Developing GIS in Small Communities for Wildfire Protection Plans

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Abstract
Throughout the United States, many communities in wildland urban interface (WUI) areas are developing Community Wildfire Protection Plans (CWPP). WUI communities that develop CWPP's are eligible for increased federal funding and assistance for fuel reduction and wildfire management projects. CWPP's may include a database of community assets and risks. Given the spatial nature of these data, a GIS often provides the best database; but because many of these communities are small, access to GIS software, expertise, and infrastructure is a serious challenge. The residents of the mountain community of Summerhaven, Arizona, in cooperation with Pima County, Arizona State Forestry, the USFS, the University of Arizona, local environmental groups, and others developed the Mt. Lemmon GIS as part of their CWPP. Based on their experience, this presentation introduces a methodology for developing a GIS in a small community with limited resources.

Introduction

Fire plays an important role in the American Southwest and other fire-adapted ecosystems. While some fires help to sustain healthy ecosystems, other fires devastate both natural and human communities, while costing millions of dollars to suppress. The fire seasons of 2000 and 2002 in the U.S. were unprecedented in scale, severity, and cost. In response, the federal government introduced a series of new wildfire policies that aim to reduce the risk of fire to at-risk communities and the environment. The new policies – including the National Fire Plan (NFP) of 2000, the Healthy Forests Initiative (HFI) of 2002, and the Healthy Forests Restoration Act (HFRA) of 2003 – all attempt to embrace the notion that fire is a keystone ecological process, while mitigating the effects of nearly a century of fire suppression policy (Stephens and Ruth, 2005). The main issue at stake however, is how best to reintroduce fire onto the landscape in a way that is acceptable, beneficial, and safe (Dombreck et. al., 2004).

To accomplish these goals and change the ways that at-risk communities think about and plan for wildfire, community-based, collaborative approaches to fire management are being encouraged by the federal government (Communities Committee, 2004; Morehouse and O'Brien, 2008; USDA and USDI, 2004). Notably, Title I of the HFRA encourages communities located in the wildland urban interface or intermix (WUI), places where human settlement meets or is interspersed with fire-prone, wildland vegetation, to develop a Community Wildfire Protection Plan (CWPP). WUI communities that develop comprehensive CWPP's are eligible for competitive federal funding. CWPP's must be collaboratively developed with and approved by the local fire department, state agencies, and government. They also provide WUI communities with the opportunity to participate in wildfire decision-making and planning activities and to take a more active role in fuel treatment projects (Steelman and Burke, 2007).

CWPP documents address issues such as the protection of life and property, community preparedness, wildfire response, and hazard mitigation, and they are meant to aid communities in planning, hazard assessment, and resource inventory (Communities Committee, 2004). A key element required for a successful CWPP is a basemap, which calls for a designation of the WUI boundary, and displays inhabited areas at risk, forested areas with human infrastructure, and forested areas at risk for large-scale fire disturbance (*Ibid*, 2004). To be effective, the basemap should be quite comprehensive and cover all of the community's assets and risks. Given the spatial nature of the basemap requirements, many communities have chosen to develop Geographic Information Systems (GIS), as a GIS often provides the best database. However, many WUI's are located in rural areas and often do not have the financial resources, technical expertise, time, or necessary equipment to develop usable GIS databases (Larson, 2002). Although additional collaboration with community residents, local universities and government, land management agencies, and other groups is common and beneficial, many WUI communities still face numerous challenges when developing a GIS.

It is within this context that the Mt. Lemmon GIS (MLGIS) Project, which is described below, was implemented in the community of Summerhaven atop Mt. Lemmon in the Santa Catalina Mountains near Tucson, Arizona. The MLGIS Project is an ongoing, collaborative effort between the Mt. Lemmon Fire District (MLFD), Mt. Lemmon Water District (MLWD), the University of Arizona (UA), Arizona State Forestry, Trees for Mt. Lemmon (TFML), Pima County, the United States Forest Service (USFS), the Catalina-Rincon FireScape Project, and other residents of the Mt. Lemmon and Tucson area. This paper describes the steps taken by the MLGIS project to create a GIS for use within the Summerhaven community, as well as to update the Mt. Lemmon CWPP, and can therefore, serve as a methodology for other WUI communities working on similar projects. However, this paper should also serve as a cautionary tale, because there are some significant challenges associated with an undertaking such as the MLGIS project. The issues faced by the MLGIS project will be explained, as well as some potential solutions to the challenges faced by the group.

Project Location

Summerhaven, Arizona, is located atop Mt. Lemmon at an elevation of 8,200 feet in the Santa Catalina Mountain Range in the Coronado National Forest just outside of Tucson, Arizona, in Pima County (Figure 1). The Santa Catalina Mountains are a sky island, a forested mountain range separated from nearby mountain ranges by desert and plains, which are ecologically diverse and home to a large number of endemic species (Sky Island Alliance, 2009).

