



LEADING BUSINESS PRACTICES IN ASSET MANAGEMENT CASE STUDY REPORT

The Leading Business Practices in Asset Management Case Study project was commissioned by the American Water Works Association (AWWA) Asset Management Committee Project Team and funded by the AWWA Technical & Educational Council.

*Report prepared by Jeffrey Stillman and Martin Jones, consultant
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Introduction

LEVEL OF PROGRESS IN UTILITY ASSET MANAGEMENT SURVEY

AWWA conducted a survey in mid-2015 to collect information on the level of progress in utility asset management. The survey covered general asset management, current state of the assets, levels of service, risk management, maintenance and reliability, and asset planning. AWWA received completed responses from 545 utilities in North America. The purpose of the survey was to support utilities seeking to advance their asset management practices and for AWWA to better understand the need for additional resources. AWWA has a number of resources available on the [Asset Management Resource Community](#) web page and facilitates presentations at conferences and webinars during the year. The *Level of Progress in Utility Asset Management* survey is available on AWWA's website.

LEADING BUSINESS PRACTICES IN ASSET MANAGEMENT CASE STUDIES

Following on from the survey, AWWA has developed case studies on some of the leading practices identified in the survey to provide more information on what leading utilities are doing. The case studies are intended to serve as a resource for other utilities to learn from their experience and to help improve asset management programs. The information will also be used as the basis for conference presentations, webinars and workshops.

A total of 13 case studies have been developed, covering five key concepts of asset management:

1. Current state of assets (asset inventory, use of geographic information systems (GIS), condition assessment)
2. Levels of service
3. Risk management (asset risk assessment and planning pipe replacements)
4. Maintenance and reliability (use of preventive maintenance approaches and computerized maintenance management systems)
5. Asset management planning (development of asset management plans and the use of business case evaluations for decision making)

In the survey 49% percent of the respondents were utilities with less than 50,000 customers; for the purpose of this report these utilities are referred to as small utilities. These smaller utilities were found to have different approaches to asset management than the larger utilities, and less likely to have an asset management program in place, so case studies have been developed for some small utilities as well as larger utilities.

Table 1 lists the 13 utility case studies and the leading practice concepts covered. Most case studies covered a single leading practice concept while some included two or three leading practices. Utilities were selected based on their responses to the survey; those large and small utilities that scored very high or high in each of the leading practices were asked to participate. The AWWA project team then interviewed each of the interested utilities to better understand their asset management programs and practices, and developed the case studies using information provided. The case studies have been developed in collaboration with the utilities, who have reviewed and approved the case studies included in this report.

Table 1 List of utility case studies and leading practice key concepts covered

UTILITY	POPULATION SERVED	CURRENT STATE OF ASSETS	LEVELS OF SERVICE	RISK MANAGEMENT	MAINTENANCE AND RELIABILITY	ASSET MANAGEMENT PLANNING
Downers Grove Sanitary District	65,000	X				
Kansas City Board of Public Utilities	158,000	X				
Marshalltown Water Works	30,000	X				
Hastings Utilities	30,000	X				
San Diego County Water Authority	3,000,000	X		X		
Portland Water Bureau	960,000		X	X		X
Brunswick & Topsham Water District	30,000		X			X
City of Annapolis	36,000			X		
Washington Suburban Sanitary Commission	1,800,000			X		X
Fairfax Water	1,800,000				X	
Des Moines Water Works	500,000				X	
Livingston County Water & Sewer Authority	10,000				X	
Mount Pleasant Waterworks	80,000					X

Leading Practice – Current State of Assets

One of the first places to start with managing assets is to know what assets are owned by the utility and what condition they are in – their *current state*. Information about the assets should be maintained in an asset register or inventory, and organized in an asset hierarchy. This should include key asset data such as material type, install date and asset condition. Linear assets can be mapped in a Geographic Information System (GIS) as well as distribution vertical assets, such as pump stations and treatment facilities.

The following questions were asked in the *Level of Progress in Utility Asset Management* survey:

- *Which of the following describes your organization's asset inventory / asset register?*
- *Does the organization have a map or a GIS with both linear assets (pipes) and vertical asset locations (e.g., booster station and tank locations)?*
- *Does the organization have a process in place to assess the condition of linear assets (distribution system pipes) and store the condition data in a spreadsheet or database?*
- *Does the organization have a process in place to assess the condition of vertical assets (mechanical, electrical, HVAC, and other asset types associated with facilities) and store the condition data in a spreadsheet or database?*

The following utilities ranked very high or high in their responses to these questions on the leading practice Current State of Assets, and case studies describing their approaches are included in the following sections:

- Downers Grove Sanitary District
- Kansas City Board of Public Utilities
- Marshalltown Water Works
- Hastings Utilities
- San Diego County Water Authority (also covers Risk Management)

Downers Grove Sanitary District

Leading Practice – Current State of Assets

BACKGROUND

The Downers Grove Sanitary District (the District) provides sewer service and wastewater treatment to a population of around 65,000 in the Village of Downers Grove and surrounding areas. The District's collection system consists of 252 miles of sewer, nine lift stations and wastewater is treated at a single wastewater treatment plant. The treatment plant was constructed in 1954 and the District has made improvements to the plant on numerous occasions, including major expansions in the early 1970s and again in the late 1980s.

The service area includes pipes that date back as far as 1904. Historic sewer construction has generally followed development patterns in the service area.

The District's asset management strategy is comprised of the development and use of tools needed to ensure the long-term sustainability of the enterprise, including the collection system. There is no dedicated asset manager or a formal asset management program; however, the District recently developed and submitted a Capacity Management Operations and Maintenance (CMOM) Plan to the Illinois Environmental Protection Agency to reduce sanitary sewer overflows and backups. The collection system is the District's most significant set of assets and asset management efforts have been concentrated here.

SURVEY RESULTS

The District ranked highest in the Current State leading practice and four of the AWWA Level of Progress Survey questions apply to the District's case study focus area.

The District's responses are shown in the following graphs, and the utility is in the most advanced category, in all cases. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.



