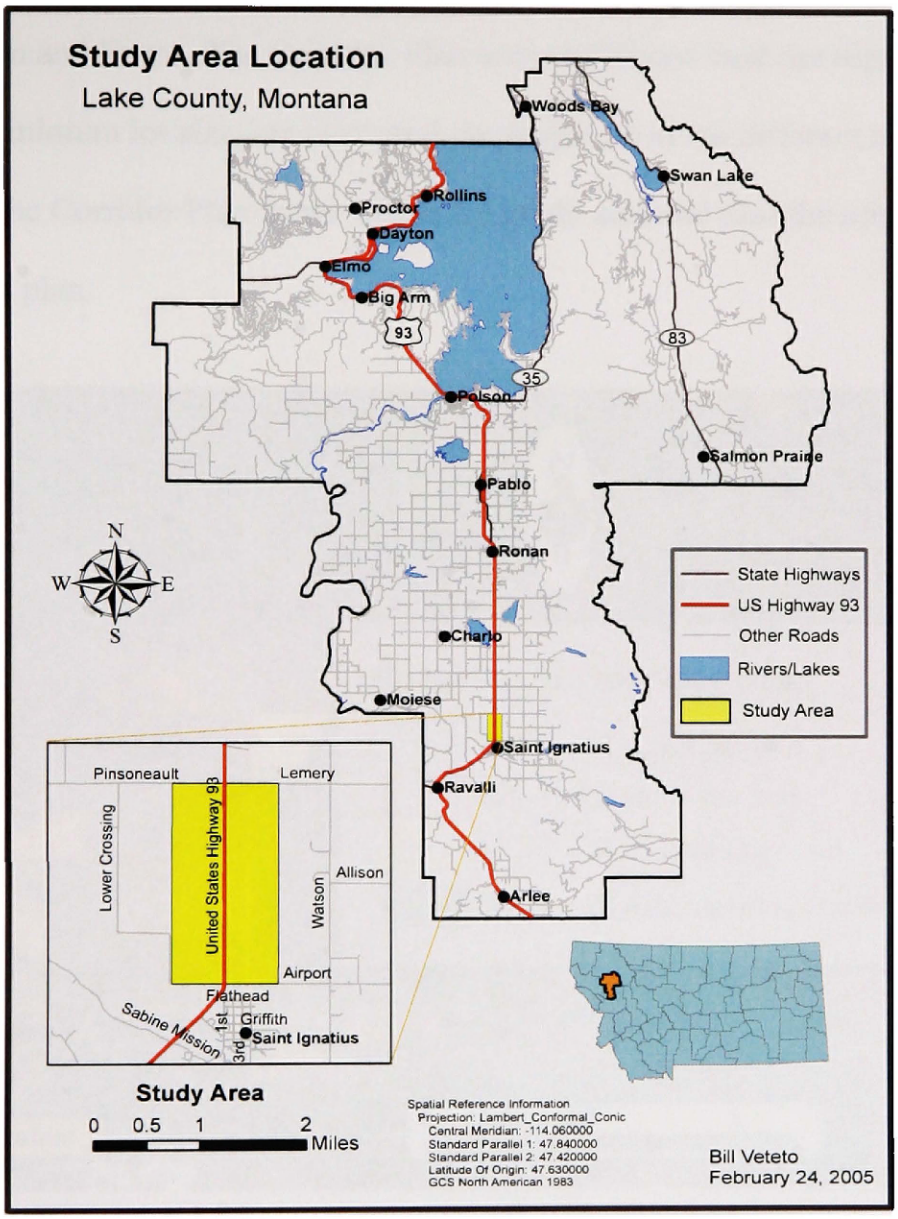

Figure 2. Location Map for Study Area

The Two Land Use Plans: The first land use plan is one that has been developed by the University of Montana's Law Land Use Clinic. For the purposes of this study, this plan is called the Highway 93 Corridor Plan. The second land use plan is the Lake County Density Map, which was approved by the Lake County Commissioners in late 2005.

