Developing a geospatial file linking application to improve data communication workflows.

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Contents

1 Introduction

A geographic information system (GIS) is one way that local governments manage their data assets. It is a framework for "gathering, managing and analyzing data" where one can relate data to a location (ESRI, n.d.-c). For instance, geospatially enabled data can be a map of city roads to provide GPS locations of a police officer's vehicle on a Computer Aided Dispatch mapping system.

Local governments, such as cities and counties, utilize various technologies to ensure optimum services to their community. These services may range from ensuring quick public safety response to emergencies to providing clean drinking water. Technology such as GIS can be a tool to complement these existing management workflows. One way that GIS can benefit local government workflows is by using spatially attributed data for emergency and disaster management activities (ESRI, 2008).

However, as local governments leverage GIS, decisionmakers must decide what information is essential to support the community and provide this geospatially enabled data in an appropriate format. For example, the mapping of community infrastructures, such as roads and utilities, allows other stakeholders to get a visual display of city assets. How local governments manage and share their data is affected by their internal workflow constraints. These constraints may affect storing and provisioning this data to other stakeholders and organizations.

In a perfect scenario, organizations have access to all the data they need to make critical decisions for the community. The underlying issue is that despite the increased use of GIS by local governments, there are geospatial specific data communication gaps in the accessibility and interoperability of key critical data in local government that impact disaster and emergency management response. These gaps can negatively impact how local governments make informed decisions. A problem that affects many organizations, including local governments, is information silos. Breaking down information silos ensures successful collaboration, allowing for better data transparency. In a case study of regional geographic information sharing practices, researchers highlighted that the highest consumer of critical utility data came from emergency managers (Artigas, Elefante, & Marti, 2009).

The Federal Emergency Management Authority (FEMA) notes the following five core capabilities for an emergency manager are: prevention, protection, mitigation, response, and recovery (Federal Emergency Management Authority, 2018). GIS can support all these capabilities. As a result of existing policies and procedures, issues affecting GIS and using GIS in emergency response activities is that not all critical data may be geospatially available. Thus, relevant geospatial data must be open and accessible. Another issue is that GIS data may be inaccurate due to the lack of proper data checks of the organization that owns the system.

To ensure that internal local government stakeholders, including but not limited to those within emergency management, have access to authoritative data, I propose to develop a geospatial solution design that would augment current geospatial applications for the City of Fairfield, California ("City"). My goal is to provide an application to communicate authoritative, spatially attributed information that is currently inaccessible for most users. One way to reduce the risks in the use of inaccurate information is to improve user access to authoritative electronic data. In addition, a user-friendly interface would improve data communication to expand the overall general health of the City's enterprise GIS.

When key utility infrastructure data is missing from the GIS, users must have the ability to access the authoritative data drawings that the GIS is sourced from in easy-to-follow steps. This paper

discusses the provisioning of a spatially enabled web-based solution that can aid in hyperlinking record drawings of key City infrastructure. The solution will utilize existing technologies and current data document management processes in the Public Works department. During emergencies, City staff should be able to look at GIS data to identify affected critical information and use an application that can connect users to essential, authoritative information.

2 Design and Methods

Up to date and easy to access information is necessary for data management workflows. At the very least, data must be in a suitable format that is easy to find. Identifying and addressing the challenges of data sharing and data governance can improve how local government stakeholders leverage the capabilities of GIS as an emergency response tool. Furthermore, if the data are not available in the desired format, there should be a mechanism to locate information.

Research for this project centered on multiple phases:

1) Literature Review:
    a. Studies on the literature to identify ways to engage organizational change to address data dissemination challenges among local governments and within the framework of emergency management
2) Current Workflow and Data Source Review:
    a. Review on public works and emergency management workflows regarding City projects that involves critical infrastructure data
        i. Identification of Current Data Capabilities and Constraints
3) Technology Review:
    a. Review existing technology
        i. Review existing data and compare it against current user needs and requirements
4) System Design and Development:
    a. Development of a geospatial-based application to serve City asset data with a web tool to efficiently consume the data and address the importance of data provision and reinforce data quality assurance.

2.1 Literature Review

2.1.1 Enterprise GIS

GIS can be coined as an “intelligence nervous system, where information bridges across multiple organizations bridging people and technology to transform how they see, think, and act”(ESRI, 2019). When one thinks of an Enterprise GIS, one can think of a system that allows a “large number of users to manage, share, and utilize spatial information” (ESRI, n.d.-a). Within the context of this study, a successful Enterprise GIS system, not only includes integrations with multiple systems, but with organization support, can drive and grow with an organization’s business goals. With an enterprise system, GIS provides benefits for “more than one layer, division, or department of an organization” (Woodward, 2020).