Utility: Downers Grove Sanitary District

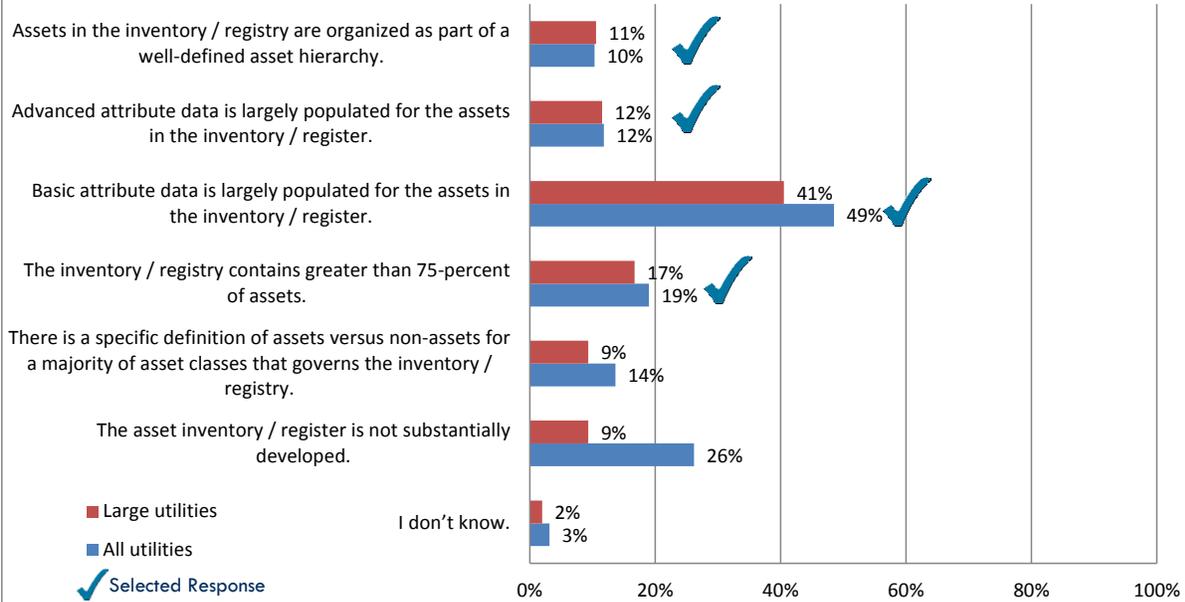
City/State: Downers Grove, Illinois

Average system demand: N/A

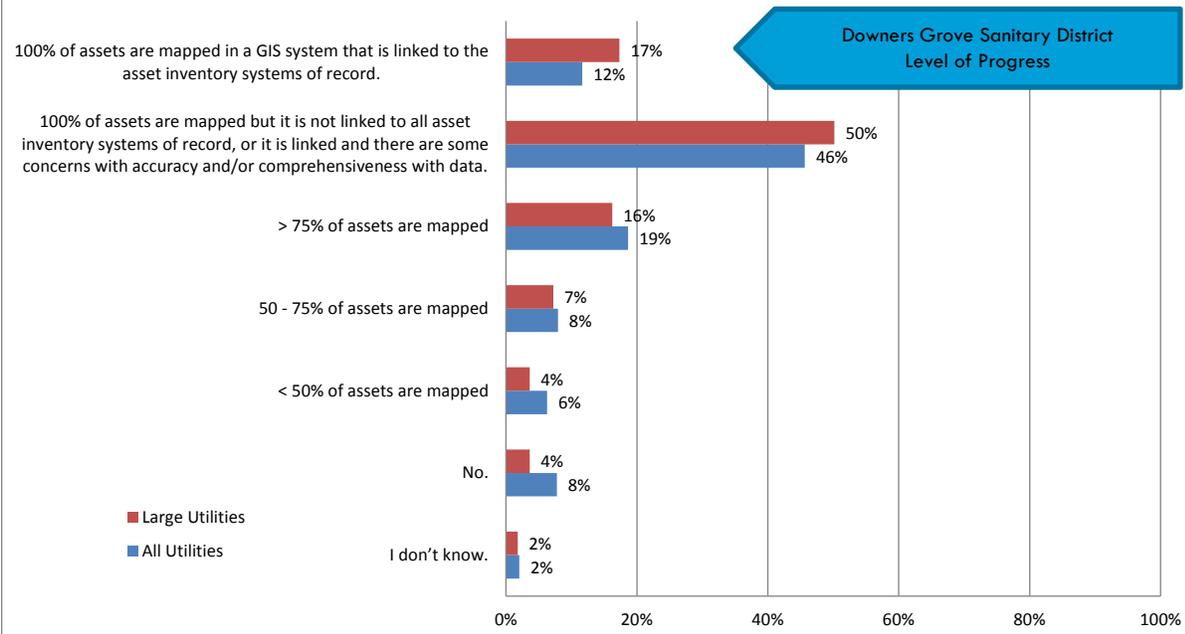
Population served: 65,000

Number of FTE staff: 34

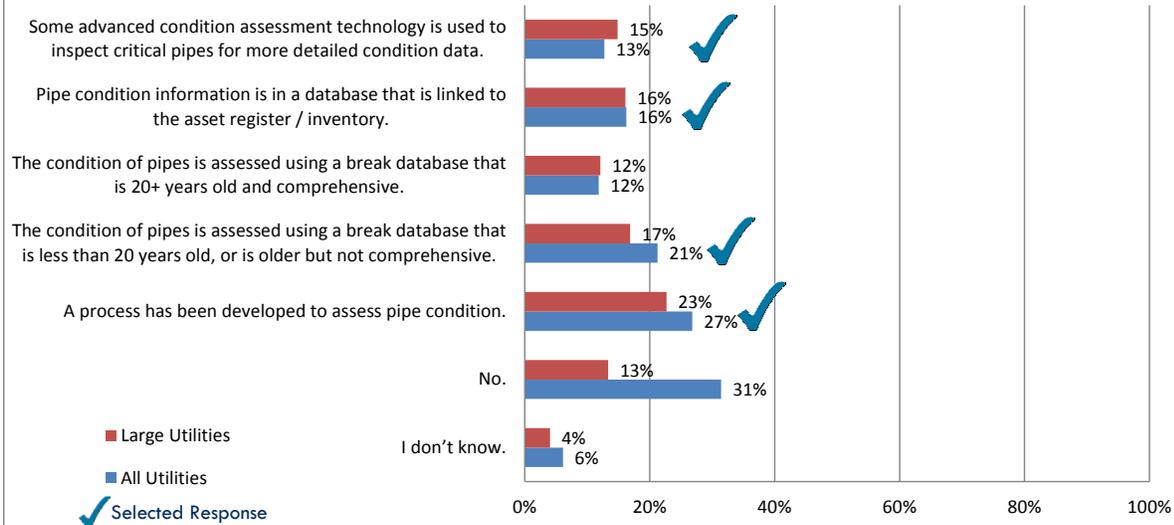
Which of the following describes your organization's asset inventory / asset register?



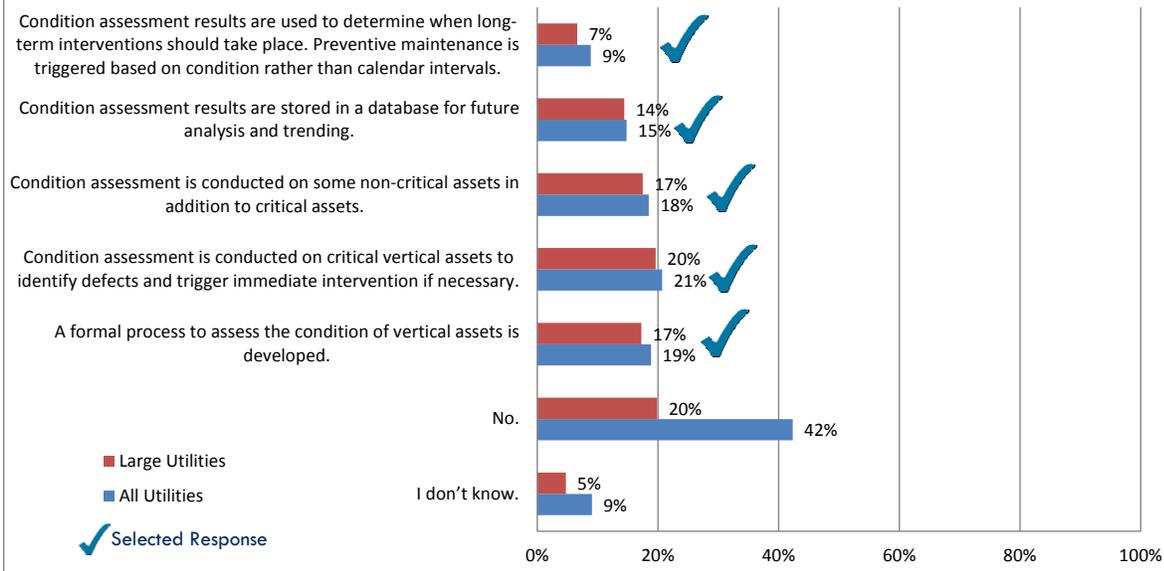
Does the organization have a map or a geographic information system (GIS) with both linear assets (pipes) and vertical asset locations?



Does the organization have a process in place to assess the condition of linear assets (distribution system pipes) and store the condition data in a spreadsheet or database?



Does the organization have a process in place to assess the condition of vertical assets (mechanical, electrical, HVAC, and other asset types associated with facilities) and store the condition data in a spreadsheet or database?



LINEAR ASSETS

Inventory, GIS and CMMS

All District sewers are recorded in a GIS database, which is supported by and linked to a CMMS. The District has dedicated significant resources and staff time to developing data handling tools needed to manage this complex asset. The District first identified and purchased the collection system database software in 1999 and has been populating the database as part of routine operations since then. Recent upgrades of the software provided GIS mapping tools that are invaluable for identifying geographic trends and patterns to assist management decisions.

The GIS and the CMMS are linked by a geodatabase so that a mapped representation of the sewer system can be shown using any of the attribute information contained in the geodatabase. Over 95% of sewers and other collection system assets are recorded in the geodatabase, with attribute information including location, size, materials, installation date, associated construction plans, and connections. The CMMS includes a complete work order history of repairs, cleaning and inspections.