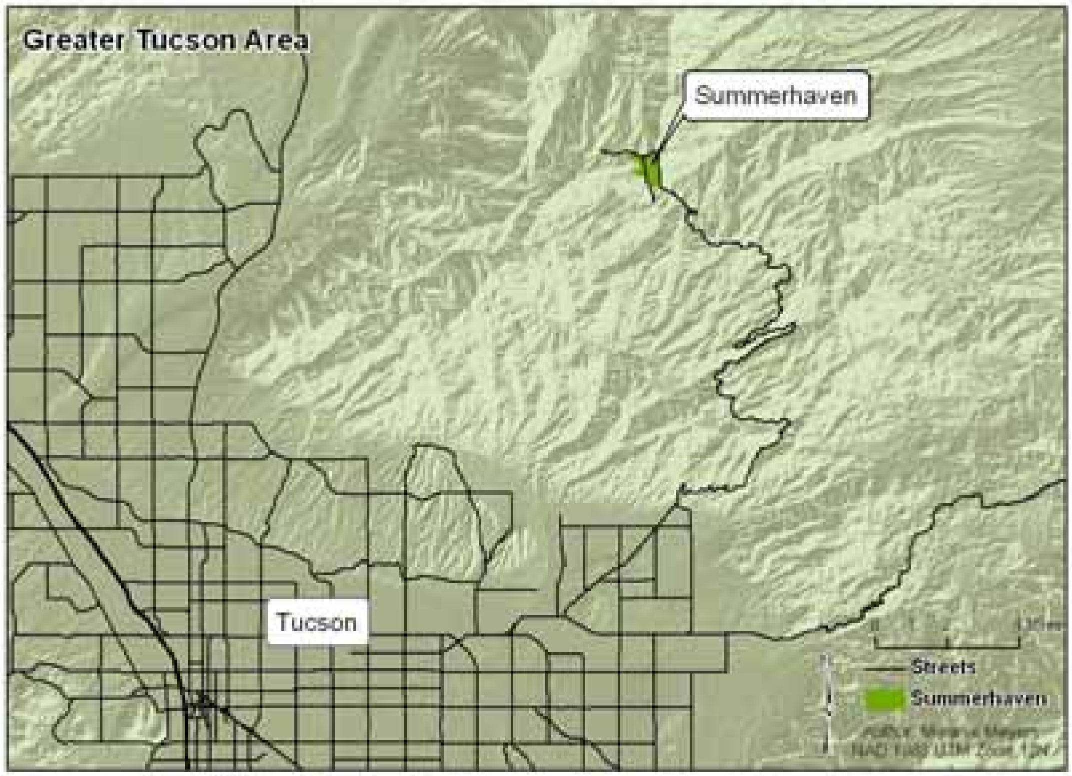

Figure 1 - Summerhaven and Tucson Area

Summerhaven is made up of mostly private land and surrounded by the Coronado National Forest under the USFS. The village of Summerhaven consists of a mixture of vacation and year-round homes, as well as a few businesses (Mt. Lemmon CWPP, 2004). There are approximately 900 parcel lots in Summerhaven, and prior to the Aspen Fire of 2003, the population of year-round residents was nearly 100. However, the post-fire year-round population is approximately ten to twenty. All of the other developments in the surrounding National Forest have special permits from the USFS. There is a small ski resort called Ski Valley adjacent to the village, which is the southernmost ski resort in the U.S., as well as observatories run by the University of Arizona.

There are only two roads that access Summerhaven: General Hitchcock Highway (also Mt. Lemmon Highway or Catalina Highway), which connects with Tucson to the south and the Control Road, which is an unpaved fire road that connects Pinal County to the north (Figure 3).

