

# Applying GIS to Sediment Ponds and Irrigation Systems in the Barton Springs Watershed of City of Austin

JARED TAYLOR

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by  
Committee:

Erik Schiefer (Advisor)

Mark Manone

Ruihong Huang

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## List of Abbreviations

COA – City of Austin

COAWPD – City of Austin Watershed Protection Department

CTWM – Central Texas Water Maintenance

GIS – Geographic Information System

GNSS – Global Navigation Satellite System

RTK – Real Time Kinematic

## Abstract

The City of Austin's Watershed Protection Department manages a series of sediment ponds created to protect the Barton Springs Watershed. The ponds are scattered throughout the Barton Springs region and the existing data was on as-builts that are difficult to access, locate on a map, interpret, and were vulnerable to loss. The goal of this project was primarily to create a geodatabase for Central Texas Water Maintenance (CTWM) and City of Austin Watershed Protection Department (COAWPD) through field data collection. The project found what sprinklers existed at these retention ponds and where the control boxes and valves were located. During the inventory process the sprinkler's condition, the make and model, whether it had a pad, and whether it was recessed were collected. This data is now available for City of Austin (COA) and their third-party maintenance contractor Central Texas Water Maintenance (CTWM) via web applications created through ArcGIS Online. Web application access provides all personnel involved with the retention ponds an efficient and accurate way to view the data in an easy to read, easy to access, cloud-based georeferenced format.

## Keywords

GIS, Geodatabase, RTK, Infrastructure, Sprinklers, Austin, Retention Pond, Water, Irrigation

## Chapter 1 Introduction

Over the past three decades, Central Texas has become a very popular place to live. This has resulted in Austin being one of the fastest growing cities in the United States (Richardson 2015). The recent development boom has had environmental impacts on the region's watersheds leading to the need of mitigations to offset the effects of development. One of these measures is the Save Our Springs Ordinance. Section 25-8-514 of the Land Development Code and the Save Our Springs Ordinance states that "All development subject to these regulations shall demonstrate that average annual stormwater discharge pollutant loads do not exceed the average annual pollutant loads produced by the site on the effective date of the project application (existing conditions loads) in accordance with the procedures established..." (Elaws.US, 2019) One of the acceptable measures to mitigate off-site runoff is through the construction of retention/irrigation systems. Retention ponds are created to allow heavy metals and pollutants to settle within the pond. The water is then filtered and dispersed onto an irrigation field, see Appendix for Environmental Criteria Manual 1.6.9.1 (Elaws.US, 2019).

The City of Austin's Watershed Protection Department (COAWPD) now finds itself with more than 35 ponds and 500 sprinklers to be maintained in the Barton Springs Zone to remain in compliance with this ordinance (see Figure 1). City of Austin (COA) has contracted the maintenance of these ponds to Central Texas Water Maintenance (CTWM), a small private local water managing company. At the start of this project, all sprinkler plans were contained in hard copy as-built documents and drawings from the developers. As-builts are detailed, blue-print like representations of the systems. At the start of the project these were all in binders that were locked away in a storage unit because the city was relocating to a new building. This presented three major problems with the existing data: it was susceptible to data loss due to staff leaving or damage to hard copies, it was difficult to access, and it was hard to interpret.

## Project Area

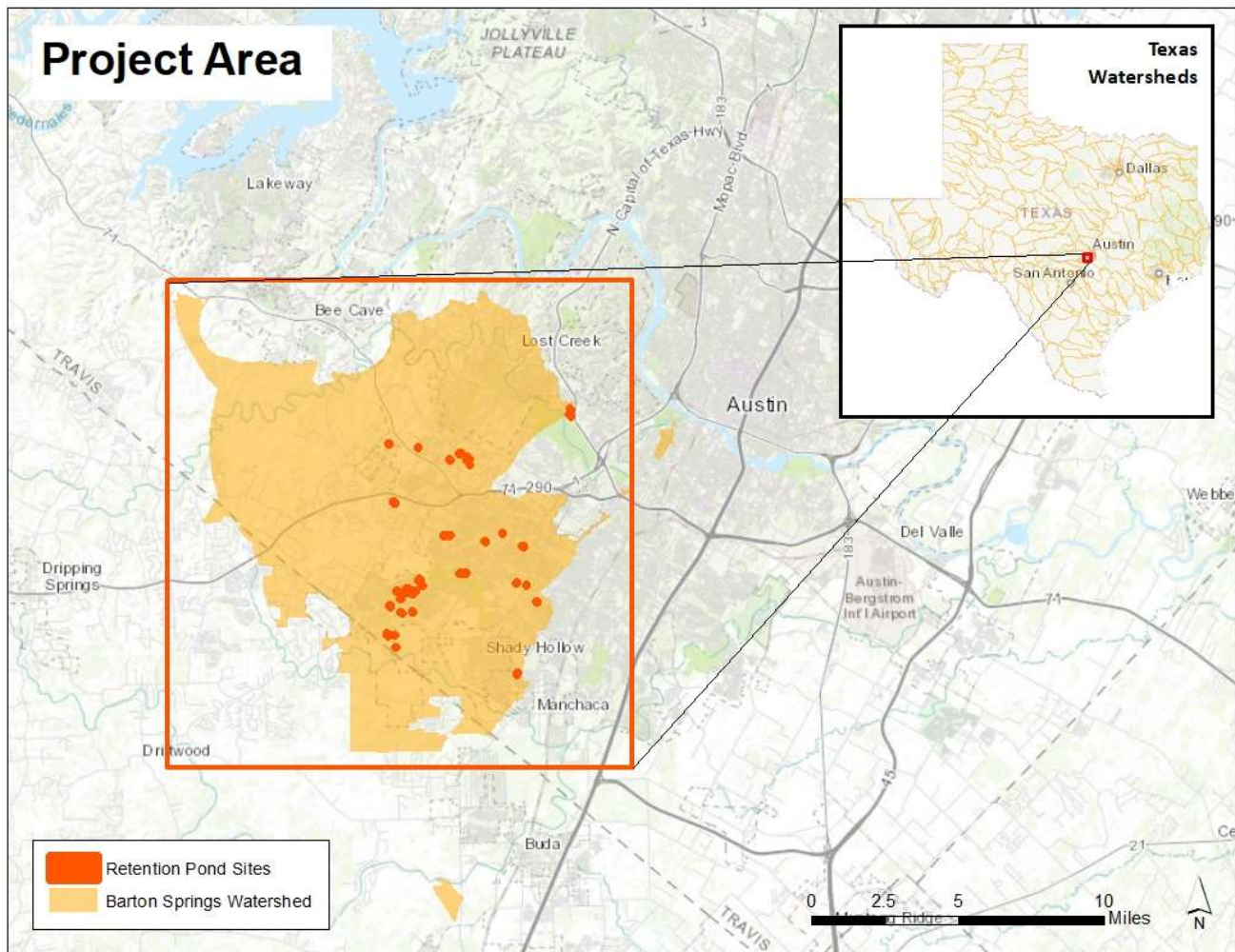


Figure 1 shows the Project Area which is in the Barton Springs Zone as called out in the Environmental Criteria Manual 1.6.9.1. This is an area to the southwest of Austin, TX

## Data Vulnerability

With the documents locked away without direct access, all knowledge of these ponds and sprinklers was usually dependent on the working knowledge of a few staff members. This created a two-fold problem. First, the data was vulnerable to data loss if the staff left or had a faulty memory of the data. Second, was the difficulty of access which I will address in the following paragraph. The direct result of this data format has been irrigation fields being built on top of pre-existing ones. Because of this, some of the preexisting lines and sprinklers were damaged or destroyed costing the city money and time. The other problem with having the data locked away in a storage unit is the possibility of the

physical loss or destruction of the data. While no actual damage had occurred to the hard copies, there was the potential for data loss due to a natural disaster occurring or negligence on the part of the copy holders. One example of this happening before was during Hurricane Katrina when much of the City of New Orleans' data was permanently destroyed in the flooding (Kerski 2012).

#### Data Difficult to Access

The existing work created problems for COA personnel because they did not have an easy way to view or interpret the data (see Figure 2 shows the currently used as-built) This required hours to be spent contacting personnel to locate ponds or sprinklers and trying to interpret as-builts of the irrigation ponds and sprinkler fields. This led to inefficiencies like the sprinkler maintenance technicians spending time and resources every year trying to relocate the same sprinkler systems based on a combination of what they could remember and what they could detect when the sprinkler system was turned on. It also resulted in planners being unable to see where all their ponds were, leading to building ponds on top of other ponds as stated above.

#### Data is Hard to Interpret

The existing data was hard to interpret. It was solely in the form of as-builts, which are paper drawings that are not necessarily to scale that are created upon completion of construction. As-builts are black and white drawings with several features present making it easy to get mixed up and even miss sprinklers when interpreting the plans (see Figure 2 shows the currently used as-built). They also have large spatial gaps in multiple views. This can create problems when one frame shows an irrigation field that is far away from a pond but there is no way to tell where the features are in relation to one another. The other problem with this lack of size or spatial reference was delays in decision making by city planners.



## Problem Statement

City of Austin faced three major problems with the existing state of their data:

1. **Vulnerability** - potential loss of data due to staff leaving or physical damage to hard copies.
2. **Difficult to interpret** - the hard to interpret as-builts take a skilled technician to read (see Figure 2).
3. **Accessibility** – the data was inaccessible and needed a central and easily accessible location containing all the irrigation ponds and fields data and locations. To solve all three problems, it was determined that compiling all the ponds, irrigation fields, and sprinkler heads data into a geodatabase was the best solution. A geodatabase would allow for cloud storage of data to prevent data loss and create a more accessible and user-friendly means of interaction (see Figure 3).

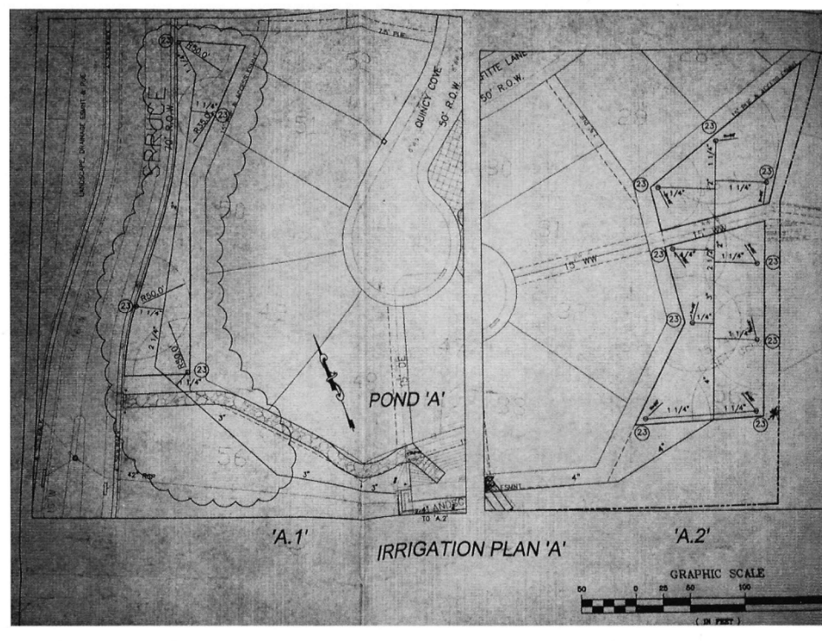


Figure 2 shows the currently used as-built that is difficult to interpret and difficult to georeference. It also takes some familiarity with the drawings to understand them because often there is no key displayed.

### Spruce Canyon - 352789



Figure 3 shows a map created from proposed geodatabase shows an easy to read and interpret map with a key and satellite imagery for ease of georeferencing in the field.

### Project Objectives

The goal of this practicum project was to create a geodatabase for CTWM and COAWPD with data collected during field surveys. This provides a cloud hosted backup of the data to prevent permanent loss, provides access to the necessary employees, and delivers a more user-friendly experience. The field surveys determined what sprinklers existed and their locations at the retention ponds and irrigation fields. It also acquired the physical locations of the control boxes and all associated valves. During the inventory process criterion pertaining to the sprinkler's condition, the make and mode, whether it had a pad, and whether it was recessed were recorded. This data is now available for COA and CTWM via web applications created through ArcGIS Online. This enables all personnel involved with the retention ponds an easy and accurate way to view the data in a format that will ensure no permanent loss of data in the future.

