

Applying GIS to Landscape Irrigation Systems:
A Case Study of the Music Academy of the West Campus in Montecito, CA

by

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For my extraordinary parents, Anna and Mike.

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List of Abbreviations

GIS	Geographic information system
CAD	Computer-aided design
MAW	Music Academy of the West
USC	University of Southern California

Abstract

Many agencies today still use outdated paper maps and construction plans to manage their utility systems. Those using outdated information and methods can benefit from a digital upgrade.

Geographic Information System (GIS) is becoming a common solution for asset management and utilities because of its ability to combine spatial and non-spatial information all in one place.

This project implements a GIS for the landscape irrigation system on the Music Academy of the West campus in Montecito, California. Campus staff were using a series of disorganized and incomplete paper maps to manage their irrigation system. They also had no information about where the main line and lateral lines were, which proved to be problematic during construction projects and pipe leaks. Transitioning the paper maps to digital GIS format proved to be a good solution. Using GIS, spatial data collection methods, campus staff knowledge, and existing construction documents, new hardcopy maps and an online web map application for irrigation management were developed for campus staff. In the future, the new irrigation map data can provide efficient solutions for future campus facility projects such as water usage analysis and leak detection device placement. Creation of GIS data for irrigation and other utility systems will likely continue to be a solution for effective asset management in the future.

Chapter 1 Introduction

This project is a case study for the Music Academy of the West (MAW), a small music conservatory in Montecito, California. On the southeastern coastline of Santa Barbara County are approximately nine acres that make up the campus – a compact area with plenty of plants to water. With only outdated documents to reference, campus staff expressed a need for updated maps of their system.

The campus itself is over 100 years old, and various undocumented pipelines have been found underground. MAW staff have a need to distinguish between their active system infrastructure and old abandoned infrastructure. Updating maps will help prevent workers in ongoing construction projects from hitting unmarked underground irrigation pipelines. Additionally, they have had water leaks in the past and did not have the resources to quickly know which valve to use to turn off the water to a specific area. They were also aware that their controller maps for their irrigation zones were inaccurate and incomplete, making it difficult to know how to water specific areas. Their goal was to have updated maps to use to manage their system more effectively. The location and extent of the campus is shown in Figure 1.

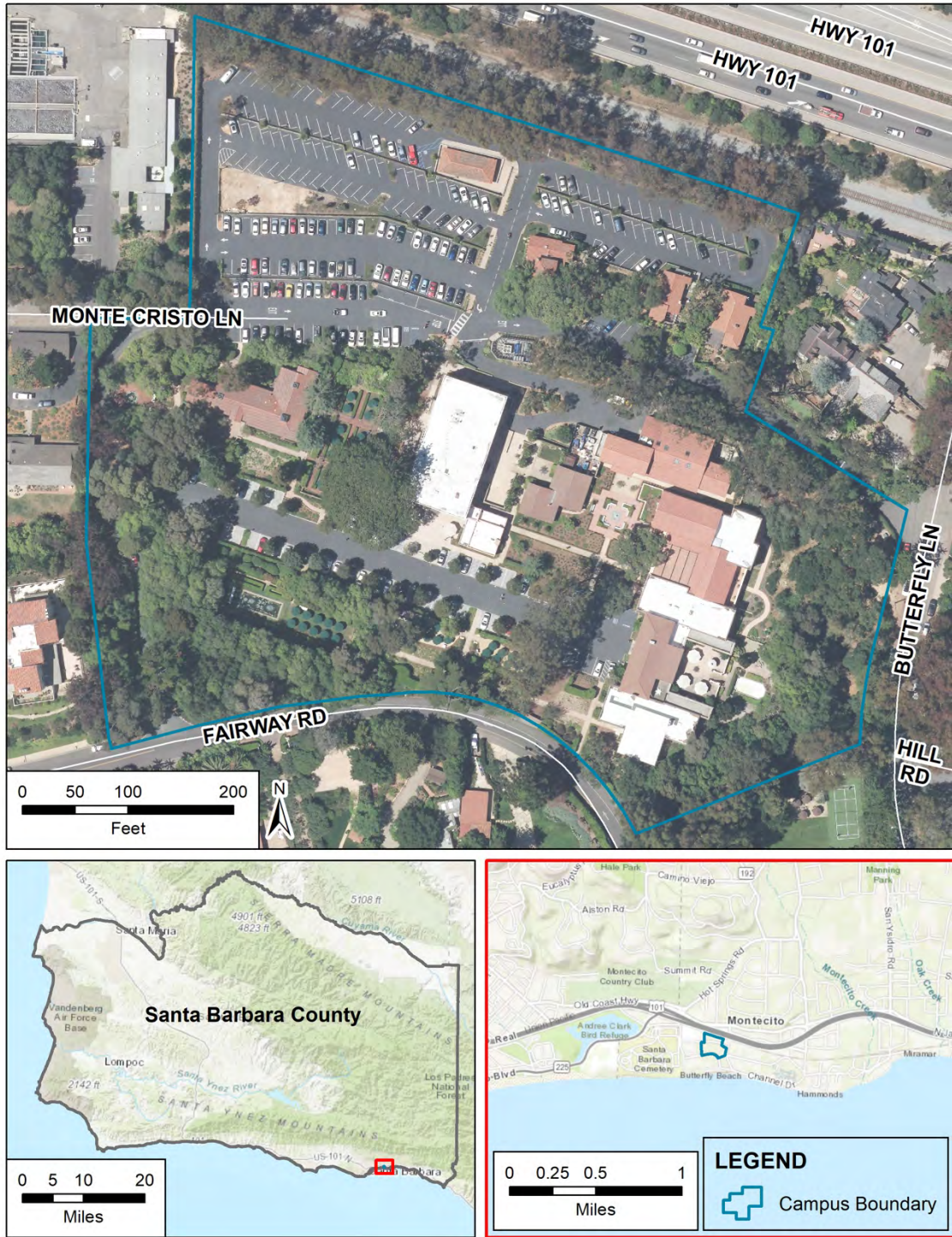


Figure 1. Location of the Music Academy of the West campus in Montecito, California

1.1. Overview of GIS and Utilities

Mapping and asset tracking are important when it comes to utility systems. Agencies that have been using outdated map atlases and mapping methods are now commonly turning to GIS as a solution. For many utility systems worldwide, GIS is in the planning or implementation stages (Cannistra 1999). For example, East Central Energy, a cooperative for electric utilities in Minnesota and Wisconsin, recently completed a massive GIS inventory for all their system assets. Team members were sent out to collect over 200,000 data points relevant to their system. In the end, the GIS inventory “improved accounting management, knowledge of underground assets for underground utility location requests,” and improved maintenance by providing system age and location information (Wick 2009, 22).

GIS is an appropriate tool for infrastructure management because it combines a visual map component with a database component. Unlike using scattered paper documents from varying sources, users can easily compare spatial relationships and details of features all in one place (Johnson and Goldman 1990). Common utilities that use GIS include gas, electric, sewer, and water. Water service districts and irrigation systems are two common types of water utilities. For this project, landscape irrigation refers to the systems installed for the automatic distribution of water to outdoor landscaping, for instance, a garden or lawn in a park.

1.2. Motivation

With the speedy advancement of electronics and software, it is important to research the process of converting system maps from paper to digital. After a construction project is done, contractors must provide finalized documents showing what changes were made and how the utility assets were built or altered. These final documents are called as-builts. As-builts are generally more detailed and more legible when they pertain to newer systems that were installed

more recently. However, they are not always completely accurate, regardless of the date they were created. Furthermore, with older systems, the documentation may be even less revealing.

Maps can still be created despite a lack of information. Figure 2 shows an example of a paper map that MAW staff were using prior to this project. It is a cropped selection taken from a construction plan that was annotated by hand. This proved to be only a temporary solution for them. The maps had not been updated when construction work was done and there were also errors in the original annotations. It is more efficient to have the data stored digitally so that updates can be made, and new maps can be more easily printed or viewed after changes are made to the system. Appendix A contains additional figures of all the old paper maps like Figure 2 that are not included in the body of this paper.

Reger (2017) studied this conversion process, referencing numerous factors affecting the mapping of a system using any existing information available, in some cases resorting to knowledgeable staff and basemap data when documentation was limited. This digital conversion will likely continue to be relevant in the field of GIS for some time until it becomes common practice to create GIS data concurrently with the installation of a system. Thus, it is an important topic in the GIS field to assist those still using outdated hardcopies.

The results of this project and similar projects may help promote the more efficient use of water. It is common for irrigation water to account for between 30% and 66% of water use in a community (Salvador et al. 2011). The state of California is constantly reminded of drought conditions and water-use restrictions. Climatologists say dry conditions will continue to be aggravated by climate change. To cope with this, there are many initiatives to evaluate the efficiency of watering systems (Rundle 2009). To evaluate an irrigation system, it is first necessary to be aware of the system layout and all relevant assets. GIS offers a solution to this task, as it allows for the storage of both spatial and tabular information. GIS can then provide the necessary tools for further efficiency evaluations, such as identifying locations to place leak detection devices. Additionally, identifying and mapping all irrigated zones on a campus can serve as the first step to further analysis. For instance, GIS maps and data can be used to compare water usage to actual water requirements for each irrigation zone.

1.3. Project Objectives

The goal of this project is to conduct a complete field inventory of the MAW campus irrigation system and create up-to-date maps for campus staff to use. MAW staff initially requested updated paper maps, however, a web map application will also be created. Although they did not ask for a web solution, it will be provided to them as an option because it will

showcase modern web GIS capabilities. MAW staff do not have experience or sophisticated knowledge of GIS, so it is possible they will eventually prefer an easy-to-use web solution over a static paper map system. Providing this web map as an option could also open the door for additional GIS work with the campus.

1.4. Thesis Organization

The remainder of this thesis document is divided into four chapters. Chapter 2 includes a literature review of related studies and concepts. Chapter 3 outlines the methodology and how the workflow was divided into various stages. The results of the project are presented and discussed in Chapter 4. Lastly, Chapter 5 discusses the project conclusions, challenges encountered, and future work.

Chapter 2 Background

In order to conduct such a project for the MAW campus, it was necessary to become familiar with similar projects that have already been completed. It was also important to research concepts that would be encountered during the project, including asset management, elements of successful cartography, and web GIS. Lastly, it required an understanding of the underlying landscape irrigation system structures and functions.

To address these elements, this chapter is organized into four sections. Section 2.1 covers GIS and Asset Management, beginning with a simple definition of asset management and a further description of the relevance of GIS for asset management. Section 2.2 covers GIS Project Management, including some recommended best practices and a review of past research done for small water systems. Section 2.3 covers Cartography and Web GIS, including guidelines for creating maps and an assessment of various web GIS options. Lastly, a brief overview of the functions and structures involved in landscape irrigation systems is covered in Section 2.4.

2.1. GIS and Asset Management

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, 26).

GIS is becoming more and more prevalent in asset management. Miner (2005) surveyed utilities and governments to create the Geospatial Technology Report, which serves as a benchmark for utilities to compare their GIS projects and usages with other utilities around the world. The report included responses from 43 different utilities and governments, primarily from

the United States. GIS database maintenance and work management were the top geospatial applications in the water, wastewater, and stormwater industry in 2004. The top geospatial technologies included GIS software, GPS, and document management (Miner 2005).

Using GIS to track spatial and tabular information over a variety of different thematic layers can reveal trends that may have otherwise remained hidden in spreadsheets or other documents. This supports more informed decision-making and the potential for the more efficient management of utility systems (Hanson 2008). GIS serves as one common tool, able to consolidate a variety of information from many incongruent sources. This contributes to its capabilities as a communication tool, since many people find it easier to understand information when it is presented as a visual map (Shamsi 2005).

For example, Makar (2017) conducted a study combining GIS with an existing asset management system for fire hydrants in Buffalo, New York. Buffalo Water struggled with aging and damaged infrastructure, particularly pipelines and fire hydrants. GIS was used to study trends in hydrant damage, and to predict where hydrants were more susceptible to damage from weather or vehicles. These conclusions could be used by Buffalo Water staff to make informed decisions about hydrant maintenance. For example, they could predict which hydrants needed to be relocated and which areas of the city would require the most attention.

A similar project was carried out by Ismanto and Mustofa (2015) for the Public Works Department of Merauke Regency in Indonesia. The department was able to develop an interactive map tool that provided all the necessary capability to access, manage, and update the information for their system of irrigation canals. They concluded that using a map as an interface was an easier and more efficient solution for making decisions. For example, it was reported that

the new GIS tools made it possible to plan for maintenance as well as monitor resource potential within the system.

2.2. GIS Project Management

2.2.1. Best Practices for Converting Utility Data to GIS

Cannistra (1999) provides a general overview of the necessary steps to take and considerations to be made when converting utility data for a GIS and emphasizes the need for structure when it comes to planning such a conversion project. In the early stages of the conversion process, “a base map must be developed” to be used as reference and help define what scale the database will use (Cannistra 1999, 59). There are different options for the method of data conversion itself including: dimensional entry using offset distances from as-builts to base map features, scanning of documents and conversion from raster to vector, capture of features through scanning or heads-up digitizing then readjusting locations to match the base map, and field inventory. Most of these methods are not perfect. For example, scanned documents can be used to create vector features, but it can be difficult to accurately acquire the information without manual review, especially when it comes to reading labels to input attributes and addressing topology issues. Additional issues can arise when as-built documents are outdated or otherwise inaccurate (Cannistra 1999).

Thus, a combination of the methods listed by Cannistra (1999) seem to be a potential solution. It seems that most as-built documents are not entirely accurate representations of what is in the field. This could be a result of the installation crew deciding to slightly modify the configuration or a subsequent project modifying a configuration after the fact. Therefore, a method using only scanned documents to either digitize or convert from raster to vector would not necessarily output a dataset accurately representing the real-world system. A combination of

scanned documents and field inventory, however, would use the valuable information from the as-builts while verifying each asset in the field along the way.

When conducting a GIS project, it is important to address the needs of the intended end-users of the data and other final outputs. Crawford (2012) implemented GIS for three utility departments in Calhoun, Georgia. This study was highly focused around the idea of completing user needs assessments for each department. Crawford (2012) used concepts mentioned by Shamsi (2005) and Cannistra (1999) to structure a basic needs assessment checklist, which includes staff interviews to identify current workflows, overall goals, existing data, and potential applications. The result of the needs assessment was a list of major functions and processes to be addressed in the GIS implementation, as requested by the users.

Asset inventory should be done in the early stages of a utility project because it allows for an initial understanding of the current state of the system. It identifies and documents gaps in the system and its data, which can then be dealt with in a more targeted manner (Heltzel 2003). Conducting a project like this will likely “take many years but the proper approach will provide increased benefits from each task required to complete the system” (Heltzel 2003, 27).

After the final GIS products are created, it can be valuable to allow users to provide feedback and ideas for future improvements. Grotefend (2017) demonstrated a process for evaluating a web map application after it was completed and made available to the intended users. A web map application was created for airport staff to interact with pavement condition report data. Airport staff who were not involved in the development of the application were chosen to evaluate the final product. These users were sent a link to the survey form through email and given ten days to respond. The survey form was created using SurveyMonkey, which allows for the rating of statements on a five-point scale as well as answering prompts with

freeform text responses. This proved to be an effective way to receive feedback on the final GIS product.

2.2.2. GIS for Small Water Districts

Reger (2017) conducted a similar project implementing GIS for a small community water district. The needs assessment was much simpler, involving a meeting with the water district staff to conclude what the project would entail. A simple assessment of the existing data and desired result is all that is needed since it is a small campus still in the early stages of its GIS journey. Early meetings with the Music Academy staff revealed the need for a simple and updated map, which required a complete field inventory. After the initial inventory and data creation process, the user may have additional needs and another assessment may be needed in the future.

Reger (2017) used a few different sources to create the final GIS data. An evaluation of existing sources concluded that the district had old computer-aided design (CAD) maps and as-builts. This information was used to create a summary of the features that would need to be collected in the field using a GPS unit. After the field data was collected, it was used in combination with the CAD maps, as-builts, and staff knowledge to create and edit the final GIS data. This study is comparable to this project in that it involves mapping a utility using limited and outdated information. The methods are similar for implementing GIS for the MAW campus, as there are only outdated as-builts and hand-drawn maps as source data. This project differs from the study done by Reger (2017) because it involves a different utility and goes beyond the creation of hard copy maps to create a web map application to allow the users to access and interact with the new data.

2.2.3. Irrigation: GIS at the Campus Level

Both Reger (2017) and Gosh (2016) reinforce the importance of referring to staff for help where existing sources are limited or non-existent. Gosch (2016) conducted a case study implementing a landscape irrigation GIS for the Veteran Affairs campus in Palo Alto, CA. This study used staff knowledge as a principal source for creating the GIS data, unlike many of the key methods used and recommended by Cannistra (1999), Crowth (2012), Shamsi (2005), and Reger (2017). Gosch (2016) used several meetings with the campus's landscape architect, who sketched details of the system by hand, which were then used as a reference to directly digitize features into ArcMap. Because of the helpful and knowledgeable staff members, Gosch (2016) created the data without field GPS collection or as-built digitization.

Gosch (2016) successfully mapped all irrigation zones, controllers, and valves for the Veteran Affairs campus. It was mentioned that an item for future work would be the inclusion of the underground pipelines into the GIS. The initial plans for the MAW project included the mapping of the pipe main lines and lateral lines along with the irrigation zones, controllers, and valves. It also reinforced the importance of working with staff members to ensure all available knowledge is considered when creating the GIS data. A combination of existing available source data and staff knowledge seemed to be the most reasonable approach for the MAW project.

2.3. Cartography and Web GIS

2.3.1. Map Creation

Creating maps requires an understanding of map elements and how to manipulate them. There are three basic map components: scale, projection, and map symbols. Scale and projection for this project are addressed in Section 3.3.1. "Map symbols can differ in size, shape, graytone value, texture, orientation, and hue" (Monmonier 1996, 19-20). Shape, texture, and hue are the

best properties to manipulate when displaying qualitative differences. To display quantitative differences, varying symbol size or graytone value is best (Monmonier 1996). It is also important to consider the purpose and intended users of the map. Careless manipulation of map elements can produce a map that is difficult to understand or use. These concepts were considered when final symbols were chosen for the map legend in both the new controller maps and the web map application.