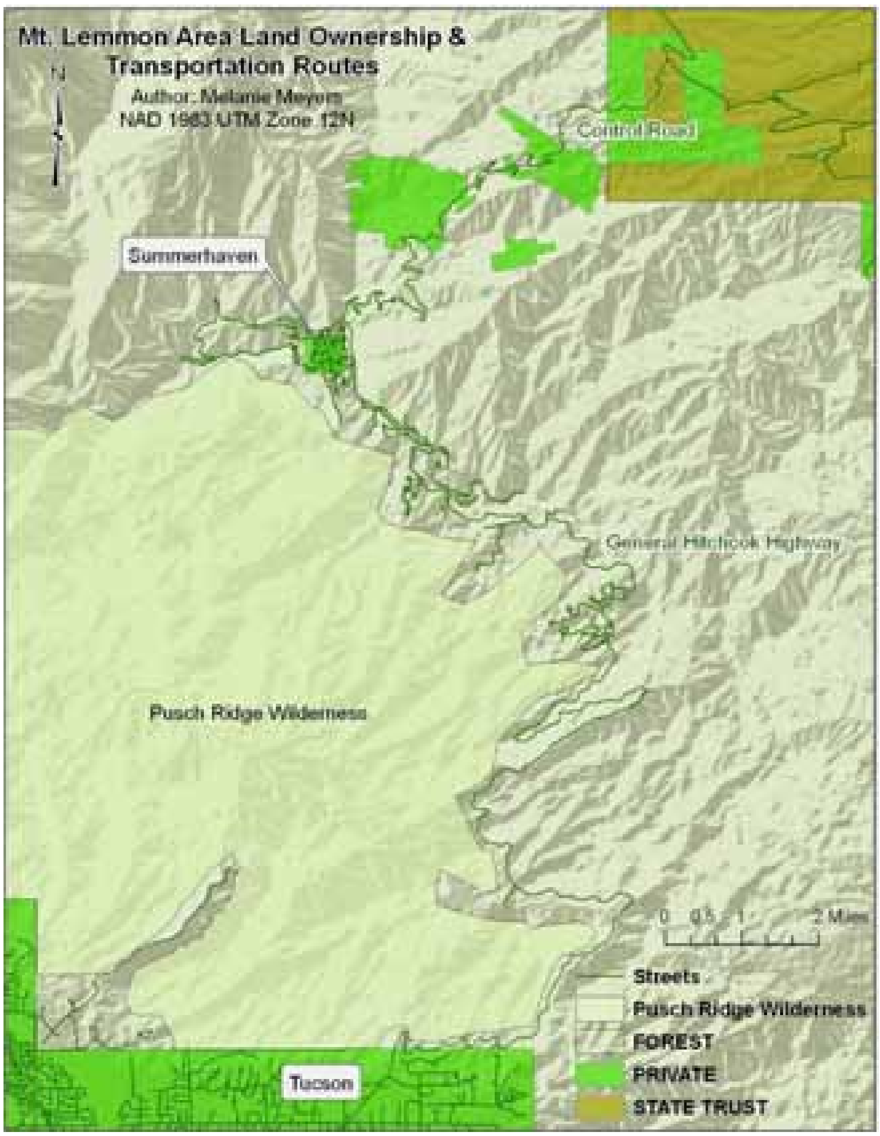

Figure 2 - Land Ownership & Transportation

The community of Summerhaven is located within the Mt. Lemmon WUI boundary, which was originally drawn for the Mt. Lemmon CWPP. The Mt. Lemmon Fire District boundary covers a similar area as the WUI boundary and includes most of the structures on the mountain (Figure 2).

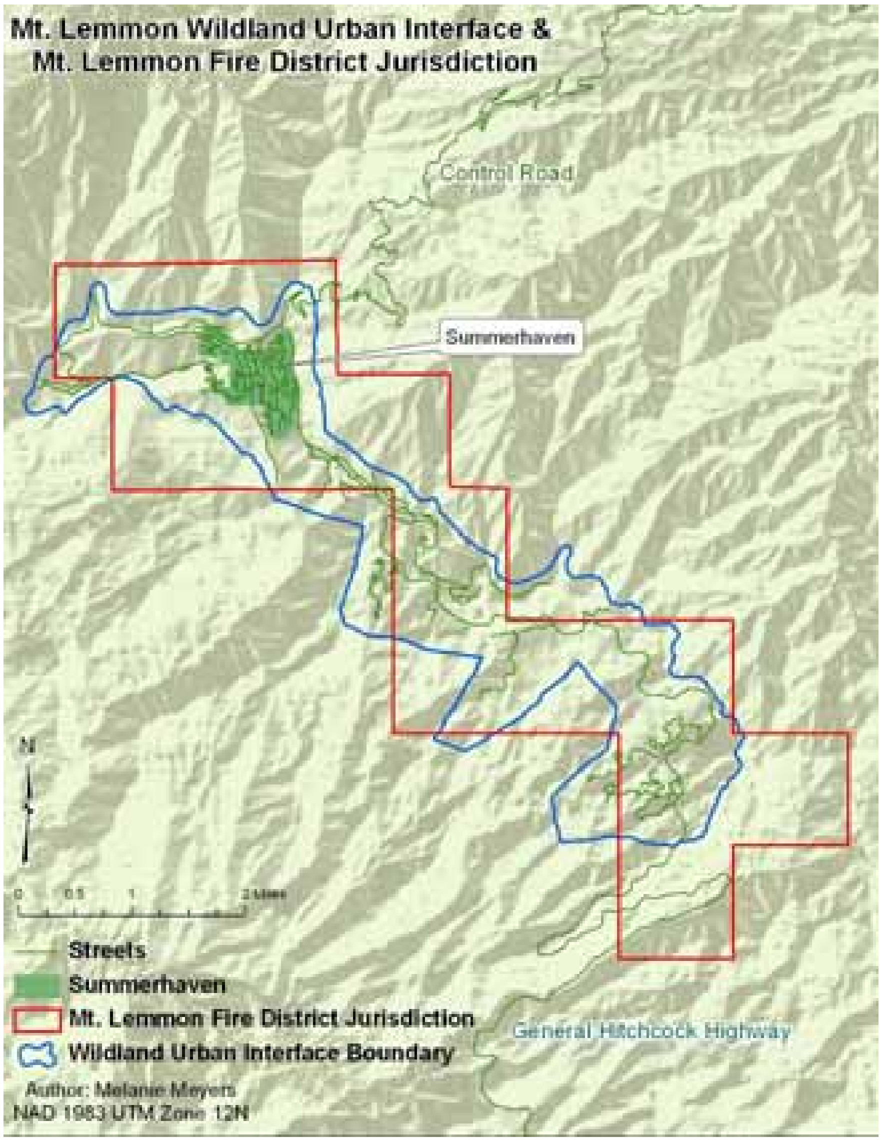

Figure 3 - WUI and Fire District Boundaries

The Mt. Lemmon GIS Project

The MLGIS Project evolved after the completion of the Mt. Lemmon CWPP in July of 2004, which was submitted approximately one year after the Aspen Fire that had burned through Summerhaven and the western side of the Santa Catalina Mountains in June of 2003. In 2002, the Bullock Fire had burned much of the eastern side of the Santa Catalinas. Together, the two fires burned more than 44% of the forested areas of the Santa Catalinas (Figure 4). The Aspen Fire was especially devastating, as it destroyed more than 300 structures in and around Summerhaven. Since the fire, much of the town has been rebuilt, but the community continues to recover.