## Chapter 2 Literature Review

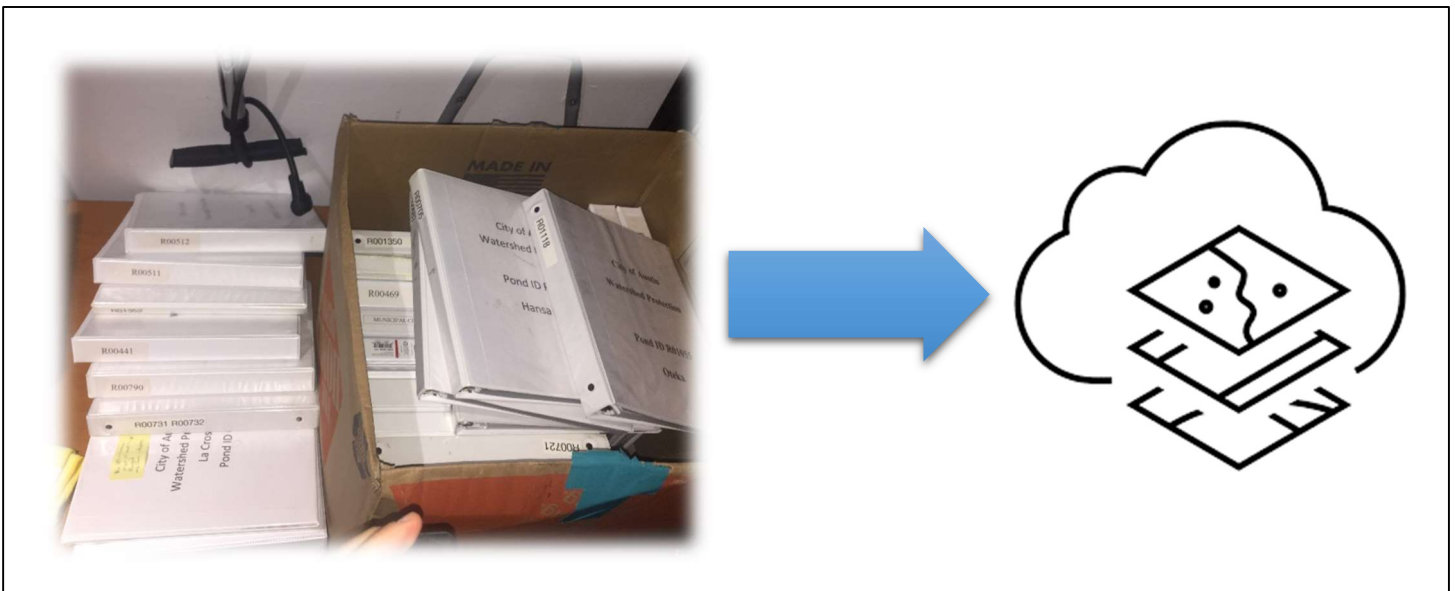
### A History of Data Storage and Record Keeping

Before the digital revolution, data was housed in large public and private libraries. The most famous library of Classical antiquity, the Library of Alexandria, at its peak was said to hold up to 400,000 scrolls which required a vast storage space (Murray 2009). Today, the United States Library of Congress is the largest library in the world with more than 167 million items on approximately 838 miles of bookshelves. The collections include more than 39 million books and other printed materials, 14.8 million photographs, 5.5 million maps, and 72 million manuscripts ([www.loc.gov](http://www.loc.gov) accessed 11/9/2018). A digital version of this library would fit on a 24-terabyte array that would fit in a small closet (Warwick 2007). A digital library requires much less space and addresses the issues of data loss and accessibility. The library of Alexandria was burnt to the ground and constituted the loss of, at that time, the world's largest resource of knowledge; an irreplaceable loss. This could have been avoided using cloud storage, where data is a.) stored in multiple physical locations and b.) accessed over a server available from any location (Mehr et al 2015). In ancient times the scholars would take journeys and visit places for months on end to survey the data in large libraries. Just as ancient texts were kept in these knowledge repositories, modern city infrastructure data is still largely stored on shelves in county records offices, and storage facilities, as was the case of my project's data (see Figure 4). This project is part of the current digital migration of hard copy data to the cloud to bring forth the aforementioned benefits.

### GIS and Asset Management

Because this project's data references spatial data, a geographic information system is the most appropriate solution. A geographic information system, or GIS, is a special type of information system in which the data source is a database of spatially distributed features (Shamsi 2002, 2005). Historically, GIS was reserved for computer scientists and land managers however, with the advent of MapQuest and

Google Maps the public has begun to interact with map applications on a regular basis. Esri, the leader in GIS software, recognizes this broader scope of use and has invested heavily in applications targeting



*Figure 4 shows the current state of the as-built data and an arrow representing the project that will convert the data into a cloud-based GIS.*

the utilities sectors. With programs like ArcGIS for Gas Utilities, ArcGIS for Telecommunications, and ArcGIS Solutions for Water Utilities (Esri 2018), the infrastructure sector has benefited greatly from the application of GIS. In 2005, Shamsi found that more than 80% of all the information used by water and wastewater utilities is geographically referenced. The ability for multiple users to view the location, construction, and condition of their targeted features from virtually any device is an incredibly useful and cost-effective tool. It allows for data from multiple disciplines to be brought together and serves as a quick way for various users of an organization to view their infrastructure. It also allows for technicians and managers to communicate more effectively. Today, the advent of ArcGIS Online and their cloud services allows field workers to collect data directly into the geodatabase (the data container for a GIS) and managers can view these real-time updates in the GIS.

Even with these new technologies, knowing exactly where assets are is an on-going problem in many organizations because a lot of the data has yet to be converted. Much time and resources are wasted tracking down who last worked on the current problem or digging through paper drawings and

maps (Davis 2007). Over the years many organizations have come to realize that GIS not only helps manage the existing utility infrastructure but can also help aid in the design for future expansion (Shamsi 2005). This has led to the current conversion of data into computer based geographic information systems (Halfaway et al 2006; Osborn 2007; Cannistra 1999; Motyka 2018). In his paper *Converting Utility Data for a GIS*, Cannistra lays out a general framework for water utilities going through the data conversion process. One method discussed is heads-up digitizing. In this technique an operator digitizes points directly onto a screen. Source maps, often as-builts, are used as a reference base for placing asset information. The base-map is then georectified using points of known features and the data from the base-map is indirectly added to the geodatabase (Cannistra 1999). Another method used in data entry is field inventory. This requires surveying equipment and is not traditionally used as the primary technique in creating a geodatabase. This data can be collected using handheld GPS units or total stations. This method is highlighted as the most appropriate for capturing data in the field (Cannistra 1999). With the advent of user-friendly applications, like Collector for ArcGIS, that allow for easy data entry directly into the geodatabase, it is more appropriate than ever. Other researchers such as Alexandra Motyka of USC who completed a similar project mapping landscape irrigation systems (Motyka 2018), and even Uzair Shamsi who wrote the book *GIS Applications for Water, Wastewater, and Stormwater Systems* (Shamsi 2002), refer to Cannistra's paper *Converting Utility Data for a GIS* as a guide to projects like this one.

### Converting the Data

Today converting infrastructure data into a GIS is the start of what goes far beyond simply knowing where specific assets are. Once the conversion has taken place, these databases serve as the foundation for asset management systems and models of entire networks. As Jack Dangermond, founder of ESRI, demonstrated in his preliminary at the 2018 GeoConX Conference in Dallas, these systems serve the end-users by ensuring compliance with regulations by tracking maintenance; speed

up response times in the event of a system malfunction; and even serve to automate mailing lists to customers affected by scheduled outages. The capabilities of these systems are incredible and new applications are still emerging. As put in Davis' paper *What is asset management and where do you start?*: "the purpose of an asset management system is 'to help you know exactly what assets you have, know precisely where your assets are located, know the condition of your assets at any given time, understand the design criteria of your assets and how they are properly operated and under what conditions, develop an asset care (maintenance) program... and perform all these activities to optimize the costs of operating your assets and extend their useful life to what was called for by the initial design and installation' (Davis 2007)."

### The Geodatabase as the Foundation

A geodatabase is a powerful foundation of any asset management system with many scalable capabilities. We have already discussed the capabilities of Asset Management Systems and the Utility Network capabilities from ESRI. Further applications include augmented reality for field workers to aid in the location of detected leaks and better workflows with the advent of ESRI's Workforce Application that can send an employee to specific assets for inspection and can be updated in the geodatabase through easy to use applications. Projects like this one are the foundations for the "smart cities" of the future, a relatively new idea in urban planning. The idea behind the smart city is an instrumented, interconnected, and intelligent city. Utility Networks that run on geodatabases integrate sensors that capture real-world data. Interconnection means the integration of those data into an enterprise computing platform and the communication of such information among the various city services. Intelligence refers to the inclusion of complex analytics, modeling, optimization, and visualization in the operational business processes to make better operational decisions (Chourabi et. Al. 2012; Harrison et al 2009).

## Chapter 3 Methodology

### User Needs Assessment and Project Setup

Prior to the start of the project, I met with CTWM and COA to determine what feature attributes to collect, the methods of collection to be used, and what application to use to display the data. It was decided field surveys would be used to determine what sprinklers exist and their locations at the retention ponds and irrigation fields, as well as the physical location of the control boxes and all associated valves. During the inventory process criterion pertaining to the sprinkler's condition, the make and model, whether it had a pad, and whether it was recessed were recorded. Data was collected using an iPad running Esri's ArcCollector and an EOS Arrow Gold GNSS Bluetoothed to the iPad to augment the accuracy to the required resolution. It was determined the data would be available for COA and CTWM via web applications created through ArcGIS Online.

CTWM was tasked with flagging the sprinklers before our field visits. For training purposes, a site visit was conducted with CTWM personnel to show me the working portions of a few systems and we went over reading the as-builts. The systems included ponds, control cabinets, wet-wells, valves, and sprinkler heads. During the training session, it was found that many of the flags were in tall grass or dense forest making them difficult to locate without some type of map. The other problem with not having a map or an as-built was not knowing how many sprinklers I was looking for at any given site. As a solution to this, I georectified the existing as-builts and created a feature class (sprinklers\_COGO) that would be visible as a base map in the Collector application developed for the project. This enabled me, the surveyor, to navigate to the feature's general area (+/- 30 ft.) during field data collection. This was a fundamental portion of the project and the project would have been very difficult without this step. See Appendix A: Georectifying Methodology with As-builts for a detailed walk through of the georectification methods.



Some of the sprinkler fields did not have as-built plans, but instead only GPS points taken by CTWM technicians on their phones during previous maintenance activities. These coordinates were entered into a separate layer named “sprinkler\_gps\_coords” and loaded into the project map as a reference layer to aid in locating sprinklers in the field.

## Database and Feature Class Construction

The geodatabase was set up by City of Austin’s GIS department in order to ensure a smooth integration with their existing datasets. One issue I ran into when updating some of the schema was when we exported the data, we had to be sure to export as a geodatabase and not a shapefile because shapefiles did not have the capabilities required to maintain some of the longer fields. The good news was, this was caught early in the QA/QC checks and served as a good reminder to perform QA/QC early and often.

## Field Data Collection

### Hardware

Because this project consisted of old and inherited sites, it was decided that we would inventory the sprinkler fields and use a global navigation satellite system (GNSS) to collect location data rather than simply converting old as-builts as has been done in other projects (Cannistra 1999, Motyka 2018). This would provide more accurate and up to date information as we had discovered location discrepancies during the training surveys. At the start of the project a Samsung tablet tethered to a phone for cellular connection was paired with the Arrow Gold GNSS receiver for data collection. The Arrow Gold is a high-accuracy Bluetooth® GNSS receiver that implements all four global constellations (GPS, GLONASS, Galileo, BeiDou), three frequencies (L1, L2, L5) and satellite-based RTK (Real-time Kinematic) augmentation. By using all four GNSS constellations and satellite signals, it can generate centimeter corrections in real time, with convergence times as low as 15 minutes, which is why it was selected for this project. At the time of the project an Arrow Gold RTK receiver cost \$7,999.



The GNSS requires a signed-in internet connection to access its RTK network which allows for centimeter-accuracy. After a few days of collection, we decided for ease of use to change from the Samsung tablet tethering system to an iPad with a cellular connection. The switch was made because the iPad battery life was longer than the Samsung tablet, the built-in cellular service streamlined the connection with the GPS, and Esri Collector ran smoother providing a better user experience.

## Software

As discussed above, both ArcMap and ArcGIS Pro were used to georectify as-builts and add data to the reference layers. I found that ArcGIS Pro, once learned, provided a better experience for me personally. In ArcMap when resizing the image or zooming in and out I had to wait for the as-built to reload and noticed a significant lag in loading time, however with ArcGIS Pro I did not have the same issues. I also noticed that my computer's fans would kick on during this operation while using ArcMap but not ArcGIS Pro. As of November 2019, this issue appears to have been fixed and both applications run smoothly. ESRI's Collector app was chosen for the software to collect the field data because it allowed for the smoothest data collection experience. With Collector, the user can collect data directly into project maps and hosted feature classes in the project geodatabase in ArcGIS Online. This eliminates the need for syncing edits, storing data in multiple locations, creating various versions of the data, and sending out updates. By using Collector in conjunction with ArcGIS Online (AGOL), COA and CTWM were able to see our updates and edits in real-time. This was another important part of the project. ArcGIS Online and the Collector App were critical components for streamlining the data collection directly to the clients.

