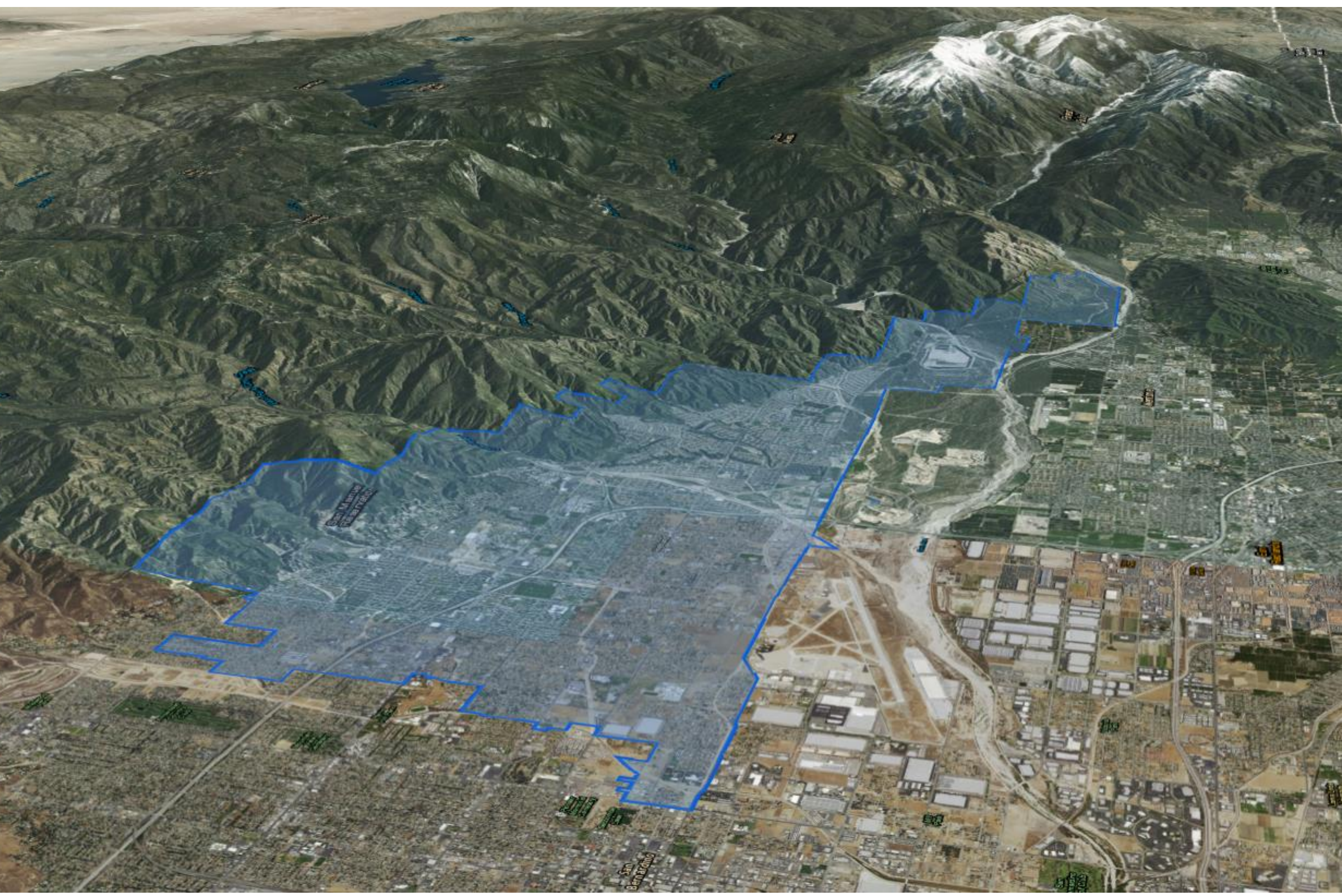

Water Main Asset Management Strategic Plan

December 15, 2018

In collaboration with

East Valley Water District

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Contents

1 Executive Summary

The University of Redlands and East Valley Water District has partnered together in identifying a specific business problem that is currently affecting East Valley Water District. Through Geographic Information System (GIS) concepts and Cityworks Asset Management Software, the University student team has created a strategic plan to enhance the District's asset management initiatives. The purpose of this strategic plan is to determine the District's assets, specifically around water mains that present the most business risk exposure to the District. This type of risk exposure will be determined by creating a model using a variety of data from the Districts assets management system, GIS, and various third-party sources.

The development of this strategic plan includes high level planning around the District's business environment to implement the project, as well as developing prototypes that will include operational dashboards and analytics applications to be used for data-driven decision-making. This plan includes a Needs Assessment analysis that will help determine the District's planning considerations to implement the Water Main Asset Management Plan.

2 Introduction

East Valley Water District (District) is a California Special District that provides water and wastewater services to a population of over 102,000 people within a 30 square mile area in the cities of Highland and San Bernardino.

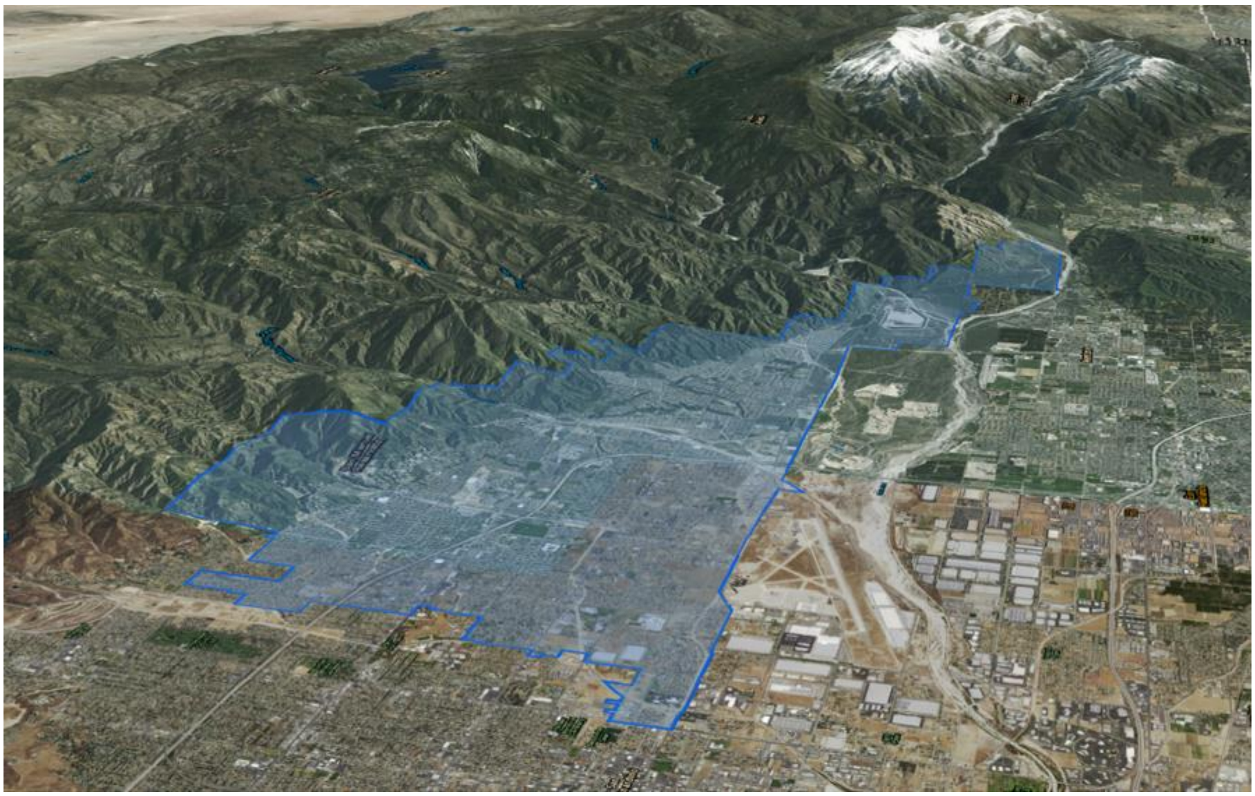


Figure 1 – East Valley Water District's service area is 30 square miles and provides water to over 102,000 people in the communities of Highland and portions of San Bernardino.

The American Society of Civil Engineers published America's Report Card on water infrastructure and assigned a D+ rating for drinking water systems in 2017 (American Society of Civil Engineers, 2017). The ASCE provided several recommendations to water utilities to raise the grade and which included "encouraging utilities to undertake asset management programs." Similar to other water utility providers in the United States, the District faces challenges in rehabilitating and replacing aging utility infrastructure that require tremendous capital improvement projects. Technology and best practices in asset management can enable the District to improve complex decision making for maintenance, operations, and capital investments to ensure safe and reliable services provided to the community.

The District currently uses a Water Main Replacement program that relies on the number of leaks and breaks from reactive maintenance. Other decision-making sources include a Water Master Plan that identifies pipes to be replaced with projected costs using water main leak and break history is the primary factor.

Systems modernization projects have resulted in the implementation of a Geographic Information System (GIS) and Computerized Maintenance Management System (CMMS). In 2009, Esri developed a GIS Strategic Plan that included a data conversion project to digitize the District's assets that include their water and wastewater systems. The last phase of the GIS Strategic Plan called for the implementation of a CMMS. The CMMS system, Cityworks, was implemented in 2013 with asset management and work order management capabilities.

The work order management system has been developed, however, the asset management system is currently being underutilized. The Water Main Asset Management Plan communicates the process and requirements that will enable the District to enhance decision making capabilities for water main replacements.

2.1 Purpose

The purpose of this Water Main Asset Management Plan is to communicate the process, requirements, and goals of implementing a risk-based asset management strategy for water main replacements. The intended target audience includes internal staff, Board of Directors, and other stakeholders.

Goals of this plan are in direct alignment with the District strategic goals and include the following:

Project Goals	District Goals and Objectives: Promote Planning, Maintenance and Preservation of District Resources
Maximize potential life of water mains.	Develop Projects and Programs to Ensure Safe and Reliable Services
Incorporate condition assessments into existing workflows for water main leaks and leaks.	
Proactively prioritize the replacement of water mains using risk-based methodologies.	
Incorporate condition assessments into existing workflows for water main leaks.	Dedicate Efforts Towards System Maintenance and Modernization
Enable data-driven decisions to rehabilitate or replace water mains.	Enable Fact-Based Decision Making Through State-of-the-Art Data Management

Table 1 - Alignment of project objectives with District's strategic initiatives.

3 Needs Assessment

3.1 District Context

The District operates and maintains approximately 300 miles of water mains within a 30 square mile service area. Water Maintenance staff conducts day-to-day activities related to water main repair and replacement. The Engineering department manages water main replacement Capital Improvement Projects, develops standards for installation and operating procedures, and maintains GIS data for the water system. Both departments work collaboratively in the event of a water main break.

The Operations Manager and Field Service Supervisor oversee water maintenance activities and manages 13 staff members. Cityworks is the primary application used by Water Maintenance staff to document their work orders. The GIS is tightly integrated with Cityworks as both systems complement each other. Cityworks captures reactive and preventative work data that includes work order type, labor, equipment, and material used on a specific asset. The asset repository is the GIS geodatabase that integrates with Cityworks. Maintenance resources can be associated with a specific asset to determine repair or replace decisions. Asset management components of Cityworks have not been leveraged.

3.1.1 Water Main Inventory

The GIS is the system of record for water mains. The official total length for installed water mains is 300 miles, however, the GIS system only accounts for 285.5 miles as shown in the figure below. New water main installations and possibly historical water main information have not been committed to the geodatabase by Engineering technicians. Water mains vary by size and material as shown in the following table.

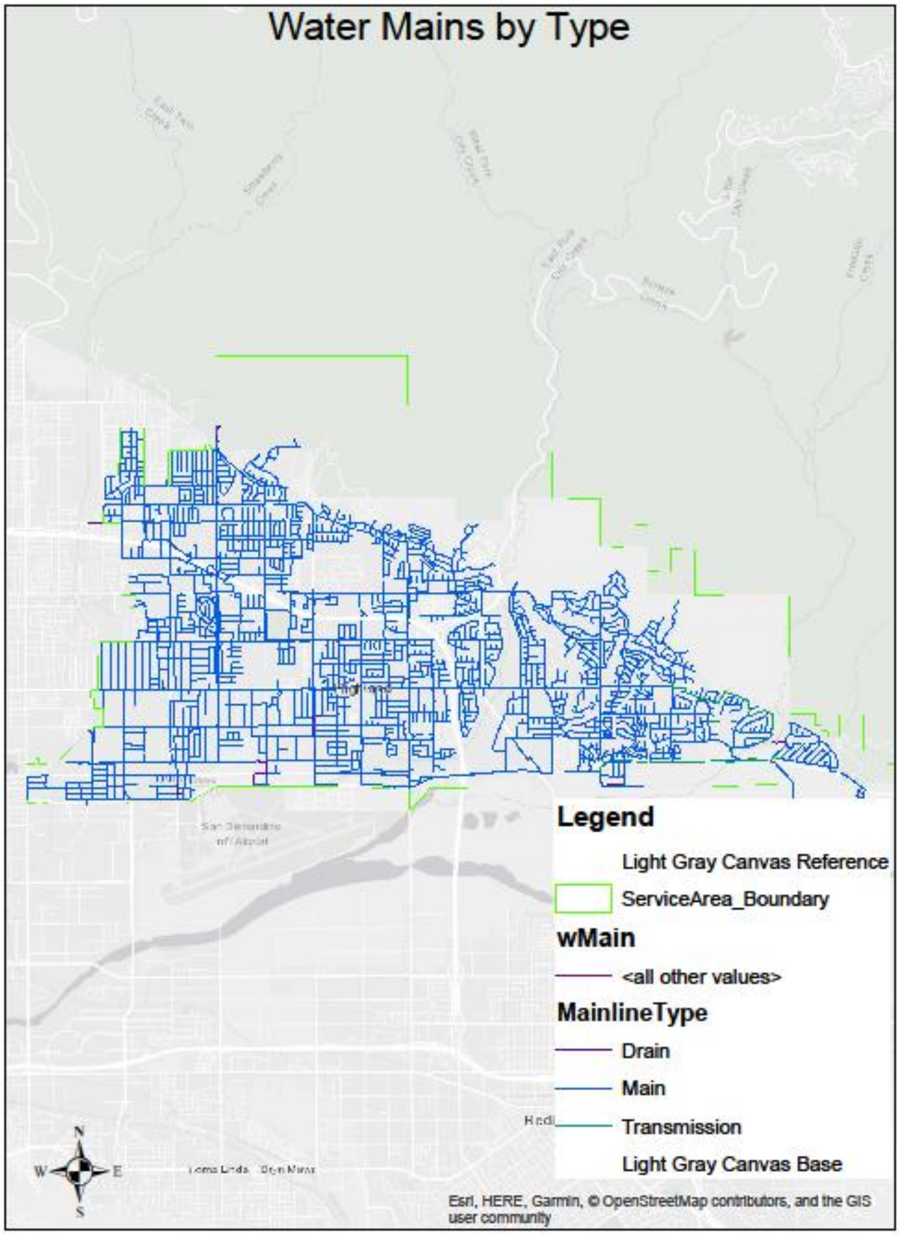


Figure 2 - Water Main Inventory by Type.

Size (inches)	ACP	CIP	CL&C	CL&W	CML	COP	D&W	DD&W	DIP	GIP	PVC	RCP	STL	UNK	Grand Total
1											98		314		412
2	10		48	17		71				359	571		5,963		7,039
3			50			36					8,895		133		9,114
4	16,454	729	133	37			19,220	9,736	277		1,762		12,106	205	60,659
5													121		121
6	291,744	2,324	6,556	2,308	706		34,117	37,277	32,462		36		10,382	52	417,964
8	251,594	244	12,133	2,029	15		7,726	30,402	192,159		1,569		6,319	246	504,435
10	7,055		18,083	4,563			13	2,596	410		233		39		32,992
12	129,795		36,793	31,875	426		447	6,129	66,060		1,470	135	6,501	444	280,074
14	7,233		1,279					1,091	13				24	18	9,659
16	29,003		33,935	2,618	291				40,593		50		178	10	106,677
18									412				120		531
20	644		11,755		501				26,093				1,789		40,781
21			7,478												7,478
24	75		5,837						1,775			762			8,449
30			5,152						1,146						6,298
36	17								14,407						14,423
78			4,610												4,610
Grand Total	733,623	3,297	143,840	43,446	1,939	107	61,522	87,231	375,807	359	14,684	897	43,991	975	1,511,718

Table 2 - Length of mains in linear feet by size and material.