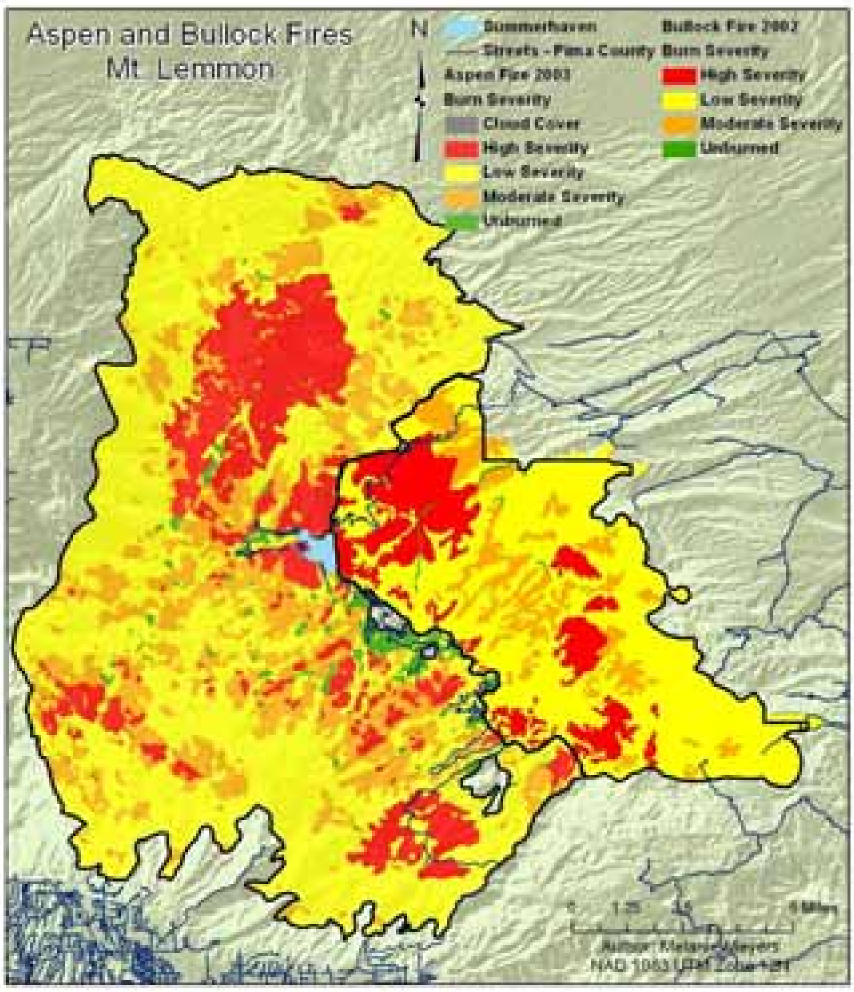

Figure 4 - Aspen & Bullock Fires

After the Aspen and Bullock fires and the completion of the Mt. Lemmon CWPP, the Mt. Lemmon community requested assistance in developing a GIS, the rationale for which was to improve the effectiveness and efficiency of the Mt. Lemmon Fire and Water Districts. The Aspen Fire provided impetus for such a project. For example, the water district lost all of its maps and records, and fire district found their maps to be inadequate for dealing with an emergency on the scale of the Aspen Fire. Trees for Mt. Lemmon became involved to help mitigate the effects of the fires on the sky island ecosystem. Initially, the community's request was unfulfilled, as it was difficult to find someone to spearhead the project, but in 2008, a number of outside organizations including UA, Arizona State Forestry, USFS, and Pima County became involved, and the MLGIS group was formed.

The purpose of the requested GIS was to create a common set of accurate and reliable data to be used collaboratively between the fire and water districts, as well as to improve upon the maps and other spatial data available in and around the community. The GIS was also intended to improve upon the Mt. Lemmon CWPP, which is to be updated in the near future. The MLGIS mission statement cites that the emphasis of the GIS is on the protection of life and property in and around Summerhaven. However, the MLGIS group also intends to use the GIS both strategically, for long-term planning, as well as tactically, to aid in carrying out day-to-day operations. Specific objectives of the GIS include developing a reliable set of data for use by Mt. Lemmon Fire and Water Districts, developing a user-friendly, dynamic system, identifying efficient ways to maintain and operate the system, ensuring fire and land management consistency with the adjacent Coronado National Forest, and sharing data with Pima County, the State of Arizona, and USFS (Plevel, 2009).

Methodology of the MLGIS Project

As explained above, the MLGIS project was a collaborative effort among numerous organizations that were all working to achieve common goals. The MLGIS participants met approximately once per month from August of 2008 to April of 2009 while developing the GIS. The MLGIS group strove to be open, transparent, and communicative with all of the participants to ensure that the project was evolving in a way that was consistent with their goals. The organization of the MLGIS project was based loosely on the methods for a GIS project planner that are described in Tomlinson's Thinking About GIS: Geographic Information System Planning for Managers (2007). Certain aspects of Tomlinson's methodology were adapted in order to accommodate the circumstances presented by the MLGIS project; however, for the most part, his methodology provided a useful guide by which to proceed in developing the project.