No.	Address	Apartment No.	Gen Location /	Subdivision Text	Property ID Tag
1	6612 BLACK...		S OF THE 2ND MH S OF OXFORD ST		

Figure 1 Downers Grove Sanitary District - Screen shot of CMMS data for a service lateral

All field crews have access to the maps and information. A GIS-generated paper sewer atlas book is issued to sewer system personnel. Tablet computers are also issued that contain digital copies of the atlas and feature files so that the sewer system and parcels in the District's service area can be shown as layers on Google Earth Pro. If field crews find an inaccuracy they report back to the database manager to correct it. For example, pipe materials and size are captured in the field and communicated to the database manager. If a pipe elevation is identified as being incorrect it would be surveyed using GPS.

Condition Assessment

The District is currently assessing pipe condition using coding from the Pipeline Assessment Certification Program (PACP) developed by NASSCO. PACP scores are assigned during routine sewer televising using Closed-circuit Television (CCTV), and manhole inspections are conducted routinely. The District has a dedicated in-house crew that performs sewer cleaning and CCTV, and has also hired contractors to carry out CCTV inspections. PACP scoring is performed by the contractors with the District carrying out a quality assurance check, and using contractors had speeded up inspections. CCTV video is stored in the Cloud and PACP scores are added to the CMMS. The CCTV program gives priority to inspect sewers with higher consequences of failure, particularly trunk lines.

A map of the results of the PACP assessment work can be seen in Figure 2. Pipe segments where data is available are shown in the yellow to red color scales, while un-ranked pipes are shown in green. The pipes are ranked according to expected remaining service life prior to failure.

The incidence of poor PACP ratings in the older sections of the system is higher than in the newer sections. As can be seen in the figure, there is a meaningful portion of pipes (4% of those that have been rated) with ratings in the range where rehabilitation or replacement should be considered within the next five-year Capital Improvement Plan (CIP) budget. At this point about 20% of the sewers are PACP rated.

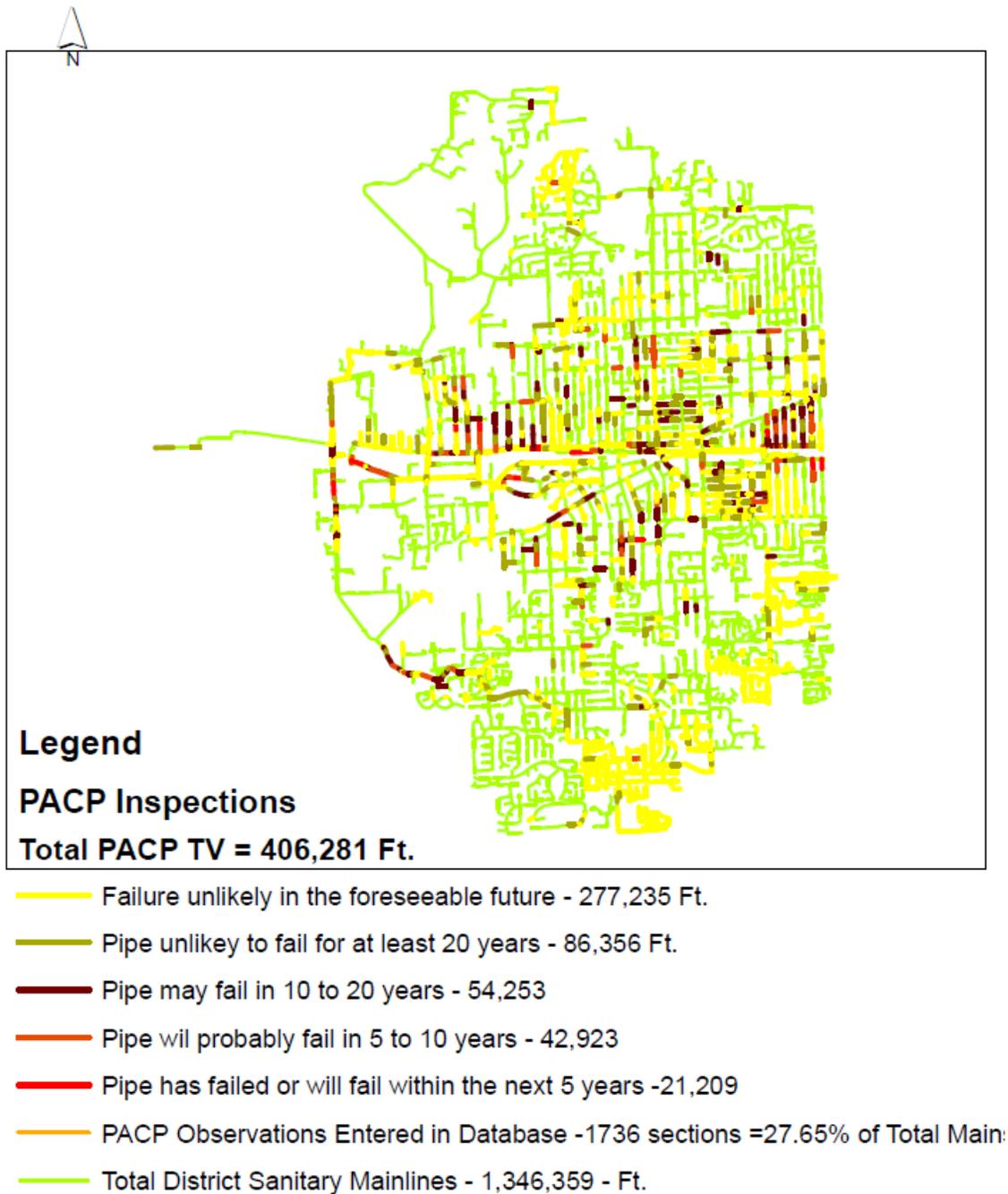


Figure 2 Downers Grove Sanitary District - Condition Grading of the Sewer System

Asset Replacement Forecasting

The District has estimated the current replacement cost of the sewer system at \$225 million in 2012 construction dollars. The proposed replacement budget for the five-year CIP is roughly \$1,550,000 per year which equates to a replacement rate of 0.7%. The District has estimated long-term replacement costs assuming a 100-year life for a sewer, which would amount to a replacement cost of roughly \$2.2 million per year spread over a 20-year period.

Levels of Service

Level of service metrics are measured and tabulated annually to evaluate effectiveness of asset management efforts. Two key operational metrics are basement backups and manhole overflows, and the District has data on these metrics going back to the 1980s. Another key metric is the amount of inflow and infiltration received at the treatment plant as measured by subtracting billed water use from total flows measured at the treatment plant. These level of service metrics are recorded in an annual operations report, and the District is also reporting on the amount of annual maintenance work activity, CCTV survey and sewer replacements.

VERTICAL ASSETS

Inventory and CMMS

The District started by maintaining records of treatment plant and lift station assets in a spreadsheet before moving to a CMMS. All non-sewer assets are included in the CMMS (around 500 major assets), including purchase and replacement costs, install dates, expected service life, condition assessment data, and cost to operate (chemical and/or energy). Maintenance history is also recorded, which includes all work orders (work done, cost of work, parts used and manpower).

The CMMS is used for financial reporting and the expected service life assigned to the assets is used to calculate annual depreciation. Each fiscal year, the fixed asset inventory is tabulated for valuation, including depreciation. New assets, replacements, and asset upgrades that extend service life are added to the inventory, while annual depreciation and removed assets are subtracted from the inventory valuation. The overall health of the utility is measured by changes in the value of fixed assets, with increasing value an indicator of financial sustainability. Valuations are performed on both the sewer and non-sewer assets.

The CMMS is also used for budgeting; tracking how much is spent on preventive maintenance and repair work. Maintenance requirements from equipment operations and maintenance (O&M) manuals are used to develop the preventive maintenance schedule, and preventive maintenance frequency is not typically adjusted for asset condition. There is a paper file system for record drawings; this has not yet been digitized to be added to the CMMS.

Condition Assessment

All treatment plant and non-sewer assets are assigned a condition score on an annual basis. The condition score is assigned mostly on visual inspection, but thermal imaging is used to identify problems with electrical equipment and vibration analysis is used on pumps. The condition is scored on a 1 to 5 scale and also considers the amount and cost of maintenance required to keep the equipment operational. The condition scores are maintained in the CMMS. Specific equipment upgrades and replacements are either identified for implementation in the pending budget preparation, or for further detailed engineering study in cases of more complex projects such as a complete lift station upgrade.

