

GIS for Asset Management for the Smallest of Water and Wastewater Utility Systems.

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## Introduction

Schultz (2012) discussed using GIS for Asset Management at a water utility. This thesis discusses the importance of mapping horizontal assets such as valves, meters, and hydrants and mapping vertical assets such as pumps and motors in a pumping station. The vertical assets are important as most of the time just the pumping station was mapped, and not each asset within the pumping station. When an asset management plan is created, each asset within the pumping station is on the plan, so it is beneficial to map each asset within the pumping station creating a detailed asset inventory. While Schultz's research is based on a larger water system, my capstone project is focused on the smallest of water systems with limited resources.

This project will focus on the use of current tools available in ArcGIS Online to develop a GIS system for water utility asset management. ESRI has a water utility solution, but after using it in previous employment in county government, I feel that it is not a proper solution for small water systems. Many small water systems only have one operator and the ESRI solution is set up to be used by many users, so their solution is not that useful, as it is too complicated, for a system that at most three people might be using. This project will be created based on a tenant ArcGIS online environment. This type of environment allows users from other organizations to be in another organization's environment as a tenant, where the environment administrators will set up all tools for the tenant organizations to use. The question this project will answer is: How can the ESRI Arc GIS Online Application be used to help with asset management for the smallest of water and wastewater utilities?

## Literature Review

Asset management is important for small water utilities. The EPA (2008) defines asset management as maintaining a “desired level of service” while keeping costs low for the life cycle of an asset (an asset being a water pipe or a mainline valve). The life cycle cost is the cost to replace, repair, and rehabilitate an asset. In addition to the EPA's definition, Schultz (2021) suggested that asset management is a strategic approach to optimizing cost-effectiveness to balance maintenance and new investment. Asset management is to manage assets “optimally and sustainably as possible” Syafiq (2023). Syafiq also added that asset management should be preventive rather than reactive.

## Critical Assets

An effective asset management plan includes critical assets, assets that are critical to water for a water utility to provide drinking water. The EPA (2008) defines critical assets as “those you

decide have a high risk of failing” (pg. 3). Determining how to classify critical assets is an important part of an asset management plan. A scoring method is commonly used to score the criticality of an asset. Anderson (2006) listed the criteria used to score the criticality of an asset and include: safety and environment, economic output, severity, condition, existing maintenance, and complexity. A weighted score of 1 to 10 is then assigned to each criterion, lower being less critical and higher being more critical. Baah (2015) applied a consequence of failure assessment using multiple factors based on socio-economic and environmental impacts. Baah’s model also uses a weighted sum with a higher number associated with a higher consequence of failure, this is found by multiplying the consequence of failure score by the probability of failure score. Baah reported that this model has limitations based on the “inherent subjectivity introduced by the decision maker.” Baah's findings provided motivation for this capstone project to determine an unbiased way for a small water utility with limited resources to assign a criticality score to assets that are the most critical.

### Life cycle cost

Life cycle cost is another part of the asset management plan. The EPA (2008) defined life cycle costing as a process to determine when an asset should be repaired or replaced. Oh et al., (2023) Provided detailed models and methods of analysis to determine if an asset should be repaired or replaced. In this costing process, it is important to maintain a budget to determine when it is best to repair or replace an asset, as my work experience has taught me that many small water utilities have difficulty maintaining a budget to repair or replace assets. The utilities will make minor repairs when needed but do not have the budget to replace assets when they are beyond repair. Designing a method to help these small water utilities assign a life cycle cost will be important for asset management and this capstone project.

### GIS Application to Small Water Utility

GIS is an important tool that can be used to assist with asset management. Munguia (2023) discussed the importance of accurate location information using GIS and GNSS technologies. Many water utility infrastructure is buried underground and without accurate location data it would be difficult to find this infrastructure to inspect, repair, and replace. A web map can be used to view the buried distribution network, so assets can be easily found in the field. Reger (2017) discussed how many small water utility systems do not use GIS as many feel that it is cost-prohibitive. These small water utility systems rely on as-built maps with data that was not collected through GPS technology and are less accurate than a GIS and GPS affords. Reger aimed to develop a low-cost GIS solution for small water utility systems. While Reger proposed using QGIS, due to its steep learning curve, I believe this application is too difficult for the staff of small water systems to use. The company I work for has an agreement with ESRI that we can provide a low-cost ESRI ArcGIS Online solution to the small water utilities we help. ArcGIS Online projects are much easier to use than many software-based GIS projects.