The methodology and process of the MLGIS project is detailed in the section below. Many of the steps taken by the MLGIS group were ongoing throughout the project depending on the scope and challenges presented by each particular step. Nonetheless, the order described below largely follows Tomlinson's (2007) prescription for designing and implementing a GIS. We feel that this process can be readily adapted for other WUI communities working to develop a usable GIS as part of their CWPP document and for other use. Therefore, the MLGIS project provides a good example for developing a usable GIS in a small community with limited resources.

At the same time, more than two years have passed since the first meeting of the MLGIS group in August of 2008. The first year was very productive and successful, but in the second year, the group met with numerous roadblocks including discontinued funding, priority shifts within some of the participating organizations, and insufficient training, infrastructure, and time, all of which make sustainability of the project challenging. Nonetheless, a great deal of good work has been completed for the MLGIS project, which was certainly not done in vain, so we will also provide some potential solutions to the sustainability problems faced by the group.

The MLGIS Project Process

The first step of the MLGIS project was to identify stakeholders. Although the process of identifying stakeholders is ongoing, the main stakeholders in the project included employees, board members, and volunteers of the Mt. Lemmon Fire and Water Districts (MLFD & MLWD), a member of Trees for Mt. Lemmon (TFML), the engagement coordinator from the joint UA-USFS Catalina-Rincon FireScape Project, and representatives from UA School of Geography and Development, Arizona State Forestry, USFS, Pima County, and the Pima County Sheriff's Department. The participants all contributed something different to the project. For example, the UA provided technical support and guidance, Arizona State Forestry did the same and was also able to help the group obtain a grant for two ArcGIS 9.3 licenses, and MLFD and MLWD members brought invaluable local knowledge. The MLGIS group often discussed and invited additional people to include. No one who wanted to participate was excluded, but for the most part, invitations to new participants were limited to specific individuals, and the project was not advertised to the community at large.

The second step was to define the goals and mission of the MLGIS group, which are outlined earlier in this paper. The engagement coordinator from the Catalina-Rincon FireScape Project wrote the first draft of the MLGIS mission statement, which was reviewed and agreed upon by all of the project participants (Plevel, 2009). However, the goals and mission of the group were dynamic and subject to change as the project progressed.

The third step was to acquire hardware and software. The fire and water districts have limited funding for the project, so the group reviewed a list of potential GIS software packages, including ArcGIS from Environmental Systems Research Institute (ESRI), RedZone, and Google Earth. Consensus was reached that ESRI's ArcGIS software was the best option, despite its higher costs than the other two options. Subsequently, a representative from Arizona State Forestry obtained a grant from ESRI for two free copies of Arc9.3 with an ArcView license for use by the MLWD and MLFD. Most members already had hardware to use for the project and some additional donations, including a computer and printer, were made to the group. UA provided access to GPS and other equipment that was needed on a temporary basis. However, limited resources for hardware, software, and technical expertise continue to be a challenge.

The forth step was to determine a project boundary and develop a basemap. The group collectively identified layers that should be included in the basemap, which were obtained from Pima County GIS and the Coronado National Forest (USFS) GIS. The basemap layers included:

- Parcel and property owner information
- Land ownership
- Township, Range, and Section (TRS) gridlines
- Township lines
- Streets
- Wilderness areas
- WUI boundary
- Mt. Lemmon Fire District jurisdiction boundary

The basemap boundary evolved from a small area, which was simply the combination of the WUI and the Mt. Lemmon Fire District jurisdiction, to a much larger area that encompassed much of the Mt. Lemmon area from milepost zero on General Hitchcock Highway to the south, to the Pinal County boundary to the north. Pima County TRS lines dictated the shape of the project area to the east and west (Figure 5**)**. All of the participants were involved in determining the extent of the project area boundary.