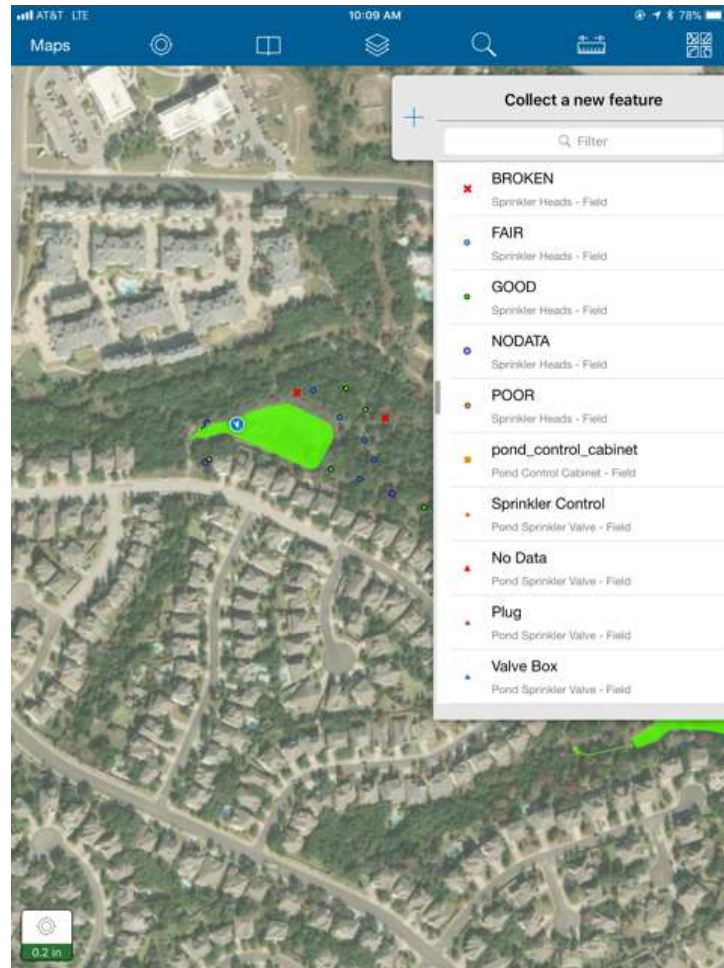


Figure 5 shows a screenshot of ESRI's Collector (now Classic) application in use on the project for data collection.

I chose to use Microsoft Excel to keep track of all the ponds and how many sprinklers they had, how many I found, and notes on things I needed to remember at these ponds. This information was later brought into ArcGIS Online for cloud collaboration and to visualize the information more readily for everyone on the project. We used attribute fields in the Ponds layer to symbolize and keep track of what ponds were complete and any GIS related notes for associates on the project.

## Overview of Workflow

### Summary of workflow:

1. Gather data on all ponds, coordinates, as-builts, and any relevant information from field personnel
2. Add useful data to field maps to aid in field data collection. This could be georectifying as-builts, entering coordinates, or even just writing down notes for access
3. Set up Collector and set the GNSS to collect in the proper projection
4. Go out and collect data
5. When back at the office, check for any features that may have missed
6. Update a spreadsheet with the sprinklers missing and any issues
7. Send in maps of problem ponds to superintendent for review and remedy
8. Revisit site with sprinkler technician and complete data collection
9. Mark the field as complete in the ponds layer

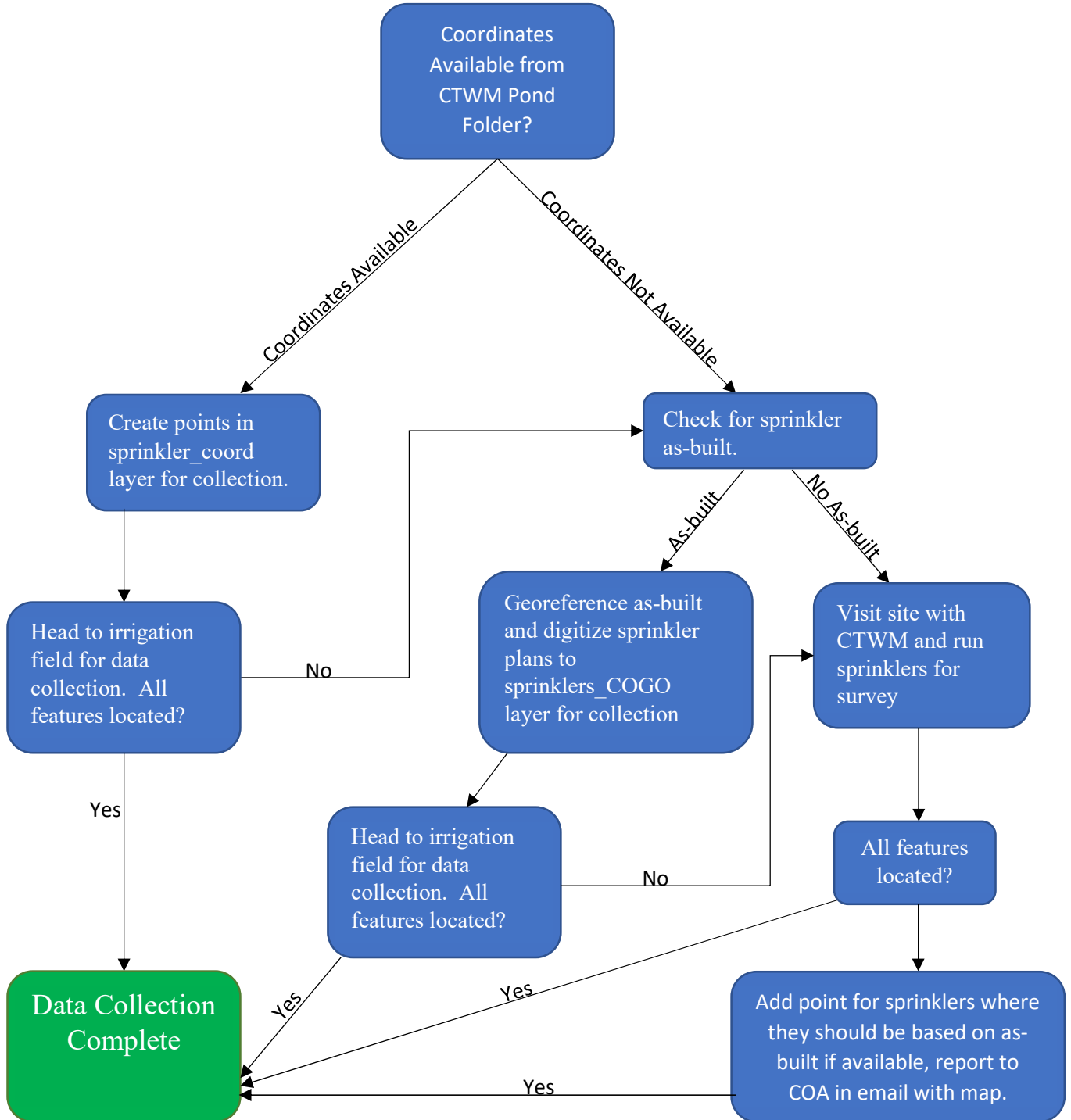


Figure 6 shows an overview of the data collection workflow used on the project. It shows the decision process of the data collection and the ways that we ensured maximum asset location.

## Chapter 4 Results

The goal of this project was to create a geodatabase for CTWM and COAWPD through field data collection. As a result, many data layers were created and submitted to COAWPD through ArcGIS Online. The project found what sprinklers existed at the retention ponds and where their control boxes and valves were located. During the inventory process the sprinkler's condition, the make and model, whether it had a pad, and whether it was recessed were recorded in attribute fields associated with the corresponding data layers. This data was made available for COAWPD and their third-party maintenance contractor CTWM at all times via ArcGIS Online (see Figure 9 shows a screenshot of the final online map). This enabled all personnel involved with the project a simple and accurate way to view the data in an easy to read and access, cloud-based georeferenced format. Section 4.1 will discuss the results of the geodatabase created in the project. Section 4.2 will discuss the ArcGIS Online web map created.

### Section 4.1 Geodatabase

This project's completion depended on the creation of a geodatabase with four data layers: Sprinkler Heads, Control Cabinets, Sprinkler Valves, and Irrigation Ponds. Figure 7 shows the final data structure used in the database for collection and submission to COAWPD. A total of all features collected is provided in Table 1 showing a summary of the geodatabase feature classes.

pond_sprinkler_head		pond_sprinkler_valve		pond_control_cabinet	
OBJECTID	OID	OBJECTID	OID	OBJECTID	OID
POND_DRAINAGE_ID	Integer	POND_DRAINAGE_ID	Integer	POND_DRAINAGE_ID	Integer
POND_MAX_ASSET_NUMBER	String	POND_MAX_ASSET_NUMBER	String	POND_MAX_ASSET_NUMBER	String
MAKE	String	LOCATION_SOURCE	String	LOCATION_SOURCE	String
MODEL	String	COMMENT	String	COMMENT	String
RECESSED	String	ESRIGNSS_FIXDATETIME	Date	ESRIGNSS_FIXDATETIME	Date
PAD	String	Type	String	GlobalID	GlobalID
OBSERVATION	String	GlobalID	GlobalID	CreationDate	Date
LOCATION_SOURCE	String	CreationDate	Date	Creator	String
COMMENT	String	Creator	String	EditDate	Date
ESRIGNSS_FIXDATETIME	Date	EditDate	Date	Editor	String
GlobalID	GlobalID	Editor	String		
CreationDate	Date				
Creator	String				
EditDate	Date				
Editor	String				

Figure 7 shows the final data structure of the feature classes in the delivered geodatabase.

Table 1 shows a summary of the geodatabase feature classes and the final total of features collected.

Layer Name	Description	Total Number of Features
Sprinkler Heads	Point	544
Control Cabinets	Point	41
Sprinkler Valves	Point	107
Irrigation Ponds	Polygon	43

During the inventory process the sprinkler's condition, whether it had a pad, whether it was recessed, and the make and model were recorded in attribute fields associated with the corresponding data layers. The attribute 'Condition' was collected, and summary of the sprinkler head conditions can be seen in Figure 11. Other attributes of the sprinklers were deemed unimportant which will be discussed in Chapter 5.

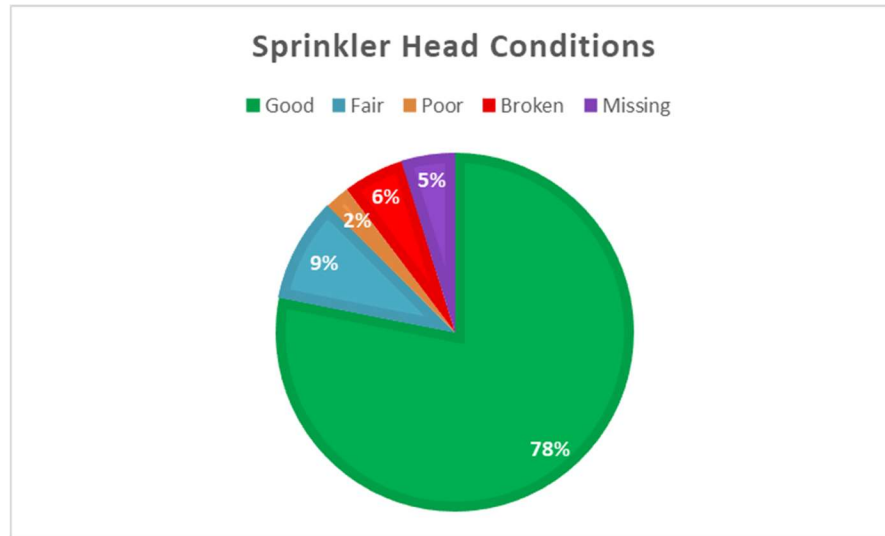


Figure 8 shows a summary of the sprinkler head conditions that were recorded during the surveys. This field was recorded in the hopes that the field technicians could use this to keep track of sprinklers in the field and incorporate the webmaps into their workflows.

## Section 4.2 - ArcGIS Online Web map

For the final online map created in ArcGIS Online as seen in Figure 9, we used a hybrid imagery base map provided by ESRI. We added the online hosted feature classes: Sprinkler Heads, Control Cabinets, Sprinkler Valves, and Irrigation Ponds to the base map at a visibility scale shown in Table 2. Zoom scale was assigned because of the density of the data and to minimize cellular data usage in the field. Sprinklers and Ponds were the only layers symbolized by unique values, discussed further in the following paragraph.