2.3.2. *Web GIS*

With the increasing use of web-based applications, GIS is no longer restricted to professionals. This leads to the need to improve user experience, which refers to “the level of satisfaction a person gets from using a product or service” (Fu and Sun 2011, 45). GIS can now be used by non-professionals who “have no concept of GIS except that they expect it to be as easy to use as a regular Web page and as fun to use as a multimedia center” (Fu and Sun 2011, 45). Thus, web applications should be “fast, easy, and fun to use” (Fu and Sun 2011, 45). Because of the importance of user experience, the workflow for this project included user training and feedback regarding the final map products.

Mobile web GIS is becoming more common in utility management. Traditionally, field inspections are done using paper notes and entered into a database at a later time. This method of updating information can be inefficient and filled with mistakes. Mobile GIS can allow users access to the data while in the field, making it easy to see assets and update them simultaneously (Shadin and Tahar 2015). To get to the point where a utility system can be managed in this way, it is first necessary to conduct projects that create all the GIS data and publish it on a web map application.

2.3.2.1. Google Maps API

There are several options when it comes to creating web map applications. One option involves using the Google Maps API, which provides a variety of customization capability. For example, one can use Google's geocoding service, animate map items, create interactive annotations, and more. Markers can be placed on points of interest, and InfoWindow Objects can function as map tips. Additionally, JavaScript map events can be set up to respond to specific user actions, such as mouse clicks, drags, and zooms (Petroutsos, 2014). This was a valid option for this project, as the desired output was a simple web map with basic functionality.

The Google Maps API was considered but deemed inappropriate for this project. One reason for this decision is that the company through which the project was being conducted was already using a different web mapping solution that was readily available. Thus, setting up a different option would be unnecessary. Google Maps requires an API key which is used to monitor the usage of the web map. When the map reaches a certain threshold of user requests, it is no longer free to use. Additionally, the user interface of many embedded Google Maps applications is not as streamlined or visually pleasing as other available solutions. For these reasons, the Google Maps API was not chosen as the method for the web map implementation.

2.3.2.2. Esri Web AppBuilder for ArcGIS

Esri Web AppBuilder for ArcGIS is another valid option for web map implementation. Web applications with simple, pre-made widgets can be quickly configured if the user has an ArcGIS Online account with a subscription. It would be possible to complete the project using the ArcGIS Online and server subscription through a student account with the University of Southern California (USC). The project goals involve creating a simple easy-to-use web application, which would be met with the simple widgets available in Web AppBuilder.

Esri Web AppBuilder was not chosen for this project for two main reasons. First, the MAW staff intended to have a solution that would last well into the future. This would not be sustainable if the data and applications were to be hosted using a USC student subscription. Second, the techniques used by the company the project was conducted through do not involve the extensive use of ArcGIS Online.

2.3.2.3. Geocortex Essentials

Geocortex Essentials 4.8 was chosen for this project because it is an existing set up used by the company conducting the project. It was ideal to adopt the web application methods already in place. Geocortex Essentials by Latitude Geographics is a solution for web map application implementation aiming to spare users the time and resources needed to single-handedly develop customized applications. It offers many features and capabilities including accessibility, reporting and printing, forms, charting, workflow, security, integrations, and instant search. It uses the ArcGIS server platform and generates web applications that are desktop and mobile friendly (Latitude Geographics Group Ltd. 2017).

2.4. Landscape Irrigation Systems

As a prerequisite to this project, it was necessary to become familiar with the basic processes and structures involved in a landscape irrigation system. A landscape irrigation system is composed of irrigation zones and their corresponding control valves. The control valves can be for drip systems or sprinkler systems. Drip systems slowly feed water to an area through a series of flexible tubes that have been placed among the plants. Sprinkler systems feed water to an area quickly by spraying it in various directions and distances. Remote control valves can be wired back to a controller station for remote and automatic operation. There are main lines, which are

connected at the water meter connection for the property, and lateral lines, which branch off from the main lines. Backflow prevention structures are installed to prevent water from flowing back into the main system, usually near the water meter connection.

Hose bibs, also called garden valves, are above-ground features that can connect to hose tubing for manual watering. Quick coupling valves are like hose bibs, as they can be used for quick and temporary access to the water supply, however, they are generally covered inside irrigation boxes. Other valves include isolation ball valves and gate valves, which manipulate the water service to smaller regions of pipe. They can be used to turn smaller pipe sections on and off (Rainbird Corporation 2017). Figure 3 and Figure 4 show some of these structures as they looked on the campus during field collection.



Figure 3: Field photo of two remote control valves (left) and a quick coupling valve (right)



Figure 4: Field photo of controller D, a wall-mounted Irritrol box with up to 12 connections

The MAW campus mostly uses three main brands of irrigation materials: Rainbird, Hunter, and Toro. Identifying these brands helped to locate assets in the field and look up their functions at the manufacturer websites when needed.

Chapter 3 Methods

The methodology for the project was fully planned in the beginning but adjusted throughout the duration of the work to accommodate several unexpected challenges that were encountered.

There was an active construction project on the campus at the start of the inventory process that made it necessary to wait to collect features in the area until after the construction was complete.

This also made the aerial imagery outdated as a basemap, requiring some new methods to be developed to adapt the project. Section 3.1 outlines the project workflow that was initially planned. Section 3.2 lists the technology and hardware requirements as well as the initial data requirements. Sections 3.3 and 3.4 discuss the completion of the project through two main steps: Data Collection and Application Development.

3.1. Workflow

The project required two main steps: data collection and application development. Data collection involved initial research, field collection, and data development. The application development involved the creation of new hardcopy maps, the development of a web application, user training, and user feedback. These steps are illustrated in Figure 5.

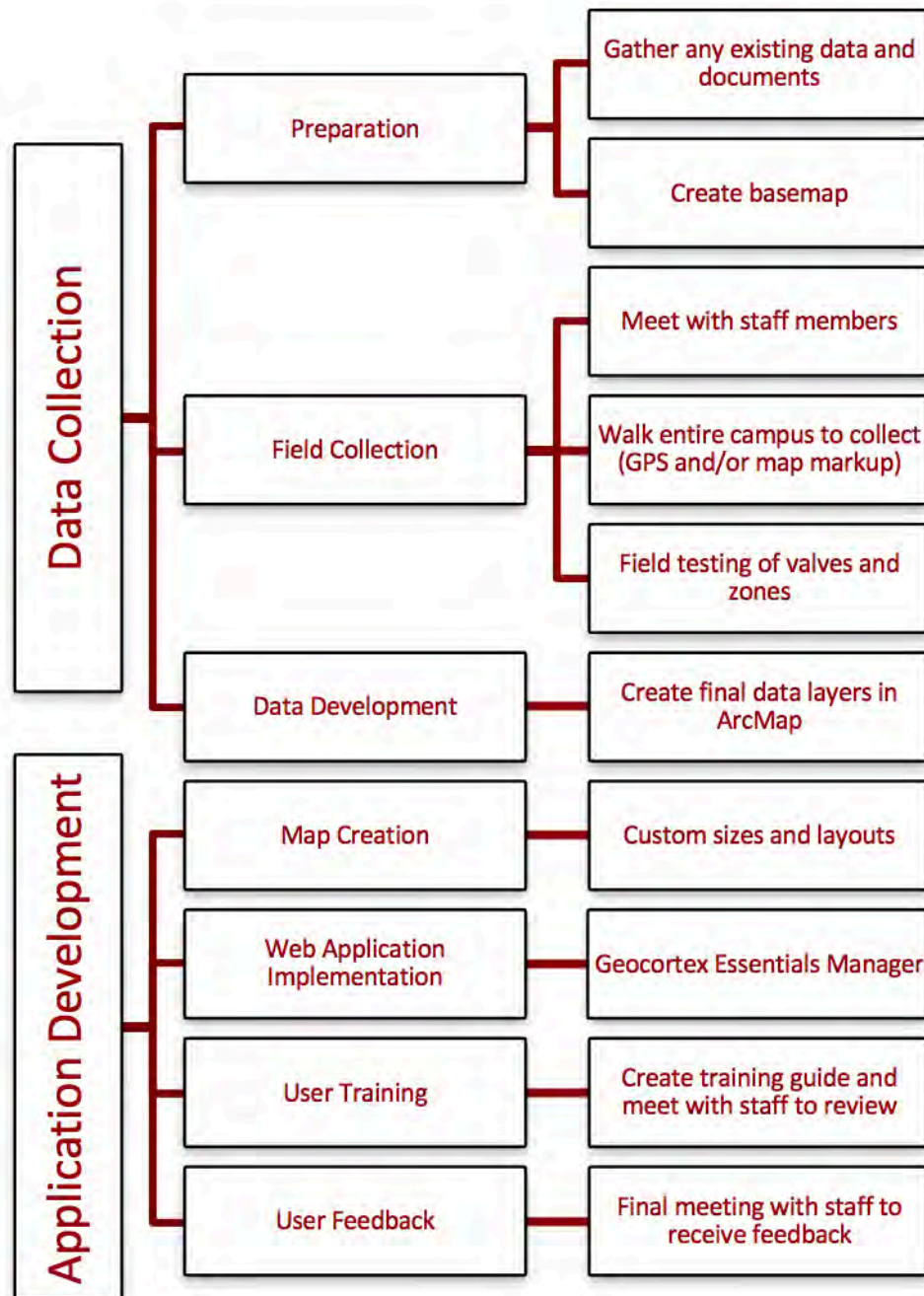


Figure 5: Workflow with two main phases: data collection and application development

3.2. Requirements

3.2.1. Technology Requirements

This project required several technologies. Special equipment was needed for the field collection and specific software was needed for the data processing, data editing, and application development. These project technology requirements are summarized in Table 1.

Table 1: Summary of project technology requirements

Equipment	Software
○ Trimble Geo 7x Handheld GPS	○ ArcPad 10
○ camera	○ Trimble Pathfinder Office 5.81
○ measuring tape	○ ArcGIS Desktop 10.5.1
	○ ArcGIS Server 10.5
	○ Geocortex Essentials 4.8

3.2.2. Data Requirements

This project demanded the collection and creation of all the features for the MAW campus irrigation system, which made up the bulk of the project data. However, some initial data items were required to start the project. The input data is summarized in Table 2.

Table 2: Initial data requirements

Data Item	Description	Scale/Precision/Accuracy
Existing engineering plans of the campus	Digital scans of documents that reference the irrigation plan.	Outdated and inaccurate
Existing hand-drawn diagrams and maps of the irrigation system	Paper documents created by past staff members that reference the irrigation plan	Outdated and incomplete
Aerial imagery of campus	Imagery to act as basemap and aid with digitization	3-inch pixel resolution aerial imagery flown in June 2015
Basemap of study area	Vector basemap of the campus created by digitization from aerial imagery	Accurate to imagery
Campus boundary	Polygon representing boundary of MAW campus	Santa Barbara County Assessor parcels dataset

3.3. Data Collection

3.3.1. Preparation

The first step was to gather all existing documentation of the system. MAW staff scanned all their hardcopies to make this step easier. Digital copies of the relevant source documents were obtained. These included construction plans and hand-drawn maps that ranged from the 1980s to the present. Using these documents, an initial list of all the features relevant to the system was drafted to serve as a guide for field collection and the final map legends. This list was then presented to staff for review, as recommended by Tomlinson (2013). However, the staff did not seem to have a complete knowledge of irrigation systems, so little guidance or feedback was received at this step. Because of this, it was decided that including more detail rather than not enough detail would be a good approach for the field inventory.

The next step was to create a base map of the study area to provide context and a background for final maps. It was important that the aerial imagery available was from 2015, recent enough for use in the project. Creation of a basemap involves choosing a map projection, digitizing buildings, points of interest, and any other additional features such as walkways (Gosch 2016). Creating a base map helps with orientation, deciding the scale and accuracy needed, and the overall project scope. California State Plane Zone V was chosen as the map projection because it is the local projection for Santa Barbara County. The basemap also revealed that the project would be covering a small area and thus required more precise and accurate final data, at least sub-foot accuracy. The basemap is shown in Figure 6. When the project started, there was an area of the campus closed off due to building demolition and construction. This is shown in the polygon outlined in red and white.

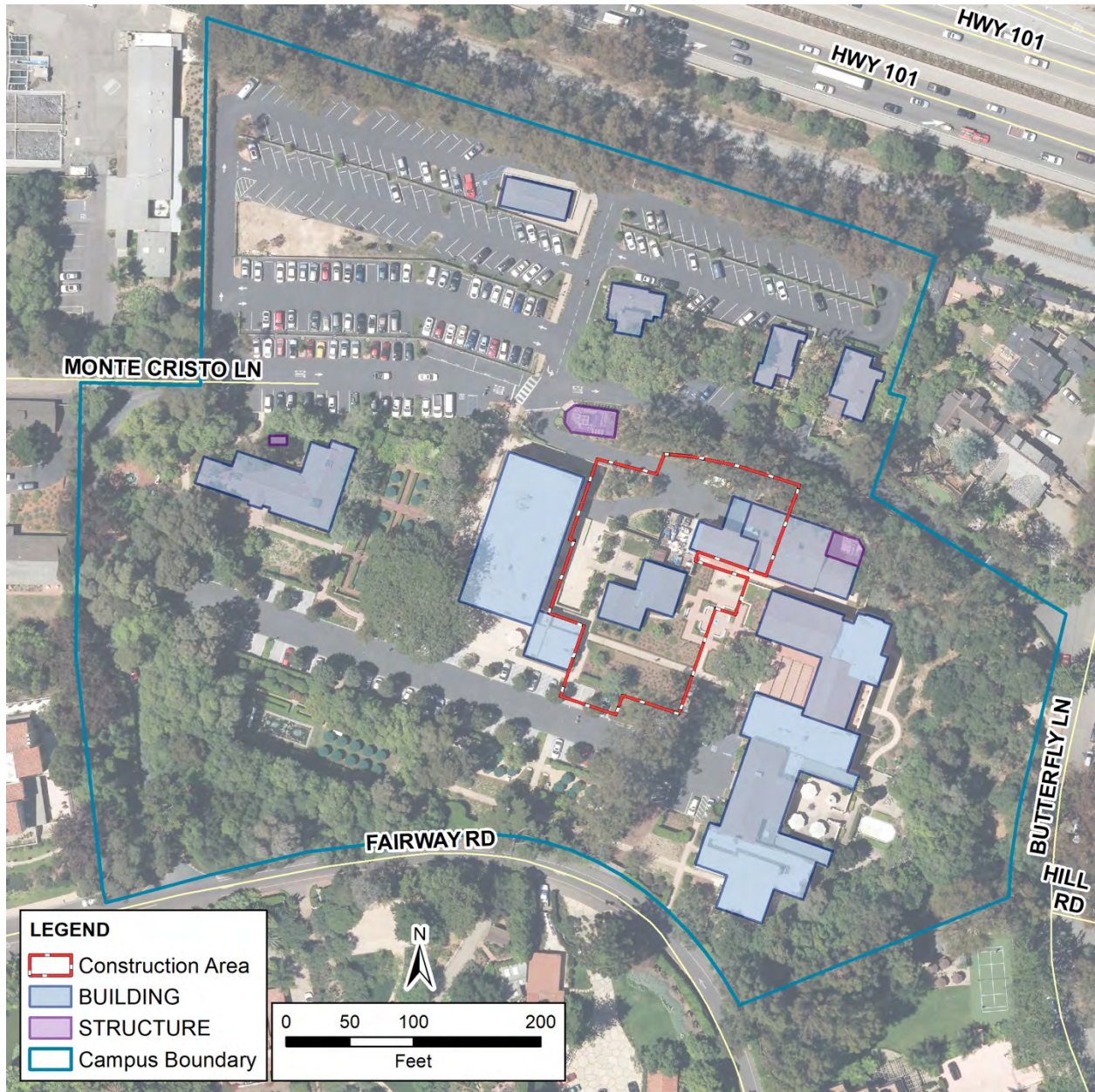


Figure 6: Initial basemap

The construction was completed later during the project, making it necessary to update the basemap. The aerial imagery was therefore outdated and did not show the new buildings, so the changes were digitized using the construction plan documents that were received from the client. Construction drawings were georeferenced in ArcMap and the new buildings inside the

construction area were digitized off the raster. This process is shown in Figure 7. The final basemap is shown in Figure 8.