## User Testing

Testing a new GIS solution is important to make sure that its design provides an easy-to-use solution for asset management. Prototyping is a method that will be used to test this GIS Web Application for Small Water Utilities. Camburn et al., (2017) defined prototyping as an artifact that approximates the features of a product. Camburn et al. presented the following objectives in prototyping, including objectives in prototype design, refinement, communication, exploration, and active learning. Camburn et al also explained that feedback is an important part of the prototype. To gain feedback on my solution, I plan on first testing the prototype with my co-workers who work with small water utilities systems for the initial feedback and then having some of the small water utilities that we work with test the prototype to provide additional feedback. Khan (2010) presented ways to test the usability of web-based GIS applications, designing tasks is a part of testing usability, it provides a way to test users' ability to navigate the product they are testing. A list of tasks is given for the users to try to accomplish while testing the product. After the test, a questionnaire can be used to evaluate the ability of the testers to do the provided task. A formal interview can be used to get feedback on the task testing.

## Datasets

A hypothetical drinking water system will be created to test out the application created for this project. The layers used for the hypothetical data are housed in two geodatabases in the company I work for, Rural Community Assistance Corporation (RCAC), SharePoint. I am currently the primary caretaker of these datasets. The layers in these datasets cover most of the assets that a small water/wastewater utility would map for asset management. The list of the layers that will be used for this project is shown in (Table 1). Other layers that will be used are a parcel dataset and the utility systems boundary when available, as some states and/or counties have data readily available. This project will be using a parcel layer from the Washington Geospatial Open Data portal (2023), the water utility system will be hypothetical, so the boundary will be made up for this hypothetical system.

Table 1 A list of all layers used in the project, listing the name of the layer, and the type. All layers are in the geographic coordinate system WGS 1984 created in 1/2024.

<b>Dataset</b>	<b>Type</b>
<b>Chlorinator</b>	<b>Point</b>
<b>Pump</b>	<b>Point</b>
<b>Building</b>	<b>Polygon</b>
<b>DistMain</b>	<b>Line</b>
<b>Hydrant_Fire</b>	<b>Point</b>
<b>Mainline_Valve</b>	<b>Point</b>
<b>WServiceLine</b>	<b>Line</b>
<b>Service_Meter</b>	<b>Point</b>
<b>Tank_Storage</b>	<b>Point</b>

<b>Well</b>	<b>Point</b>
<b>TransMain</b>	<b>Line</b>

Asset Management is an important part of this project, so the attributes chosen for each layer need to provide as much information as possible to be added to an asset management plan. These fields are shown in (Table 2). In addition to these fields needed for asset management, the point objects(as in meters, valves, and hydrants) will include fields populated with information related to the high-accuracy data collection with a GNSS unit, ESRI (n.d.).

Table 2 A list of attributes for the point layers used in the project with descriptions for the field.

<b>Field</b>	<b>Description</b>
<b>SYSASSET_ID</b>	<b>Name of asset</b>
<b>MANF</b>	<b>Manufacturer of the asset</b>
<b>Type</b>	<b>Type of asset</b>
<b>Size</b>	<b>Size of asset</b>
<b>Notes</b>	<b>Notes on asset</b>
<b>DateInstalled</b>	<b>Date asset was installed</b>
<b>Criticality</b>	<b>How critical the asset is based on a score of 1-5 with 5 being the most critical.</b>
<b>Condition</b>	<b>The condition of the asset is based on a score of 1-5 with 5 being in bad condition</b>
<b>CriticalityScore</b>	<b>Criticality multiplied by condition</b>
<b>OrgValue</b>	<b>The original value of the asset</b>
<b>LifeExpect_Yrs</b>	<b>The life expectancy of the asset</b>

## Methodology

### Creation of the GIS Web Application

Many steps go into the creation of the GIS web application and this section will cover those steps. I have created an ArcGIS Pro project as a master project to create separate projects for each water utility that I work with (Figure 1). In this master project, there is a master file geodatabase that has all layers used to cover assets used for water/wastewater utilities. The datasets section of this capstone project gives an example of some layers and fields within the master file geodatabase. The layers to be used in the GIS web application are chosen by the water/wastewater utility when I meet with them to start a GIS project. The master ArcGIS Pro project has a map for publishing, with all layers and symbology ready for publishing to ArcGIS Online.