Table 2 shows the layer visibility scale settings that were used on the webmap. More densely spaced features were kept to smaller scales to reduce business and aid in navigation of the maps.

Layer	Visibility Scale
Sprinkler Heads	1:9,000
Control Cabinets	World
Sprinkler Valves	1:9,000
Irrigation Ponds	World



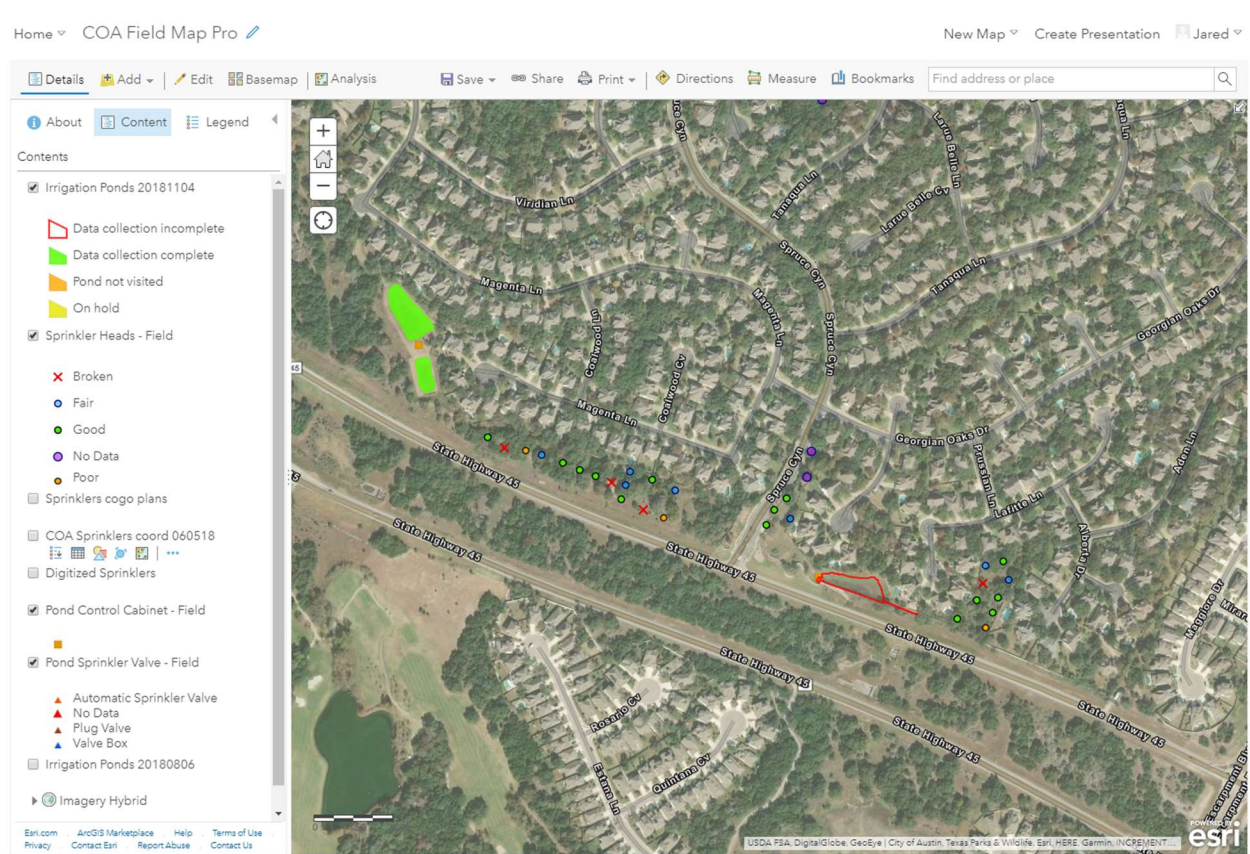
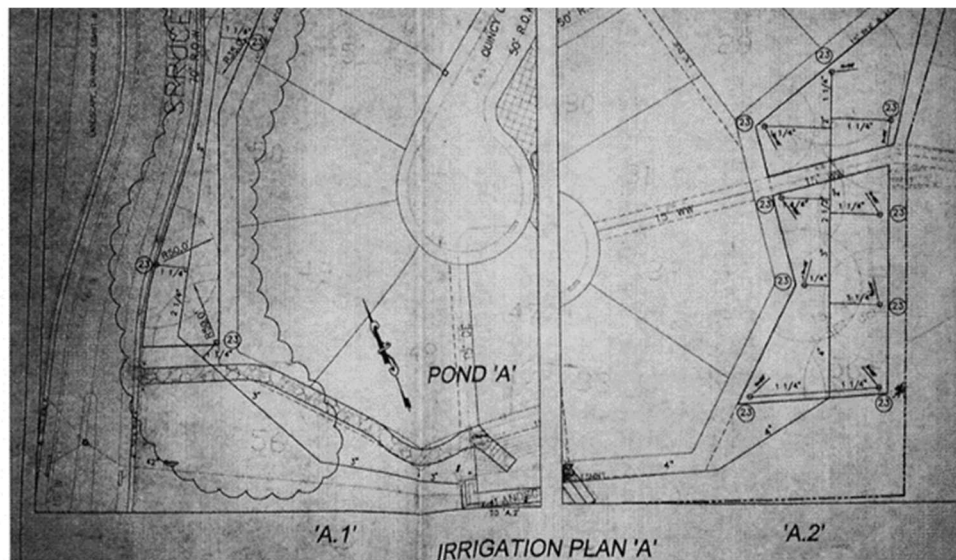


Figure 9 shows a screenshot of the final online webmap in ArcGIS Online. This new map is interactive and contains data on all the ponds in one searchable, scrollable, and easy to interpret location.

The maps created using the new geodatabase were used for communicating specific issues and questions with COAWPD during the data collection process; which will be further discussed in Chapter 5. A web map viewer application was created for CTWM to view within a browser on mobile devices in the field as seen in Figure 9. The top image in Figure 10 shows a comparison of an old as-built map (top) with the new web map (bottom). The lower image in Figure 11 shows the same pond, but in the mobile web map. By providing an online map that is GPS enabled, along with a base map for spatial reference, the ability to see where these sprinklers are in the real world has been made significantly easier. Another advantage of an online map that uses attributes is that the symbology of layers can be used to communicate important data to aid users. Sprinkler heads were symbolized to show their condition and whether they had been found. I also symbolized ponds based on their completion status to view if there



were any sprinklers missing and if more attention was required. See the lower image of Figure 10 shows a comparison of an old as-built map (top) vs. the new web map for examples of the updated symbology.

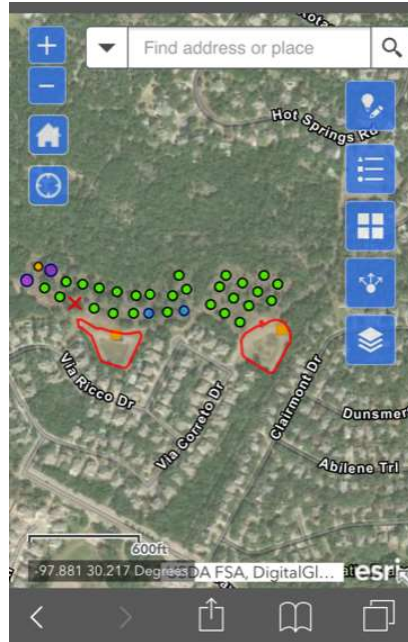


**Spruce Canyon - 352789**



Pond Sprinkler Heads	Pond Control Cabinet	Pond Sprinkler Valve	Irrigation Ponds
✗ Broken	■ Pond Control Cabinet	▲ Automatic Sprinkler Valve	□ Data collection incomplete
● Fair		▲ No Data	■ Data collection complete
● Good		▲ Plug Valve	■ Pond not visited
● No Data/Missing		▲ Valve Box	■ On hold
● Poor			

Figure 10 shows a comparison of an old as-built map (top) to new web map (bottom). The new map is much easier for anyone to use and will aid in the maintenance and planning in this area for many years to come.



*Figure 11 shows a webmap browser application created for CTWM field personnel that enabled use of the product in the field*

## Chapter 5: Discussion & Conclusion

### Discussion

During this practicum I encountered very few problems. I attribute this to the guidance of my mentor David Pritchard, the direction of the GIS Analysts at COAWPD, and my years of experience with field data collection. In this section I will talk about some of the unanticipated issues, the developments that took place during the project, and what I learned from those experiences that may help others in performing a similar project. In the Conclusions section, I propose further work that could be done with this dataset.

## Unanticipated Issues

I enjoyed the iterative process involved in creating and collecting the data. It was great to be able to try things out and keep what worked and eliminate what did not. Issues I encountered included:

- Mid-way through the project, the project manager decided it was no longer worthwhile to record the condition and the model of the sprinkler. This sped up the data collection process while still providing the data they needed.
- One thing that was great to see over the course of the project was how much easier it became for users to discuss locations using screen shots of the webmaps (see [Appendix B](#)).
- Even communications done through text messages were greatly improved by the use of the webmaps created in the project (see [Appendix C](#)).
- Some of the sprinklers could not be found on my first visit. The way we mitigated this was by going out with a CTWM technician and turning on the sprinklers so that I could try and find it while it was on. This worked well, except in instances where we found there was something causing the entire system to fail. The sprinkler's that were still unable to be located after that were marked as missing and would be further investigated for repair by CTWM.
- When updating some of the schema, data had to be exported as a geodatabase and not a shapefile because shapefiles did not have the capabilities required to maintain some of the longer fields.
- Construction was underway at two of the larger fields preventing me from data collection. I waited for 5 months for construction to be completed, but unfortunately after that time I moved away from the project location before the ponds became available for data collection.
- Some cabinets controlled two ponds. Because the key attribute used to relate cabinets to ponds was the Pond ID number, this made it difficult when one cabinet related to two ponds. In the

end, I just made a comment on the Ponds feature to let the analyst at COAPWD know about the anomaly.

## Conclusion

This project demonstrated the need, and now ease, of storing the locations of assets. By keeping a system of record that is spatially enabled, assets can be mapped and analyzed spatially along with a list of attributes. Further development ideas for this geodatabase would be to map out the irrigation lines to offer a more complete picture during repairs and to help avoid them during the planning stages. Another further development could be a related maintenance log table to keep track of maintenance performed on the sprinklers. Field personnel already submit forms for the work that they do, and this would be relatively easy to incorporate in Collector or Survey123 now that there is an existing geodatabase. The table would link to the sprinklers through a unique identifier, and this way problem areas and sprinklers could start to be identified by location and even manufacturer. This ties back to the idea that the geodatabase really is the foundation. Once the geodatabase is built, systems can be built on top of it and capabilities increased with little effort. This is part of the current digital transformation that we are experiencing right now. There is a call to eliminate “siloed” data wherever possible. Merriam-Webster.com defines siloed as “kept in isolation in a way that hinders communication and cooperation: separated or isolated in a silo.” By maintaining a single system of record in the geodatabase we can not only eliminate redundancies in data, but also begin to implement business rules through topologies. These rules can range from only allowing a 6” valve be put on a 6” pipe, to presenting a warning notification when field activities are scheduled within a specified distance from each other.

Another buzz word in the information technology at the moment is “scalability.” Merriam-Webster.com defines scalability as: “capable of being easily expanded or upgraded on demand.” The

geodatabase appears to be one of the most scalable pieces of technology that exists today. Brian Cross, director of Professional Services at ESRI, puts it this way “In the beginning of the database years, people talked about the foreign key that was the field in the database that linked things together so that you could link systems, and this was a very powerful concept that opened up a lot of opportunities.

Geography is the ultimate foreign key. Everything happens somewhere and that is the crux of what the geospatial cloud does. It integrates everything from all kinds of systems and all business systems in space and now in time. By doing this you can do analytics and see patterns that are not possible unless you are working in a map (Esri 2019).” This project also demonstrates how affordable it has become to build an online, incredibly accurate geodatabase. Collecting the data for this portion of the COAWPD’s geodatabase was a privilege.