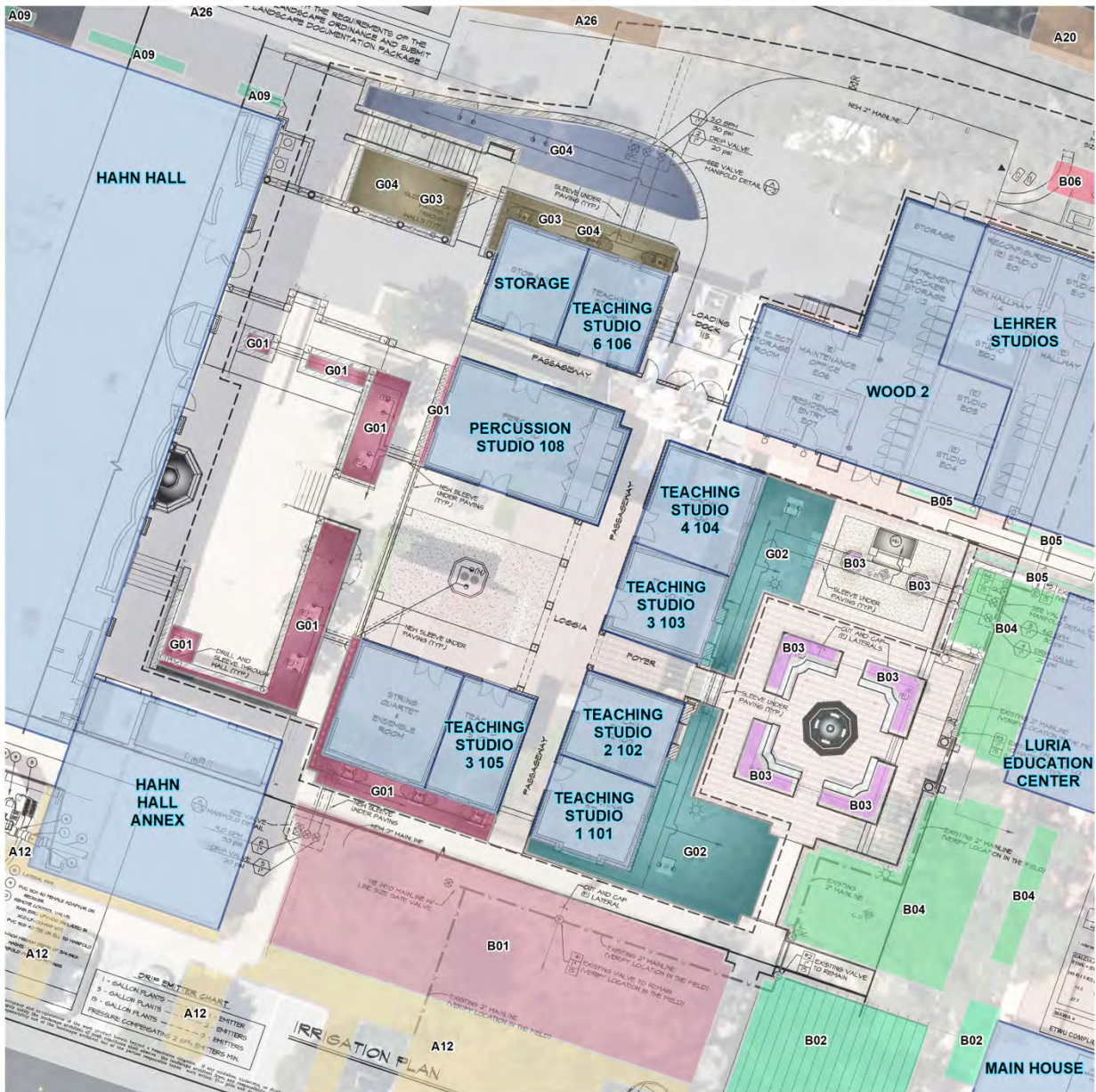


Figure 7: Accounting for the new construction area using a georeferenced document

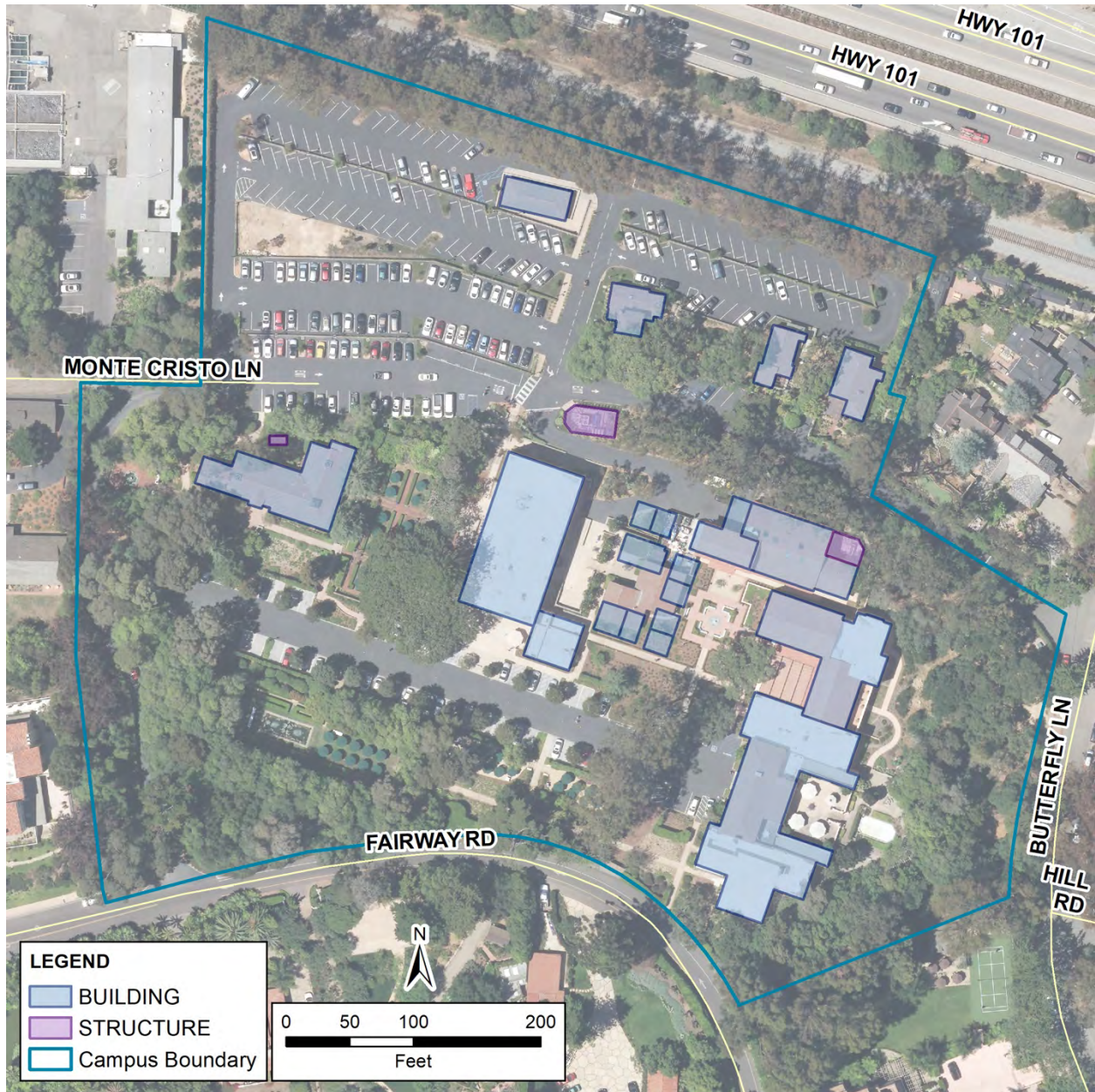


Figure 8: Final basemap of the campus after the initial construction work was complete

3.3.2. Field Collection

The first step of the field collection process was to meet with the staff members who regularly work with the irrigation system. Three different staff members agreed to walk the campus and share their general knowledge of the system. This helped to learn where some of the major structures were and what they looked like. The meetings revealed that some of the

controller boxes would be locked, requiring contact with a staff member who could unlock them. Meeting with staff also established a relationship so future questions could be asked and addressed in a timely manner. Staff members overall expressed a general lack of knowledge of the system, which explained why they asked for assistance in the form of GIS.

Walking the campus with staff members made it possible to plan the basic structure and design of the data to be collected. The highest priority GIS layers to be completed in this project were the controller stations, control valves, and irrigation zones. The controller stations are boxes that are wired to remote control valves, enabling users to turn valves on and off remotely. These controller stations can be represented by point locations in the GIS data. Control valves control the water supply to irrigation zones, either through sprinklers or drip tubing. Not all control valves are wired back to controller stations, these are called manual control valves. Control valves can also be represented by point locations. The irrigation zones themselves are represented by polygons, illustrating the area that receives the water when its associated control valve is turned on.

Main lines and lateral lines are represented with polyline features. Backflow preventers, valves, hose bibs, and sprinklers are all smaller features within the system, and are represented by point features. There were several structures encountered during the field inspections that could not be identified as one of the assets previously mentioned, so a category of miscellaneous point features was also included. This was done to keep potentially irrelevant data out of the main data layers, but still preserve the excess data in case it was needed later. Lastly, assets that were visible above the ground but were broken or disconnected were included as an abandoned point. This was meant to help staff members begin to identify areas of the campus that are not part of the active system. MAW staff could then decide to reconnect old structures back to the

system, leave them disconnected, or remove them altogether. For example, there were several old sprinkler heads found that were capped closed and left in the ground, as well as hose bibs that would not release water when turned. Figure 9 shows all the data layers that were initially planned for the field collection process. The layer names are shown in blue and the attributes are shown in white.

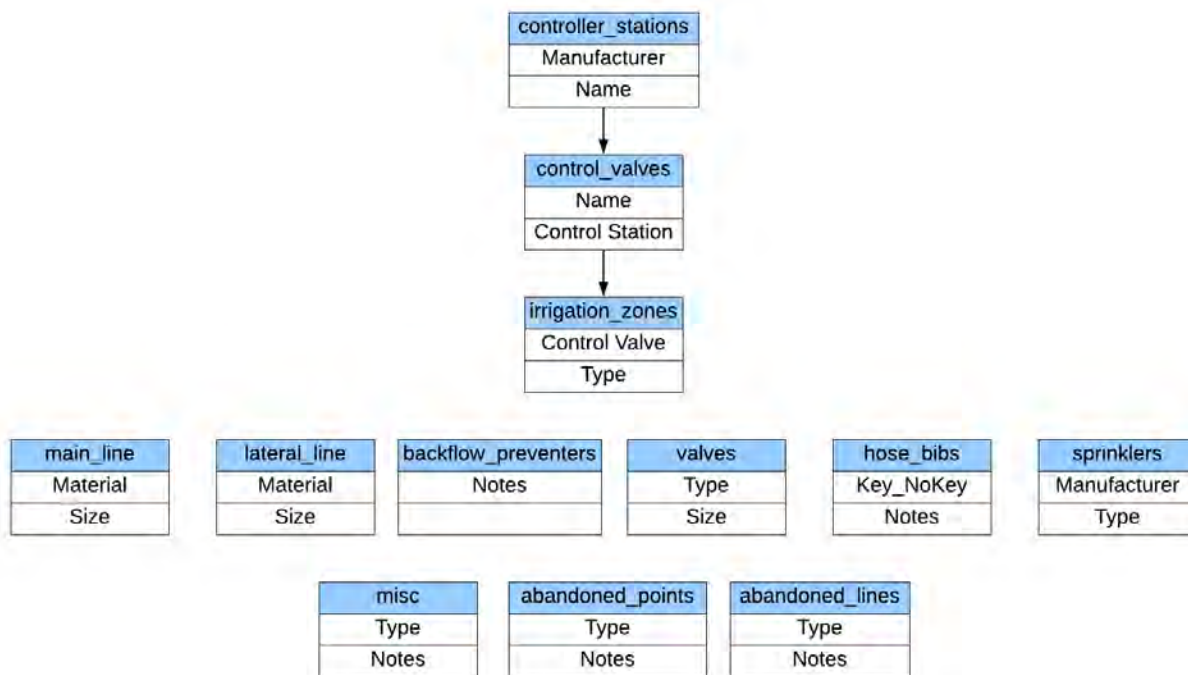


Figure 9: Plan for field collection of GIS data layers and attributes

The initial field collection entailed walking the campus building by building and tracking the collection areas. A Trimble GPS unit running ArcPad 10 was used, and photographs were taken of each structure collected to assist with identification and location adjustment. Assets that were inaccessible, such as those within bushes, were collected using a measuring tape to measure an offset distance. This method was chosen over usage of the Trimble device's laser range finder because it was simpler and faster for structures that were mostly covered with foliage. The field data was post-processed in Trimble Pathfinder Office using the base station in Tajiguas, CA. The

campus has heavy tree cover in many areas, so the photographs showing locational context were important for manual adjustments that would be needed later in the office.

After completing more than half of the inventory, it was decided that GPS collection was unnecessary in some smaller areas where structures were under too much tree canopy or simply too close together to discern in GPS data. Instead, the basemap was printed out and structure locations were carefully sketched in the field. These marked-up maps were then taken back to the office where they were used to digitize the features in ArcMap. Figure 10 shows an example of such an area near Controller C where the valves were simply too close together to collect with the level of GPS accuracy available.



Figure 10: Dense line of above-ground control valves for Controller C

3.3.3. Data Development

The field data was used to create the final data layers in ArcMap 10.5.1. The initial plan was to use the field data as a starting point and compare the information against the as-builts and other drawings to estimate configurations. However, the documents did not match the true field configurations closely enough, making it necessary to rely completely on the field data to create the new features in ArcMap. The lack of accurate documentation also proved to be a big challenge in regard to creating underground pipe data, so that task was set aside and reassessed later in the project.

The documents were inaccurate in some areas, and other areas were missing documentation altogether. For example, some maps referenced control valves that could not be located in the field, while other irrigated areas were not included on any of the documents altogether. Because of these discrepancies, it was deemed necessary to do field testing of the entire campus. This involved manually turning control valves on and off to reveal what zones they controlled and what the boundaries were. Each control valve was manually turned, then the shape of the zone was sketched on a paper basemap to later be digitized in ArcMap. As it became clear, zones were assigned a control valve ID as an attribute to track which valve controls which zone. Staff members were a helpful resource for the field testing, providing another pair of eyes to check for water flow in the test areas as well as assistance with turning valves on and off.

During the field testing stages, there were several areas that were identified as problem spots that required further testing and involvement with the landscaping staff. These question areas were documented, and maps were created that summarized each question. This allowed for easy communication of issues to staff members who were then able to resolve the questions on

their own time. There was a total of five question maps made during this process. Figure 11 shows one of these maps. It includes three questions about areas that could not initially be identified as part of a zone. These were temporarily numbered as “unknown” zones so they could be easily referred to. For this specific area, MAW staff noted the zone UNKNOWN09 had been disconnected as a part of the construction plans but had since been reconnected with zone A09. Zone UNKNOWN03 simply had drip tubing that was heavily buried, and it was concluded that it received water with zone A26. Lastly, zone UNKNOWN07 was discovered to be controlled with zone B06 after a second round of testing. The other four maps contained similar questions that were addressed with the same method.



Figure 11: Example of a map created to organize questions for the MAW landscaping staff

The data was finalized in a flat, shapefile structure due to the need for it to be published as online map services. However, certain steps were taken to provide the major relationships

between the layers if they were to be converted to a geodatabase in the future. Figure 12 shows a diagram of the final data structure, showing connections and common fields for a potential relational database format in the future.

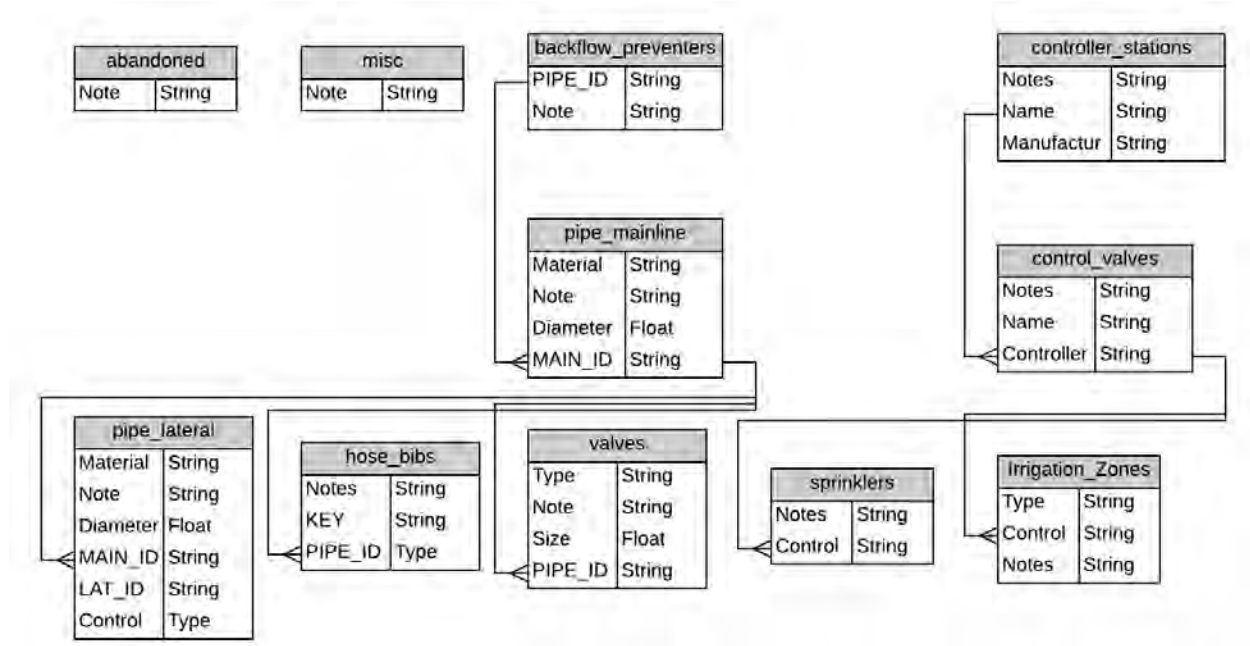


Figure 12: Final data structure showing potential relationships for future database format

3.4. Application Development

3.4.1. Map Creation

After the data was developed, it was used to create new maps of the system. There was a total of seven controller zones on the campus that were each individually mapped. Each controller box was measured for size so custom page sizes could be set for each map. This ensured that the maps, when printed, would fit into their controller box. These maps are discussed in more detail in Section 4.2.

3.4.2. Web Map Application Implementation

The final data was published to map services using ArcGIS server. These map services were then read by Geocortex Essentials 4.8, which provides an interface for web map application configuration within the browser. This setup is shown in Figure 13.



Figure 13: Web application setup

A total of three map services were created. The first was the “Irrigation” service, which included all the point-type surface assets. Second was the “Irrigation Zones” service, which contained just the irrigation zone polygons. This was isolated to a single map service because Geocortex Essentials only allows for transparency slider adjustments within the application on entire map services. It was important for the user experience to provide the ability to adjust the transparency of the zones without also making the point features transparent. Last was the “Campus Features” map service, which included all the basemap layers. Figure 14 shows the map services in ArcCatalog stored within a folder to separate them from other unrelated map services.

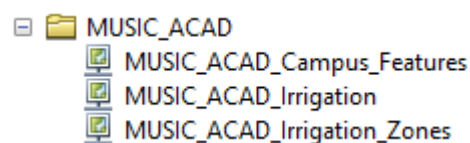


Figure 14: ArcGIS Server map services shown in ArcCatalog

3.4.3. User Training and Feedback

Once the final map products were created, the intent was to train the users, so they could use and understand the new application. A guide document was prepared which covered all the basic buttons and functions on the web application. Because of the complexity of the project and lack of communication between landscaping contractors and MAW staff, there was delay in identifying more than one user for the initial feedback process. A meeting was held where the campus facilities manager was given the guide and walked through the map application. This meeting allowed him the opportunity to ask questions and provide initial feedback. In the future, all potential users will be asked for final feedback after using being trained. Ideally, the final web map application and maps will have met their needs and will be used to manage their system going forward. The need for a more expanded user assessment is discussed further in Section 5.2.5. The guide document that was provided to the user is included in Appendix C.