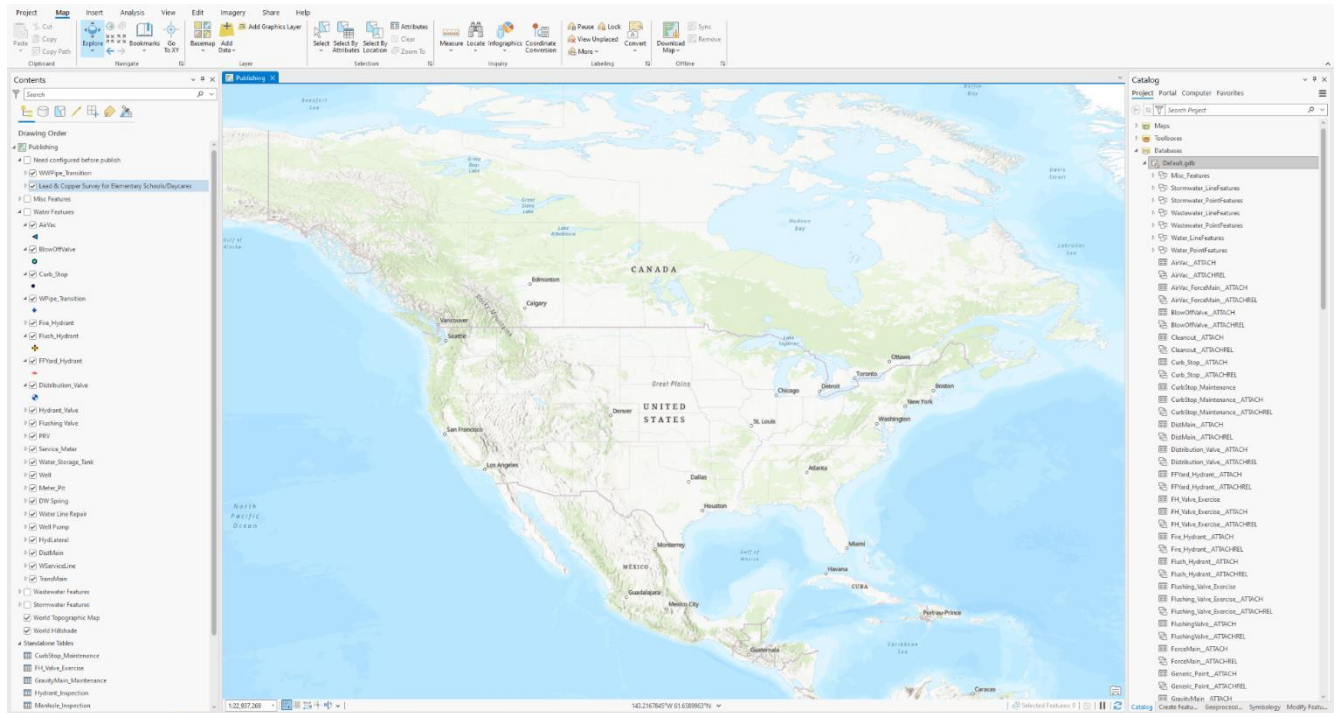


Figure 1 The master project used to create the hosted feature layers. This project has all the layers needed set up with symbology. A map is created and the needed layers from the publishing map are dropped into the map that will be used to publish the feature layer.

When starting a project with a new water/wastewater utility I open the master ArcGIS Pro project and save it as a new project with the name of the water/wastewater utility. In this new project, I created a new map to be used as the ArcGIS Online feature layer. I moved all the layers that I wanted in this feature layer from the publishing map to the new map created for the feature layer. I added any other authoritative layers I can get from other sources as a local parcel layer from the county the water/wastewater system is in. This map is then shared as a hosted feature layer to ArcGIS online, making sure to allow for editing, syncing, and exporting.