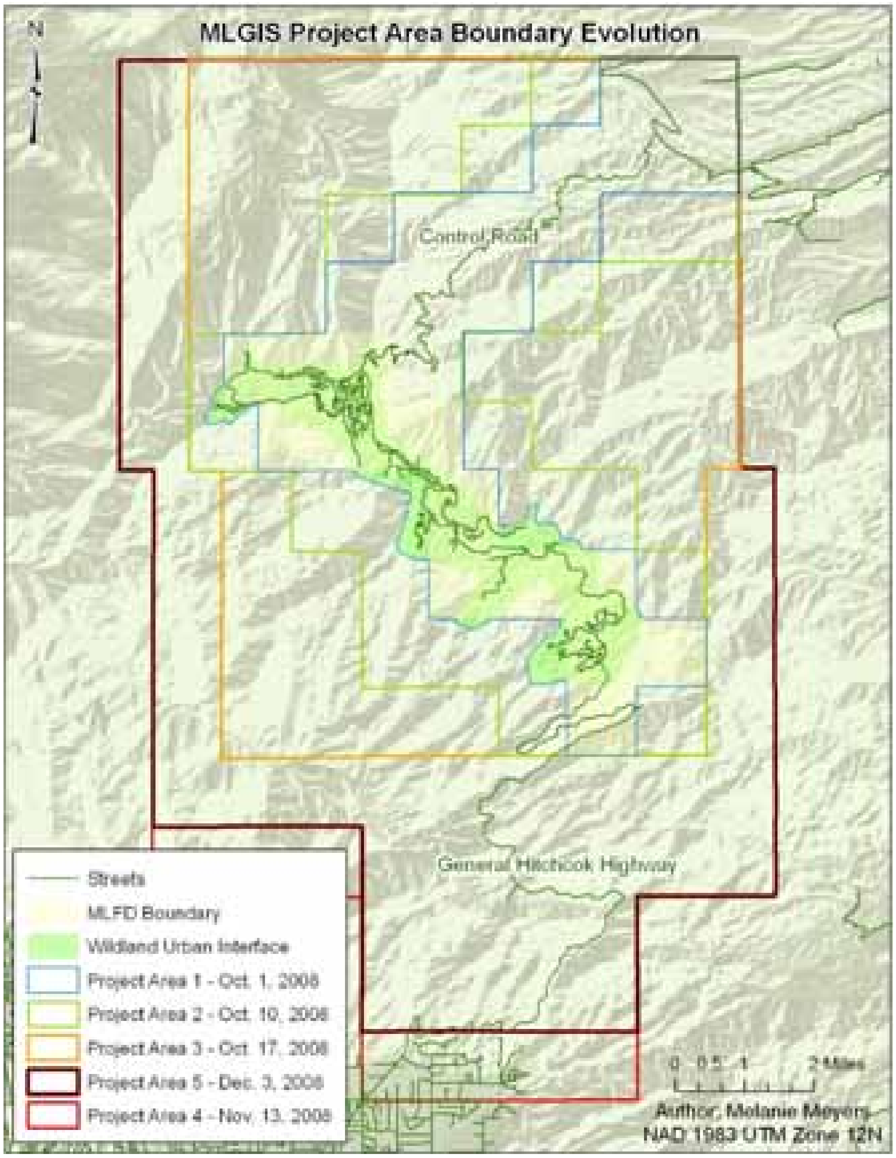

Figure 5 - MLGIS Basemap Boundary Evolution

In order to organize the layers that were collected for the basemap, a geodatabase and feature datasets within it were created in a common coordinate system – North American Datum (NAD) 1983, Universal Transverse Mercator (UTM), Zone 12 North, which was also chosen collectively by the group – in ArcGIS 9.3. All of the basemap layers collected from the various

GIS departments were imported into the appropriate feature datasets and clipped to, or reshaped to match, the basemap boundary to ensure vertical and horizontal integration. The feature datasets included in the geodatabase are named “Basemap”, which contains the features listed above and other similar data; “Infrastructure”, which contains features such pipes, meters, hydrants, etc.; “Invasive Species”, which are cheatgrass points and polygons collected by Trees for Mt. Lemmon to aid in eradication efforts; “Mt. Lemmon Fires”, which are fire perimeter and severity polygons; “Pima County Data”, which is data for the whole county; and “Transportation”, which includes roads, trails, trailheads, etc. (Figure 6). Over the course of the project, any additional data that was collected was imported into the master geodatabase, which was maintained on a computer at UA.

Figure 6 - MLGIS Geodatabase Structure

The structure of the database mirrors the different areas of interest identified by the group. Each of the different feature datasets in the geodatabase contains features that have similar properties or uses. Features were identified for inclusion in the database at the meetings and using the Information Product Description Form explained below. All of the features included in the geodatabase can be used by at least one of the different agencies involved in the project, and many of them are shared features that can be used by all of the agencies.

The fifth step was to train group members to use the software and hardware. Initially, many of the participants had limited experience with ArcGIS, so group members with more experience conducted informal training throughout the course of the project. One MLGIS member purchased a copy of ArcEditor 9.3 and a tutorial. Consequently, he was able to teach himself how to digitze a large portion of the MLWD water system from an AutoCAD file, and from memory, into the GIS, primarily using a Digital Orthophoto Quarter Quadrangle provided by Pima County. However, more formal training is required in order to efficiently use the GIS. Therefore, an instruction manual for using the MLGIS is being developed, which will include details on how to make maps from templates, add or update layers in the geodatabase, share any updates to the database with the group, add or update metadata, and more. The instruction manual is meant to be a document that could easily be adopted to fit other communities and projects. At the same time, an instruction manual alone cannot replace the utility and necessity of at least some formal GIS training.

The sixth step of the project was to determine what additional data needed to be collected. In order to determine what kinds of data and outputs group members wanted, an

Information Product Description (IPD) form, as described by Tomlinson (2007: 32), was developed for participants to complete describing the layers they felt should be included in the database, as well as any cartographic, tabular, or text products they wanted (Appendix A). The purpose of the IPD was to ensure that all of the participants had the opportunity to contribute to the development and content of the GIS.

The seventh step was to collect any additional data that had been identified in the IPD's. The data collection process included using GPS to log points, inventories of existing files and maps, collection of aerial photography, collection of other important spatial and non-spatial data, and digitizing of features using the aerial photos and local knowledge of the area. All of these data were processed and imported into the master geodatabase. Some of the results of the data collection process are displayed in Figure 7.