Chapter 4 Results

Numerous data layers and map products were generated as a result of this project. GIS data for the campus was created to represent base information as well as the irrigation system. The creation of this new data was critical in order to create the final map products. The GIS data was used to create new controller maps to be printed and used by staff members. It was also published and displayed on a web map application, allowing users to interact with it in a web browser. Section 4.1 summarizes the data that was created for the project. Section 4.2 describes the creation of the new maps for each controller box. Section 4.3 covers the web map application's basic structure, interface, and functionality.

4.1. Completed Base Data and Irrigation Data Layers

The completion of the project depended on the creation of numerous data layers. These data layers were necessary to be used for creation of the controller maps using ArcMap as well as for use as map services on the web application. The final base data was comprised of three layers. Buildings were polygon features representing the footprint of each building on the campus. Points of interest were point features that were used to label important campus features varying from gardens to firetruck access gates. Table 3 summarizes the total number of features that were created to represent the campus base data.

Table 3: Summary of final base data

Layer Name	Description	Total Number of Features
Buildings	Polygon	23
Points of Interest	Point	10
Campus Boundary	Polygon	1

The irrigation system was comprised of nine data layers, all point features except for the irrigation zone polygons. Pipeline data was included in the initial project plan, but it could not be completed within the project time window. The challenges regarding the pipeline data are discussed in Chapter 5. Table 4 summarizes the total number of features that were created to represent the campus irrigation system.

Table 4: Summary of final irrigation system data

Layer Name	Description	Total Number of Features
Controller Stations	Point	7
Control Valves	Point	76
Irrigation Zones	Polygon, some multipart features	77
Backflow Preventers	Point	2
Valves	Point	27
Sprinkler Heads	Point	302
Hose Bibs	Point	38
Miscellaneous	Point	36
Abandoned Structures	Point	24

4.2. Individual Zone Maps for Each Controller Box

Controller maps for all seven controller boxes A through G were recreated using the new data. The maps only included a few of the data layers due to their small size. Each map shared the same legend, which is shown in Figure 15. Two controller maps are discussed in this section in detail to show a comparison between the old maps and the new maps. Appendix B shows the additional controller maps that were created but not included in the body of this paper. For comparison, the additional old controller map counterparts can be found in Appendix A.

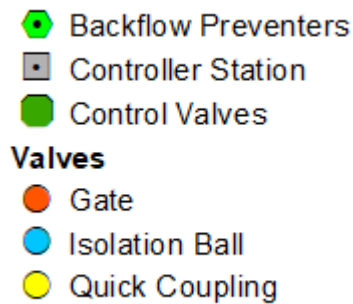


Figure 15: Common legend for the controller maps

Figure 16 shows the results for the area around controller C. The left panel shows the map that had previously been used. The right panel shows same area after the project was completed. The original map shown in the left panel was found to be incorrect. It showed only six zones when there were seven remote control valves. It highlights a zone in purple showing a continuous irrigation zone that was actually found to be divided into two using valves C01 and C07 as shown in the right panel. It also delineated larger zones along the eastern side that were not watered by controller C at all. These erroneous zones are highlighted in light blue in the left panel. These zones actually corresponded with controller A entirely, and were not associated with controller C.

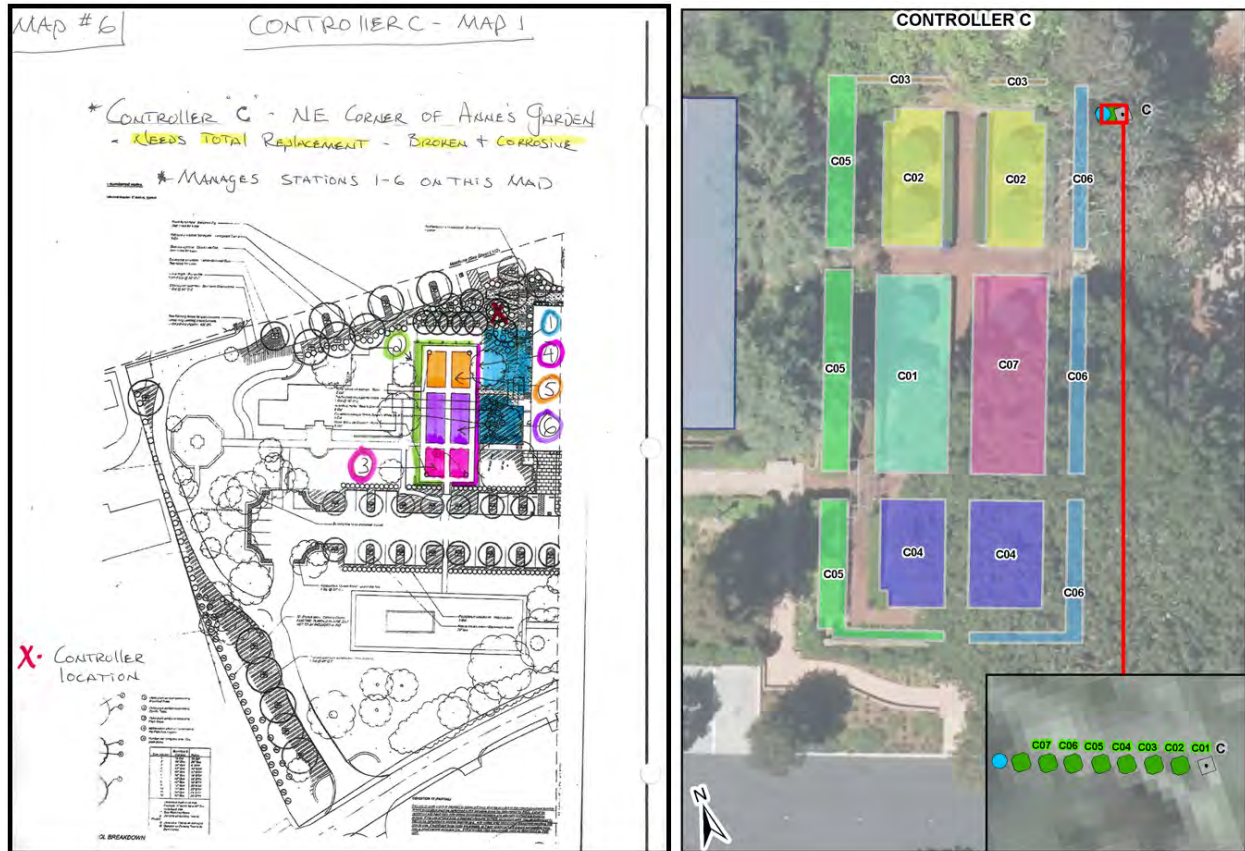


Figure 16: Comparison of new controller map to old controller map for area C

Figure 17 shows the results for the area around controller E. The top panel shows the map that had previously been used. The bottom panel shows same area after the project was completed. It is clear that the original map was incomplete, as it did not reference the battery-controlled area around the perimeter nor did it show sprinkler zone E02 on the eastern side. Not only was it incomplete, but it was also erroneous, showing the light green area as continuous when it is actually split between E01 and E03. The new map shows the location of controller E itself, the associated remote control valves, and the corresponding zones that receive water. It is a more complete picture of the area showing all related structures and how they feed water to each location.

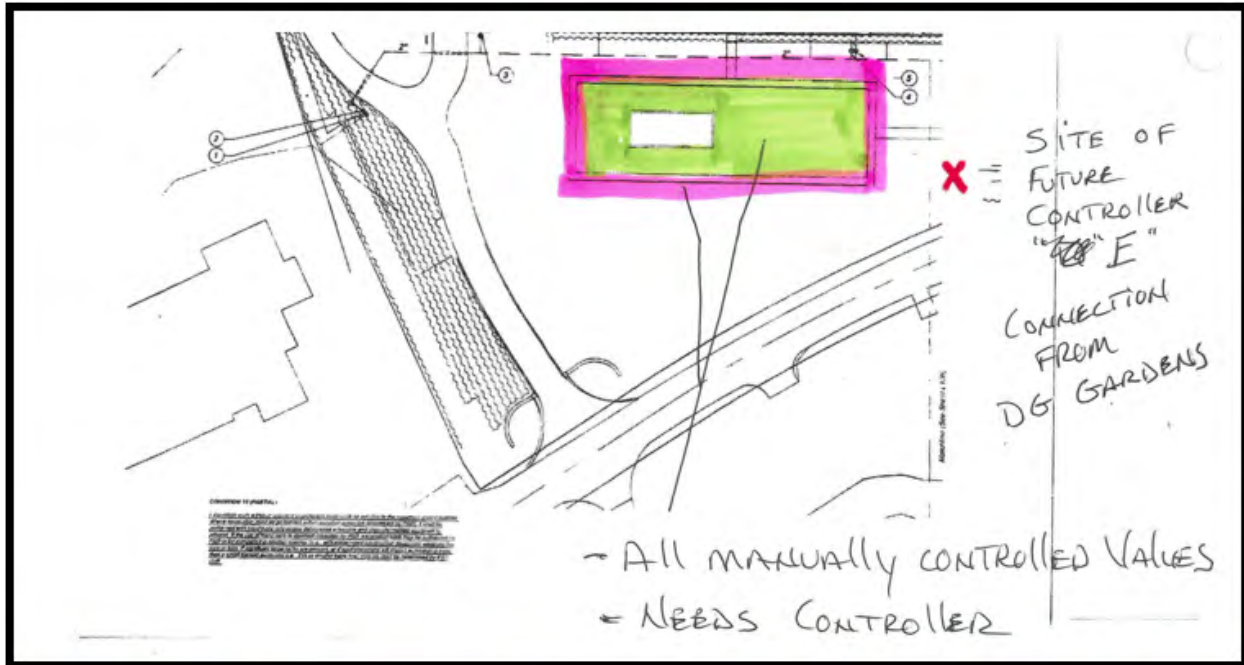


Figure 17: Comparison of new controller map to old controller map for area E

4.3. Web Map Application

4.3.1. Interactive Web Application Interface

The final web map application can be accessed in a web browser by a URL shared with the users. A MAW staff username and password was set up requiring users to login. Figure 18 shows the web application as it looks once login credentials are accepted and it is initially opened in Google Chrome on a laptop computer.

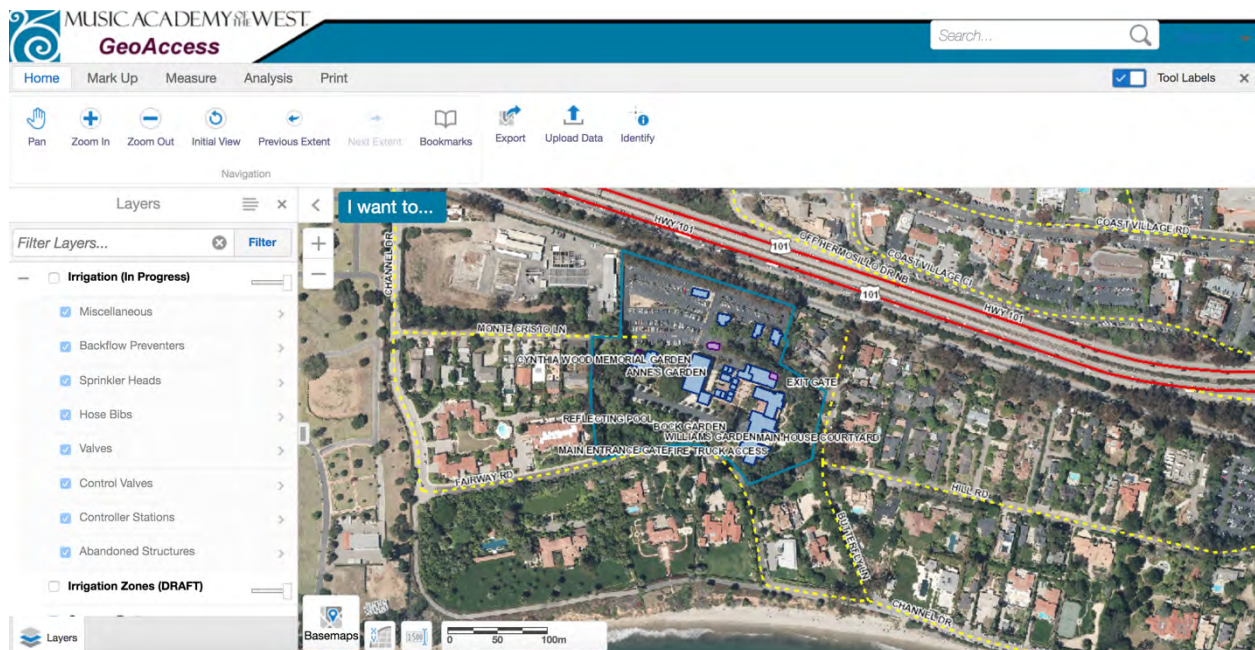


Figure 18: Web application interface

4.3.2. Functionality: Navigation, Analysis, Print, and Search

The application has a toolbar with four tabs: Home, Mark Up, Analysis, and Print. All the tabs and associated tool buttons are shown in Figure 19. The Home tab contains basic tools essential for navigating around the map such as pan and zoom. It also contains a basic export tool which saves a simple graphic of the current map view. The Mark Up tab contains tools that allow the user to add drawings to map. There are options to change color and line types, as well as add text annotations in differing fonts. Drawings can be exported to different formats and saved, for

example, vector drawings can be downloaded in shapefile format. The measure tool allows the user to measure on the projected map area. Distance and area measurements can be added as drawings to show dimensions of map features.

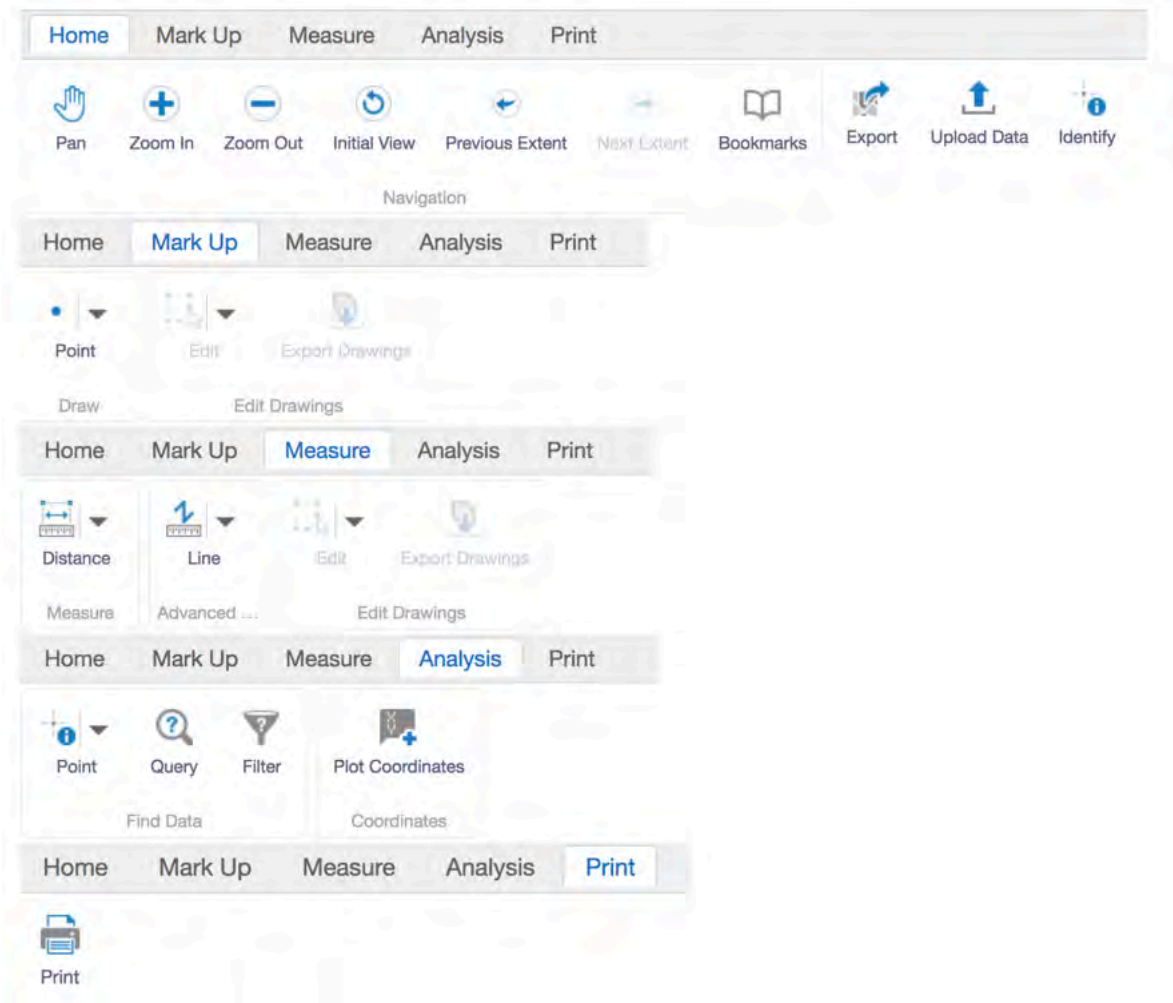


Figure 19: Tabs and tools within the web application toolbar

The Analysis tab contains tools that help the user interact more deeply with the map layers. Users can do a simple mouse click and drag to identify features on the map and view their attributes. The Query tool allows for more complex data interaction. Users can set clauses and return data that fits their query statement. For example, Figure 20 shows a simple query setup

that returns all the control valves that are related to controller A. Additional conditions can be set to find map features that have specific qualities. The Filter tool follows the same concept but for the visual map area. The user can set desired conditions for a layer and apply a filter to the map to make only those features that met the filter conditions visible.



The screenshot shows a 'Query' dialog box with a title bar containing a hamburger menu icon and a close button. The 'Data Source' dropdown is set to 'Control Valves'. The 'Map Area' dropdown is set to 'All'. Below these, the text 'Find results in Control Valves where:' is followed by two radio button options: 'All of the following must be true' (which is selected) and 'At least one of the following must be true'. A condition is entered in the fields below: 'Controller' followed by an equals sign and the value 'A'. At the bottom, there are two blue links: 'Add Condition' and 'Add Subclause'.