2.1.2 Use in Local Government

Local governments can leverage enterprise GIS technology to deploy data across the city network to allow its use across multiple city departments and divisions. Local governments utilize GIS as an operational and decision-making tool. The system can map out the current land use development

projects that have been approved in the city to provision visual maps of an underground sewer line. Local governments have also provided public web platforms where the public can visualize GIS data specific to their community. Real-life examples are maps that show city road conditions to the locations of the nearest park (City of Santa Clara, n.d.; NYC Parks, n.d.; Virginia DOT, 2018).

Furthermore, recent studies expand on the merits of integrating Building Information Models (BIM) to GIS as an effective infrastructure and urban development tool for 'smart cities'. These building information models can provide a 3-dimensional model of indoor and underground infrastructure that can be spatially connected to GIS (Yamamura, Fan & Suzuki, 2017). However, data interoperability issues from BIM from AutoCAD based have been limiting factors in successful integrations with GIS in the absence of data standards (Ohori, Biljecki, Diakite, Krijnen, Ledoux & Stoter, 2017).

2.1.3 Use in Emergency Management

There is a considerable body of literature and resources that provides information on how local governments can respond to various emergencies and disasters with GIS. Examples of this usage include standard operating procedures specific to natural disasters as well as implementation guidelines for sharing and managing data (National Alliance for Public Safety GIS Foundation, 2019; National Public Safety GIS Alliance Foundation, 2016; Wildfire Coordinating Group & Subcommittee, 2014). Local governments are tasked to reduce risks to the community through emergency management processes. To provide an effective emergency response, data utilized by local governments should be "comprehensive, accurate, timely, and accessible" (Laefer, Koss, & Pradhan, 2006).

In the response capabilities of emergency management, the advent of social media has brought a new focus on how organizations such as cities should deal with data. These studies discuss the challenges local organizations face when dealing with the speed of community provisioned data. Due to social media providing a highly accessible source of information, governments must develop ways to bridge communication challenges. Information from social media can be problematic in emergency response if the information is inaccurate (Alexander, 2014; Elbanna, Bunker, Levine, & Sleigh, 2019). As the public can avail themselves to geospatially enabled information such as maps of hazardous weather events, local governments are expected to provide quick responses based on publicly available data (Geospatial Technology and Applications Center, 2019).

In mitigating emergencies, GIS can provide the ability to visualize and synthesize multiple layers of information (Cova, 1999). Data managed by one authoritative department can be just as relevant to another authority. The United States Department of Transportation (US DOT), maintains a geospatial dataset of underground pipelines that span across the country (USDOT PHMSA, n.d.). Local GIS analysts, upon verified access, can download a GIS dataset and provision a map. The map could be used to show the level of risk of a school's vicinity to a pipeline transporting jet fuel to the local military base. When used as part of the emergency management workflow, GIS can provide a view of where these hazards are located, what type of material is transported, and show who or what departments are the managing authority. Thus, having the ability to view and analyze the data does not solely reside with the US DOT, when their data can be equally crucial for other agencies. GIS can increase efficiencies by removing duplicative data efforts and providing access to centralized authoritative data for use in emergency management (Gunes & Kovel, 2000).

2.1.4 Data Sharing

There have been numerous studies affecting issues with data sharing. Authors have suggested that within the data sharing realm amongst public agencies, data sharing reduces risk and data duplication (Higgins, Taylor, Lisboa, & Arshad, 2014). However, the study was posited with the need for formal data sharing agreements amongst agencies. On the other hand, there may be difficulties in establishing formal data sharing processes when an emergency is in progress. The literature on local government practices recognizes that data sharing successes amongst local governments are contingent on continued education on data sharing best practices such as ensuring a centralized network of data sharing (Harvey & Tulloch, 2006).

Due to internal organization constraints, the data that are shared may be inadequate for emergency response. However, the uncertainty about geospatial data remains and as geospatial data use in emergency response increases, data quality is equally essential (Perdikaris, 2011).

2.1.5 Applications of Geospatial Data Sharing Tools and Sources

While national-level data sources of critical geospatial data can augment emergency management operations such as the provision of wildfire heat sources from NASA satellites or through various national level thematic data found through the geoplatform.gov website, much of the data may not be suitable at the local level. (Federal Geographic Data Committee, n.d.; NASA, 2019). Other data sources can be obtained through the Homeland Infrastructure Foundation Level Data web page, however only upon approved authorized access, which may delay response.

