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# Development Of A GIS Fiber Optics Assetmanagement System For The City Of El Paso

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DEVELOPMENT OF A GIS FIBER OPTICS ASSET  
MANAGEMENT SYSTEM FOR THE CITY  
OF EL PASO

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## **Dedication**

For her enormous support during my studies and the elaboration of this thesis, I would like to thank my beautiful wife Anne-Laure.



DEVELOPMENT OF A GIS FIBER OPTICS ASSET  
MANAGEMENT SYSTEM FOR THE CITY  
OF EL PASO

by

LUIS FERNANDO QUINTANA, Bachelor of Science

THESIS

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The University of Texas at El Paso  
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for the Degree of

MASTER OF SCIENCE

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THE UNIVERSITY OF TEXAS AT EL PASO

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I am also thankful to the City of El Paso for funding the work and providing valuable input throughout the entire project. The meaningful cooperation provided was essential to the success of this endeavor.

Finally, I would like to acknowledge the participation of the University of Texas at El Paso research staff from both the Regional Geospatial Service Center and the Center for Transportation and Infrastructure Systems involved in the GFOAMS research project.

## **Abstract**

The GIS Fiber Optics Asset Management System (GFOAMS) was developed for the City of El Paso, to manage the public fiber optics infrastructure. Using a map-driven interface, the GFOAMS is composed of three modules: inventory, documents, and images. Its interactive multilayer data structure contains information for Junction Boxes, Conduit Runs, and Cables for twelve fiber optic systems across the city. The fiber optics network stored in the GFOAMS connects city buildings and facilities such as police departments, fire departments, municipal courts, health administration building, public transportation facilities/Sun Metro, libraries and others. Applications of the GFOAMS include tools to easy access fiber optics detailed information, conduct proximity infrastructure buffer analysis, and generate what-if “smart maps” to support decision analysis. The GFOAMS is now fully implemented and has been used for organizing daily interventions, managing leasable fiber optics Conduits, and planning new fiber optics developments. Managing the fiber optics assets effectively for the City of El Paso is crucial to keep up with the new needs of broadband, and communications. This thesis covers the most relevant aspects of the developed GFOAMS framework, placing it in the asset management context and background and detailing usage possibilities and applications.

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## **Chapter 1: Introduction**

Asset managers around the world have the challenge to operate, maintain, repair and renew aging infrastructure with limited funds. Asset management is a systematic decision-making approach to preserve, operate, expand, and improve of infrastructure (Garaibeh, 2010). This is especially true for federal departments, regional governments, and counties when dealing with sizeable municipal infrastructure portfolios serving large populations. Managed assets usually include complex, interrelated underground networks, buildings, roads, and bridges (Vanier, 2001).

The potential repercussions to the community for mismanagement of the public assets range from increased health threats and safety risks, reduced economic competitiveness, inefficient maintenance strategies, reduction in the value of a nation's assets, to diverting funds from other programs (Vanier, 2001). In addition, public agencies facing increased organization and budget needs with limited staff resources will be required to deal with complex administrative processes and high public expectations of accountability and levels of service (USDOT, 1999).

Given the vast amount of data collected, stored, maintained, and analyzed, asset management requires the implementation of integrated systems to facilitate the decision-making process. Managing this “built environment” represents a major and rapidly growing cost to public agencies (Vanier, 2001). The latest advances in the technology provide instruments for asset managers to efficiently tackle the complexities of the process. Geographical Information Systems (GIS) stands out as a great tool for asset management. GIS relates database records and their associated attribute data to a geospatial location, creating a “smart map” to visualize the assets and analyze the relationship among them. Visualization of the generated maps is enhanced by the layering of data capabilities (Vanier, 2004).

Fiber optics forms part of the series of manageable assets that municipal governments are tasked to handle. The vast importance of fiber optics in the modern era is due to the data-intensive nature of telecommunications, undergoing transformation from narrow-band to broadband. Applications of fiber optics technology are widespread and involve the transmission of voice, data, and video over distances of a few feet to hundreds of miles. In municipal governments such the City of El Paso, fiber optics is

crucial to the existence of Intelligent Transportation Systems (ITS) and efficient telecommunications across departments in different buildings across cities (Alwayn, 2004; Hecht, 2006).

## **1.1 Motivation**

As a motivation for this research and subsequent thesis, the author pondered on the impact of having an appropriate asset management that makes use of the latest computing tools and technologies such as the Geographical Information Systems (GIS). Today, more than ever, public asset managers have sizeable asset networks and limited funds to maintain them. It is then crucial to provide asset managers with tools that enhance productivity and increases the cost-efficiency of the overall process.

## **1.2 Objectives**

The goal of the research presented in this thesis, is to explore the advantages that implementing an asset management program using a GIS platform, and to execute the project, exploring the possible courses of action and selecting the most cost-effective and appropriate. The managed asset to which the GIS platform is to be implemented is the Fiber Optics infrastructure assets owned and operated by the City of El Paso, Texas. The extensive data contained in the GIS Fiber Optics Asset Management System (GFOAMS) was gathered from field surveys, staff interviews, meetings, maps, and diagrams, and assembled into a GIS framework in the computer program ArcMap 10 by the Environmental Software Research Institute (ESRI).

## **1.3 Thesis Organization**

This thesis is divided into six chapters. Chapter 1 serves as a brief introduction to the GFOAMS project and the importance of having a reliable GIS tool for asset managers. To place the GFOAMS within context, Chapter 2 gives a broad view of the existing literature in the topics of asset management, computational tools in asset management, and fiber optics as a manageable asset. The following chapters concentrate in different aspects of the GFOAMS. For example, Chapter 3 focuses in the data collected and methods of collection, the modules that form the GFOAMS and other relevant aspects. As a means to exemplify the ease of use of the platform, Chapter 4 explains in brief the usage of the GFOAMS. Four

specific applications of the GFOAMS platform are presented in Chapter 5. Finally, Chapter 6 exposes the author's summary of the topic, along with conclusions and recommendations.

## **Chapter 2: Literature Review**

In order to appropriately give a context for the creation of the GFOAMS it is important to clearly define the cornerstone, which is the asset management paradigm, the tools, and the asset itself, the fiber optics. In the next subsections, each topic will be discussed and defined to give a better understanding of the scope and capabilities of the GFOAMS.

### **2.1 Asset Management**

According to the U.S. Department of Transportation's (1999) Asset Management Primer, asset management is "a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short- and long-range planning."

In the early nineties, the asset management paradigm emerged from the private industry, from ideas of W. Edwards Demming, Malcolm Baldrige among others. It was quickly evident that this discipline yielded good results and was successful in companies requiring substantial asset bases for operations, e.g. electrical companies, telecommunications companies, railroads, etc. In the private industry the focus was to maintain a prescribed level of service at the lowest cost possible, and assets that didn't meet these criteria were sold. When asset management started migrating into the public sector, as elected officials and public agency managers noted these advancements, although profit was not a motive the basic concepts of performance and cost-effectiveness equally applied (USDOT, 2007).

Asset management involves inspection and data collection, condition assessment, performance evaluation, prediction of future performance, planning and prioritizing maintenance and repairs, and evaluating technical and economical alternatives (Halfwy, 2002). These systems are goal and data driven and include components for data collection, condition assessment, needs analysis, performance evaluation, prediction of future performance, technical and economical evaluation of what if scenarios, budget preparation, and prioritization of maintenance and rehabilitation interventions when funds are constrained. Through asset management systems governmental agencies can improve infrastructure

information accessibility, enhance and sharpen decision-making, make more effective investments, and decrease overall operating costs (NYDOT, 2008; OCED, 1999).

### **2.1.1 The Six ‘Whats’ of Asset Management**

According to Vanier (2001), the answers to the following questions are established to be the basis of asset management:

1. What do you own?
2. What is it worth?
3. What is the deferred maintenance?
4. What is its condition?
5. What is the remaining service life?
6. What do you fix first?

Most municipalities are able to respond fairly well to the first two questions but fail when trying to tackle the remaining four.

### **2.1.2 Main Expenditures in Asset Management**

The largest expenses in asset management could be categorized in two broad groups that fall within the realm of the last four ‘Whats’ above: (1) maintenance and repair operations; and (2) capital renewal. The diagram in Figure 1 shows this relationship.

Maintenance and repair operations refer to interventions to ensure an asset reaches its optimal service life (CICA, 1989). Capital renewal involves a comprehensive action to completely replace an existing asset. According to the National Research Council (NRC,1996), maintenance and repair expenditures should not include funding to essentially change the function of a facility or expand its service life beyond the original design, but only actions taken to restore a system or equipment to its original capacity (NRC 1996). To establish capital renewal it is necessary to determine the service life of the assets which can range from 10 to 100 years for infrastructure components (Vanier, 2001).

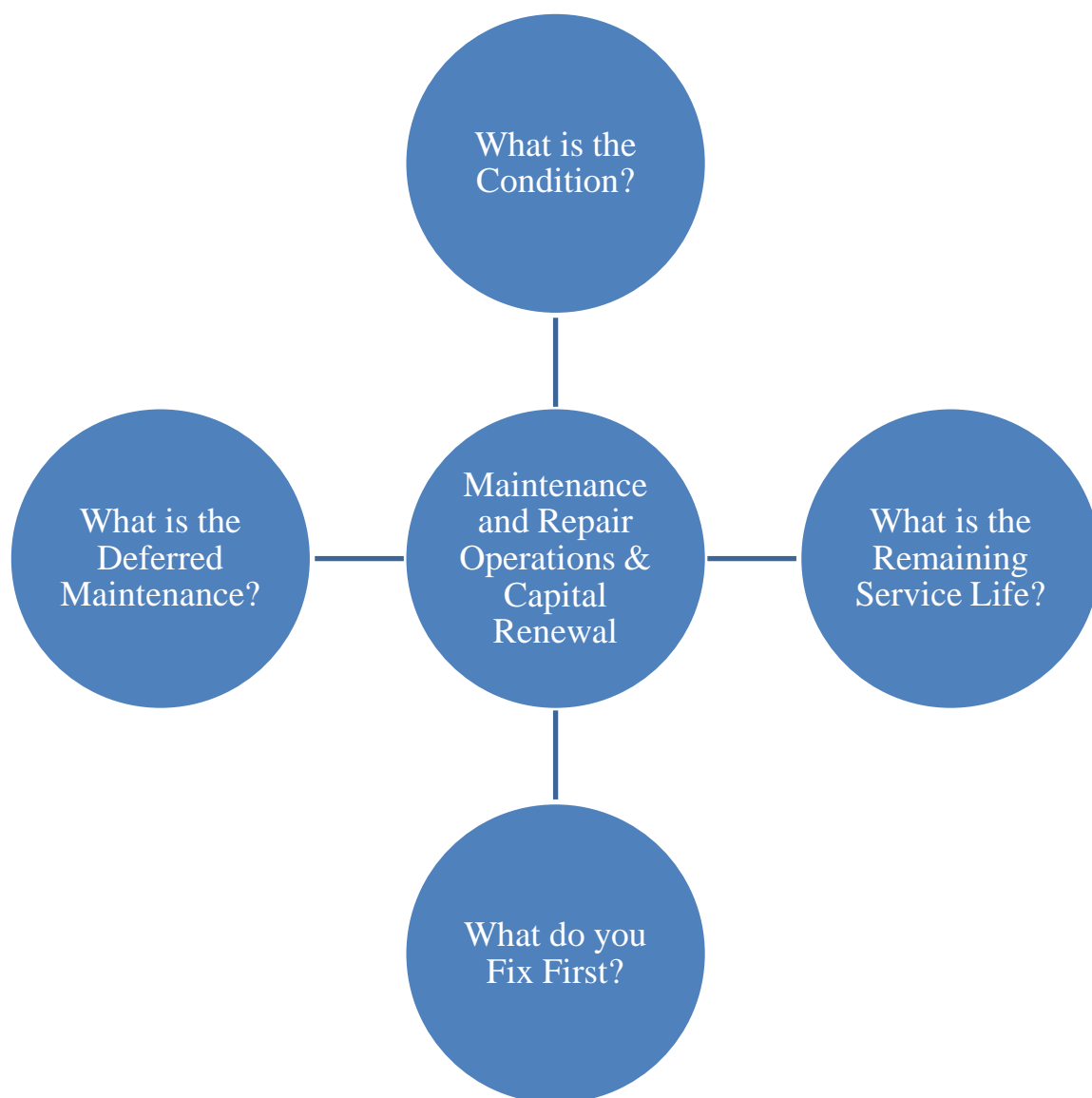


Figure 1: Main Expenditures Related to Four ‘Whats’ in Asset Management.

Since funds for maintenance are insufficient to cover all municipal infrastructure maintenance and repair needs, maintenance deficits accumulate and infrastructure deteriorates more rapidly, leading to premature failures that in the end result in higher expenditures and lower returns for the investments. The maintenance deficits are caused, in part, by the lack of information about the condition of the assets. Efficient and suitable decision-support tools, loaded with quality data, are vital to assist managers in their efforts to allocate funds more efficiently to preserve an adequate and sufficient infrastructure network in overall good condition.

## **2.2 Implementation of Computer-Based Tools for Asset Management**

In the last two decades, the use of computer-based asset management systems has significantly improved the operational efficiency for preserving infrastructure assets (Halfwy, 2006). In the context of infrastructure asset management, reliable information is the key to better decision making processes (CERF, 1996). In order to reduce maintenance, repair and renewal costs, municipalities need to rely on trustworthy, complete and up-to-date data, solid engineering principles and accepted economic values. The tools that serve to this very purpose can deal with the inventory and condition data management and reporting, maintenance management, operation management, multi-objective optimization, life-cycle cost analysis (LCCA) probabilistic deterioration models, or analytical simulation tools for performance (Halfwy, 2002).

Multiple computational tools have been incorporated in asset management systems. The most popular tools are Computer Aided Design (CAD), CAD Facilities Management (CADFM); and relational databases such as the Computerized Maintenance Management Systems (CMMS) and Geographical Information Systems (GIS). The latter offers great advantages for the modern asset manager as it is an exceedingly powerful and expandable tool that is becoming the norm for asset managers. GIS systems will be discussed more deeply within the context of infrastructure asset management in the following section.

## **2.3 Geographical Information Systems: 21st Century Tool for Asset Managers**

GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows the user to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts (Chang, 2011). Some of the operations where GIS can be a helpful tool are data storage, mapping, data exchange, decision support, engineering analysis, and planning (Chang, 2011). According to Artz (2009), the advantages of geospatial data and GIS usage are many, which include:

- Greater efficiency that translates into cost savings;
- Better decision making;

- Improved communication among teams and departments;
- Better geographic information recordkeeping; and
- New paradigm by geographically managing assets.

As outlined by Pryzbyla (2002) the seven major obstacles to successfully implement GIS in public works functions are the following:

1. Clear and quantitative definition of financial payback at the beginning of the project;
2. Lack of vision for GIS implementation and advantages;
3. Treatment of GIS as a mere technology (not a people issue);
4. Internal bureaucratic barriers;
5. Balancing whether projects will be developed in-house or outsourced;
6. Budgeting and financial aspects; and
7. Treatment of GIS as a capital expenditure, as opposed to an operating expense.

Once these obstacles have been overcome and the system is implemented, GIS is recognized as a versatile tool for its ability to capture, store, and manage spatially referenced data such as points, polylines and polygons (vector data), or as continuous fields (raster data). GIS assists in modeling applications and managing data that would otherwise be compromised or impossible to store in aspatial databases. In addition to managing vector and raster data, it can also serve as a platform to establish multiple relationships across the data records including additional tables and documents that lack spatial properties but are interrelated with the model being described. Map-based engineering analyses are also benefited with the use of GIS technologies. Common operations such as area and perimeter computation, flow path length measurement, and nearest distance determination, can be performed seamlessly and used to derive model-dependent parameters (Miles, 1999).

Presenting analyses results on a map is one of the greatest advantages of GIS implementation. Spatial and aspatial correlations and parameters become evident and, in a sense, tangible to the asset managers or engineers working with the data. The interactive character of the asset managers' interaction with the generated information opens a new dimension to the usage of GIS. The



revolutionary fashion to interactively display the data, leads to the discovery of new, otherwise hidden relationships.

There are several technologies related to GIS that enhance its capabilities and facilitate the implementation of decision-making frameworks. The following are some of the widely utilized tools to gather data employed in GIS: Global Positioning System (GPS), Portable Digital Assistants (PDA) and Mobile Computing, and Remote Sensing.

### **2.3.1 GPS**

The GPS system makes use of a network of 24 Navigation Satellite Timing and Ranging (NAVSTAR) satellites around the earth following precise orbits. It was developed by the US Department of Defense and became fully operational in 1994. Its use has been opened to the public for accurately determine positions around the globe. The high end GPS devices can achieve accuracies of up to subcentimeter differential, with the usage of carrier phase and dual frequency receivers (Chang, 2011).

### **2.3.2 PDAs and Mobile Computing**

While advantageous in the field for their small, handheld format, PDAs are powerful tools. If combined with GPS technology, PDAs can be of great help when collecting information in the field allowing for seamless data entry on pre-fabricated input sheets, visualizing collected data on-the-fly, and minimizing the risk of errors in data transcription to the main database. Mobile computing provides a similar service to PDAs, except that the more robust hardware (i.e. processors, monitor, full keyboard, etc.) present in mobile computing permits more complex operations and a ‘full’ interface. However, these systems have limited mobility when compared to PDAs and the price range is still high, comparatively.

### **2.3.3 Remote Sensing**

In the GIS context, remote sensing refers to the gathering of information by using images collected with the aid of aircraft or satellite. Indeed, this method of data collection is a very practical and economical alternative to field surveys to locate exposed infrastructure such as buildings, roads, or

manholes. However, the usefulness of this technique is hindered when the visibility is limited (e.g. when surveying underground utilities, or when interference exists because of vehicles, trees or buildings, etc.) and the geospatial accuracy is deficient when compared with GPS technologies.

## **2.4 Basics of Fiber Optics and its Relevance as a Manageable Asset**

Among the infrastructure systems that municipal asset managers across the country oversee, telecommunication assets are one of the key elements of such systems, as they are the base for efficient communication that permits the functioning of municipal governments. One of the pillars of a modern telecommunication network, due to the ongoing transformation from narrow-band to broadband, is the fiber optics system of a municipality; the importance of which is described hereafter.