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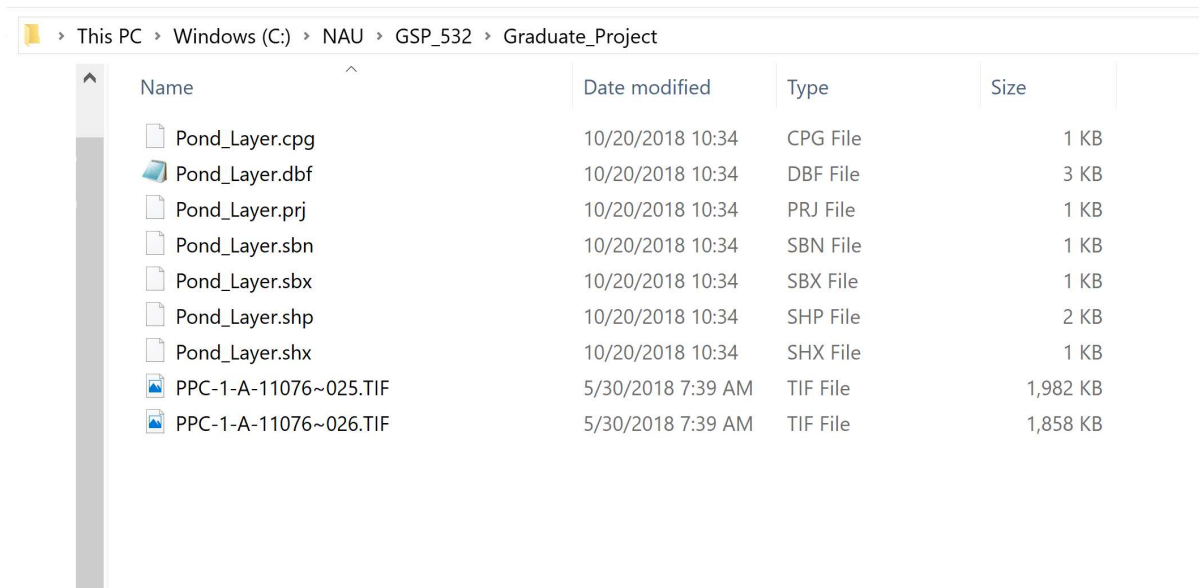
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## Appendix A: Georectifying Methodology with As-builts

### Part 1 – Download the Files

The first step is downloading the data to your C drive. ArcMap can have problems accessing files when they are stored in the 'My Documents' folder so it is good practice to create file folders on the C drive. It is also important that file pathways contain no spaces. For example, if you were to want a file folder NAU 532, it should be NAU\_532. Once the files are downloaded proceed to Step 2.



Name	Date modified	Type	Size
Pond_Layer.cpg	10/20/2018 10:34	CPG File	1 KB
Pond_Layer.dbf	10/20/2018 10:34	DBF File	3 KB
Pond_Layer.prj	10/20/2018 10:34	PRJ File	1 KB
Pond_Layer.sbn	10/20/2018 10:34	SBN File	1 KB
Pond_Layer.sbx	10/20/2018 10:34	SBX File	1 KB
Pond_Layer.shp	10/20/2018 10:34	SHP File	2 KB
Pond_Layer.shx	10/20/2018 10:34	SHX File	1 KB
PPC-1-A-11076~025.TIF	5/30/2018 7:39 AM	TIF File	1,982 KB
PPC-1-A-11076~026.TIF	5/30/2018 7:39 AM	TIF File	1,858 KB

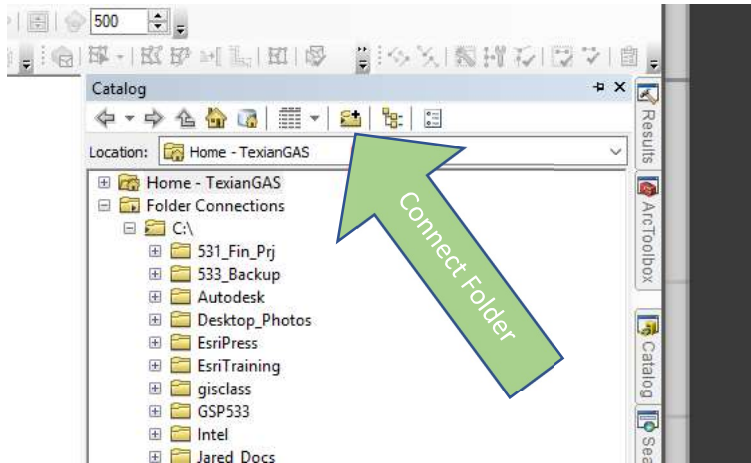
### Part 2 – Import the as-built into ArcMap

Key Term:

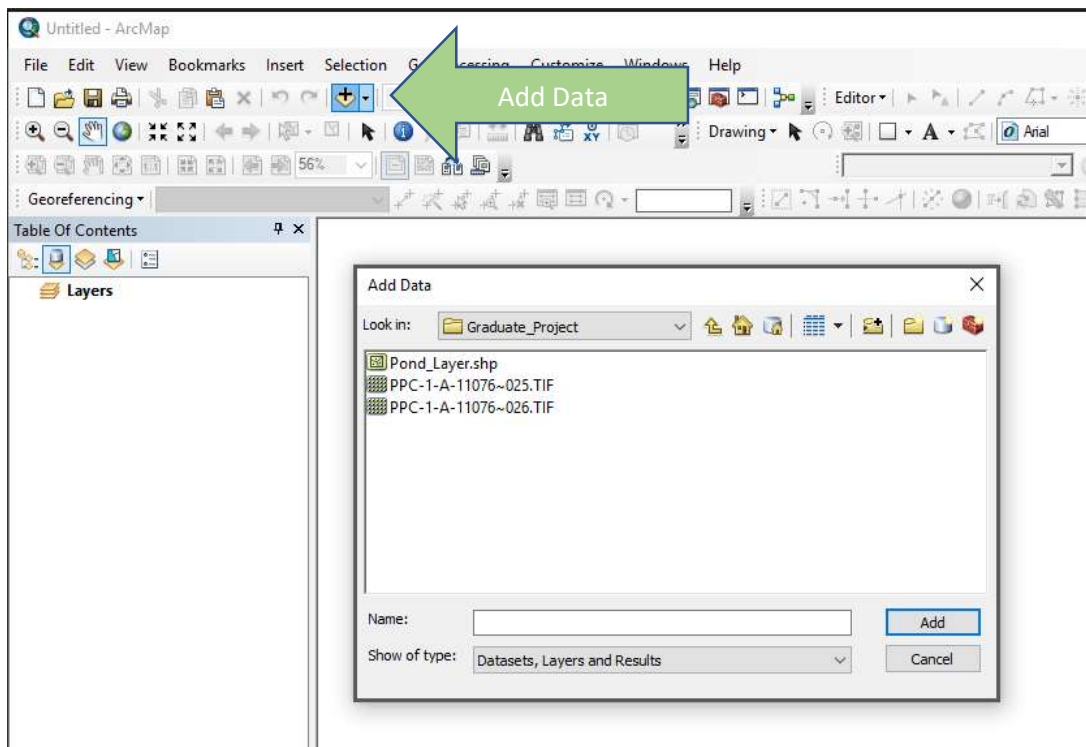
**As-built** - As-builts are like blueprints, however they are created after something is built to reflect the state of the final product.

1. Open ArcMap and start a new blank map.
2. Connect your file in ArcCatalog using the connect folder button shown below. Click the button and browse to the folder you created for this project.



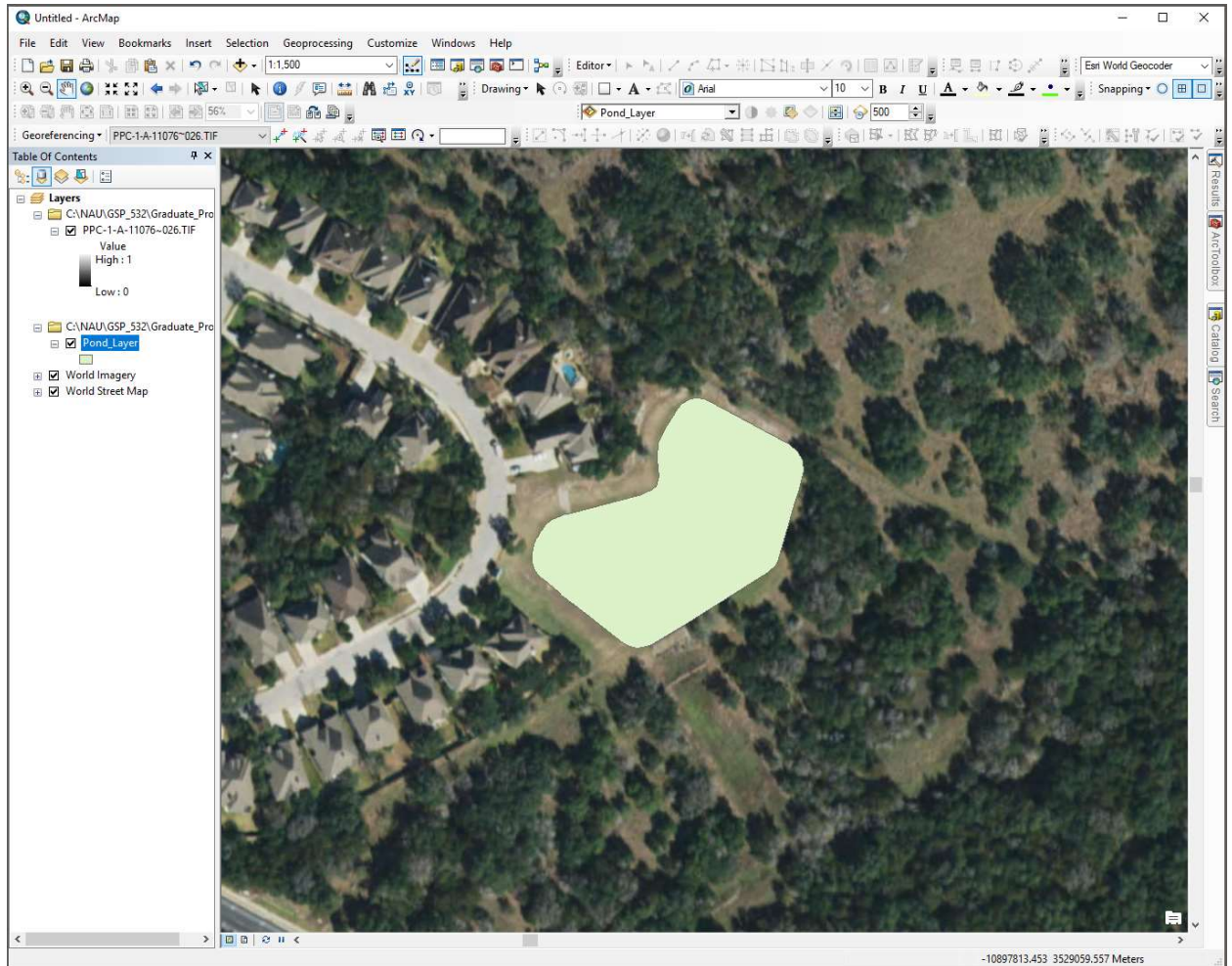


- Once connected, add the ponds layer by clicking the add data button and finding the ponds shapefile



- Now it is a good time to add a base map to get an idea of where this pond is. Click on the dropdown to the add data button and select 'Add Basemap' and select the Imagery basemap. Follow the same steps to add the Streets basemap.

5. Next click the 'Add Data' button and add the raster file PPC-1-A-11076~026.TIF Select yes for create pyramids and click ok when the Unknown Spatial Reference warning appears. We are going to fix that in the next part of this project. At this point your project and TOC should appear as the image below.



## Part 3 – Georectify the As-built

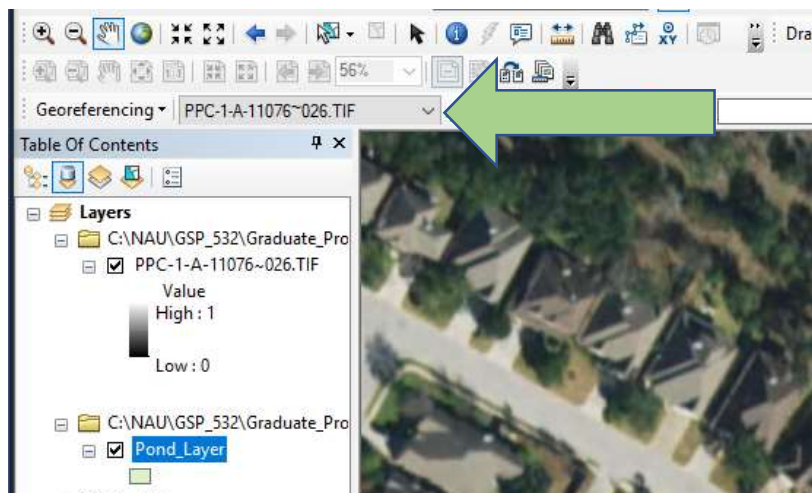
Key Term:

**Georectification** - A form of image rectification that transforms an image and a map onto a common coordinate system (YourDictionary, 2018).