BENEFITS

While age and depreciation status can provide general guidance and ways to tabulate and benchmark overall financial health, condition assessment, effectiveness, criticality, and life cycle cost are more important considerations for identification and implementation of upgrades and replacements. Valuing the assets based on current replacement costs has enabled the District to assess future asset replacement needs and plan for future replacement costs.

The sewer condition assessment program has identified replacement needs and the District has been able to prioritize sewer rehabilitation and replacement.

“We used to rely on people’s tacit knowledge of the assets. Now I can’t imagine managing the assets without the systems and data we now have in place. We are better equipped to deal with the regulators and were able to develop a comprehensive CMOM plan, and our information on manhole overflows exceeded their expectations” - Nick Menninga, General Manager Downers Grove Sanitary District.

Kansas City Board of Public Utilities

Leading Practice – Current State of Assets

BACKGROUND

The Board of Public Utilities (BPU) is a publicly owned administrative agency of the Unified Government of Wyandotte County/Kansas City, Kansas, and is self-governed by an elected six-member Board of Directors.

The BPU has provided 100+ years of service to Wyandotte County, serving 63,000 electric and 50,000 water customers.

The utility serves 127.5 square miles of Wyandotte County. Electric services are provided within the Kansas City, Kansas (KCK) area, and water is supplied to KCK, as well as portions of suburban Wyandotte, Leavenworth, and Johnson counties. The water system includes a state-of-the-art water treatment plant, three pump stations, and over 1,000 miles of water pipes over 130 square mile service area.

The asset management program is not formally documented within any type of program manual or document. However, BPU follows Kansas Department of Health and Environment's (KDHE), A.M. Kan Work and Kansas Municipal Energy Agency guidelines on fiscal responsibility through the use of asset management practices. On an annual basis BPU submits the AMIQ survey to KDHE which is utilized to award points for obtaining SRF loan funds. Each year, BPU has scored high enough on the AMIQ survey to ensure it is first in line for these funds for utility projects.

SURVEY RESULTS

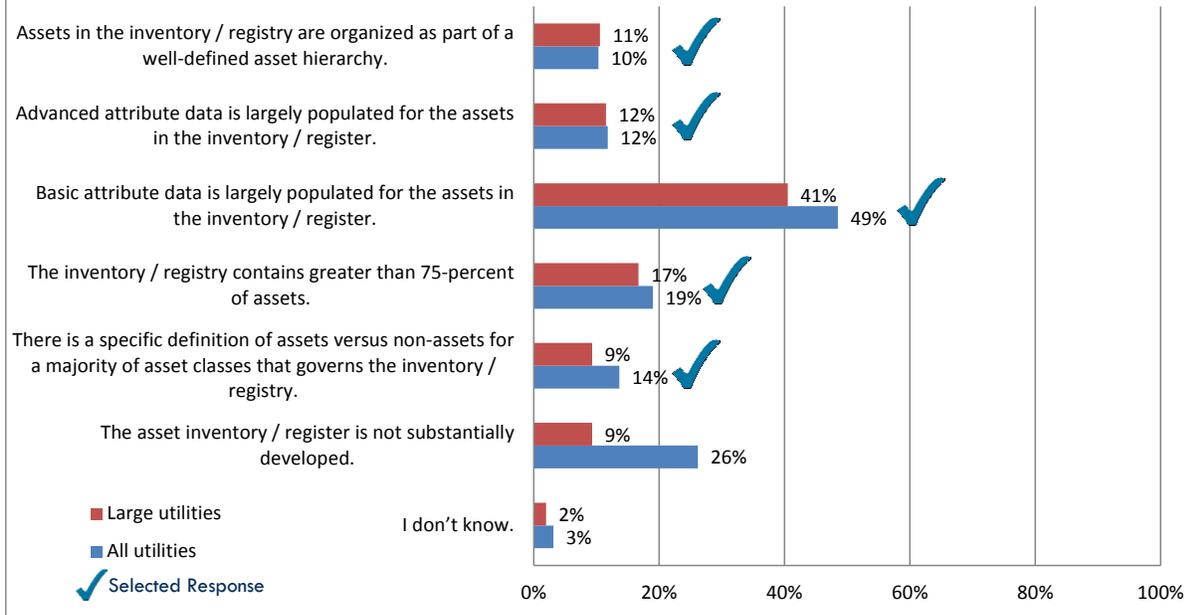
BPU ranked highest in the Current State leading practice, and two of the AWWA Level of Progress Survey questions apply to the case study focus area.

BPU's responses are shown in the following graphs, and the utility is in the most advanced category, in all cases. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.

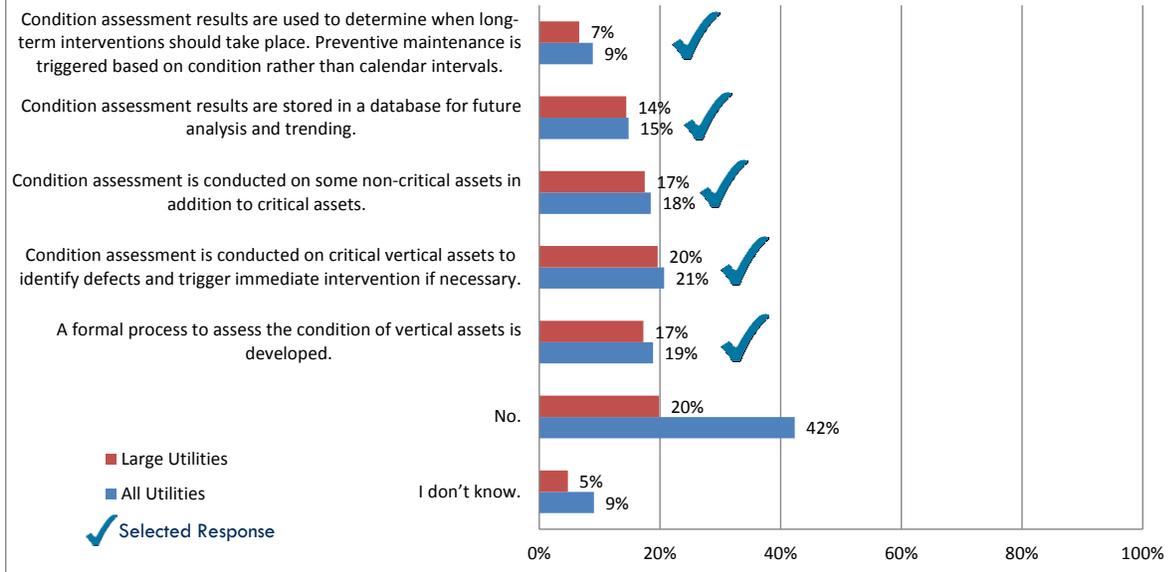


Utility: Board of Public Utilities
City/State: Kansas City, Kansas
Average system demand: 38 MGD
Population served: 158,000
Number of FTE staff: 600+ (includes electric utility)

Which of the following describes your organization's asset inventory / asset register?



Does the organization have a process in place to assess the condition of vertical assets (mechanical, electrical, HVAC, and other asset types associated with facilities) and store the condition data in a spreadsheet or database?



ASSET INFORMATION

BPU has adopted a proactive stance to managing its assets by collecting necessary data and managing maintenance and replacement activities in its computerized maintenance management system (CMMS). The CMMS implementation originated in the water treatment plant environment. Initially, the asset inventory data collection was a group effort completed by operations staff shortly after closing the Quindaro Water Plant in 2000. Operators were tasked with gathering and collating information from O&M manuals, name plates, drawings, specification books, and contracts from plant design and construction.



Figure 3 BPU - Sample name plate for a motor control center

With the construction of the Nearman Water Treatment plant, there was a formal process to define and gather asset information when the plant went on-line. That information is still valid today, and as things change it is updated in the CMMS accordingly. Data was originally collected during and shortly after plant construction, and Excel spreadsheets were used to store the information by functional location or system. Plant staff collected this data, which helped with use and acceptance of the CMMS, and it also helped staff become familiar with the new plant. All vertical asset data for the plant is in the CMMS and includes systems, locations, assets, item master, inventory, as well as purchasing information.

With the CMMS implementation originating in the plant environment, asset data for vertical assets is more complete. Over 75% of vertical assets (approximately 3,200) are loaded into the CMMS and structured within an asset hierarchy for navigation as well as cost rollup purposes. The hierarchy is well defined, including systems, locations, assets as well as parent and child relationships. When the new system was being rolled out, training and communication helped staff to understand and navigate the hierarchy in addition to the CMMS software.