Most of the installed water mains are made with asbestos cement pipe (ACP) followed by ductile iron pipe (DIP). ACP was installed extensively in the past due to its low cost, light weight, and resistance to corrosion. In present day, it is not the material of choice due to asbestos and the pipe breaks easily if not installed properly. Over time, the pipe softens and loses its strength due to internal calcium leaching from potable water or soil conditions. DIP is now generally recognized as the industry standard for water systems. Its characteristics include high strength, durability, and resistance to corrosion.

The District currently faces the risk of water main breaks due to the age and total miles of ACP pipe installed as shown in Table 2.

Age (years)	ACP	CIP	CL&C	CL&W	CML	COP	D&W	DD&W	DIP	GIP	PVC	RCP	STL	UNK	Grand Total
0-10	32,571		57,045	36,856			5,042	50,270	61,955		1,836	762	11,165	52	257,554
11-20	16,062		4,275	791	291		2,122	4,191	170,206		1,599	20	2,651	437	202,646
21-30	85,602		16,609	145	418		1,226	24	97,827		273		6,178	77	208,378
31-40	155,654		20,610	396	559		238	59	1,930		7,500	115	603	24	187,688
41-50	107,989	15	4,550	10	104		812	573	1,252		2,268		599		118,172
51-60	180,824	1,745	16,247	2,913	30	107	14,593	3,449	547	359			782	109	221,705
61-70	23,443		3,809	782			20,619	14,633	690				4,504	37	68,517
70+	1,825	379					592	60	7				149		3,012
Grand Total	603,971	2,139	123,145	41,892	1,402	107	45,244	73,259	334,415	359	13,475	897	26,631	736	1,267,672

Table 3 - Length of mains in linear feet by age group and material.

3.1.2 Water Main Leak History

Since the beginning of 2006, 4.457 leaks or breaks have been documented in the geodatabase. From 2017 and 2018 (as of 12/12/2018), Water Maintenance workers recorded a total of 205 service leaks and 118 main breaks. Reactive maintenance activities costs include equipment, labor, and material which totaled approximately $150,000 in 2017 and another $111,000 in 2018.

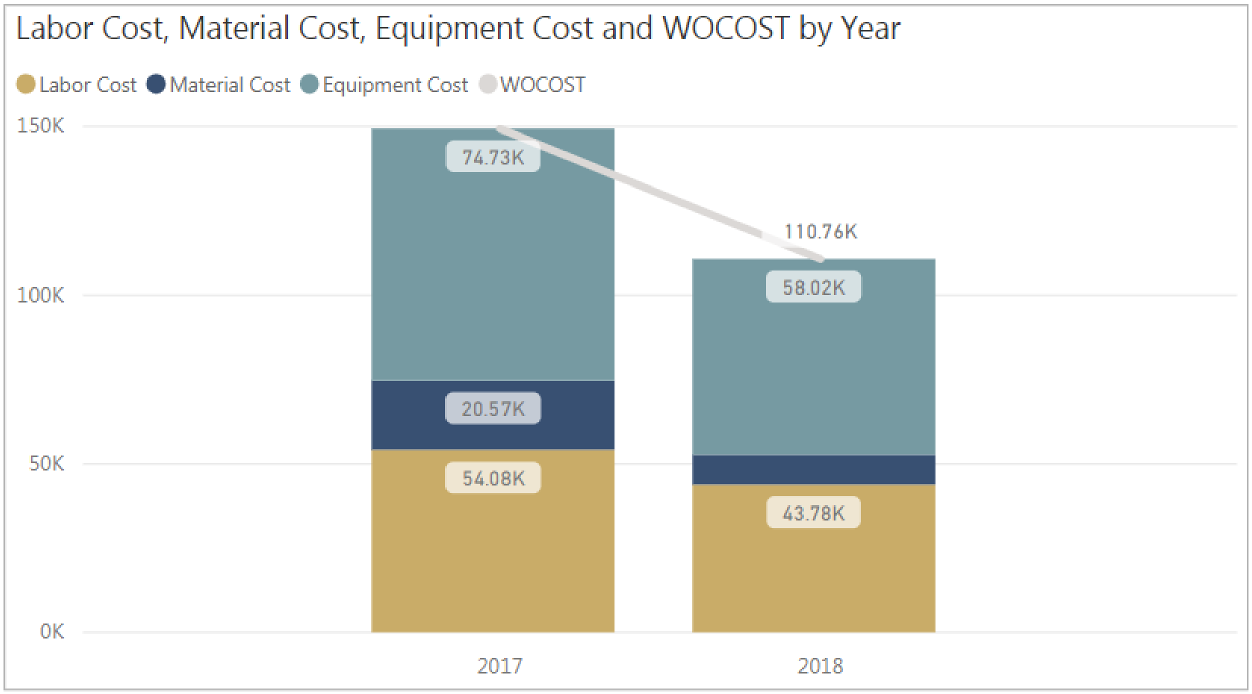


Figure 3 – Equipment, labor, and materials costs for water maintenance presented in Power BI using Cityworks work order data.

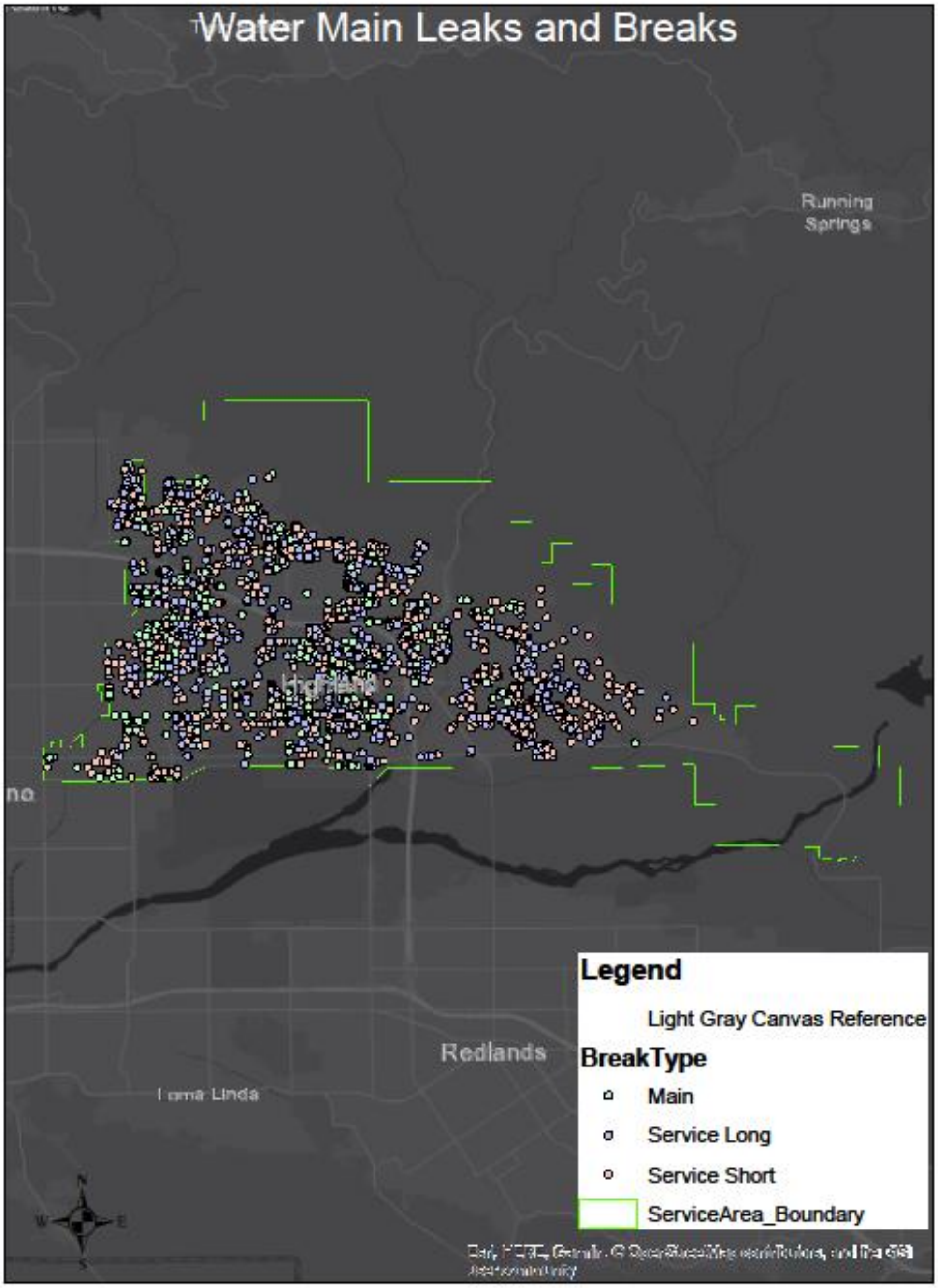


Figure 4 – Historical water main leaks and breaks by Break Type.

3.1.3 Regulation

The Senate Bill No.555 is a bill that relates to urban retail water suppliers: water loss management. Current law requires California to achieve a 20% reduction in urban capita water use by December 31st, 2020 (Wolk, S, 2015). This Senate Bill will require each urban water supplier to submit a completed and validated water loss audit report for the previous fiscal year. These water loss audit reports will be made available on the internet to for cross comparison across water suppliers and open to the public for viewing.

The movement forward of this bill will require State Water Resource Control Board, that no later than July 1st, 2020 to adopt rules requiring water suppliers to meet performance standards for the volume of water losses. The State Water Resource Control Board through this bill will be required to contribute up to $400,000 using available funds from the previous fiscal year towards procuring water loss audit report validation assistance for urban water suppliers (State of California, 2015).

3.2 Business Processes

3.2.1 Water Main Leak Business Process

The initiation of the water main leak process can originate from the District's preventative and reactive work activities or as a result from a citizen reporting an observed incident. Customer service receives notification through the following channels: phone call, email, and website. A work order for a water main leak is then created in the computerized maintenance management system (Cityworks) by Water Maintenance staff.

The work order collects location-based data, asset, work flow data, and costs associated with equipment, labor, and material. Additionally, water loss in gallons is collected in the work order to satisfy regulatory reporting requirements. The asset collected in the work order is a specific asset, water main in this case, that is a system of record in the GIS database. Once a work order closes, the following staff members are notified with the results through email and Cityworks: Customer Service department, Water Maintenance staff, and Engineer staff.

3.2.2 GIS Related Business Processes

GIS Data Maintenance

Ongoing data maintenance work activities are performed by two full-time staff members of the Engineering department that utilize a variety of Esri developed GIS applications to maintain the geo-database. Attributes for asset data, including all water lines, are frequently updated as a business process. Data quality verification and update requests can initiate from water maintenance staff if they notice a discrepancy in the field compared to what the GIS is reporting.

Managing the GIS Infrastructure

The District's Network Administrator and Information Technology Manager manage the GIS infrastructure responsible for the operations of the GIS system. Components of the GIS system managed by District staff include server management, networking, cybersecurity, database management, and communications.

GIS Support

The District currently holds Small Utility Enterprise License Agreement with Esri that includes support services for incidents related to software. A consultant, Miller Spatial, has provided support services since the implementation of the GIS system. Support services include day-to-day support, single purpose projects, custom development, integration services, strategic guidance, and other services to further the District's GIS initiatives.

3.3 Business Needs

3.3.1 Asset Lifecycle Management

To ensure effective investing around assets, East Valley Water District must assess the lifecycle of existing water mains in the District. The first phase in the lifecycle is considered one of the most critical, the approach to reduce overall risk exposure in the design phase is considered front-end minimization of risk. The difference between assessing risk in this phase as opposed to risk exposed during the operating lifecycle phase, is that at the operating level phase the risk reduction is restricted to implementing procedures that have limited effectiveness's as opposed to taking action in the design phase based on the data driven results assessed through the lifecycle management solution that East Valley Water Districts utilizes.

The illustration below showcases the lifecycle journey and its various stages. Using Geodata enables an assets geolocation, which allows the data to be understood visually on a map. Therefore, having that data visually shown improves the validity and improves the data collection throughout the asset's lifecycle. (Engineering, 2015)

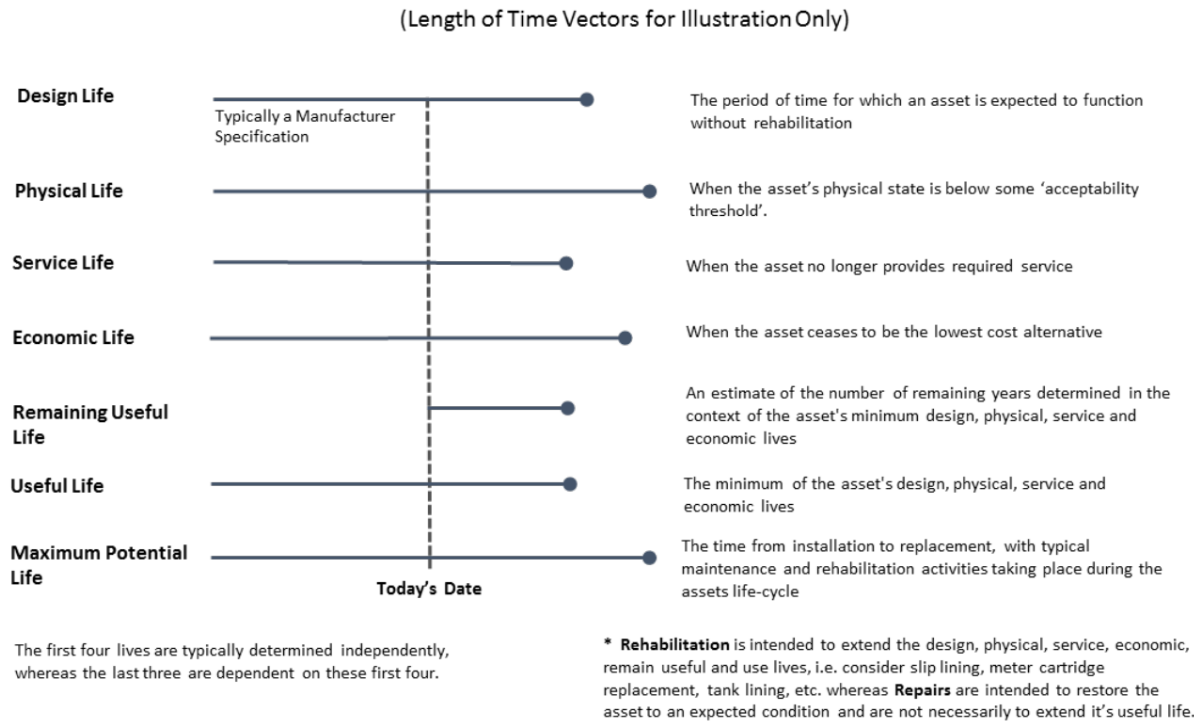


Figure 5 – Asset Lifecycle Management used to maximize potential life of asset.

3.4 Application Needs

The advantages of integrating GIS with other systems, solutions, and products is that GIS has the ability to improve organizational integration. All software will be utilized to create an information product that will provide managers the ability to make strategic decisions. GIS also provides various approaches to view, question, understand, visualize and interpret data. For example, the District can reveal relationships, trends, and patterns of a section of water line that require reoccurring maintenance.

3.4.1 Insights for ArcGIS

Insights for ArcGIS is web-based data analytics made for advanced location intelligence (ESRI, 2018). The District employees are able to explore data and perform advanced analytics such as spatial, statistical, and predictive analysis. Insights is a very critical program that allows employees to join spatial and tubular data. When the data is combined various analytics can be ran, analyzed, and sent to other ArcGIS products such as Operations Dashboard.

3.4.2 Operations Dashboards

Operations Dashboard for ArcGIS is a configurable web app that provides location-aware data visualization and analytics for a real-time operational view of people, services, assets, and events (ESRI, 2018). Users can use dashboard to view the activities and Key Performance Indicators (KPI) most vital to meeting the District's objectives. Operations Dashboard for ArcGIS leverages all the ArcGIS data that is collected and integrates data from other sources, including real-time feeds, to give additional context and scope. The District is able to monitor, track, and assess the critical factors for successful operations in real time. Field workers can use data analytics to support strategic and tactical decisions across the organization.