Figure 20: Example of the Query tool in the Analysis tab

The Print tab has a tool that allows users to generate and download cartographic maps in various formats. Print templates of varying sizes and orientations were configured and can be populated by data from the map application when the user makes a request. The user can choose a print layout, output format, resolution, scale, map title, and compilation date. Figure 21 shows the options available for map printing in the application. Figure 22 shows an example of a map that was created using the Print tool. The application populates the custom print template with the map layers the user made visible and outputs a clean, cartographic product. User mark up and measurements that were added to the map area are also included on the generated map files.

Print Map ×

Select Layout
8.5 x 11 Landscape

Output Format
Pdf

Resolution
200 DPI

Map Scale
Current Scale - 1: 883

Map Title
Music Academy of the West

Compiled Date
Compiled on ##-##-####

Figure 21: Print Map menu



Figure 22: A map generated using the Print tool

The map area is configured with map tips for most of the features. Users can click on a feature to highlight it and display a pop-up window with a summary of the feature's attributes. An example of a map tip is shown in Figure 23.

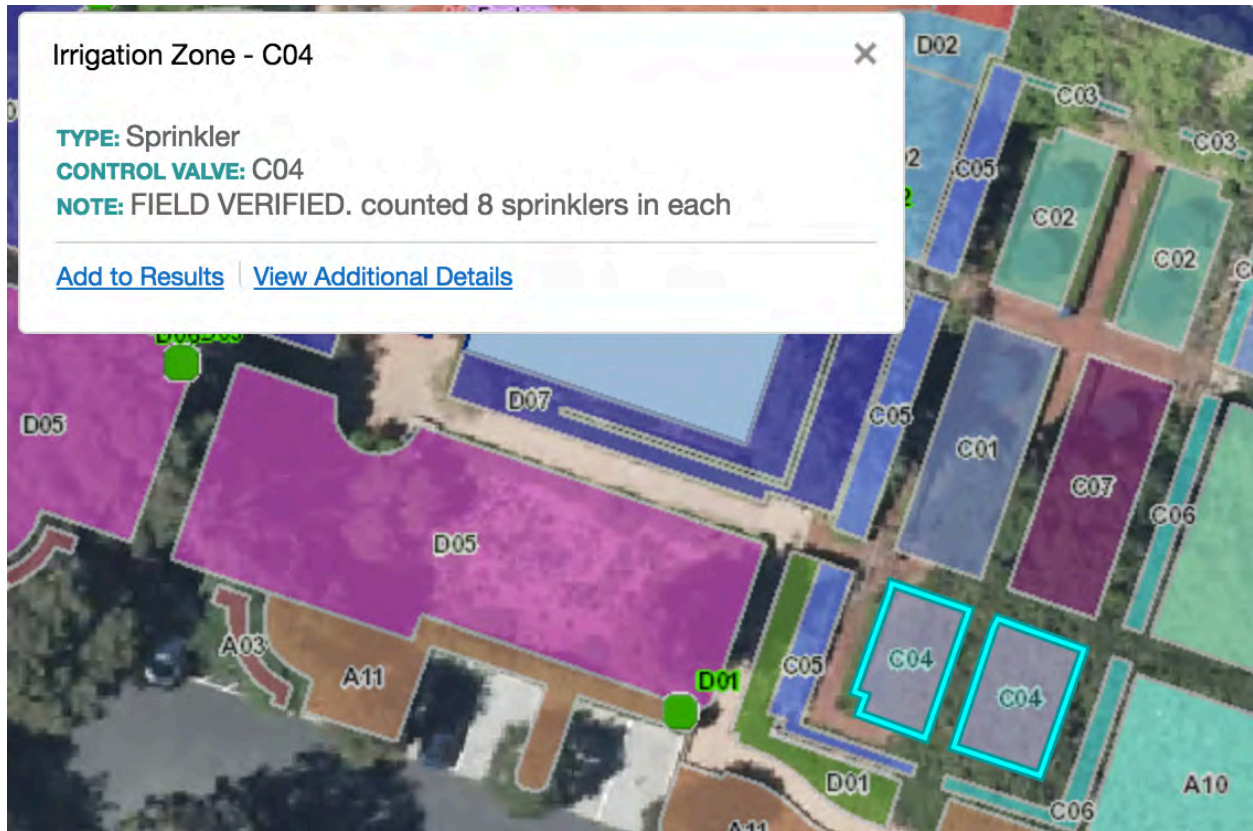


Figure 23: Example of a map tip for an irrigation zone feature

Finally, there is a search bar on the top right corner, and layers can be set to participate in global search. Users can type in any desired term and the application returns results containing that term. For example, the user could search for a particular building on the campus, or find a valve by its ID.

Chapter 5 Conclusion and Discussion

There were many challenges faced during the project. The documents that were planned to be used to validate the data were too inaccurate and staffing for the landscaping turned out to be very disorganized and spread thin. These challenges combined with the lack of time made it necessary to plan for several future improvements such as additional data collection and field work. Section 5.1 discusses the challenges and limitations of the project in more detail. Section 5.2 outlines the plan for future improvements on the project. There were some shortcomings in terms of project success, mostly related to the lack of pipeline data and the nature of the contracted landscaping support. The project overall met its objectives because the corrected controller maps were completed, and the web application was well-received. The overall conclusions and achievements of the project are discussed in Section 5.3.

5.1. Challenges and Limitations

5.1.1. Lack of Accurate System Documentation

At the start of the project, it was believed that the system was fully documented in the form of construction drawings and plans. However, the provided documents ended up offering very limited usable information. They were not representative of the surface features that were collected in the field. This made it difficult to gather information from the documents with any level of confidence.

5.1.2. Dispersed and Limited Staff Knowledge

The campus facilities director was the main client, as he initially requested the GIS services. However, he was not knowledgeable of the irrigation system and was not the direct staff responsible for tending to the landscaping. The campus has a unique situation in that they

have contracted out their landscaping services to several different companies throughout the years. Thus, the facilities director passed us on to several people from different landscaping service companies in the process who all had bits and pieces of knowledge to contribute, depending on which areas of the campus they had worked.

It was initially thought that one of the campus groundskeepers would be the main contact for questions related to the field collection and testing. However, the meeting with him revealed that he was reluctant to participate in the inventory process and turned out to not be very helpful in terms of overall system knowledge. It was later noted that their main landscaping staff were with a contracted company called Plowboy. Two Plowboy supervisors were briefed on the project and its goals. They were able to identify and contact two field staff members who worked on the campus landscaping several days each week who were available to meet and help troubleshoot questions. It was later revealed that there was another landscaping contractor called Brightview that was involved with several construction projects in the past, including the recent construction project highlighted in Figure 8.

There were also additional contracted companies that had been involved with the campus landscaping in the past, and it was a convoluted process to meet with separate contacts and discover new contacts along the way. The lack of communication between all the various contractors made it clear why the facilities director wanted to update their maps and begin to create a common tool for the system going forward.

5.2. Future Work

5.2.1. Revise Data Structure

Using a flat shapefile format was necessary because of the existing company workflow and setup with ArcGIS Server and Geocortex. In the future, it would be productive to upgrade

from shapefiles to a geodatabase with relationships and topology. This would make it easier to edit the data when the system is altered. Additionally, this would provide the configuration needed to eventually allow the users themselves to make simple edits to the data in real time using the web application. It would be efficient to have the users take more responsibility of the data in this way. As mentioned in Section 3.3.3, some small steps were taken toward this end goal when setting up the attributes for each data layer. However, there are still additional challenges that need to be overcome before the web application can allow for real-time user edits.

5.2.2. Collect Additional Attribute Information

The new data could benefit from more detailed attribute information. The next step towards asset management after completing a GIS inventory is condition assessment (Heltzel 2003). With the GIS features as a base representing the accurate locations of all the assets, each asset could then be assessed for its condition. Adding this information to the web map would allow for easy viewing of condition information and enable MAW staff to more easily see where maintenance is needed and could help them reduce the number of leaks and breaks in their system.

Additionally, collecting the flow rates for control valves would provide more insight into the overall water usage of the campus. This would be helpful for MAW staff to know since they stated they have had concerns from their water district in the past.

5.2.3. Create Pipeline Data

MAW staff originally requested maps for their entire landscape irrigation system. This request was partially fulfilled by this project. The project successfully mapped the surface features of the system in a full inventory and resolved confusion with irrigation zones as they

relate to each control valve. The shortcoming of this project was the lack of maps showing precise locations of irrigation mainlines. A major issue MAW staff have is that they do not have confidence when excavating during construction projects, as they have had a lot of accidents hitting irrigation pipes underground. When they have leaks, they are unable to isolate the affected area of the campus and instead are forced to turn off water to the entire campus when these breaks occur. This issue was discussed with MAW staff and it was concluded that the desired pipeline dataset could not be created as initially planned by using the GIS inventory in combination with the construction documents. This was simply because the construction documents were incomplete and did not parallel the field inspections. In the future, a pipeline tracing project would be necessary in order to accurately map the mainlines in the GIS. This would involve hiring a contractor to conduct the pipe tracing work and provide a deliverable showing where all the relevant pipelines are located.

5.2.4. Label Control Valves and Control Boxes in the Field

New GIS IDs were assigned to assets during the project and it will be necessary to tag the remote control valve lids in the field so they match the new maps and the web application. This will also require the establishment of a method for updating the lids every time the data is updated. For example, if any new remote control valves are added to the system they will receive a new GIS ID and will therefore need to be tagged with their IDs after they have been added to the GIS.

5.2.5. Train and Receive Feedback from More Users

The user feedback portion of the project was planned to be much more thorough. Within the project timeframe, it was only possible to train and receive feedback from one user. It was a meeting where the user was given the guide document and shown the web application

functionality first hand. Informal feedback was received, and it was very positive in terms of the final products. Before the project, staff had no access to accurate and updated campus maps. After the project, they have new maps of their system and the ability to view and interact with the data, as well as the ability to print their own custom maps. Negative feedback was mainly that the final maps were still lacking the desired pipeline data as discussed in Section 5.2.3.

5.3. Project Conclusion

This project involved the creation of custom data and products. The process was a valuable learning experience in terms of applying GIS to landscape irrigation systems in general. The same methods and data concepts could be executed to map landscape irrigation systems for any other study areas of any size. This is particularly valuable to offer as a service to new clients who have similar problems managing their system and may need help with such a task. Similar concepts can also be applied to different utility systems beyond landscape irrigation.

This project also helped to show the importance of adjusting methods and plans according to challenges faced. For example, the data collection methods transitioned from using a GPS unit for each point to the use of annotation on printed base maps. It was simply more applicable to such a small study area at such a large scale. Additionally, the use of georeferenced as-builts in combination with field measurements was helpful for positioning structures in areas of bad GPS signal. These documents were originally meant to provide all the intelligence on the system, but instead were used mostly for basemap purposes.

The project concluded by partially meeting the original objectives. The first objective was to conduct a full inventory of the campus irrigation system. This involved countless visits to the campus to complete the field collection. This objective was met as all the surface structures were collected and mapped in the campus GIS. Cleaning up this data involved extensive testing

of valves and controllers. However, the data portion fell short because pipeline data could not be created. The lack of pipeline data was noticed in the web application and contributed to the shortcoming of the project overall.

The second objective was to recreate the maps for each controller box. This was completed successfully, as each controller box received an updated map showing the associated valves and zones. The pipeline data was not crucial for these maps.

The third objective was to create a web application that was impressive and usable for management of the irrigation system. This objective was partially achieved. The application was shown to the campus facilities director and he was very impressed with its functionality and interface. He was pleased to find that he was able to interact with the data and print his own maps. This would have completely met his initial request for new management maps had the pipeline data also been included. Overall, it was a success because he expressed the desire to continue using the web application and continue our client-contractor relationship to maintain and improve the data.

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Wick, Robert. 2009. "A team approach to GIS asset inventory: east central energy combines teamwork and rugged data collection hardware in project." *GEOconnexion International* 8, no. 3: 22-23