Municipal or regional Governments or stakeholders need safe, efficient, and reliable telecommunication systems that involve sizeable investments in infrastructure to transfer data and information between buildings to the desktop terminals or computers (Goff, 1999). One of the examples within a public infrastructure management scheme where fiber optics plays a major role is the Intelligent Transportation Systems (ITS). The reach of ITS can be varied in extent and can include smart highways with intelligent traffic lights, automated tollbooths, and changeable message signs, and video controlled management of traffic (Alwayn, 2004).

Fiber optics have become the industry standard for the terrestrial transmission of telecommunication information and will continue to be a major player in the delivery of broadband services. More than 80 percent of the world's long-distance traffic is carried over optical-fiber cables. Applications of fiber optics technology are widespread and involve the transmission of voice, data, and video over distances of a few feet to hundreds of miles. Carriers use optical fiber to carry analog phone service. Cable television companies also use fiber for delivery of digital video services. Intelligent transportation systems and biomedical systems also use fiber-optic transmission systems. Optical cable is also the industry standard for subterranean and submarine transmission systems (Alwayn, 2004; Hecht, 2006).

Cities, especially in downtown areas, are crisscrossed with underground and above-ground utilities installations. In the case of fiber optics, which include Junction Boxes, Conduits, and Cables,

among other elements, the installation is usually done below the surface of the municipal right-of-way using techniques such as open trench when the terrain and application permit, and trenchless techniques such as Horizontal Directional Drilling (HDD) or, more recently in highly congested areas such as downtowns and university campuses, in-sewer or in-pipeline that take advantage of the already existing infrastructure to interconnect buildings or reaching from the backbone to the “last mile” (Atalah, 2002). The complexities of said networks make it elemental for the asset manager to have the latest GIS tools. Figure 2 is an example of what can be found in the field when exploring Junction Boxes in heavy-data traffic areas such as downtowns or universities. It is evident that without a proper asset management system in place, keeping track of hundreds of Junction Boxes, Cables and Conduits would be nearly impossible.



Figure 2: Junction Box Featuring Several Cables and Conduits.

### **Chapter 3: GIS Fiber Optics Asset Management System (GFOAMS)**

During the last 20 years, the City of El Paso, Texas, has been developing a fiber optics network to, among other things, connect its major buildings and facilities and manage its Intelligent Transportation System (ITS) for traffic management control and camera activated signal timing. Due to the large span of time in which installations, additions and repairs to the fiber optics network, the staff heads and technicians have either retired/quit or were transferred to other departments. In the process, valuable data might have been lost due the inherent inflexibilities of physical data repository structure, and the unorganized know-how transfer. Due to the ITS department fiber optics management unification efforts taking place in The City of El Paso since the year 2006, the conversion and access of reliable and updated physical installations and paper records through a modern and interactive tool such as GIS has become a need in the 21st Century (Ozogar, 2011; Leyva, 2011).

With the vision to enable the City of El Paso to make more effective decisions based on reliable fiber optic infrastructure information, which would be accessible through GIS software, a project was conducted to develop the GIS Fiber Optics Asset Management System (GFOAMS) for the City of El Paso. The latter came about after a need was recognized for the verification and subsequent updating of information regarding the municipal fiber optic infrastructure system, along with additional data collection in an easily accessible framework in GIS.

The GFOAMS forms part of an ongoing project to digitize the data pertaining to infrastructure assets of the City of El Paso. So far, the program involves fiber optics, stormwater drainage, and transportation.

The project involved the review of existing records to extract data for the fiber optics network, and a series of supervised field surveys to verify and collect data for the network. It was very important for this effort to discard erroneous data or to streamline existing attributes in order to have a reliable system. Figure 3 is an example of the anomalies found in the databases. Finally all the information gathered passed through an integration process that finally lead to the development of the development of the GFOAMS.

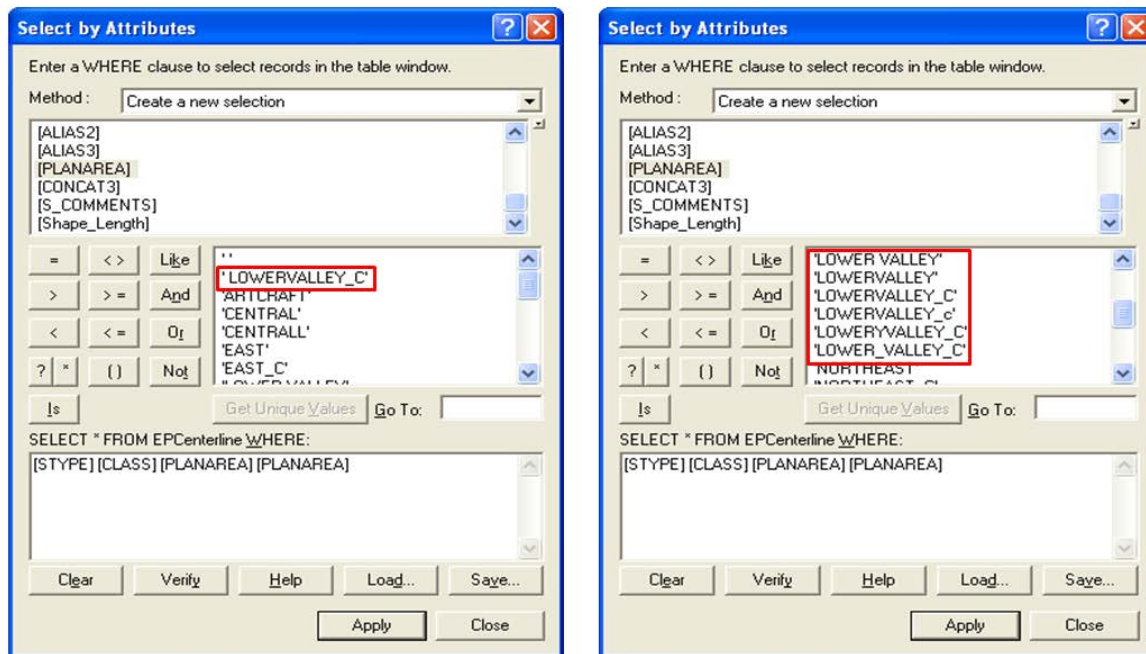


Figure 3: Example of an Anomaly Found in the Original Databases.

The need for extensive in-field surveying of the infrastructure and the substantial amount of lab work analyze and process to the collected data, the City of El Paso decided that outsourcing the project to the university was the best option. Although certain common GIS practices exist among municipalities and local governments, the potential for developing a single GIS solution that will serve the specific needs of many counties is minimal (Venigalla, 2007). The latter exemplifies the need to decide if it resulted more convenient to implement a pre-developed package or to develop an in-house solution.

In order to select the most appropriate platform in which to develop the GFOAMS framework, several software packages were analyzed. Some of them were stand-alone GIS software solutions and some were add-ons to GIS ‘mother’ software such as ESRI’s ArcMap 10. At the end, it was deemed that the option that had the highest cost-benefit ratio that would translate into a much more successful execution and implementation of the project was an in-house solution using off-the-shelf tools in ArcMap 10. The reasons included, but were not limited to:

- The City of El Paso’s Geographic Information Systems Division has already been working with ArcGIS for more than ten years;

- The Regional Geospatial Center at the University of Texas at El Paso is a high-level expertise center with ample experience in the management of ArcGIS;
- Data standardization purposes within both organization; and
- No additional investment needed, as the city already has access to ESRI's ArcGIS licenses.

### **3.1 Fiber Optic Systems**

After deciding upon the main layers of the GFOAMS framework, one of the first tasks was to decide upon a specific set of characteristics, or attributes that must be collected. GPS, PDAs and Remote Sensing were the mixture of the GIS tools used. This process was a combination of:

- 1) Deciding upon which layers to collect information. It was chosen to survey the three most important components of the network that are: (1) the Junction Boxes that house the splices (junction points within a two fiber strands are joined together making a continuous optical guide) and allow the handling of the Cables, (2) the Conduit Runs that are the longitudinal stretches of underground Conduit to connect point A to point B, (3) and finally the Cables that carry the information. Additionally, a table was created to keep track of the Cable slack that accumulated in the system;
- 2) Analyzing existing records in paper (drawings, schematics, design and as-built plans, etc.);
- 3) Carefully revising of what attribute categories were missing or deemed unnecessary from historic records;
- 4) Cross checking list attribute categories with stand-alone or add-on software solutions evaluated; and
- 5) Discussing with the City of El Paso personnel the collection strategies for this project and for the future.

Once all the attribute categories were decided upon, an interface for the PDA-based GPS location system used, the Trimble® Geo XT, in ArcPad 8.2. The usage of a PDA based GPS system, including a 'field survey template' to be used when collecting information, helped the seamless data transfer minimizing errors by the usage of pre-established fields and dropdown menus. Also, notes were taken using a paper form, where information regarding the actual schematics on the field or complex



questions that arose, was carefully written down. Additionally, pictures and measurements were taken to complement the geospatial information gathered. Figure 4 and Figure 5 are examples of the field surveys that were executed for the GFOAMS project.



Figure 4: Fiber Optics Surveying Crew at the El Paso Airport.



Figure 5: Fiber Optics Surveying Crew in Doniphan Park Road.

In the GFOAMS project a total of twelve main fiber optics systems that connect city buildings and facilities such as police departments, fire departments, municipal courts, health administration building, public transportation facilities/Sun Metro, libraries and others, were surveyed. The systems included: Backbone, Doniphan, Piedras, Hawkins/Airport, Downtown, TMC-1 (Airway Boulevard), TMC-2 (George Dieter Drive), TMC-3 (Sunland Park), North Doniphan, Redd Road, Fonseca, Yarbrough, and Zaragoza. Also, several segments connected to the aforementioned systems were also surveyed (e.g. Mesa Hills Drive and the Pat O'Rourke Recreational Center). For many of the systems, subsystems were recorded to indicate which major facilities are connected using the different Junction Boxes and Conduits.

Table 1 provides information about the systems included in the GFOAMS project, including location, general direction, and number of Junction boxes, Conduit, and Cables.

Table 1: Fiber Optics Systems in GFOAMS

System Name	Location	Direction	From	To	Junction Boxes	Conduits	Cables
Backbone	City-wide	East-West (Misc)	N/A	N/A	88	99	15
North Doniphan	Westside	North-South	Mesa	Borderland	31	30	19
Downtown	Downtown	Misc.	N/A	N/A	128	163	43
Fonseca	Eastside	North-South	Cesar Chavez	Delta	14	13	1
Redd Rd.	Westside	East-West	I-10	Mesa	14	13	3
Doniphan	Westside	North-South	Osborne/Sunset	Doniphan Park	23	24	3
Piedras	Central	North-South	Montana	Wyoming	6	5	2
Hawkins/Airport	East Side	Northwest-Southeast	Stinson	Long Term P. Lot	45	43	4
TMC-1	Eastside	North-South	1-10	Founders	43	42	19
TMC-2	Eastside	North-South	Vista del Sol	Montana	35	34	16
TMC-3	Westside	East-West	Mesa	Doniphan/Frontera	49	49	30
Yarbrough	Eastside	North-South	Vista Del Sol	San Paulo	21	27	6
Zaragoza	Eastside	North-South	Rojas	Cesar Chavez	80	80	30

The next subsections explain in further detail about the systems that appear in Table 1. If subsystems were recorded, it will be mentioned into each major system's description.



### 3.1.1 Backbone System

The Backbone system fiber connects many of the systems running through El Paso with the City Hall. It covers approximately 26 miles. The Backbone system was not surveyed, and was only integrated into the GFOAMS based on data and GIS files provided by the City of El Paso. Due to the extensive nature of the Backbone system, eleven subsystems run through this trunk line. Three examples of the subsystems would be: City Hall (CH) to Northwest Corral, CH to Police Department Headquarters, or Fire Department Headquarters to Police Department Headquarters.

The Backbone system is represented in Figure 6 and includes:

- 88 Junction Boxes,
- 15 Cables, and
- 95 Conduit Runs.

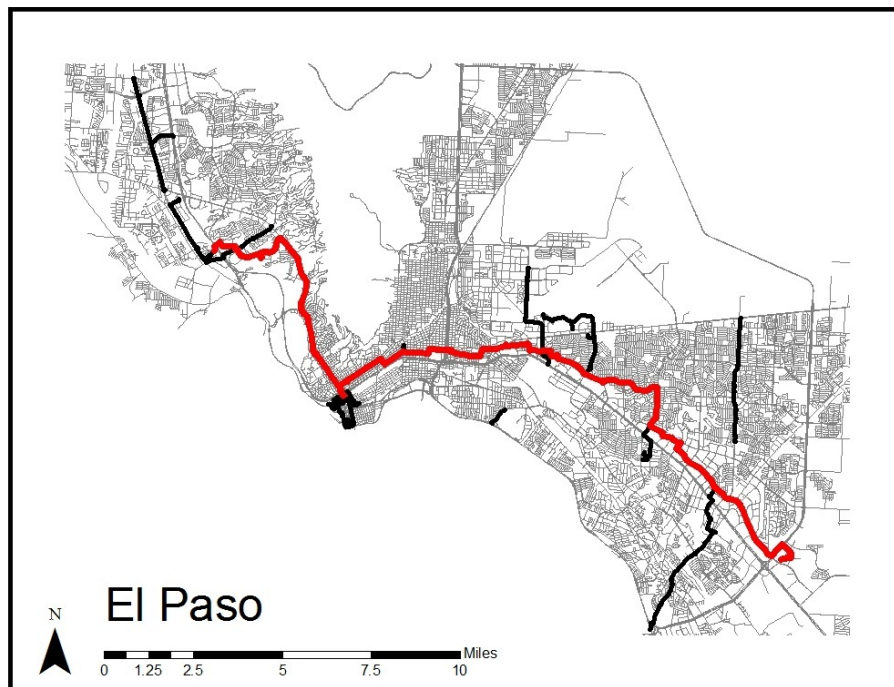


Figure 6: Layout of the Backbone System in the GFOAMS.

### 3.1.2 North Doniphan System

Traffic Management makes use of the North Doniphan system. It connects controllers and cabinets and enables monitoring of Closed Circuit Television (CCTV) cameras. Covering approximately 3.5 miles, the N. Doniphan system runs along Doniphan St. from Mesa St. to Borderland Rd.

The North Doniphan system is represented in Figure 7 and includes:

- 31 Junction Boxes,
- 19 Cables, and
- 30 Conduit Runs.

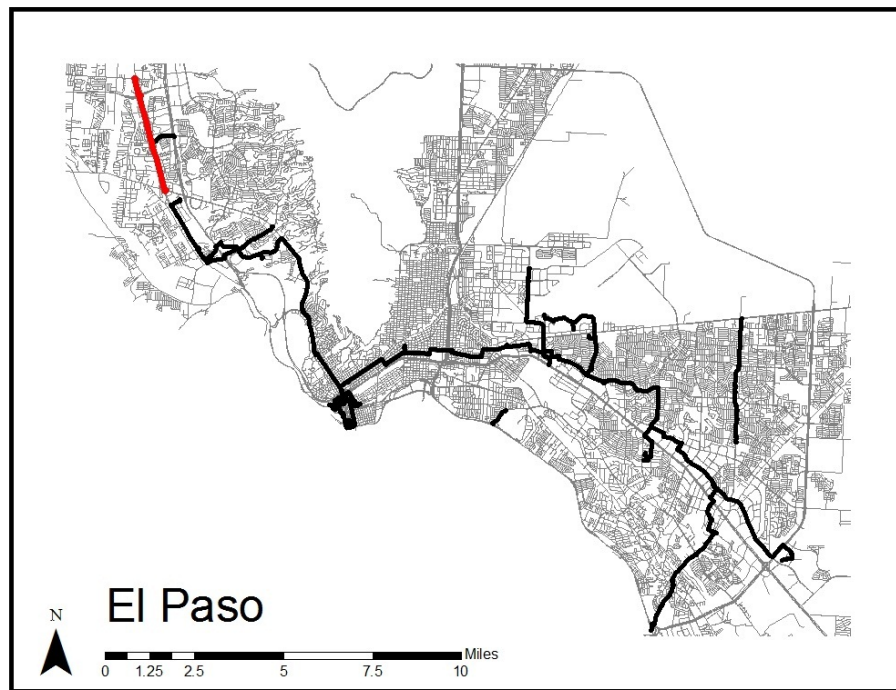


Figure 7: Layout of the North Doniphan System in the GFOAMS.

### 3.1.3 Downtown System

The Downtown system covers approximately 7.5 miles. Some of the main streets it runs along are Campbell St., Chihuahua St., Durango St., Missouri Ave., San Antonio Ave., Santa Fe St., and Stanton St.. The following are three of the almost twenty subsystems currently included in the Downtown System: City Hall (CH) to Downtown Transit Terminal, CH to Paso del Norte Bridge, and CH Traffic Management to 4th Street.

The Downtown System is represented in Figure 8 and includes:

- 128 Junction Boxes,
- 43 Cables, and
- 163 Conduit Runs.

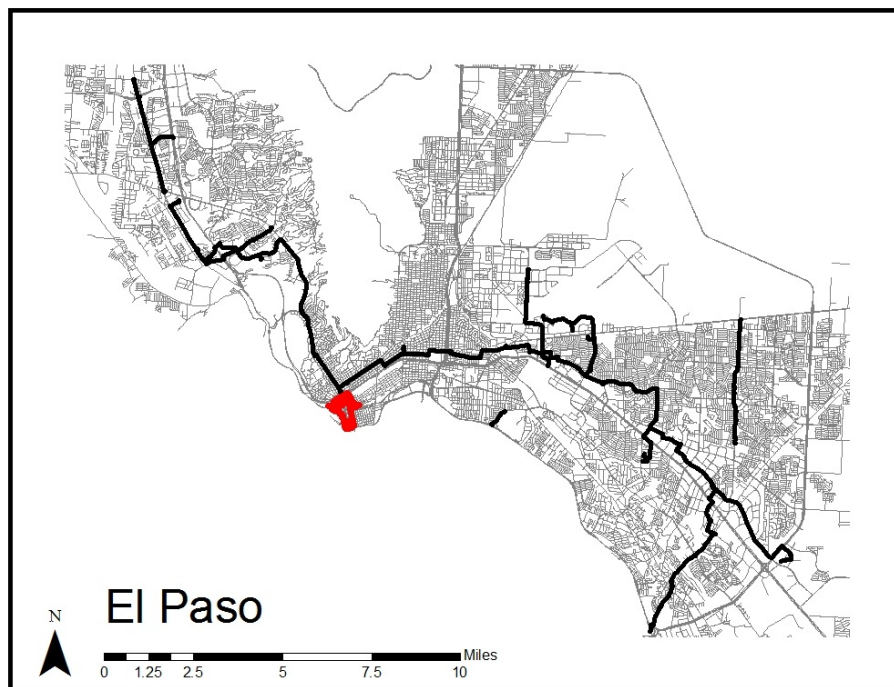


Figure 8: Layout of the Downtown System in the GFOAMS.