3.4.3 Cityworks

Cityworks is a Web GIS-centric enterprise asset management system. Users apply Cityworks to manage, track, analyze, and score infrastructure assets. Cityworks is compatible with most Esri ArcGIS products (Cityworks, 2018). Utilizing both Cityworks and ArcGIS, the District is able to track a projects maintenance from start to finish. Also, the District is able to use GIS data to monitor risk and prevent foreseen damages with predictive analytics. Employees can now discover additional operational insights to make informative decisions.

3.4.4 Microsoft Power BI

Power BI is a business analytics solution that lets users visualize data and share insights across the organization, with the option to embed them in any app or website. Software allows users to connect hundreds of data sources and bring data to life with live dashboards and reports (Microsoft BI, 2018). Utilizing Power BI, the District can collect and publish real-time content that users within the organization can access in the office or out in the field. If a fieldworker wants to break ground and investigate a possible leak, the worker can provide real time details on the inspection and can perform analysis from start to finish. The District provides data-driven alerts regarding possible risky pipe lines. Also, users can interact with reports, graphs, and other visual analytics.

3.5 Data Needs

3.5.1 Condition Assessment Data

Incorporate condition assessment data collection into work orders. Condition assessment of water mains provides high value when used as a factor for to determine the Probability of Failure. The data can also be used to determine the expected useful life of a water main and support "repair or replace" business decisions.

3.5.2 Water Main Break Evaluation – Data Collection

Water Maintenance staff collects water main break data by creating work orders in Cityworks. Data collection efforts include capturing costs that include labor, equipment, and material. The asset (water main) is also attached to the work order to associate maintenance costs. Additional data collection could improve analysis and decision-making capabilities. It is recommended that the American Water Works Association (AWWA) Main Break Evaluation form be used as a guide to collect more data.

MAIN BREAK EVALUATION
(page 1 of 2)

FIELD DATA FOR MAIN BREAK EVALUATION: PROJECT NUMBER ___________					
Date of Break: ______________		Time: ________	☐A.M.	☐P.M.	
Name of Person Filling the Form:					
Type of Main: ______________					
Size (OD): ______in._		Joint: __________		Cover: ___ft ___in	
Wall Thickness at Failure: ________in.		Other:			
Nature of Break:					
☐ Circumferential		☐ Longitudinal; Clock Position: ___	☐ Both	☐ Leak	
☐ Blowout	☐ Joint	☐ Sleeve	☐ Split at Corporation	☐ Other	
Apparent Cause of Break:					
☐ Water Hammer (Surge)		☐ Defective Pipe	☐ Deterioration		
☐ Corrosion		☐ Improper Bedding	☐ Operating Pressure		
☐ Temperature Change		☐ Differential Settlement	☐ Contractor/Third Party		
☐ Other: ______________					
Pipe Location Information:					
☐ Paved	☐ Unpaved	Traffic: ☐ Heavy	☐ Medium	☐ Light	
Type of Street Surface: __________		Weather:	☐ Sunny	☐ Cloudy	
Type of Soil: __________		Resistivity: __________		ohms/cm	
Electrolysis?	☐ Yes	☐ No	Corrosion?	☐ Inside	☐ Outside
Other:	☐ Rocks	☐ Voids	Proximity to Other Utilities: ________		
	Depth of Frost ________in.		Depth of Snow: ________in.		
Comments:	______________				

MAIN BREAK EVALUATION
(page 2 of 2)

OFFICE DATA FOR MAIN BREAK EVALUATION: PROJECT NUMBER ___________				
Name of Person Filling the Form:				
Weather Conditions During Previous Two Weeks: ______________				
Sudden Change in Air Temp:	☐Yes ☐No	Average Temp: ___°F Rise: ___°F Fall: ___°F		
Sudden Change in Water Temp:	☐Yes ☐No	Average Temp: ___°F Rise: ___°F Fall: ___°F		
Historical Pipe Data:				
Type of Main: ________		Class/Thickness: ________	Laying Length: ________ft	
Date Laid: ________		Design Operating Pressure: ________psi		
Previous Break Reported?	☐Yes ☐No	Pressure at Previous Break? ________psi		
Historical Installation Data:				
Bedding:	☐ Gravel	☐ Sand	☐ Native Material ________	
Backfill:	☐ Gravel	☐ Sand	☐ Bank Run Sand and Gravel	☐ Rock
	☐ Native Material: ________			
	☐ Other: ________			
Compaction:	☐ Natural	☐ Water	☐ Compactors	☐ Vibrators
	☐ Other: ________			
Comments:	________			

OTHER DATA	
Location of Break: ______________	Map Number: ____
Reported By:	______________
Damage:	______________
Repairs (Equipment, Materials, Labor): ______________	
Repair Difficulties (if any): ______________	
Installing Contractor: ______________	

AWWA Checklist

Figure 6 – AWWA Main Break Evaluation form can be used as a reference for data collection .

4 Implementation Plan

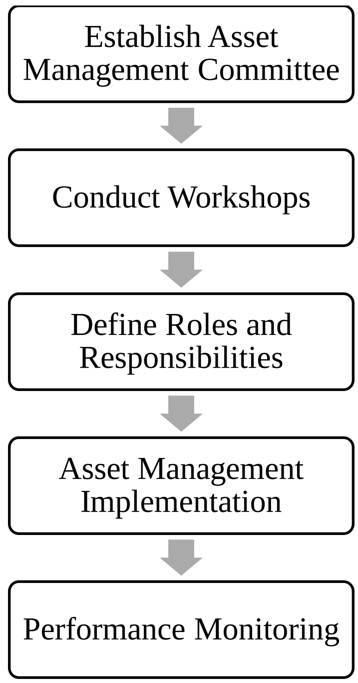


Figure 7 – Water Main Asset Management Implementation Plan process overview.

4.1 Establish Asset Management Committee

The Asset Management Committee (AMC) will be responsible for supporting and making decisions pertaining to actions that impact the District's assets, including operational procedures and the use of technology. Governance is defined as a process to establish effective and efficient use of technology and asset management best practices that will enable the District to achieve its goals and objectives. The AMC will include cross-functional members from each department that will participate in a collaborative manner to ensure asset management objectives are aligned with the District's top priorities.

Members will analyze departmental and inter-departmental business processes to identify areas for improvement with technology. The group will collaboratively assess the impacts to changes in business processes that may affect operations or quality of service. The AMC will provide guidance to changes and communicate them to staff and ensure District-wide compliance.

Other tasks include identifying, reviewing, and analyzing Key Performance Indicators (KPIs) in terms of how technology can be applied to better capture, measure, and report KPIs to determine operational efficiency and effectiveness. Members are encouraged to participate and contribute to creative thinking sessions. The Chair will facilitate the innovation process by documenting ideas and reviewing historical ideas with members.

4.2 Conduct Workshops

4.2.1 Asset Management Workshops

The Asset Management workshops will provide an overview and the purpose of asset management. All stakeholders are encouraged to attend these workshops to understand the District's status of asset management and the scope of this project. Benefits and risks should be described to the respective target audiences.

4.2.2 Technology Workshops

The technology workshops are for end-users impacted by proposed changes. Changes to applications will result in changes in the business process. It is important to communicate these changes to staff and seek input about concerns and risks. Change resistance mitigation should be considered when making changes to software and workflows.

4.3 Define Roles and Responsibilities

The District's primary asset classes are water and sewer. Asset management best practices recommend aligning functional roles with asset classes. For this specific project, a group of people from multiple functional roles is required due to the different skillsets required for planning and implementation. All roles, responsibilities, and expectations will be clearly defined to ensure standardization across the District.

4.3.1 Staffing

The figure below illustrates the staff members required to plan and implement an asset management program for water mains.

Figure 8 – Staffing requirements to support project implementation and operations.

4.4 System Configuration

The existing system currently satisfies the requirements to complete this project. Existing technology will be leveraged and includes workstations, servers, applications, or the network. Configuration changes to the Cityworks and GIS applications will be required to implement the project. Test and development environments exist for Cityworks, along with a test environment for the GIS system.

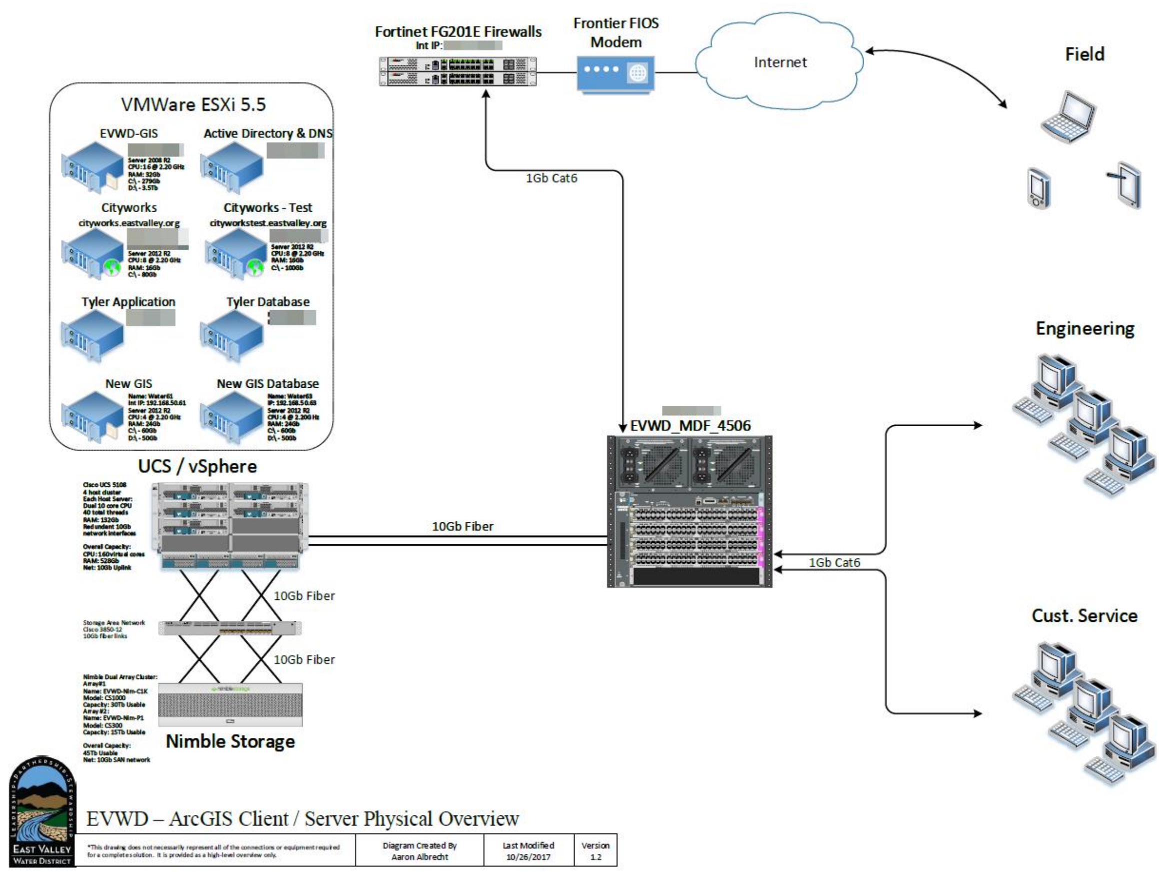


Figure 9 – Existing system configuration required to support the project.

4.5 Asset Management Implementation

4.5.1 Asset Inventory

The first step in conducting asset management activities is to complete an asset inventory and maintain its accuracy. This is critical because the asset registry serves as the foundation of an asset management system. The District's geodatabase is the current system of record for all infrastructure assets, including water mains. The following figure demonstrates the structure of an asset registry.

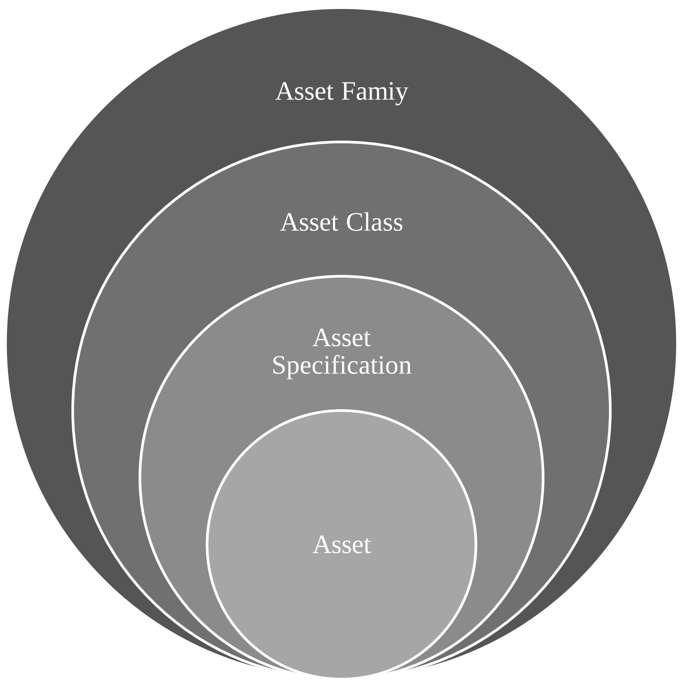


Figure 10 – Asset registry diagram is similar to geodatabase.

Using the asset registry figure from above, the District's water mains are structured in the following manner in the geodatabase:

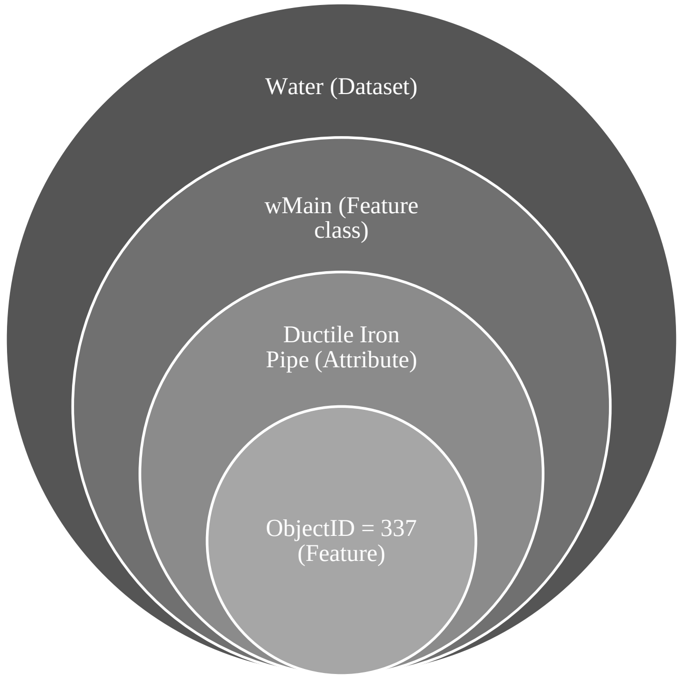


Figure 11 – GIS water main represented as asset registry class.

As of this writing, there are 14,321 records in the “wMain” dataset. It is known that not all water mains have been accounted for as the GIS system under reports the length of water mains when compared to the official miles reported in public documents. The cause of missing records is attributed to a backlog on data maintenance activities in the Engineering department when new water mains are added to the District’s infrastructure.

In addition to data maintenance performed by Engineering staff, a recommendation to adopt Collector for ArcGIS for field staff will enhance the District’s data quality. Water Maintenance staff typically report mapping inaccuracies through paper or email. The Collector mobile app will allow field staff to submit ‘redlining’ activities to Engineering in the event they discover inaccurate data pertaining to water mains or other assets.

4.5.2 Inventory of Programs

The District manages and operates a variety of programs such as water quality testing, hydrant flushing, and lead testing. The Water Main Replacement program plays a vital role in asset management and is funded by Capital Improvement Projects (CIP). Existing Capital Improvement water projects are estimated at $22.1 million and includes pipe, hydrant, and other asset replacements. A Water System Master Plan (WSMP) is conducted at 5-year intervals and provides a comprehensive analysis of the overall system and proactively determines future CIP's.