Nearman Water Treatment Plant - Horizontal Collector Well - Maintenance Points - DCU1							
EQUIPNUM	LOCATION	EQ_DESC	Eqp. Descriptions	MANUFACT	MODEL_NUM	SERIAL_NUM	VENDOR
ELECTRICAL DATA:							
PMT1	ELEC_HCW1	Pad Mount Transformer 12.4/4160 (PMT-1)		Cutler Hammer	3500/2800KVA	PEB0134	Cutler Hammer
PMT2	ELEC_HCW1	Pad Mount Transformer 12.4/4160 (PMT-2)		Cutler Hammer	3500/2800KVA	PEB0145	Cutler Hammer
PMT1RES	ELEC_HCW1	Resistor for Neutral (PMT-1) 400A, 10s		Cutler Hammer	2400V400A/0s	G451046A2201ED17	Cutler Hammer
PMT2RES	ELEC_HCW1	Resistor for Neutral (PMT-2) 400A, 10s		Cutler Hammer	2400V400A/0s	G451046A2201ED17	Cutler Hammer
MCLU2TIEBKR	ELEC_HCW1	MCLU2 Main Tie Breaker		Cutler Hammer	CATNUME210SCE		Cutler Hammer
MCLU2TIEBKRD	ELEC_HCW1	MCLU2 Main Tie Breaker Digitrip Monitor		Cutler Hammer	DIGITRIP3000	002570	Cutler Hammer
MCLU2MAIN1BKR	ELEC_HCW1	MCLU2 Main No. 1 Breaker		Cutler Hammer	CATNUME210SCE		Cutler Hammer
MCLU2MAIN1BKRD	ELEC_HCW1	MCLU2 Main No. 1 Breaker Digitrip Monitor		Cutler Hammer	DIGITRIP3000	002562	Cutler Hammer
MCLU2MAIN1BKRIQA	ELEC_HCW1	MCLU2 Main No. 1 Breaker IQ Analyzer		Cutler Hammer	6000SERIES	000492	Cutler Hammer
MCLU2MAIN2BKR	ELEC_HCW1	MCLU2 Main No. 2 Breaker		Cutler Hammer	CATNUME210SCE		Cutler Hammer
MCLU2MAIN2BKRD	ELEC_HCW1	MCLU2 Main No. 2 Breaker Digitrip Monitor		Cutler Hammer	DIGITRIP3000	002570	Cutler Hammer
MCLU2MAIN2BKRIQA	ELEC_HCW1	MCLU2 Main No. 2 Breaker IQ Analyzer		Cutler Hammer	6000SERIES		Cutler Hammer

Figure 4 BPU - Sample of data collected by staff during plant construction

Basic attribute data is largely populated for the assets in the inventory including Asset ID, Description, Location, Install Date, Manufacturer, Vendor, O&M Data, Specification Data, and Size. In addition, spare part and asset condition data is also stored with the majority of assets.

With regards to distribution system assets, over 50% of assets are loaded into the CMMS and fully integrated with the GIS. CMMS integration with GIS is in the process of being implemented to support distribution system assets. BPU recently converted all of its GIS data from one platform to another for the purposes of implementing the CMMS GIS integration component. Spatial positioning of assets was collected utilizing RTK GPS for a high degree of location accuracy. One-hundred percent of the distribution system assets are mapped within the GIS with approximately 50% of those integrated with the CMMS via the integration framework at this time.

To evaluate the quality of its data, BPU gathered a selection of data and evaluated it using IBM Watson, which scores the quality of the data set. It got a high-quality rating in the 90% range for the submitted data.

BPU has also invested in integration of the CMMS with other key information systems. In addition to GIS, the CMMS is also integrated with the Supervisory Control and Data Acquisition (SCADA) system and the document imaging system. SCADA integration is used to support preventive maintenance work order generation based on run-time meters. Document imaging integration is used to support access to specification books, shop drawings, and O&M manuals from within the CMMS asset record.

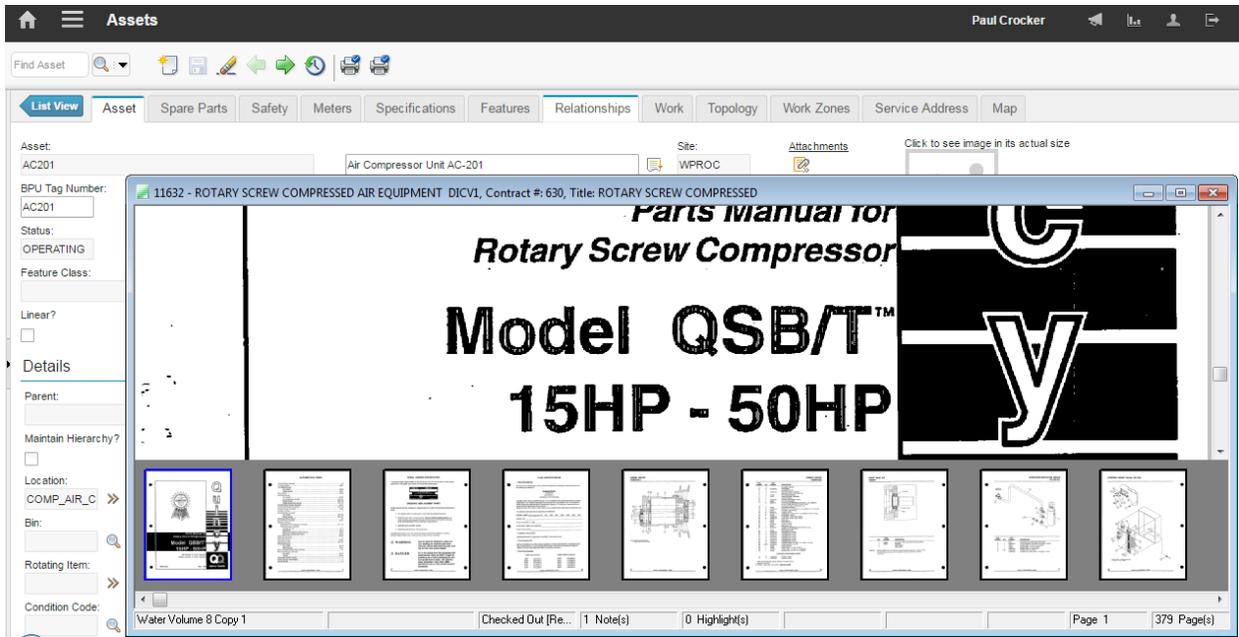


Figure 5 BPU - Sample documentation opened from within CMMS using App Enabler

Some metrics are in place in the CMMS on a dedicated start center. Key measures include preventive maintenance (PM) performance (75%) and work orders completed on time (62%). This is a noted area for continual improvement based on staff availability.

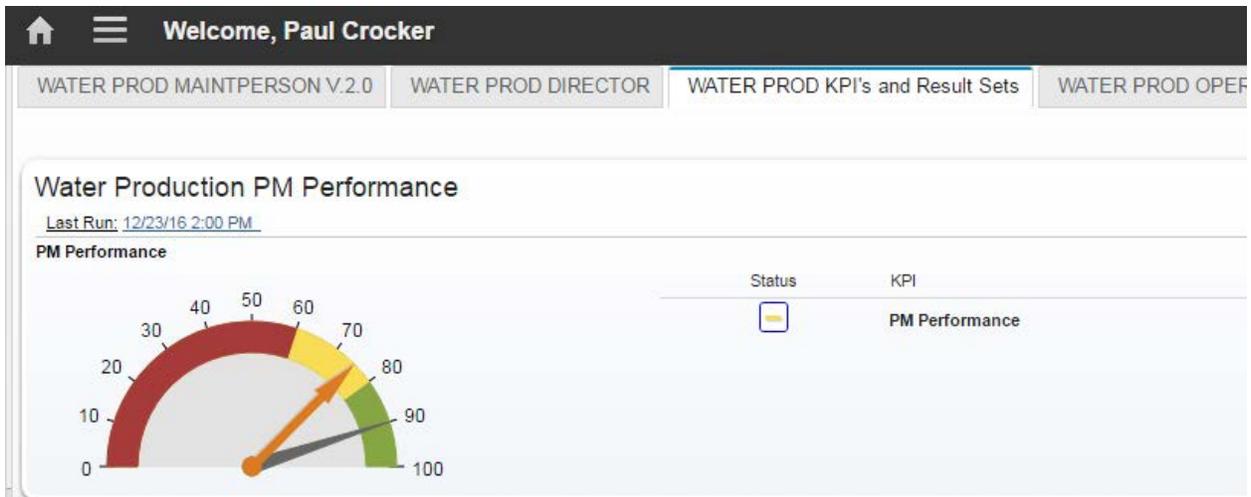


Figure 6 BPU - Water production KPI for PM performance from dedicated start center

CONDITION ASSESSMENT & MONITORING

BPU maintenance practices utilize a combination of reactive, preventive and predictive maintenance strategies. PM schedules are based on both calendar/schedule based intervals as well as meter-based schedules. As previously mentioned, a portion of PM work orders are generated based on run-time hours of equipment obtained through the SCADA system update of meters configured in the CMMS. Other PM work orders are generated based on defined intervals (elapsed time), while an additional portion are initiated based on asset condition information obtained through predictive maintenance practices.