### 3.1.4 Fonseca System

With approximately 0.5 miles, the Fonseca system runs along Fonseca Dr. from Cesar Chavez Memorial Highway to Delta Dr..

The Fonseca system is represented in Figure 9 and includes:

- 14 Junction Boxes,
- 1 Cable, and
- 13 Conduit Runs.

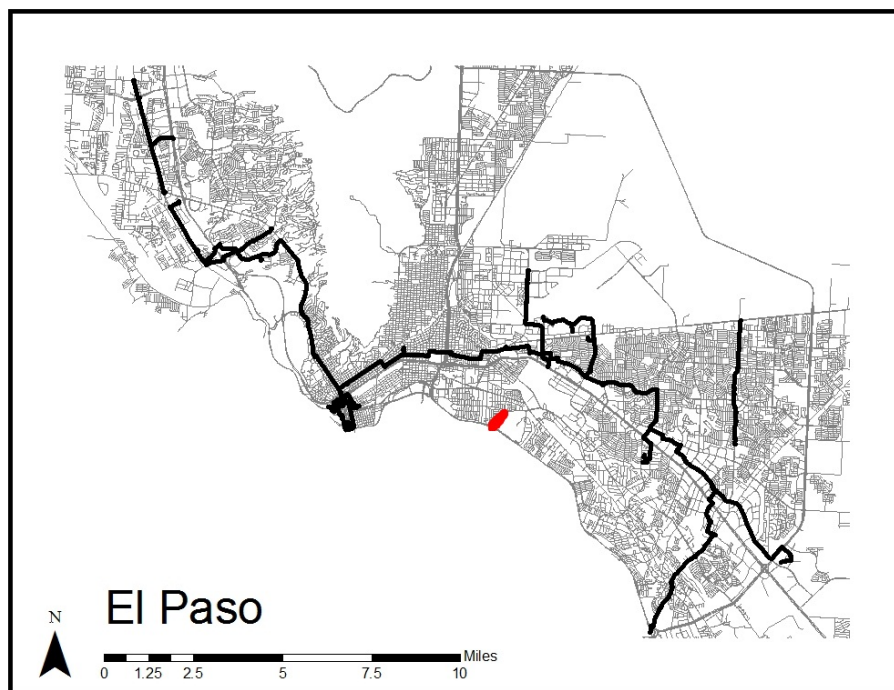


Figure 9: Layout of the Fonseca System in the GFOAMS.

### 3.1.5 Redd Road System

Redd Road is a system utilized by Traffic Management. It covers roughly 0.75 miles and runs along Redd Rd. from Desert Blvd. to Doniphan Dr.

The Redd Road is represented in Figure 10 and includes:

- 14 Junction Boxes,
- 3 Cables, and
- 13 Conduit Runs.

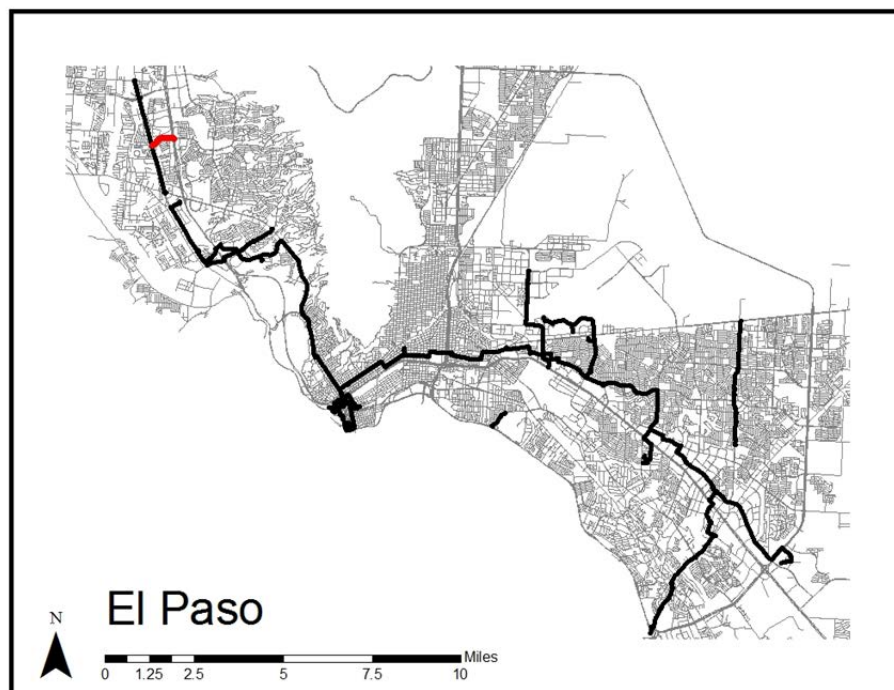


Figure 10: Layout of the Redd Road System in the GFOAMS.

### 3.1.6 Piedras System

The Piedras System covers approximately 0.25 miles. It connects the backbone at Wyoming Avenue with the Five Points Transit Terminal, running north on Piedras Street. The subsystems running through the Piedras system include: City Hall to Police Department Headquarters, and 5 Points Transit Terminal to Police Department Headquarters.

The Piedras system is represented in Figure 11 and includes:

- 6 Junction Boxes,
- 2 Cables, and
- 6 Conduit Runs.

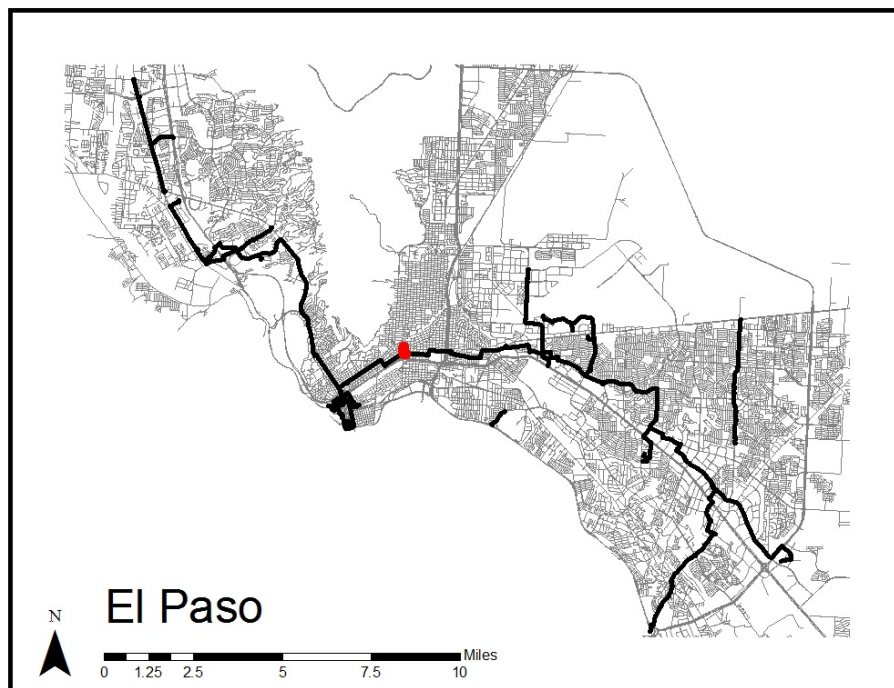


Figure 11: Layout of the Piedras System in the GFOAMS.

### 3.1.7 Hawkins/Airport System

The Hawkins/Airport combined system, which covers approximately 4.25 miles, begins on Viscount Blvd., runs north on Hawkins Blvd., enters into the El Paso International Airport boundaries at the northernmost point of Hawkins Blvd., and runs west until it meets the airport's main terminal. The subsystems running through it include: Fire Department Headquarters (HQ) to Police Department HQ, International Airport to City Hall, WHS Tower, and Fire Department HQ to International Airport.

The Hawkins/Airport system is represented in Figure 12 and includes:

- 45 Junction Boxes,
- 4 Cables, and
- 43 Conduit Runs.

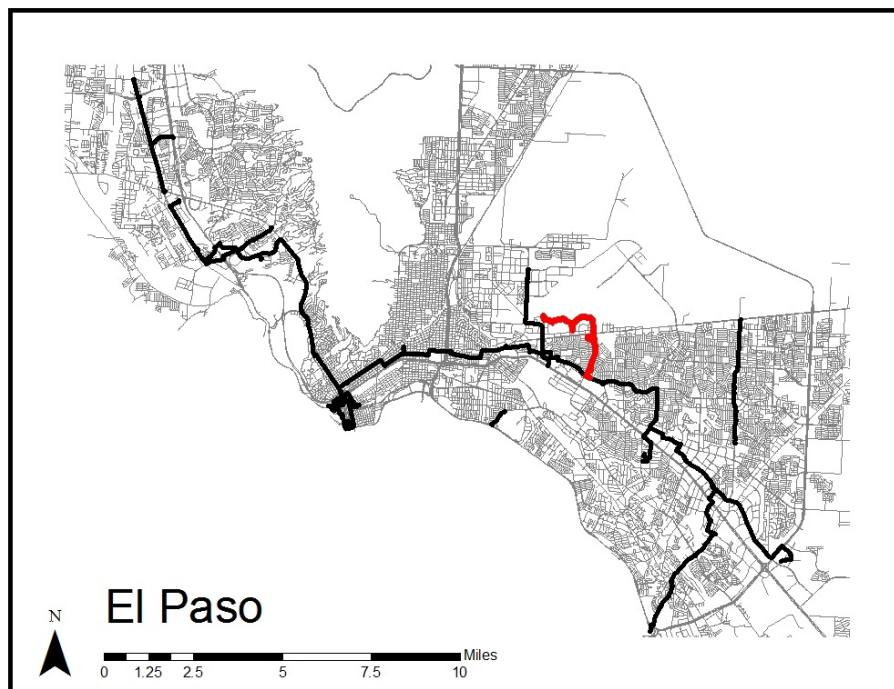


Figure 12: Layout of the Hawkins/Airport System in the GFOAMS.



### 3.1.8 TMC-1 System

The TMC-1 system covers approximately 3.3 miles. It begins at I-10, runs north on Airway Blvd., turns onto Airport Rd. and continues north until Founders Blvd.

The TMC-1 system is represented in Figure 13 and includes:

- 43 Junction Boxes,
- 19 Cables, and
- 42 Conduit Runs.

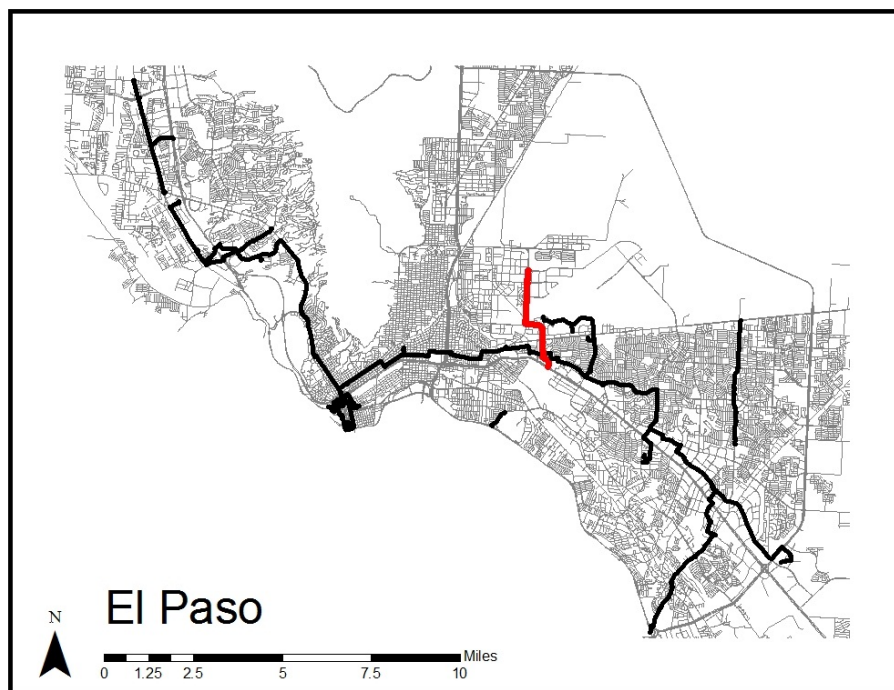


Figure 13: Layout of the TMC-1 System in the GFOAMS.



### 3.1.9 TMC-2 System

The TMC-2 system covers approximately 3.7 miles and runs along George Dieter Dr. from Vista del Sol Dr. to Montana Ave.

The TMC-2 system is represented in Figure 14 and includes:

- 35 Junction Boxes,
- 16 Cables, and
- 34 Conduit Runs.

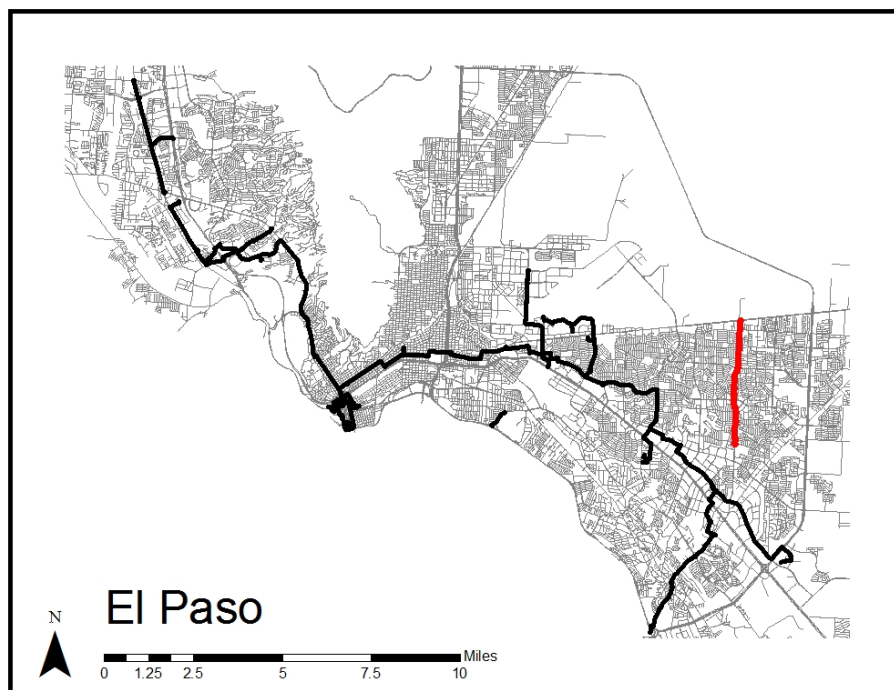


Figure 14: Layout of the TMC-2 System in the GFOAMS.

### 3.1.10 TMC-3 System

The TMC-3 system covers approximately 3 miles. It runs along Sunland Park Dr. and Doniphan Dr., beginning at Mesa St. and ending at the Northwest Regional Command Center.

The TMC-3 system is represented in Figure 15 and includes:

- 49 Junction Boxes,
- 30 Cables, and
- 49 Conduit Runs.

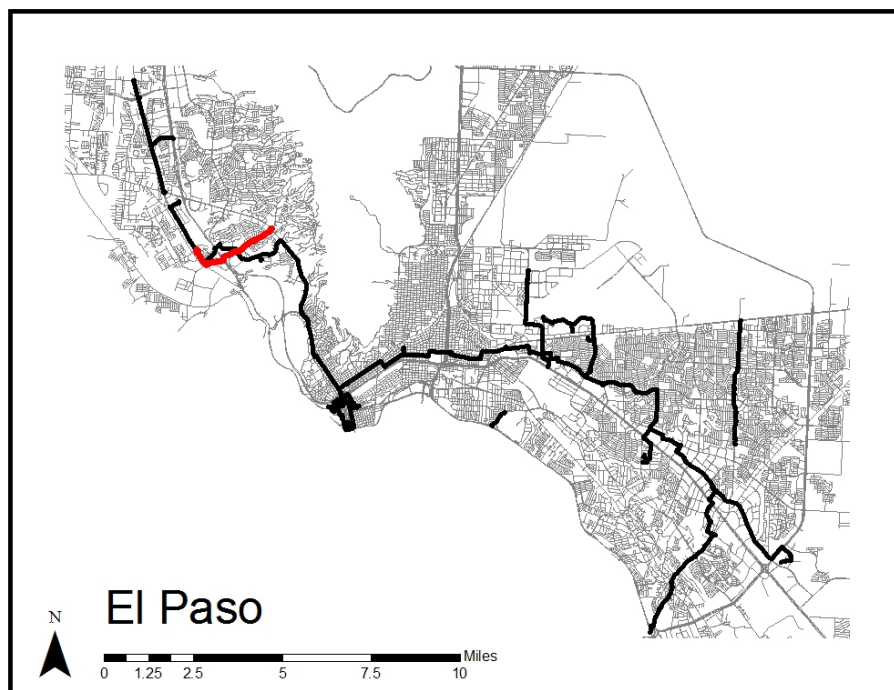


Figure 15: Layout of the TMC-3 System in the GFOAMS.

### 3.1.11 Yarbrough System

The Yarbrough system covers approximately 1.75 miles. It runs along Yarbrough Dr. and Lafayette Dr., beginning at Vista Del Sol Dr. and ending at the Municipal Service Center. The Municipal Service Center to City Hall subsystem was the only one that was recorded for the Yarbrough System.

The Yarbrough system is represented in Figure 16 and includes:

- 21 Junction Boxes,
- 6 Cables, and
- 27 Conduit Runs.