A WSMP was completed in 2014 and a new WSMP is currently being drafted. In 2014, the total projected capital costs were $184.3 million with $32.2 million attributed to pipelines. During the discovery session of the new WSMP, consultants requested condition assessment data of water mains to enhance their analysis. Condition assessment data was not used due to the lack of data.

In Fiscal Year 2018-2019, the District scheduled the replacement of approximately 8,400 linear feet of water mains in areas where leaks were frequently reported. The funding source for this $200,000 project is through operating revenue. A new transmission main was also budgeted for the fiscal year at $1.1 million.

4.5.3 Determine Levels of Service

As indicated in the District's current adopted Budget (East Valley Water District, 2018), the Water Maintenance program has established four Key Performance Indicators (KPIs) that are aligned with the District's strategic goals and objectives:

- Provide timely response and assessment of customer leak concerns (avg. time)

  - Within 4 hours
- Exercise a set number of gate valves annually
- Number of staff members with D-3 certification or higher
- Average annual equipment and safety training hours per staff member

The first KPI pertains to this project, specifically the “assessment” portion of customer leak concerns. The assessment can be improved by collecting condition assessment ratings for water mains to be used in a risk management framework. Other KPI’s that impact the District’s Levels of Service should be considered to monitor system performance and customer service:

- Number of water main breaks per 100 miles of pipe
- Unaccounted for water (real water loss)
- Infrastructure Leak Index (ILI)
- Reactive maintenance costs
- System availability

Engineering staff is the foundation for the project as they are responsible for the Water System Master Plan, water system specifications, CIPs, and Risk Model Development for this project. Water Maintenance staff will require training to understand the new Risk Model to uniformly collect condition assessment data for water mains. They ultimately maintain the water system and possess the most intimate knowledge of physical conditions of the water system. Several Technical functional roles will be responsible for understanding Engineering’s risk model and will need to modify applications and databases to collect new data. Technical staff will also be deploying new tools such as Collector and Insights. Finally, collaboration with

Finance staff is necessary to plan for the budgeting of water main replacements and gain a better understanding of depreciating assets with the new information using a risk-based approach.

4.5.4 Identify and Calculate Risks

The primary driver and desired output for this project is to calculate the risk and determine the severity consequences for a water main using a risk model. Decisions to prioritize water main replacements will be data-driven using a reproducible method that is both transparent and fiscally accountable.

4.5.5 Business Risk Exposure Model

Engineering staff, GIS staff, and an Asset Management subject matter expert will be tasked with developing a risk model using this simplified equation:

Business Risk Exposure = (Likelihood of Failure) x (Consequence of Failure)

The Probability of Failure (PoF) is the likelihood of the water main failing in a given period and represented in a decimal or as a percentage. The Consequence of Failure (CoF) are observable events should a water main fail and include service, environmental, social, and health concerns. The Business Risk Exposure (BRE) represents the level of risk exposure the water main is likely to present to the District should the water main potentially fail.

It is recommended that the District begin with a simple model using a limited number of factors. The model can be adjusted in the future as new data becomes available through data collection or GIS analysis. The following figure demonstrates how complex a model can be developed by using a higher number of factors in the PoF or CoF:

Probability of Failure	Consequence of Failure
• Age • Condition assessment • Material • Capacity • Installer • Soil characteristics • Physical loads • Maintenance history (leaks and breaks) • Fault lines	• Capacity • Population served • Critical facilities served (hospitals, airports, businesses) • Budget impacts • Health/welfare concerns • Levels of service • Safety concerns

Table 4 – Factors to consider for Probability of Failure and Consequence of Failure ratings.

The BRE results are then classified into Risk Classes and can be used to prioritize water main replacement projects. A higher BRE score indicates a high-risk exposure level. An action should be assigned to each risk class.

RISK CLASS	EXAMPLE OF ACTION AND NEXT STEP
EXTREME	HighPriority In CIP/ Annual Operational Frequency
HIGH	Standard Priority In CIP/ Bi-Annual Operational Frequency
MEDIUM	Low Priority In CIP/ 1 In 5 Years Operational Frequency
LOW	1 In 10 Years Operational Frequency
NEGLIGIBLE	Wait for a problem to arise

Figure 12 – Risk class classification categories with recommended action example.

4.5.6 Modify Water Main Attributes

In the geodatabase, the water main asset's attributes are modified by adding new attributes from the BRE Model. The following data columns are added:

Data Column (attribute)	Data Type	Description
POF	Short Integer	Probability of Failure Score
COF	Short Integer	Consequence of Failure Score
BRE	Short Integer	Business Risk Exposure Level
ConditionAssessment	Short Integer	Condition Assessment Score

Table 5 – Water main attribute additions to support business risk model.

An asset-level based analysis can be conducted using factors from the risk model. Various information products will use this data to identify trends and patterns, monitor performance, and justify decision-making.

4.5.7 Determine Risks and Consequences using GIS Analysis

4.5.7.1 Soil Corrosion Risk Analysis

USA Soils Corrosion Steel layer was obtained through Esri's Living Atlas. The dataset was created by the USDA Natural Resources Conservation Service and consists of decades worth of data collection on a county by county basis. The darker tones indicate highly corrosive soil that deteriorates iron in steel at higher rates and can lead to a reduction in a water main's expected useful life.

A GIS technician will need to create a polygon layer for highly corrosive soil and analyze intersect relationships to steel pipes. The risk model will assign more weight to the probability of failure in pipes that were installed in highly corrosive soil.

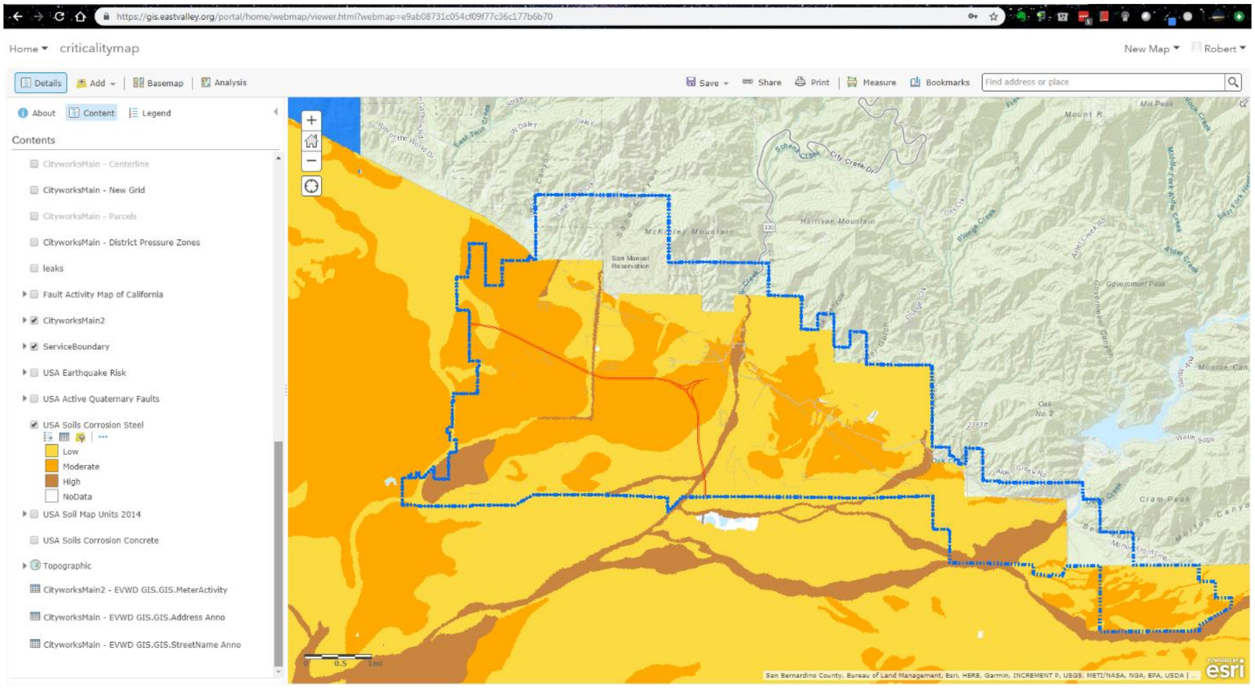


Figure 13 – Soil corrosion layer obtained from Esri's Living Atlas.

4.5.7.2 Determine Service Impact using Valve Isolation Trace Analysis

The Valve Isolation Trace Analysis uses the geometric network of water mains and simulates a water main break to determine the number of customers that will be impacted. The consequence of failure score correlates with the number of customers impacted by a water main break. The figure below displays red colored water mains with higher consequences due to the number meters impacted.

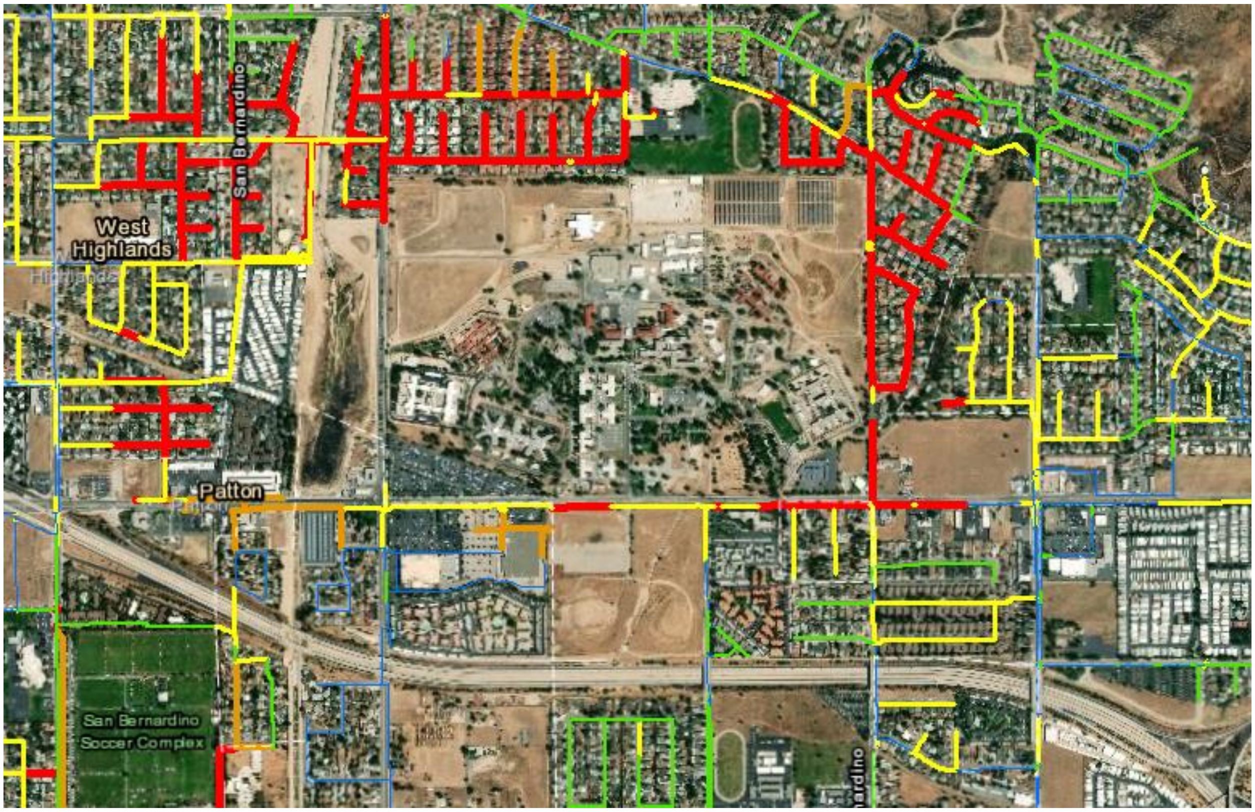


Figure 14 - Water mains symbolized based on consequence of failure due to number of meters impacted.

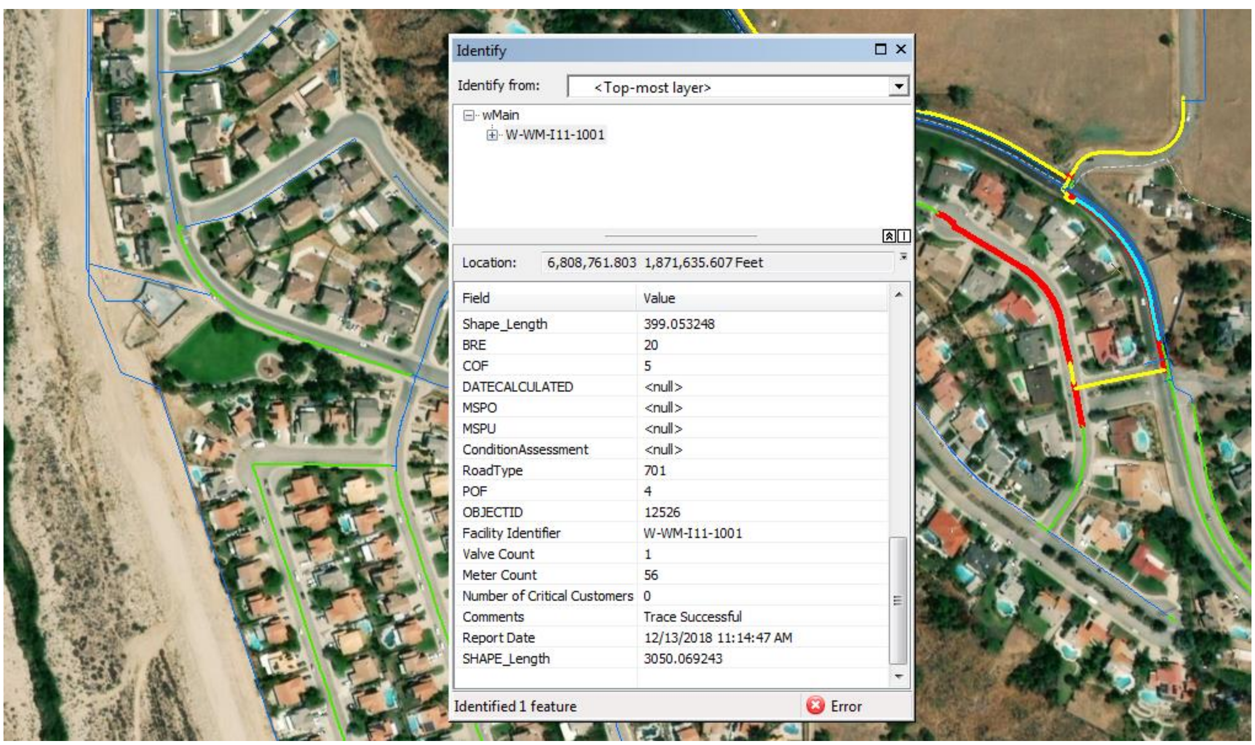


Figure 15 - Valve isolation trace analysis result for a specific water main identified in the GIS.

The results of the analysis produce a new dataset named "MainsWithTraceSummary" that include a record for each water main, valves involved, number of meters impacted, and identified critical customer. This dataset will be used in the Business Risk Exposure model and other analytical tools.