From a predictive maintenance and asset condition monitoring standpoint, BPU has an extensive lubrication analysis program as well as the beginnings of a vibration analysis program. BPU is in the process of evaluating vibration analysis service providers, and the staff hopes to have a program in place in which BPU staff will be trained to collect the vibration data, which will then be provided to a third party for analysis and reporting.

BPU has developed a comprehensive lubrication analysis program to assess the condition and identify predictive or preventative maintenance needs for nearly all of its mechanical equipment significant to the water treatment plant. Samples are gathered and analysis is run on all large motor bearings as well as all basin equipment. Assets in the CMMS are aligned with the laboratory utilizing the same nomenclature and identification standards. Reports are reviewed and maintenance is adjusted to correct any detectable problems.



Newly purchased filter cart

Lubrication analysis reports (see Figure 7) are stored at asset and/or work order level within the CMMS (and are also available from the laboratory website). The analyses contain trends over time and are used to adjust maintenance procedures accordingly. For example, when a negative report for high particle counts is received staff may deploy the filter cart to clean the fluid. When oil analysis shows the oil additive pack is showing signs of depletion, or the acid number is changing, a work order will be scheduled to change the fluid. This use of condition data to determine maintenance activities is very different from how work was originally scheduled which was based purely on elapsed calendar time. This has resulted in overall cost savings in labor and materials.

The program was successfully implemented due to support from upper management but also from enthusiasm for implementing best practices at a grass roots level. Because of the success and realized savings of the lubrication analysis program, BPU has begun other initiatives to make the program even more successful. This includes modifications to equipment to enable them to be sampled while running as well as modifications to accommodate filter cart quick connects.



Lubricant Analysis Report

North America: +1-800-537-7683

0	1	2	3	4
NORMAL	ABNORMAL		CRITICAL	

Overall report severity based on comments.

Account Information		Component Information		Sample Information	
Account Number: 593000-3020-0011 Company Name: KANSAS CITY BOARD OF PUBLIC Contact: JENNIFER WIEDNER/PAUL CROCKER Address: 4301 BRENNER ROAD KANSAS CITY, KS 66104 US Phone Number: 913-573-9251 913-645-1662		Component ID: RWP5MTR0DEBRG Secondary ID: RWP5MTR0DEBRG Component Type: ELECTRIC MOTOR Manufacturer: US MOTORS Model: 6810P Application: PLANT/INDUSTRIAL Sump Capacity: 70 qt		Tracking Number: 15328N01075 Lab Number: H-151408 Lab Location: Houston Data Analyst: RNF Sampled: 12-Jul-2016 Submitted: 12-Jul-2016 Received: 14-Jul-2016 Completed: 18-Jul-2016	
Filter Information		Miscellaneous Information		Product Information	
Filter Type: NONE Micron Rating:		Miscellaneous: WO 90212		Product Manufacturer: LUBRICATION ENGINEERS Product Name: 4040 QUINPLEX WHITE OIL (H1) Viscosity Grade: ISO 150	
Comments	Suggest vibration analysis be performed or reviewed (as applicable). We recommend an Analytical Ferrogram be performed for this sample to clarify the type of wear and/or contamination present. Please contact Customer Service for additional test information. Suggest inspecting this unit for EXCESSIVE WEAR; Bearing metal is at a SEVERE LEVEL; Particle count undesirable at the smaller micron levels. Viscosity is MODERATELY LOW. Causes include contamination, incorrectly identified viscosity grade, or adding a different viscosity grade to the component.				

Sample #	Wear Metals (ppm)										Contaminant Metals (ppm)			Multi-Source Metals (ppm)					Additive Metals (ppm)					
	Iron	Chromium	Nickel	Aluminum	Copper	Lead	Tin	Cadmium	Silver	Vanadium	Silicon	Sodium	Potassium	Titanium	Molybdenum	Antimony	Manganese	Lithium	Boron	Magnesium	Calcium	Barium	Phosphorous	Zinc
1	82	0	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	6	0	1	0	43	2
2	24	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2	649	1
3	22	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	704	1
4	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	686	3

Figure 7 BPU - Example Lubrication Analysis Report

Future enhancements to the lubrication analysis program are planned to include more filter carts so that carts can be dedicated to specific fluid families and placed in locations where they can be quickly accessible. Having a single filter cart sharing duties across fluid families requires extensive effort to reconfigure the cart (filter changes, draining hoses, storage of filters for next use, etc.) for each change in fluid. Other improvements would also include employing ultrasonic lubrication for grease guns; identification of all lubrication points with tags to show the fluid each component takes, quantity, and periodicity; and lastly, continued staff training and certification.

BENEFITS

BPU has realized many benefits from its asset management efforts. From an asset awareness standpoint, having complete asset information accessible within the CMMS that includes information such as performance ratings and linkages to O&M manuals and shop drawings results in more informed staff and better maintenance practices. Ultimately this results in a lower cost of maintenance and increased responsiveness to equipment downtime.

BPU utilizes the CMMS to generate their Lock Out Tag Out Reports directly from Work Orders via the built-in functionality of Lock Out Tag Out, Hazard, and Safety modules within the CMMS.

With the implementation of the lubrication analysis program, significant savings in labor and materials have been realized by more efficient and effective scheduling of work. Instead of

changing fluids every outage based on elapsed calendar time, utilizing actual condition of the lubricants allows for less wasteful practices and increased equipment uptime. Savings include not only the cost of fluid, but also the labor involved with changes (approximately 50% savings over past practices).

BPU Water Processing Maintenance Staff were recently recognized for an [Uptime Award Special Recognition Award: Innovative Use of Photography for Maintenance](#) at the International Maintenance Conference 2016 in Bonita Springs Florida.



Paul Crocker of BPU receiving the Uptime Award

Marshalltown Water Works

Leading Practice – Current State of Assets

BACKGROUND

Marshalltown Water Works (MWW) serves a population of approximately 30,000 in the City of Marshalltown and is a wholesale provider to a rural water system serving an additional 10-15,000 people in surrounding communities. Groundwater is extracted from nine wells and treated at a 12 MGD conventional lime softening facility. Water is distributed through a system of 150 miles of water distribution mains which includes a booster station, four elevated storage tanks and three ground storage tanks (an additional storage tank is being constructed).

As a small utility MWW does not have the revenue or manpower to implement a full-fledged asset management program. Instead it has focused on the areas where it can get the biggest bang for the buck.

The General Manager and Director of Water Production attended an EPA asset management seminar on the Fundamentals of Asset Management in 2010, which provided information on how a utility could get started in asset management. They saw the value in asset management and identified some initial improvements to make, which included implementing a CMMS and developing a more inclusive mains break database.

