The Mapping of Saint Mary's University of Minnesota Campus Using a Geographic Information System (GIS)

Susan M. Meier
Department of Resource Analysis, Saint Mary's University of Minnesota, Winona, MN 55987

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Abstract

A GIS map of the Winona Campus of Saint Mary's University of Minnesota (SMU) campus did not exist before this effort. The purpose of this project was to create a model that would depict the many features of the campus. This project began in 2000 and a campus GIS was created using ArcView 3.2 software. This GIS included: buildings, forest, trees, streams, athletic fields, bike trails, gas lines, fire hydrants, highways, roads, sidewalks, parking lots, and handicap parking. A GIS application could be displayed interactively at the information kiosk found at the entrance of SMU campus. If done, this would allow visitors to view the campus and to travel and find campus locations easily. A GIS could also be used by the SMU Maintenance Department for building projects and campus expansion.

After this GIS was created, a network analysis was performed to find the best route from the campus to restaurants and motels in Winona. Finally, an analysis involved the creation of a model to represent the land on campus that is either occupied or unusable, such as the bluffs, versus land that is available for future development.

Introduction

Saint Mary's University of Minnesota was founded in 1912, since that time many new features have been added to the campus. In the process of searching for a map of the SMU Winona campus, it was found that there were indeed several maps; however, most were outdated, due to the expansion over the past years. Also, in the past when a new map was developed to depict a new feature on campus, such as fire hydrants, it did not incorporate features that were on previous maps. This resulted in several stand-alone maps, rather than one map that integrated all the features on campus. With a Geographic Information System (GIS), it is easier to develop new maps and to integrate new features into an existing map. A GIS of Saint Mary's University campus had never been created prior to this project. This project began by creating a GIS which incorporated many features that existed previously on separate maps, such as buildings, forest, trees, streams, athletic fields, bike trails, gas lines, fire hydrants, highways, roads, sidewalks, parking lots, and handicap parking.

If desired, a GIS could be displayed interactively at the information booth found at the entrance of SMU campus. The GIS would allow visitors to view the campus, as well as travel through and find locations quickly and easily. In addition, a GIS could also be used as a base layer by the SMU Maintenance Department for building projects and campus expansion.

After the GIS was created, a network analysis was performed to find the best route from the campus to restaurants and motels in

Winona. Another analysis involved the creation of a model to represent the land that is occupied versus land that is available for future development. The occupied land areas are based on siting analysis criteria including space, handicap accessibility, and fire codes. The university reviews these criteria when planning and building new additions on campus.

Methods

To begin the project, a rectified aerial photograph of the Winona campus was obtained. The photograph was taken in 1992. The projection and datum were in Universal Transverse Mercator (UTM) and North American Datum 83, respectively.

The majority of this project was completed in the year 2000 using ArcView version 3.2. ArcView is a Geographic Information System (GIS) that operates on a desktop computer. In ArcView, data can be displayed graphically as maps, charts, tables, and layouts. These data can then be changed and manipulated to represent certain information, spatially or statistically. Data can be added, edited, or enhanced for specific criteria that can be utilized in a GIS.

After the photograph was obtained, it was added as a new "theme" to a view within ArcView. Having this photograph as a base layer theme made it possible to digitize.

The digitizer extension used in this project was a software product that was loaded into ArcView for added digitizing capabilities. This digitizing technique was chosen because it was easier and less time consuming. Digitizing in this manner was done by turning on the digitizer extension and using the polygon tool. Under View, "add theme" was selected. This added a new layer as a polygon, point, or line, depending on what was desired. For example, polygons were chosen for buildings and points for trees. On the Theme menu, "start editing" was chosen before clicking on the "draw polygon" or the "draw point" tool, to allow the addition of polygons/points to be overlaid as themes into the view. The many themes and layers created in this project were as follows: roads, sidewalks, parking lots, buildings, athletic fields, trees, forest, stream, bike trail, handicap parking spaces, cameras, and gas lines.

Results/ Discussion

Buildings Layer

Buildings were digitized as polygons. Buildings and parking lots were relatively easy to digitize because they were the largest and most easily recognized feature on the photograph image. The building layer consisted of a polygon for each building. A corresponding table was created that contained the name and type of building. Each building had a corresponding record in the attribute table that was automatically made when each polygon was created. One field in the table identified the type of building. An example may be "administrative / residence hall." This meant that part of the building was used for administrative duties, while another part of the same building was used as a residence hall. The second field associated with each building was the name of the building (i.e. Hendrickson Center).

Parking Lot Layer

After the parking lots were added to the view, a theme table was added to further describe each lot. The theme table was created automatically after the polygon was digitized into the view. Two records were added to the table. These two records specified the color of the lot and who was allowed to use each lot. Parking lots on the Winona campus are specified by their color. Students pay for a permit and are assigned to park in a specific lot. This allowed for quick information access for visitors, students, and/or staff when driving onto the SMU campus.