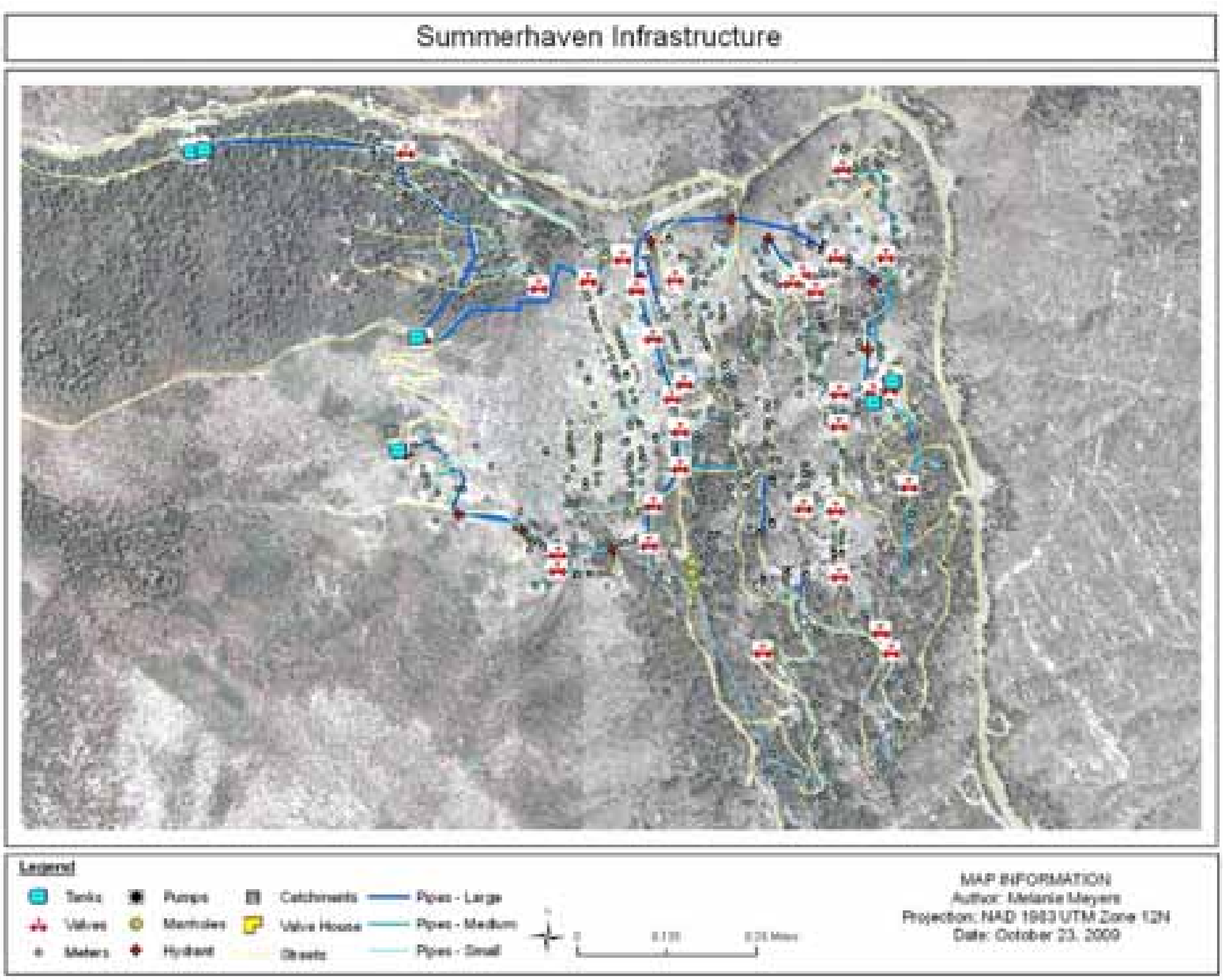

Figure 7 - Data Collected for the MLGIS

The eighth step of the project included assimilation and normalization of the data and generation of outputs. Throughout the course of the project, maps and other products were developed and displayed to group at the meetings, via e-mail, and with a website maintained at

UA. Copies of the most recent master geodatabase were frequently distributed to the group members in order to ensure that everyone had access to the most recent version, even if they were not directly involved in each step.

The ninth step was to assess the project. Even with an ongoing project, it is still important to take the opportunity to review what has already accomplished, what still needs to be accomplished, and initiate a discussion on how best to proceed (Tomlinson, 2007: 164). To that end, Ms. Meyers' Master's research completed at UA in 2009 assessed the MLGIS project through interviews and a focus group with project members. The results of her research indicate that while the MLGIS project has been successful at achieving many of the goals set down in its mission statement, the group is still largely limited by infrastructure challenges, including access to equipment, training, time to work on the project, and future database sustainability. At the same time, the process of working on the project has been beneficial through the development of relationships, an improved understanding of GIS, and a GIS with which to update the CWPP.