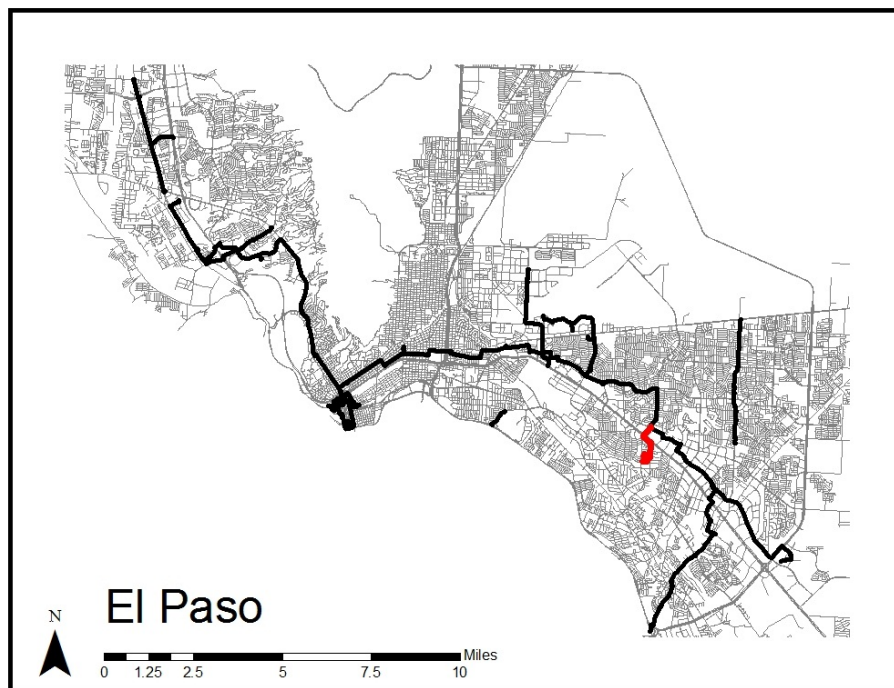


Figure 16: Layout of the Yarbrough System in the GFOAMS.

### 3.1.12 Zaragoza System

The Zaragoza system covers approximately 5.5 miles. It runs along Zaragoza Rd. from Rojas Dr. to Zaragoza International Bridge. The data for this system originated from the internal files of the City of El Paso as it was not surveyed for the GFOAMS. The subsystems running through the Zaragoza System are: Zaragoza International Bridge to Mission Valley Regional Command Center (MVRCC), Mission Valley Transit Terminal to MVRCC, and MVRCC to City Hall.

The Zaragoza system is represented in Figure 17 and includes:

- 80 Junction Boxes,
- 30 Cables, and
- 80 Conduit Runs.

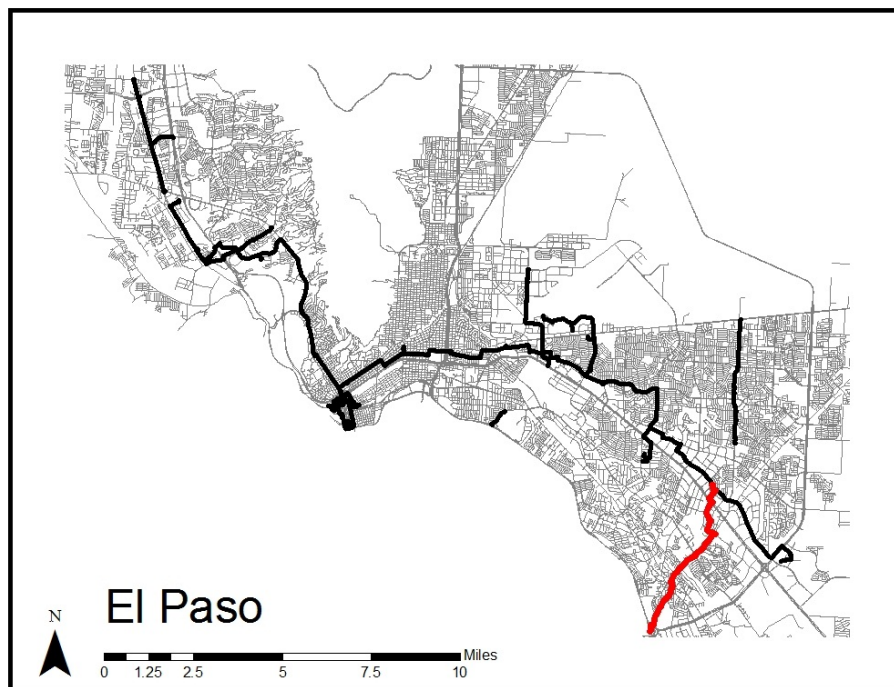


Figure 17: Layout of the Zaragoza System in the GFOAMS.

### **3.2 Quality Assurance and Quality Control Process**

It is imperative for an asset manager to have the certitude that the data that is being analyzed for planning and management purposes is of the highest quality, and updated to the latest developments to represent the current conditions in the field. Hence, to ensure that the data collected had the quality expected, a series of control layers were established. Below is a description of them:

- All the surveys were performed with the aid of at least two crew members of the El Paso Department of Transportation (EPDOT). While photos and all the measurements were taken, the information was confirmed with the veteran personnel in order to accurately record all the required information. Due to the complex system of underground Cables, in addition to years-worth of dirt, dust and debris, it was vital to have individuals in the field whose expertise made data collection process accurate.
- Every two weeks a meeting with the senior staff would take place to formulate questions based on the findings in the field and the photos and measurements taken. Once the team made sure that the data represented accurately the infrastructure in the field, the GFOAMS database would be updated. Figure 18 is an example of the diagrams that were made to discuss the routes that Cables followed in complex segments of the systems with the City of El Paso personnel.
- At the moment of data transfer to the main database from the handheld devices, a back check with the notes taken in the field would be performed. Also, remote sensing using high resolution aerial imagery was used to corroborate the location of the surveyed features.
- A total of three preliminary deliveries of the GFOAMS product were made to make sure that it conformed to the requirements and norms of the City of El Paso. If questions came up from these deliveries, they were quickly clarified in the bi-weekly meetings.

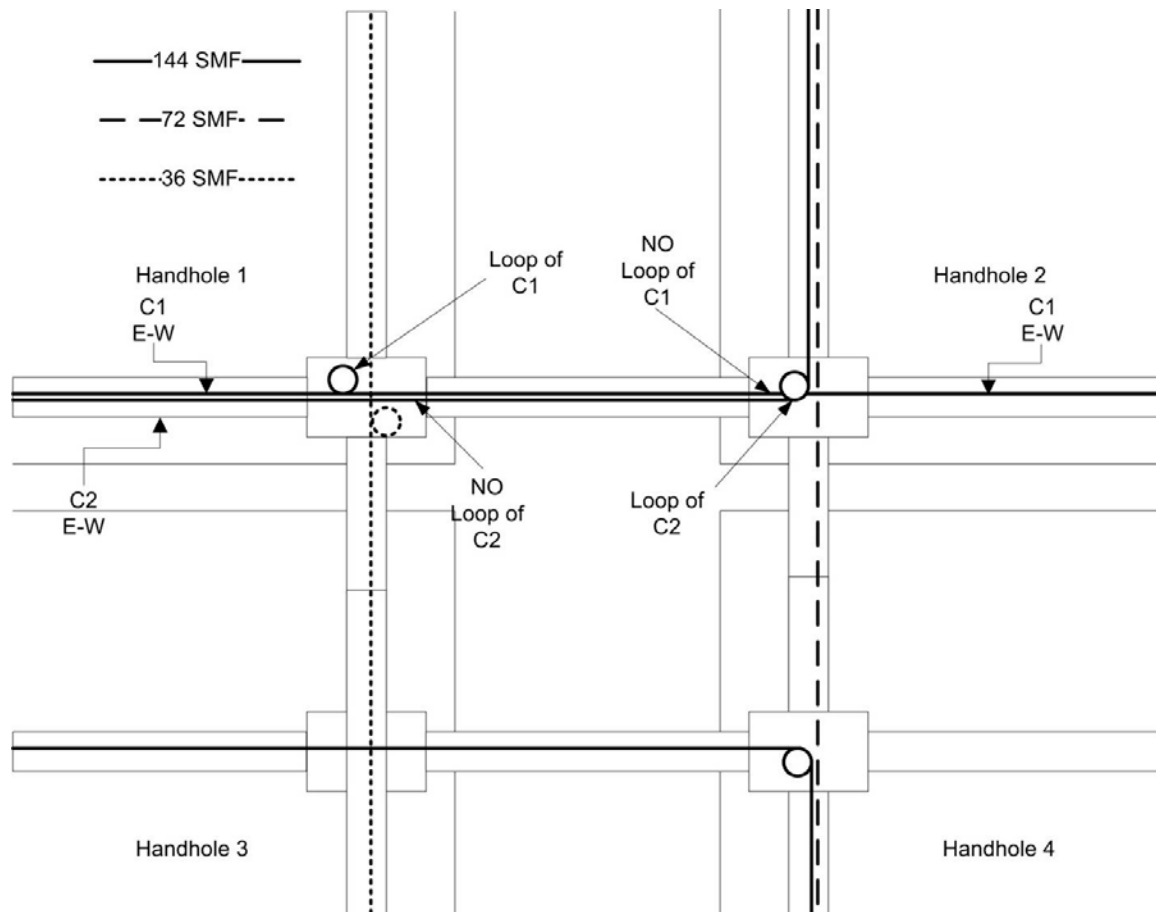


Figure 18: Sample Diagram of Cable Paths in Downtown Area.

### 3.3 GFOAMS Framework Structure

Features related to the fiber optic systems in the City of El Paso were identified and recorded. They were subsequently entered into the framework, defined by Halfwy (2002) as “a computational model that defines a reference architecture and provides a number of common domain-specific services that are required to implement the software.”

The GFOAMS framework is composed of three individual layers: Junction Boxes, Conduit Runs, and Cables. These layers house the feature attribute data collected in the field. Each provides a geographic representation of the feature and is are represented in the ArcMap as either a geographically referenced point or polyline. In addition to geographic representation, each layer houses a unique feature Attribute Table within ArcGIS, allowing information/metadata on individual features to be referenced.

Figure 19 shows the main structure of the GFOAMS framework which is composed of three distinct modules accessed through the GIS map-driven interface: (1) the inventory module, (2) the documents module, and (3) the images module. One of the advantages of using an expandable platform for the GFOAMS is that the framework can be adapted to include additional modules in the future. Each module is discussed in further detail in the following subsections.

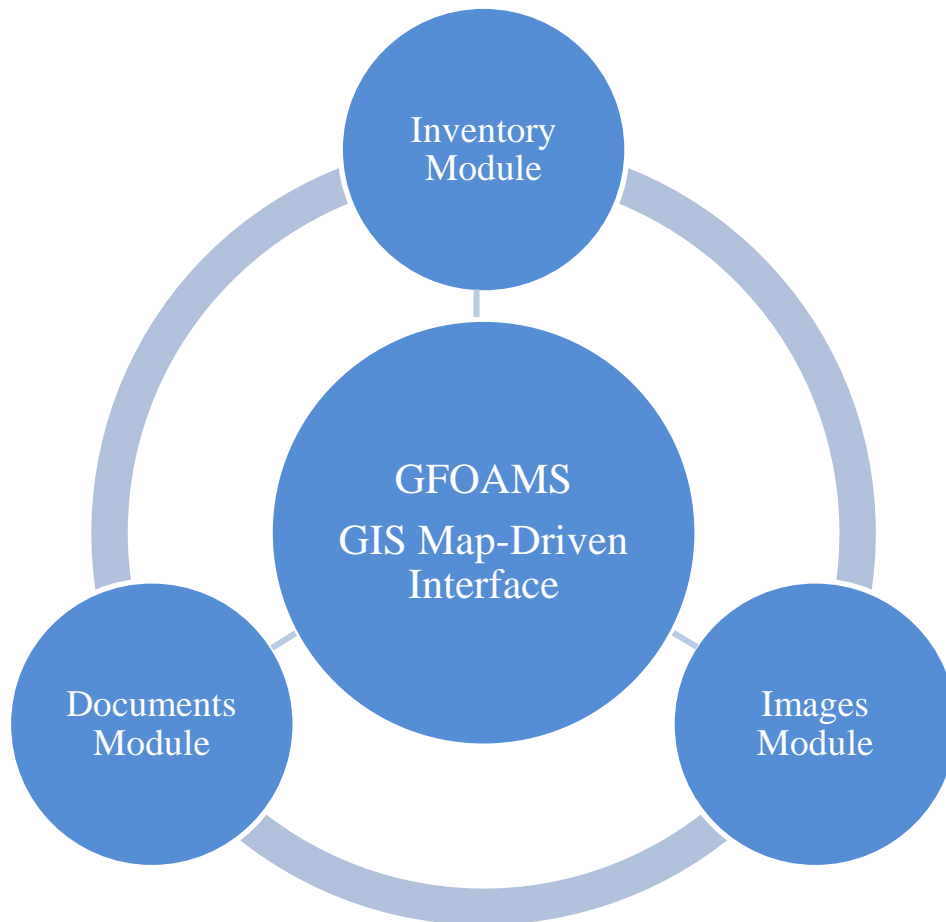


Figure 19: GFOAMS Framework Modules.

### 3.3.1 Inventory module

The inventory module consists of three tables that represent a component of the fiber optics infrastructure system for the City of El Paso. Each table stores information on the main attributes of a type of asset (e.g. a Conduit Run, a single Cable or a Traffic Management Cabinet). The attributes may

be relating to inspection date, material, depth or many others, depending on the specific table being discussed. In order to readily access the data across the different tables, a series of Relates, an ArcMap functionality that allows the user to make connections between different tables based on specific attributes. The data dictionary presented in Table 2 displays the titles of the chosen attributes for the Junction Boxes, Conduit Run, and Cables layers. Also, an additional table was included in the GFOAMS to keep track of the slack in Cables for future use in attenuation calculations or similar applications.

Table 2: List of Fields of Attributes Collected for GFOAMS

<b>Junction Boxes Layer</b>	<b>Conduit Runs Layer</b>	<b>Cables Layer</b>
Comments	Application	Actual Db Loss
Conduit 1	Cable ID 1	Calculated Db Loss
Conduit 2	Cable ID 2	Cable Size
Conduit 3	Cable ID 3	Comments
Conduit 4	Cable ID 4	Conduit ID
Conduit 5	Cable ID 5	Construction Year
Conduit 6	Cable ID 6	Cumulative Db Loss
Depth	Cable ID 7	Cumulative Length
Document Link 1	Cable ID 8	Dark Fiber Strand(s)
Document Link 2	Color	Input Date
Document Link 3	Comments	Editor Name
Input Date	Conduit Location	Fiber Count
Editor Name	Conduit Size	Fiber Owner
Grantee	Conduit System	Identification Number
Identification Number	Conduit Type	Lit Fiber Strand(s)
Images	Input Date	Maintenance
Image Link	Editor Name	Manufacturer
Image Link 2	Fiber User	Mode
Junction Location	Grantee	Object Identification Number
Junction Type	Identification Number	Shape*
Length	Image Link	Shape Length
Maintenance	Maintenance	Sheath Number
Object Identification Number	Material	Subsystem
Online Link	Object Identification Number	System
Shape*	Service Area	Type
Splice	Shape*	
Subsystem	Shape Length	
System	Street(s)	
Width		

Also, the implementation of Hyperlinks within the Attribute Table of the Junction Boxes allows the user to gain access to the other modules that compose the GFOAMS framework. This method



provides a user friendly access to the information while browsing the map and the features contained in it.

### **3.3.2 Documents Module**

The documents module consists of drawings and maps, design and as-built plans, schematics and other documents are relevant to the features spatially represented in the GFOAMS framework. In fact, the established system before the implementation of the GFOAMS was structured with these elements. The advantage that the framework provides is the ability to spatially relate all features and attributes in an interactive map, giving the user the opportunity to link all the relevant files to be swiftly reached. This is a great improvement from the previous paper document system(or its electronic equivalent, with files and folders) piled up in storage rooms, where relevant documents are out of hand obstructing effective retrieval for management and planning purposes.

### **3.3.3 Images Module**

The images module is the repository where all the images relevant to the infrastructure assets are stored. In every field survey, one or more photos were taken for each Junction Box, and the Cables and Conduit Runs connecting through them. In some occasions, the layout of the Cables inside was so complex that in order to support the measurements being made, several pictures were necessary to express doubts during the bi-weekly meetings; these pictures will also provide further reference for asset managers or personnel in charge of the repair, renewal or replacement to learn more about the actual asset. Pictures are an effective support, and complement the data stored in the tables.

In order to access the pictures, Hyperlinks are established in the Junction Boxes table. To facilitate the view of the sometimes multiple pictures, a Portable Document Format (PDF) file contains the images at medium-high resolution. Similarly, using an attribute field that contains a raster dataset, lower resolution images are stored within the geodatabase (the common data storage and management framework for ArcGIS) to have an alternate way of accessing the images from the map and to avoid the complete loss of the module in case of deletion of images from the repository.

## Chapter 4: Usage of GFOAMS in ArcMap

This chapter is a brief summary of the main functionalities described in the user guide presented to the City of El Paso to illustrate the ease of use of the GFOAMS system (Quintana, 2011).

### 4.1 Editing GFOAMS

One of the most important aspects of an effective asset management system is the constant updating of the databases. New information needs to be added as soon as it becomes available, giving the asset manager the assurance that the data is solid and reflect the conditions in the field.

In the next subsections, specific examples will be described to illustrate the simple and efficient updating process of the created framework.

#### 4.1.1 Adding Comments or Editing Other Existing Fields

Asset managers need to be in close communication with personnel in the field to gain knowledge of the condition of the managed infrastructure. In the event that something out of the ordinary is spotted, such as a blocked Junction Box or an accumulation of dirt/debris on top of one, the personnel in the field may use a PDA device with GPS capabilities to pinpoint the location of the asset; or, conversely, use physical reference location points such as intersections or places of interest, and transmit the information via e-mail to the asset manager to be easily added to the database. If this is performed routinely, a well-populated condition knowledge base can be constructed to schedule routine maintenance operations and preventive actions.

In the GFOAMS, taking advantage of the ArcMap platform, making additions to the database is very simple. The first step is to enter in the Editing Mode of the databases, which is shown in Figure 20.

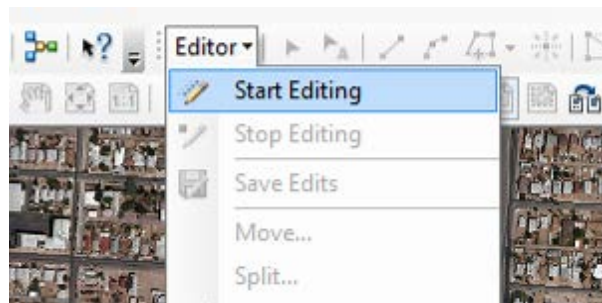


Figure 20: Entering Editing Mode to Make Changes to the Database.

To make changes in the database, the Attribute Table containing the features has to be opened. Once inside this visual interface, which is already inter-related with the rest of the tables representing the rest of the georeferenced layers, the data can be worked with. This process is described for case of the Junction Box layer in Figure 21. The prompt for adding comments is shown in Figure 22.