There have been efforts at the regional level to address this issue of data access, where states such as California, have leveraged national and state-level geospatial data repositories to provide information feeds for local government emergency response (California Office of Emergency Services, 2019). Amongst local governments in emergency management, cities can use GIS web technologies to provide the public information about nearby wildfires and road closures utilizing state-level information from the state fire management authority, the office of emergency services, and from the highway patrol (Redding GIS, 2019). It is also important that organizations ensure that collected data is stored and provisioned in a manner to ensure its optimum efficiency (Rahman et al., 2020).

2.1.6 Data Governance

The implications of not having access to quality information at the local level during emergencies can negatively impact an effective response during emergencies. It does not benefit a municipality when stakeholders need to take time to mine for data within a data network when otherwise early planning would have established a common file repository. Local government stakeholders require access to correct and timely data to address a situation adequately. Benfeldt, Persson, & Madsen (2019) report that utilizing collective action theory would help organizations overcome challenges with data governance. Provisioning simple participatory methods for data mapping protocols allows for a greater sense of ownership in the results and an incentive to strategically plan to improve data. (See, Calo, Bannon & Opdyke, 2020). When data governance is an organization's goal, there is potential for specific data to be valued as a master asset and managed in a proper workflow.

The significance of data governance can be linked to how change can occur within an organization. Research suggests that managers should focus their energy on leadership and organization culture to foster changes at all levels. Additionally, if decisionmakers also see success cases from similar

external agencies, there is a greater inducement to start similar initiatives within their own organization. One suggestion is that people may be amendable to change if changes are not overwhelming. By addressing small victories at a time, change may be likely to occur (Demski, 1993; Wu & Chu, 2021).

Research on data sharing success has identified technical compatibility as an essential function. The opportunity to share data is lost if there is a perception of data being too difficult to use, find, or provision. Additionally, to mitigate data sharing challenges, there needs to be incentives to share data (Bharosa, Lee, & Janssen, 2010; Brunetto, Xerri, & Nelson, 2013; Gil-Garcia & Sayogo, 2016). Recent literature on setting data boundaries between survey-level data and GIS data has reinforced that on a professional level, it is important to set standards that provide a distinction on the use of specific GIS data. The author seeks to increase knowledge by establishing determinations between authoritative survey level data or GIS data (Joffe, 2018).

2.2 Data Sources and Current Workflows

Having access to the system of record is key in mitigating emergencies. There have been recent incidents in the past 2 years where the lack of key information almost disrupted telecommunications networks that supported critical City utilities (S. Hamilton, personal communication, June 25, 2021 & April 8, 2022).

2.2.1 As Built Records and Document Management

As part of their day-to-day processes, City staff view infrastructure through intranet web and mobile based geospatial mapping applications. To access data missing from the GIS, City staff utilize authoritative records drawings ("As-Builts") to manage City Infrastructure.

As-Builts are official systems of record. Aside from official physical copies stored in a filing system, these As-Builts are also provisioned in the form of PDF copies and stored in a file-based folder system and used to update the City's geospatial databases. In addition, these records can be sources of utility infrastructure from Subdivision development projects to Capital Improvement Projects.

Currently, document management is done via a Windows file-based storage system where these files are stored in a folder called "Scans" and accessed via Windows File Explorer. Within the Scans folder, the following conditions exist:

- A standardized proper name folder
- Common name that can be matched to a GIS record
- Data folders are organized by subtype
- The files located within these folders are authoritative records
- They may contain graphics files of As-Builts such as PDFs, TIFF files or copies of Computer Aided Drafting data (AutoCAD).

An example of the folder management system is noted in Figure 1, where the folders under Subdivisions are identified with a "SUB-" and an incremental identification number (Figure 1).