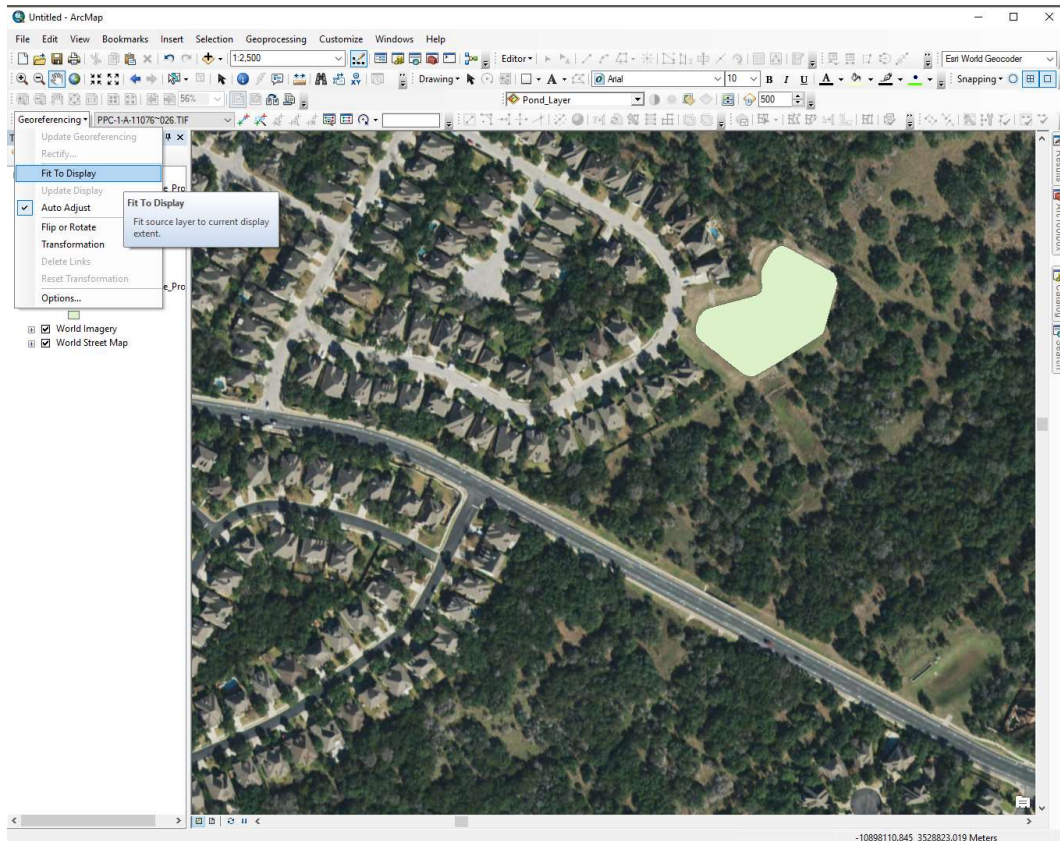
At this point, you might be wondering where your image is. Because it lacks a spatial reference it will not be displayed with the other objects from your TOC. We will now use the georeferencing toolbar to bring the map into view. If it has not been already, click on the Customize tab and enable the Georeferencing toolbar and dock it where you like (Customize > Toolbars > Georeferencing).

Georeferencing

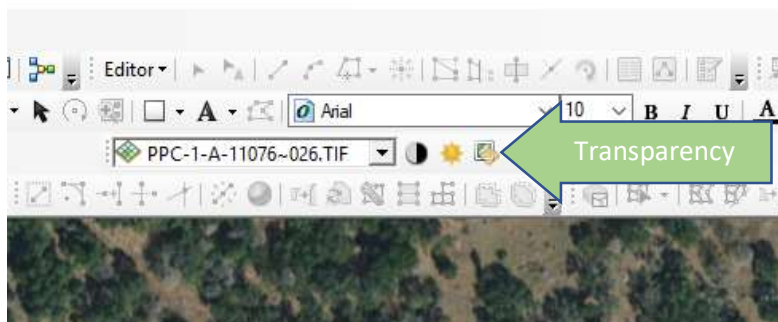
1. The .TIF should be selected, but if not, be sure it is selected in the georeferencing toolbar.



2. At this point I would recommend using windows explorer to view the TIF in your image viewer to get an idea of how far out you need to zoom out.
3. Zoom the map out and once you feel like you have it in a good position that the as-built will fit well over click on Georeferencing in the Georeferencing toolbar (see image on next page)



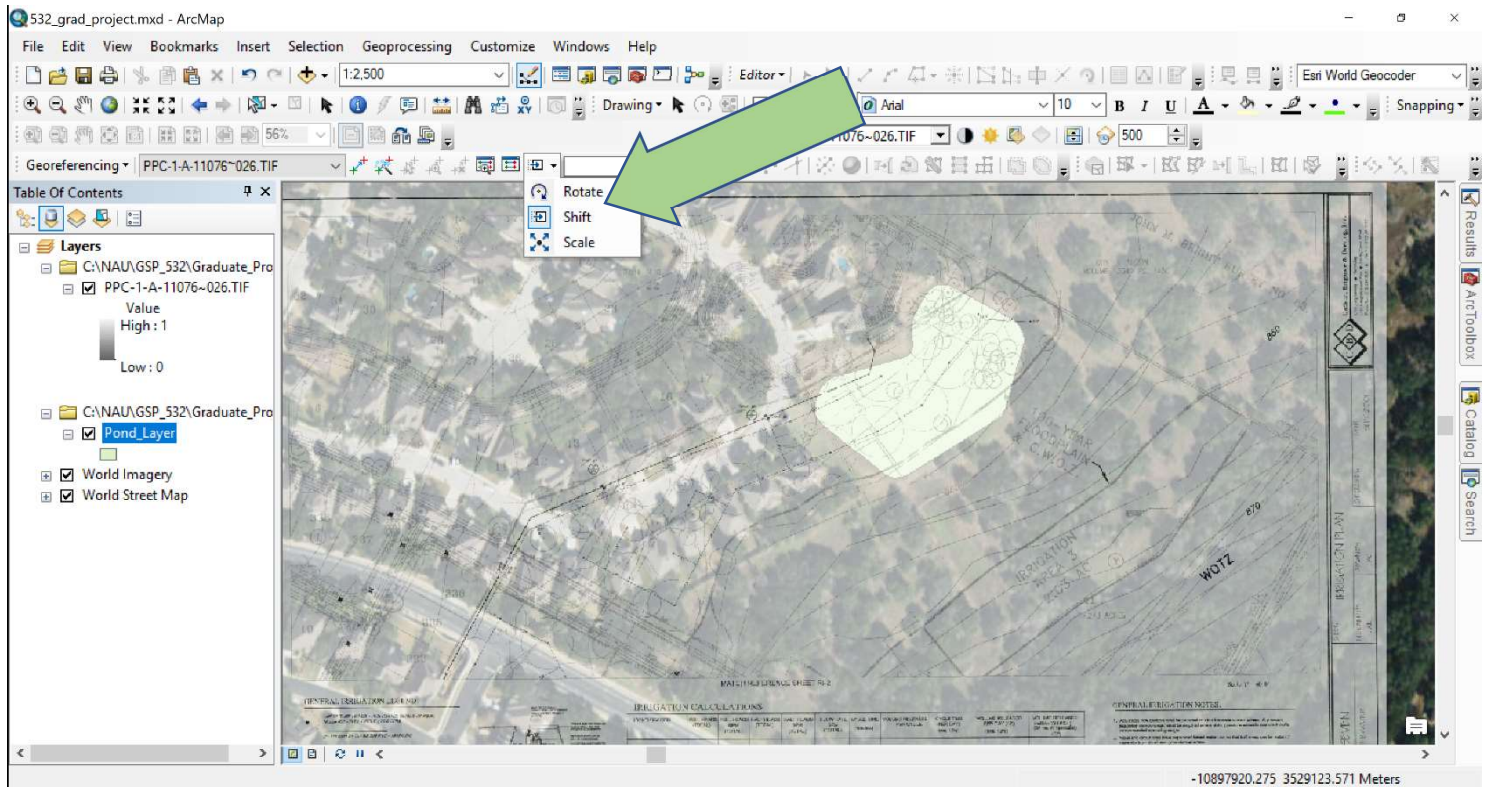
4. At this point it is a good idea to make sure the 'Effects' toolbar is turned on, if not follow the steps you used to turn on the Georeferencing bar to turn on the Effects bar. Once turned on select the TIFF layer. Click on the transparency and adjust it to 40%, or whatever allows you to see what's on the TIFF and behind it.





- From the far right on the Georeferencing tool bar click the dropdown and select the shift tool.

Zoom in near the pond and align the outline of the pond over the shape file.



- This gives a good starting point, from here start to look at the way the as-built overlaps the streets and the parcels. Use a combination of the Rotate, Shift, and Scale to line up the map with the roads the best you can. This is the hardest part so expect it to take some time. It doesn't have to be perfect, but if the closer you can get it in this stage, the more accurate the sprinkler points will be. \*\*\*HINT: Streets, street corners and fence line corners are good points of reference for alignment. Should look something like the following:



error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS error. This value describes how consistent the transformation is between the different control points. When the error is particularly large, you can remove and add control points to adjust the error. Although the RMS error is a good assessment of the transformation's accuracy, don't confuse a low RMS error with an accurate registration (ArcGIS, 2019).” I used a 1<sup>st</sup> Order Polynomial (Affine) for the transformation. I tried to get the as-built as close to lined up with the imagery as possible using the Shift, Scale, and Rotate tools before I added control points. The more precise the alignment, the easier it was to place the control points in. I generally received an RMS error somewhere between 3 and 4 meters. Below is an example of the Link Table and RMS for this particular georeferencing:

Link								
Total RMS Error: Forward:2.52308								
	Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
<input checked="" type="checkbox"/>	1	17.35426099	18.13769689	-10897667.98...	3528944.3700...	-1.11460825	-3.37256238	3.55197530
<input checked="" type="checkbox"/>	2	7.36574421	14.10033686	-10897878.50...	3528856.7134...	0.67339824	0.23206178	0.71226249
<input checked="" type="checkbox"/>	3	6.09507059	11.16088062	-10897905.80...	3528794.7481...	0.82495753	0.91452147	1.23162675
<input checked="" type="checkbox"/>	4	6.25222982	11.81538218	-10897902.10...	3528805.3315...	1.07989924	-2.37174655	2.60602457
<input checked="" type="checkbox"/>	5	6.01659082	19.42249516	-10897906.59...	3528965.1401...	0.17189114	-2.46185665	2.46785022
<input checked="" type="checkbox"/>	6	6.14337362	18.70966606	-10897905.01...	3528954.5568...	-0.79463145	1.87196867	2.03364349
<input checked="" type="checkbox"/>	7	13.40612082	15.61725314	-10897752.34...	3528892.6442...	-1.38796622	0.42724085	1.45223447
<input checked="" type="checkbox"/>	8	8.24705544	13.56368456	-10897862.67...	3528847.4003...	-2.07025834	1.65230754	2.64879025
<input checked="" type="checkbox"/>	9	16.09719040	19.11876688	-10897690.69...	3528970.6964...	2.61731812	3.10806528	4.06330210

☒ Auto Adjust
 Transformation: 1st Order Polynomial (Affine)
 ☐ Degrees Minutes Seconds
 Forward Residual Unit : Unknown



The result should look something like this:



- Once you are satisfied with the control points and confident that your as-built is georectified properly (parcels and streets all line up very closely), click on Georeferencing in the georeferencing toolbar and select 'Rectify'. In the window that appears browse to your project folder for the output. In the name type as\_built for the output.