The Highway 93 Corridor Plan: The goal of the Highway 93 Corridor Plan is to mitigate possible growth resulting from the current expansion of Highway 93 North between Polson and Evaro. The Corridor Plan uses traditional land use regulations such as setbacks, minimum lot size, etc to control development in the different zones. Figure 2 below shows the Corridor Plan zones within the study area and also the minimum lot sizes from that plan.

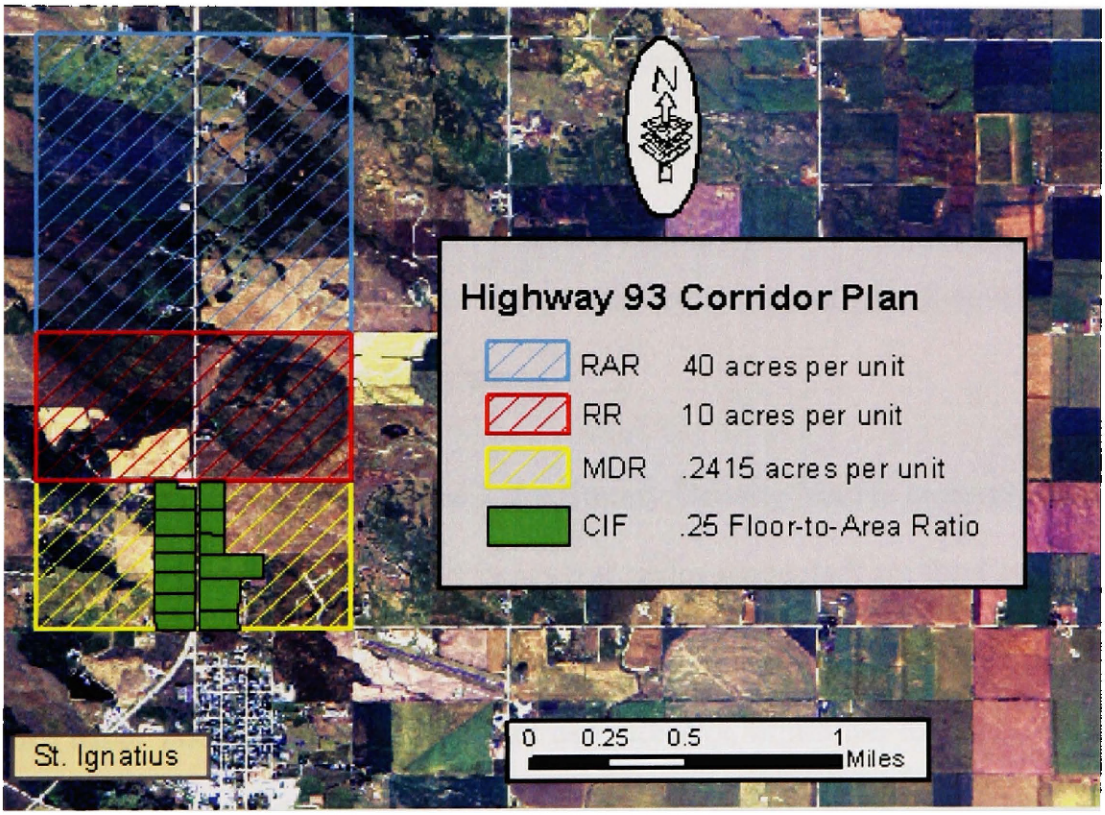

Figure 2 – Study Area zoning from the Highway 93 Corridor Plan

The northern zone, the Rural Agricultural Resource District (RAR), has an allowed density of 40 acres per unit. The low density is meant to preserve the zone primarily as agricultural land.

The central zone in the study area, the Rural Residential District (RR), has an allowed density of 1 unit of housing per 10 acres. This density is meant to allow moderate residential development while also preserving the rural character of the area.

