San Marcos Buildings Evacuation Routes

San Martian Evacuators

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Abstract Efficient exit routes during emergency situations are vital for the safety of staff and the public in facility buildings. A standardized sequence was developed for emergency preparedness maps for the city of San Marco (CoSM) to ensure that safety procedures are met and for optimized navigation. The original maps installed in the buildings were outdated, inaccurate, and often missing vital features. To ensure effective navigation, these maps were updated through data collection, standardization, and geographic information systems (GIS) techniques. Only three buildings were selected to implement these updated static maps; City Hall, Grant Harris, and the Municipal Building. New data was collected through ArcGIS Field Maps and further cleaned up and standardized on ArcGIS Map Viewer. The data provided from CoSM had inaccuracies and missing features that further needed to be updated. Once these features were collected and updated, these datasets utilized Python Toolbox, that implemented the Least Cost Path and Euclidean Distance techniques to create an emergency route. A standardized template was developed with this Python Toolbox, to automate these emergency routes for the rest of the San Marcos' facilities. The data collected and routes established for the three selected facilities will be implemented in the existing CoSM Facilities Viewer app to ensure proper navigation and operational efficiency for staff members and the public.

1. Introduction

1.1 Problem Statement

Sustaining emergency preparedness maps within facilities allows staff to safely navigate out of their building in a quick and efficient manner during an unexpected situation. Historically, in the City of San Marcos (CoSM), their facilities have used faulty emergency preparedness maps that are outdated and often include inaccurate hand-drawn features. The CoSM tasked the San Martian Evacuators (SME) with creating emergency preparedness maps for their facilities through data collection, implementing cartographic standards, defining data schema, and lastly, delivering static maps. The main objectives of the SME include: (1) developing standards ensuring similar data within all locations, (2) creating updated and accurate maps and data that are both maintainable and shareable, and (3) producing static maps to be displayed within three selected buildings for staff and visitor use. The three buildings that will implement these standards include City Hall, Grant Harris, and the Municipal Building.

This project incorporates geographic information sciences (GIS) techniques, utilizing Least Cost Path and Euclidean Distance within a Python Toolbox to create emergency routes and further implement these standards. These GIS tools are beneficial because they will ensure proper symbology, a clear template layout, high quality exit routes, and proper posting guidelines that are implemented within the SME collected data from the three selected facilities. ArcGIS online applications, like Field Maps, Field Maps Designer, and Map Viewer, were all additionally executed in this project for aspects such as data collection and map creation.

Before creating new standards and implementing these GIS functions, only ten key emergency preparedness features were believed to be established within the map. However, after data collection and incorporating Python scripts, thirteen more features were included. New features, like rally points and security restricted areas, have been included in these evacuation maps to ensure a descriptive understanding of each facilities' design and to further support GIS tools. Additionally, some features, like map postings and first aid, were not found in the building so proposed locations were included. Additionally, in our proposal, five buildings were requested to be studied by the client and were determined to meet our established standards. However, our scope was minimized to three buildings with the client's approval. This change was addressed due to the time constraint and to ensure the smooth advancement of the project's completion.

This project will cater to the City's Emergency Preparedness Team, established in 2022, to help ensure safety within the city-owned building located the San Marcos area. Having emergency evacuation routes ensures workplace safety among staff and allows them to be prepared and respond effectively in the event an emergency transpires. With the creation of a fire evacuation standard, this will allow a uniform plan amongst facilities to produce operational efficiency and proper navigation.

1.2 Importance of Emergency Preparedness Standardization

With GIS applications, disaster response has become increasingly efficient with real-time mapping of the emergency and the implementation of evacuation routing or resource allocation to the areas in need (Gunes and Kovel 2000; Pu and Zlatanova 2005). Standardization plays a key role in organizing, communicating, and enhancing the accuracy of multiple maps. Cartographic standards for forward-facing safety maps that are accessible internally and to the public provide greater stability and structure for evacuation preparedness mapping. These elements include the standardization and generalization of cartographic symbols such as the utilization of the standard symbology for emergency exits and fire extinguishers, the creation of data collection standards for the sharing of data in spatial data infrastructures, and increased quality control standards for maps (Đapo, Divjak, and Pribičević 2020; Coetzee et al. 2018; Cintra and Nero 2015). Through the incorporation of these standardized cartographic elements into the three buildings being mapped, these homogenized elements can then become the new template for future buildings being mapped for emergency routing within the CoSM building network.

1.3 Scope

The City of San Marcos has fifty-four facilities within its city limits. Originally, for this project, the SME were tasked to create fire evacuation routes for five selected buildings; City Hall, Grant Harris, Municipal Building, San Marcos Activity Center, and San Marcos Public Library. However, due to the longevity of the project, and with client approval, the SME changed focus to only three of the selected buildings, as seen in Figure 1. City Hall, Grant Harris, and Municipal Building were the three selected facilities that were implemented in this standard map. This project took thirteen weeks starting on January 28th, 2026, through its completion on April 29th, 2026.

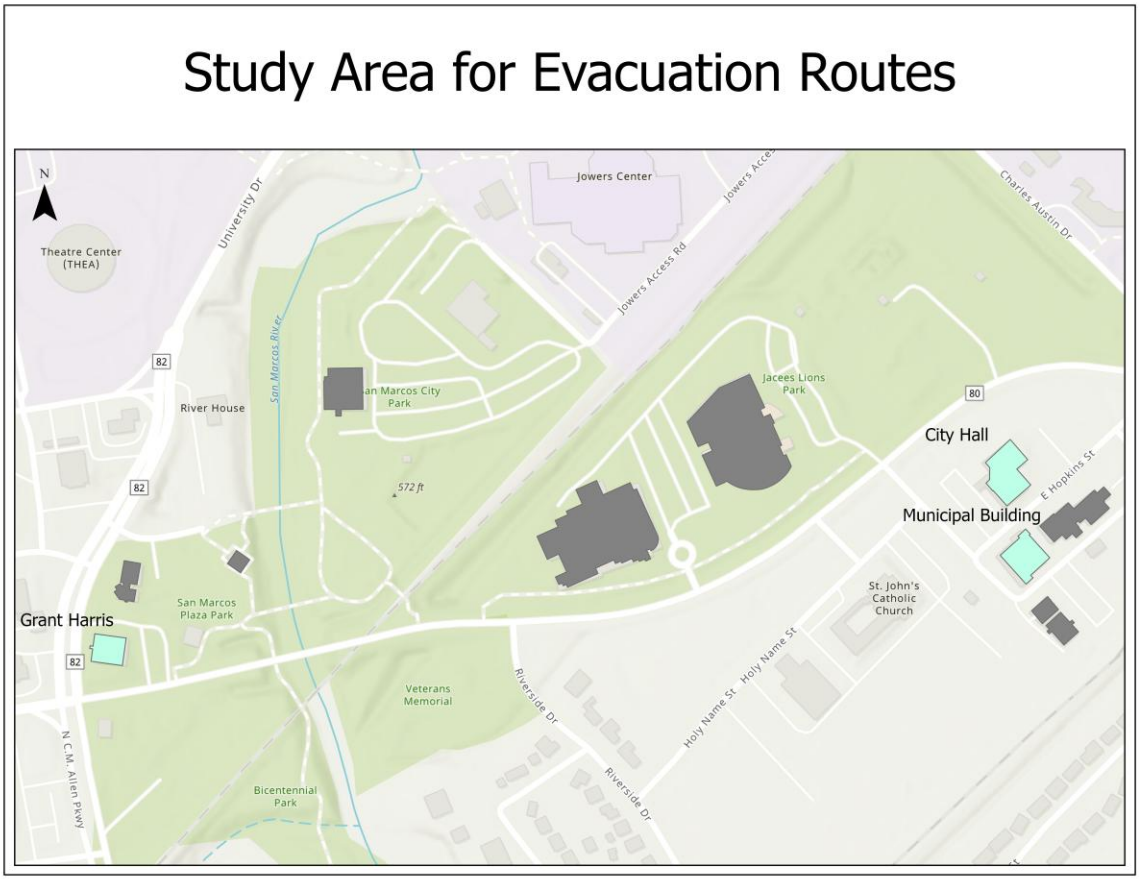


Figure 1. Area of interest

2. Data

The data utilized in this project came from two different sources: CoSM provided data and data collected by the San Marcos Evacuators (SME) during site visitations at the three selected buildings: City Hall, Grant Harris, and the Municipal Building. At these locations, the data was collected using Field Maps and compiled in ArcGIS Online. Both data sources implemented NAD 1983 State Plane Texas S Central FIPS 4204 (US Feet) as their projection. These sources of data were separated into two different use cases. The first portion of the data used features like doors, walls, and entry/exit points, with these features being used to create routing lines for primary and secondary evacuation routes and later modified and analyzed in ArcGIS Pro. The other portion of the data will be used as key information on the static map postings and sent to the CoSM for their existing Facilities Viewer app. After updating the CoSM data and the data collected from SME there were a total of twenty-three features.

2.1 Data Given by City of San Marcos

In the beginning of the project, CoSM provided the SME baseline data to be utilized and updated. This given data has seven features including Entry Points, Assets, Walls, Doors, Security Zones, Rooms, and Building Footprints, as can be seen in Table 1. These features employed NAD 1983 State Plan Texas S Central FIPS 4204 (US Feet) as their projection; this led the data collected by the SME to reflect the same. The provided data was then compiled into an excel document and edited for standardization. The data was split into three major sections (rooms, doors, and walls), then further color coded by the building type, as can be seen in Figure 2. With standardization, the information mainly looked at was consistency in building names, such as all City Hall buildings being named "City Hall" and not "City Hall of San Marcos" or other naming conventions. This collected data was then imported back into ArcGIS as a csv file, and then further implemented back into the master data table for the project.

Table 1. Master data list: CoSM

Feature Layer	Spatial Object	Attribute	Status
Door	Line	Floor, Building, Type	Updated
Wall	Line	Floor, Building, Type	Updated
Assets	Point	Floor, Building Name, Type, Reference Code, Comments, Asset Number	Updated
Entry Points	Point	Floor, Building, Location, Door Type, Door Material, Access Control, Reader Type, Lock Type, Exit Type, Fail Type, Notification System, ADA Opener	Updated

Building Footprints	Polygon	Building ID, Name	Updated
Room	Polygon	Floor, Building, Department, Space, Type, Room Number, Room Name, Occupants	Updated
Security Zone	Polygon	Floor, Building, Type	Updated

		621	Polyline Z	Municipal Building	3	Wall	Drywall	{FAEB8DEB-5F19-489A-A87D-20321C5FACAA}	dwanke@sanmarcostx.gov	6/22/2023 19:53
		732	Polyline Z	Municipal Building	3	Wall	Drywall	{FBE06EA0-7029-4D2F-B56E-9A043EE13145}	MBoffa@sanmarcostx.gov	6/28/2023 13:28
		815	Polyline Z	Municipal Building	3	Wall	Drywall	{997E95C5-3276-4623-B682-FE00B2C9535A}	MBoffa@sanmarcostx.gov	6/28/2023 14:41
		816	Polyline Z	Municipal Building	3	Wall	Drywall	{6A819C6B-BFE8-4E04-B621-7204337D2811}	MBoffa@sanmarcostx.gov	6/28/2023 14:41
		817	Polyline Z	Municipal Building	3	Wall	Drywall	{3A5C2FAA-084B-42AC-A2E4-6899B5A8AEC0}	MBoffa@sanmarcostx.gov	6/28/2023 14:41
		935	Polyline Z	San Marcos Activity Center	1	Wall	Drywall	{031F4075-3E4A-4F4E-B8C6-3DFF4F0D578B}	MBoffa@sanmarcostx.gov	8/11/2023 16:55
		936	Polyline Z	San Marcos Activity Center	1	Wall	Drywall	{66055CF6-6EA7-4728-AF1B-A27497E855A7}	MBoffa@sanmarcostx.gov	8/11/2023 16:55
		937	Polyline Z	San Marcos Activity Center	1	Wall	Drywall	{1DFC1ACF-3DD2-4105-B930-FBC61BE01427}	MBoffa@sanmarcostx.gov	8/11/2023 16:55
		938	Polyline Z	San Marcos Activity Center	1	Wall	Drywall	{A3930E5A-BA3D-492C-B214-62067A0E4E29}	MBoffa@sanmarcostx.gov	8/11/2023 16:55
		939	Polyline Z	San Marcos Activity Center	1	Wall	Drywall	{7E9E69CF-9B6E-4CCC-A432-E1E1E2D794A9}	MBoffa@sanmarcostx.gov	8/11/2023 16:55

Room_Data Door_Data Wall_Data (2) +

Figure 2. Color-coded standardization tables split into rooms, doors, and walls

Overall, the data given by the CoSM was of high quality, but there were some issues with certain sections of the data. One major data issue with the CoSM data would be the given door data acting as barriers for exit route creation, as the doorways were acting as part of the walls and not as an open hole that could be entered or exited when using exit routing. This barrier can be seen in Figure 3. The original door data was then updated with the collected door data by the SME site visitations via ArcGIS Field Maps and ArcGIS Online for accuracy and precision. This new feature allowed for the creation of proper doorways for exit routes using Model Builder, which will be further discussed in methodology. For this purpose, the walls were required to be changed into lines using the Polygon to Line tool to make the process of door creation easier and to automate the process for future CoSM buildings implementing this procedure. This process of doorway creation is extensive, using multiple ArcGIS tools for the purpose of automation and will be further covered more extensively in Methodology.