I opened the newly created feature layer in an ArcGIS Online Web Map. At this time any web layers can be added to the map as requested by the water/wastewater utility, and an example of this would be the national wildfire layer. After I have all the layers needed for the web application, I save the web map and name it (Utility's Name) Experience Builder Web Map. After saving the first map, I will then remove all layers from the map that are not part of the original feature layer and save the map as a (Utility's Name) field map. The field map is used for use in the ArcGIS Field Maps application for use in the field.

I opened the field map in Field Map Designer, at this time I have not thought about the design of field map fields and popups, so far now I have used the defaults. I used Field Map Designer to create an offline area to be able to field maps to be run in offline mode. This is also a good place to find out if there is anything wrong with any of the layers as the Field Map Designer will check the layers to make sure they are set up correctly.

The Experience Build Web Map is used to create the Experience Builder Web Application (Figure 2). In the past I used the Launchpad theme with the older Web App Builder, this option is also a template option in Experience Builder, so I decided to use that option for my initial design. I added some basic widgets for viewing, editing, and exporting data. I added the edit, table, selection, and draw widgets. Unlike with the older Web App Builder, each widget needs some programming, mainly assigning what layers can be edited and viewed. I decided to have the legend show always on the left side of the application and the layers list on the right. After initially forgetting to add the basemap selection widget, I added it after some initial feedback. The application was now ready for testing.

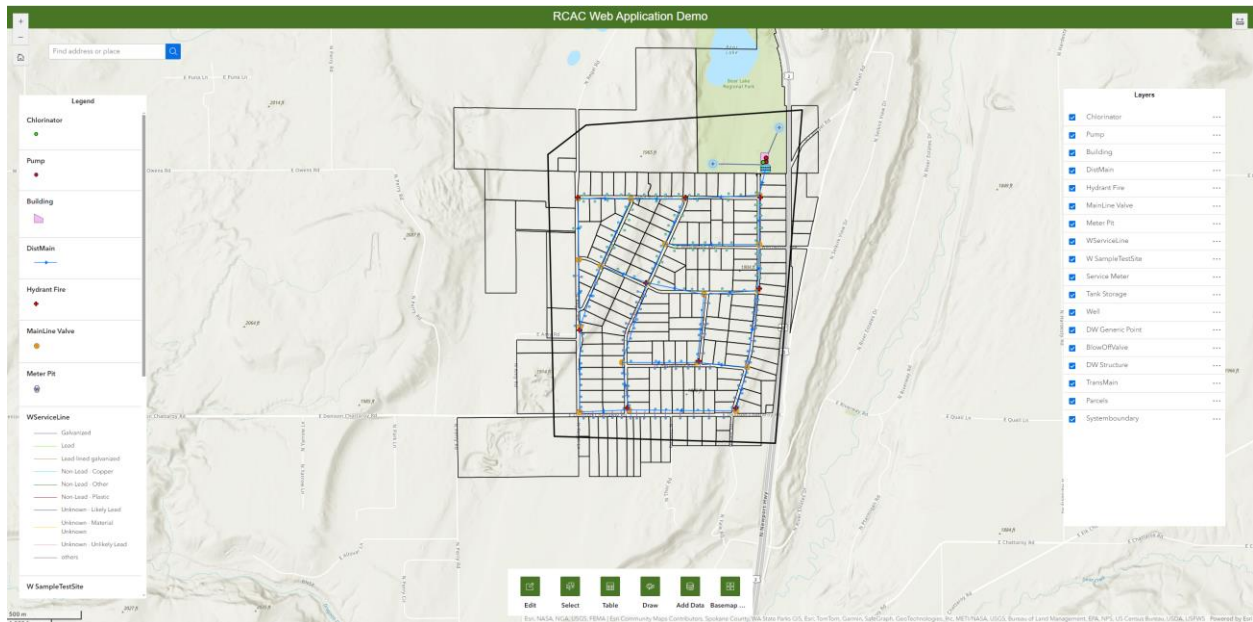


Figure 2 An example of the ESRI Experience Builder prototype used for testing for this capstone project.

## Testing the GIS Web Application

Now that a prototype has been created for the GIS web application, testing is needed to make sure the application is functional and user-friendly. I first sent the prototype to a past GIS mentor to give it a quick look. After some feedback, I made some changes to the web application before starting the official testing for this capstone project. My plans for testing were to send the prototype and a task list to my co-workers who have GIS projects or might work on GIS projects in the future. Then if there is time to connect with members of the water utilities that I have worked with in the past.