Table

wMainsWithTraceSummary

OBJECTID *	Facility Identifier *	Valve Count	Meter Count	Number of Critical Customers	Comments	Report Date
10158	W-WM-J13-1163	3	8	0	Trace Successful	12/13/2018 8:44:19 AM
10159	W-WM-L15-1077	3	0	0	Trace Successful	12/13/2018 8:47:39 AM
10160	W-WM-L15-1076	3	0	0	Trace Successful	12/13/2018 8:47:41 AM
10161	W-WM-L15-1080	2	4	0	Trace Successful	12/13/2018 8:47:43 AM
10162	W-WM-L15-1079	3	0	0	Trace Successful	12/13/2018 8:47:45 AM
10163	W-WM-L16-1045	2	18	0	Trace Successful	12/13/2018 8:47:47 AM
10164	W-WM-L16-1041	2	18	0	Trace Successful	12/13/2018 8:47:49 AM
10165	W-WM-L15-1122	5	0	0	Trace Successful	12/13/2018 8:47:51 AM
10166	W-WM-L15-1124	5	0	0	Trace Successful	12/13/2018 8:47:53 AM
10167	W-WM-L16-1028	2	18	0	Trace Successful	12/13/2018 8:47:55 AM
10168	W-WM-L16-1005	2	4	0	Trace Successful	12/13/2018 8:47:56 AM
10169	W-WM-M16-1019	3	0	0	Trace Successful	12/13/2018 8:47:58 AM
10170	W-WM-M16-1018	2	17	0	Trace Successful	12/13/2018 8:48:00 AM
10171	W-WM-M16-1026	2	8	0	Trace Successful	12/13/2018 8:48:02 AM
10172	W-WM-L16-1064	4	0	0	Trace Successful	12/13/2018 8:48:04 AM
10173	W-WM-L16-1062	4	0	0	Trace Successful	12/13/2018 8:48:06 AM
10174	W-WM-L16-1061	4	0	0	Trace Successful	12/13/2018 8:48:08 AM
10175	W-WM-L16-1063	4	0	0	Trace Successful	12/13/2018 8:48:10 AM
10176	W-WM-L16-1053	3	0	0	Trace Successful	12/13/2018 8:48:11 AM
10177	W-WM-L16-1052	3	0	0	Trace Successful	12/13/2018 8:48:13 AM
10178	W-WM-L16-1050	3	0	0	Trace Successful	12/13/2018 8:48:15 AM
10179	W-WM-L16-1014	2	4	0	Trace Successful	12/13/2018 8:48:17 AM
10180	W-WM-L16-1015	2	4	0	Trace Successful	12/13/2018 8:48:19 AM
10181	W-WM-L16-1017	2	0	0	Trace Successful	12/13/2018 8:48:21 AM
10182	W-WM-L16-1016	2	0	0	Trace Successful	12/13/2018 8:48:23 AM

1 (0 out of 4654 Selected)

wMainsWithTraceSummary

Table 6 - Attribute table for water main valve isolation trace analysis.

4.5.8 Business Risk Exposure Analysis

The goal is to predict the future by calculating the Business Risk Exposure (BRE) level for each water main to determine the water main's expected useful life. The accuracy of the prediction increases based on the quality, volume, and variety of data. The BRE value can also be used to prioritize the replacement of water mains based on risk.

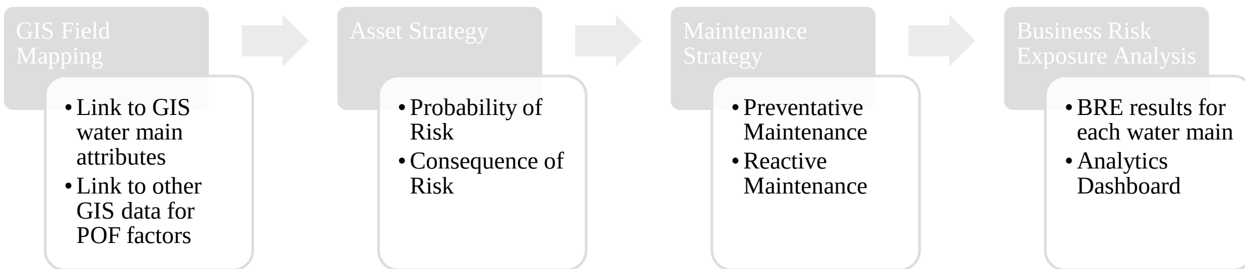


Figure 16 – Business Risk Exposure Analysis configuration process in Cityworks Operational Insights.

The first step in building the model is mapping GIS fields from the water main asset with the model using Cityworks Operational Insights. Risk factors are using data sources from the GIS and Cityworks databases.

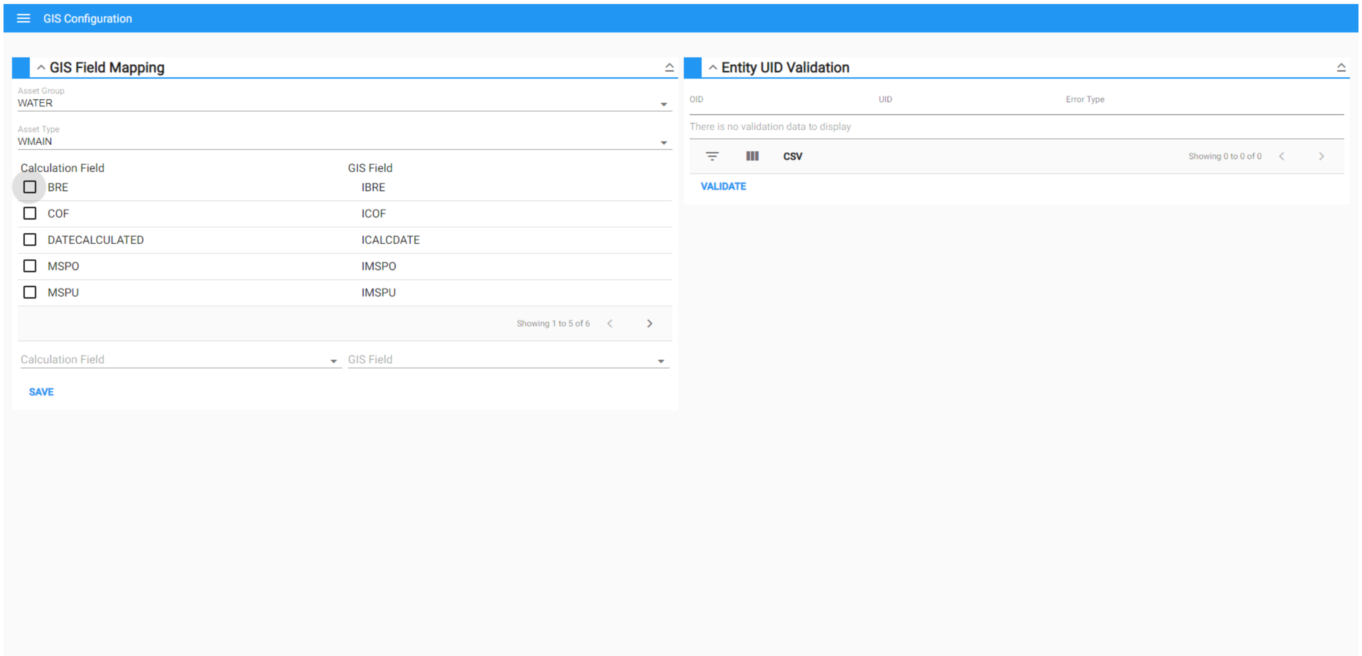


Figure 17– GIS Field Mapping in Cityworks Operational Insights

The Asset Strategy Setup step includes configure the POF and COF factors. The screenshot below displays how Risk Factors are assigned weights for scoring.

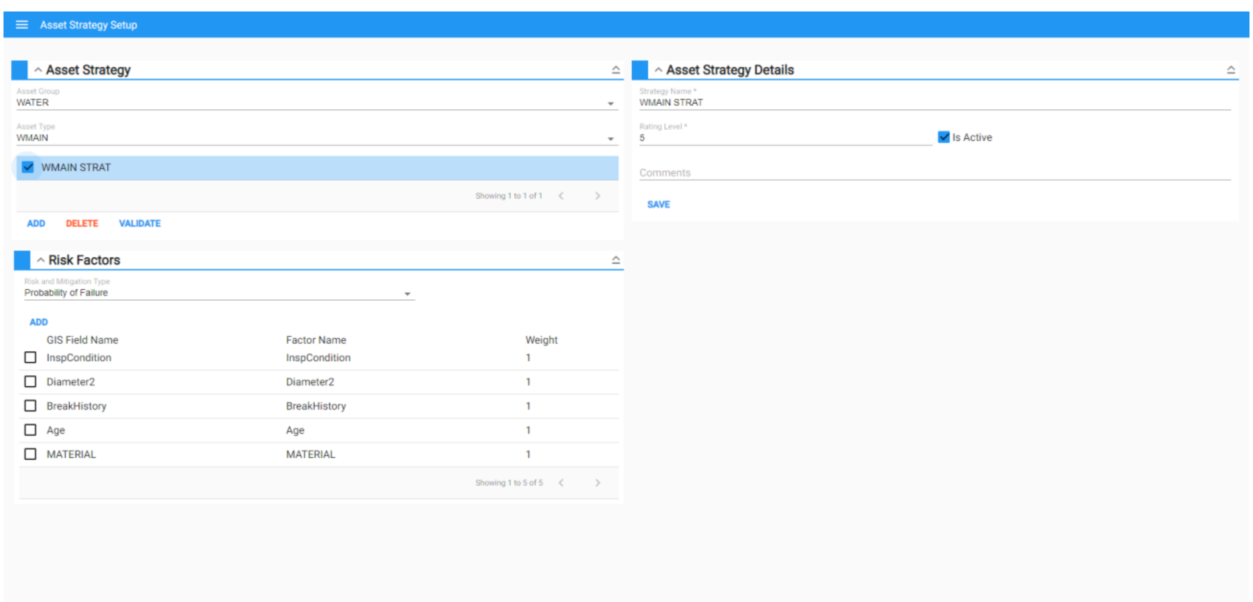


Figure 18 - Configuring Probability of Failure using risk factors.

The final step in the Asset Strategy Setup is to configure the COF. Similar to POF factors, each COF factor can be assigned a weight.

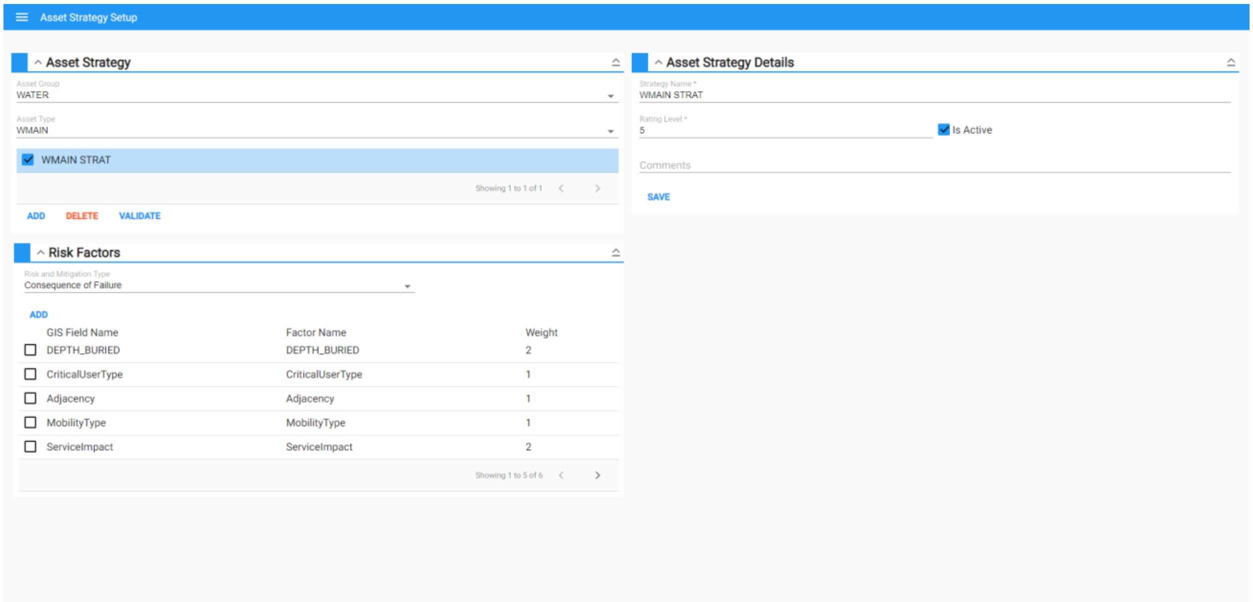


Figure 19 - Configure Consequence of Failure factors in the Asset Strategy Setup

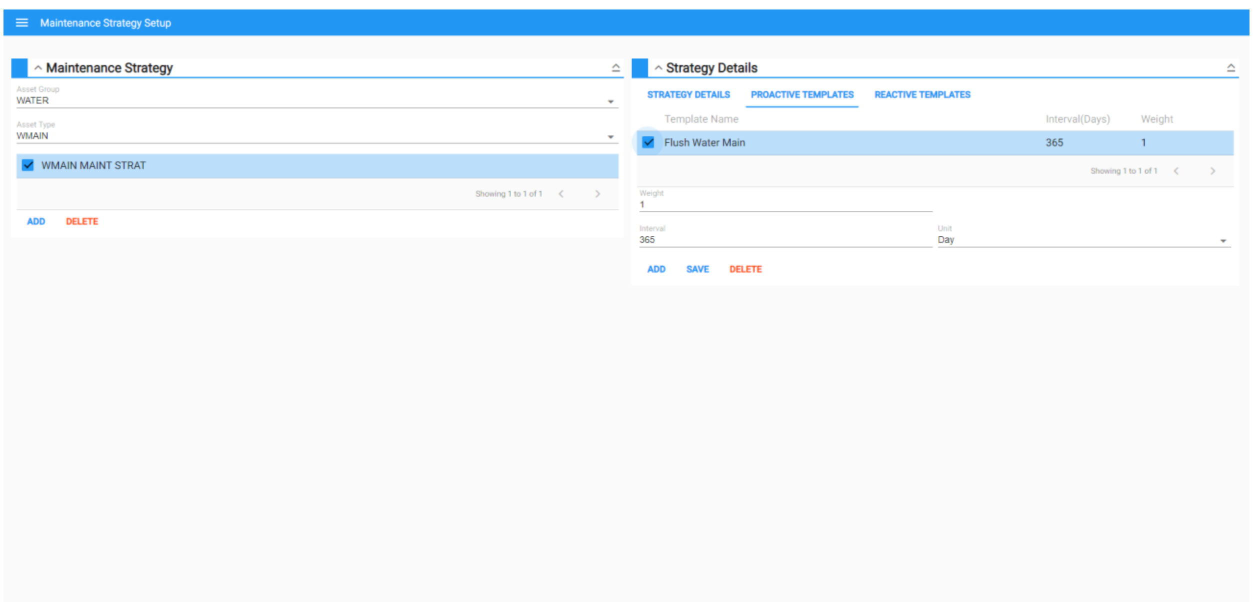


Figure 20 – Configure Proactive Maintenance for water maintenance strategy.

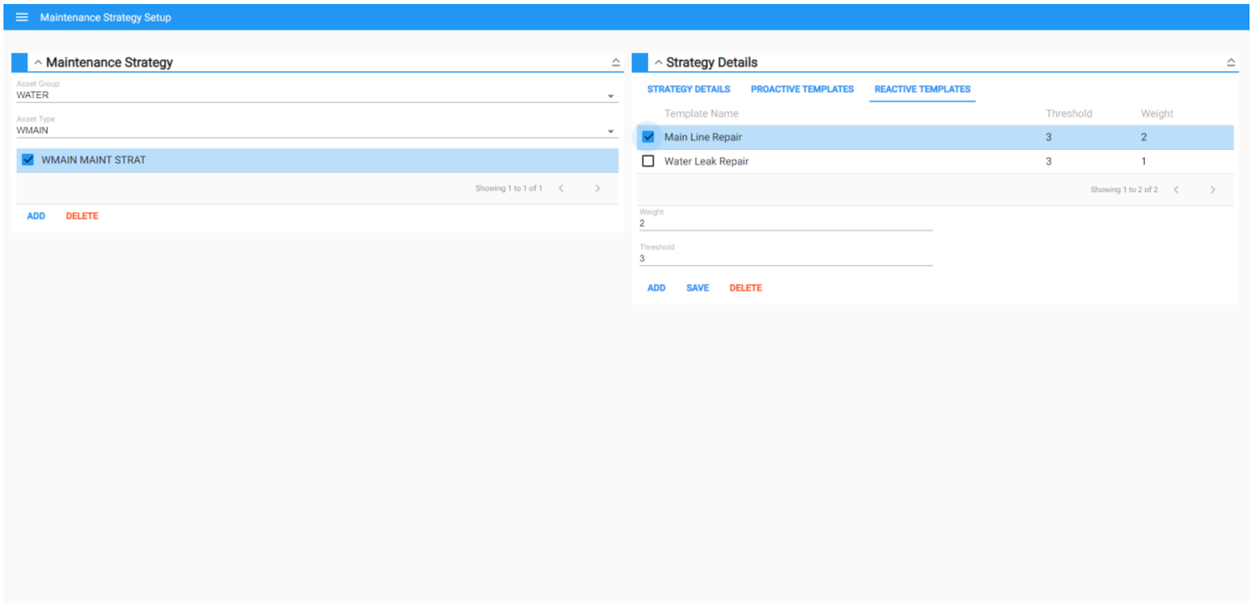


Figure 21 – Configure Reactive Maintenance using Water Line Repair and Water Leak Repair maintenance activities.