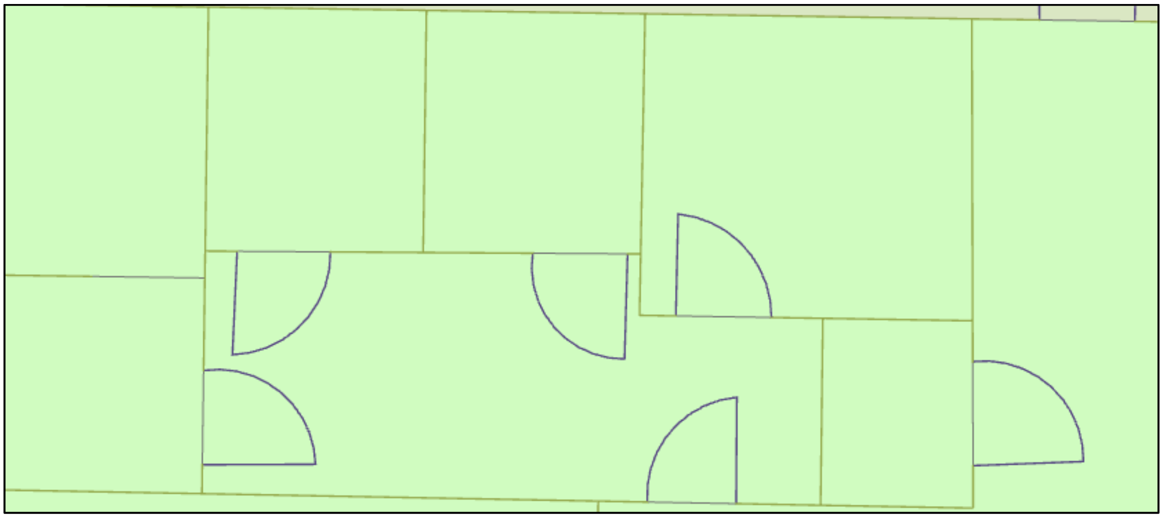


Figure 3. Closed walls with no gap for doorways

One minor issue that was found with the data would be that certain walls no longer existed and needed to be removed manually through the deletion of wall segments. Notes were made about these changes during field visits. Another issue would be with doors that were placed in spots where there are no walls, as can be seen in Figure 4, with these additional doors being manually removed. Certain buildings also had missing rooms that were not accounted for in the floorplan, having to be produced with the Create Polygon tool. Finally, rooms that were isolated with no doors had to be referenced with the collected SME data and given doorways through the doorway creation method detailed in methodology.

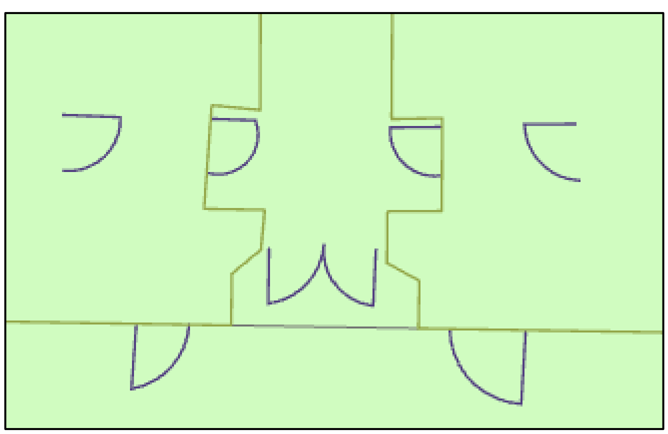
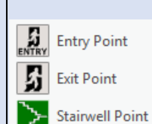


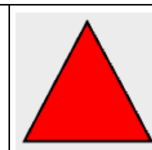
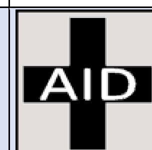
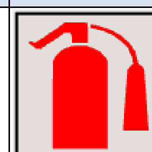
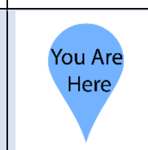
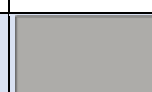
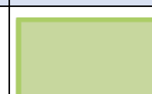
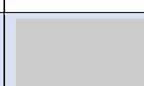
Figure 4. Walls placed in the middle of a room

2.2 Data Collected by San Martian Evacuators

Data collection of different features in the city buildings was a major aspect of this project. This data was needed for static maps placed inside of select city buildings, for the CoSM Map Viewer application, and for emergency exit route creation. Additionally, the CoSM provided data that had missing or inaccurate errors that needed to be vetted by site visitation. A total of fifteen features were collected between the three selected sites, as seen in Table 2. Additionally, the SME included features from the standard fire safety plans from the 2024 International Fire Code, like secondary evacuation routes and rally zones (Code 2024). This data was put in the projection of NAD 1983 State Plane Texas S Central FIPS 4204 (US Feet) to reflect the CoSM data. Using the Field Maps application, data was collected on March 6th, March 9th, and March 25th, 2026.

Table 2. Master data list: SME

Feature Layer	Spatial Object	Attribute	Symbology
Defibrillator (AED)	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Doors	Point	Floor Level, Asset Number, Building, Access Type, Lockset Type, Door Type, Additional Information	
Elevator	Point	Floor Level, Asset Number, Building, Access Type, Additional Information	
Emergency Exit Signage	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Entry Exit Points	Point	Floor Level, Asset Number, Building, Access Type, Entry Type, Lockset Type, Door Type, Additional Information	

Fire Alarms	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Fire Alarm Control Panel	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Fire Alarm Pull Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
First Aid Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Fire Extinguisher Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Map Posting Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Rally Points	Point	Asset Number, Building, Relative Location, Additional Information	
Parking Lots	Polygon	Building, Additional Notes	
Rally Zones	Polygon	Building(s), Zone Number, Relative Location, Additional Information	
Security Restricted Areas	Polygon	Floor Level, Building, Access Type	

To expand, data was collected through the process of visiting the sites of City Hall, Grant Harris, and the Municipal Building. A map in Field Maps Designer was created to implement forms attached to the features. The form elements included Radio Buttons, Text – Single Line, Text – Multiline, and Number – Integer. Most of these forms asked for each feature's floor level, asset number, building name, access type, and additional information. Once the forms were all established, the group members went to each of these three sites and used both their smartphones and tablets to map the locations of the point features via the Field Maps app. The process of collecting data involved selecting a feature in the app, selecting its location based on the floor plan, taking a picture of the data source with a smart device, and then further labeling and filing out the form information (i.e., building name, floor level). Additionally, during these site collection days, notes were made to alter the old floor plan data provided. Due to these sites being indoors, a GNSS device could not be utilized, causing us to select the relative location of each feature based on the floor plans provided. Each feature had additional information with descriptions relative to its type, such as doors being labeled on if they were a slide or swing, or what type of lockset they used. Two of the point features, first aid locations and map posting locations, included proposed locations in the additional notes, since they either had no data collected or little to none. These proposed locations can be referred to for the CoSM client. For the polygon features, each of them were sketched using the Esri imagery Base Map to minimize complexity. There were three polygon features; Parking lots, Rally zones, and Security Restricted Areas. For Rally zones, we defined this feature as being over fifteen meters away from the selected building, and additionally the area being over 45 meters wide. Security Restricted Areas are defined as areas that are not accessible for public use.

This step of data collection also heavily involved the simultaneous process of ground truthing as well, or the continual process of checking the accuracy and precision of given CoSM data against the presently collected data in the three visited buildings. Members of the SME would find inaccuracies in the floorplans site visitations, such as certain areas being mapped as closed rooms in the floorplan of Municipal Building just being open hallways instead. Another ground truthing issue would be checking the precision of certain doorways, making sure they were not completely misplaced on the base floorplans and were later updated in ArcGIS.

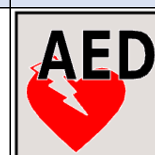
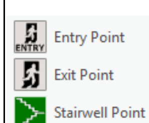
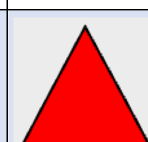
After data collection, these fifteen features were then edited in Map Viewer to place collected data in a more precise location. Furthermore, the application was used to fix and separate data that was overlapping to be more differentiated, such as features collected on the first and second floor of the Municipal Building. Each feature was also organized and given standard responses to ensure uniformity amongst attributes. An example of this would be changing all floor levels to reflect the label "Floor One", instead of "floor one" or "Floor 1". Every attribute was cleaned up to reflect this orderliness.

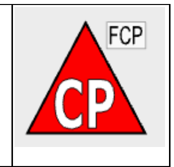
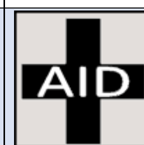
A major part of data standardization is the implementation of a standardized symbology for features used in the static maps and the Facilities Viewer app to ensure consistency across current and future maps. To meet this requirement, symbology was collected from within the ArcGIS Pro Symbology panel and downloaded from an ArcGIS Pro Stylesheet (Rogers 2021). Additionally, neither symbology sets had an icon for emergency signs, so one was downloaded from the website Vecteezy (Ali 2026). This symbology has then been compiled into the master data table for ease of access, shareability, and to act as a reference for the CoSM for future building maps.

2.3 Final Updated and Compiled Master Data Set

After data collection and updating the CoSM provided data, there were a total of twenty-three features, seen in table three. SME collected fifteen of those features. Six of them were updated from the CoSM provided data. Five of those features spanned from the floor plans, which were divided into three separate buildings and further by floor level. The other updated feature is labeled Fixed Walls with Door Gaps. This was created from the cleaned-up walls that were turned from polygons to lines, to create gaps in the doorway. Both data sets were utilized to create two features, Primary Evacuation Routes, and Secondary Evacuation Routes via Python scripts, a process that will be covered more extensively in methodology.

Table 3. Final master data list

Feature Layer	Spatial Object	Attribute	Symbology
Fixed Walls with Door Gaps	Line	Floor Level, Building	
Primary Evacuation Route	Line	N/A	
Secondary Evacuation Route	Line	N/A	Multi-Color Lines
Defibrillator (AED)	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Doors	Point	Floor Level, Asset Number, Building, Access Type, Lockset Type, Door Type, Additional Information	
Elevator	Point	Floor Level, Asset Number, Building, Access Type	
Emergency Exit Signage	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Entry Exit Points	Point	Floor Level, Asset Number, Building, Access Type, Entry Type, Lockset Type, Door Type, Additional Information	
Fire Alarms	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	

Fire Alarm Control Panel	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Fire Alarm Pull Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Fire Extinguisher Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
First Aid Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Map Posting Locations	Point	Floor Level, Asset Number, Building, Access Type, Relative Location, Additional Information	
Rally Points	Point	Asset Number, Building, Relative Location, Additional Information	
City Hall Floor Plan One	Polygon	Floor, Building, Department, Space Type, Room Number, Room Name, Occupants	
Grant Harris Floor Plan One	Polygon	Floor, Building, Department, Space Type, Room Number, Room Name, Occupants	
Municipal Building Floor Plan One	Polygon	Floor, Building, Department, Space Type, Room Number, Room Name, Occupants	
Municipal Building Floor Plan Two	Polygon	Floor, Building, Department, Space Type, Room Number, Room Name, Occupants	

Municipal Building Floor Plan Three	Polygon	Floor, Building, Department, Space Type, Room Number, Room Name, Occupants	
Parking Lots	Polygon	Building, Additional Notes	
Rally Zones	Polygon	Building(s), Zone Number, Relative Location, Additional Information	
Security Restricted Areas	Polygon	Floor Level, Building, Access Type	

3. Methodology

A flow chart was developed to showcase the process of creating the Python ToolBox script, seen in Figure five. This Python ToolBox application is needed to create the evacuation routes for analysis and to further make the static maps for the selected buildings. A descriptive analysis of each segment will be addressed in the following subsections. Additionally, this workflow shows the final deliverables of the project.