The southernmost zone, the Medium Density Residential Area (MDR), has a minimum lot size of .2415 acres per housing unit. The higher permitted density is meant to guide the most intensive residential development into the area immediately adjacent to St. Ignatius.

The fourth zone, the Commercial Industrial Floating District (CIF), is meant to provide for attractive commercial and industrial development within the Medium Density Residential Area. It is important to note that the Highway 93 Corridor Plan limits commercial and industrial development to the CIF District, and that a CIF district can only be located within a MDR district. Thus, commercial and industrial development is generally not allowed in RR and RAR zones.

Lake County Density Map: The Lake County Density Map is currently in place in Lake County. The Density Map differs in several major respects from the Corridor Plan. First, the Density Map applies to all of Lake County. Secondly, density is the only land use control used. The Density Map does not use setbacks, minimum lot sizes, or other traditional land use controls. Within the study area, the Lake County Density Map divides the study area into three large zones (see Figure 3 below). The boundaries of these three zones are identical to the boundaries of the three largest zones in the Highway 93 Corridor Plan (the RAR, RR, and MDR Districts). This is because the boundaries of the Highway 93 Corridor Plan were based upon those of the Density Map.

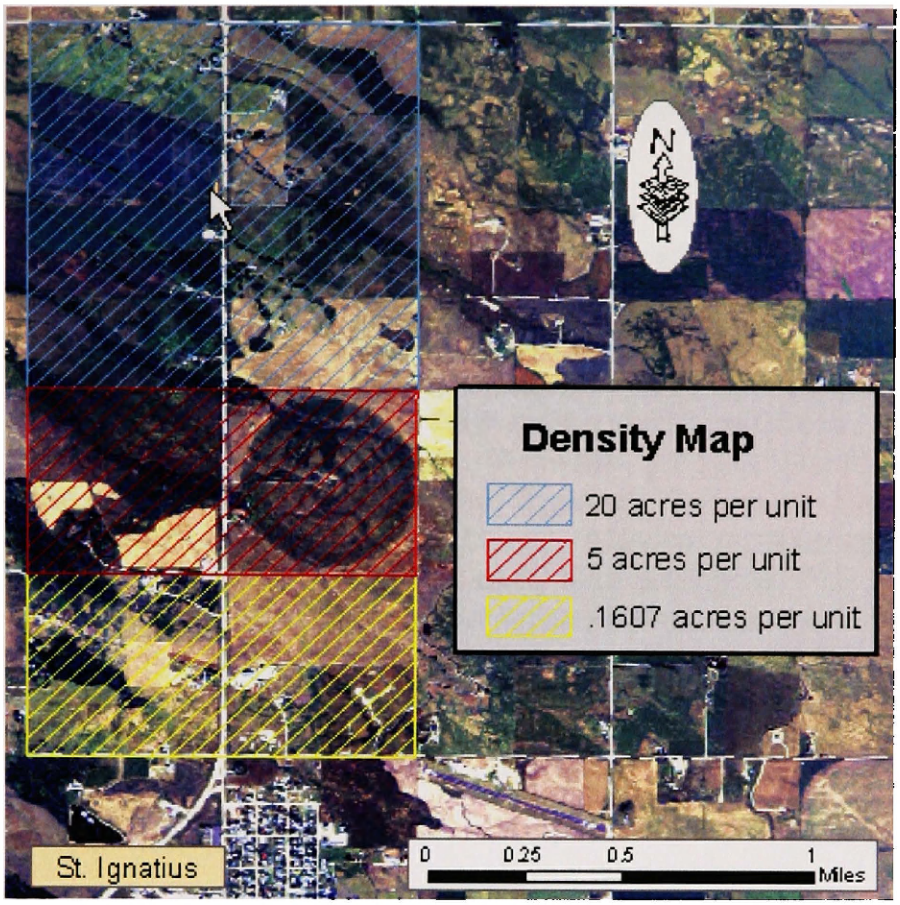

Figure 3. Study Area Zoning from the Lake County

The Density Map is intended to guide more intensive future development towards existing cities and towns and less intensive future development towards areas far from population centers. In doing so, the Density Map is meant to achieve two purposes: (1) to direct growth to where infrastructure can be provided in the most cost effective manner, and (2) to preserve the rural character and natural resources of Lake County.