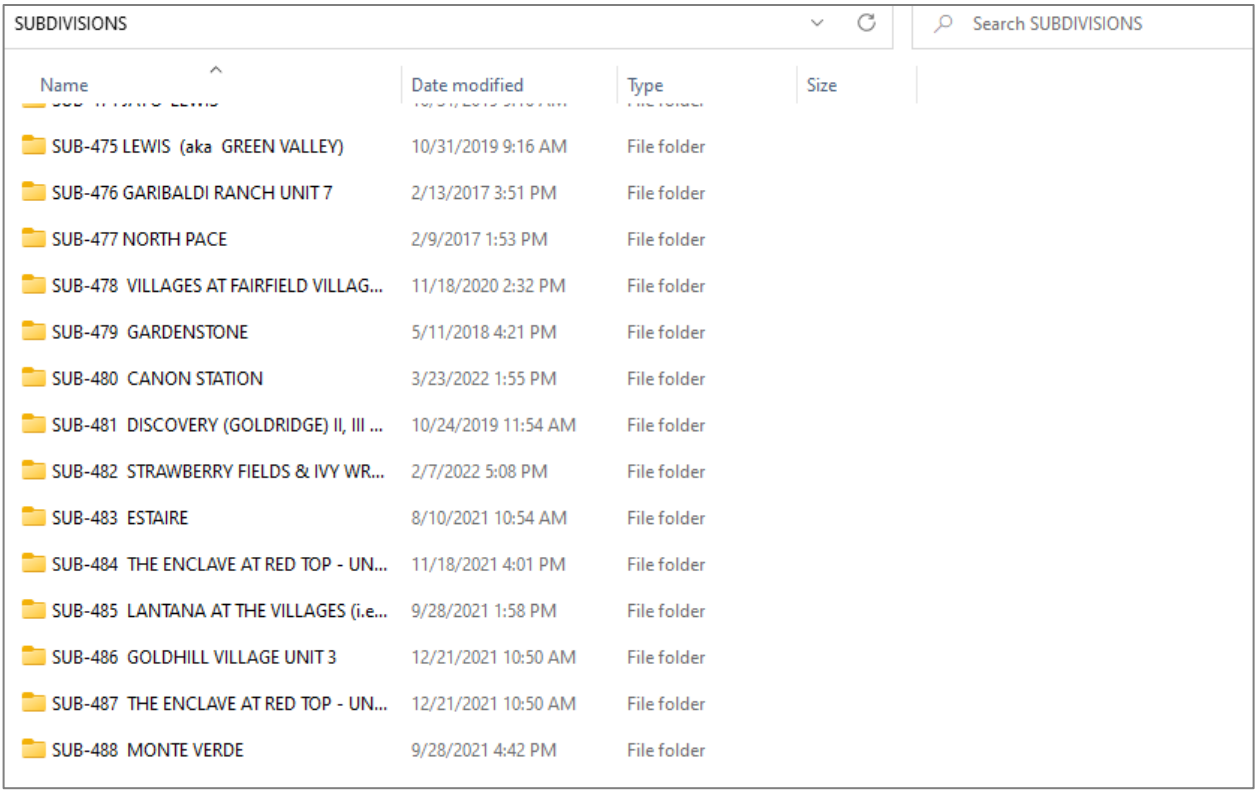

Figure 1. Screenshot of Current File Folder Document Management System for Subdivision Files.

These subdivision folder names are also documented on an Excel spreadsheet called the Binder Index. The Binder Index noted the subdivision number (SUB-#), description, map scale reference, the name of the developer/engineer of the project and an associated year (Figure 2).

Number (SUB-#)	Description	Scale	Engineer or Surveyor	Date
SUB-479	GARDENSTONE	A.S.	C&D	2/23/18
SUB-480	CANON STATION	A.S.	CBG	2/18/18
SUB-481	DISCOVERY (GOLDRIDGE) II, III, & IIIA	A.S.	CBG	10/17/17
SUB-482	STRAWBERRY FIELDS & IVY WREATH			
SUB-483	ESTAIRE	A.S.	MERIDIAN	10/22/18
SUB-484	THE ENCLAVE AT RED TOP - UNIT 1	A.S.	ISAKSON	5/1/19
SUB-485	LANTANA AT THE VILLAGES			
SUB-486	GOLDHILL VILLAGE - UNIT 3			
SUB-487	THE ENCLAVE AT RED TOP - UNIT 2	A.S.	APEX	6/10/21
SUB-488	MONTE VERDE			

... | Street Const | Studies | Subdivisions | Survey PM | Tr ...

Figure 2: Figure 2. Screenshot of Binder Index Table.

While most City departments can access this information, various issues affect their best and efficient use. The files located within these folders may be difficult to find without pre-existing knowledge of the file name or guidance from technical engineering staff. File folder access must be granted for City staff from departments outside of Public Works. Additionally, copies of critical infrastructure files may be located within user's personal file shares, or a digital version may not exist, leading staff to source a physical copy. Lacking the knowledge to conduct a thorough record search can impact City staff's ability to address emergent issues with maintaining the City's infrastructure (physically and geospatially).