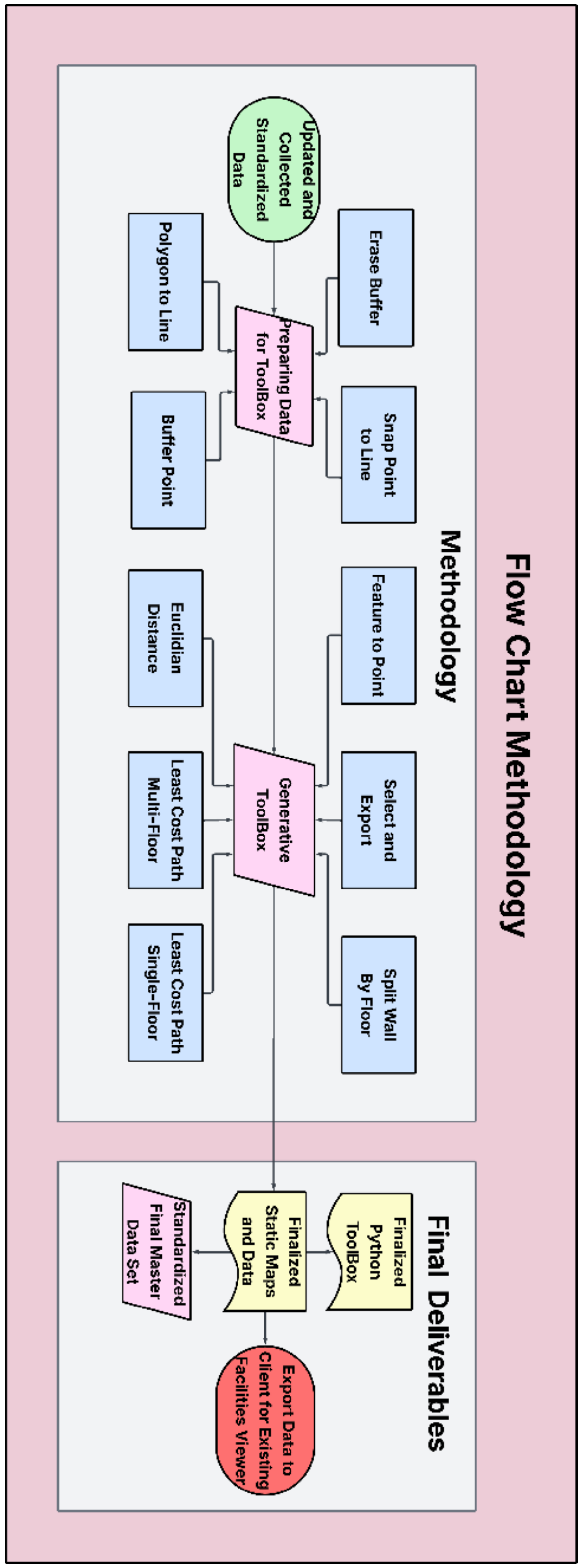


Figure 5. Data Flow Chart

3.1 Model Builder Application Process

To better modify the master data list, SME utilized ModelBuilder to aid in the creation of efficient and effective evacuation routing. Seeing how there was an issue with the door gaps in the base datasets, SME sought to rectify that by creating and running a Door Erase Buffer Model to ensure all rooms had proper exits for routing. Before creating an automated model, research needed to be done into how to create space for doors. The simplest solution was to utilize the snapping of door features to the appropriate walls, running a two feet buffer from those walls, and then erasing the building lines using the established buffers. Below can be seen the generated model, Figure 6, that implements all these procedures in ArcGIS.

The first step in the model is the utilization of the Polygon to Line tool, as all of the walls in the given CoSM floorplans are polygons and need to be transformed into lines for the snap tool to function. This is because the given door points need something to snap to, as polygons do not have anywhere to receive a snap from a point. The Snap tool is then implemented, where a five-foot range is established for the given point to the nearest line edge. A two-foot buffer zone is then established around the snapped point in the Buffer tool for doorway gap creation in the given wall segment. Finally, the Erase tool is then input with the Building Line and Door Buffer zone to create a Line Buffer Gap that will function as a doorway for the process of exit routing. A major issue with the model is that there needs to be a check done after each tool is run to make sure that the desired results have been produced due to the model being prone to error. The major issue with the snap tool is that the doorways can be prone to snapping in the corner of a room, an error that our group was unfortunately unable to amend.

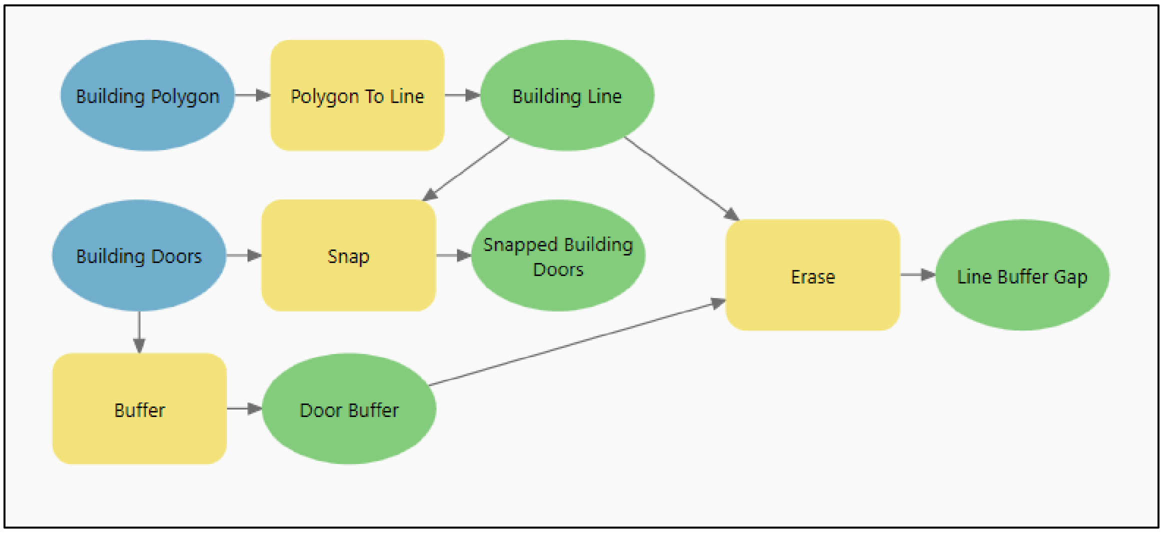


Figure 6. Doorway creation model

3.2 Toolbox Generation

Once all the data was in the correct spots, the process of tool generation could begin. A Python toolbox was required for this process, as it needs to run multiple iterations. For route creation, there are specific tools that need to be run before they can be fully actualized. This means creating tools that will Select and Export feature classes per building, a tool that changes Features to Points for polygons, a tool that runs Euclidean Distance for rooms, and then Least Cost Distance for single and multi-floor buildings.

These tools are all very intricate in their own ways, as they all produce their own outputs. Select and Export allows the user to select a feature within a Geodatabase (GDB), search within its attributes for a specified field, and then export that selection as a new feature. This is then run multiple times for different features. Using these new features, the next tool to be run would be the Feature to Point tool. This tool allows the user to create points from room polygons for further analysis. Utilizing the point features, the user runs the Euclidean Distance tool, which creates distance calculations from each room within the building. Those features are then utilized in the next tool, which is the Least Cost Path (LCP) tools. The single-floor tool runs LCP from each room, utilizing the

Euclidean Distance, to then generate a route to exit points specified in the parameters. The multi-floor LCP does the same, but for floors above the ground floor, all the rooms lead to stairs to the lower floors. With these applications, every possible evacuation route can be generated out of a building, and then further compiled all into one GDB for easy mapping. Once these processes are completed, a map will then be created for the selected building that the script has been run for. Examples of the created maps from these run scripts can be seen later in Results for the respective buildings of Grant Harris, City Hall, and Municipal Building.

For the process of data collection and the implementation of the Python scripts through the given toolbox, a Standard Operating Procedure (SOP) document will be given and should be followed for maximum efficiency. This is an instruction document that gives step by step documentation on how to operate the toolbox. If the given steps of data collection and then usage of the python tools are accurately followed, the given processes submitted by the SME will be utilized to their maximum capacity.

3.3 Static Map Creation

Static Map Creation for the given buildings was a major requirement of the project and one that required extensive time. The process of map creation utilized ArcGIS Pro, working off the already created base maps, and map editing utilized Adobe Illustrator. Cleaning up the symbology so there was no overlap was an important step, specifically with the fire extinguisher locations, first aid locations, fire alarm pull locations, and AEDs often being located near each other and resulting in some form of overlap that needed to be corrected. Next, editing the doorways to show swing direction and opening was another key step, specifically so that firefighters would be able to glance and know how to enter a room. After that, the manual route creation from hallways to exit doors using the pen tool in Adobe Illustrator was the next step in the process of map creation. The pen tool was used specifically to increase clarity and conciseness in the creation of routes. The final step was creating individual maps with specific "You Are

Here" points for each of the map posting locations. These processes were the key steps in the creation of static maps to be utilized by the CoSM.

3.4 Data Implication

Once the maps and data are officially completed, they will be transferred to the client. The data is uploaded to an ArcGIS organization, Facilities Viewer app, that is accessible to our client. Furthermore, the client will implement our tools and standardization into their own website for upkeep and for both faculty and public use. With the updated data standardization, CoSM can ensure that evacuation routes can be implemented throughout the city's facilities.

4. Results and Discussion

4.1 Results

As a result of the methodology, SME was able to generate raw data maps of evacuation routes that can then be implemented into CoSM in app web viewer. The raw data for these buildings are shown below in figures 7-9.