Save As

Cell Size: 0.055029

NoData as: 16

Resample Type: Nearest Neighbor (for discrete data)

Output Location: C:\NAU\GSP\_532\Graduate\_Project

Name: as\_built Format: TIFF

Compression Type: NONE Compression Quality (1-100): 75

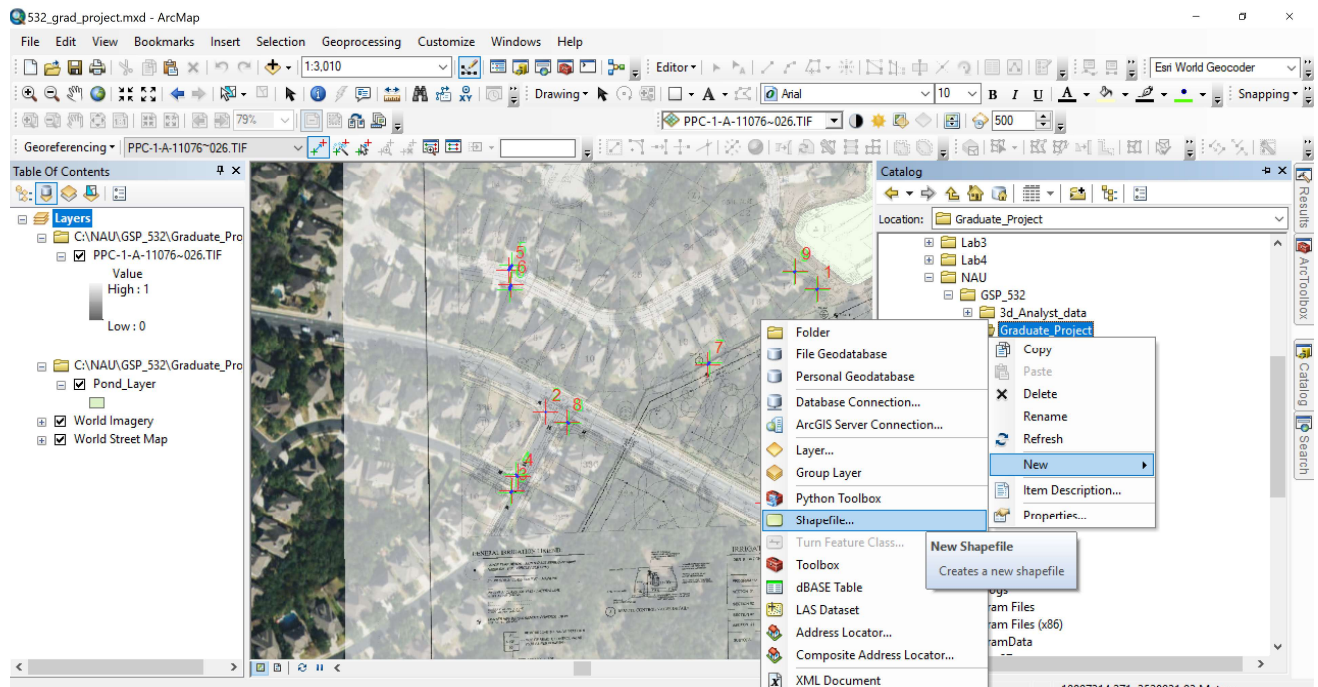
Save Cancel



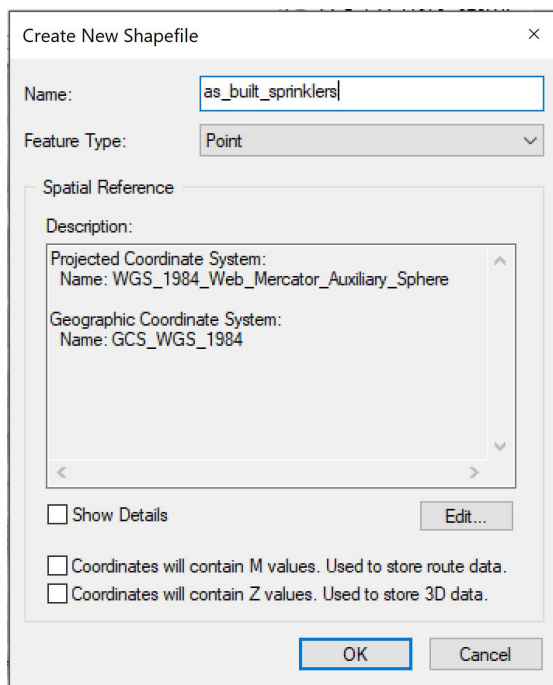
## Part 4 – Creating a New Point Layer for Sprinklers

Now that we have our basemaps in position, we are ready to create a point layer for the sprinklers in the sprinkler field using a process called heads up digitizing. In this part of the project we will:

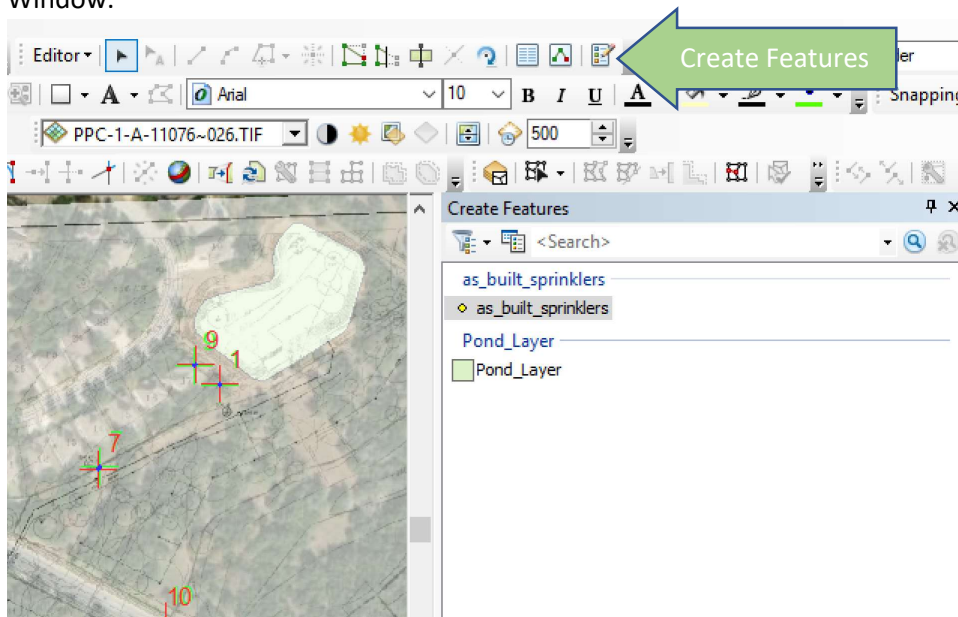
- Use ArcCatalog to create a new sprinkler\_as\_built feature class (point layer)
  - Create features in that point layer using the as-built as a baselayer
1. In ArcMap, go into the ArcCatalog tab and locate your project folder. Right click on the project folder and select New > Shapefile



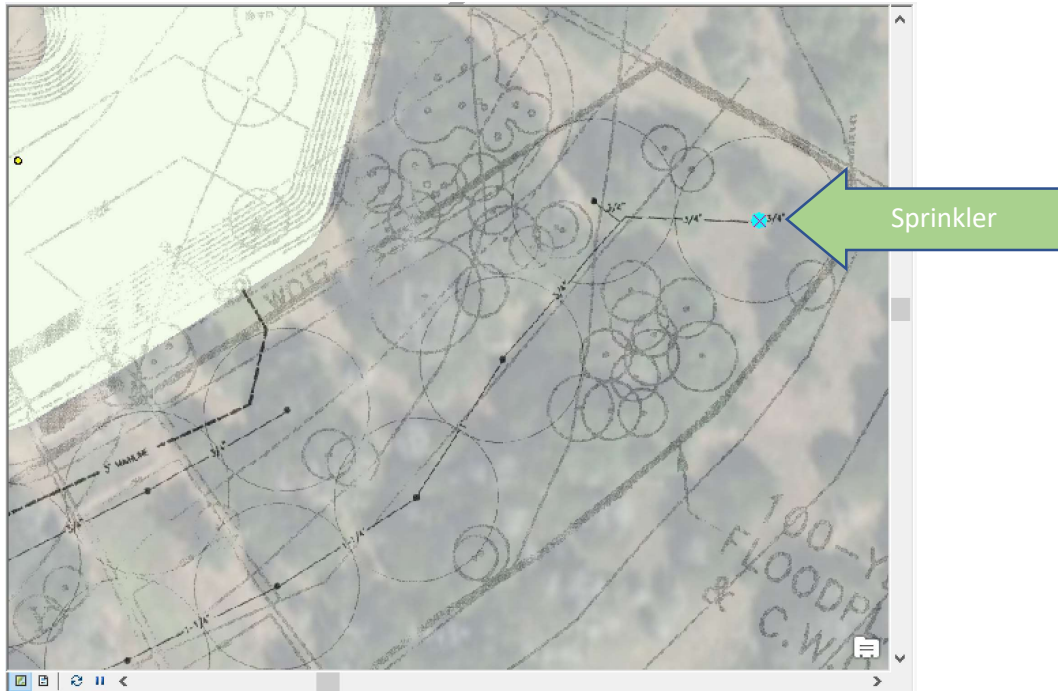
Name the file as\_built\_sprinklers and click Edit to browse to WGS 1984 Web Mercator Auxiliary Sphere. (Projected Coordinate Systems > World > WGS 1984 Web Mercator (auxiliary sphere) as shown below.



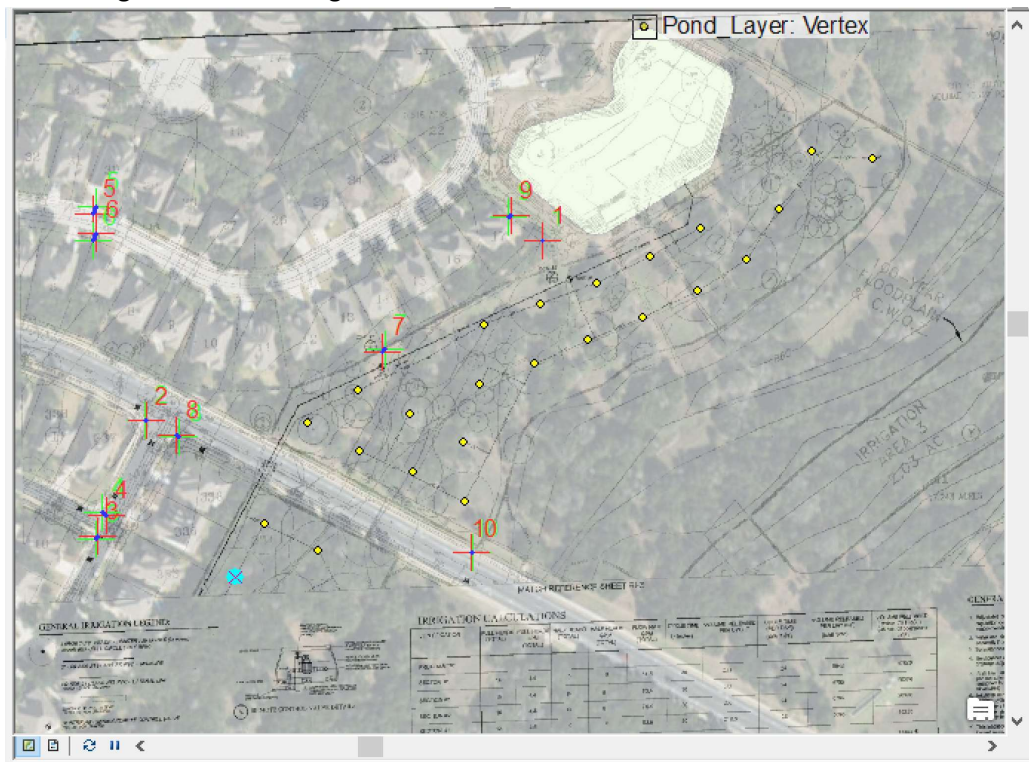
2. Symbolize the new point layer a bright color that will contrast with the background.
3. If the Editor toolbar is not enabled, enable it now using the same steps as the other toolbars. On the Editor toolbar, click Editor > Start Editing to start an editing session.
4. After starting the editing session, click the Create Features to bring up the Create Features Window.



5. Zoom in and find the sprinkler points on the as-built. Add points using the Create Features tool. The sprinklers are the points in the center of the large radius along the pipe. This could be found by reading the key on the as-built.



6. Add points to create features for all the sprinklers. When you are finished it should look like something like the following.



Click Editor on the Editor toolbar and select Stop Editing and Save Edits.



## Appendix B: Email Example Using New Maps

Appendix B shows an example of how the webmap was able to improve email communications about spatial data.