The task list I created was to find out how difficult the functions of the GIS web applications are to use. The task list gave many tasks to perform and asked how difficult it was to perform and any comments on the tester had on the task. All the tasks also had an additional section with



detailed help to perform the task as an option (Figure 3). The task list noted to have the tester state if they needed to use the extra help while performing the task.

**The list of the task:**

**Task 1: Use the search function to find and zoom to 28504 N Cottonwood Rd, Chattaroy, WA 99003**

**Task 2: Click on the meter for 28504 N Cottonwood Rd, Chattaroy, WA 99003, and check the service address field to make sure you're at the right meter. Based on how close you zoomed in you might have clicked on multiple features, you can use the arrows on the lower left-hand corner of the pop-up to change what feature is selected.**

**Task 3: Click the edit function and then click on that same service meter from the last step. You will now see the attributes of that service meter. You now can edit the fields, edit the notes field, and update that field to say "Inspected (today's date) (Your Name)". Make sure to click update when done.**

**Task 4: Use the select tool to select all the assets of this water system. While selecting open the table tool and go to the Service Meter tab, click on actions on the upper right hand corner (the 4 circles) click export to csv. This should download a csv of all the meters in the system.**

**Task 5: Use the measurement tool or the draw tool to find the length in feet of the main from the water tank south of the pumphouse to the first mainline valve. What is the measurement in feet?**

**Task 6: Change the Basemap to Imagery**

**Task 7: With the add data tool, from the Living Atlas search for the National Weather Service 72 Hour Temperature Forecast and it to the map.**

**I also added a section for comments:**

**How was the general layout of the application?**

**How was the look and feel of the symbology (the features/ items in the Legend)**

**Were the tools easy to find?**

**Any other comments you might have?**



Click on the meter for 28504 N Cottonwood Rd, Chattaroy, WA 99003 and check the service address field to make sure you're at the right meter. Based on how close you zoomed in you might have clicked on multiple features, you can use the arrows on the lower left-hand corner of the pop up to change what feature is selected.

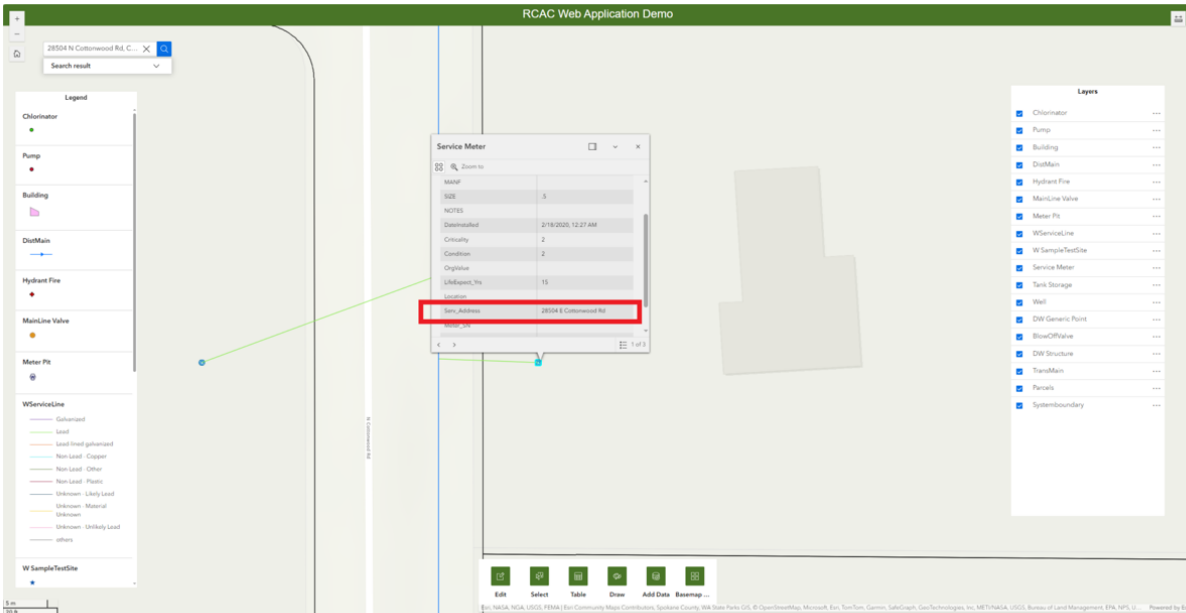


Figure 3 An example of a section of the task list where extra help was provided to perform the task.