Tim Wilson, the Director of Water Production explains MWW’s asset management approach: *“We have taken more of a slow and measured approach to help us determine what are our critical needs, and what can be done to prepare for repair, replacement, maintenance to make sure that we are using that equipment or process as long as possible. This approach has allowed us to demonstrate quick wins to the entire staff which has helped gain the support that has been necessary to implement further improvements.”*

SURVEY RESULTS

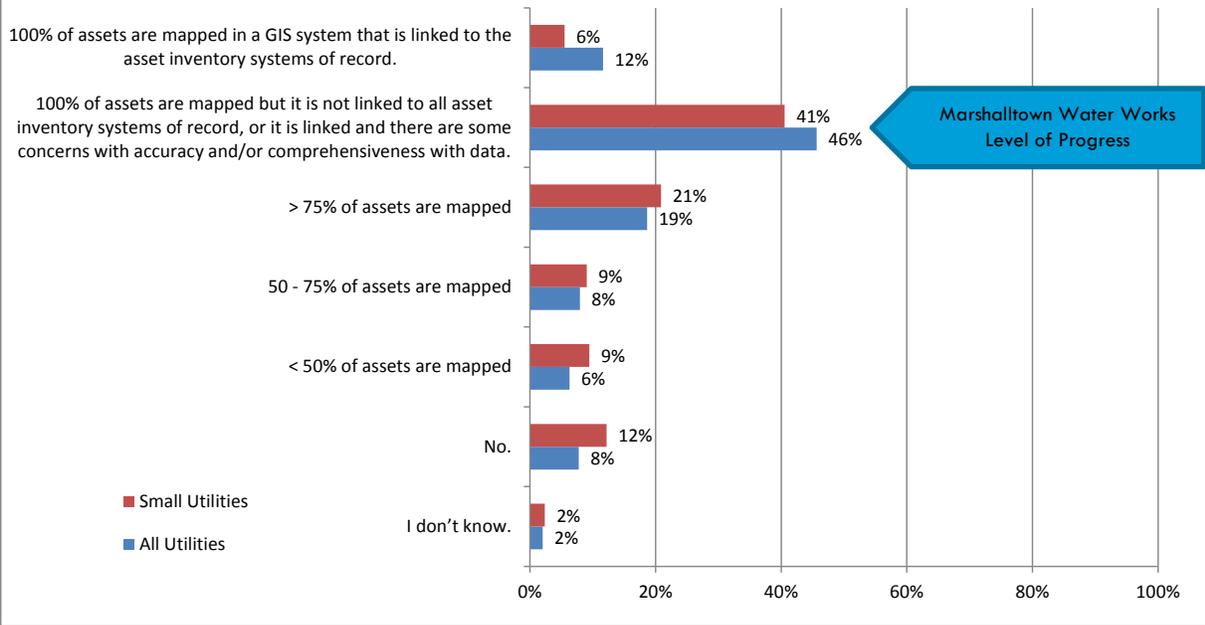
MWW ranked high in the Current State leading practice compared with other small utilities in the case study focus areas of GIS and condition assessment.

MWW’s responses are shown in the following graphs, and the utility is in the most advanced category for vertical asset condition assessment. The graphs also show the responses from all the other participating utilities and the responses for the small utilities.

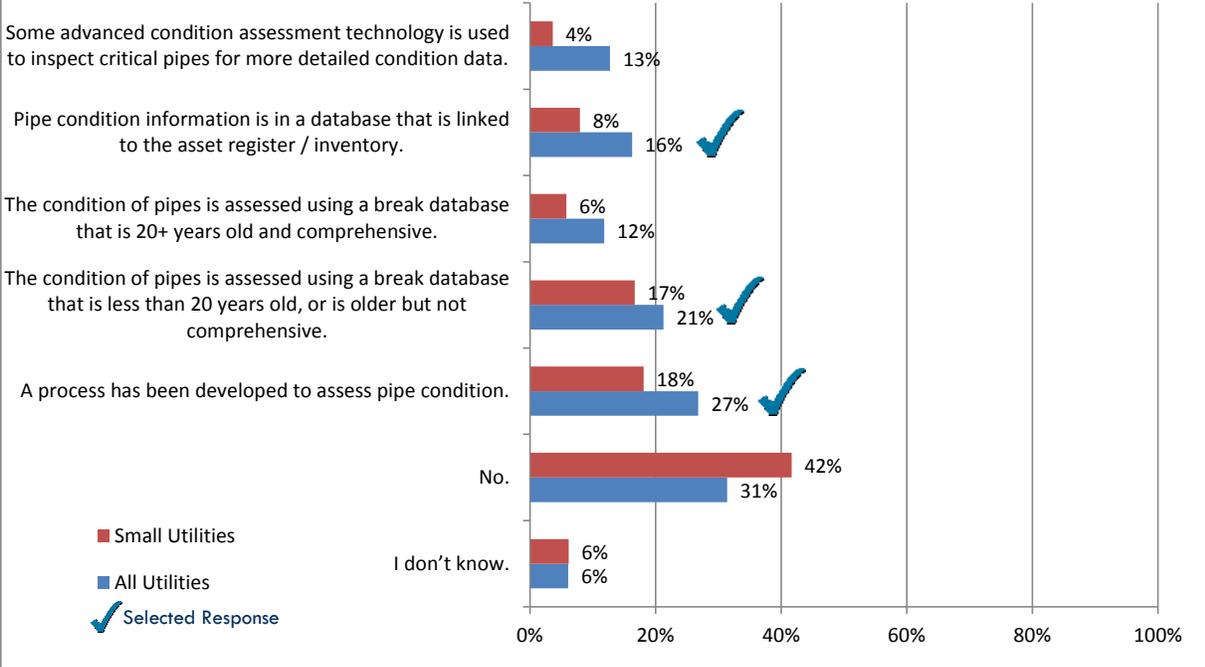


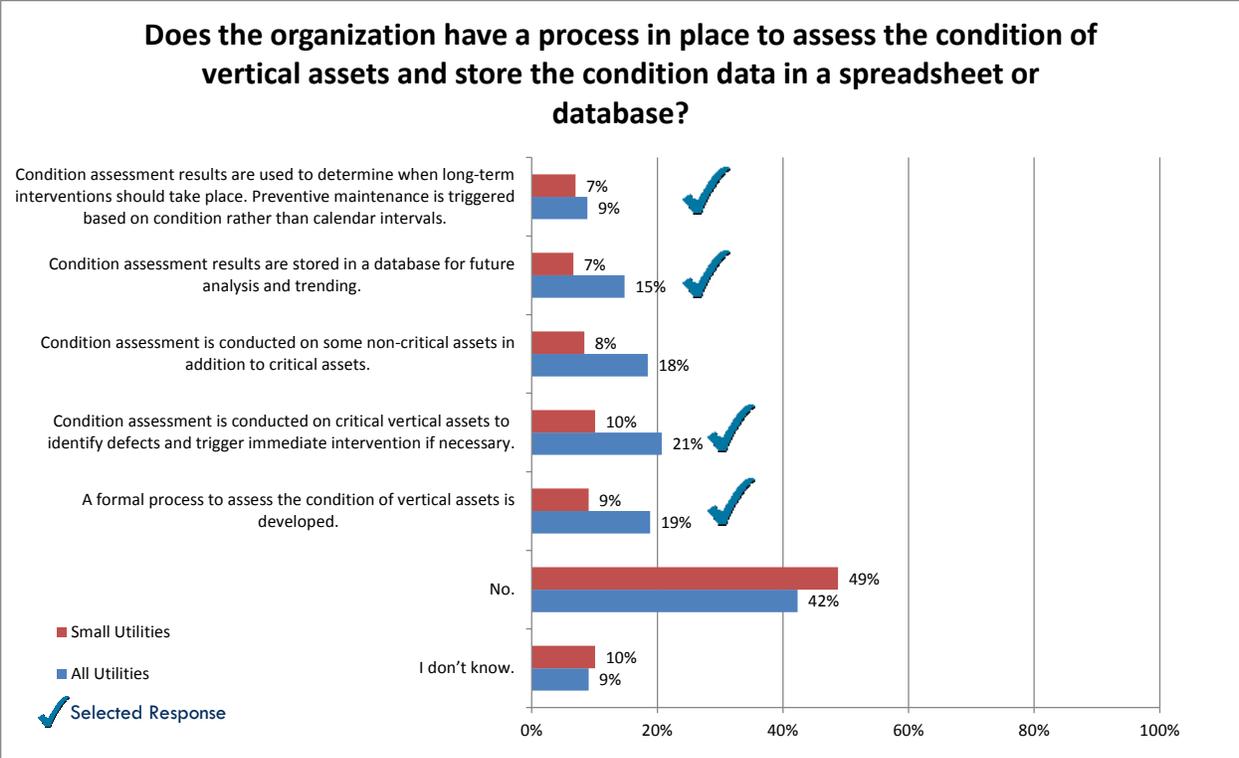
Utility: Marshalltown Water Works
City/State: Marshalltown, Iowa
Average system demand: 6 MGD
Population served: 30,000 (and bulk supply to 10-15,000)
Number of FTE staff: 21

Does the organization have a map or a geographic information system (GIS) with both linear assets (pipes) and vertical asset locations?