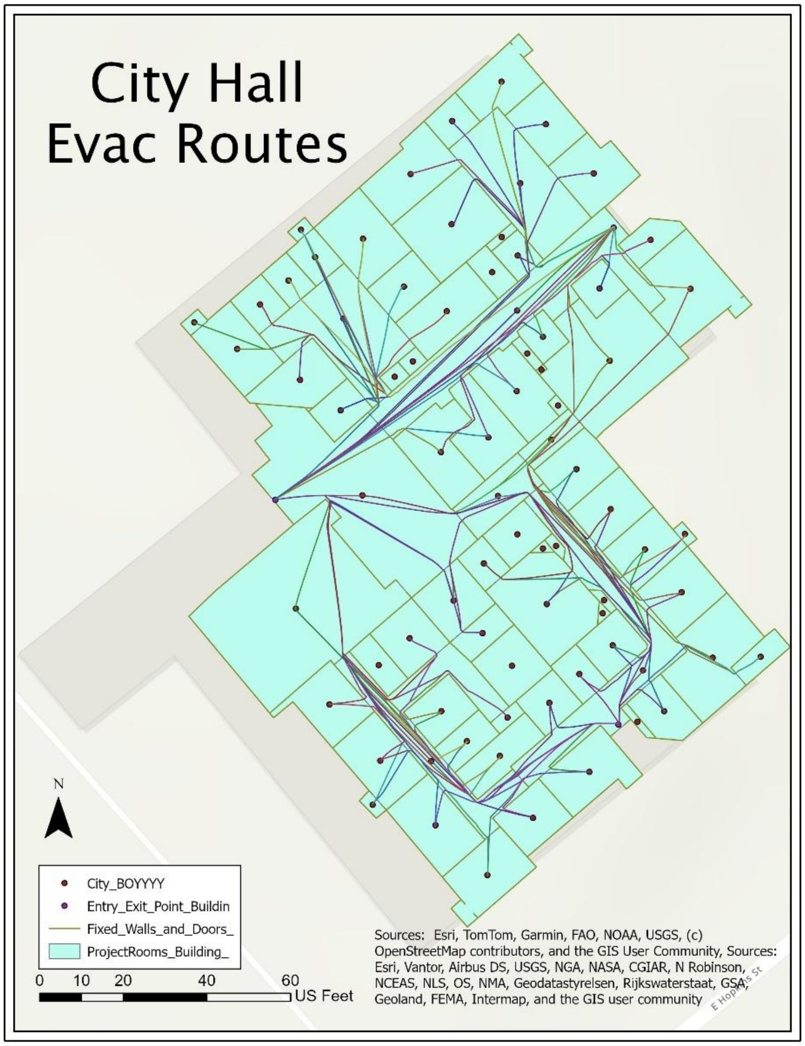


Figure 7. The evacuation route analysis of City Hall

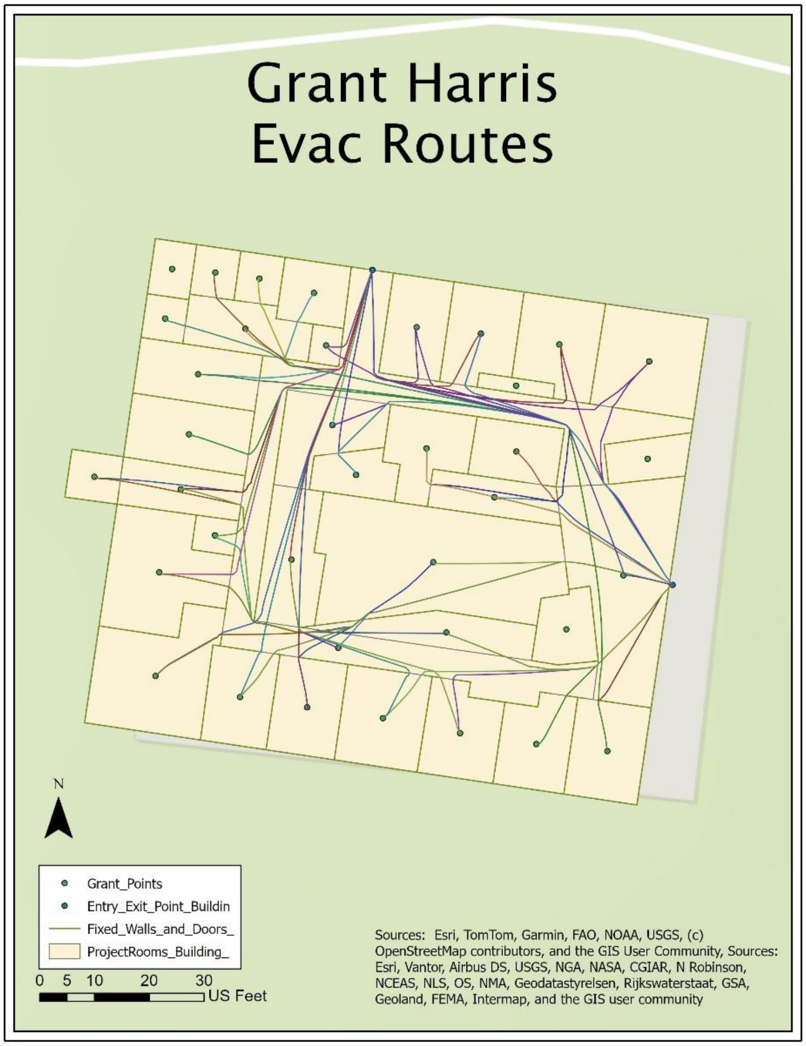


Figure 8. The evacuation route analysis of City Grant Harris

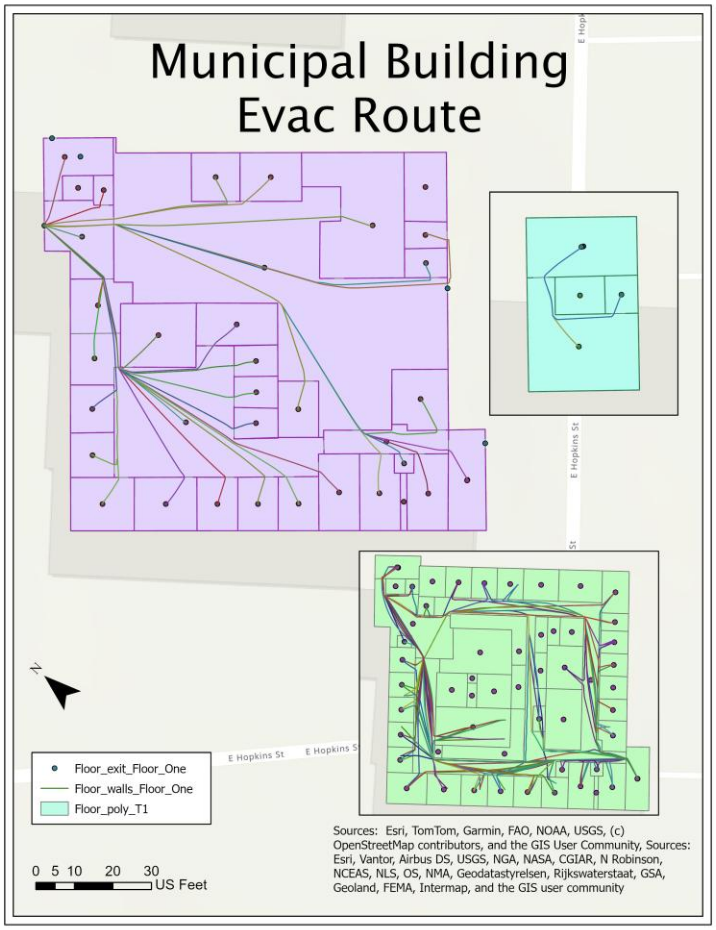


Figure 9. The evacuation route analysis of the Municipal Building

Standardized static maps were finalized and produced for usage in the CoSM buildings of Grant Harris, City Hall, and Municipal Building respectively for staff and visitor usage. The static map that will be utilized in Grant Harris can be seen in Figure 10. For City Hall, their static map can be seen in Figure 11. The static maps that will be placed on the first, second, and third floor of the Municipal Building can be seen in Figure 12, Figure 13, and Figure 14 respectively. Additional static maps of each map posting location can be found in Appendix III. These maps will be hung up inside of their respective buildings with generalized emergency routing, rather than detailed room-by-room routing to prevent map clutter, that is shown in a clear and concise manner. Additionally, key emergency and exit features are mapped out with appropriate symbology that is standardized among all CoSM building maps.

In addition to static maps, CoSM employees will have access to these building maps with the supplemental features on their computers and mobile devices via the Map Viewer application as well. Once the data is uploaded to our client, the CoSM Facilities Viewer app will have more detailed emergency routing that can be used to path out of a given room by clicking on it rather than the generalized routing given from the static maps. A preview of what the CoSM Facilities Viewer app map will look like for City Hall can be seen in Figure 15. For Grant Harris, their preview can be seen in Figure 16. Finally, the preview for Municipal Building in the Facilities Viewer app can be seen in Figure 17. The maps produced by the SME are now the baseline that the CoSM can use to replicate and produce more evacuation route preparedness maps for current and future buildings.