Appendix A: Old Controller Maps

IVIAp = 11

CONTROLLER H - MAP 1

• CONTROLLER A - BACK OF CLAYSENS HALL
| Lg. SILVER BOX

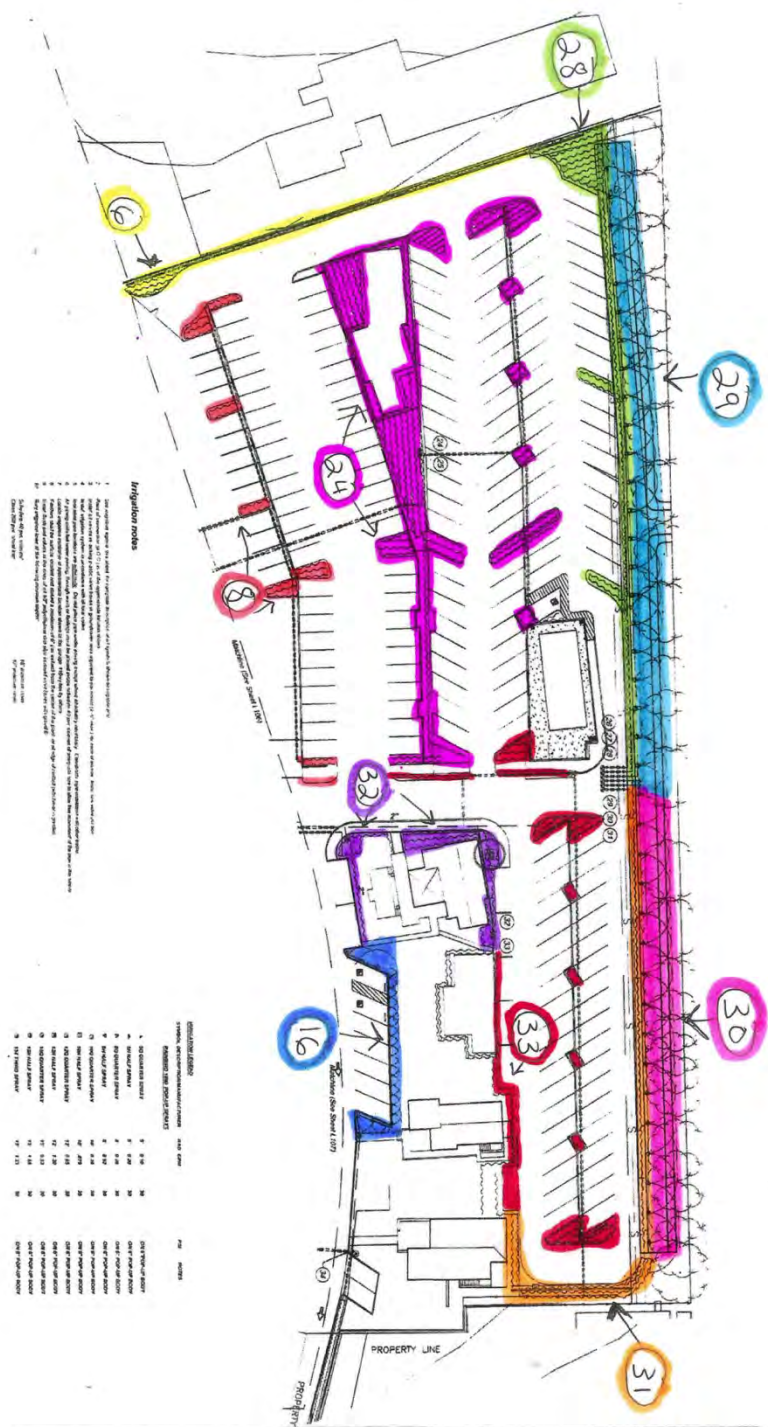


MANAGES STATIONS 1-15
ON THIS MAP

X- DENOTES CONTROLLER LOCATION

MAP #2

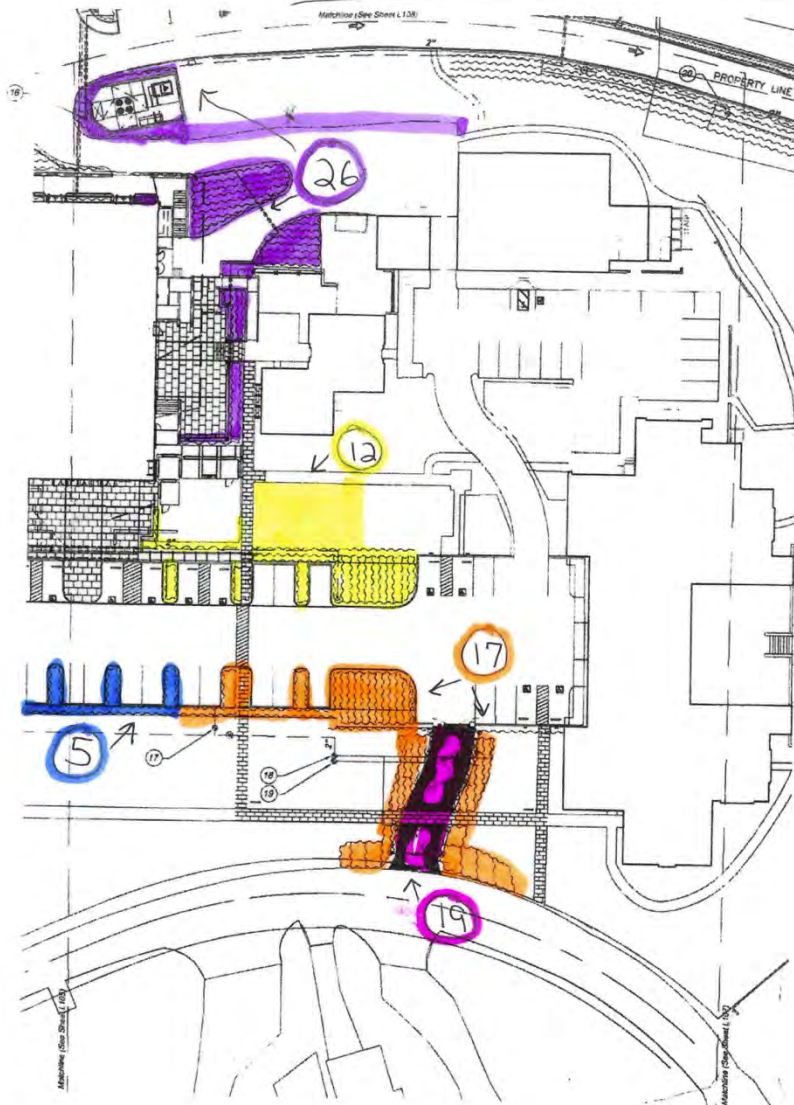
CONTROLLER A- MAP 2



- CONTROLLER A - BACK OF CLAYSENS HALL
- Lg. Silver Box
- MANAGES STATIONS 6, 8, 16, 24, 29-33 ON THIS MAP

MAP # 4

CONTROLLER "A" - MAP 4

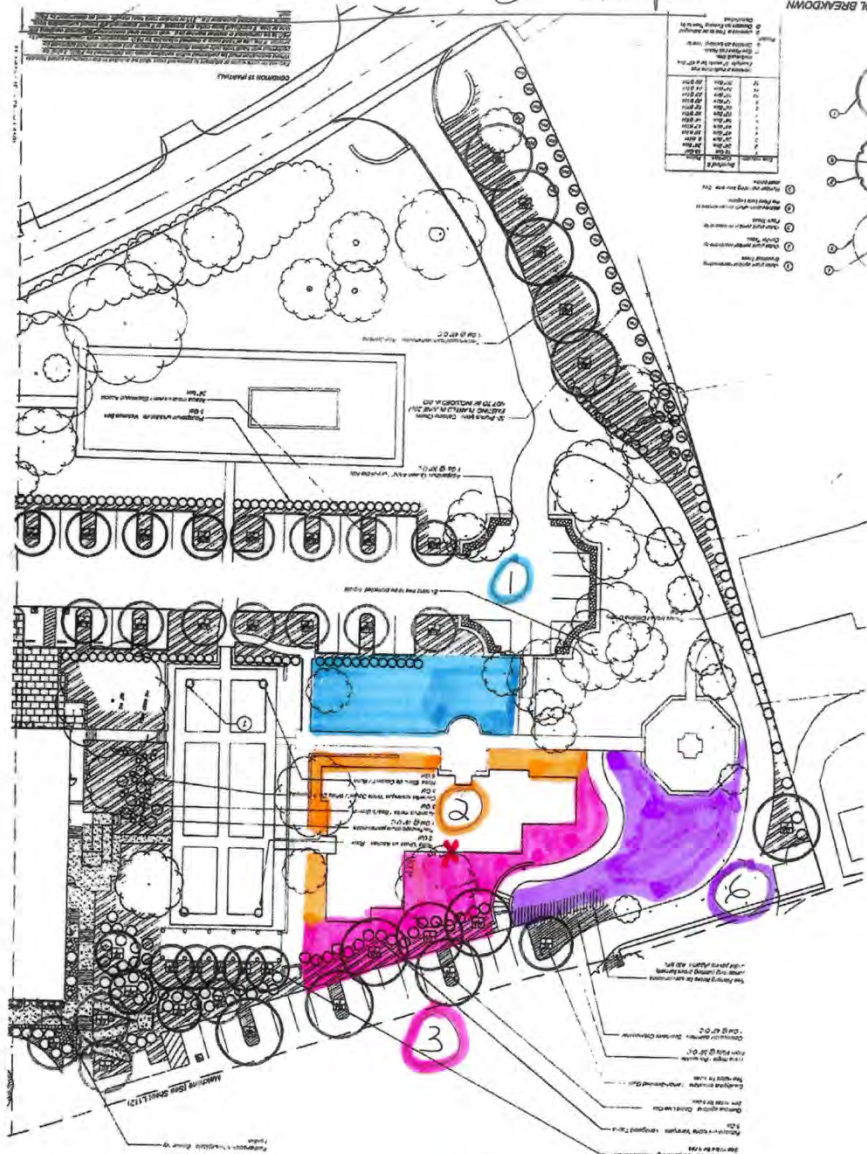


* CONTROLLER "A" - BACK OF CLAYSSENS HALL
Lg. SILVER BOX

* MANAGES STATIONS 5, 12, 17, 19, 26 ON THIS MAP.

MAP
#5

CONTROLLER "B" - MAP 1



X - DENOTES CONTROLLER
LOCATION

- * CONTROLLER "B" - ATTACHED TO BACK WALL OF CLAYSENS
 - SMALL BOX ON WALL
 - IRRITROL MANUFACTURED - NEW UNIT RECOMMENDED

* MANAGES STATIONS 1, 2, 3, 6 ON THIS MAP

Map # 7

Music Academy
Timer B, Irrigation Chart

NOTE WELL:
INSTALL ALL VALVES SHOWN
IN PHASE 20 AREA AND STRIP
AND MARK MAINLINE AND LATERAL LINES AS
NEEDED FOR PHASE 20 WORK AS PART OF
PHASE 20 WORK

X- DENOTES LOCATION OF MUTATED

MAP 9 | MANUAL AREA



X

SITE OF
FUTURE
CONTROLLER
"E"

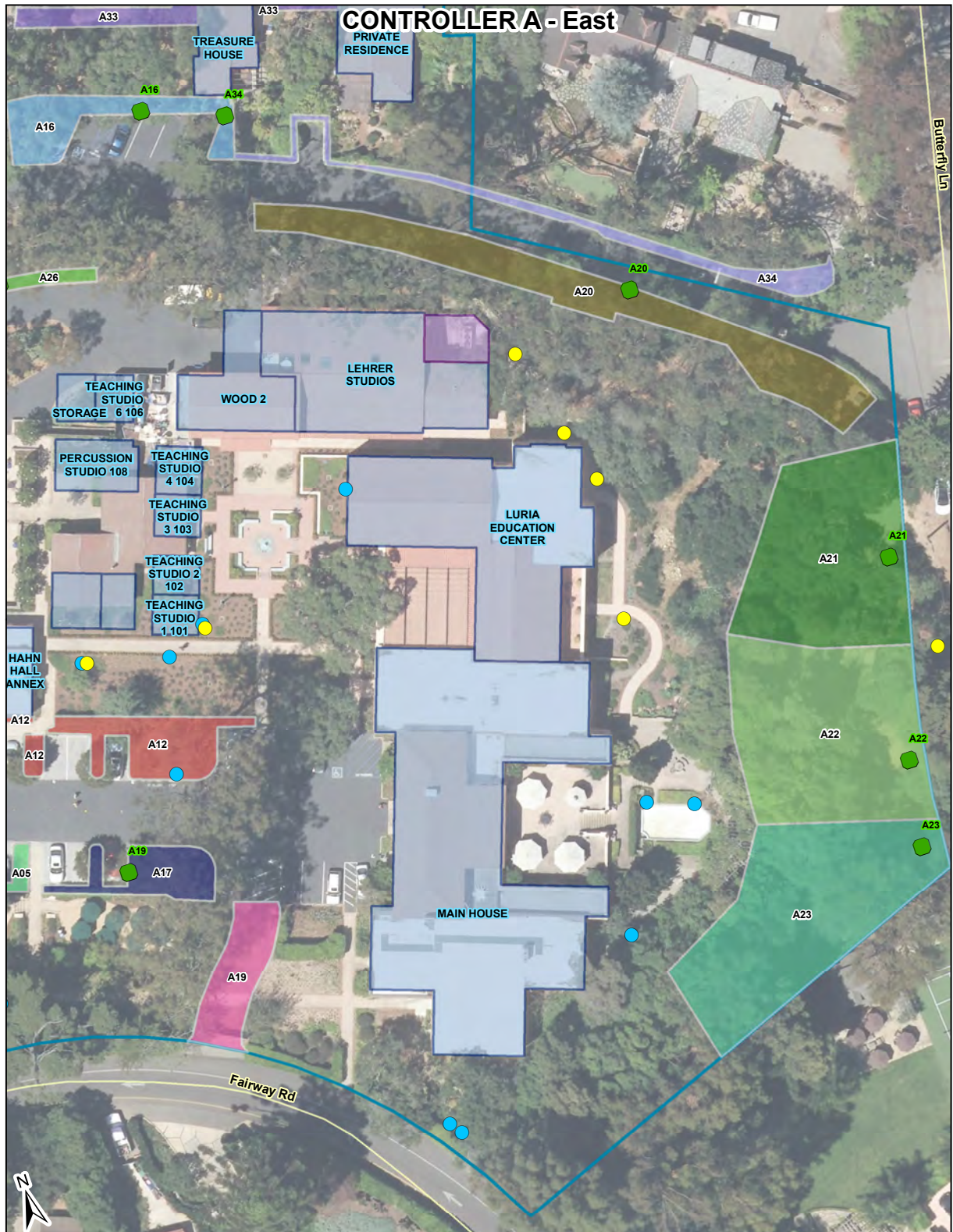
- All MANUALLY CONTROLLED VALVES (5)
- NEEDS CONTROLLER

X

DENOTES VALVE LOCATION + FUTURE CONTROLLER

Appendix B: New Controller Maps



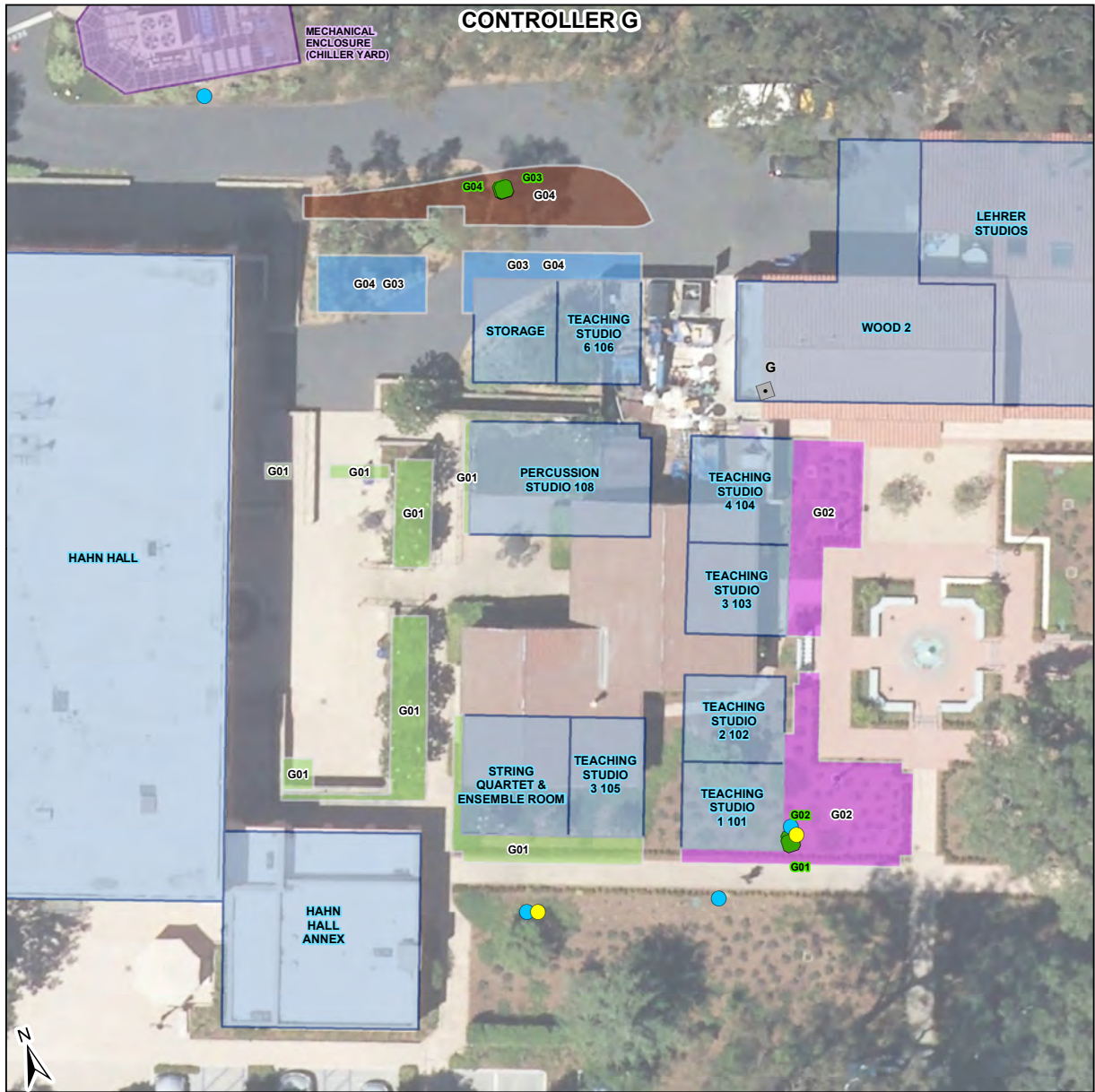






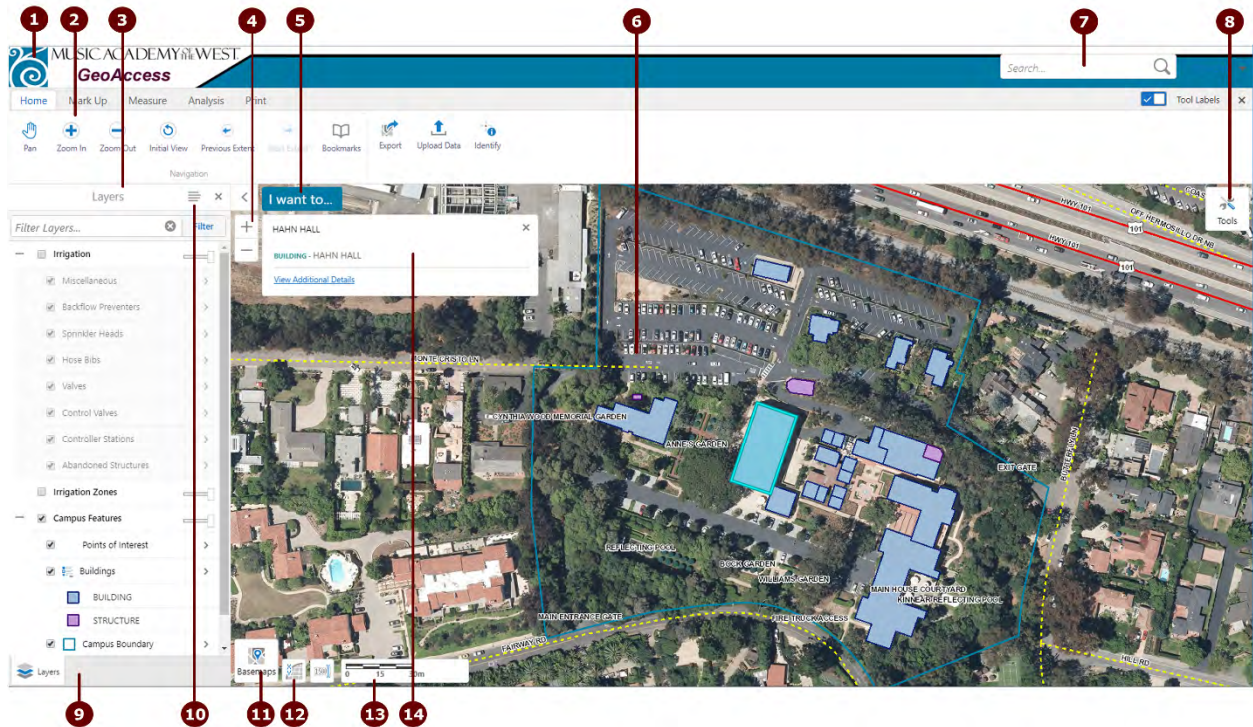













Appendix C: User Training Document

MAIN SCREEN

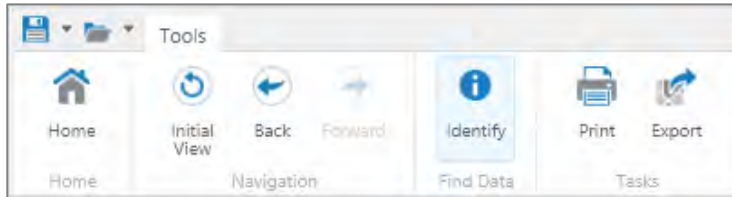


Number	Screen Element
1	Title Bar: Displays the title of the application and the logo or name of a particular organization.
2	Toolbar: The Toolbar contains the tools that control how you interact with the map. In some applications, there are several sets of tools that are grouped by function. In more complex applications, the toolbar can have multiple tabs containing groups of tools.
3	Information Panel: The Information Panel is an area that has multiple purposes. It is used to list important information. For example, it displays Map Layers where you can select different layers to hide or show on the map. If you do a search or you use an Identify tool, it displays a list of map features in the Results List. At other times, the Information Panel contains a menu that you can use to perform tasks, for example, print or export the map. Each time you use the panel for a new function, it is opened in a separate tab that appears at the bottom of the panel. You can click each tab to return to that function.
4	Zoom slider: Use this slider to zoom in or out on the map by clicking the + or - or by dragging the marker up and down.
5	I Want To Menu: A menu of shortcuts to frequently-used tools. This menu tries to anticipate what you will want to do most often.
6	Map: The map window where you interact with the map by zooming, panning, annotating, or right-clicking to get more information.
7	Search box: You can type in the name of a feature to search for it on the map. It is also possible to search map services.

	Toolbar icon: Shows or hides the Toolbar when you click the icon.
	Information Panel Tabs: Displays a tab for each function you open in the Information Panel. Click a tab to activate that function in the Information Panel.
	The Show Layers/Show Legend button: Allows you to toggle between the map legend and the map layers in the Information Panel. The legend only displays symbols for the layers that are active on the map. The legend items change with the scale of the map. The Filter in the bottom right corner of the Information Panel allows you to limit the information listed in the panel.
	Base Map menu: Lists the Base Maps that you can select, for example, a street view that shows a map or an image view that shows satellite images. The Base Map menu also lists any Layer Themes if there are any in this application.
	XY Coordinates: Allows for the display of the x, y coordinates that tracks the location of the cursor within the map. You can set the format for each coordinate system with a list of formats to choose from.
	Scale: The current scale of the map.
	Map Tip: Map tips appear when you click on a feature listed in the Results List, or when you use one of the Identify tools. In some maps, if you hover over a feature on the map, a map tip appears. Click View Additional Details to find more information about the feature in the map tip.