**From:** [Jared@TexianGeospatial.com](mailto:Jared@TexianGeospatial.com) <[Jared@TexianGeospatial.com](mailto:Jared@TexianGeospatial.com)>

**Sent:** Tuesday, October 02, 2018 3:07 PM

**To:** Boger, Matthew; Fordyce, William

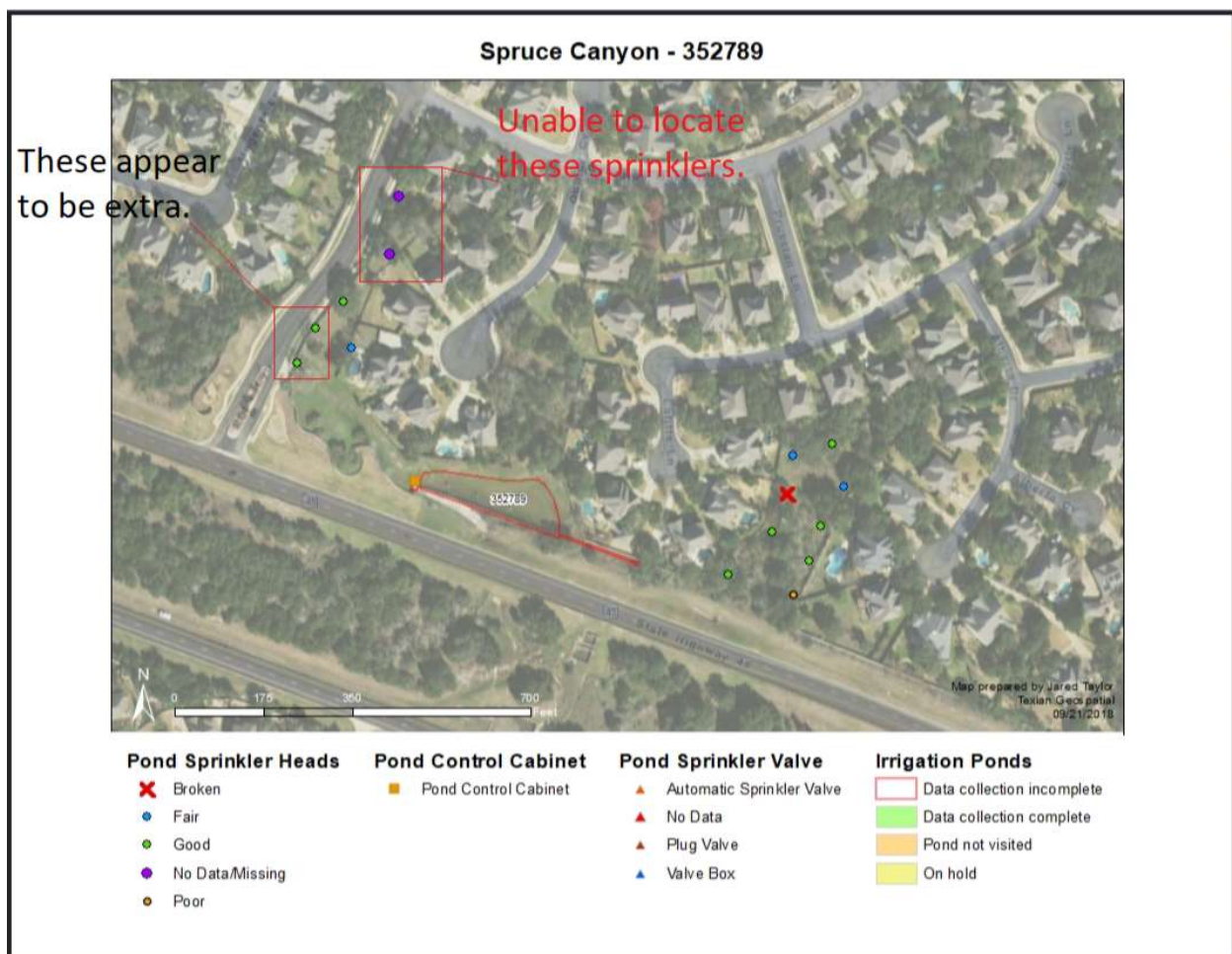
**Cc:** Leonard; Anthony Hernandez; Ben Gray; David Pritchard; Davis, Daniel; DeLano, Geoffrey

**Subject:** Sites Differing From As-Builts (1712872, 1712885, 352789)

Hi Guys,

Thanks for letting me know on those other ponds, I really appreciate you guys being available for the questions. I have a couple of different types of questions today. These ones are built slightly different than the as-builts show so I wanted to ask how to proceed on them.

Spruce Canyon – 352789 This pond has 2 extra sprinklers but is missing two (see below). I wasn't sure if it mattered but I thought it warranted asking about since it was different from the as-built.

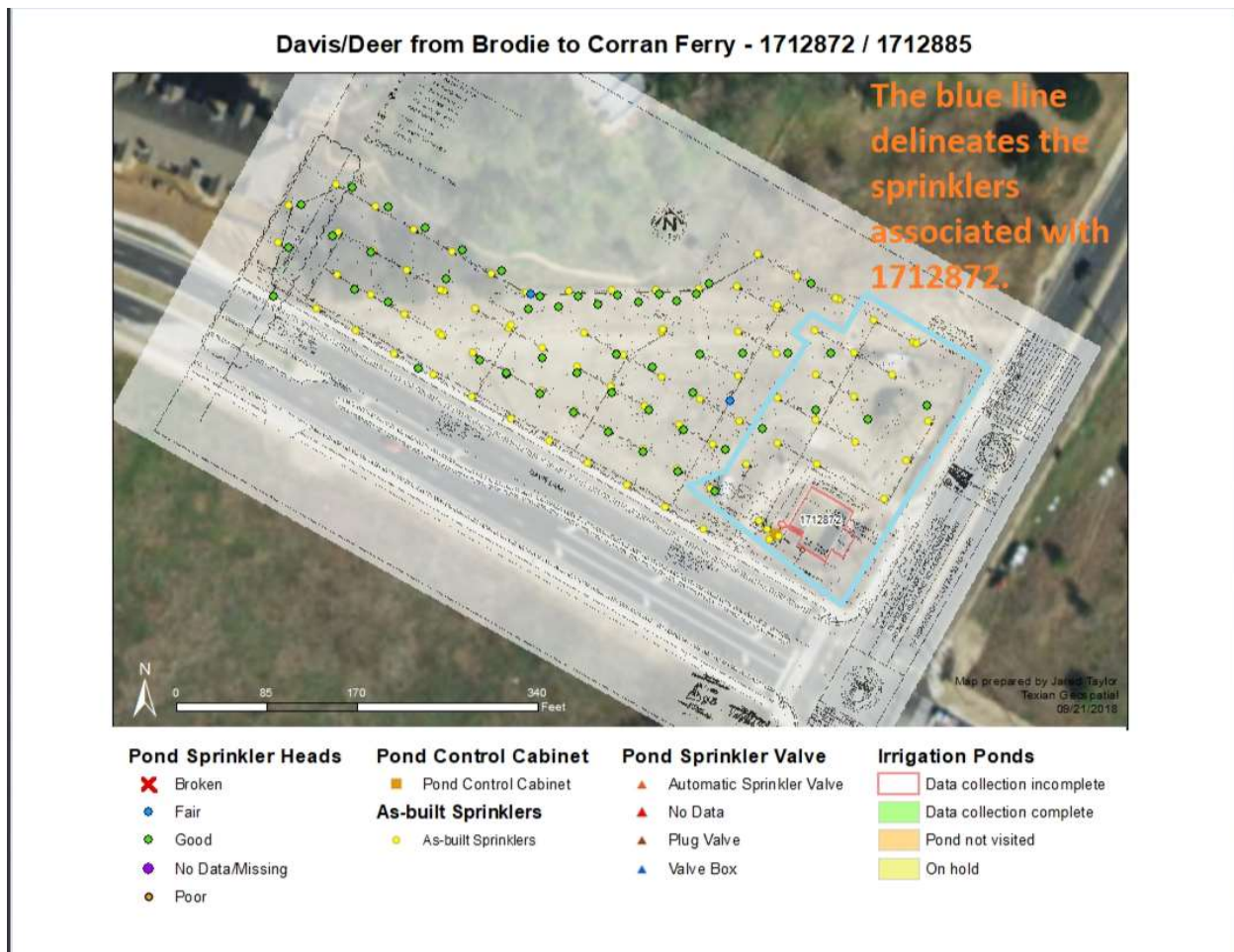


Davis/Deer from Brodie to Corran Ferry - 1712872 / 1712885

These sprinklers vary quite a lot from their as-built so I am not sure how you will want to move forward.

Pond 1712872 is missing 11 in a system of 17

Pond 1712885 is missing 13 in a system of 61 but is built differently than shown in the as-built.



Let me know if you guys have any questions on these and if you need anything else from us just let me know.

Hope you're having a great day,

Jared Taylor | GIS Analyst

p: 254-709-4402

e: [Jared@TexianGeospatial.com](mailto:Jared@TexianGeospatial.com)

## Appendix C: Text Messages Using Webmaps

### Example Conversation 1

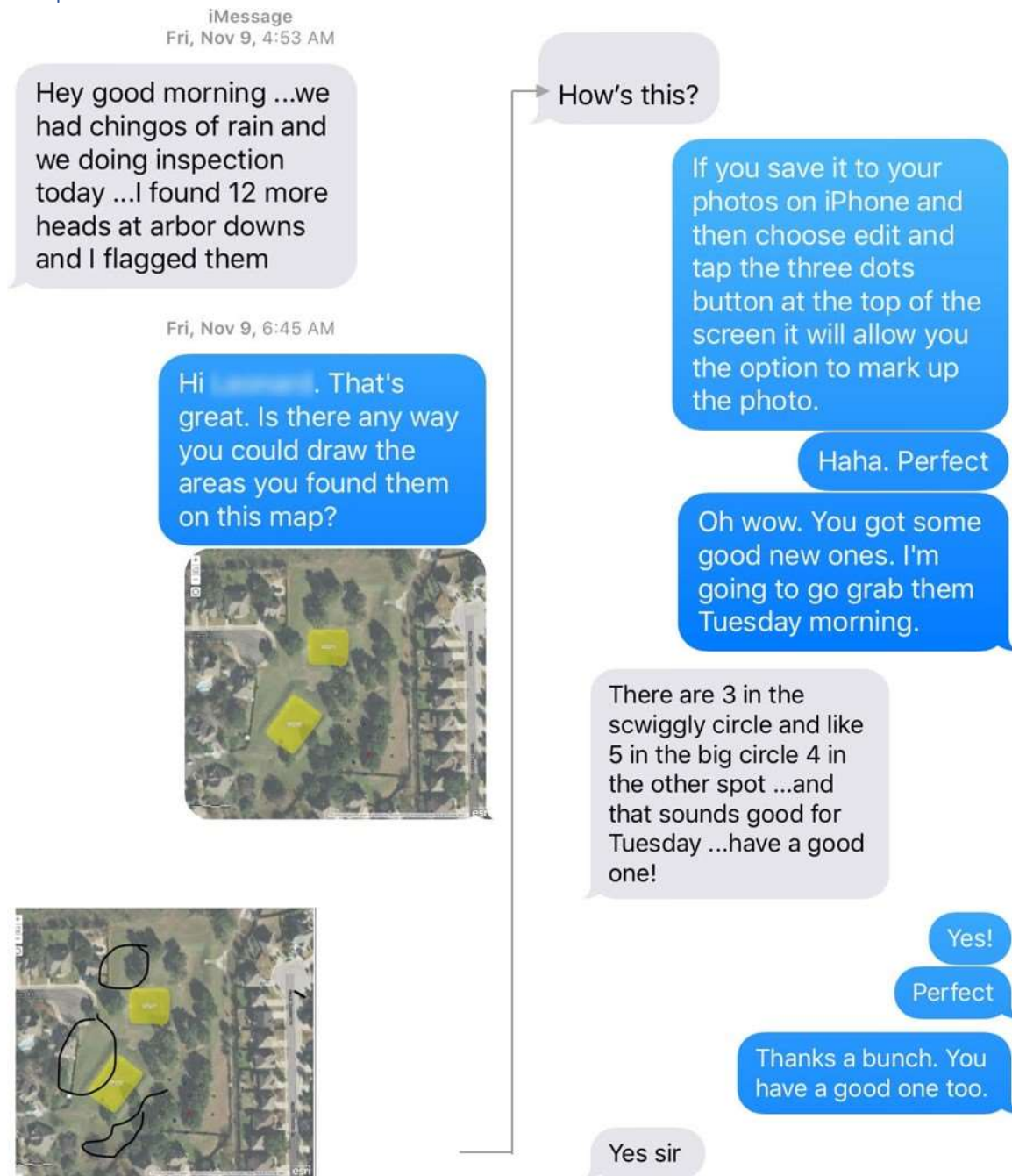



Figure 12 shows a text conversation where a field technician and I were able to communicate much easier because of the webmap. In this example he had located new sprinklers by turning them on and wanted to let me know where to find them to GPS when I could get out there.



## Example Conversation 2

Mon, Jan 21, 9:42 AM

Hi [redacted], here is a screenshot of the Oteka irrigation field.



Purple we were unable to find and the red X was a broken one.

Got it thanks

The notes say that the broken one the body of the sprinkler is blown out and it is inside a large bush of that helps.

Ok, yeah!! that's what I remembered under bush... I'll go locate it and get it replaced thanks again

Mon, Jan 21, 10:52 AM

Perfect...the map helped us find the head awesome

Great! Glad to hear it. Thanks for letting me know. Always nice when it works out.

Read 1/21/19

Figure 13 shows a text conversation example where I was able to send a screenshot of the webmap to the technicians in the field of the sprinklers that existed and the ones that were marked for repair. This enabled them to find the sprinkler much faster.