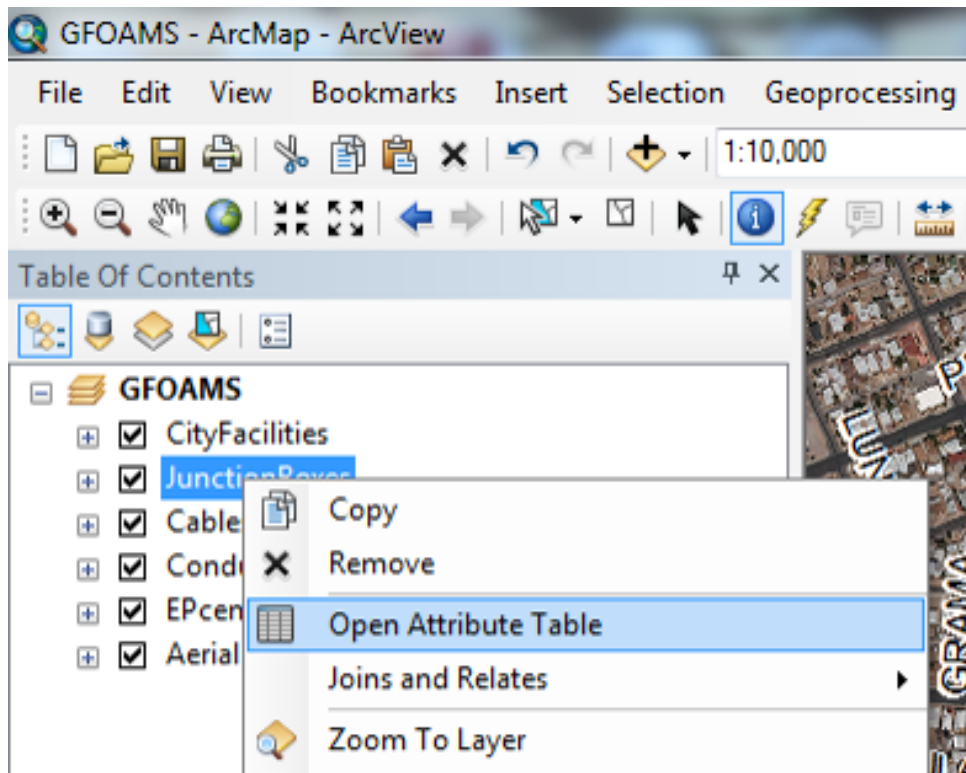


Figure 21: Opening the Junction Boxes Attribute Table to Add Text Data.

OBJECTID *	Shape *	ID	GRANTEE	COMMENTS	IMGLNK	ED
6	Point ZM	332	City of El Paso	X Anomaly found	TMC-1-54	UTE

Figure 22: Entering a Sample Comment to the Junction Boxes Attribute Table.

4.1.2 Editing a Portion of a Feature

If one of the systems that was not surveyed needs to be adjusted in any of its features (Location of Junction Boxes, and Polylines of Conduit Runs or Cables), or a new system needs to be added manually rather than importing the locations collected with the aid of a GPS enabled PDA, ArcMap enables the user to easily modify the existing georeferenced features. Once in editing mode, it suffices to select the desired layer to be edited and to double-click the feature to prop the toolbar to make changes. As shown in Figure 23, a segment of the Backbone fiber could simply be modified, for example, by adding additional vertices to modify its route.

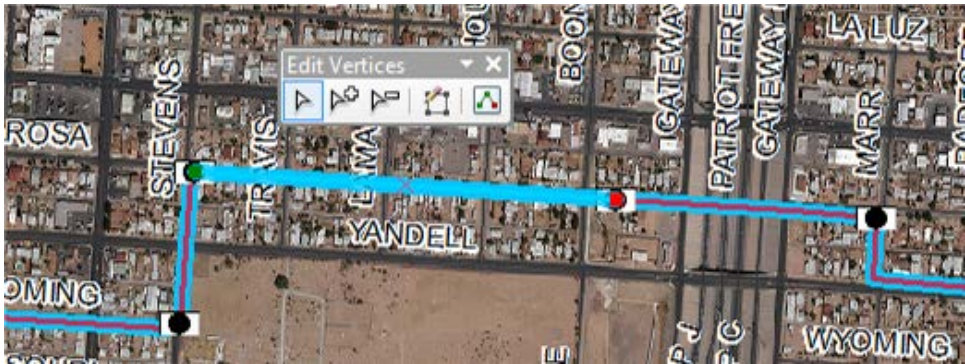


Figure 23: Editing the Path of a Conduit Run.

To facilitate this sort of operations in crowded areas, or when selection of the right feature is difficult, toggling the selection options as shown in Figure 24 can help complete the task.

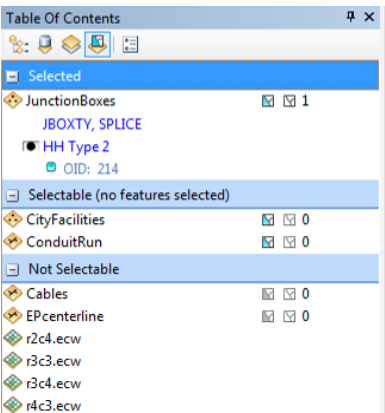


Figure 24: Setting Selection Options.

## 4.2 Navigating in GFOAMS and Locating Features, Systems, or Subsystems

In GFOAMS there are three ways to swiftly locate features or groups of features such as systems and subsystems. The methods make use of the embedded capabilities of the software and of internal conventions when creating the databases. In the next subsections, the navigation by Bookmarks, and searching by attribute queries and Find tool will be briefly explained.

### 4.2.1 Using the Find Tool

The Find tool is the one of the methods to locate features in the GFOAMS. In the example shown in Figure 25, the results that appear in the lower segment of the dialog box represent the features that are identified with the City Hall to (Downtown) Library subsystem. It is now possible to select, zoom or gather information from any of those features.

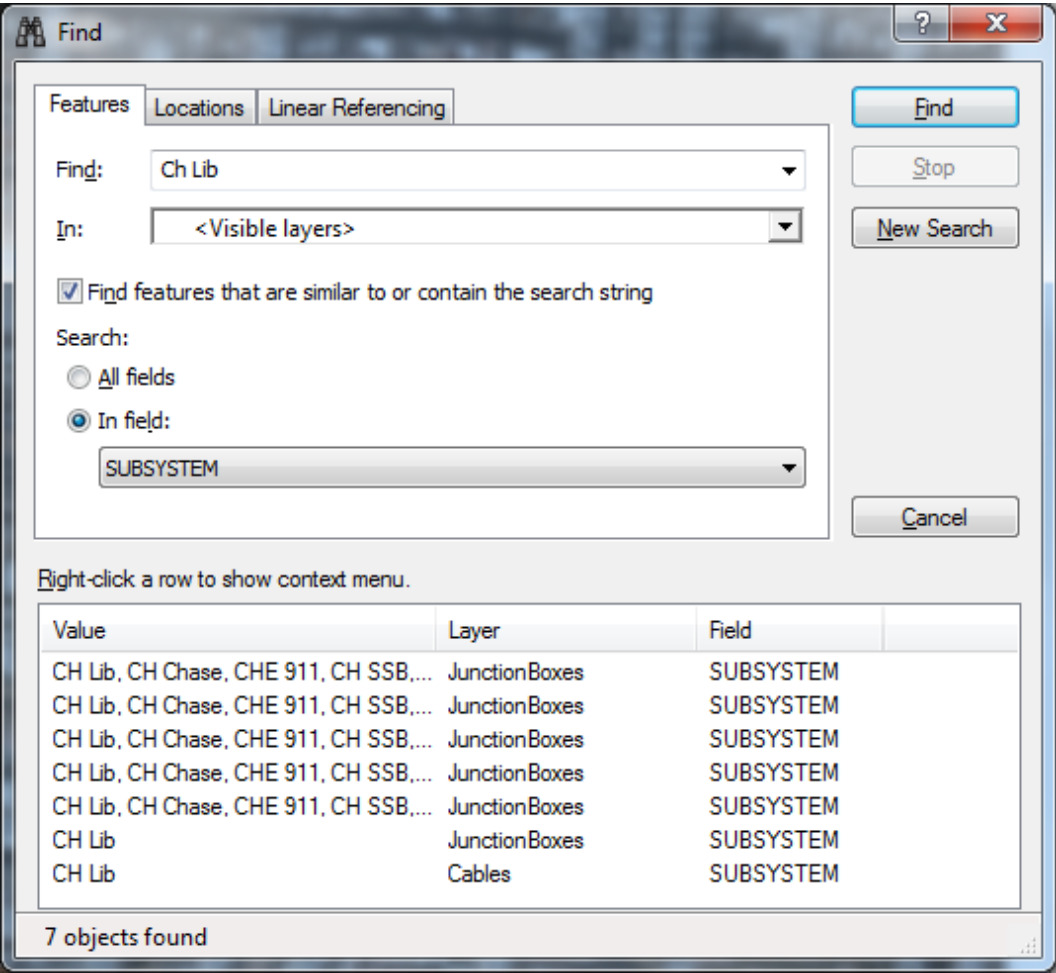


Figure 25: Find Dialog Box Results for City Hall – Library Subsystem.

## 4.2.2 Using the Bookmarks Feature

A total of twelve Bookmarks have been installed into the GFOAMS to facilitate navigation across the systems described in Chapter 3. The Bookmarks are an efficient tool to pan and zoom to desired sections of the map with a single click.

Also, new Bookmarks can be easily added to the GFOAMS by zooming and panning to the desired region of the map by selecting the Create function from the Bookmarks menu.

## 4.2.2 Selecting by Attributes

Features or subsystems can also be located using the Select By Attributes tool. It suffices to generate an SQL expression, such as the one shown in Figure 26. The syntax in this example is in the form *[Subsystem] LIKE '\*Abbreviation (or fragment of it) for the desired subsystem\*'*, and will return a selection of all the features that contain the introduced acronym in the field *Subsystem*. ArcMap allows the user to save the generated queries and load them in the future with ease, which can save precious time to asset managers.

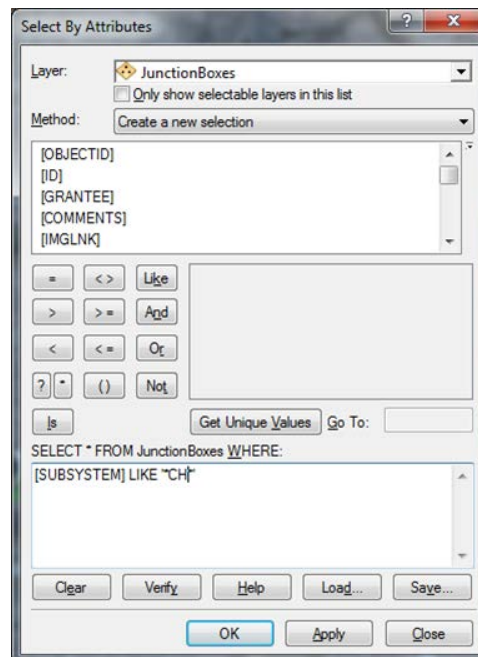


Figure 26: Query Formulation in Select by Attributes Dialog Box.

## 4.2 Browsing Information Pertaining to Features in the Databases

The GFOAMS databases store a wealth of information that is crucial for the asset manager. The inter-related system of tables containing the data allows for a seamless connection among the different features that compose the fiber optics network in the City of El Paso. In order to take advantage of the geospatial dimension of the data, an in-map browsing of the features' information is necessary. In the next subsections, the usage of the Identify tool will be defined along with the established data structure that permits browsing the data.

### 4.2.1 Relates in Attribute Tables

Within GFOAMS a series of relationships (known in ArcGIS as Relates) among the Attribute Tables are established to allow the user to browse information about fiber Cable slack lengths, Conduits adjoined to Junction boxes, and Cables housed within Conduits. Figure 27 shows an example of the Relate dialog box for the Junction Box layer.

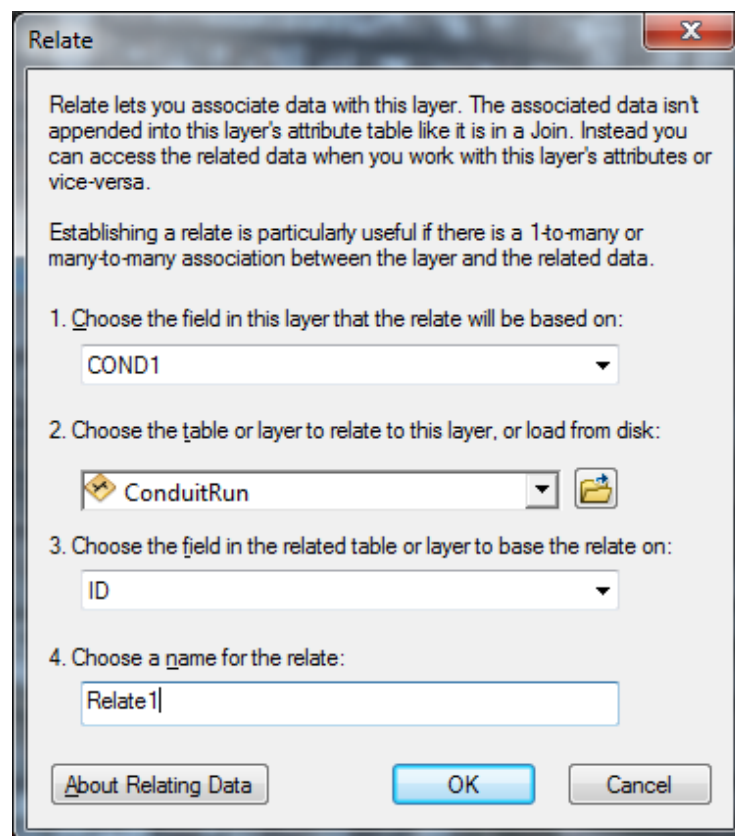


Figure 27: Settings for Sample Junction Box Relate.



In order to give full functionality to the relationships between the layers, a series of similar Relates must be established for different Attribute Tables. The dialog box presented in Figure 28 shows the six Relates that are established within the Junction Box layer.

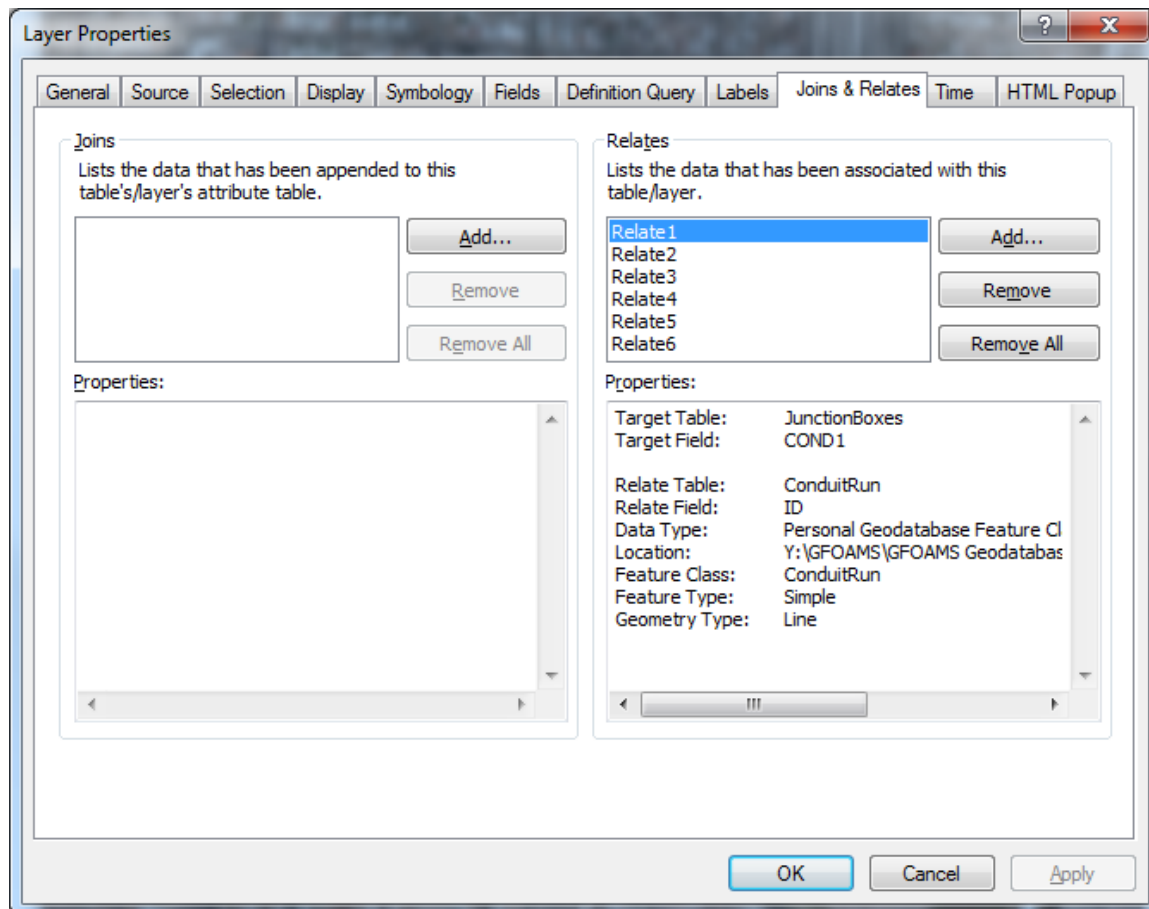


Figure 28: Relates Established in the Junction Boxes Layer.

#### 4.2.2 Identify Tool to Browse Related Features

By using the Identify tool it is possible to gain access to information of the feature being identified and its related features. For example, to access information on the Conduit intersecting with a junction box, the Junction Boxes layer 'tree' must be expanded. The subsequent branches will yield information for features related to those Conduits, namely the Cables hosed in them. Figure 29 shows the 'tree' structure of data that the usage of 'relates' yield.