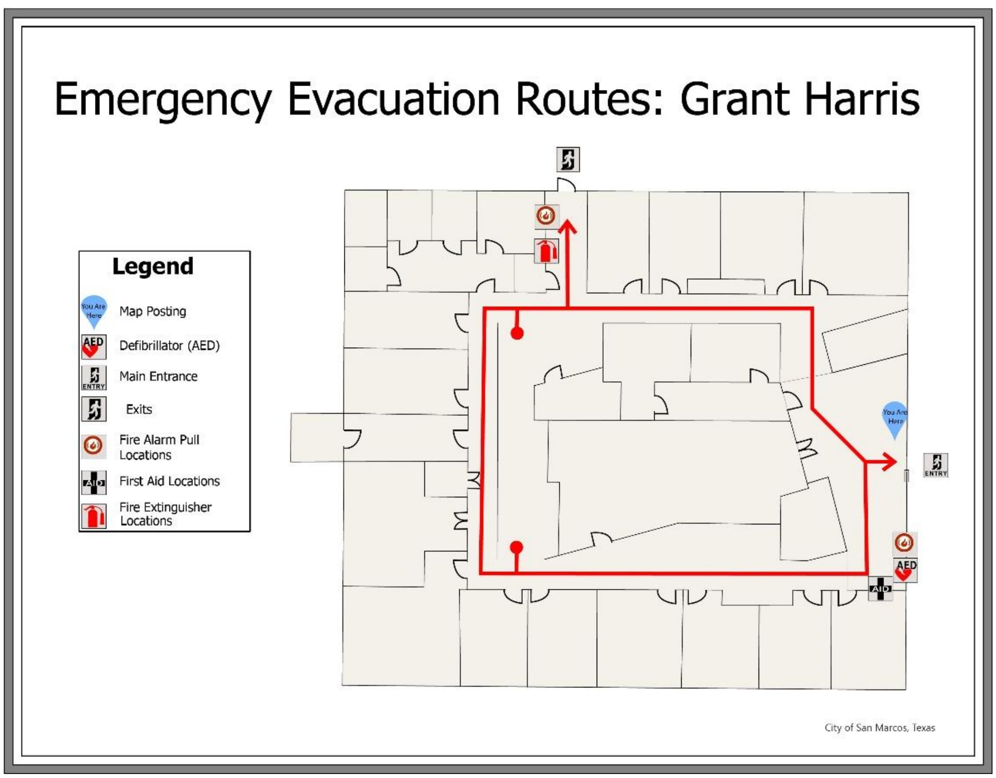


Figure 10. Static map of evacuation routes for Grant Harris

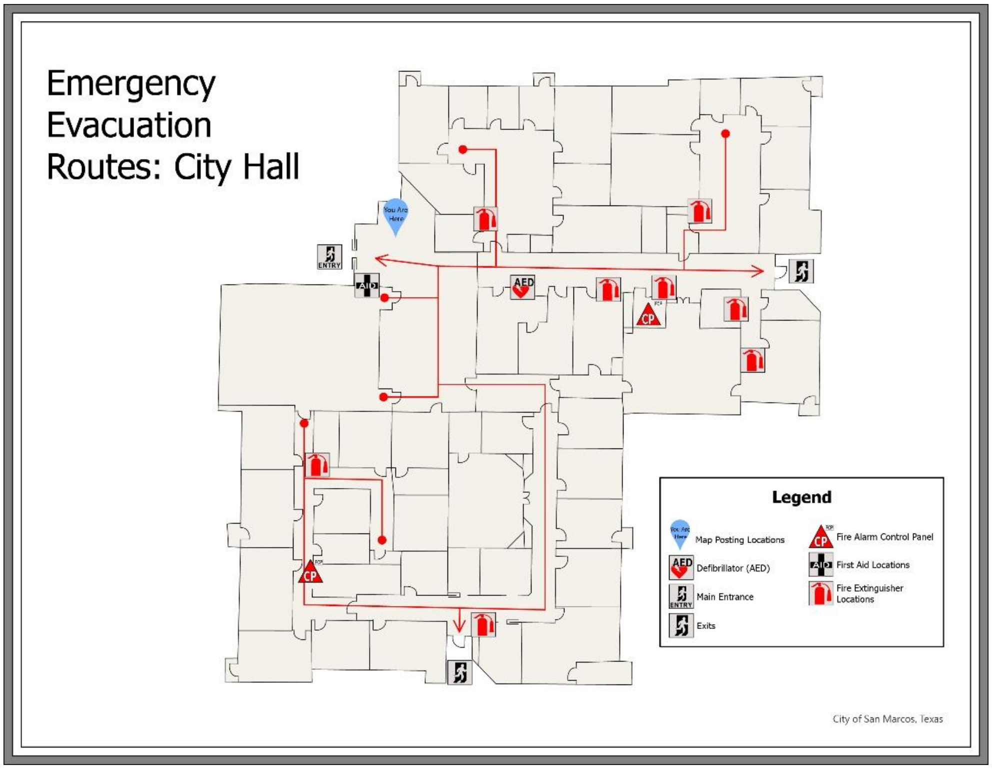


Figure 11. Static map of evacuation routes for City Hall

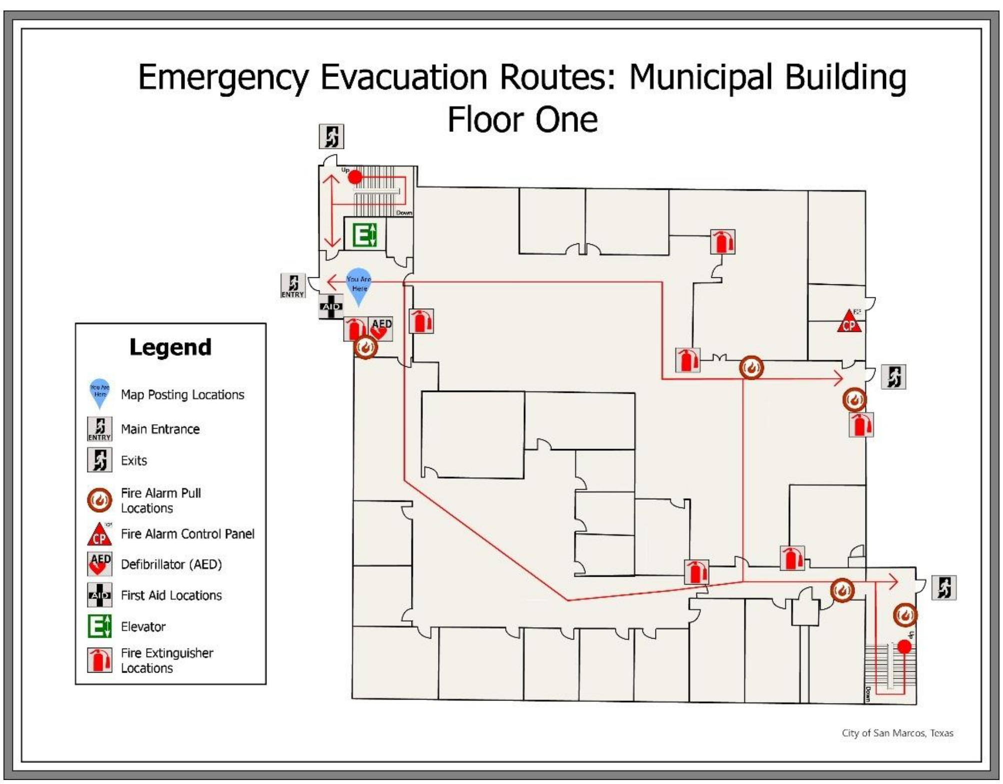


Figure 12. Static map of evacuation routes for the Municipal Building floor one

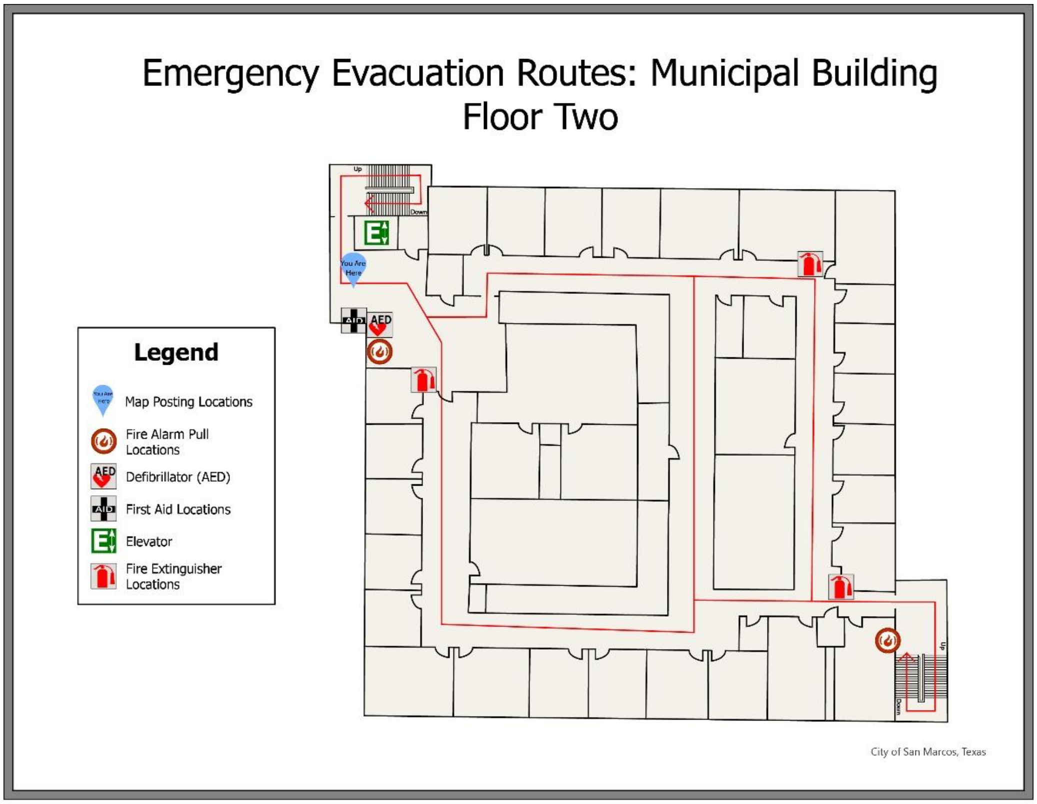


Figure 13. Static map of evacuation routes for the Municipal Building floor two

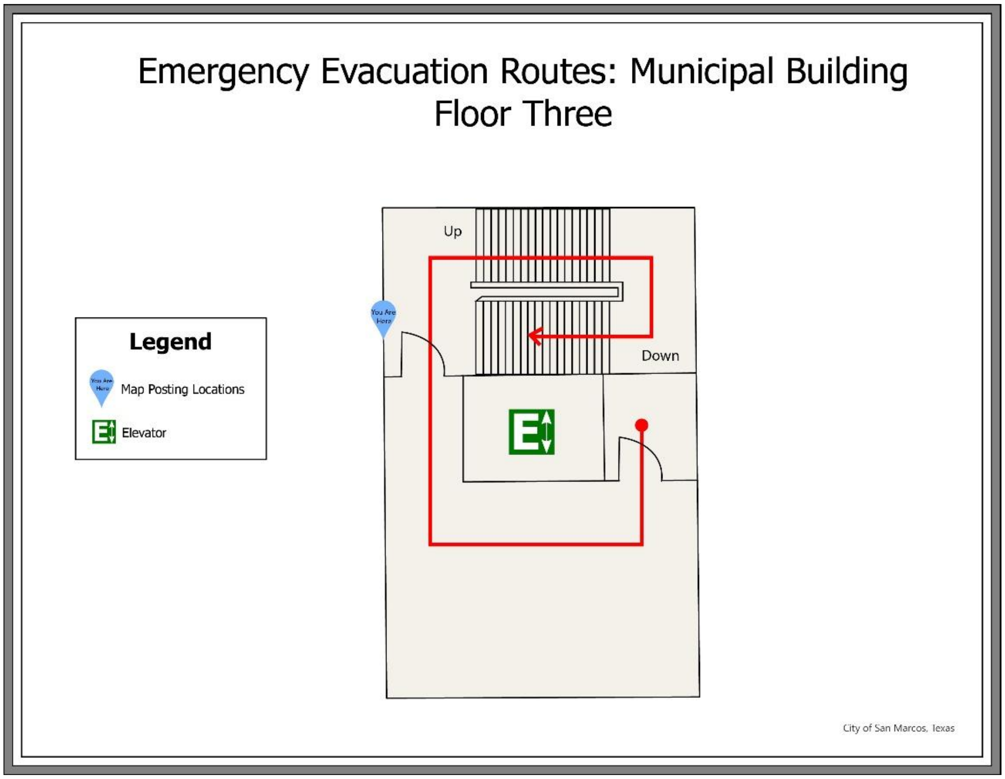


Figure 14. Static map of evacuation routes for the Municipal Building floor three

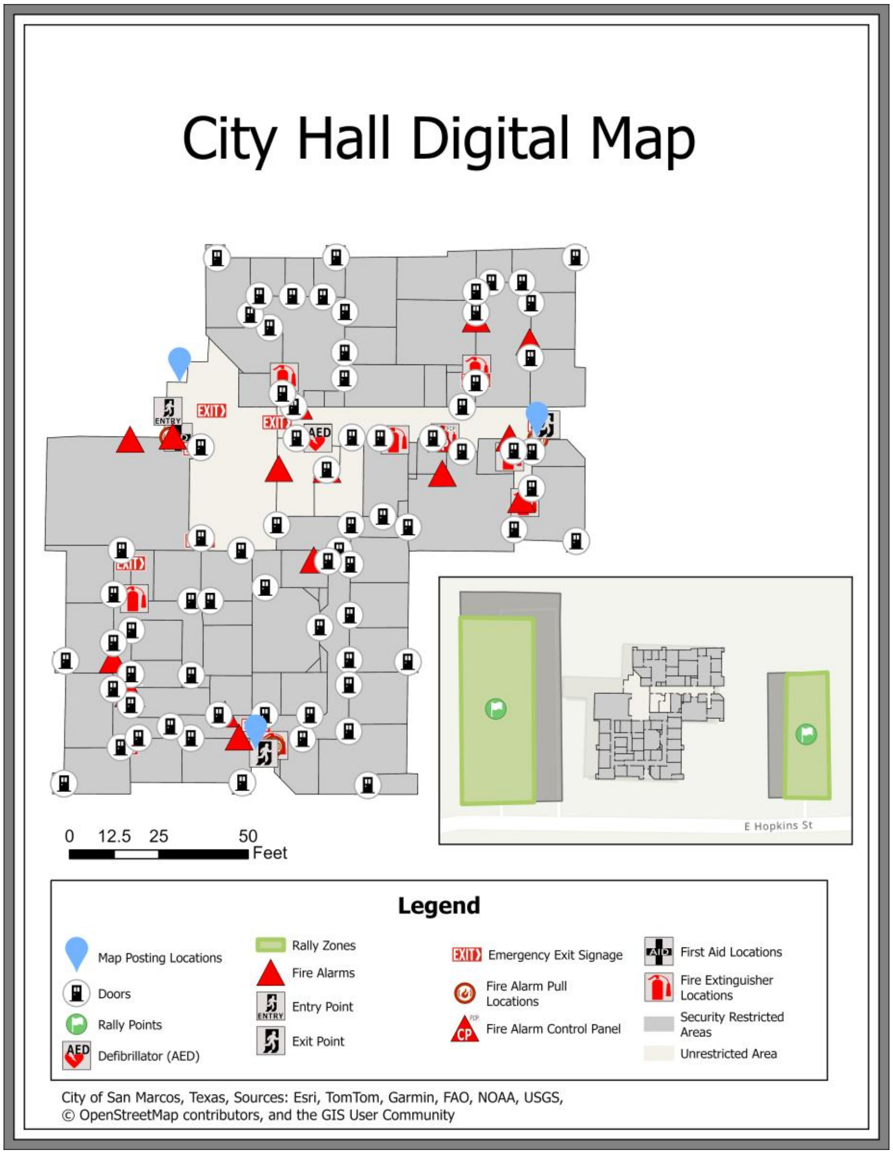


Figure 15. Preview of City Hall seen through San Marcos Facilities Viewer App

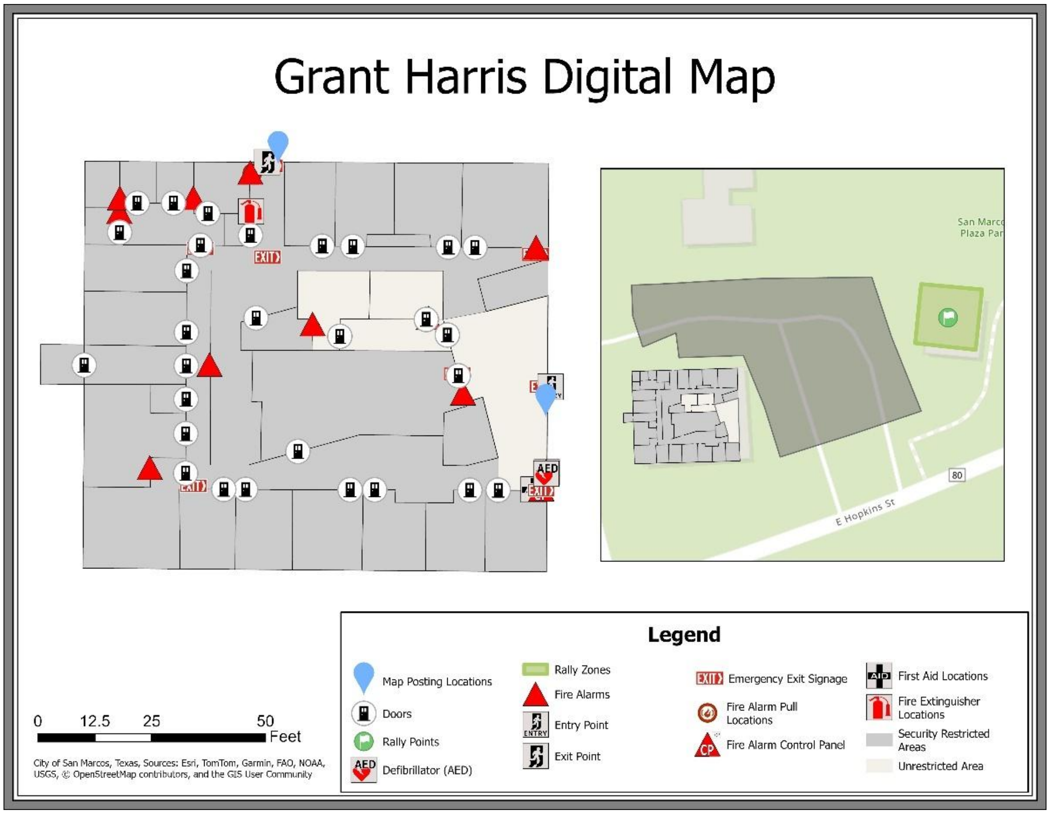


Figure 16. Preview of Grant Harris seen through San Marcos Facilities Viewer App

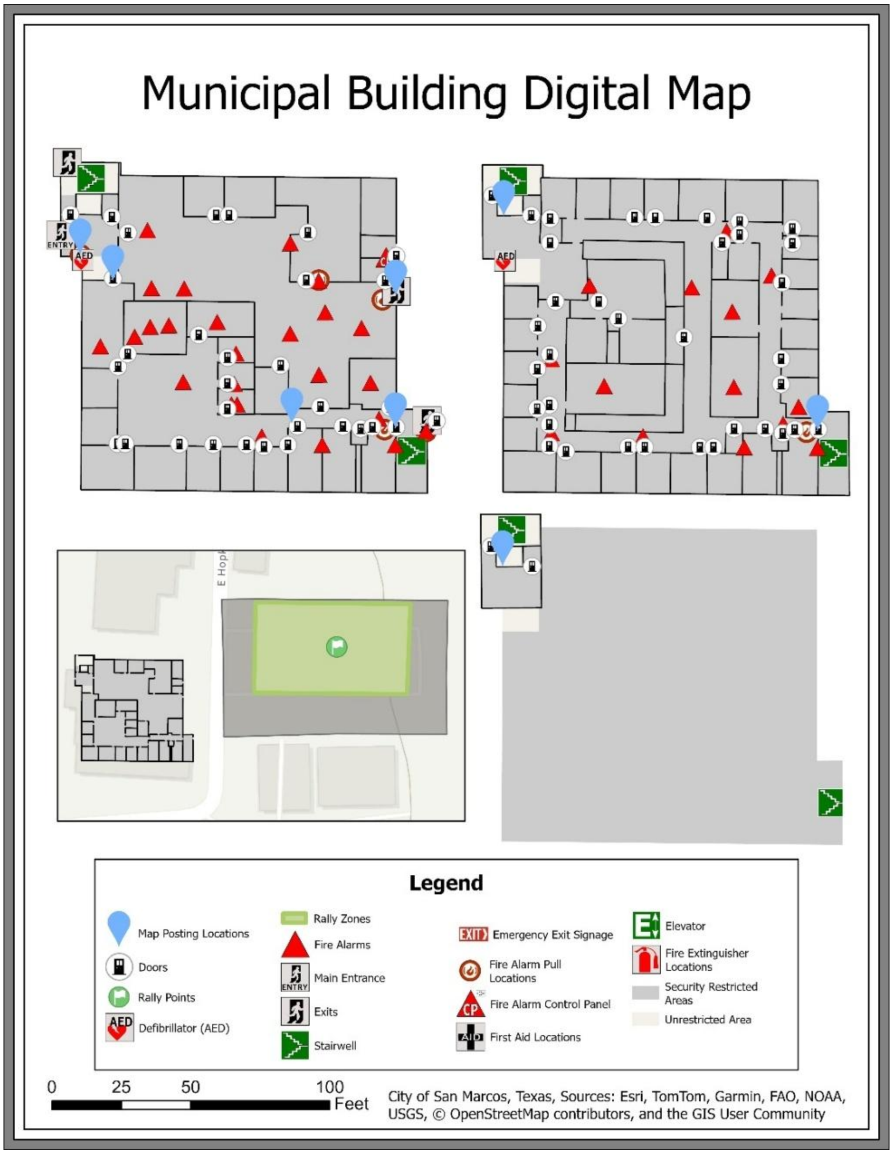


Figure 17. Preview of the Municipal Building seen through San Marcos Facilities Viewer App

Another important feature is the implemented Standard Operating Procedure (SOP) set up for future map creation and emergency routing. There are step by step instructions on how to run the toolbox, as shown in the Evacuation Tool Walkthrough. This document allows any user to input collected data of a given CoSM building into the Python Toolbox and create an emergency exit route for the given building. This process is done through the implementation of the Select and Export, Feature to Point, Euclidian Distance, and Least Cost Path tools, as can be seen in Figure 18. Through the utilization of updated collected data and proper implementation into the given Python Toolbox, there can be high quality and efficient maps created by the CoSM for current and future city buildings.