Getting back to the results of the testing of the GIS web application prototype, I interviewed the people who tried out the application to discuss the results of the testing. I made changes based on the feedback provided. Future work on this capstone project will be to conduct more testing after updates are made on the GIS web application.

## Results

I did reach out to eight people oh have hours to work on GIS-related projects, but I only got feedback from two people. The following is the feedback that I got.

The feedback I got from the first tester:

The tester's feedback is in bold.

Use the search function to find and zoom to 28504 N Cottonwood Rd, Chattaroy, WA 99003

**Difficulty: 1**

**Comments: Easy! Paste the address into the search bar. Auto zooms.**

Click on the meter for 28504 N Cottonwood Rd, Chattaroy, WA 99003 and check the service address field to make sure you're at the right meter. Based on how close you zoomed in you might have clicked on multiple features, you can use the arrows on the lower left hand corner of the pop up to change what feature is selected.

**Difficulty: 1**

**Comments: Had to zoom out of property to see the water meter.**

Click the edit function and then click on that same service meter from the last step. You will now see the attributes of that service meter. You now can edit the fields, edit the notes field and update that field to say "Inspected (today's date) (Your Name)". Make sure to click update when done.

**Difficulty: 2**

**Comments: Had to click the "edit" button several times while I had the meter selected and refer to the screenshot below to get the edit screen for the particular meter to pop up.**

Use the select tool to select all the assets of this water system. While selected open the table tool and go to the Service Meter tab, click on actions on the upper righthand corner (the 4 circles) click export to csv. This should download a csv of all the meters in the system.

**Difficulty:1**

**Comments: Easy! It took a moment to select all assets.**

Use the measurement tool or the draw tool to find the length in feet of the main from the water tank south of pumphouse to the first mainline valve. What is the measurement in feet?

**Difficulty: 3**

**Comments: 581 feet. Hard to get the measure tool to line up exactly since the zoom doesn't seem to snap to assets.**

Change the Basemap to Imagery

**Difficulty: 1**

**Comments: Easy!**

With the add data tool, from the Living Atlas search for the National Weather Service 72 Hour Temperature Forecast and it to the map.

**Difficulty: 1**

**Comments: Easy! It was the first item on the list. But this colored over the map**

General Comments on the Applications please rate 1 to 5 one being low and 5 being the best.

How was the general layout of the application?

**Rating: 4**

**Comments: This looks like & almost has the functionality of the water system maps I've used in ArcPro in the past.**

How was the look and feel of the symbology (the features/ items in the Legend)

**Rating: 5**

**Comments: The symbology feels very familiar to me.**

Were the tools easy to find?

**Rating: 4**

**Comments: This was more or less intuitive. They are easy to find but a little harder to use (i.e. have to be in the right place to select / edit, have to use zoom skillfully to find/measure features, etc.)**

Any other comments you might have?

## Results from the second tester:

The tester's feedback is in bold.

Use the search function to find and zoom to 28504 N Cottonwood Rd, Chattaroy, WA 99003

**Difficulty: Very easy.**

**Comments: I like the selective search where items that match are displayed as you type in your criteria. This speeds up the process. The default zoom level was too much though. The view was so close that it all looked blank and I had to zoom out to get context to the property lines, other lots, streets, etc.**

Click on the meter for 28504 N Cottonwood Rd, Chattaroy, WA 99003 and check the service address field to make sure you're at the right meter.

**Difficulty: Moderately difficult.**

**Comments:** The service address was incorrect (E Cottonwood Rd), but actually selecting the service meter was harder than it should be. I kept selecting the service Line, not the meter and had to zoom in as far as I could and had to select several times before the meter was accessed. I can use the greater and less than signs in the lower left corner of the popup to cycle through to the meter, but that isn't intuitive.

While the service meter popup is up, click the edit function and edit the notes field and update that field to say "Inspected (today's date) (Your Name)". Make sure to click update when done.