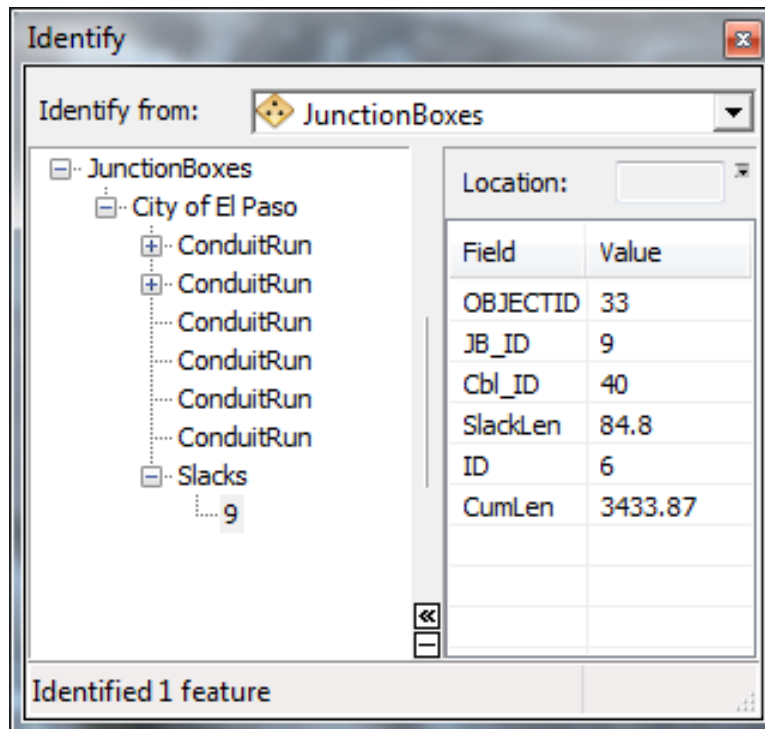


Figure 29: Identify Dialog Box Displaying Features Related to Junction Box.

During the GFOAMS surveys, it was noted that many Junction Boxes contained large amounts of slack Cable left from the installation by design, serving in case of a Cable severing or other eventuality. The City of El Paso requested to record the approximate lengths of these coils and store it in the GFOAMS in a separate 'Slacks' table.

In order to maintain the logic structure of the Relates installed in the GFOAMS, an arbitrary field was designated as the identifier, because the one automatically given by ArcGIS is modified every time a feature is deleted. This would result in an immediate loss of all relationships for the features housed in the GFOAMS.

## 4.3 Accessing Pictures

In order to accurately assess the present condition of the assets and decide on emergency maintenance requirements on tools/equipment and labor, external documents are internally linked to the GFOAMS platform. The new subsections discuss the process of retrieving these files to make use by the asset manager in charge of the network.

### 4.3.1 Accessing Pictures via the Hyperlink Tool

The established system of picture hyperlinks makes usage of the hyperlink tool in conjunction with the hyperlink base within ArcMap. As shown in Figure 30, the hyperlink base is established as an outside source within the same folder as the map file. This, in conjunction with the instruction to store relative pathnames, enables the users of the GFOAMS to simply copy the DVDs delivered into a new computer without breaking the hyperlinks.

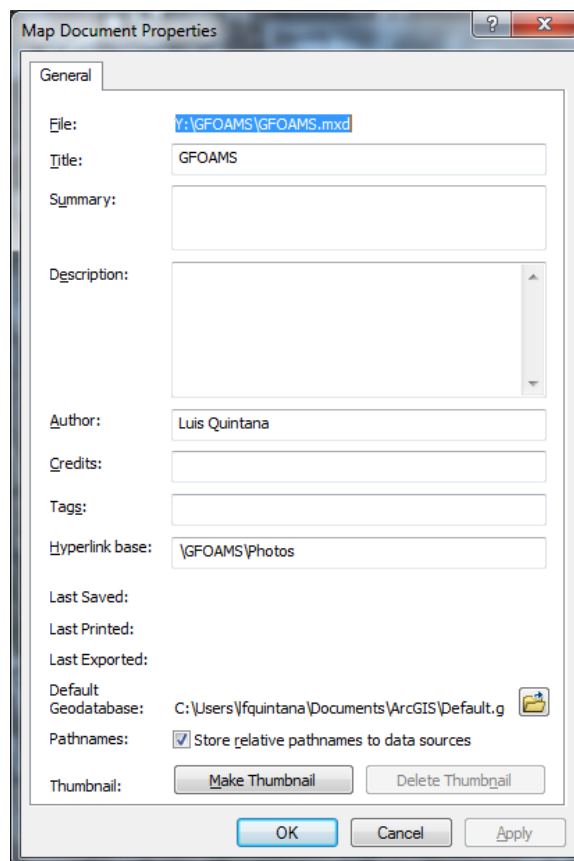
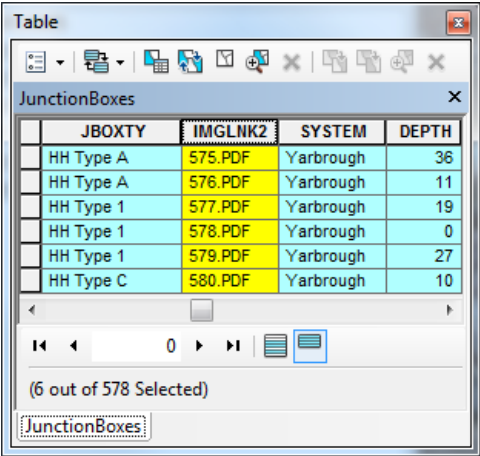


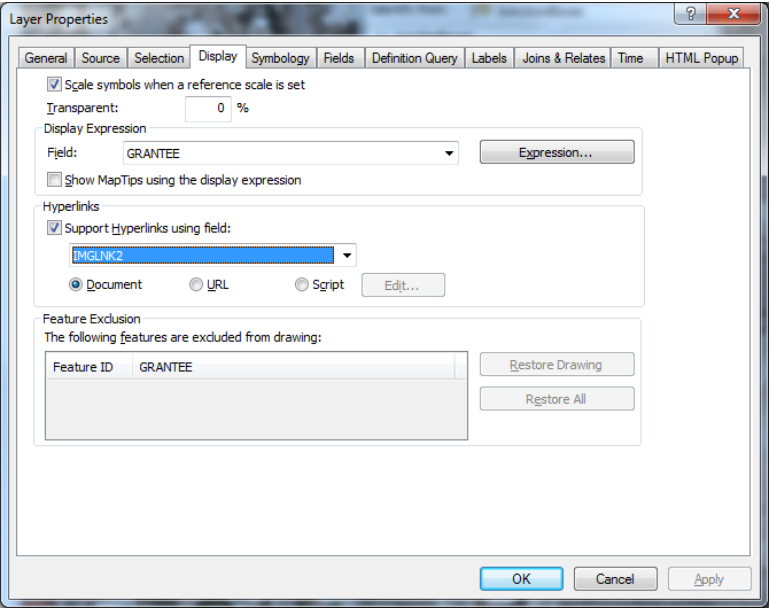
Figure 30: Hyperlink Base and Relative Pathnames Setup.

The pictures taken during the field surveys are stored in the system as PDF files to enable the easy retrieval of the images in case several photos were taken at the same location. As seen in Figure 31, the field IMGLNK2 of the Junction Boxes Attribute Table, is used to store the filenames for the pictures. Accordingly, the hyperlinks are enabled in that layer, using the aforementioned field, as shown in Figure 32.



JBOXTY	IMGLNK2	SYSTEM	DEPTH
HH Type A	575.PDF	Yarborough	36
HH Type A	576.PDF	Yarborough	11
HH Type 1	577.PDF	Yarborough	19
HH Type 1	578.PDF	Yarborough	0
HH Type 1	579.PDF	Yarborough	27
HH Type C	580.PDF	Yarborough	10

Figure 31: Field Containing Hyperlinks to Photos.



Layer Properties

General Source Selection Display Symbology Fields Definition Query Labels Joins & Relates Time HTML Popup

☒ Scale symbols when a reference scale is set

Transparent: 0 %

Display Expression

Field: GRANTEE Expression...

☐ Show MapTips using the display expression

Hyperlinks

☒ Support Hyperlinks using field:

IMGLNK2

☒ Document ☐ URL ☐ Script Edit...

Feature Exclusion

The following features are excluded from drawing:

Feature ID GRANTEE Restore Drawing Restore All

OK Cancel Apply

Figure 32: Hyperlink Display Settings for the Junction Box Layer.

The system put in place to number the Junction Boxes, as described in subsection 4.3.2, is also used for designating names for the PDF documents housing the pictures. For example, the Junction Box ID for the first PDF document shown in Figure 31, 575.pdf, contains photos taken for Junction Box ID #575 in the GFOAMS.

In order to access the pictures the user only has to select the Hyperlink tool and place it atop the Junction Box for which the images are being sought. Once the cursor is in place the path for the PDF file should appear, as shown in Figure 33.



Figure 33: Retrieving Photos Using Hyperlink Tool.

#### 4.3.2 Accessing Pictures via the Identify Tool

Given the importance of asset management systems, redundancy in the storage of the photos taken during the field surveys was built into the GFOAMS. Aside from the hyperlinking of the images described in the previous subsection, the images are also stored directly in the geodatabase that the GFOAMS uses to store the rest of the information pertaining to the network. This will allow the user to access the photos even if the links are broken or the photos are deleted from the system.

In order to access those images, the Identify tool is used to click on the desired Junction Box. Once inside the 'Identify' dialog box, the raster stored in the IMG field can be clicked to pull the photo taken for that particular point. This process is shown in Figure 34.

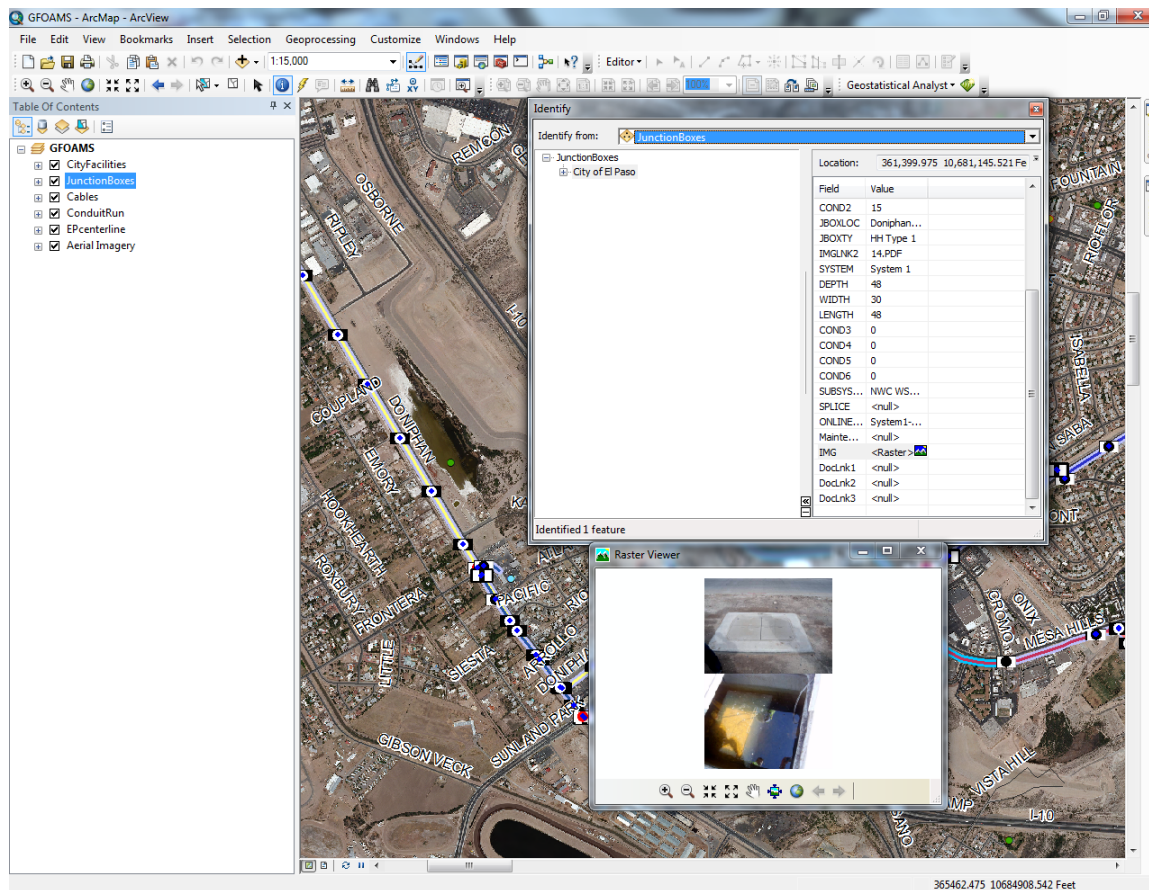


Figure 34: Retrieving Photos Using Identify Tool.

### 4.3.3 Accessing High-Resolution Images Directly on the Hard Drive

In some occasions the labels of the Cables housed in the Junction Boxes are too small to be accurately read on the PDF files described in subsection 4.3.1. It is then that retrieving original high resolution photos taken in the field might be useful.

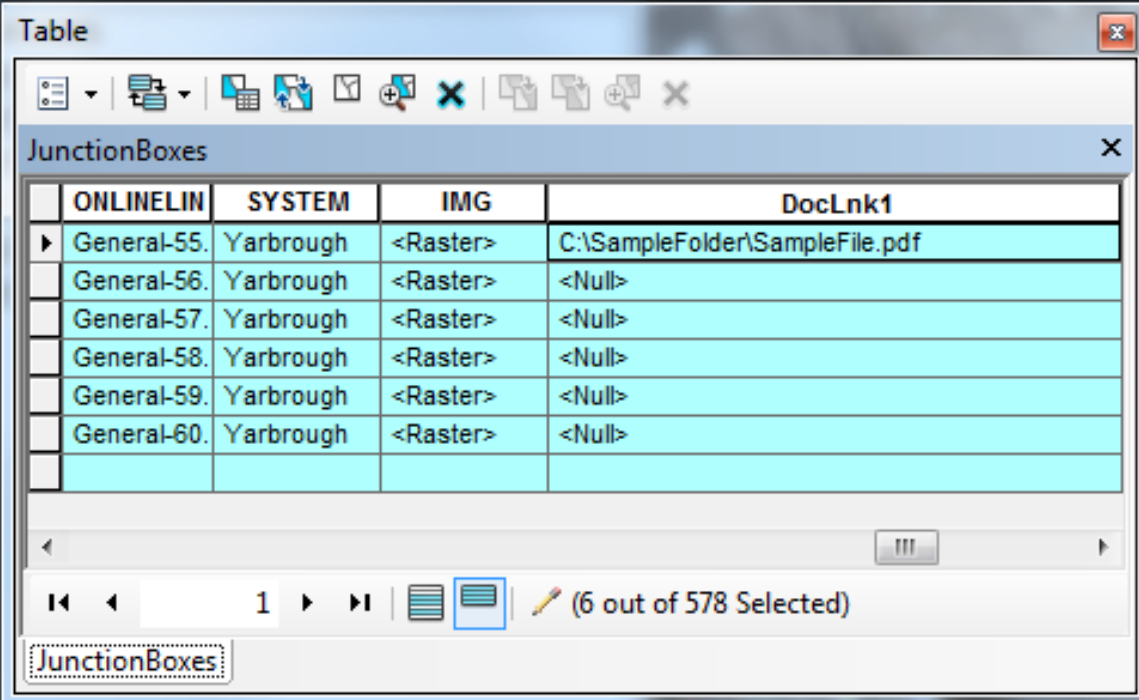
The original high resolution JPEG versions or the photos are saved on the DVDs delivered to the City of El Paso. Organized into different subfolders housed within the main photos folder, the files can be easily reached by looking for the system and the information contained in the Attribute Table.

### 4.4 Accessing and Adding External Document Hyperlinks

Links between GFOAMS and external documents can be established through a simple process. Accessing external documents can help the asset manager to make routine maintenance decisions and assist for planning purposes. The GFOAMS is already set up to receive three different hyperlinked files in the Junction Box Attribute Table, as requested by the City of El Paso.

#### 4.4.1 Adding Hyperlinks to Documents

Using the installed fields is very simple and allows for an easy access to files. The established fields are found under the names DocLnk1, DocLnk2, and DocLnk3. Starting editing mode is required in order to add a document hyperlink to a particular junction box. Once in editing mode, with the Junction Box Attribute Table open, the document hyperlink fields can be easily edited to accommodate the path for the files. In the example provided in Figure 35, the document SampleFile.PDF can be hyperlinked by typing the following path: C:\SampleFolder\SampleFile.pdf.



	ONLINEIN	SYSTEM	IMG	DocLnk1
▶	General-55.	Yarbrough	<Raster>	C:\SampleFolder\SampleFile.pdf
	General-56.	Yarbrough	<Raster>	<Null>
	General-57.	Yarbrough	<Raster>	<Null>
	General-58.	Yarbrough	<Raster>	<Null>
	General-59.	Yarbrough	<Raster>	<Null>
	General-60.	Yarbrough	<Raster>	<Null>

Figure 35: Sample Document Hyperlink in Junction Box Attribute Table.

#### 4.4.2 Accessing the External Document Hyperlink

In the same fashion that images from the field surveys are accessed using the Identify tool, external documents are accessed directly from the Identify dialog box by clicking the Thunderbolt icon that appears next to the file path of the established hyperlink.

## **Chapter 5: Applications of the GIS Fiber Optics Asset Management System**

With the GFOAMS, the asset manager will have the capability of performing numerous tasks having an impact on the day-to-day management of the fiber optics network. GFOAMS is currently fully implemented by the City of El Paso. GFOAMS includes tools to facilitate access to the inventory and visualize any specific details of the fiber optics Conduit network. These tools allow the generation of a smart maps of specific fiber optics elements in the sub-system network. GFOAMS allows the City quick access to reliable information, enhancing their maintenance program to avoid any telecommunication disruptions as these would have an adverse impact not only in the emergency relief programs to mitigate disasters but also in daily operations

The wealth of information, the spatial properties of the features, and the detailed images and documents make the implementation of numerous applications possible. The next subsections describe four sample applications for the purpose of illustrating the capabilities of the GFOAM, and due to the scalable nature of the ArcGIS platform utilized, more applications can be implemented in the future easily, as described before..

### **5.1 Accessing Key Fiber Optics Information through Hyperlinks**

One of the most important resources that an asset manager can have is to have quick access to the documents that are relevant to the geographically represented features in the map. In the past, asset managers had to rely solely on sizeable amounts of paper records to access information for the diverse systems that they managed; cabinets and map drawers would fill up document rooms to the point of being unpractical and problematic to retrieve documents. With the advent of computing systems and electronic version of the documents, the task became in a sense easier, but still accessing documents could be a daunting task as the information was dispersed in different computers, servers, and databases used for this purpose.