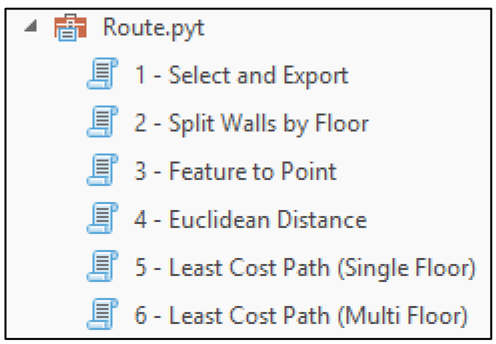


Figure 18. Python Toolbox

4.2 Discussion

This project has enabled the CoSM to be able to create emergency maps that are of higher quality for all city buildings by following the implemented Standard Operating Procedure (SOP) and through utilizing the Python scripts for exit routing and doorway creation. If quality emergency maps of high standards want to be created by city employees, careful consideration needs to be taken with the base maps supplied by the CoSM as there might be aspects of the data that are unreliable. The most likely unreliability that can occur within CoSM data would be changes to the floorplan of a building by either the removal of or addition of features that have not been reflected in current maps. Additionally, needing to change the walls from polygons to lines, to create a gap for the doorway. Without this change, these maps can create inaccurate exit routes when implementing the hypothetically inaccurate given CoSM base map data into the Python workflow, potentially causing confusion and impediment in the event an emergency arises.

For there to be quality maps created by the CoSM, the SOP put forth by the SME is highly recommended to be followed and implemented. The major section of the SOP that is recommended to be followed is the field collection data by CoSM employees at city facilities mapping out emergency features and updating building floorplans to make sure that there are no inaccuracies or errors. For the created scripts to be utilized efficiently, it is necessary for the data to be of high quality and accuracy. By following this SOP, the implementation of standardization and detailed exit routes can be utilized to create efficient navigation that will effectively increase safety levels of CoSM employees and building visitors.

The CoSM has been given a base SOP to work on and implement into future emergency map creation, as well as the ability to make it more efficient in certain aspects as well. This includes the implementation of more efficient places to place static building maps, as the places SME maps have been planned to be placed original spots near exits. These spots are not conducive to proper emergency routing when an employee or visitor is in the middle of a building trying to flee an emergency, where more productive placements in central corridors or highly trafficked rooms could be utilized.

4.2.1 Limitations

A major limitation of this project would have to be certain aspects of data collection, such as rooms that were labeled as limited faculty areas and could not be accessed by group members, preventing the collection of data in these rooms. These rooms include the Grant Harris Deputy’s Office and the Fire Exhaust Room on the first floor of the Municipal Building. The data collected from these rooms was made with a rough estimation of what emergency feature(s) would be in the rooms based on other data collected from rooms and testimonials from city employees rather than being able to physically verify and confirm the validity of the contents of these rooms. This leaves room for more hypothetical human error that can cause inaccurate maps to be created and implemented. Another limitation would be the mis apparent scope of the project at first, with major aspects of data collection and editing not being fully realized. All city locations have certain data aspects with some sort of error, whether due to human data collection issue outdated floorplan. This causes the need for ground truthing, the manual checking of data by a CoSM employee. Due to the amount of labor that was not realized, this caused a need to reduce the number of buildings covered from five to three, as the total amount of time needed to collect data was not fully realized by the SME team. Finally, human error can occur at the different user defined steps such as field collection, data management, and preprocessing.

5. Conclusion

The SME worked with the CoSM to enhance the evacuation routing and standards and safety procedures of selected city buildings for the purpose of increased safety, as well as the implementation of these procedures in other current and future CoSM buildings. Static maps were successfully created to be placed inside of the select city facilities, digital maps that can be viewed and interacted with through the city Facilities Viewer app, and a Python Toolbox that can be utilized for exit routing using Euclidean Distance and Least Cost Path. The maps created will provide a blueprint for future data collection when conducting site visitations for map implementation. These automated workflows utilized through the Python Toolbox will automate the processes of emergency exit routing and significantly reduce the time needed to create emergency exit routing maps, a significant boost to the productivity of the CoSM. Additionally, the standardization of symbology will reduce the confusion that might occur with different symbology found at different CoSM facilities when either trying to create maps or evacuate in the event of an emergency.

Overall, this project has helped to support city-management goals and supplement the future work of the CoSM through the creation of SOP that future CoSM maps can be modeled off and a Python Toolbox that will ensure symbology standardization, coherent template layout, and highly efficient exit routing in these implemented maps. Through these implementations, safety evacuation procedures and standards can be improved upon and enhance the efficiency of evacuating a building during an emergency. The implementation of these features and standards will allow for a proper uniform evacuation standard and efficient navigation amongst all CoSM buildings. ensuring proper safety procedures in the case of an emergency

6. References

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Appendix 1: Group Members Contribution

Livy Rocha (Project Manager): As project manager, I oversaw everybody's work, delegated tasks, communicated with the client, set up out of classroom meetings, and communicated greatly with group members by checking up on them and their work. Greg, Sam N., and I mainly emailed back and forth with our client. I set up dates to meet with our client for data collection for two of the buildings, while Sam N. did the other building's meeting time. Additionally, I communicated with the other CoSM team and my group to get a date for our outside of class presentation. I often delegated tasks between group members and set deadlines for those tasks. Additionally, Greg and I played a major role in aiding both questions, revisions, and overall helping others with their tasks. Additionally, we met outside of class on multiple occasions that I helped facilitate. For the project aspect, I mainly worked on the data collection portion. I created the ArcGIS Online Field Map Designer application; where I created fifteen features and attached 5-6 forms to each of them. Additionally, I went to all three data collection days. For data clean up and standardization, I did most of the work on the Map Viewer portion, except for doors which Sam N. and Sam M. did. For the written material for the project, I did a lot of writing and editing. For the first proposal, Sam M. helped me edit the entirety of the paper, but for the final report Sam N. helped me edit the entire paper. For the final paper, I wrote the abstract, introduction, and half of the data portion. Again, with my role as project manager my communication and delegation skills helped with the completion of the project.

Samantha McLennon (Project Manager Assistant): As project manager assistant, I aided Livy, the project manager in communicating with peers, assessing peers' tasks, and helping with delegation. I tried my best ability to aid team members when they needed help with tasks. For data collection, I went to two buildings to collect features. I was unable to go to the third building due to class conflict. I helped aid in the writing portion of the proposal and editing the entirety of it with Livy. My main task for this project was creating the final product maps. I created the scope, the thirteen static evacuation route maps, and three digital maps. This was a tedious process with the designing aspect of it, leading it to consume most of my time. All of the group members aided me in this map creation, however, I did the majority of it.

Noah Hanson (GIS Developer): Developed the pre-processing model to create the gaps necessary for the toolbox to run. I came up with the idea of using a python toolbox and assisted Greg in part of the toolbox's creation. I created the Data and methodology flow charts. Worked with the team doing field work using ArcGIS Online and Field Maps to collect SME data. Created the Excel spreadsheet for the standardized master data sheet from CoSM data. I worked with the team on creating static maps in ArcGIS Pro. Additionally, worked with Samantha on the digital maps. Helped with creating, proofreading, and revising different documents in collaboration with others throughout the paper.

Sam Niemeyer (GIS Analyst): Worked with the team in field collection of data utilizing ArcGIS Field Maps and helped with the implementation of that data back into ArcGIS Online and Pro. Helped to edit and standardize the given data from the CoSM in Excel and ArcGIS Pro. Assisted in the creation of maps with Samantha for the digital and static maps. Sam wrote the Data section, Results and Discussion section, and Conclusion section of the final report. Helped to edit the paper and all of the sections as well. Worked on the final poster in organizing and writing. Worked on the final presentation in creation, writing, and editing.

Greg Rollman (GIS Programmer): Generated Numerous different scripts for the Python toolbox, Spent hours researching what lines of code had to be input into the toolbox, generated numerous different tools to run within the toolbox, created parameters for each tool, and debugged the overall script to ensure efficient capabilities, and wrote additional documents for Python tool instructions. Aside from Python coding, created raw data maps using the output from the Python toolbox, assisted with writing methodology in the report, assisted with formatting presentations and animations, assisted in time management within the group when Livy was missing, helped create static maps, and was present in data collection at City Hall and Municipal Building.

Appendix II: Metadata

File Name	Description
Master_Data_List.html	This includes all of the data SME collected from the three sites and the updated CoSM data. It includes all of the attributes attached to each feature.
Evacuation_Tool_Walkthrough.docx	A description of how the Python ToolBox works and how to implement the data.
SME_Python_Route_Tools.pyt	This is the Python ToolBox script containing all the tools for route generation.
Static_Map_Grant_Harris_Location_One	This is a static map of the emergency evacuation routes of Grant Harris from the first “You Are Here” location.
Static_Map_Grant_Harris_Location_Two	This is a static map of the emergency evacuation routes of Grant Harris from the second “You Are Here” location.
Static_Map_City_Hall_Location_One	This is a static map of the emergency evacuation routes of City Hall from the first “You Are Here” location.
Static_Map_City_Hall_Location_Two	This is a static map of the emergency evacuation routes of City Hall from the second “You Are Here” location.
Static_Map_City_Hall_Location_Three	This is a static map of the emergency evacuation routes of City Hall from the third “You Are Here” location.
Static_Map_Municipal_Building_Floor1_Location_One	This is a static map of the emergency evacuation routes of the Municipal Building from the first “You Are Here” location on floor one.
Static_Map_Municipal_Building_Floor1_Location_Two	This is a static map of the emergency evacuation routes of the Municipal Building from the second “You Are Here” location on floor one.

Static_Map_Municipal_Building_Floor1_Location_Three	This is a static map of the emergency evacuation routes of the Municipal Building from the third “You Are Here” location on floor one.
Static_Map_Municipal_Building_Floor1_Location_Four	This is a static map of the emergency evacuation routes of the Municipal Building from the fourth “You Are Here” location on floor one.
Static_Map_Municipal_Building_Floor1_Location_Five	This is a static map of the emergency evacuation routes of the Municipal Building from the fifth “You Are Here” location on floor one.
Static_Map_Municipal_Building_Floor2_Location_One	This is a static map of the emergency evacuation routes of the Municipal Building from the first “You Are Here” location on floor two.
Static_Map_Municipal_Building_Floor2_Location_Two	This is a static map of the emergency evacuation routes of the Municipal Building from the second “You Are Here” location on floor two.
Static_Map_Municipal_Building_Floor3_Location_One	This is a static map of the emergency evacuation routes of the Municipal Building from the first “You Are Here” location on floor three.