Athletic Fields layer

Athletic fields were easy to digitize into a shapefile as well, but some were estimated for size. The softball and baseball fields were relatively accurate, due to their distinguishable appearance on the photograph layer. Other athletic fields were known to be in relative areas mapped here; however, their exact locations are not shown. This was due to the less noticeable difference in the field surface on the photograph image.

Roads and Stream Layer

The roads and stream layers were not digitized as lines, but rather as polygons. This allowed for more accuracy on the actual width.

Sidewalks Layer

Sidewalks were added in a different manner than the road and stream layers, because they had to be divided into two separate layers within the same theme. Sidewalks needed to have two polygons surrounding each area to designate the difference between the outline of the sidewalk and the outline of the grass. For most areas, if only one polygon was added around a sidewalk that contained an area of grass within it, then only a large polygon of sidewalk would have shown up on the map. This complication was resolved by classifying the two areas as unique values and then assigned a “1” or a “2” in the legend editor. This code then corresponded with a certain color that separated the two areas easily by sight on a map.

After digitizing both areas of the sidewalk layer, each polygon was assigned to a “1” or a “2”, in the table which coincided with the view. Next, a classification by number was assigned as follows: sidewalk = 1 and grass = 2.

Bike Trial Layer

On the SMU campus, a new bike trail was constructed by the city of Winona in 2000. It was a continuation of an existing trail, which surrounded Lake Winona. The main objective of the new bike trail was to keep pedestrians traffic from using Highway 14. Many pedestrians and bikers previously traveled along this highway since it was the only route to gain access to the city from the moderately populated outskirts of Winona, such as Knopp Valley and Gilmore Valley. People traveled south on HWY 14 from Knopp Valley and from various locations on Gilmore Valley Road, including homes in the Gilmore Valley. Both of these areas are located near SMU, hence the need to travel along the highway on the edge of SMU campus. Residents in Knopp Valley benefited from an underground tunnel that connected to the bike trail and went under Highway 14. This eliminated a potentially dangerous situation when crossing the busy highway. The City of Winona and SMU agreed on an easement along HWY 14, so college students and residents could safely travel to their destinations.

Another interesting fact about the bike trail shared by Mr. Roger Connaughty (Former Head of Maintenance Dept., 2000, SMU Winona, MN) is that the city had to build a bridge that would cross Gilmore Creek as well as the Gilmore Creek Dike. The U.S. Army Corp of Engineers constructed a dike to protect residents from possible flooding in the future. The bridge also had to be able to withstand a 500-year flood, considering the fact that two 100-year floods had occurred within three years in the last decade.

Because the bike trail was a new addition to the campus, it was not found on the original photo used for the control layer, therefore, it could not be digitized it into the view. In order to add it into the view, a Global Positioning System (GPS) was used.

The entire new section of the bike path was recorded using a GPS Trimble Unit. In order to record this linear traverse, the path had to be walked with the GPS receiver in hand, making sure not to lose the signal. The GPS receiver recorded and stored a number of points along the traverse. Next, Pathfinder Office was used to transfer these points into the computer. These points were then opened to view the raw data. By zooming in close, it was easy to see points that were outliers to the others. These were deleted. These remaining points were then grouped together into one line and exported into a file. ArcView recognized the x and y coordinates from the file and allowed this data to be entered as a new theme. The bike trail was a line feature that became a new layer in the view, as a line. The symbol chosen was a square with a biker in the middle.

Because the new bike trail theme was entered into the view as a line shapefile, it showed up as a line on the map, but was not easily identifiable as a "bike" trail. One could look at the SMU campus map and realize by looking at the theme name, or see that the "purple" line represented the new bike trail, however it was not as easy to see just by quickly looking at the map alone. To enhance the map's appearance, and to allow easy recognition of the bike trail, symbols were added. These symbols of squares with little bikers in the middle were added. The symbols were also the same color as the line already used to represent the bike trail on the map.

The following map shows the SMU campus with all of its basic features: HWY, Bike Path, Buildings, Roads, Sidewalks, Parking Lots, Forest, Streams, and Athletic Fields (Figure 1).

Tree Layer

The tree layer was joined to the map in the same manner as the polygons layer, except it was specified as a point layer. Each tree was added by simply clicking above a tree on the photo layer. A small point or dot appeared wherever there was tree. These points were enhanced with tree symbols for easy recognition and added a realistic or life-like view to the map. The symbols were loaded from the palette manager found in the legend editor. The following map shows the SMU campus with all of its basic features along with the location of the trees (Figure 2).