The documents module of the GFOAMS deals specifically with the need to access documents while browsing features in the map. Figure 36 shows the direct retrieval of a document in PDF, containing information about a fiber optics system, from the Identify tool dialog box.



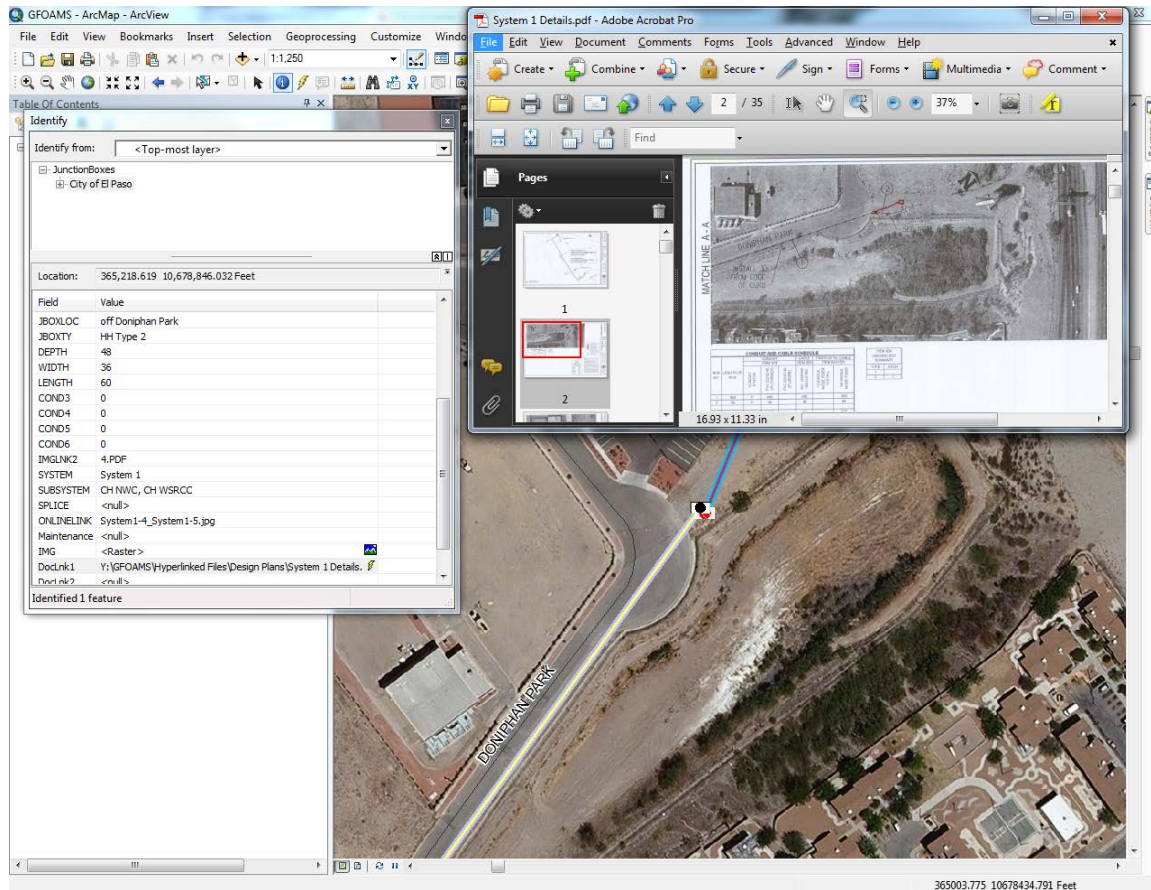


Figure 36: Accessing Information Through Photos and Documents.

In the same sense that documents and files help the asset manager to better control the infrastructure, detailed pictures of the actual asset increases the capabilities of the GFOAMS framework. The need of costly mobilizations to the field can be minimized by taking on-the-fly decisions from the office. For instance, in the case of a rupture of the Conduits and/or fiber optics Cables inside during an excavation, the asset manager can dispatch an emergency repair team with all the necessary tools to open the nearby Junction Boxes, and give the required service to repair the damage to quickly reestablish service. An example of such scenario is shown in Figure 37, where it can be seen that there has been a malfunction in the lid opening system of a Junction Box in question, possibly due to soil displacements.



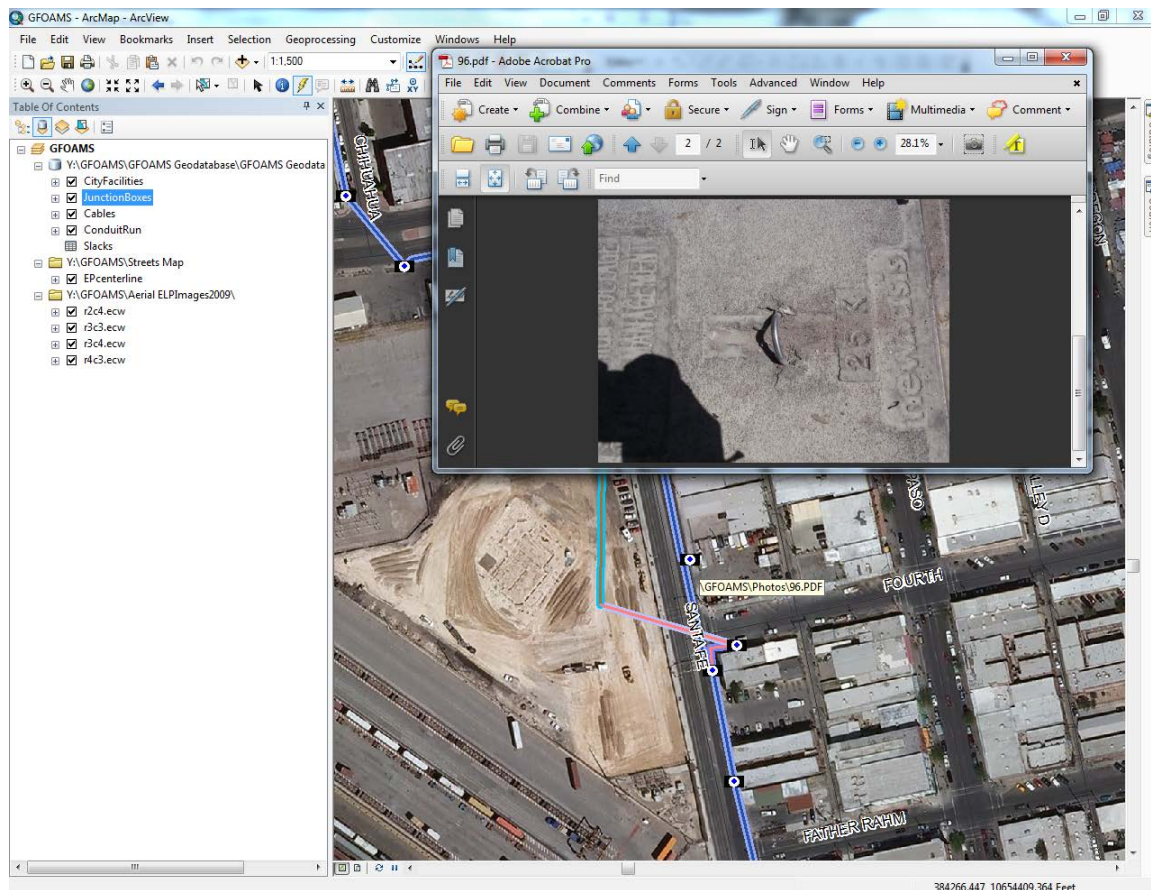


Figure 37: Jammed Junction Box Lid Observed Through the GFOAMS.

## 5.2 Future Planned Paths Repository

In order to better coordinate with the stakeholders involved in the development of new fiber optics networks and the management of the existing ones, asset managers need to explore the alternatives. With GFOAMS, all planning documents, drawings, and, specifically in this case, paths for future infrastructure, are entered simpler and more efficient manner. Moreover, the visualization of the georeferenced assets allows for analyzing the interactivity between the existing infrastructure and the proposed additions. In the example displayed in Figure 38, the proposed fiber optics Conduit path, symbolized with a thick red line, can be evaluated in more detail, given the availability of showing comprehensive, in-site information. This not only makes the process swifter, but sharing the information and analyzing interactions also ensures a better fund allocation scheme, that will save precious resources to the municipality.

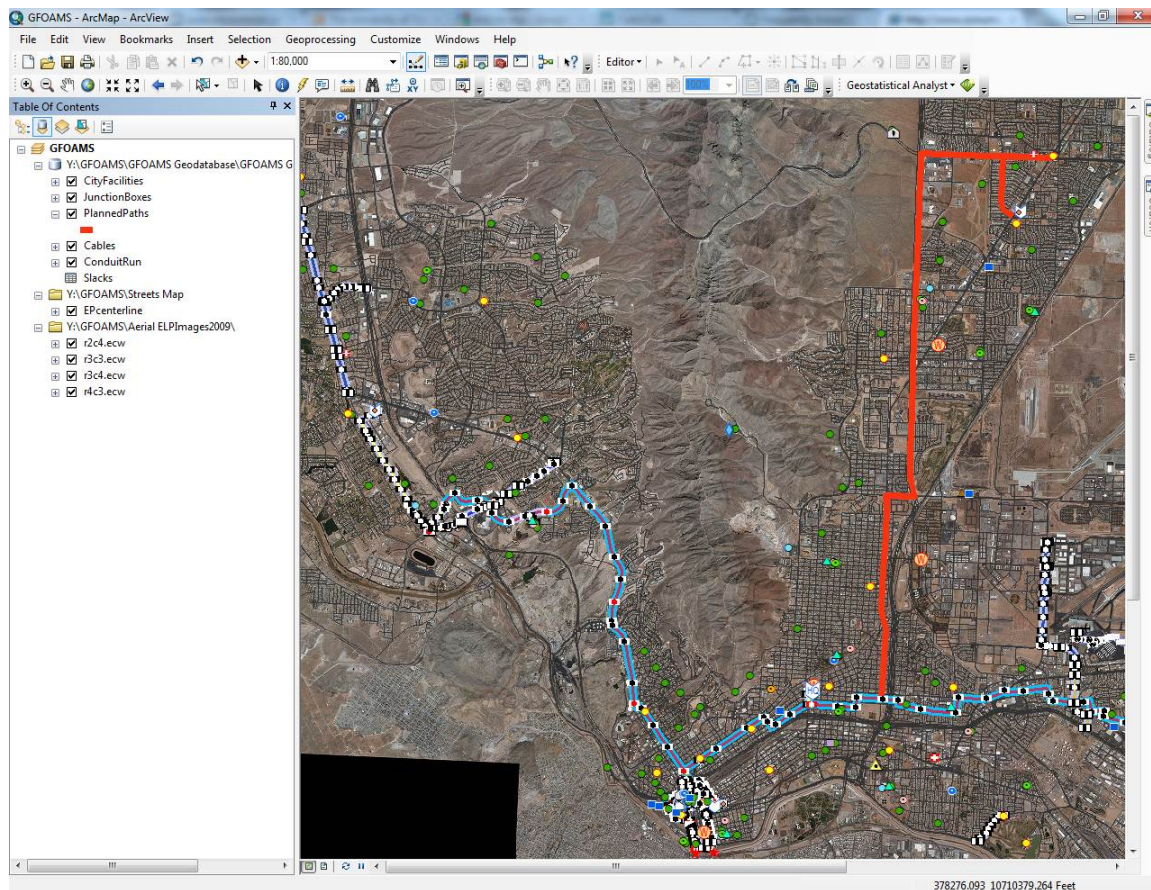


Figure 38: GFOAMS Used for Planning Fiber Optics New Developments.

### 5.3 Managing Leasable Fiber Optics Strands or Conduits

Another advantage of a fiber optics asset management system is the capability to facilitate municipal agencies to lease their assets. In the case of fiber optics, extra space in city-owned Conduits can be leased to install additional Cables. Also, unused or ‘dark’ fiber strands, which are the individual fiber optics Cable contained in the bundles referred to as Cables, can be leased to third parties.

The City of El Paso had is currently reviewing the right-of-way leasing scheme for new installation of fiber optics by telecommunication companies. With the usage of GFOAMS, and through a better management of the fiber optics asset, a new leasing process and could enable the city to increase received revenues by leasing existing Conduits and Cables. An improved knowledge about the fiber optics infrastructure will certainly aid the Financial Departments in assessing adequate fees and possibilities for the new leasing scheme.



To illustrate the possibilities, Figure 39 shows a stretch of city-owned fiber optics assets with a length of almost 20,000 feet. According to a study by Atalah et al. in Bowling Green State University (2002), the construction cost per 1,000 feet ranges from \$20,000-\$25,000 using Horizontal Directional Drilling (HDD), or in-sewer installation using the Sewer Telecommunication Access by Robot (STAR), and up to \$60,000 using open trench methods. Using Atalah’s (2002) figures of new fiber optics construction, a telecommunications company would invest between \$400,000 and \$1,200,000, in addition to the right-of-way fees that must be paid to the city. These numbers set a large margin for the City of El Paso to establish a leasing scheme that would generate revenue, and, at the same time, save money to the telecommunications company.

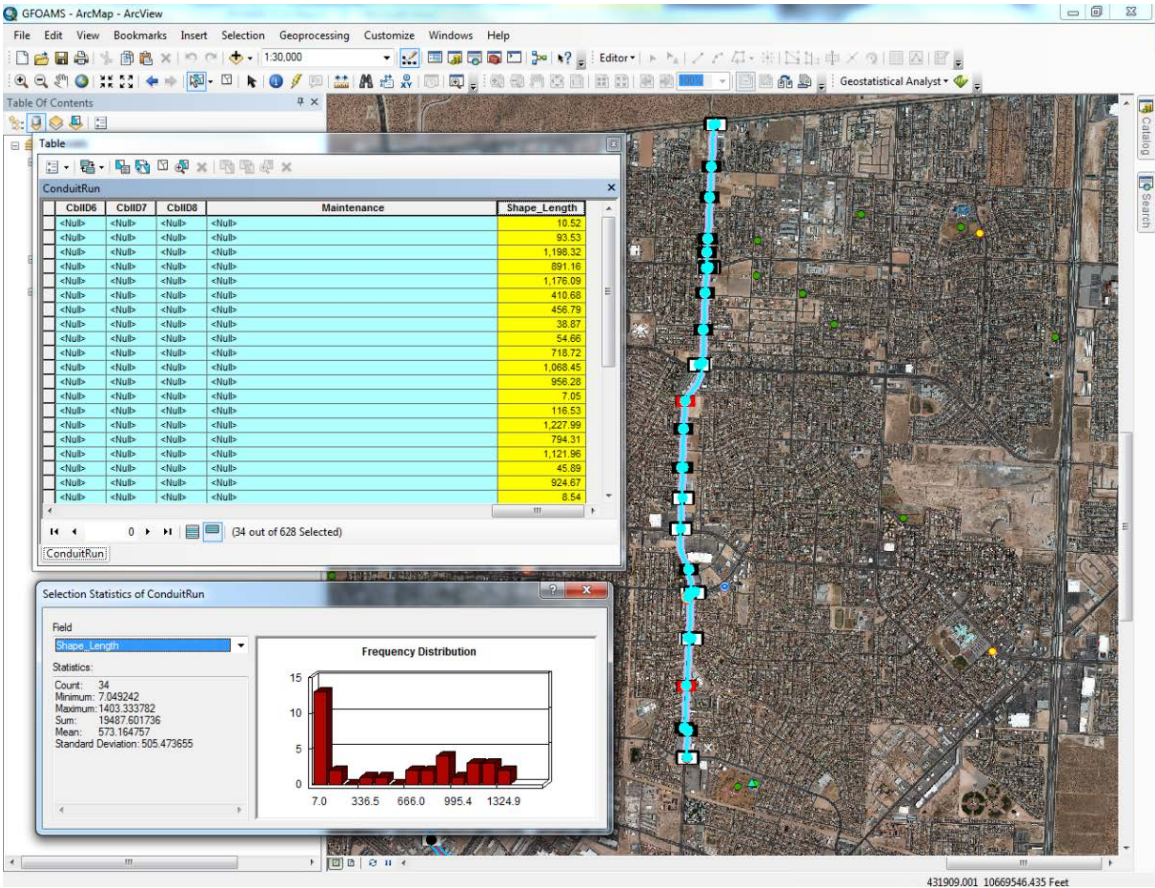


Figure 39: Length Calculation to Estimate Conduit Leasing Revenue.

## 5.4 Proximity Infrastructure Buffer Analysis

Using ArcMap's built-in functions and the extensive dataset that was collected and carefully put together during the GFOAMS project, it is possible to expand the reaches of its capabilities. For instance, the 'proximity buffer' function plotted in Figure 40 shows the buffer zones located 100, 500, 1,000 and 2,500 feet from the installed Conduit Runs in the City of El Paso. Different buffer zones can be established for analyzing distinct scenarios when planning new routes.