**Difficulty:** Very Difficult

**Comments:** I would expect there to be an 'edit' function right on the asset popup. If there is, I can't find it. The edit function that is listed at the middle bottom of the form seems to be a global function for adding assets with no relation to the selected meter.

Use the select tool to select all the assets of this water system. While selected open the table tool and go to the Service Meter tab, click on actions on the upper righthand corner (the 4 circles) click export to csv. This should download a csv of all the meters in the system.

**Difficulty:** Not too bad

**Comments:** What I wanted to do was to 'rubber band' a selected number of service meters and then download them, not all the meters in the system. The Select function didn't seem to support this.

Use the measurement tool or the draw tool to find the length in feet of the main from the water tank south of pumphouse to the first mainline valve. What is the measurement in feet?

**Difficulty:** Easy

**Comments:** No problems with this

Change the Basemap to Imagery

**Difficulty:** Easy

**Comments:** Intuitive

With the add data tool, from the Living Atlas search for the National Weather Service 72 Hour Temperature Forecast and it to the map.

**Difficulty:** Moderate

**Comments:** I can add the overlays, but they seem to blot out all my relevant asset data.

General Comments on the Applications please rate 1 to 5 one being low and 5 being the best.

How was the general layout of the application?

**Rating: 3**

**Comments: It seems like most of the functions are present, and it may be that I'm just coming in cold and training would be helpful. I do think that some of the processes should be moved around and polished.**

How was the look and feel of the symbology (the features/ items in the Legend)

**Rating: 4**

**Comments: Symbology was fine. I could tell the difference between a meter and the nearby hydrant**

Were the tools easy to find?

**Rating: 2**

**Comments: The measuring tool was, but edit function for individual assets is still a mystery to me and I don't care for the position or functionality of the global tools at the bottom of the form.**

Any other comments you might have?

**I like the add-on overlays. I always appreciate ways to make static data more interactive (live pressures, valve positions, operational status, run time hours, etc.). I purposely ignored the step by step instructions that follow, because I wanted to come in cold, pretending I was some client or customer.**

**Pertaining to the edit function, it is still awkward to me even after following the cheat sheet below.**

Table 3 shows the combined difficulty scores between the two testers.

<b>Task</b>	<b>Difficulty</b>
<b>1</b>	<b>1</b>
<b>2</b>	<b>3</b>
<b>3</b>	<b>4.5</b>
<b>4</b>	<b>1.5</b>
<b>5</b>	<b>2</b>
<b>6</b>	<b>1</b>
<b>7</b>	<b>2</b>

## Discussion

Being the first time setting up a prototype application for testing, I did not realize how hard it was going to be to get people to test the application. Everyone I asked to test the application had many hours to be able to test the application and had a work reason to test it out. This GIS web application is the future of how the company I work for will be using GIS, so I was hoping that people would help with testing it.

Having experience with the older ESRI Web App builder, it was a learning experience learning how to use ESRI Experience Builder. There are many ways that Experience Builder Functions compared to the older Web App Builder. Some functions and widgets are in the older Web App Builder, but not in Experience Builder. During the term of working on this capstone project some of the functionality of Experience Builder changed. Using the select tool to be able to select and export was not an option at the start of this capstone project, but it was added making it easier to export data. This would have changed a task on my task list.

I was able to address some of the issues brought up during the testing. The default zoom for the search function was able to be adjusted within the Experience Builder settings. Many of the issues brought up are issues that cannot be resolved by making changes to the web application itself due to the functionality of Experience Builder. The select and export issue has now been made much easier to use since an update to Experience Builder. Future work on this project would be to add an about section to the web application take will link to a tutorial on how to use the web application. The editing functionality of Experience Builder is a problem and I hope that ESRI will add some more functionality in the future.

## Practical Use in the Field

I got a chance to use this capstone project with real data from a water utility system. The week preceding the field collection of data I noticed that somehow the hosted feature class was corrupted after trying to make an offline data collection area in Field Maps. I decided to start over and use the new datasets I was developing for this capstone project and create a new hosted feature set. I was able to get Field Maps working and created an Experience Builder web application using the template I used for the capstone project. The first day of field mapping went well with no issues, the second day we tried to map a meter, and the meter data would not sync. I had to make a new meter layer and remove the old one and this resolved the issue.