In looking at the Scans folder, I found more than 70 listed file folders that represented a subject type. However, within the Binder Index file, there are 17 tabs that represent the subject types. This brings up the question why were not all the data stored in the Scans folder documented in the Binder Index spreadsheet?

2.2.2 Geospatial Data and Data Sharing Workflows

The City's Information Technology Department maintains a production level Enterprise geodatabase that contains key City utility infrastructure for all City departments. However, there continue to be data governance issues regarding standardized workflows to ensure data accuracy.

One of the current GIS data editing workflows between City departments has been through email requests. City staff would request data updates and provide referenced source data. If data were not available, GIS staff would conduct document searches in the Scans folder. If data is unavailable in the Scans folder, they reach out to various Public Works staff for guidance to find the correct subject matter expert. Depending on the utility type, a documented quality control process to ensure GIS data accuracy and preciseness may or may not exist. Having a way to link to associated As Built records easily improves this process.

2.3 Technology Review

The City utilizes ESRI and Microsoft technologies on an enterprise level. Enterprise agreements allow the City to leverage a multitude of applications and tools that support the City. ESRI's GIS desktop software (ArcMap and ArcPro) and open-source python tools are used to prepare data and to create a web-based application to manage and provision data internally to City staff and externally, to the public (ArcGIS Online and ArcGIS Enterprise).

Current document processes store files within the Windows File folder storage system where direct file folder links from GIS data is limited to desktop software such as ArcMap and ArcPro. In researching potential solutions, Microsoft's Internet Information System (IIS) was identified as a tool to leverage a browser-based solution to access the Scans folder. The browser-based applications allow a flexible experience for users to access applications without installing applications on their computers.

2.4 Prototype development and design

Studies by Carrion et al. (2016); Edelson & Ferster, (2013) and Graham & Buntain (2017) in developing a geospatial web-based tool to provision historical public works data were used as the basis for my prototype application. These studies evaluated the creation of a geospatial database or a web interface tool that maps out locations of historical documents. The intent is to create an application that can overcome challenges during earlier project phases. While these studies may not specifically relate to mapping critical utility data, the concept of linking non-spatially attribute data such as scanned maps to related GIS data was used. For this project's scope, I focused on linking authoritative "As-Built" data to Subdivision geospatial data. City Public Works staff utilize critical utility infrastructure information found in the Subdivision folder. They would like a simple way to view project files and if needed, have a simple way to update information.

2.4.1 Establishing file path links

To link files to geospatial data, I needed to start with an initial list of relevant files and their file locations. As this did not exist, this needed to be created. Using a modified python script from Liew, 2020, that would read the Scans folder, the script would read through a designated file folder and list each file's Windows absolute file path.

The resultant tables were then imported into ArcGIS Pro where the records were sorted, and file folder paths were parsed into a separate column and summarized to create a new table index of individual file folders. Two files were created, one that indexed a Subdivisions folder (files that contained the tentative approvals) and another that indexed the Sub Final folder (file that related to final map approvals). These two tables were joined to the Subdivisions Feature Class layer and an updated Subdivisions layer was created to include file path links to the Subdivisions and Sub Final folders.

Within the ArcGIS Pro application, the file path links were successfully tested. Selecting a record would allow the user the ability to link to file folders that contained the associated files. Then, I published the feature class layer to the web. Within ArcGIS Portal, users can leverage the geospatial functionalities to view GIS data.

Initial tests on leveraging web layer access to file folders were initially unsuccessful. Every time a user clicked on the file link; nothing would happen. With the ArcGIS Pro application, similar steps would result in a new file folder window populated with the associated files. Further research on file links indicated that web browsers did not support direct file links. In fact, doing so posed security risks (ESRI, n.d.-b; Laweric, 2019). As a result, the initial solution was to advise users to copy and paste the file paths into a file browser based on a spatially selected record (Figure 3).