An asset-based level of analysis will be conducted using the Cityworks Operational Insights application. The risk factors and consequences ultimately drive the analysis using the risk model. The forecast will assign the Business Risk Exposure level for each water main using a weighted calculation from the risk model.

4.6 Performance Monitoring

Using existing data and new data collected from modified business processes, information is presented in various information products. Using this information provides the basis to make data-driven decisions from measuring key performance indicators and identifying trends and patterns.

Figure 22 – Data is transformed into knowledge. Information products enhance the decision-making process and are provided in the GIS Design and Prototype Deliverables section.

4.7 Implementation Schedule

WATER MAIN ASSET MANAGEMENT PROJECT SCHEDULE

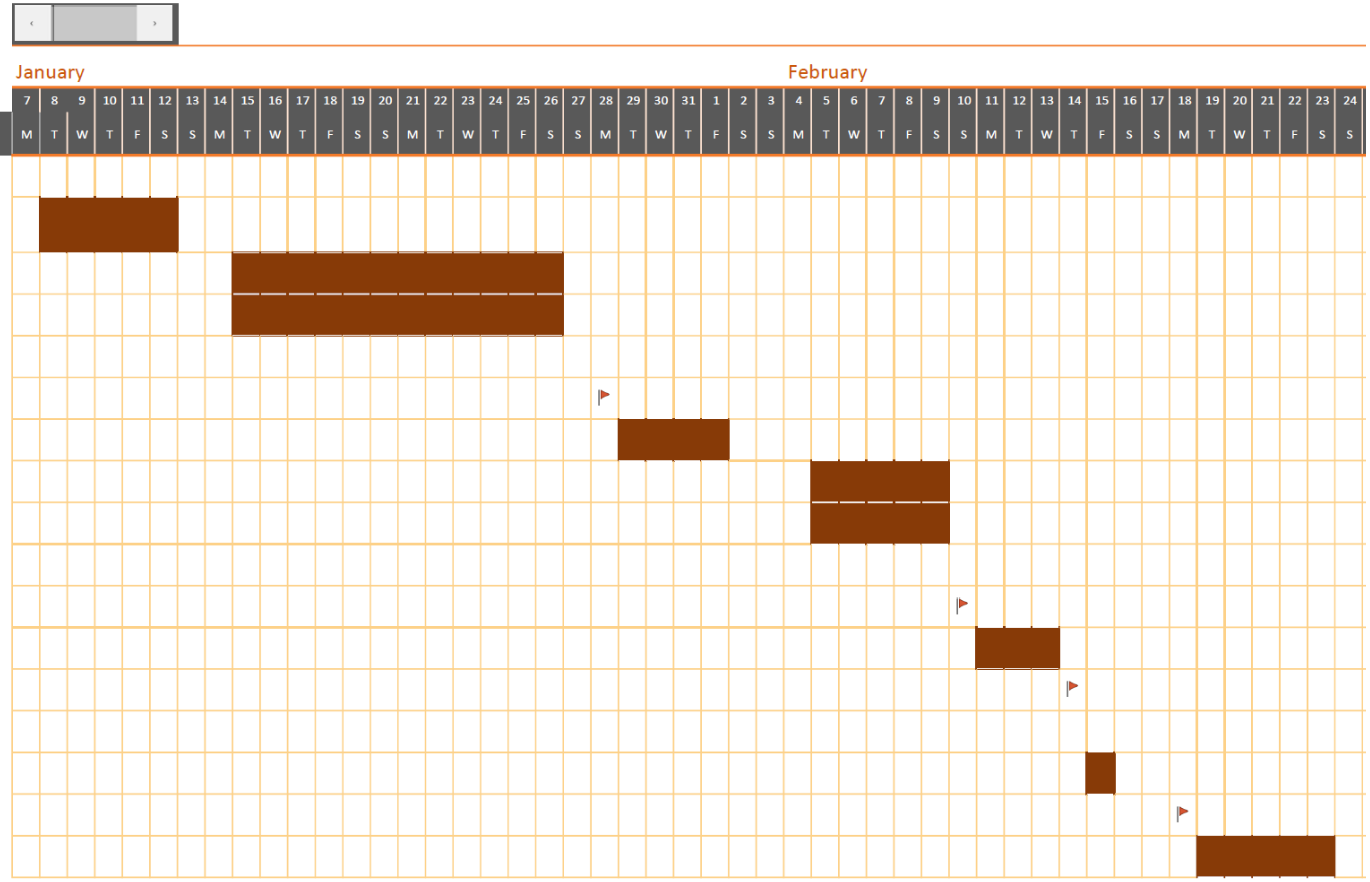
East Valley Water District

1/7/2019

0

1

Milestone Descriptio	Progress	Start	No. Days
Phase 1			
Establish Asset Management Committee		1/7/2019	7
Conduct Workshops		1/14/2019	14
Define Roles and Responsibilities		1/14/2019	14
Phase 2			
Asset Inventory		1/28/2019	1
Inventory of Programs		1/28/2019	6
Determine Levels of Service		2/4/2019	7
Identify and Calculate Risks		2/4/2019	7
Business Risk Exposure Model		2/10/2019	2
Modify Water Main Attributes		2/10/2019	1
GIS Analysis (Risks and Consequences)		2/10/2019	5
Business Risk Exposure Analysis		2/14/2019	1
Phase 3			
Valve Isolation Trace Analysis		2/14/2019	3
Business Risk Exposure Analysis		2/18/2019	1
Insights for ArcGIS Development		2/18/2019	7



4.8 Cost and Benefits

4.8.1 Costs

Tasks	Estimated Total Hours	Estimated Internal Labor Costs	Estimated External Labor Costs	Estimated Task Cost
Phase 1				
Establish Asset Management Committee	8	$ 480.00		$ 480.00
Conduct Workshops	80	$ 4,800.00		$ 4,800.00
Define Roles and Responsibilities	40	$ 2,400.00		$ 2,400.00
Phase 2				
Asset Inventory	8	$ 480.00		$ 480.00
Inventory of Programs	80	$ 4,800.00		$ 4,800.00
Determine Levels of Service	120	$ 7,200.00		$ 7,200.00
Identify and Calculate Risks	160	$ 9,600.00		$ 9,600.00
Business Risk Exposure Model	160	$ 9,600.00		$ 9,600.00
Modify Water Main Attributes	2	$ 120.00		$ 120.00
GIS Analysis (Risks and Consequences)	8		$ 760.00	$ 760.00
Business Risk Exposure Analysis	4		$ 380.00	$ 380.00
Phase 3				
Valve Isolation Trace Analysis	8		$ 760.00	$ 760.00
Business Risk Exposure Analysis	8		$ 760.00	$ 760.00
Insights for ArcGIS Development	40	$ 2,400.00	$ 760.00	$ 3,160.00
Totals	**726**	**$ 41,880.00**	**$ 3,420.00**	**$45,300.00**

4.8.2 Benefits

- Ensure safe and reliable services
- Reduce water loss

- Reduce reactive maintenance costs and activities
- Reduce business risk exposure
- Provide a framework and direction for future water main replacements
- Provide a decision-making tool for prioritizing Capital Improvement Projects
- Supply additional data for future Water System Master Plans
- Justify water main replacement projects to the Board of Directors and Rate Payers

4.8.3 Mitigating Identified Risks

Risk	Risk Mitigation
Training staff is critical for the success of the project. Specific training by function is recommended to support workflows between departments.	Consider staffing requirements and identify impacted stakeholders. Seek their input to changes in business processes and application changes. Determine each target audience's training style and conduct thorough initial training followed with periodic training.
A weak alignment with Finance could devalue the benefits of the project.	Include a Finance in the Asset Management Committee and conduct Finance specific workshops, if necessary, to gain buy-in.
Lack of documentation could underreport the return on investment. Properly documenting benefits captured, or auditing cost savings should be planned thoroughly.	Use information products developed to communicate results in KPIs to monitor performance.
A lack of top management support could hinder the process. Changes to business processes will occur and top management support will help mitigate change resistance.	Cleary communicate the purpose and benefits of asset management. Provide recurring performance reports and other measures of success.
Siloed efforts in the organization could result in implementation failure. This is an enterprise-wide project that requires subject matter experts and decision-making from multiple departments.	Conduct periodic Asset Management Committee meetings. Members of the AMC are delegated the responsibility of communicating changes and collaborating with their respective departments.

Table 7- Identified risks and risk mitigation recommendations.

5 GIS Design and Prototype Deliverables

5.1 Data Model

Cityworks and the GIS are the two primary systems used throughout this project. The relationship model is shown below and displays how a water main is associated with a Cityworks work order.

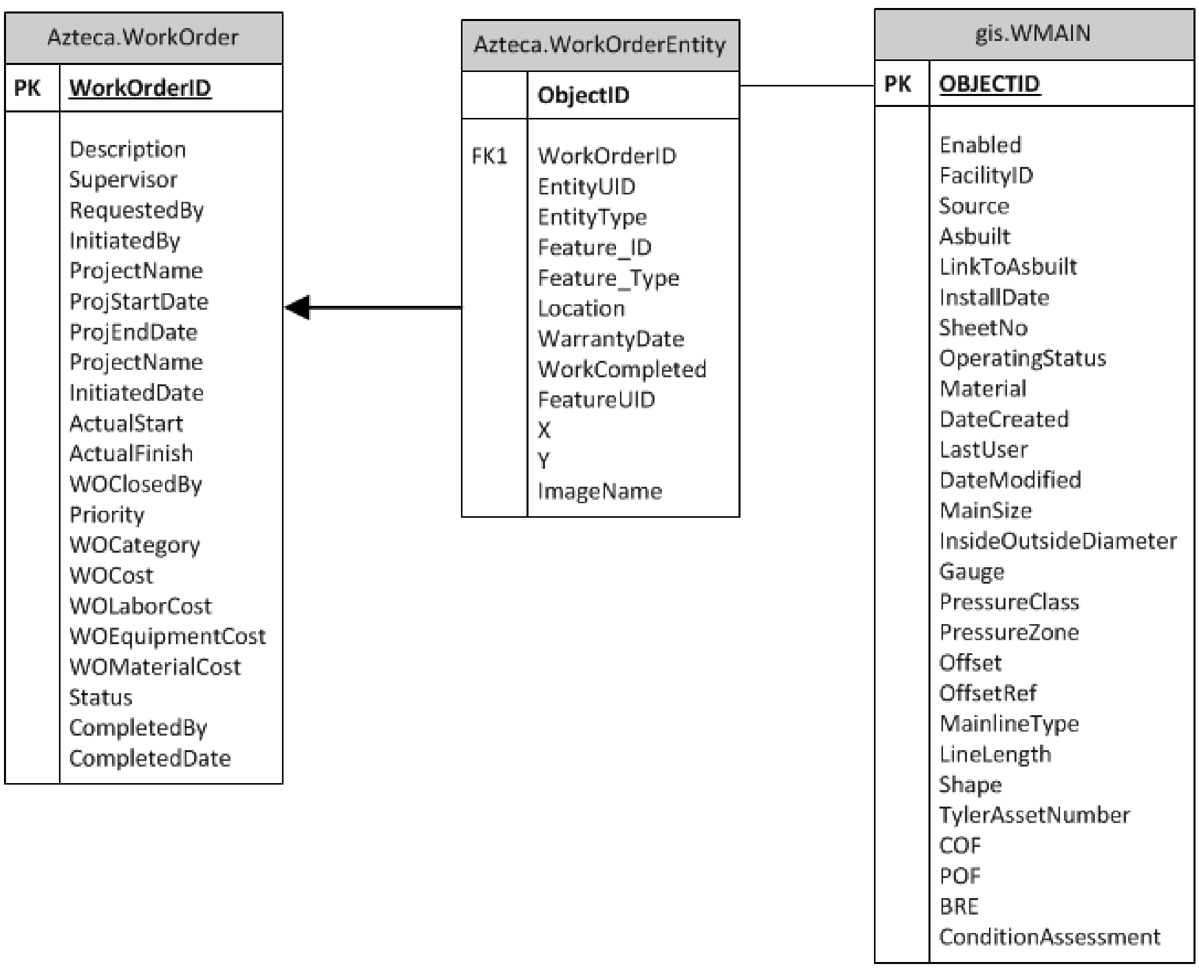
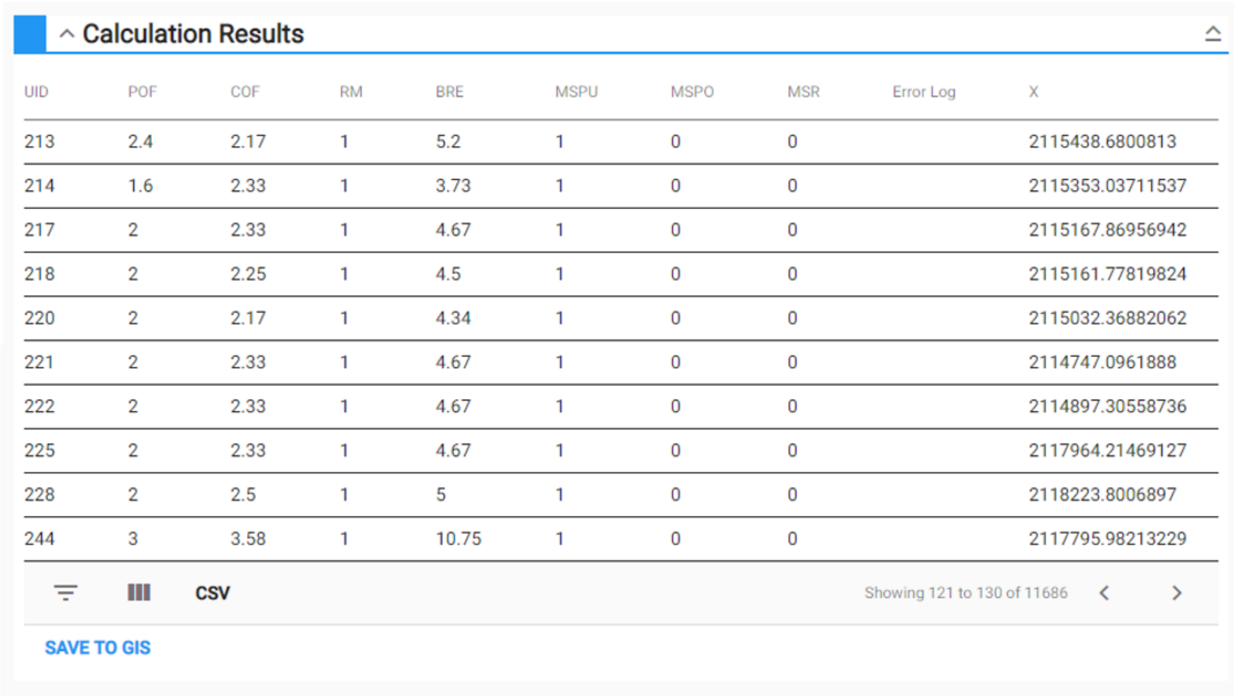


Figure 23 – Cityworks work order and GIS water main data relationship.

5.2 Business Risk Exposure - Cityworks Operational Insights

Using Cityworks Operational Insights, the BRE analysis provides the level of risk for each water main. The system integration between Cityworks and GIS allow the results to be updated in the water main attribute table in the GIS. The BRE data will leveraged in the Cityworks Analytics Dashboard and other information products.



Calculation Results

UID	POF	COF	RM	BRE	MSPU	MSPO	MSR	Error Log	X
213	2.4	2.17	1	5.2	1	0	0		2115438.6800813
214	1.6	2.33	1	3.73	1	0	0		2115353.03711537
217	2	2.33	1	4.67	1	0	0		2115167.86956942
218	2	2.25	1	4.5	1	0	0		2115161.77819824
220	2	2.17	1	4.34	1	0	0		2115032.36882062
221	2	2.33	1	4.67	1	0	0		2114747.0961888
222	2	2.33	1	4.67	1	0	0		2114897.30558736
225	2	2.33	1	4.67	1	0	0		2117964.21469127
228	2	2.5	1	5	1	0	0		2118223.8006897
244	3	3.58	1	10.75	1	0	0		2117795.98213229

CSV

Showing 121 to 130 of 11686

SAVE TO GIS

Figure 24- Results of Business Risk Exposure analysis for each water main using Cityworks Operational Insights.