Camera Layer

Point symbols of "little cameras" were used as another layer. This layer was used to represent the photography in the project. Various photos were taken around campus using a digital camera, or they were downloaded from the SMU campus Internet site. Br. Roderick Robertson, (Chair Communications, 1999, SMU Winona, MN) took the photos found on the Internet. Susan M. Meier took all other digital photographs, specifically for this project. The following sites were photographed for this project: Jul Gernes Swimming Pool, Hendrickson Center, St. Mary's Hall, College Center Plaza, Oakes Plaza, Gilmore Creek, Gilmore Waterfall, Resource Analysis Lab, Resource

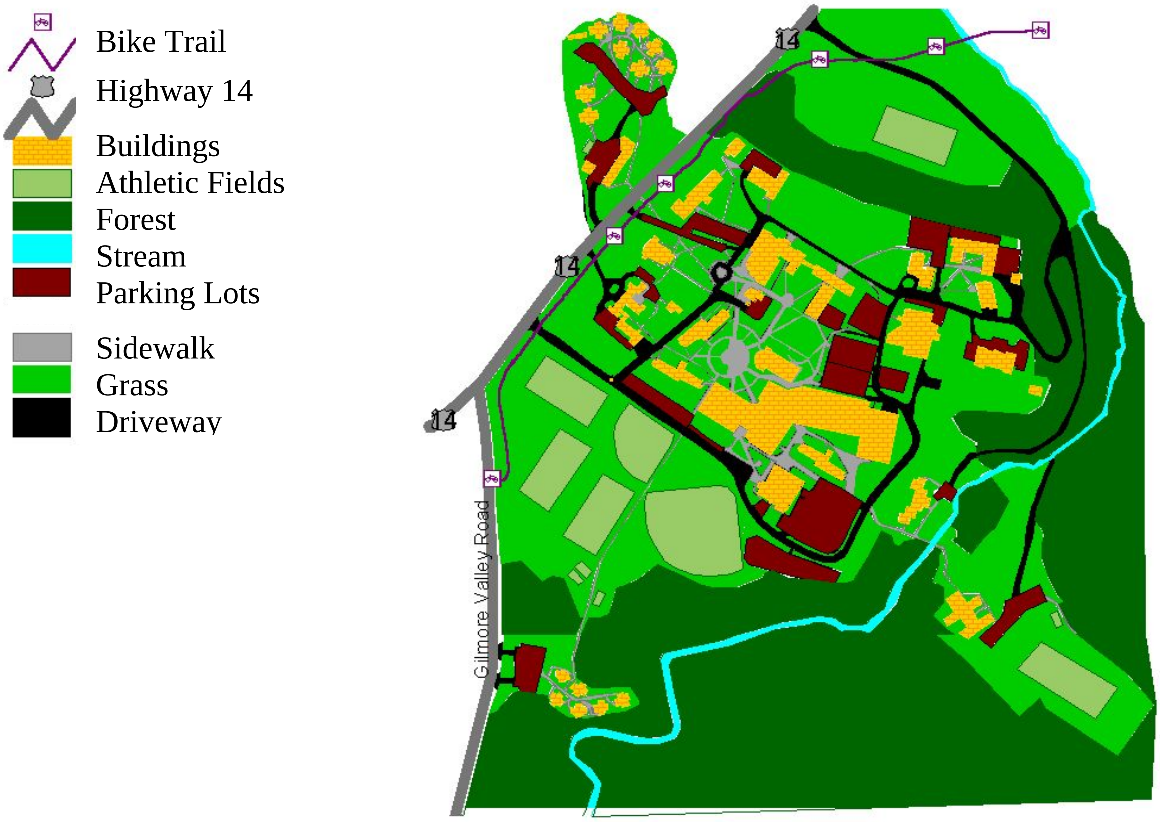

Figure 1. This map shows the SMU campus with all of its basic features: HWY, Bike Path, Buildings, Roads, Sidewalks, Grass, Parking Lots, Forest, Streams, and Athletic Fields.

Figure 2.   This map shows the SMU campus with all of its basic features along with the location of the trees.

Analysis Lounge, McEnery Center (Library), and Campus entrance information booth, Performance Center, Adducci Science Center, Clock Tower, athletic fields, ice rink, and the Hillside Conference Center. These photographs were chosen to best represent the SMU campus.

These photographs allow someone to identify their location on campus and provide a sense of direction. Most of these pictures consist of the artwork in various places on campus or other easily identifiable landmarks, such as the Oakes plaza and the College Center Plaza. Some photographs were merely taken for aesthetic reasons (i.e. Gilmore Creek or waterfall) and some photographs were simply basic places found on any campus (i.e. swimming pool or hockey rink). Two photos were taken of the Resource Analysis (RA) Lab and RA lounge. These photos were taken was to show where they are located on campus and where a project like this was completed.

These photographs provided an "all-around" view of the SMU campus.

The symbols that were used for these small cameras were found on the Internet and were saved as images. These images were then loaded into the palette manager.

The photographs were entered into the GIS using "Hot links." Hot links is a tool that links a graphical feature with an outside feature, such as a photo. Using Hot Links one can connect a feature on a map with an image, text file, chart, or a video clip. In this project, the features were the points marked with cameras. These cameras were linked to digital photographs that were taken around campus. When a GIS user 'clicks' on a camera, the digital image of that specific area on campus appears. The following map shows the SMU campus with its basic features along with small cameras that represent where photographs were taken (Figure 3).