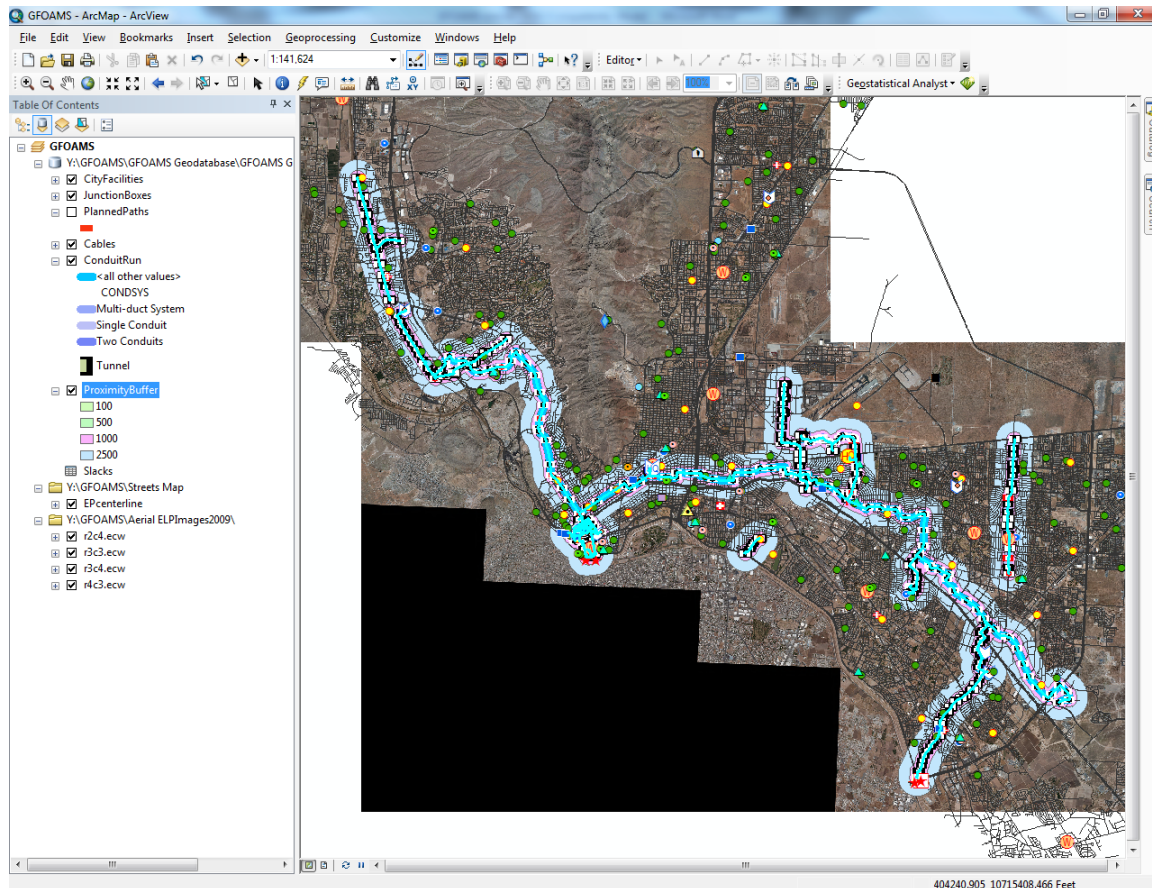


Figure 40: Proximity Infrastructure Buffer Analysis of the Conduit Runs.

Maps generated from buffering analysis allow the user to visualize the facilities located within certain ranges of the existing fiber optics system and identify if they are connected to the network. This type of analysis helps the planning of new additions to the fiber optics network. According to the City of El Paso, the public's safety is the current focus and the priority for extending the fiber optics network to remaining unconnected buildings. The ranking is as follows: (1) Police Departments, (2) Fire

Departments, (3) Municipal Courts, (4) the Health Administration Building, (5) Public Transportation Facilities/Sun Metro, (6) and Libraries.

## **Chapter 6: Summary Conclusions and Recommendations**

### **6.1 Summary**

Asset management is critical for efficient fund allocation within any organization, as it is the case with municipal governments with large infrastructure portfolios. Given the current and prevalent scarcity of funds that municipalities encounter, it is important for asset managers across the country to have the most advanced technological tools to tackle the day-to-day tasks they face, including the challenge of long-term management and planning. GIS offers an excellent platform to manage municipal assets, as it relates physical features with geospatial characteristics, with a complex database capable of storing varied information.

This thesis is the result of a two year project performed by the University of Texas at El Paso for the City of El Paso to develop and implement a GIS system to manage the fiber optics assets own and operated by the municipality. The project involved the review of existing records to extract data, and a series of supervised field surveys to verify and collect data for the network. Then, the information gathered was integrated and finally the GFOAMS platform was developed.

For the GFOAMS project, a total of twelve systems were included, adding georeferenced information and relevant data about the installed infrastructure. Also, an extensive catalogue of photos was created to assist in asset management tasks.

Composed of the inventory, documents, and images modules, the GFOAMS framework contains a wealth of georeferenced information that will allow for several analyses useful for planning purposes. The employed ArcGIS platform is expandable and able to accommodate improvements in the data structure and the technology to yield better results for the City of El Paso, rendering the GFOAMS framework an outstanding tool for asset management purposes.

## 6.2 Conclusions

- a) The database previously used for managing the fiber optics assets in the City of El Paso contained, in numerous instances, anomalies, inaccuracies or outright errors that made asset management a difficult task. Fortunately the GFOAMS effort successfully compiled high quality data in a GIS framework which resulted in improved management strategies.
- b) Having an asset management program assisted by a GIS tool such as GFOAMS greatly increases the capacity of a municipality to administer infrastructure network. Better path analysis for future expansions of the fiber optics network will be possible with the GFOAMS resulting in an improved funding allocation process.
- c) GFOAMS has many applications, besides of the ease of access of data mentioned above, embedded in the program to enhance the asset management processes. The following points refer to the applications described in Chapter 5.
  - The inclusion of detailed photos, along with the diverse documents that describe the elements of the infrastructure network is of great help when designing emergency repair strategies. The careful study of the stored photographic record stored, easily retrieved from the GFOAMS can increase the efficiency at the time of deploying emergency repair teams.
  - The GFOAMS represents an excellent platform to plot the planning of Conduit paths, location of Junction Boxes, and other assets as it allows for a historic record that is easily shareable with the rest of the stakeholders.
  - A shareable platform such as GIS is ideal for collaboration among different departments and stakeholders that take part in the decisions that the asset manager takes. The GFOAMS platform will certainly aid the leasing scheme design for the City of El Paso's fiber optics networks.
  - Visualizing the proximity of the different facilities that serve the City, increases the effectiveness of the planning process. Making use of this capability of the platform, in conjunction with the highly detailed and accurate inventory collected during the field

surveys, permits for planning in a more inclusive process, revealing patterns otherwise obscured in an aspatial database environment.

- d) The GFOAMS is a highly scalable platform that can accommodate improvements to the data or to the applications giving increased functionality to the asset manager.

A flowchart defining the major steps for the development and implementation of the GFOAMS is presented in Figure 41. It could be applied by other cities with the need of managing their fiber optics assets and help the implementation process from the lessons learned in the GFOAMS.



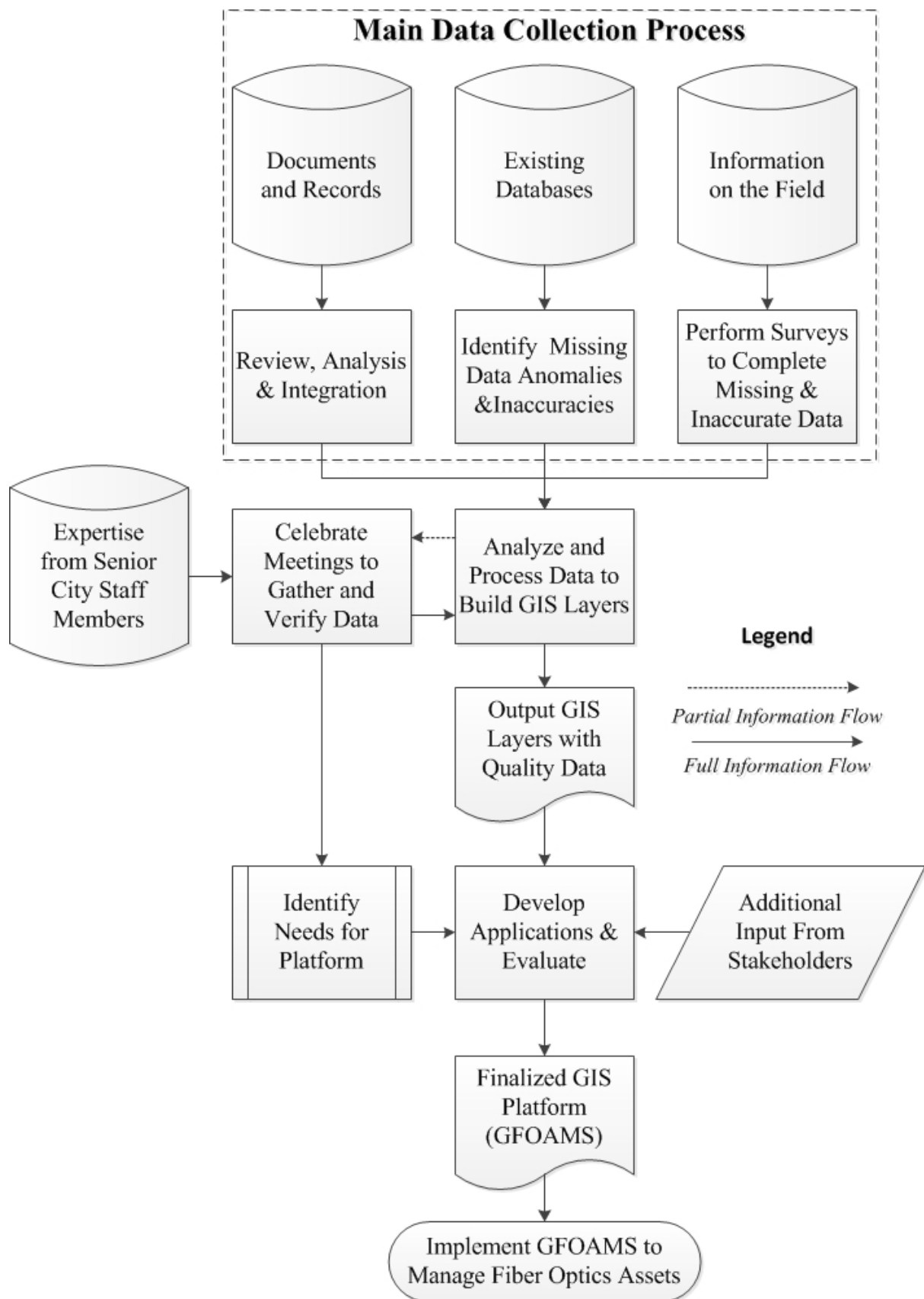


Figure 41: Flowchart for Development of the GFOAMS.

The initial steps are marked in the dotted rectangle as “Main Data Collection Process”. In this process, there are three components that will be the source of most of the data that was gathered for the GFOAMS:

- Documents and Records: This includes maps, diagrams, as-built plans or any other electronic or physical file that might improve the understanding of the currently installed assets. The fiber optics network system of the City of El Paso is extended and complex, therefore it is of extreme importance to get acquainted with the conditions in the field or in the laboratory, to foresee scenarios that could hinder the progress of the project.
- Existing Databases: Comma Separated Value (CSV) or Microsoft® Excel files, SQL databases or even old and out-dated georeferenced databases in GIS, or any other database that might be accessed constitutes this source. These databases in the case of the City of El Paso contained multiple errors, as well as anomalies and inaccuracies that had to be identified before heading to the field. This part of the process proves to be crucial as a deep understanding of the existing databases, along with the records mentioned in the point before, allows saving time and resources.
- Information on the Field: For the GFOAMS this was one of the main focuses as the databases and documents were outdated and had plenty of errors, anomalies and inaccuracies. Therefore, information that accurately represented the conditions in the field was collected via field surveys with the aid of PDAs equipped with GPS, photographic cameras, measuring tapes, and notes, along with information provided at the spot by the personnel from the El Paso Department of Transportation that assisted these visits.

After all the data has been gathered from the above described processes, the next step is to analyze and process it to identify potential confusions later on in the development of the GIS platform. In order to ensure this process does not oversee critical details, or to clarify when situations are complex, it was important to have guidance from senior officials from the City of El Paso. The reason for a

“partial” information flow is that the GFOAMS team at that stage was not providing results or data to the City, but rather asking for input to specific questions with the aid of photographs, diagrams or other mediums of support. The City, in turn, would clarify the doubts during these meetings or would make additional research in their files to find the answers. This whole process was fed by the combined expertise from the City of El Paso personnel.

Once the high quality data was acquired, the effort was focused on building the GIS layers. Since the platform for the GFOAMS is GIS based, the data is contained in integrated georeferenced layers.

At the same time that the GIS layers were being developed, the functionalities and applications presented in this thesis were requested by the personnel from the City of El Paso. The requests for applications was then studied and evaluated to develop the platform and the tools that constitute the GFOAMS. In this process, other stakeholders, such as El Paso County, were involved to include their feedback and expand the reach of the GFOAMS.

The final step was to deliver the finalized system denominated GFOAMS and implement it to make use of the wealth of information contained along with the functionalities and applications developed.

### **6.3 Recommendations**

An asset management system needs to include the latest information that reflects the conditions in the field. The data can quickly become almost obsolete if a procedure is not implemented to keep the information in the database up-to-date

The recommendations that the author makes based on this study are:

- a) Establish upon specific standards for data handling and storage. Each GIS department works differently, and the efforts made to any similar project must be in tune with their current approaches in order to ensure the success of the GIS asset management program.
- b) Define a well-planned action plan for the initial field surveys. If the field surveys are planned routinely and ahead of time, the collection of data will be made simpler. Out in the field, there are several obstacles that will impede following a rigid schedule, but with a defined strategy the scenarios (such as blocked Junction Boxes, inaccessible cabinets, vehicular traffic concerns, extreme climate events) can be evaluated and mitigation tactics can be anticipated.
- c) Develop a communication bridge with all the stakeholders involved in the asset management program. In the case of the GFOAMS, the stakeholders included the City of El Paso, the County of El Paso and the University of Texas at El Paso, among others.
- d) Monitor and evaluate the implementation of the system in order to discover potential niches for improvement. Additional tools can always be added in the future to increase the functionality of the GFOAMS. An example of such tools could be an automated and integrated attenuation calculator for the fiber optics Cables within each system.
- e) Design a “database maintenance” program and designate responsible parties for collecting and adding new information. It is of utmost importance for asset managers to work with the latest information from the field.

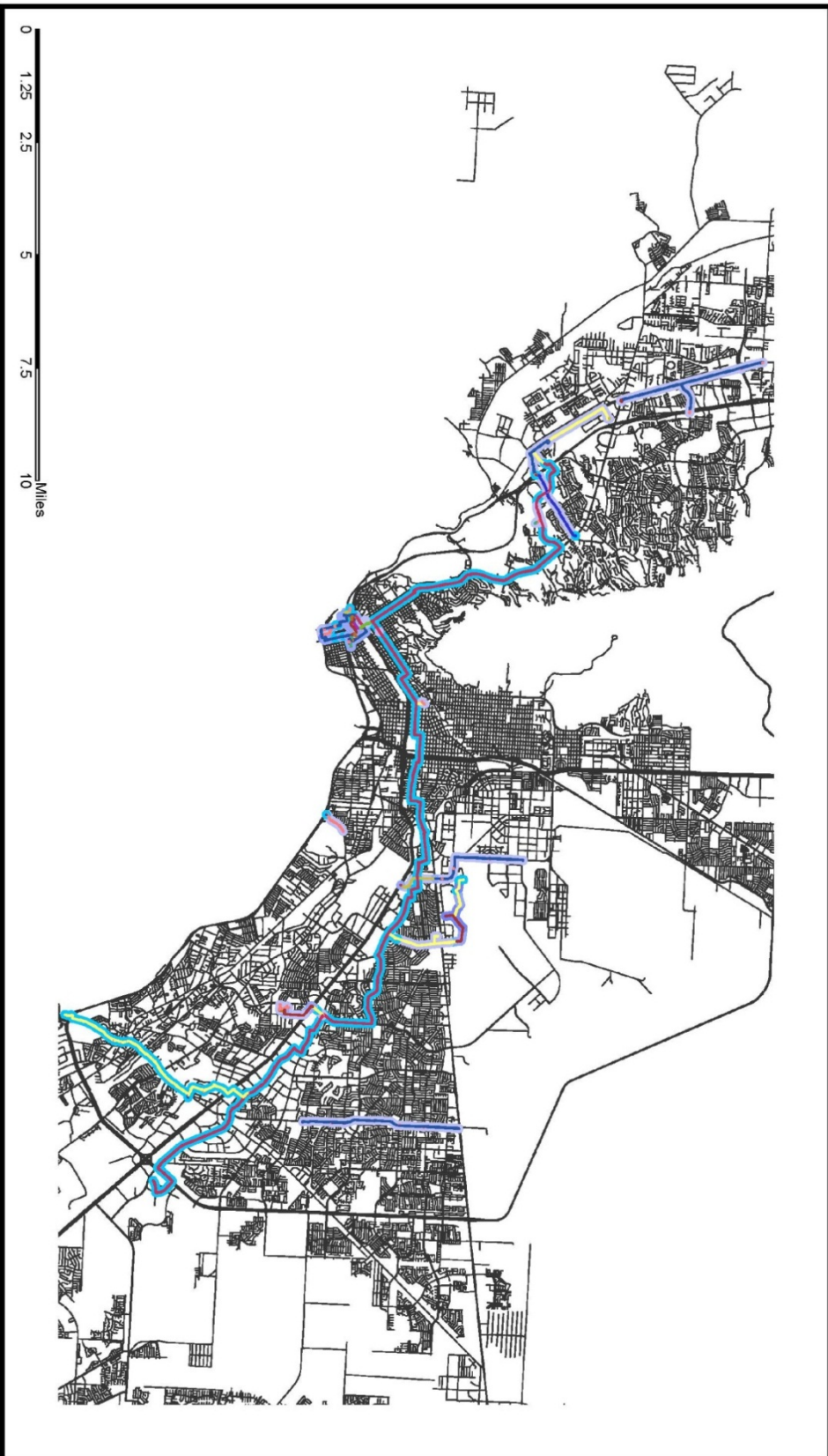
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## **Appendix A – Diagram of the GFOAMS**

## GFOAMS: El Paso





## **Vita**

Luis Fernando Quintana Landeros was born in the city of Chihuahua, Chihuahua, Mexico, to Cosme Quintana and Marta Landeros de Quintana. He completed all his studies in Chihuahua and started his higher education in the Instituto Tecnológico y de Estudios Superiores de Monterrey Campus Chihuahua. After finishing all the courses that were offered in that Campus, Luis decided to continue his studies in the University of Texas at El Paso (UTEP). Five semesters after being transferred, Mr. Quintana was awarded a Bachelor of Science in Civil Engineering from UTEP. Mr. Quintana enrolled in the Masters of Science in Civil Engineering in the Spring of 2010, and married Anne-Laure Quintana later that year in July. During his studies in UTEP, Luis participated in extra-curricular activities such as the Associated General Contractors of America, El Paso Chapter, participated in Engineering in Practice at UTEP, a collaborative group of students, faculty members and licensed professional engineers awarded by the NCEES, and became an International Road Federation Fellow in 2011. Also, he worked the last year of his bachelor's and the entirety of the master's program as a research assistant for the Center for Transportation and Infrastructure Systems (CTIS) under the supervision of Dr. Carlos M. Chang-Albitres in different projects such as the Ports of Entry Operations Plan of El Paso, Technical and Training Support for Metropolitan Transportation Commission's (California) Pavement Management, and the GIS Fiber Optics Asset Management System (GFOAMS).

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