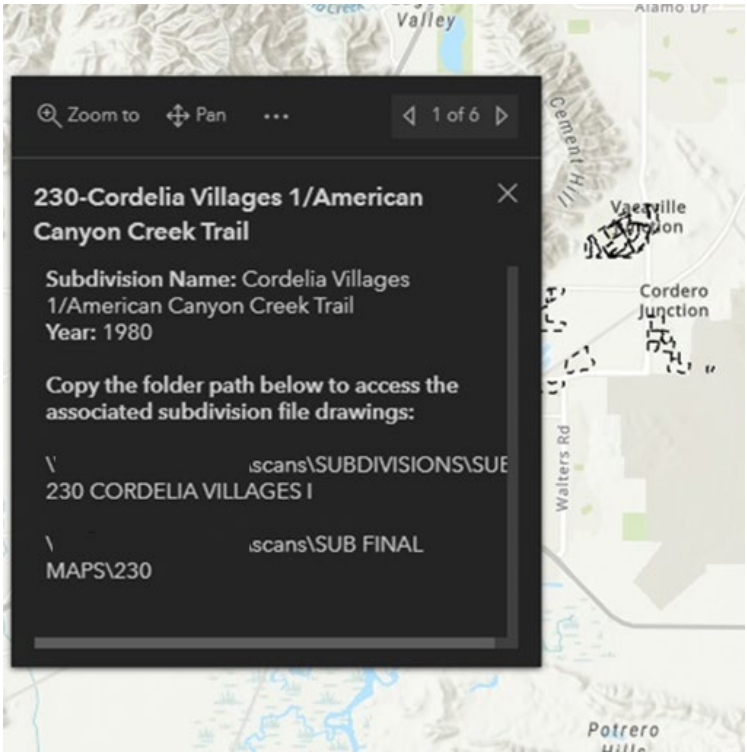

Figure 3. Screenshot of Initial File Mapping Location Information.

In evaluating alternative file linking options, one solution was to attach each related file to the GIS feature class layer via an upload process. ESRI's current desktop solutions include geoprocessing tools that allow for file attachments to a geodatabase. Once attached, users can easily open the related image files. This was evaluated and deemed not to be a feasible solution as this meant maintaining a second copy of files. This could lead to confusion over which file copy was more authoritative and would require document management across multiple systems. This option does not disqualify future processes where authoritative data can be attached to GIS records.

2.4.2 Virtual Directory

The concept of the virtual directory was posed as a possible solution to the file folder linking issue. I met with the Information Technology (IT) network infrastructure team to discuss options regarding file folder links. In working with IT staff, the Scans folder was linked via a virtual directory created through a Microsoft IIS web server (Microsoft, 2022) and access was managed via a group

managed service account (gMSA). According to ESRI (2021), in their resource documentation for ArcGIS Enterprise, a gMSA “is a special Active Directory domain account that provides automatic password management. The account cannot be used for interactive logins and is restricted for use on only a predefined group of servers." By applying security and access permission measures in the form of gMSA, the team was able to reference file folders without having to migrate the data. Once it was configured, we were able to treat file folder links as virtual links. Instead of provisioning an absolute file path for file links in a web environment, access to related records were now available through hyperlinks within the City’s internal network. If the user was using the City’s internal network, they could access record folders with a read-only online access.

2.4.3 Application

With access to files set up through a virtual directory and the Subdivisions layer set up in an ArcGIS online web map, the next step was to set up the application interface. ArcGIS Experience Builder was used to develop the application. The tools provisioned within ArcGIS Experience Builder allow for web application customizations without having to develop code. Within an Experience Builder site, users can embed stand-alone ArcGIS applications to create a more integrated experience. Two applications were configured and embedded within an Experience Builder site, a dashboard application, and a web editing application. Within the site, a button on the top right allows for users to toggle back and forth between the dashboard and the editing windows (Figure 4; Figure 5).