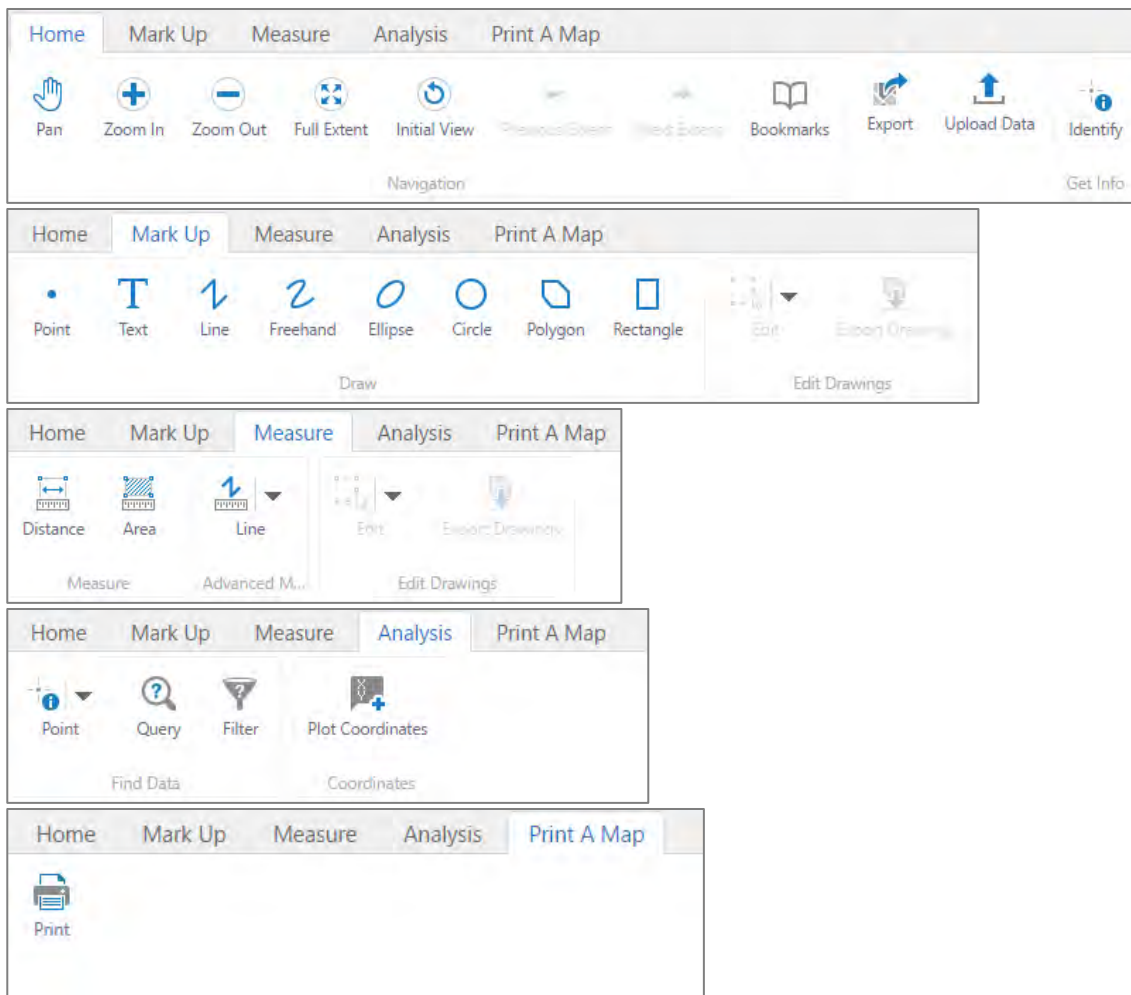
THE TOOLBAR

The toolbar in the application can contain any number of tools, groups of tools, or tabs containing several groups of tools. It is usually customized to suit a particular purpose. Customization means that the toolbar of your application may be very different depending on how it is going to be used. A simple application may have only one toolbar tab with a few essential tools available.



Example of a simple toolbar

A complex application may have multiple tabs each containing many groups of tools grouped by function.








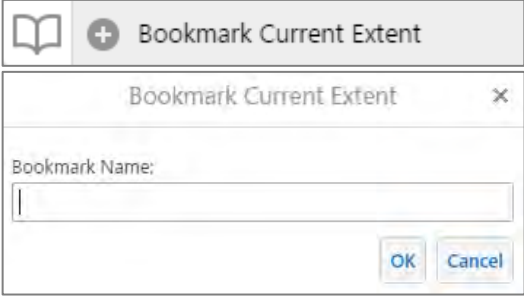




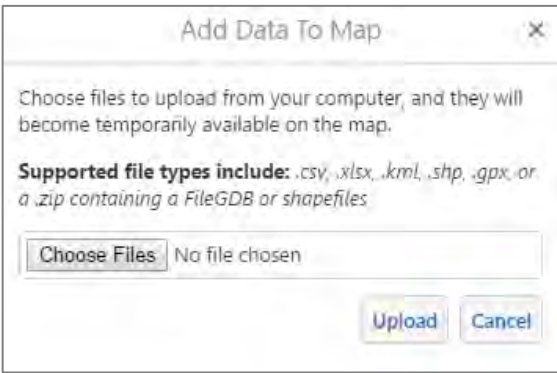

Example of a complex toolbar showing multiple tabs and groups of tools

A toolbar may contain tools that are arranged differently. It is also possible that groups or individual tools have a different name or icon.

HOME TOOLS

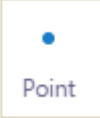




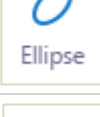
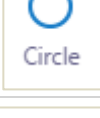




Most of Home tools help you to move around the map. For example, zoom, pan or jump to specific views or bookmarks.

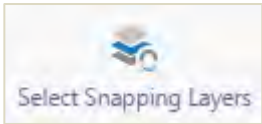

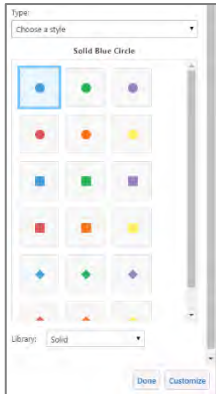


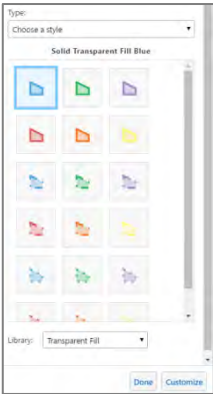
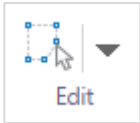

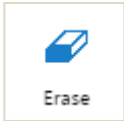

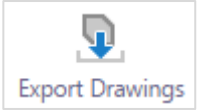
Use this tool... ▼	To... ▼
 Pan	Pan (move) the map in any direction. To pan the map, click on it and drag in any direction. Use the Pan tool to return to panning when you have used other tools.
 Zoom In	Zoom in when you click on the map or when you click and drag a window over an area.
 Zoom Out	Zoom out when you click on the map or when you click and drag a window over an area.
 Initial View	Return to the original view (extent) that the map was at when it opened.
 Previous Extent	Return to the previous view (extent).
 Next Extent	When you have gone back to a previous view, jump forward to the next view again.
 Bookmarks	<p>Click to see the saved bookmarks and jump to a map extent. To add a bookmark for the current extent, click the Bookmarks button, then click Bookmark Current Extent.</p>  <p>Type in a name for your bookmarked extent and click OK.</p>
 Export	Open the Export a Map Image dialog box and select the image format that you want to export the map into.

 Upload Data	<p>Use Upload Data to temporarily upload your own files into the application for display. Data must be formatted correctly. For instance, tabular data must contain X and Y coordinate information or address information. Shapefiles must be uploaded with at least the 3 mandatory associated files (.shp, .shx, .dbf).</p> 
 Identify	<p>Identify data at anywhere on the map.</p> <p>To identify data at a single location, use a single click at the point of interest. All the features beneath the point you click are listed in the Results List.</p> <p>This tool can also be used by dragging a rectangle over an area on the map. All the features beneath the rectangle you draw are listed in the Results List.</p>

MARK UP TOOLS















The Mark Up tools allow you to add notes and drawings to the map. These can be included in map exports and print-outs.




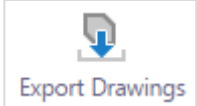
Use this tool... ▼	To... ▼
 Point	Draw a Point on the map. Click or tap a map location to add a point.
 Text	Add Text to the map. Click on the map and type the text.
 Line	Draw a straight Line or a complex line made up of multiple straight segments. Double-click to stop drawing.
 Freehand	Draw freely on the map in any direction. Hold the mouse button down, then draw a Freehand line. Release the mouse to stop drawing.
 Freehand Shape	Draw freely on the map in any direction. Hold the mouse button down, then draw a Freehand shape. Release the mouse to stop drawing.
 Ellipse	Draw an Ellipse on the map. Drag in different directions to change the shape and size of the ellipse.
 Circle	Draw a Circle on the map. Drag into the center or outwards to change the size of the circle.
 Polygon	Draw a Polygon on the map, clicking to change direction. Double-click to stop drawing.
 Rectangle	Draw a Rectangle on the map. Click and drag across the map. Drag in different directions to change the shape and size of the rectangle.
 Enable Snapping	Enable snapping while creating drawings on the map. Snapping will allow the user to “snap to” or trace other layer features. The cursor will change to a circle to indicate snapping is active.
 Disable Snapping	

Use this tool... ▼	To... ▼
	<p>Select the map layers to participate in snapping. The layer list is opened in the Information Panel.</p>
	<p>Choose the style of a drawing before placing it on the map. Pick the color, shape, font, texture, etc. There are different style options for different Mark Up tools (points, text, lines, and areas).</p> <div>     </div>
	<p>Edit Drawing Menu Click the drop-down arrow to open the tools for editing existing drawings.</p>
	<p>Edit any text or drawing added to the map. Click the drawing to edit. Rotate the drawing by clicking and dragging the square above the marquee in the middle of the graphic. Move the drawing by clicking and dragging it. To edit shapes or lines, click the drawing and drag any of the points in any direction to change the shape of your drawing. To edit text labels, click Edit Drawing and then the Styles button. Type in new text.</p>
	<p>Erase an existing drawing. Click on individual drawings to remove them from the map.</p>
	<p>Clear all drawings on the map at once.</p>
	<p>Download all drawings in shapefile format.</p>

MEASURE TOOLS







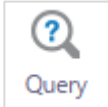
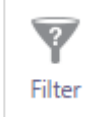
The Measure tools help you measure distances and areas anywhere on the map. This can be used to measure specific features from each layer.


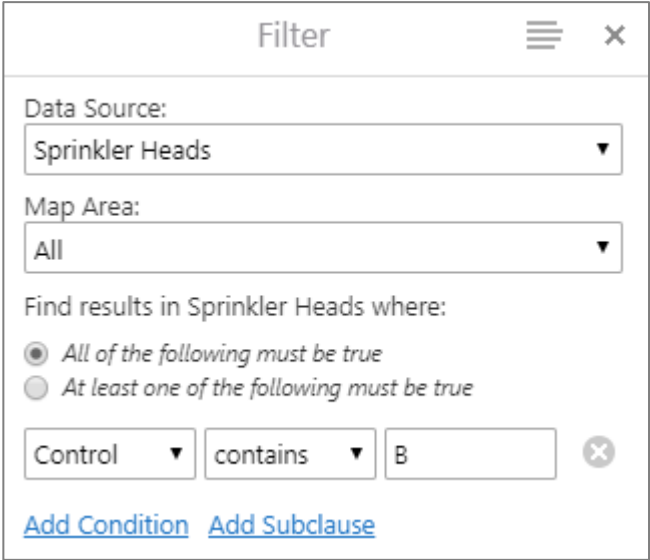

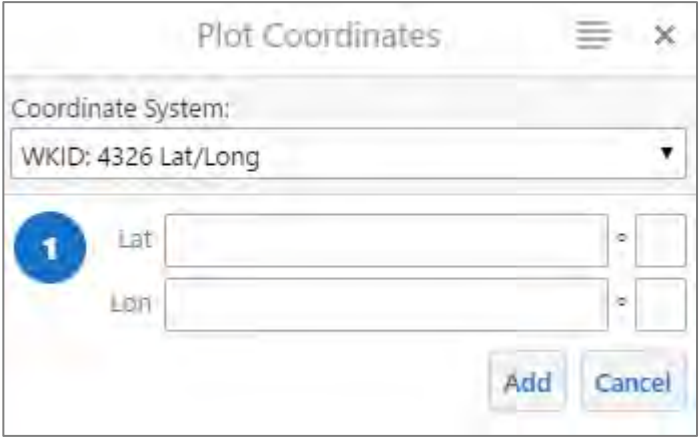
Use this tool... ▼	To... ▼
 <p>Distance</p>	Measure distances on the map by drawing a line. Draw a single straight line or a complex line made up of multiple straight segments. Double-click to finish drawing.
 <p>Area</p>	Measure an area of the map by drawing a shape. Double-click to finish drawing.
<div>Feet (ft) ▼</div> <div>Feet² (ft²) ▼</div>	Change the unit of measurement on a drawing to other options like Yards, Meters, Nautical Miles etc.
<div>  <p>Enable Snapping</p> </div> <div>  <p>Disable Snapping</p> </div>	<p>Enable snapping while measuring on the map. Snapping will allow the user to “snap to” or trace other layer features. The cursor will change to a circle to indicate snapping is active.</p> <p>Click again to disable snapping.</p>
 <p>Select Snapping Layers</p>	Select the map layers to participate in snapping. The layer list is opened in the Information Panel.
<div>  <p>Measure ▼</p> </div> <p>Advanced Measurement</p>	<p>The Advanced Measurement tools allow you measure custom lines and shapes. You can get information about length and areas by using varying tools to draw on the map.</p> <p>For freehand measurements, click and hold to draw a freehand line or shape. Release the mouse to finish the measurement.</p>
<div>  <p>Line</p> </div> <div>  <p>Freehand Line</p> </div> <div>  <p>Freehand Shape</p> </div> <div>  <p>Ellipse</p> </div> <div>  <p>Circle</p> </div> <div>  <p>Polygon</p> </div> <div>  <p>Rectangle</p> </div>	
<div>  <p>Edit D... ▼</p> </div> <p>Edit Drawings</p>	<p>Edit Drawing Menu. Measurements are automatically added as drawings. Just like Mark Up drawings, measurements can be edited, erased, and cleared using the Edit Drawings tools.</p>

Use this tool... ▼	To... ▼
 Edit	<p>Edit any text or drawing added to the map. Click the drawing to edit. Rotate the drawing by clicking and dragging the square above the marquee in the middle of the graphic. Move the drawing by clicking and dragging it. To edit shapes or lines, click the drawing and drag any of the points in any direction to change the shape of your drawing. To edit text labels, click Edit Drawing and then the text. Type in new next.</p>
 Erase	<p>Erase an existing drawing. Click on individual drawings to remove them from the map.</p>
 Clear	<p>Clear all drawings on the map at once.</p>
 Export Drawings	<p>Download all drawings in shapefile format.</p>

ANALYSIS TOOLS

The analysis tools provide custom search capabilities either by interactive find data methods or defining data searches with specific conditions.

Use this tool...	To...
 <p>Point</p>	<p>Find Data using different types of identify tools. Click the pull down arrow to change tools. All the features beneath the point you click or shape you draw are listed in the Results List.</p> <div>     </div> <div>  </div> <p>Point Freehand Line Polygon</p> <p>Rectangle</p>
 <p>Query</p>	<p>Query map layers based on attributes and/or spatial conditions. Features that meet the query condition(s) will be returned in a Query Results list in the Information Panel.</p> <div> <div>Query</div> <div> Data Source: Control Valves </div> <div> Map Area: All </div> <div> Find results in Control Valves where: <input checked="" type="radio"/> All of the following must be true <input type="radio"/> At least one of the following must be true </div> <div> Controller = A </div> <div> Add Condition Add Subclause </div> </div> <p>To set up a query:</p> <ol style="list-style-type: none"> 1. Data Source. Select the map layer to which the query will apply. 2. Map Area. Choose to query only the features in the current map extent or to query all features on the map. 3. Conditions. Build conditions for the query. Select the field of interest, an operator, and a value. For example, to find all remote control valves that are wired to Controller A, choose “Controller = A” 4. Search. Click search to get the query results list.
 <p>Filter</p>	<p>Filter map layers based on attributes and/or a spatial filter. When filters are applied, the map view updates to show only the features that met the conditions.</p>

Use this tool... 	To... ▼
	<div data-bbox="423 273 1068 829">  <p>Filter</p> <p>Data Source: Sprinkler Heads ▼</p> <p>Map Area: All ▼</p> <p>Find results in Sprinkler Heads where:</p> <p><input checked="" type="radio"/> All of the following must be true <input type="radio"/> At least one of the following must be true</p> <p>Control ▼ contains ▼ B ✕</p> <p>Add Condition Add Subclause</p> </div> <p>To set up a filter:</p> <ol style="list-style-type: none"> 1. Data Source. Select the map layer to which the filter will apply. 2. Map Area. Choose to filter only the features in the current map extent or to query all features on the map. 3. Conditions. Build conditions for the filter. Select the field of interest, an operator, and a value. For example, to display only sprinkler heads that are part of Controller B, choose “Control contains B”. 4. Filter/Clear. Click “Filter”. The map view updates to only display features that met the filter conditions. To return to the normal view, you must click “Clear” to ensure all features have been made visible again.
 Plot Coordinates	<p>Plot coordinates on the map by clicking at the point of interest or by typing in known X and Y values.</p> <div data-bbox="423 1228 1117 1661">  <p>Plot Coordinates</p> <p>Coordinate System: WKID: 4326 Lat/Long ▼</p> <p>1 Lat: <input type="text"/> ...</p> <p>Lon: <input type="text"/> ...</p> <p>Add Cancel</p> </div> <p>Click the drop-down arrow next to “Coordinate System” to choose the format for the coordinates.</p> <p>Click the “...” button on the right side of any plotted coordinate to open the Coordinate Actions Menu where you can edit or delete the coordinate.</p>

Use this tool...
▼

To... ▼

Plot Coordinates

Coordinate System:
WKID: 4326 Lat/Long

1

Lat: 34.43555° N
Lon: 119.62034° W

⋮

2

Lat:

Lon:

Add

Cancel

Coordinate 1 Actions

✕

Hide Coordinate

Temporarily hide this coordinate.

✎

Edit

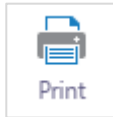
Edit the location of this coordinate.