5.3 Business Risk Exposure Analysis – Cityworks Analytics Dashboard

The Citworks Analytics Dashboard represents the BRE results visually and provides analytics that represent the overall risk for the entire water system. Data sources include water main attribute data, work order history, and the asset management strategy developed in the Business Risk Exposure model.

Interactive data drilldown capabilities allow the District to determine the likelihood of a specific water main failing, along with the service impact, using POF, COF, and BRE information. Each measure can be used as KPIs to monitor the performance of the system and asset management efforts.

Figure 25 – Cityworks Analytics Dashboard presenting the water system business risk exposure level and KPIs to track asset management efforts.

5.4 Main Breaks and Water Loss Control Dashboard – Operations Dashboard

The Water Loss Control dashboard displays water maintenance activities and water loss information in Esri's Operations Dashboard application. The dashboard uses Cityworks data collected by field staff from Water Main Repair work order types.

The dashboard shown below provides a monthly view to Operations, Water Maintenance, Engineering, and Conservation department staff members. Operation maintenance strategies can be modified based on location and work activity data. The number of main breaks, customer leaks, and gallons lost from leaks are KPIs that can be measured and monitored.

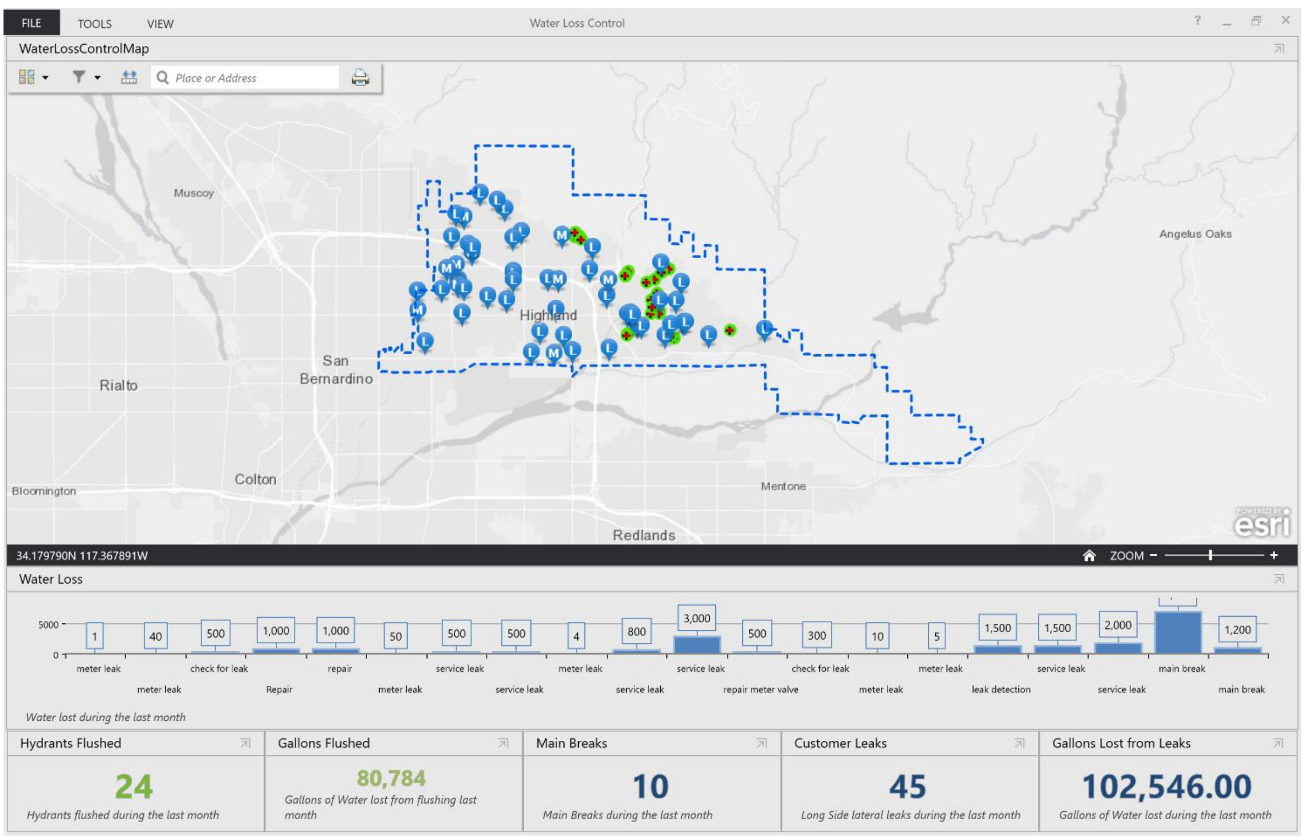


Figure 26 – Water Loss Control Operations Dashboard with KPIs and maintenance history.

5.5 Water Maintenance Analytics - Power BI

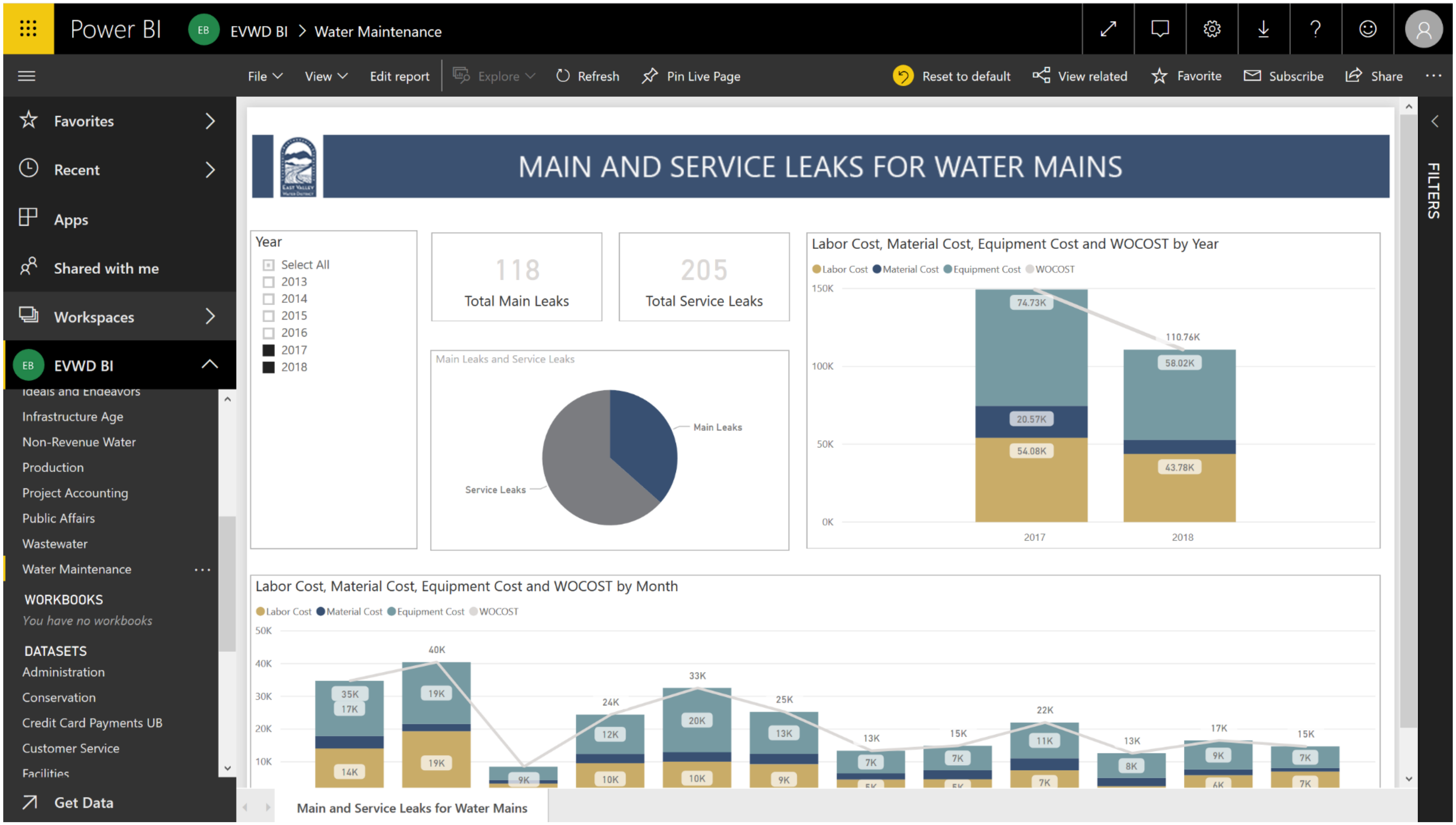


Figure 27 – Power BI displaying Water Main Break and Service Leak analytics using Cityworks work order data.

5.6 Age of Infrastructure Analytics – Power BI

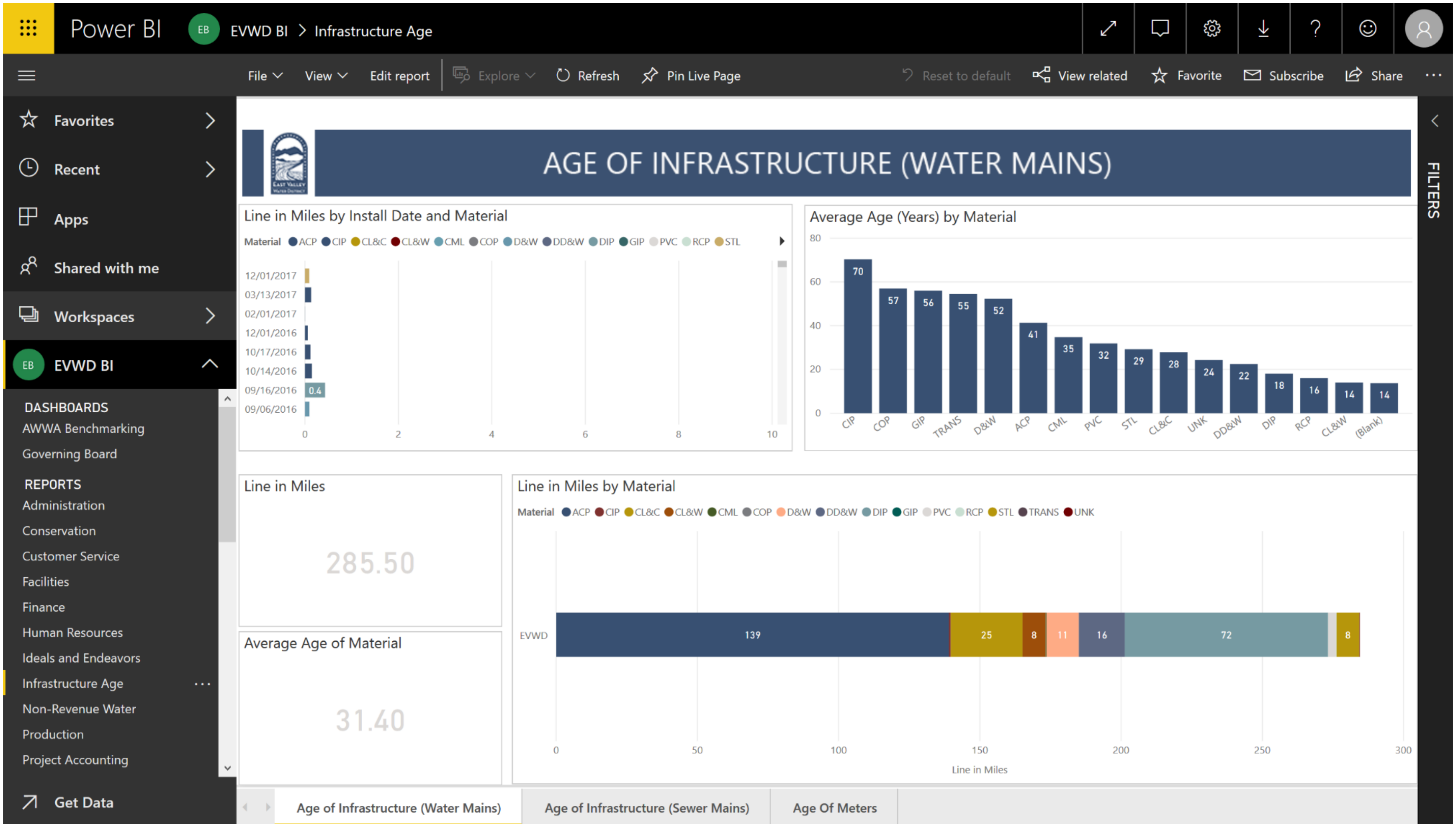


Figure 28 – Power BI displaying Age of Infrastructure analytics for water mains using data from the GIS database.

5.7 Asset Management Analytics – Insights for ArcGIS

Insights for ArcGIS is a web-based spatial business intelligence application capable of using multiple data sources to create analytics tools. Cityworks and GIS data are used to create cards that display statistical data related to asset management. Location analytics provide hot spot areas that present the most risk to the District.

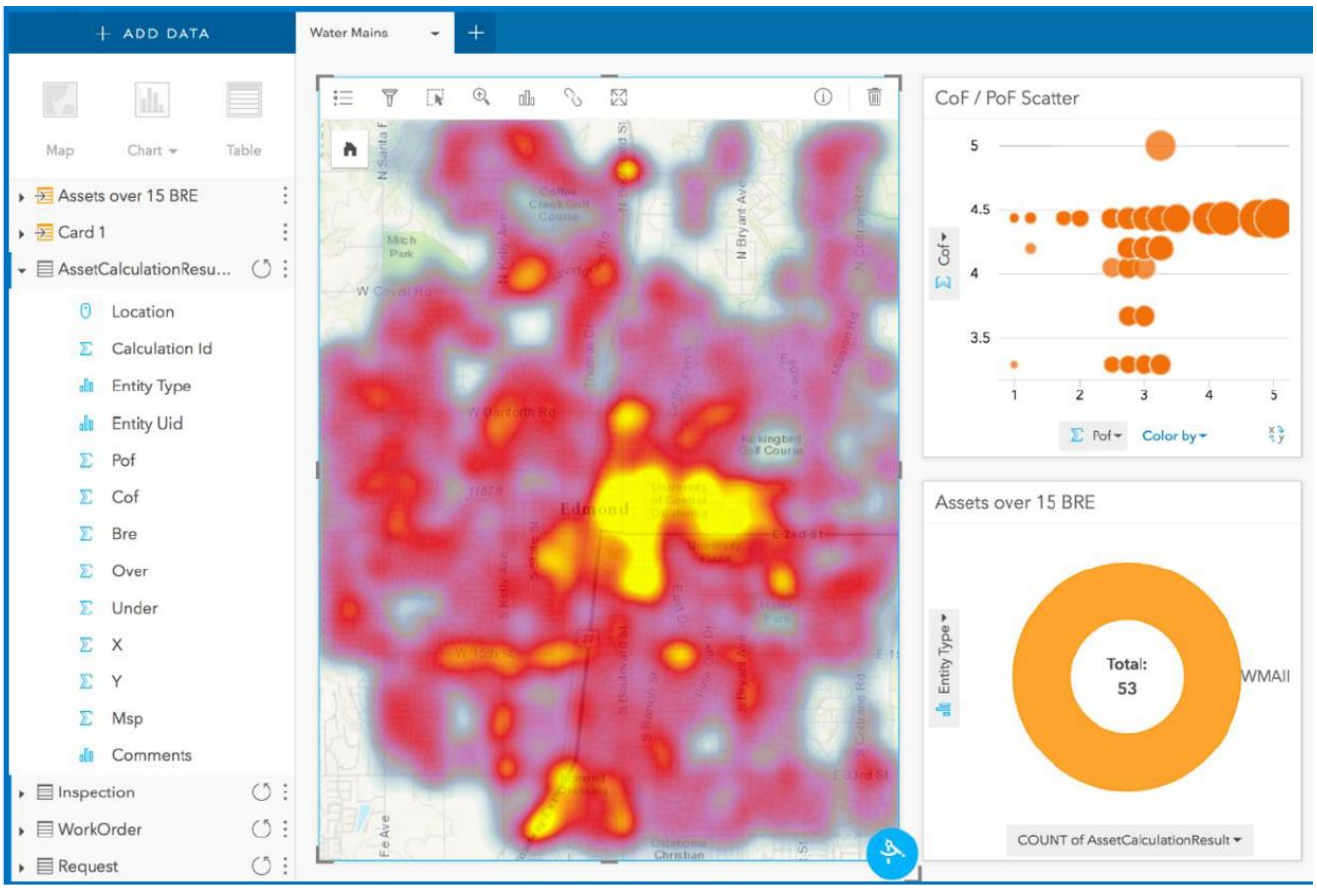


Figure 29 – Insights for ArcGIS displaying various risk reports using location analytics.