The focus of this capstone project is the use of the Experience Builder web application, so this was tested during this field mapping project. The first issue I noticed is using the web application with a small monitor. The Public Works staff that was to use the web application had a very small monitor and I set up the web application with a big monitor, so I did not know how hard it was to use with a smaller monitor. I will have to consider that with future modifications of the web application. More issues came up with the editing functionality, as the Public Works employee who was given a field worker user type with editor abilities was not able to use the edit functionality of the web application. I checked the internet for a solution and was able to do

some troubleshooting. I had to change the permissions to the web application for everyone within the organization to be able to access it. I did not like this as an option as I do not want members from other organizations to be able to edit data of other organizations. This fixed the issue, and the Public Works employee could now edit. Just to check, I changed the sharing permissions on the web application back to only people in the group and it still worked. This was just another case of ESRI products with bugs and having to find workarounds. Overall, the work on this field project was a success. The Public Works employee was happy with the web application and some of the issues we had helped with a deeper understanding of the whole application.

## Final Takeaways

Working on this capstone project I learned that there will always be things that do not go your way when working on a project. The lack of responses to the web application prototype testing was very disheartening, but I could only work with what I got as feedback. Learning how to use Experience Builder and dealing with bugs helped me understand the program more and that patience is needed when working with GIS. I have now created a field worker user type in my ESRI environment to test permission issues when creating new applications since everything seems to work well for the administrator but could work differently for a field user. I now know to consider monitor size when creating applications, while having the legend and layer boxes always up looks good on my monitors, it might take up too much room on a smaller monitor. Overall, what was created for this project does satisfy its original goal of creating an asset management tool for small water systems. There will future work making the web application part of the project to be more user-friendly as I get more feedback on it and more field testing.



## References

- Anderson, D., Keleher, P., & Smith, P. (2006). Towards an Assessment Tool for the Strategic Management of Asset Criticality. In *Engineering Asset Management: Proceedings of the 1st World Congress on Engineering Asset Management (WCEAM) 11–14 July 2006* (pp. 1232-1242). Springer London.
- Baah, K., Dubey, B., Harvey, R., & McBean, E. (2015). A Risk-Based Approach to Sanitary Sewer Pipe Asset Management. *Science of the Total Environment*, 505, 1011-1017.
- Camburn, B., Viswanathan, V., Linsey, J., Anderson, D., Jensen, D., Crawford, R., ... & Wood, K. (2017). Design Prototyping Methods: State of the Art in Strategies, Techniques, And Guidelines. *Design Science*, 3, e13.
- EPA (2008) *Asset Management: A Best Practices Guide*. United States Environmental Protection Agency. <https://www.epa.gov/dwcapacity/about-asset-management>
- ESRI (n.d.). Prepare for high-accuracy data collection. <https://doc.arcgis.com/en/field-maps/latest/prepare-maps/high-accuracy-data-collection.htm>
- Khan, Z. A., & Adnan, M. (2010). *Usability evaluation of web-based GIS Applications*. Blekinge Institute of Technology.
- Oh, W., Cho, C., & Lee, M. (2023). Life Cycle Cost Method for Safe and Effective Infrastructure Asset Management. *Buildings*, 13(8), 1983.
- Munguia, E. (2023). *Creating a Web GIS Solution for Collecting, Analyzing, and Viewing GPSed Water Meters in Tucson, Arizona*. The University of Arizona.
- Reger, C. M. (2017). *Bringing GIS to a Small Community Water System* (Doctoral dissertation, University of Southern California).
- Schultz, A. J. (2012, December). *The role of GIS in Asset Management: Integration at the Otay Water District*. In *Masters Abstracts International* (Vol. 51, No. 04).
- Syafiq, M., & Azri, S. (2023, December). A Review on the GIS Usage In Spatio-Temporal Risk Assessment in Asset Management. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1274, No. 1, p. 012005). IOP Publishing.
- Washington Geospatial Open Data portal (2023). Current Parcels. [https://geo.wa.gov/datasets/e8f2df3ed92843738f3dd778e92e93fc\\_0/explore](https://geo.wa.gov/datasets/e8f2df3ed92843738f3dd778e92e93fc_0/explore)