Appendix III: Supplementary Static Maps

<u>City Hall Building</u>

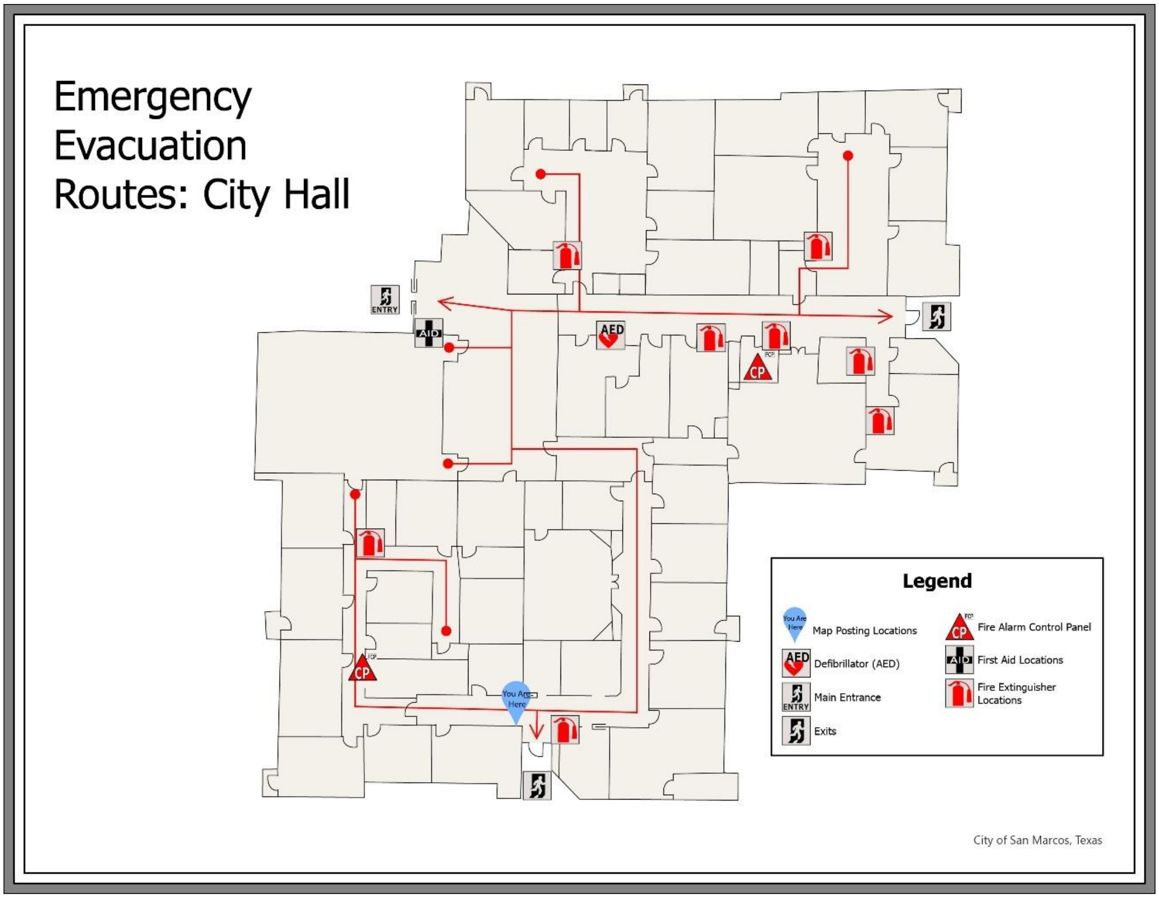

Figure 18. Static map of evacuation routes for Grant Harris: Supplementary map two

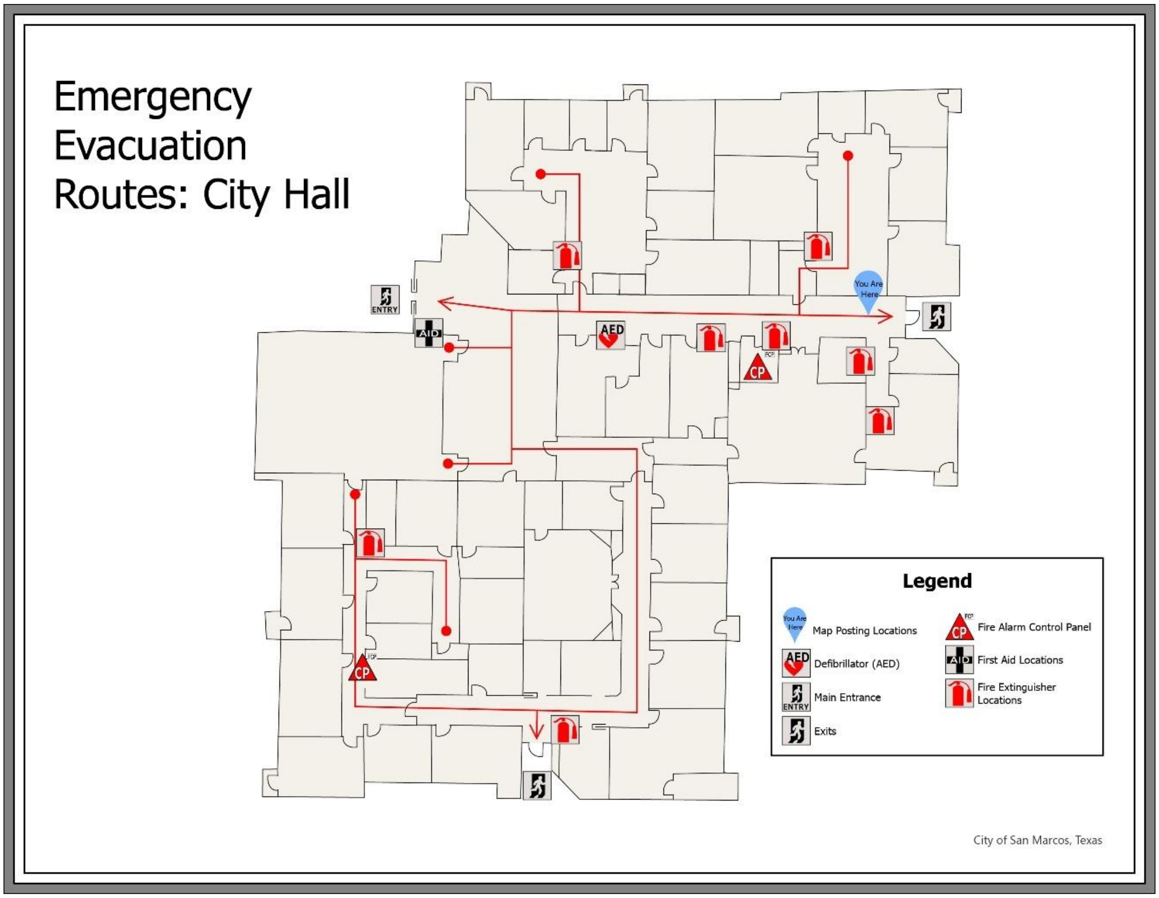

Figure 19. Static map of evacuation routes for Grant Harris: Supplementary map three

<u>Grant Harris Building</u>

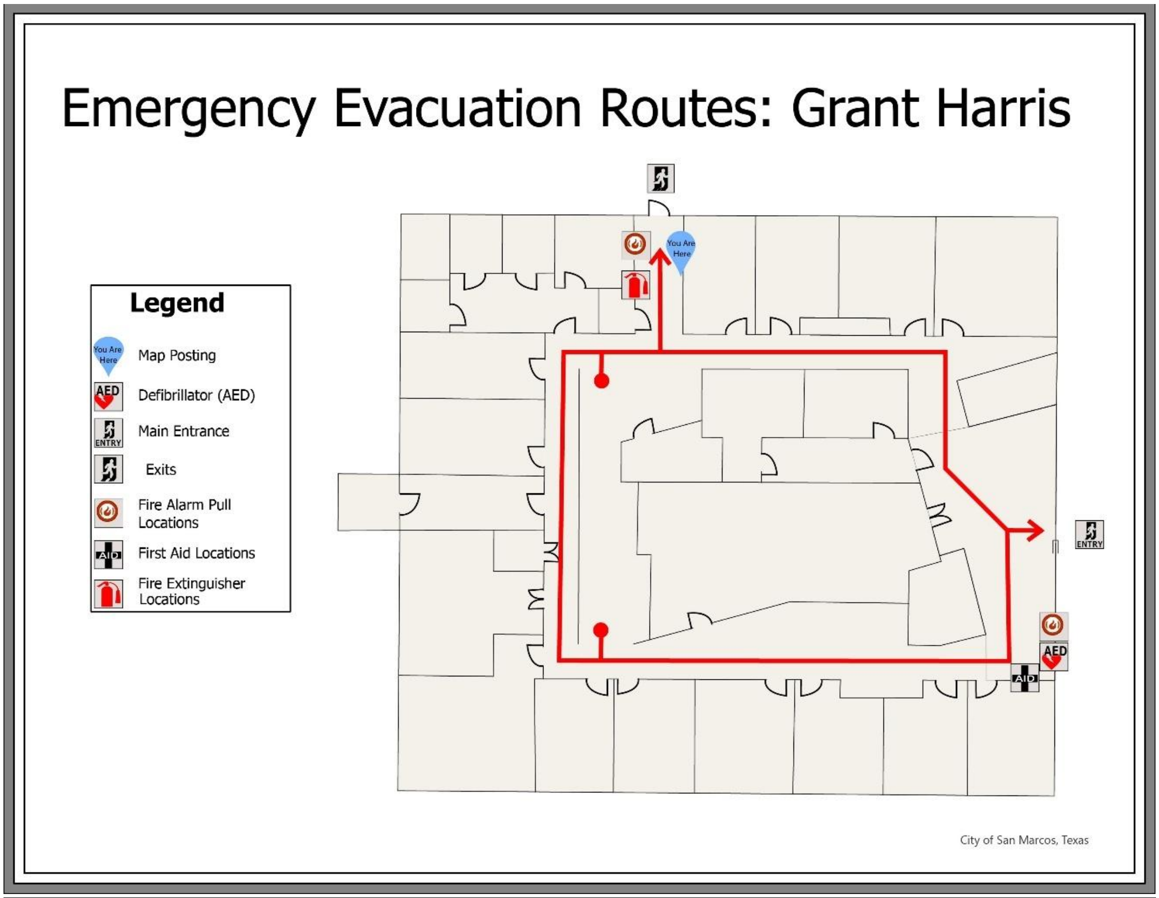

Figure 20. Static map of evacuation routes for Grant Harris: Supplementary map two

Municipal Building

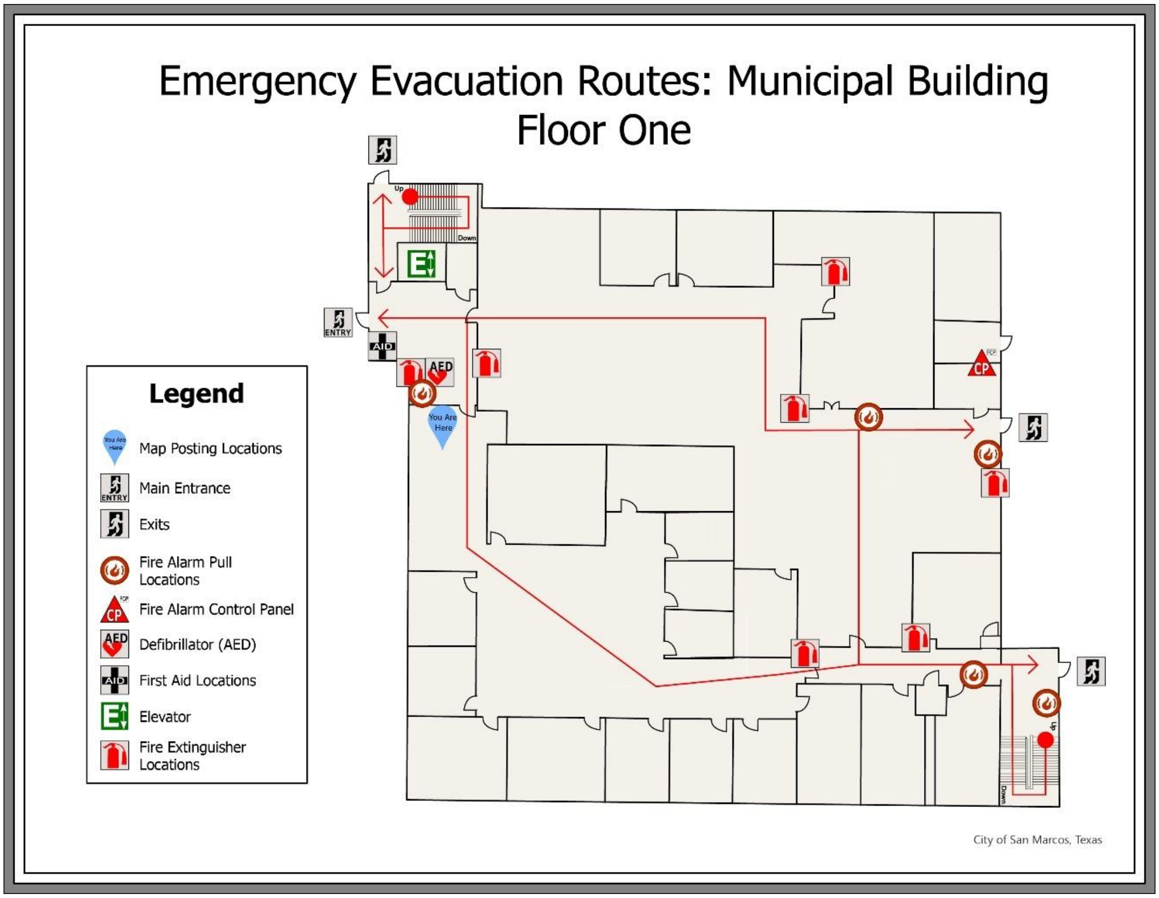

Figure 20. Static map of evacuation routes for Grant Harris: Supplementary map two, floor one