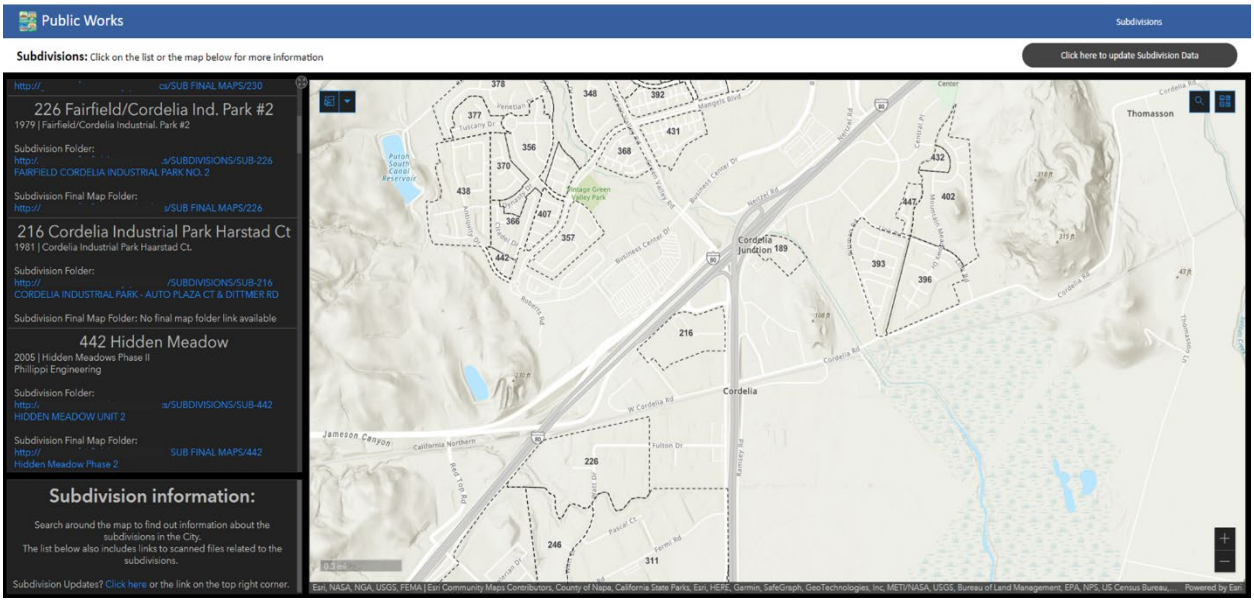

Figure 4. Screenshot of Application with Dashboard View.

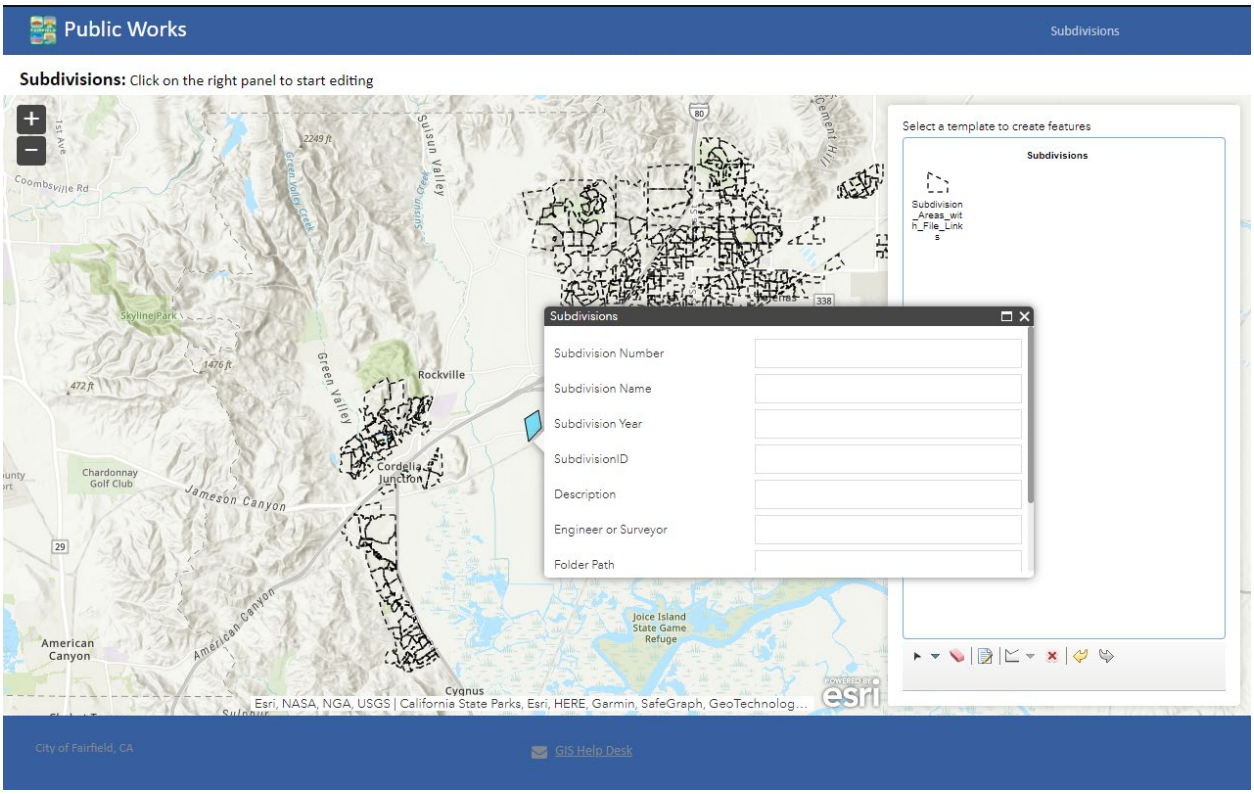

Figure 5. Screenshot of Web Editing Tool.