In the northernmost zone of the study area (marked in blue in Figure 3), the allowable density is 20 acres per unit. In the central zone of the study area, the allowable density is 5 acres per unit. In the southernmost zone of the study area, the Community Growth Area (CGA), the Density Map allows 12 units per acre unless the area is annexed into a municipality. However, a density of one housing unit per .1607 acres (7000 square feet per housing unit) was chosen after consultation with Lake County planning staff.

This allows the CGA area to be modeled with single-family residential housing and a comparison made with the MDR area from the Highway 93 Corridor Plan.

Focus Areas for the 3D models for the Land Use Plans:

- Requirement for screening vegetation in commercial areas: The Highway 93 Corridor Plan requires that screening vegetation be used around commercial businesses in the CIF area. The Density Map has no such regulations.
- Density in residential areas: In both of the 3D models, the zone closest to St. Ignatius has the highest allowed density. The Highway 93 Corridor Plan has a minimum lot size of .2415 acre, while the Density Map has a maximum density of .1607 acre per unit. One major goal of this study is to determine if 3D modeling is an appropriate way to present differences in density between plans.
- Degree of Realism: Another aim of this research is to determine if the models display a sufficient degree of realism – both in the rural and residential areas – to show the differences between two land-use plans.

Survey Questions:

1) On a scale of 1 to 5, with 1 being the least realistic and 5 being the most realistic, how would you rate the degree of realism of the high-density residential areas in the 3D models?

2) Do you think the degree of realism in the high-density residential areas is sufficient for use in showing differences in the plans to a general audience?

3) Do you think that the area surrounding the study area needs to be modeled in order to present a more realistic scenario?

4) On a scale of 1 to 5, with 1 being the least realistic and 5 being the most realistic, how would you rate the degree of realism of the rural areas of the 3D models?

5) Do you think the degree of realism in the rural areas is sufficient to for use in showing differences in the plans to a general audience?

6) (a) When looking at the housing density in the residential areas of the two 3D scenarios (the MDR and CGA areas), is there a noticeable difference in housing density between the two scenarios? (b) Do you think that a 3D scenario is an effective way to visualize differences in residential density? (c) IF YES, how would you rate the effectiveness of the contrast on a scale of 1 to 5?

7) (a) Do you think that the 3D scenarios are adequate to model the difference between the screening vegetation requirement in the commercial section of the Highway 93 Corridor 3D scenario? (b) Does the 3D scenario present compelling evidence that a screening vegetation requirement should be used? (c) IF YES, on a scale of 1 to 5, how would you rate the effectiveness of the screening presentation?

8) In which of the land use zones in the Highway 93 Corridor 3D model did you think the 3D modeling appeared to be the most realistic? (a) medium density residential area (b) rural residential district (c) rural agricultural resource district (d) commercial zone.

9) (a) Three different means of showing the 3D presentations to audiences are listed below. Please rank the presentation methods in the order that you think they would be most effective: (i) a forum setting with a moderator navigating through the 3D scenarios and narrating for the audience, (ii) an Internet setting where users could access the 3D models at their convenience, but would have to navigate for themselves, or (iii) as a prerecorded flythrough on a web site or on a DVD that would show one or more flightpaths through the 3D scenes. (b) Explain the reasons for your choice.

10) It took approximately two hundred man-hours to create these 3D scenarios. Do you think that – in this case – the benefits of the 3D scenarios in the general planning process would justify the time and expense in creating them?

11) Choose the price range that you think would be tolerable to justify the expense to create these two 3D visualizations:

e. <$1000
f. $1,000 to $2,000
g. $2,000 to $3,000
h. >$3,000

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