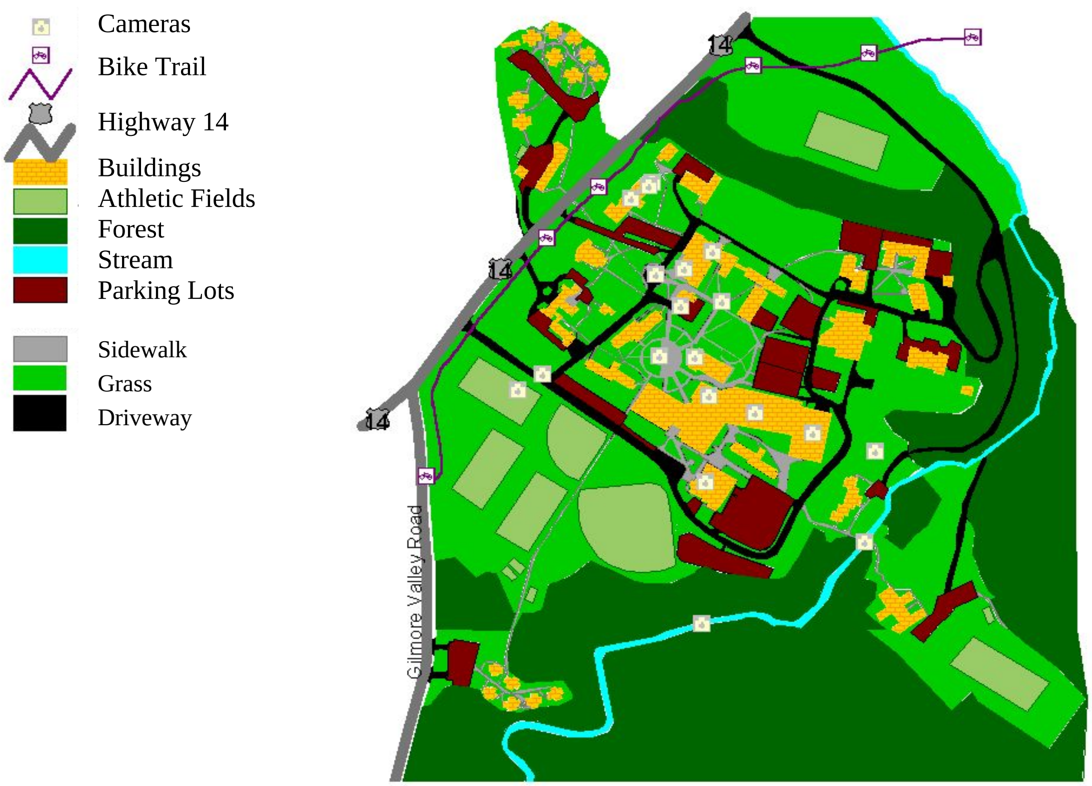

Figure 3. This map shows the SMU campus with its basic features along with small cameras to represent where photographs were taken of that area.

Handicap Layer

Like any campus or public facility, Saint Mary's University buildings are handicap accessible and nearby parking spaces are designated. For easy access to buildings, nearby parking lots have specific parking spaces for the disabled. Handicap spaces were located throughout the campus. However, a disabled visitor would likely want to know which parking space is the closest to his/her destination.

At first a global positioning system was used to geographically locate handicap spaces, so they could be easily placed on the map. It was found in the field, that it was difficult to get readings from the GPS receiver. This was mainly due to the fact that most handicap spaces are located near buildings, which decreases the ability of the satellite's signals to reach the receiver. Another reason is that trees are planted in the grass surrounding parking lots and most handicap spots are found along the edge of most parking lots. Whether the blockage to the GPS receiver was due to the buildings or the tree cover, it posed a hindrance in the use of this method. To resolve this problem, a GPS receiver was not used. Instead, location by mere sight were recorded in the field and later placed in the GIS.

Handicap Parking spaces were affixed to the general location in the parking lots by adding a point theme. The traditional handicap symbol was used for easy identification of handicap parking spaces on the map. Blue was the chosen for the symbol, to represent the color commonly associated with handicap parking signs and permits. The following map of SMU campus displays all of its basic features as well as Handicap Accessibility (Figure 4).

Fire Hydrant Layer

In case of an emergency, the location of all fire hydrants is a necessity. Fire hydrants are found in a variety of places on the

Figure 4. This map shows SMU campus with its basic features also showing handicap accessibility.