2.4.3.1 ArcGIS Dashboard

The ArcGIS dashboard was set up to provide an interactive list of subdivisions on the left sidebar with links to the file records. Users can scroll down the list or pan around the map. As they use the application, either the list updates or the map pans based on the desired action.

Then, utilizing Arcade expressions, the subdivisions list was set up to either provide the link to the associated records or if data was missing, a message noting the file folder did not exist. The benefits of the arcade expression are the customization functionalities that can be developed within the ArcGIS suite of applications (Figure 6).

Setting up conditional statements within the arcade expression ensures that there will be some form of record relating to file links. In the screenshot of the dashboard application (Figure 4), there is a missing link to the one of the file map folders for 216 Cordelia Industrial Park Harstad Ct. The goal is that by explicitly noting the missing file, staff would be prompted to remedy the issue.

```
//set your variables for the URL links
var folderPath = $datapoint.folderurl
var finalmapfolderPath = $datapoint.folderfinalurl

//if statement is both folderPath and finalmapfolderPath are not empty
if (!IsEmpty(folderPath) && !IsEmpty(finalmapfolderPath)){

return {
 textColor: '',
 backgroundColor: '',
 separatorColor:'',
 selectionColor: '',
 selectionTextColor: '',
  attributes: {
   v_folderpath: folderPath,
   v_finalmappath: finalmapfolderPath
  }
}}

//if finalmapfolderPath is empty
else if (!IsEmpty(folderPath) && IsEmpty(finalmapfolderPath)){

return {
 textColor: '',
 backgroundColor: '',
 separatorColor:'',
 selectionColor: '',
 selectionTextColor: '',
  attributes: {
   v_folderpath2: folderPath,
   v_finalmappath2: 'No final map folder link available',
  }
}}

//if folderPath is empty
else if (IsEmpty(folderPath) && !IsEmpty(finalmapfolderPath)){

return {
 textColor: '',
 backgroundColor: '',
 separatorColor:'',
 selectionColor: '',
 selectionTextColor: '',
  attributes: {
   v_folderpath3: 'No file folder link available',
   v_finalmappath3: finalmapfolderPath,
  }
}}

// if both folderPath and finalmapfolderPath are empty
else {

return {
 textColor: '',
 backgroundColor: '',
 separatorColor:'',
 selectionColor: '',
 selectionTextColor: '',
  attributes: {
   v_folderpath4: 'No file folder link available',
            v_finalmappath2: 'No final file folder link available',
  }
}}
```

Figure 6. Arcade expression script.

2.4.3.2 Web Editor

Users can click on the web editing tool via the “Update Subdivision Data” button. The goal is to provide a simple interface for users to select records or draw general subdivision boundaries where there is missing data, precisely the folder path locations. Following this step allows the City staff to document resources unknown to other City staff. For making updates, the editing tool allows for quick data entries. The indexing steps previously noted solved most workflow issues, so with a lot of the work done, there is a greater incentive to ensure file linking updates. The reasoning is that one may be more likely to finish a smaller subset of updates within a reasonable timeframe versus manually updating a more extensive set of records. Furthermore, GIS staff can adjust the needed geospatial data based on submitted information (Figure 5).

3 Conclusion

From day-to-day activities to large scale regional emergencies, authoritative data access affects local governments. With this system, the goal was to ensure data access for the City (specifically for the Public Works department) by provisioning a centralized workflow through a simple, easy-to-use application while using existing technologies and current data document management processes. In addition, by setting up a geospatial data editing workflow, the goal is to increase interdepartmental awareness of data and responsibilities.

Indexing files and creating a linking tool improves workflows and staff productivity. By provisioning the file folder-based data via a virtual directory, this project improved access to City staff. Ultimately, Arcade expressions simplify how the data is presented to the user in a more visually appealing format. The application offers a solution to increase interdepartmental awareness of current data and associated data responsibilities. Efficiently provisioned data enhances the data quality and improves how the City responds to emergencies.

There has been evidence that the City departments have a greater interest in improving GIS with authoritative data with this project. As a result, City departments have acknowledged the need for enhanced GIS workflows and have started to take steps to allocate additional resources (budgets, staffing). By utilizing the application developed with this project, City staff can use the system as a data governance tool to visually see where data gaps exist and take steps to address those issues. This application will not be able to iron out all the concerns with provisioning authoritative data, but it is a strong step in building a foundation for managing data workflows.

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