Current State of the MLGIS Project

As stated earlier, despite a successful first year, the MLGIS project met with some obstacles in the second year, which have made the project's sustainability more challenging. First, some of the funding for a UA representative to work on the project ran out, and although that person continued to work on the project through other means, a great deal of momentum was lost along with the funding. Second, some of the momentum in Summerhaven slowed down due to personnel changes in the fire district. Third, the project had no clear leader, in part, due to its collaborative and participatory nature, and with the loss of momentum from some of the organizations, as well as a lack of time, training, infrastructure, and other factors to sufficiently support the project, the MLGIS project came to nearly a dead halt in the late fall of 2009. In short, although the process outlined above was successful in creating a GIS that met the standards of the MLGIS mission and the CWPP, the culmination of factors were beyond the scope of a GIS planner (or planners) to solve.

At the same time, due to all of the hard work in the first year and the process outlined above, the MLGIS database and many of the associated products are nearly complete. The main issue at stake now is how best to use and maintain the GIS that has been developed and sustain its capacities into the future. To that end, some of the participants are working to find a solution to the sustainability challenges. There are a couple of potential solutions. First, the group could identify a stable partner that is not limited by funding or infrastructure, such as Pima County, to house the GIS and manage any necessary updates. A second option would be to develop a cooperative agreement with other similar communities throughout southeastern Arizona to build similar systems. A third option would be to identify an entrepreneur who could develop a business, project, or organization to provide GIS services to WUI communities. The second and third options require more investment from the communities, while the first does not.

Conclusions

Despite some of its challenges, the MLGIS project nonetheless provides a useful case study for other WUI communities that are working to develop a GIS for their CWPP. The methods described by Tomlinson (2007) provided a useful guide throughout the project, while the steps described in this paper illustrate the potential process and challenges that other WUI communities might face when designing and implementing a GIS. The MLGIS group was able to overcome many of the common challenges faced by WUI communities when developing a GIS, such as access to GIS software, expertise, and infrastructure, by collaborating with numerous outside agencies and organizations. This collaboration helped MLGIS develop strong and important relationships, both internally and externally, and also provided important access to equipment, knowledge, and other support. However, there are still numerous challenges that the MLGIS group must overcome in order to develop a sustainable, comprehensive, and user-friendly GIS for Summerhaven and the Mt. Lemmon area. Therefore, there is a great deal of opportunity for further collaboration with other WUI communities, groups with GIS expertise, and wildfire planning and management agencies, which would be beneficial not only to Summerhaven but to WUI communities throughout the U.S.

References

Communities Committee (March 2004). Preparing a Community Wildfire Protection Plan: A Handbook for Wildland Urban Interface Communities. Retrieved 01/24/2009, from http://www.communitiescommittee.org/pdfs/cwpphandbook.pdf

Dombreck, Michael P., Jack E. Williams, and Christopher A. Wood (2004). Wildfire Policy and Public Lands: Integrating Scientific Understanding with Social Concerns across Landscapes. *Conservation Biology*. *18*(4), 883-889.

Larson, Jim (2002). GIS and Rural Communities: Geographic Information SystemApplication for Small Government. *URISA 2002 Annual Conference Proceedings and Exposition Proceedings.*

Morehouse, Barbara J., and Sara O'Brien (2008). Facilitating Public Involvement in Strategic Planning for Wildland Fire Management. *The Professional Geographer*. *60*(4), 495-507.

Mt. Lemmon Wildland Urban Interface Plan for Forest Health Wildland Fire Management – The Community Wildfire Protection Plan (July 2004). Cooperative effort between The Citizens of Mt. Lemmon, Mt. Lemmon Fire District, Trees for Mt. Lemmon, Pima County, Arizona State Land Department, and USDA Forest Service.

Plevel, Steve (2009). Mt. Lemmon GIS Mission Statement (*draft*).

Sky Island Alliance (2009). Sky Island Alliance Website. Retrieved 08/19/09, from: http://www.skyislandalliance.org/

Steelman, Toddi and Caitlin A. Burke (2007). Is Wildfire Policy in the United States Sustainable? *Journal of Forestry*. *105*(2), 67-72.

Stephens, Scott L. and Lawrence W. Ruth (2005). Federal Forest-Fire Policy in the United States. *Ecological Applications*. *15*(2) 523-542.

Tomlinson, Roger (2007). *Thinking About GIS: Geographic Information System Planning for Managers.* ESRI Press: Redlands, CA.

USDA [U.S. Department of Agriculture] Forest Service and USDI [U.S. Department of the Interior] Bureau of Land Management (2004). The Healthy Forests Initiative and Healthy Forests Restoration Act: Interim Field Guide. FS-799. Retrieved 01/17/09, from: http://www.fs.fed.us/projects/hfi/field-guide/

Appendix A: IPD as described by Tomlinson (2007)

INFORMATION PRODUCT DESCRIPTION FORM

Questions to consider when completing this document:
What outputs do you need this GIS to generate in order to benefit your organization?
What data is need to created the outputs that you require?
What is the benefit of having each product?

TITLE OF PRODUCT:

NAME (of individual who needs product):

SYNOPSIS (explanation of product):

MAP REQUIREMENTS:

LIST REQUIREMENTS (tabular data):

SCANNED DOCUMENTS (additional requirements):

IMAGE REQUIREMENTS:

SCHEMATIC REQUIREMENTS (i.e. diagrams, etc.):

FREQUENCY OF USE:

PRIORITY (1 being the highest – 10 being the lowest):