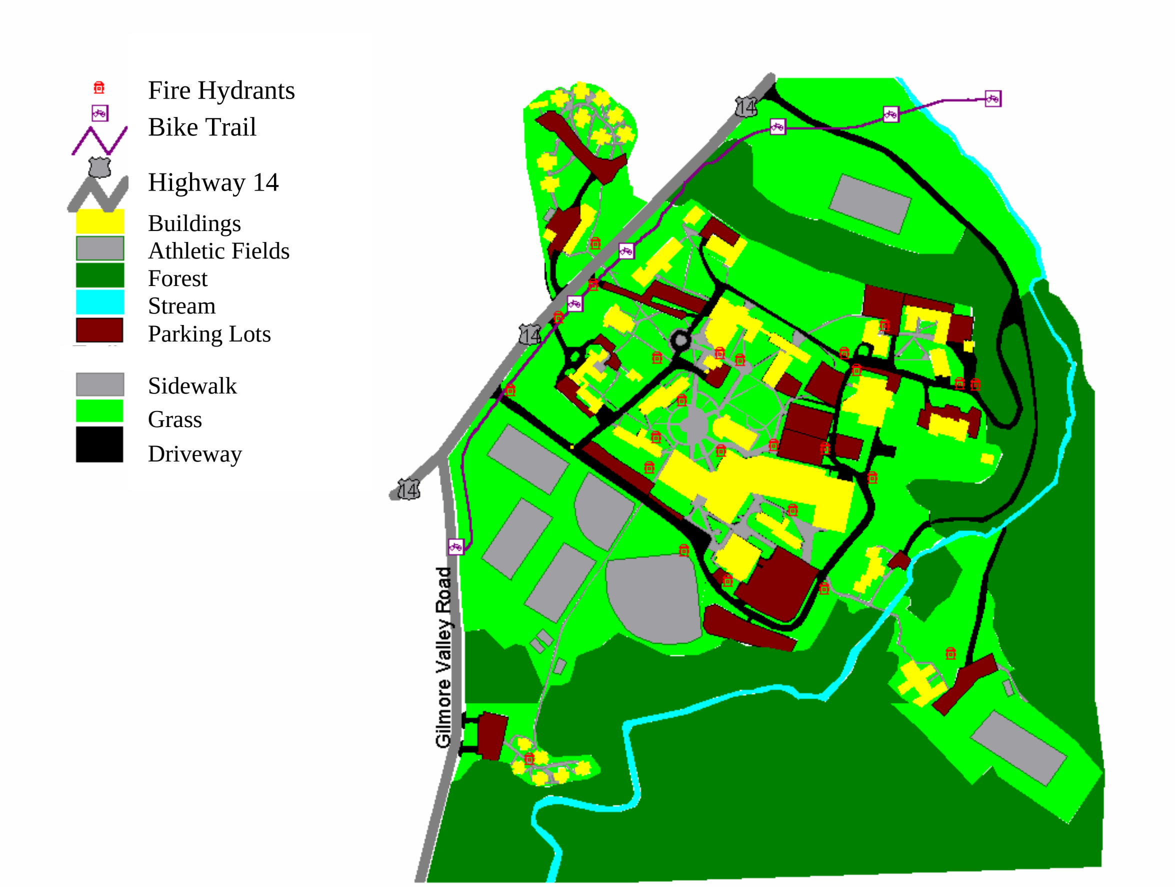

Figure 5. This map shows the SMU campus with all of its basic features along with fire hydrants, showing their accessibility.

Winona campus, ensuring immediate accessibility. With the help of the Maintenance Department, a map was found which displayed the location of all fire hydrants on campus. Using that map, fire hydrants were added as a new theme or layer to the view. To annotate the location of the fire hydrants, tiny red fire hydrants were used as the symbols. Red was the color chosen to depict "emergency" and to reflect the standard color of a fire hydrant.
The following map of SMU campus displays all of its basic features along with the location of all the fire hydrants (Figure 5).

Utility Layer

A copy of the map that displayed the utility lines on SMU campus was obtained from Tim Stensgard, (Master Electrician, 2000, SMU Winona, MN). Along with the main utilities map, there were eight other enlarged sections of the map. To get these maps into this project, they had to be in a digital format. The maps were too large to scan, so they were taken to a local printing company. At this printing company, they were scaled down and copies were made to fit 8.5 x 11. Another reason the maps had to be taken there was because on the map the various utility lines were represented by different colors, and SMU did not have a color copier. copier. Once these maps were in color and the correct size, they were scanned and represented digitally. This saved time, since the map did not have to be digitized using heads-up digitizing. These scanned images were saved as tiff image files. ArcView was used again to portray these images in a new view. Also, the enlarged images were hot linked to the main utility map. Symbols of stars were used on the utilities map. When clicking on the star, the zoomed-in image was displayed.

Later, these maps were found to be of little importance, because it was hard to relate the utility view with the SMU map view. Therefore, Tim Stensgard provided a further description of the utility lines. Gas lines were registered and added as a new theme in the view. The ArcView extension, Image Analyst, allowed the images to be registered. This registration process allowed a scanned image to be georeferenced similar to the SMU map view. A common theme in the scanned image and the SMU map view were chosen. The building theme was chosen and copied from the SMU map view and placed in a new view called the utility view, which contained the scanned image. The building theme was converted from an image to a shapefile. When the building theme was active and the align tool was on, control points were placed on the view to connect the two views. The newly registered view had some distortion along the outside but was accurate in the center. The gas lines were digitized as line features into the map. The gas lines were made into a theme and copied into the SMU map view.

Although the date on the map was 1999, it was apparent that it was a couple of decades old. There were buildings half drawn on the map and others that were missing. Despite the fact that this map was old, the utility lines remain in the same spots and the data was deemed useful.

After digitizing the gas lines, it was easy to see their location in relation to other features on campus, and where they entered buildings. Having the pre-existing gas lines on the map can be helpful as SMU considers the best position for a new addition on campus (Figure 6).