🗑

Delete

Delete this coordinate and remove it from the map.

PRINTING



The Print function in the application provides users the ability to create their own maps using a variety of existing map templates. When you print a map, you have several options that make it possible to set up precisely how your map should be printed, including the layout, format, resolution, and scale.

To Print a Map:

1. On the **Print** toolbar, click the **Print** icon.

The Print Map dialog opens. The map is set at the current extent but can be adjusted at any time by panning and zooming the map.

Print Map

Select Layout
8.5 x 11 Landscape

Output Format
Pdf

Resolution
200 DPI

Map Scale
Current Scale - 1: 298

Map Title
Music Academy of the West

Compiled Date
Compiled on ##-##-####

☒ Lock print preview with map

Print Cancel

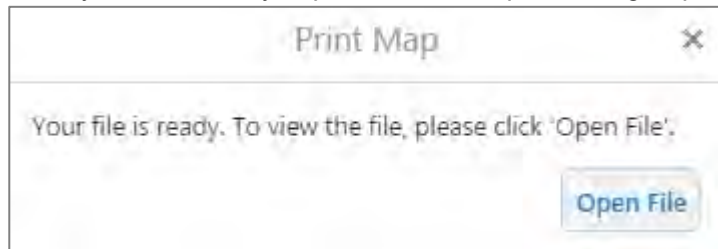
Options for printing the map in the Print Map dialog box

2. Select any of the following options:
 - **Select Layout:** The layouts on your map may have different options.

- **Output Format:** Choose **PDF**, **PNG**, **JPEG**, **GIF**, **BMP**, or **TIFF** format. The Output Formats available can change depending on which Layout you select.
- **Resolution:** Choose either **Low**, **Medium**, or **High** resolution.
- **Map Scale:** Choose any of the following:
 - **Current Scale:** Prints the map in the scale the map is currently using.
 - **Current Extent:** Adjusts the scale to ensure that the whole viewable map is printed.
- **Map Title:** Type in a custom title for the map. "Music Academy of the West" is the default title.
- **Compiled Date:** Type in a date for the map produced.

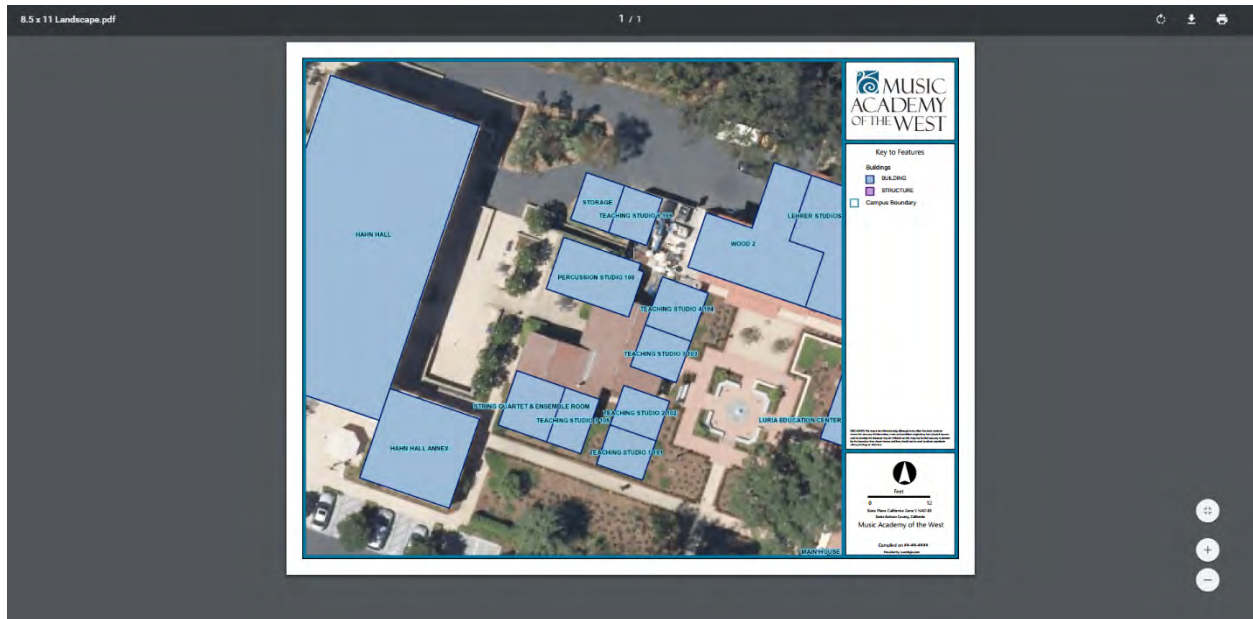
3. Click **Print**.

When your file is ready to print, a Print Request dialog displays.



4. Click **Open File**.

Depending on your choice of file format, the file opens in your PDF Reader or in your Browser window.



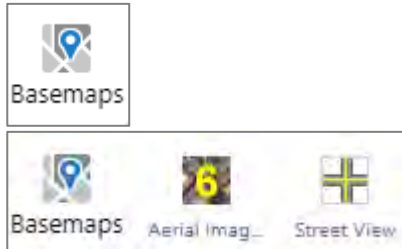
PDF print file open in Google Chrome browser window

6. Do one of the following:

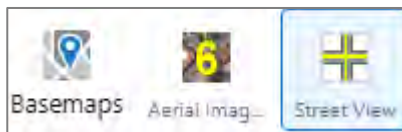
- In Adobe Reader, click the **Print** icon, and then click **OK**.
- In your browser, click **File | Print**, and then click **OK**.
- In a browser with no File menu, right-click the title bar, select **Print** from the title bar, and then click the **Print** button.
- Or you can choose to save the document as a file.

BASEMAPS

You can change the underlying basemap theme for the map environment. The default basemap is set to the **Aerial Imagery** theme. You can see what other basemaps are available by clicking the **Basemaps** icon on the lower left.

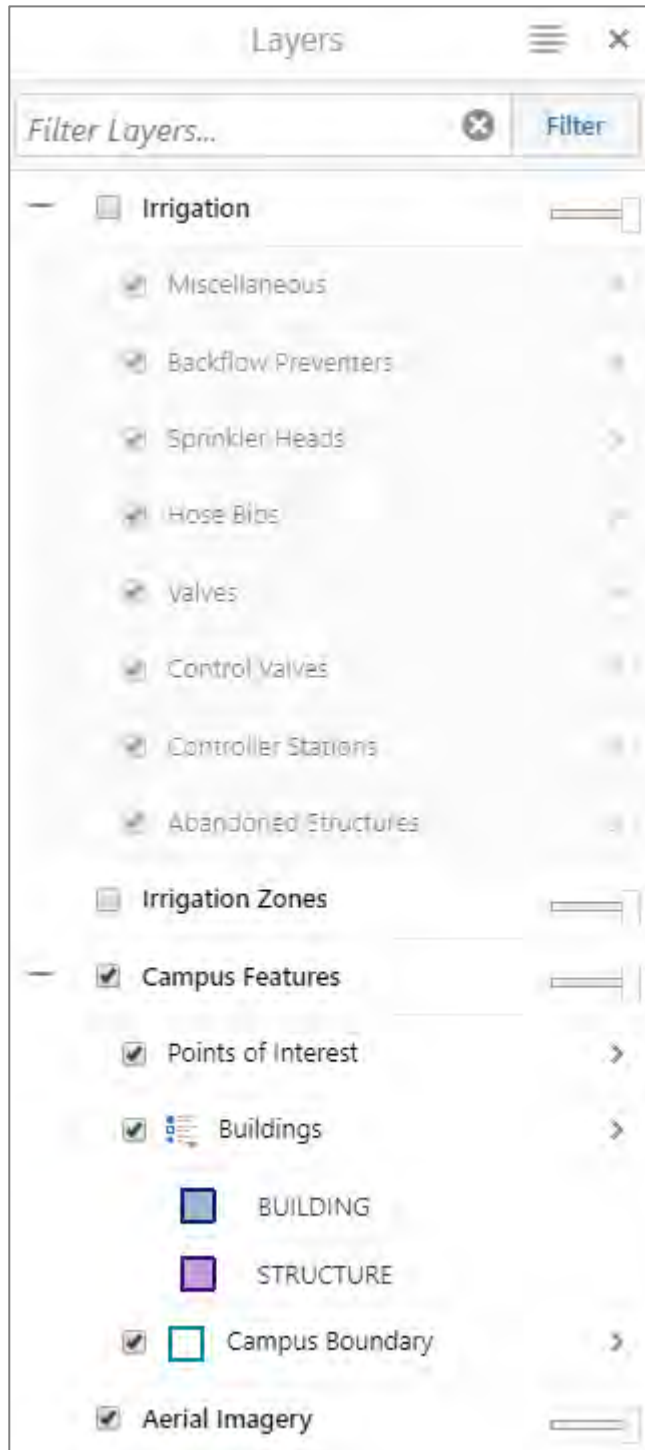


To switch to another basemap theme, simply click its icon.

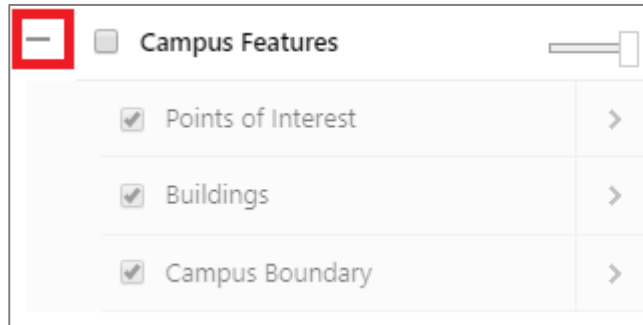


MAP LAYERS

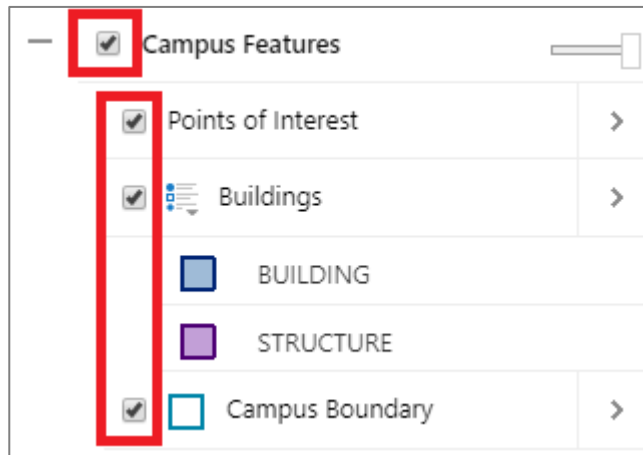
The data in the application consists of “**layers**”. Individual layers have been grouped and placed into Operational Categories.



You can see what layers are available by expanding the Operational Categories.



To turn on a layer so it is visible on the map, both the layer and the Operational Category must be checked.



Each Operational Category has a transparency slider control located to the right of the Operational category wording. Usually by default, the transparency slider is set to 0%.





Layer transparency set to 0% (slider set all the way to the right)

By moving the transparency slider to the left you increase the transparency % for the layers in the Operational Categories.



Layer transparency set to about 50% (slider set in the middle)

SEARCH WINDOW

The search window performs a search on all the existing map layers within the application. Search results are returned in a list organized by map layer. Clicking on an individual list item allows you to zoom to and highlight the feature.



For example, you can search by Irrigation Zone. Searching by Irrigation Zone will return all features related to that zone name (zone, control valve).



IDENTIFY RESULTS

Once you use the Identify or Search tools on features, you get a list of results. The results window has several options to choose how you engage the information.

The results window shows a short synopsis of the features that were identified. Results are sorted by map layer.

Click on the desired category to see the individual features that were identified inside that category. For example, clicking on “(3) Control Valves”.

Identify Results (17)		
17 Results Found		
(1) Buildings	>	...
(5) Sprinkler Heads	>	...
(1) Hose Bibs	>	...
(2) Abandoned Structures	>	...
(3) Control Valves	>	...
(5) Irrigation Zones	>	...

Control Valves (3)		
Control Valve - D06	>	...
Control Valve - D07	>	...
Control Valve - D05	>	...




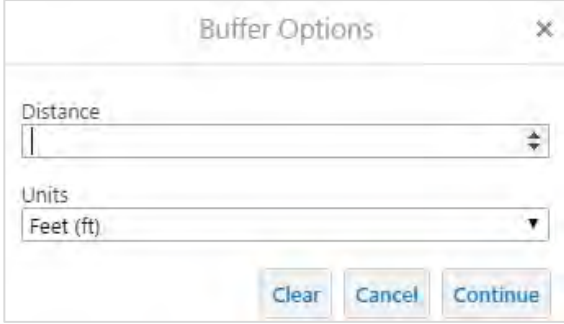

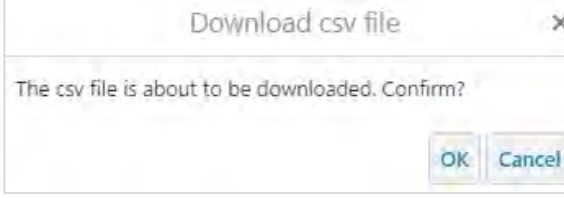

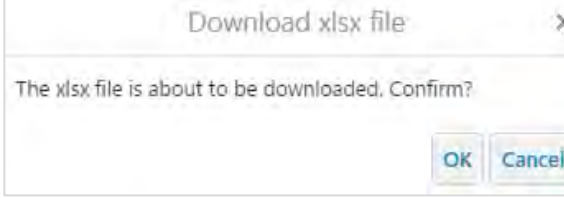

After clicking on an individual entry in the results window, the corresponding feature on the map is zoomed to and selected. The results window then displays more detailed information about the feature.

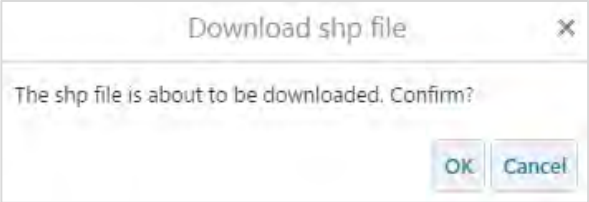


Control Valve - D05		
Description		
CONTROLLER: D		
NOTE:		
Details		
FID		
75		
Shape		
N/A		
Notes		
Name		
D05		
Controller		
D		


PANEL ACTIONS MENU















The **Panel Actions Menu** on the top right of the Results Window allows for a wide variety of data export functions. After identifying features, there are a number of actions that can be taken to get information about the results. The tool options available in the Panel Actions Menu are described in the table below. They may vary depending on what types of features are contained in your results list.

 Switch to Table View results in table format	Switch to Table opens all identified features in a larger table view along the bottom of the screen. The table includes tabs along the top for each layer that was included in the identify process.
 Switch to List View results in list format	Click Switch to List to return to the initial results view.
 Show Buffer Options Identify features near these results	Identify additional features within a certain distance of your results. In the Buffer Options dialog, enter the buffer distance, choose units, and click Continue. <div data-bbox="724 821 1284 1142">  </div>
 Export to CSV Export Results to CSV	Opens the Download csv file dialog. Click OK to download a CSV file of the results. There may be several files depending on how many map layers were included. <div data-bbox="724 1257 1284 1453">  </div>
 Export to XLSX Export Results to XLSX	Opens the Download.xlsx file dialog. Click OK to download an Excel file of the results. <div data-bbox="724 1535 1284 1730">  </div>
 Export to Shapefile Export Results to Shapefile	Opens the Download.shp file dialog. Click OK to download a shapefile of the results. There may be several files depending on how many map layers were included.

	 <p>Download shp file</p> <p>The shp file is about to be downloaded. Confirm?</p> <p>OK Cancel</p>
 <p>Run a Report Run a Report on the Selected Results</p>	<p>Opens the Choose Report dialog in the Information Panel. Different reports may be available depending on what features are selected.</p>  <p>Choose Report</p> <p>The following reports are available for the features you selected:</p> <p>Mailing Labels - Owner <i>Covers 7 of 39 selected features</i></p> <p>Mailing Labels - Occupant <i>Covers 7 of 39 selected features</i></p>

 The **Result Actions Menu** on the right end of features in the Results Window is similar to the Panel Actions Menu, but is geared toward individual features and layers. The tool options available in the Result Actions Menu that were not already covered in the previous table are described in the table below. They may vary depending on what types of features are contained in your results list, and if you click the menu from a layer result or an individual feature result.




 <p>Zoom to All Zoom to extent of all results</p>	<p>Zoom to All adjusts the map extent so all results within the particular layer are visible.</p>
 <p>Save Results Save the list of results for future use</p>	<p>Save Results allows you to save the results (either all those within the layer or an individual feature). The result(s) are given a name and can be reopened during the session.</p> <p>Open Saved Results allows you to return to any results that were previously saved during the same session.</p>
 <p>Open Saved Results Choose from a list of saved results to view them</p>	
 <p>Zoom to Feature Zoom to this feature on the map.</p>	<p>Zoom to the selected feature in the map.</p>
 <p>Pan Pan the map to center this feature.</p>	<p>Move to the feature in the map without changing the current scale.</p>

 Copy to Drawing Layer Copy this feature to the drawing layer	Click to create a copy of the feature as a Mark Up drawing. It can then be edited using the style and edit drawing tools.
 Combine Results Perform advanced operations with multiple lists of results	Open a menu of advanced options for working with your results. <div data-bbox="808 390 1395 825"> <div>Combine Results</div> <div>  Add to results Combine a saved set of results with your current results list </div> <div>  Subtract saved results Remove a saved set of results from your current list of results </div> <div>  Match intersecting results Only show results that are in both your current list and a saved set of results </div> </div>
 Remove from Results Remove this feature set from the current collection of results	Remove all features within the particular layer from the list of identified features. Use this tool to remove unwanted features from a list before using an export method.
 Remove from Results Remove this feature from the current set of results	Remove the feature from the list of identified features. Use this tool to remove unwanted features from a list before using an export method.

GEOLOCATION



Geolocation uses the device's GPS capability to find your location and display it in the map view.

 Find Me	The Find Me tool places a blue dot on the map representing your current location and zooms to it.
 Track Me	The Track Me tool follows your location as you move without adjusting the map extent or scale.
 Follow Me	The Follow Me tool tracks your location as you move and pans the map extent as necessary.