5.8 Valve Isolation Trace Analysis Results

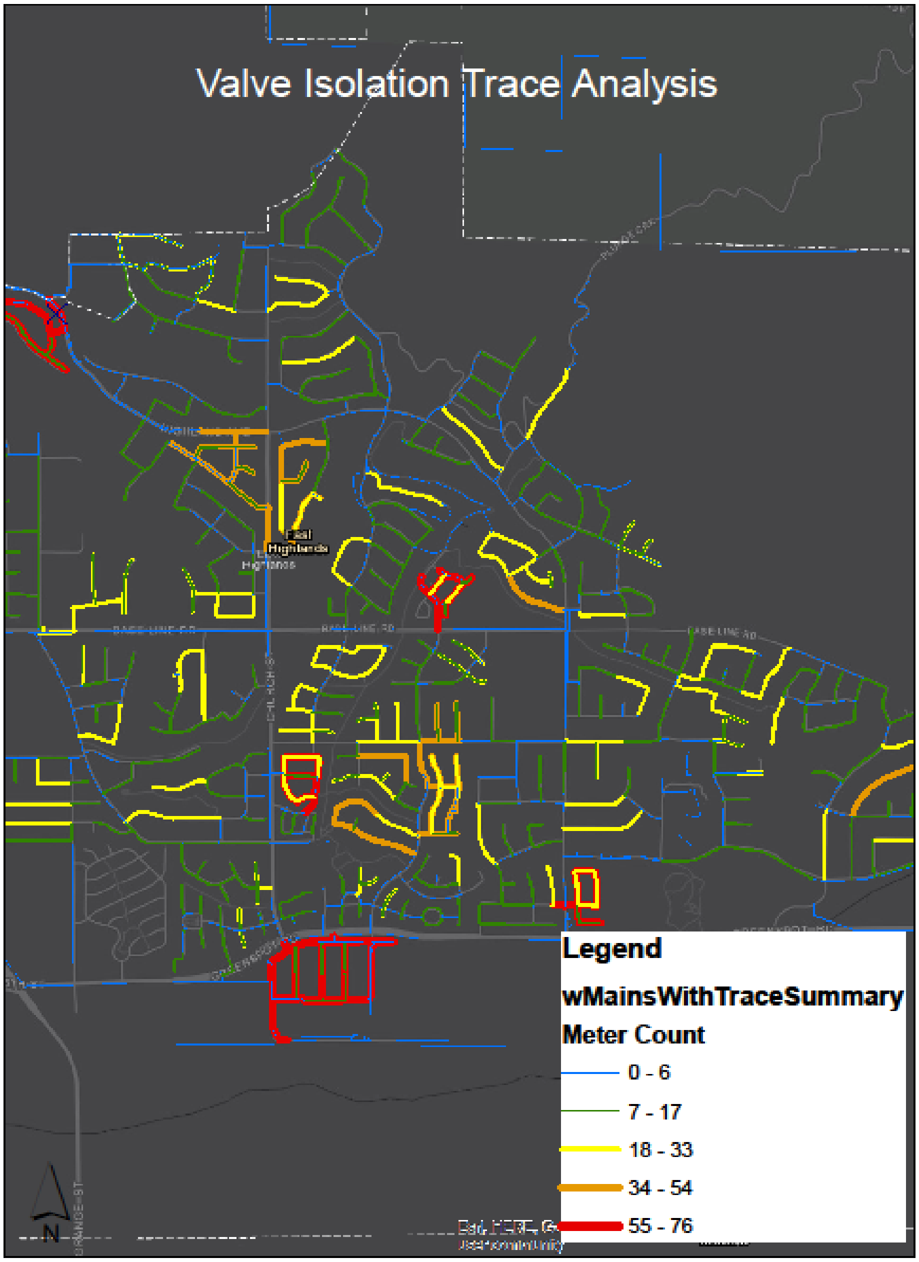


Figure 30- Valve Isolation Trace Analysis results showing customer service impact levels from individual water mains based in the number of meters impacted.

5.9 Probability of Failure Results

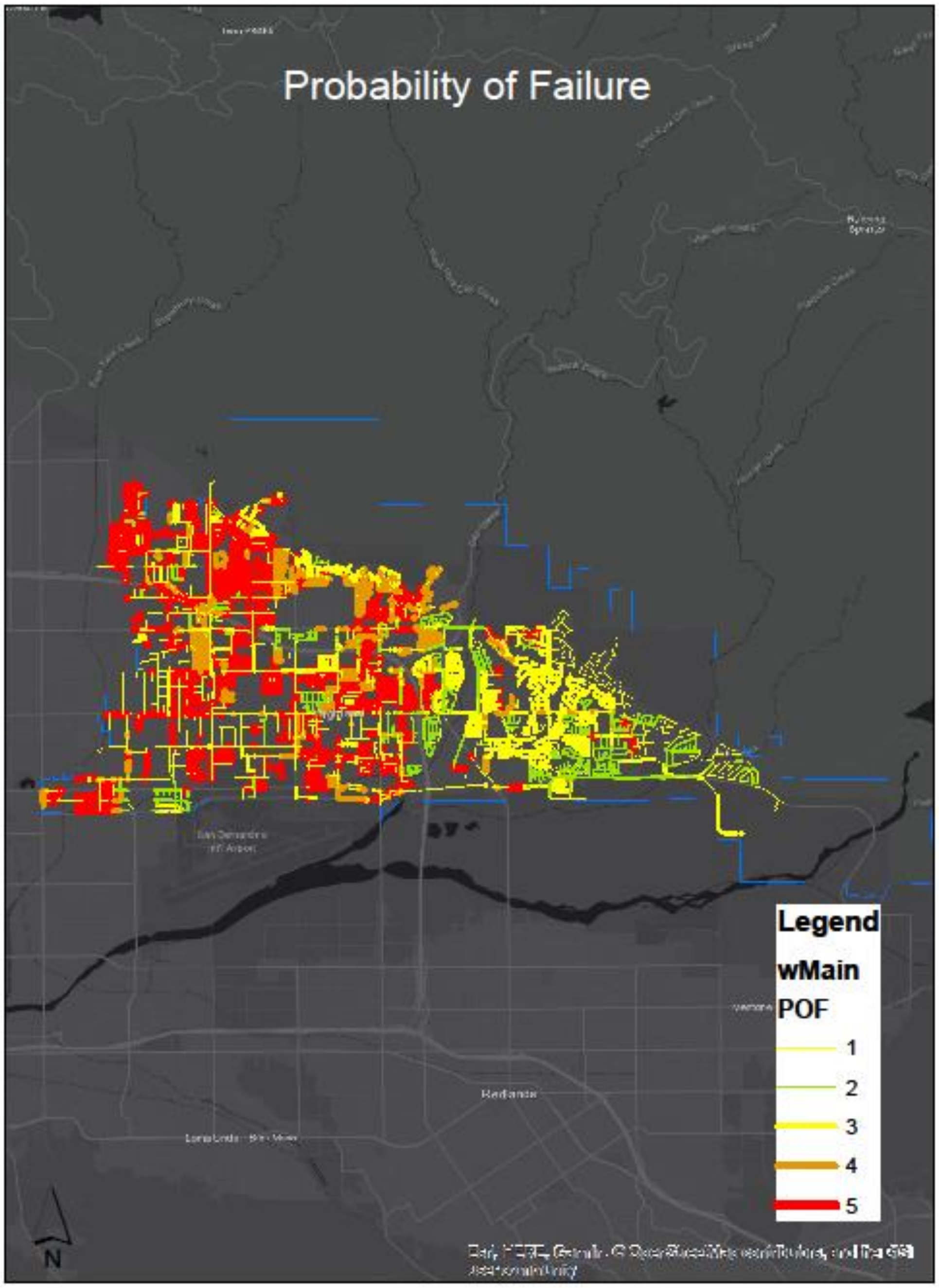


Figure 31 – Probability of Failure results displaying water mains that are most likely to fail.

5.10 Consequence of Failure Results

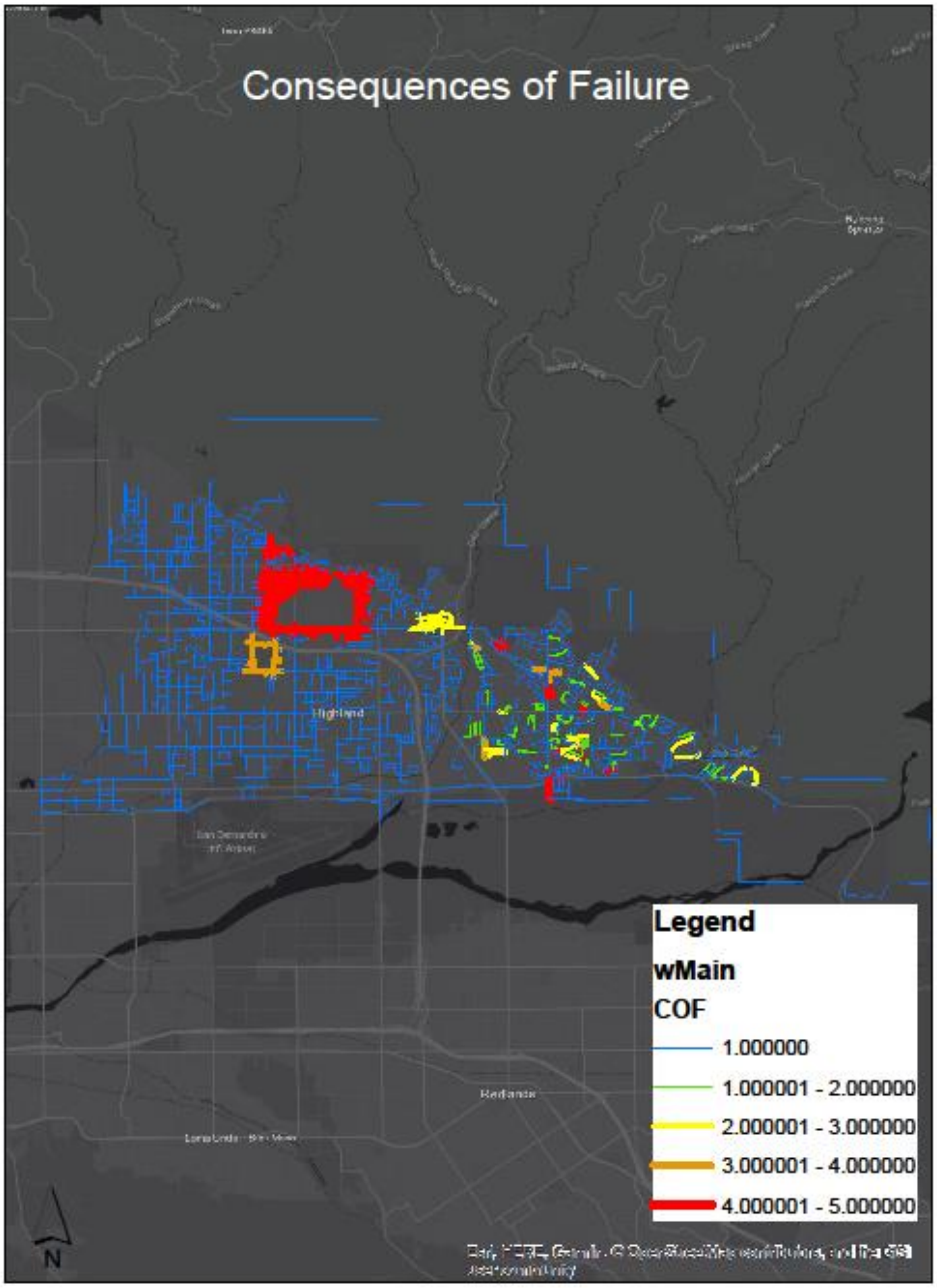


Figure 32- Consequence of Failure results display water mains based on service impact levels.

5.11 Business Risk Exposure Results

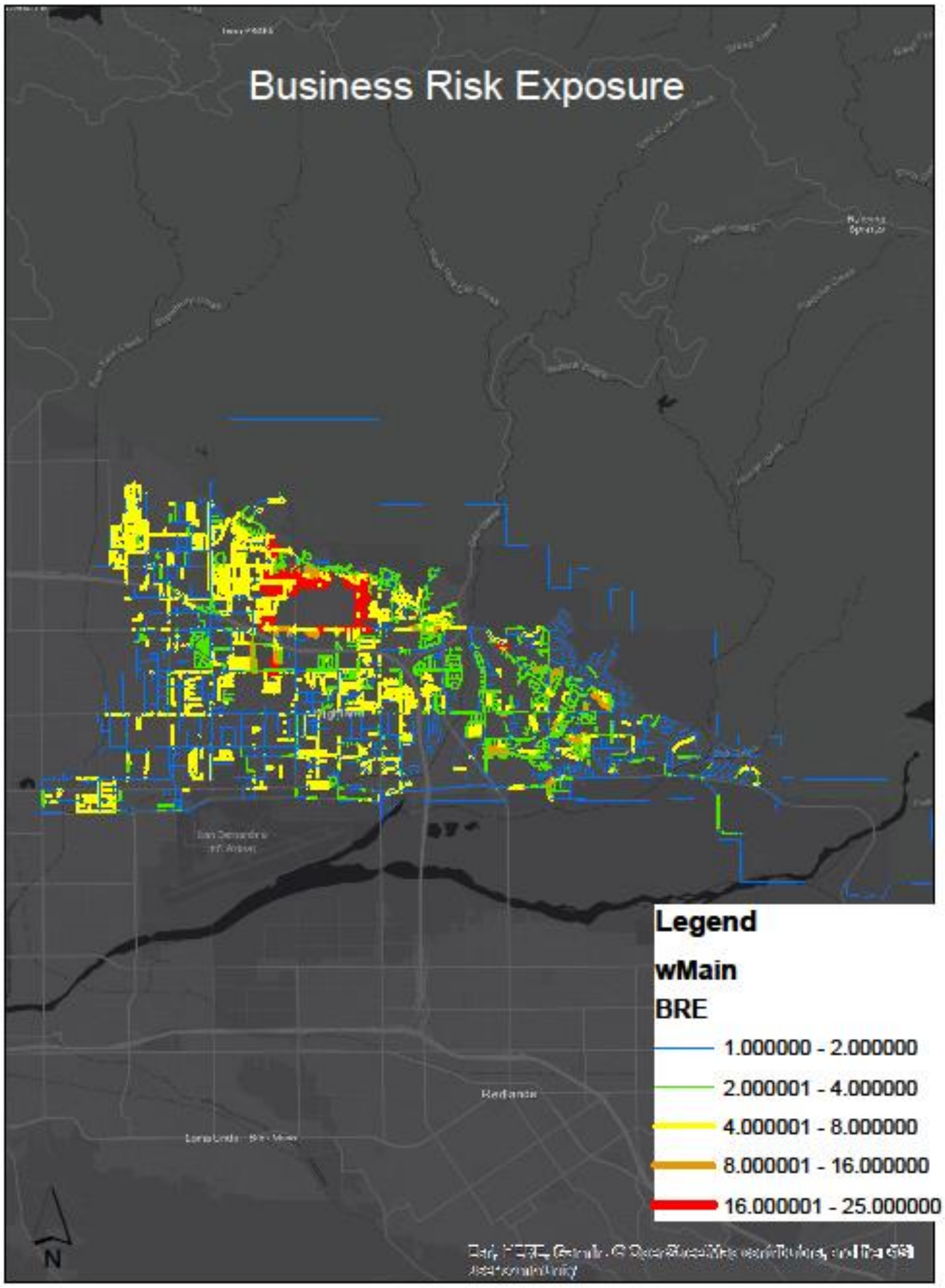


Figure 33 – Business Risk Exposure level for each water main determined by the BRE model

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