Figure 6. This map shows SMU campus with its basic features along with the gas lines.

New Additions

When new additions are proposed on any site, many issues must be taken into consideration before the final decision to build can be reached. Saint Mary's University of Minnesota (SMU) must address numerous factors when deciding to add new features on campus. To get a better idea of exactly what features are considered, Mr. Roger Connaughty (Former Head of Maintenance Dept., 2000, SMU Winona, MN) was consulted. An informal interview was conducted to get a better understanding and discuss the decision process that takes place when new additions are considered for the SMU campus.

First, they determine the necessity of a new building. Also the use of the building or other feature is considered, followed by an elaborate siting analysis that goes along with finding a location for the new facility. The major point that Mr. Connaughty emphasized was that all facilities are different, thus different considerations must be made for all, regardless of whether the item is a tree or a building. During this project, Saint Mary's University started the construction of a new residence hall. For the construction of this new residence hall, several factors are discussed below. Some of the factors may be seen as major obstacles when adding in new structures, and other factors only pose slight problems.

The main factor that SMU had to consider for the new residence hall was the need for handicap accessibility. According to the Americans with Disabilities Act (ADA), SMU must provide adequate facilities for the disabled. This Act played an important role in the location of the residence hall. The plans were to include a turn-around driveway for easy access when a disabled person arrives by car. The residence hall was built into a hill so in addition to the entrance on first floor, there is an entrance to the second floor on the top of the hill. Due to the ADA regulations, SMU cannot build beyond that hill and into St. Yon's Valley without providing a 24-hour shuttle service.

Fire codes also play a role in the decision process as well. The fire codes play a minor role in the distance that one residence hall can be built from another; however, they become more of a factor when a common wall is connecting two buildings. In this case, the common wall separating the new building from the old building must be a certain thickness, which is determined to not burn through in less than four hours. That is, according to fire code, it should take four hours for a fire to burn through a common wall that lies between the two connecting buildings. This was previously addressed by SMU when the Recreational Athletic Center (RAC) was built on the Winona Campus. At that time, the student center, swimming pool, track and the hockey rink were all combined into one building.

When performing the siting analysis, some factors are seen as obstacles while others are not. Along with the two factors mentioned above, the ADA and fire codes, space can be an obstacle. Space could be an issue and pose a huge problem if the plans are bigger than the site. Other factors, such as sidewalks and gas lines are not seen as obstacles, because they both can easily be replaced.

Trees and soil are important ecological factors to consider. SMU does not mind removing some trees when adding new features to campus as the university has many transplantable trees growing beyond St. Yon's Valley. Soil may play a role in new additions to a site. Depending on the type of structure being built, the soil at the building site may need to be changed. This happens because some types of soil may not accommodate some types of buildings. It may be necessary to bring in a different type of soil to rectify the situation and assure stability.

When a site analysis was originally performed for the Gilmore Creek Hall Residence Hall, SMU planned ahead and they performed another site analysis for the land next to it. They added gas lines to eventually be used in that location. This second parcel of land is now the site of the new Hillside residence hall. Since the gas lines were already on site, it was helpful in the construction.

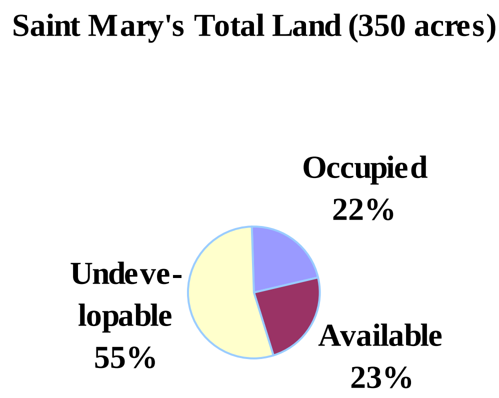

Figure 7 This chart shows how the SMU total land is divided into Occupied, Available, and Undevelopable Land

Analyses

Considering all of the above factors, a model was created using this information. This model displays buffers that were created to find the amount of land that SMU has available for future building projects. One analysis for this project shows the relationship of existing features to possible new additions, such as the new residence hall and the new bike trail. This takes into account occupied land, the available land, and the undevelopable land on campus. The size of SMU campus is 350 acres. Fifty acres are bluffs and are considered undevelopable as defined by this model. The total available land consists of forest, roads, and sidewalks and is 21.056 acres.