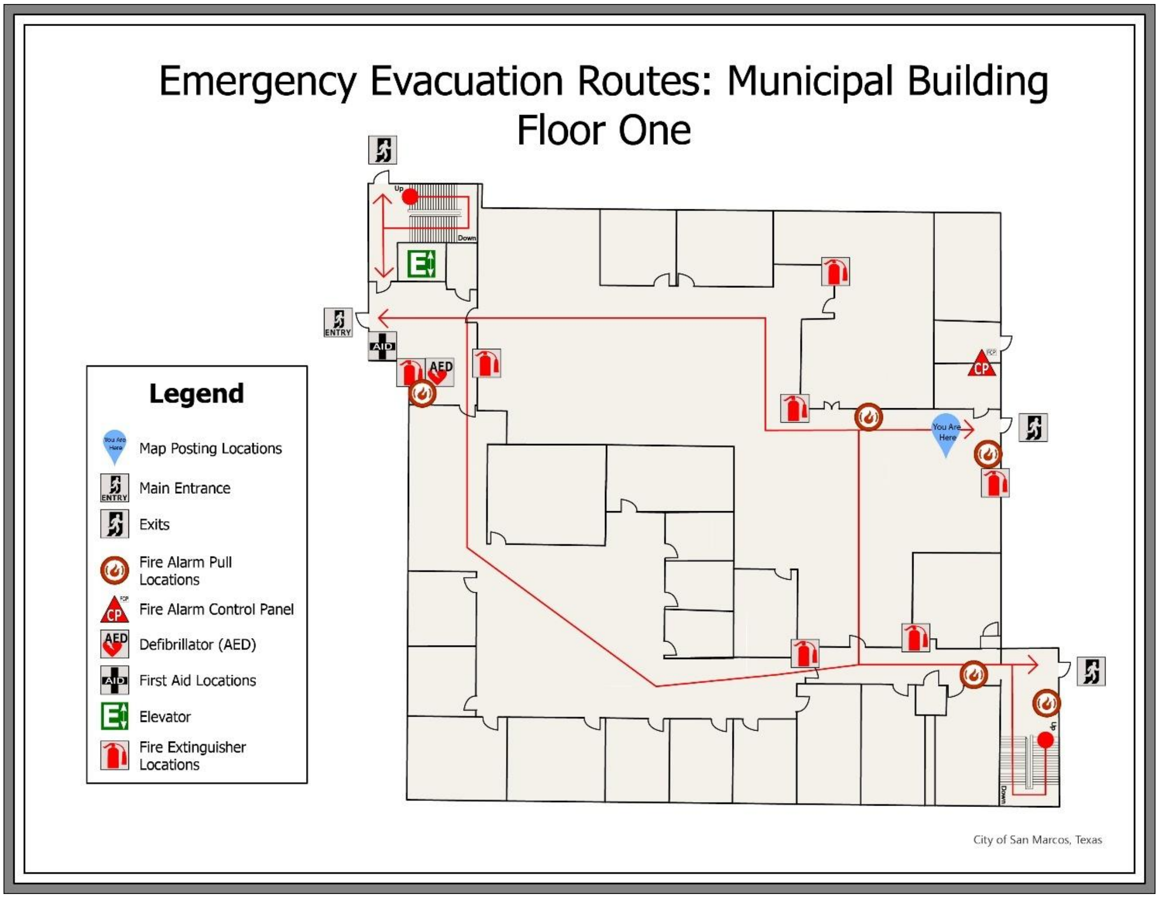

Figure 20. Static map of evacuation routes for Grant Harris: Supplementary map three, floor one

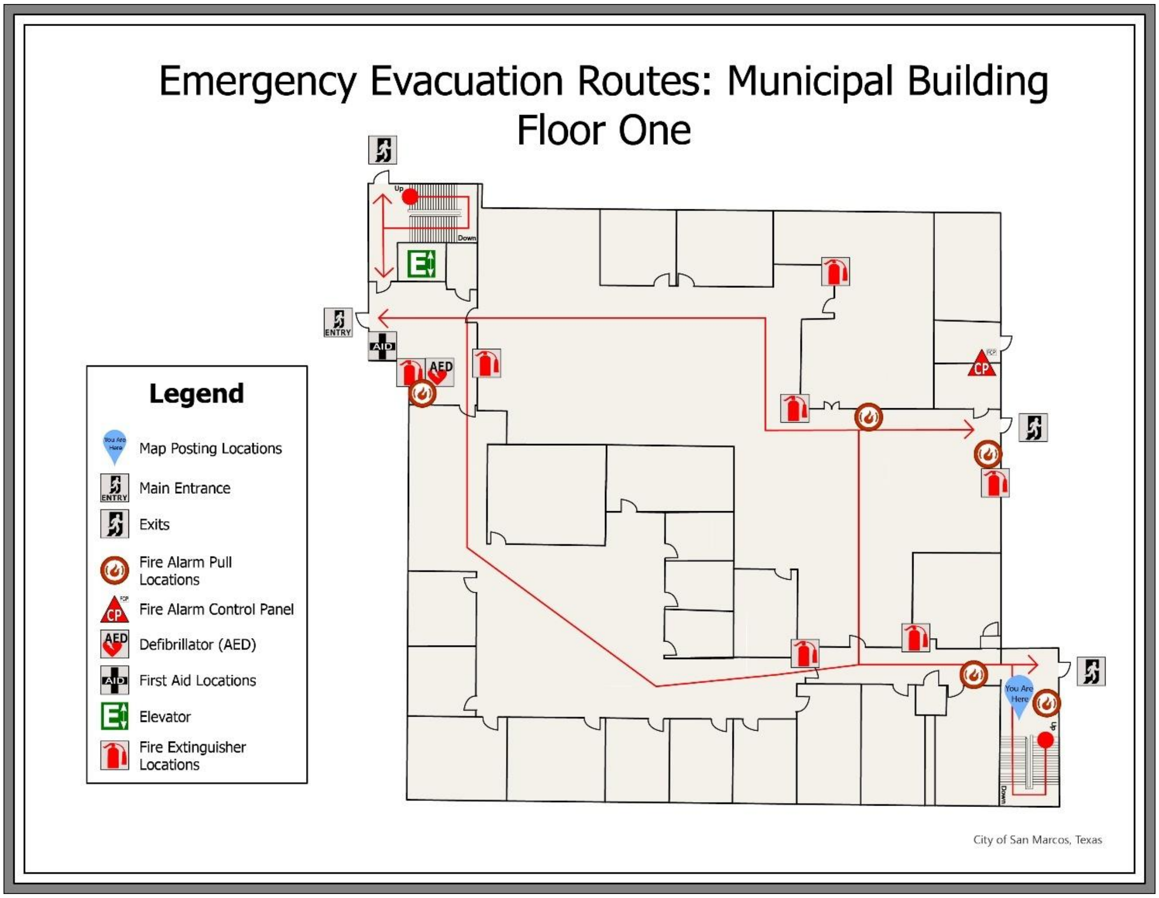

Figure 20. Static map of evacuation routes for Grant Harris: Supplementary map four, floor one

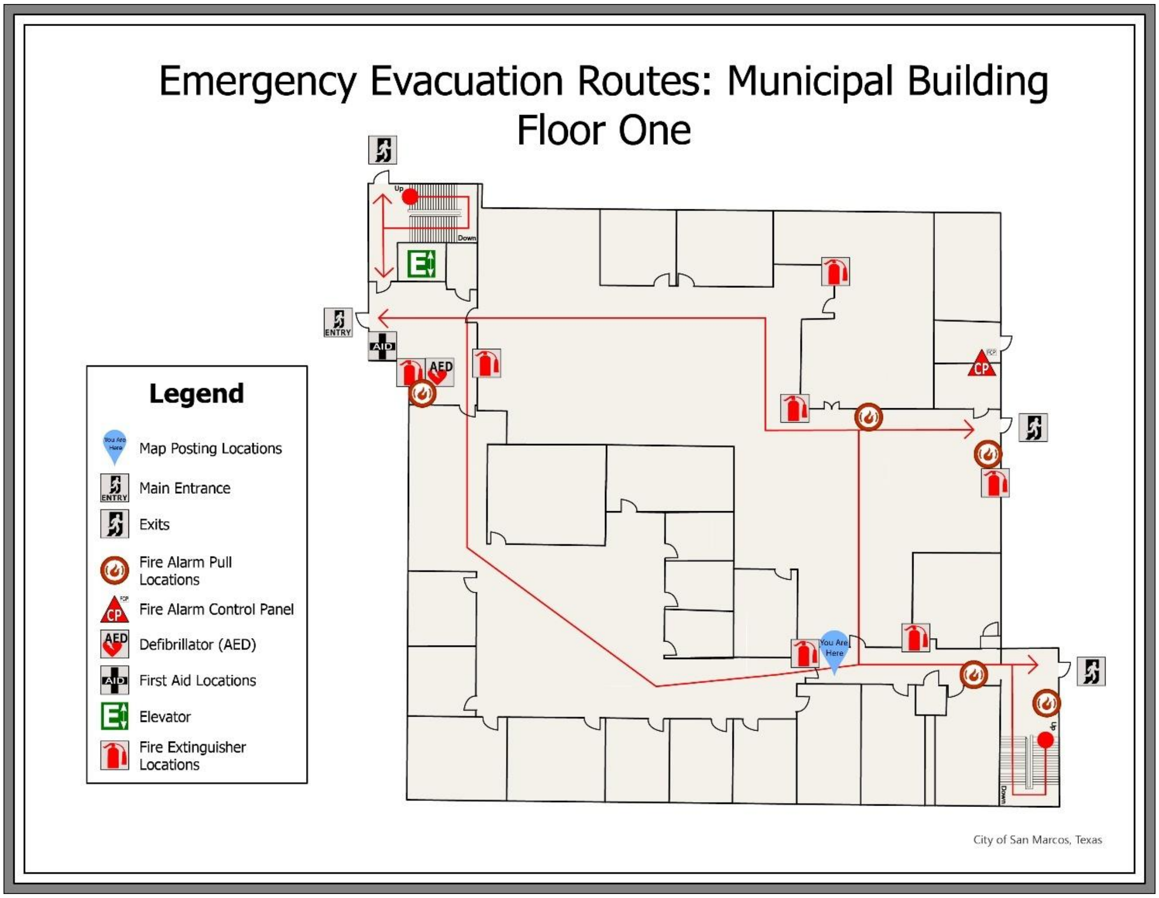

Figure 20. Static map of evacuation routes for Grant Harris: Supplementary map five, floor one

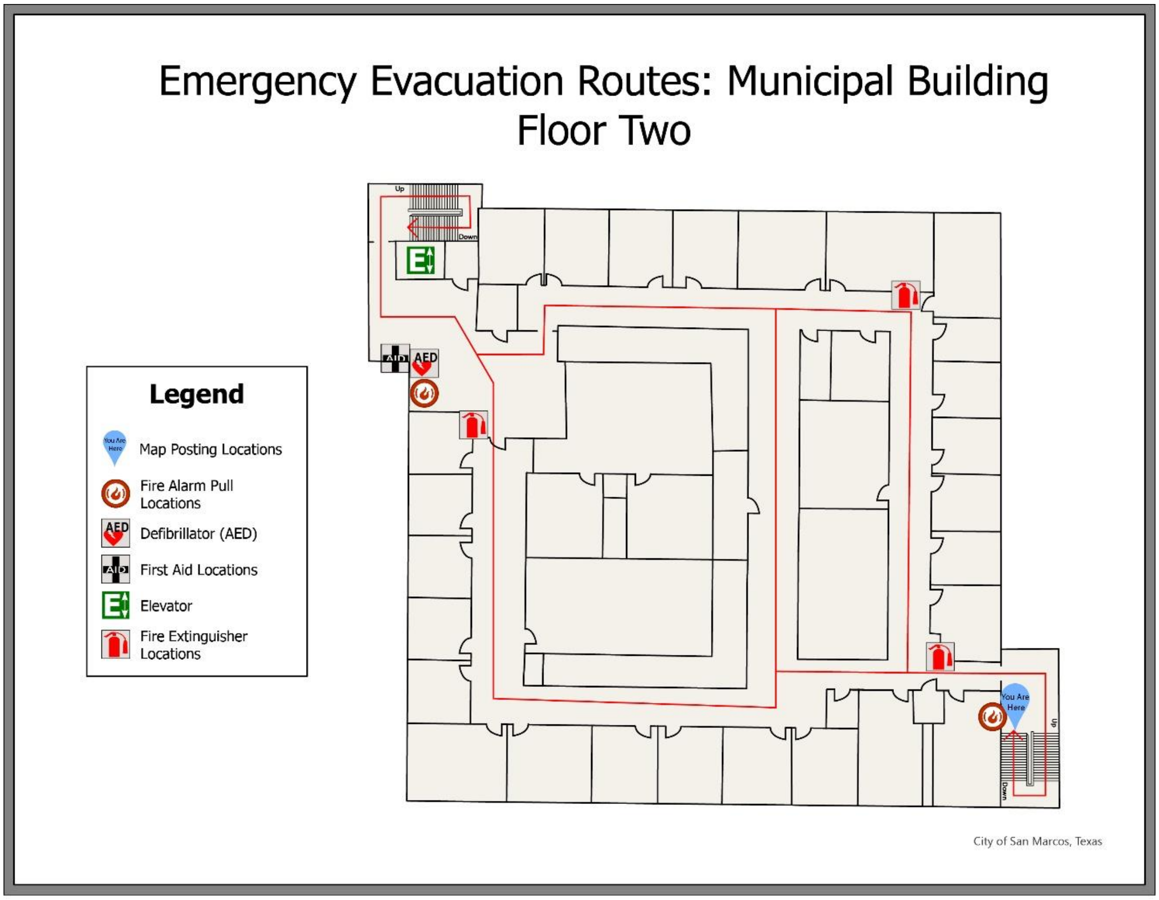

Figure 20. Static map of evacuation routes for Grant Harris: Supplementary map two, floor two

Appendix IV: Additional Contacts and Resources for Information Collection

Informational Websites

ICC Digital Codes: 2024 International Fire Code (IFC)
https://codes.iccsafe.org/content/IFC2024P1/chapter-4-emergency-planning-and-preparedness#IFC2024P1_Pt02_Ch04_Sec404

Note. This website includes supplementary information for setting up emergency preparedness standards and features.