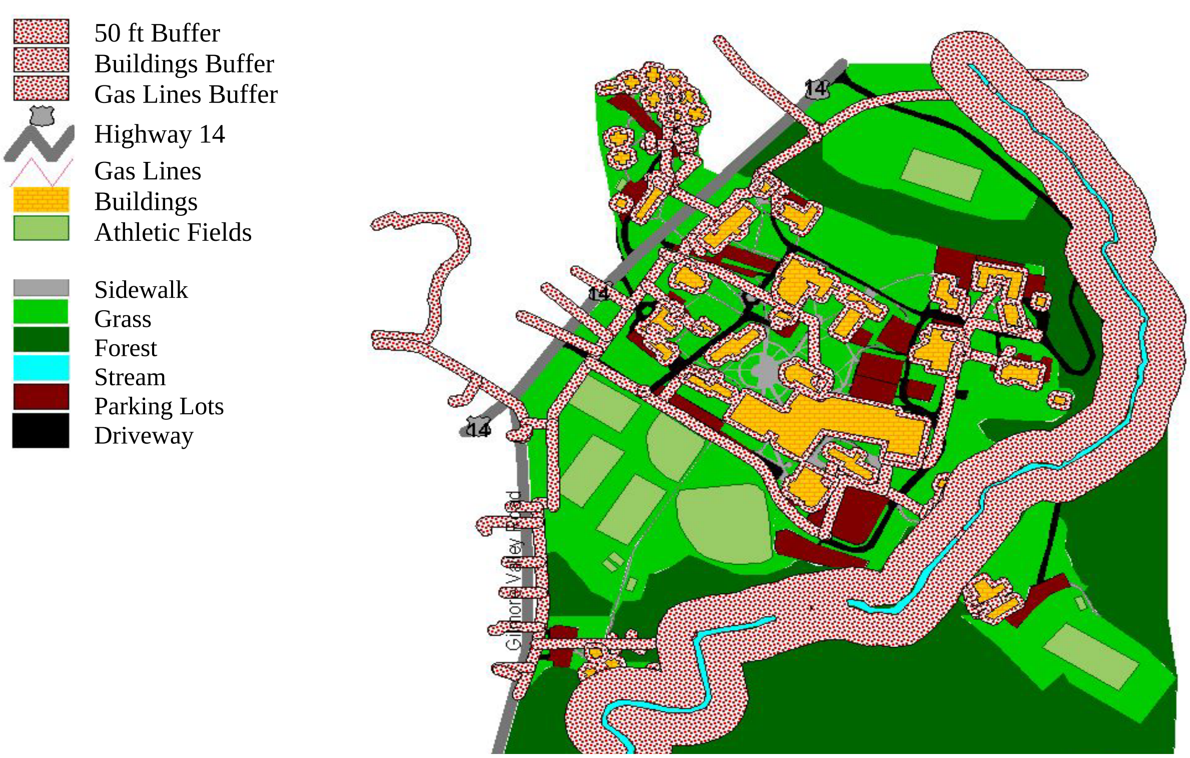

Figure 8. This map shows the model created to determine which land is occupied due to building codes and floodway limits.

The occupied land consists of many different areas fitting into four different categories. These categories are Aesthetics, Athletics, Concrete, and Buffers. The Aesthetic category covers all areas that SMU would not build a new feature on. One example of this category would be the area located in front of Saint Mary's Hall. If anything were built in this area, it would hide the historic front of Saint Mary's Hall. The aesthetic areas on SMU total 1.143 acres. The Athletic areas consist of the baseball field, softball field, and soccer fields. The athletic total is 0.538 acres. The concrete category covers all concrete that SMU would not build on. These areas include the two plazas, and parking lots and are 1.834 acres in size. Figure 7 displays how the SMU total land is divided into Undevelopable, Occupied, and Available land.

A model was created using the buffer and erase commands in the Geoprocessing Wizard extension. This extension allowed a model to be created using a number of buffers based on distance. The buffer distances chosen were eight feet around gas lines, eight feet from buildings, and 50 feet from Gilmore Creek. The buffer distance for the gas lines and buildings was generated on mere hypothetical reasons, but could definitely be changed if a new feature was important enough. According to Mark Molar (City of Winona Port Authority, 2000, Winona, MN) the buffer distance of 50 feet for the Gilmore Creek was chosen based on the flood way limits and slope. All features, except the buffered themes, were merged and erased from the view, showing areas of available land versus occupied land. The buffers cover all areas on campus that were created in the new buffer model depicting how SMU would not build there. This buffered area totals 17.035 acres. The figure above shows the buffers created in this model (Figure 8).

Restaurant and Motel Locations

This new GIS could assist a visitor in becoming familiar with the SMU Winona campus in relation to surrounding features. The two features in Winona that were included in this project are restaurants and motels. If a visitor travels a considerable distance to Winona, he/she will probably plan to stay overnight, hence the need for motels on the map. Whether it is a long stay or a day visit, visitors will also probably want to dine at a Winona restaurant.

A network analysis was performed which indicates the best route between SMU and these motels and restaurants. The network analysis was completed using the ArcView extension "Network Analyst ™." Before using the extension, a street coverage of Winona was placed on top of the existing project. The "clip" command was used to display only the streets located in the city of Winona. This clipped coverage was then used as a base layer in placing the locations of the various restaurants and motels in Winona. The restaurants and motels were added as a point theme layer. Each point was given a symbol to best represent its theme. A knife and fork was used as the symbol to represent a restaurant and a bed was used as the symbol to represent a motel. Figure 9 displays the location of the restaurants and motels in relation to SMU campus.

New Village Layer

A section of SMU campus, called the New Village, was not on the original photograph of campus due to its location across the highway. The photograph was zoomed in towards the center of campus, cutting off this area as well as some bluffs and forest. The bluffs and forest area were of less concern than the many buildings found in

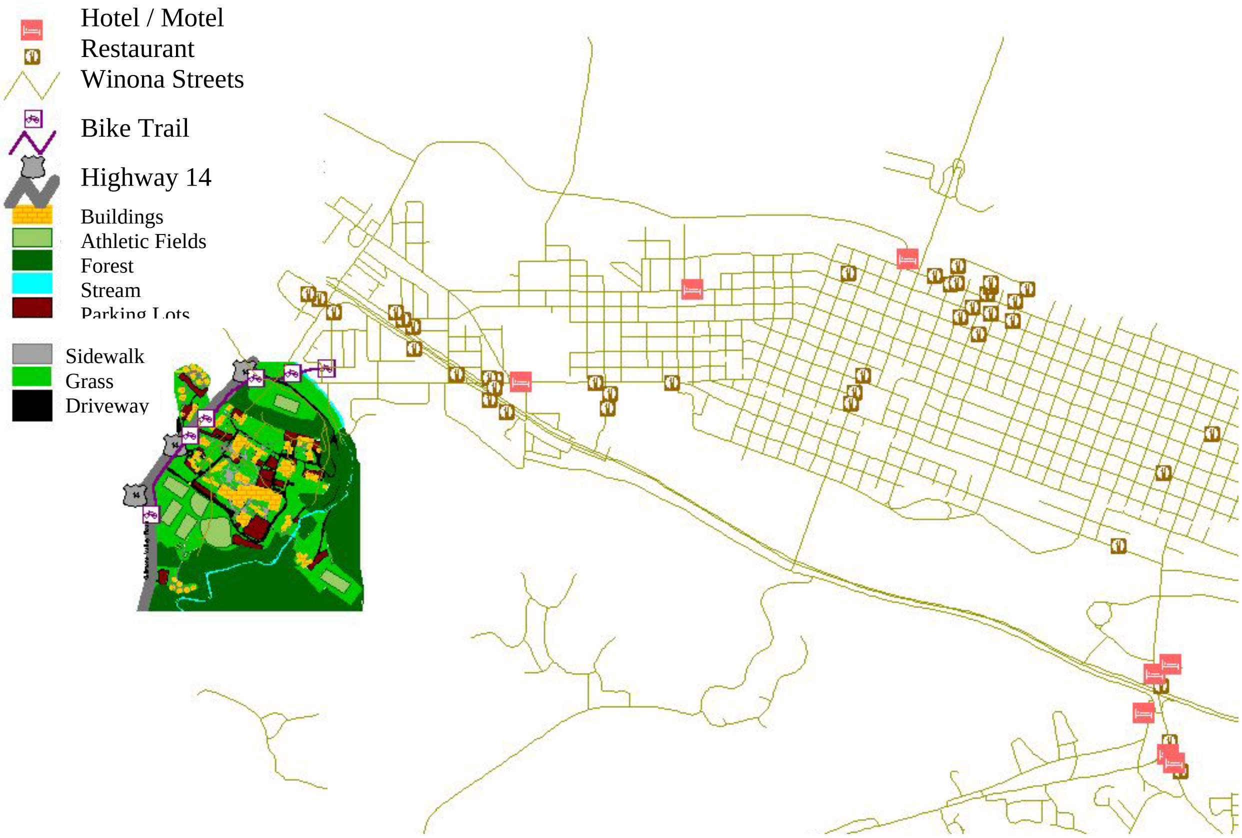

Figure 9. This map shows SMU in relation to Winona's motels and restaurants.

the New Village area. Originally, these areas were going to be placed into the GIS map using the GPS receiver. This did not happen, due to weather restrictions. Instead, a 1992 Digital Ortho Quad (DOQ) photograph was used. It did not have great accuracy but made it possible to locate each building and the sidewalk areas.

Conclusion

Hopefully SMU will consider placing a computer system in at the front entrance of campus to be used by visitors. It could contain maps showing "You Are Here" and also a "Print" button if a printed map is needed.

To expand on this project in the future, a table could be created for trees, indicating which type of tree and how old each is. Cross-country trails located in the bluffs behind SMU could also be entered into the project by using a GPS. More photographs could be taken from more areas on campus. Another possible addition would be to include a sprinkler system map.

This integrated GIS of the Winona campus of Saint Mary's University of Minnesota campus was created in 2000. GIS technology can make map-making for SMU much easier and faster for the future and result in more complete, accurate, and up to date maps. Regularly, new GIS updates need to be made by reviewing information on the old maps and making sure all features are included on new maps and that they are accurately depicted.

Acknowledgements

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References

Connaughty, Roger. 20 Sept 2000. Personal Communication. Retired Head of Maintenance Dept. SMU Winona, MN.

Molar, Mark. 2000. Personal Communication. City of Winona Port Authority, Winona, MN

Br. Robertson, Roderick. 1999. Personal Communication. Chair Communications, SMU Winona, MN

Stensgard, Tim. Master Electrician, 2000, Personal Communication. Maintenance Dept., SMU Winona, MN