Does the organization have a process in place to assess the condition of linear assets and store the condition data in a spreadsheet or database?





GIS, ASSET INVENTORY AND LINEAR ASSET CONDITION ASSESSMENT

The GIS was developed by both looking through initial distribution system drawings and comparing that against real experience in the field. Initial information was added in the mid-1990s and over time paper information has been converted into electronic data. For the most part, the initial system drawings proved to be accurate; pipe diameters and pipe conditions are updated as necessary when improvements are made and repairs are completed that identify something different than what was indicated in the drawings.

Asset data in GIS includes water main diameter, age, material, break history and flow data, as well as valve and hydrant locations. Data exists for the entire distribution system and the data is generally very accurate and with good coverage. There is data on material for more than 80% of the pipes.

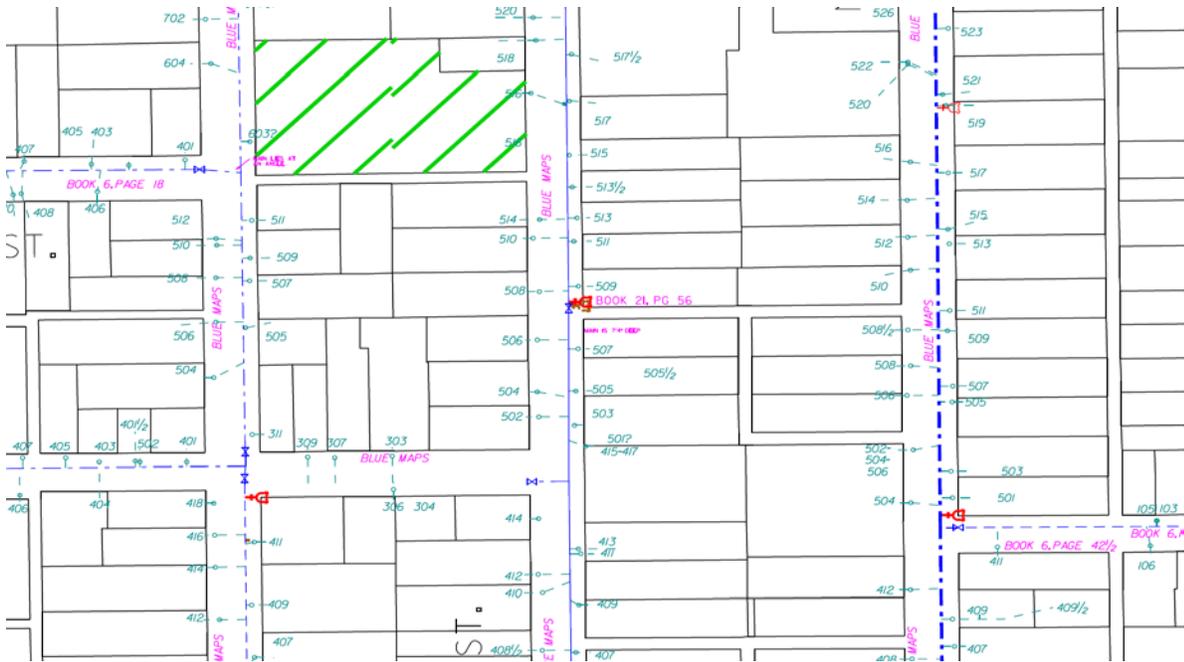


Figure 8 MWW - Extract from the GIS

Field crews utilize tablets with electronic maps, but they are not directly linked to GIS as MWW cannot justify the cost of a fully integrated system.

Main break data is collected by the field crews and recorded and stored in the GIS by staff. Information including measurements, locations, pipe diameter, and type of break are all recorded and documented in the system. The main break data is analyzed in the GIS to determine problem areas in the system and identify replacement needs. The main break analysis is assessed in conjunction with information on pipe age, pipe condition, pipe bedding and soil condition to prioritize water main replacements in the CIP.



CMMS AND VERTICAL ASSET CONDITION ASSESSMENT

The CMMS has been in place for the past four years and covers all the vertical assets in the system: tanks, towers, pumps and all equipment at the treatment facility itself. The CMMS is a commercial software package and replaced the previous excel version. Asset data has been collected and updated over the four years on an as needed basis, for example: when setting up a new preventive maintenance schedule, or performing corrective maintenance in the event a piece of equipment fails. Data attributes that are recorded include installed date, initial cost, total maintenance expenditure on the equipment, and the amount of reactive maintenance. A lot of equipment is over 40 years old but there is a high level of redundancy. There is a field for criticality (low, medium or high) which has been assigned based on operations staff experience. The software allows MWW to track expenditures (i.e. parts & labor) and parts used for repairs and maintenance.

Pick Equipment From Active Records.

OK Cancel Find Filter Print Export

Equipment #	Description	Location	Department	Type	Metered	UD1 - Manufact	UD2 - Model #	UD3 - Serial #
Air Handler Mech. Room	Air Handler Mech. Room	Treatment Plant Mech. Room	1700-Production	HVAC	False	Trane		
Air Handler Pump Room	Air Handler Pump Room	Treatment Plant HSP Room	1700-Production	HVAC	False			
Back Wash Blower	Filter Backwash Blower	Treatment Plant HSP Room	1700-Production	Process	False			
Back Wash Flow Meter	Plant Back Wash Flow Meter	Treatment Plant HSP Room	1700-Production	Process	False	Bailey Fisher Porter-	10 DX3111ADD20P198W015882	
Back Wash Flow Valve	Plant Back Wash Flow Valve	Treatment Plant HSP Room	1700-Production	Process	False	Limtorque	L120	M183245
Blow Off Pit North	North UFC Blow Off Pit	Treatment Plant	1700-Production	Process	False			
Blow Off Pit South	South UFC Blow Off Pit	Treatment Plant	1700-Production	Process	False			
Boiler #1	North Weil-McLain Ultra Efficient 399	Treatment Plant Mech. Room	1700-Production	HVAC	False	Weil-McLain Ultra	39 383-500-706	
Boiler #2	South Weil-McLain Ultra Efficient 399	Treatment Plant Mech. Room	1700-Production	HVAC	False	Weil-McLane Ultra	3i 383-500-706	
Boiler Recirc. Pump	Recirculation Pump for Boiler System	Treatment Plant Mech. Room	1700-Production	Pump	False			
Boom Sprayer	Boom Sprayer for Back of Gator	Morton Building	1700-Production	Grounds Equipme	False			
Booster Pump #1	Booster Pump #1	Booster Station	1750-Distribution	Booster Pump	False	Fairbanks Morse	5" 5822A	K2D39295-505067
Booster Pump #2	Booster Pump #2	Booster Station	1750-Distribution	Booster Pump	False			
Booster Pump #3	Booster Pump #3	Booster Station	1750-Distribution	Booster Pump	False	Fairbanks Morse	6" 2824C/ 50HP Mar	K3T1-059782
Bulk Water Fill Station	Bulk Water Fill Station	Treatment Plant	1700-Production	Misc.	False			
Chem Feed Chlorine North	North Chlorine Pump	Treatment Plant Chlorine	1700-Production	Chemical Feed	False	Blue-White	M2	
Chem Feed Chlorine South	South Chlorine Pump	Treatment Plant Chlorine	1700-Production	Chemical Feed	False	Blue-White	M2	
Chem Feed Chlorine Spare	Spare Chlorine Pump	Treatment Plant Chlorine	1700-Production	Chemical Feed	False	Blue-White	M2	
Chem Feed Chlorite	Chlorite Building	Chlorite Building	1700-Production	Chemical Feed	False			
Chem Feed Fluoride	Fluoride Pump	Treatment Plant Garage	1700-Production	Chemical Feed	False			
Chem Feed Fluoride Spare	Fluoride Pump	Treatment Plant Garage	1700-Production	Chemical Feed	False			
Chem Feed Phosphate North	Phosphate Chemical Feed North UFC	Treatment Plant	1700-Production	Chemical Feed	False	BIF/Lutz-Jesco	1272-21-9210A	73733-8
Chem Feed Phosphate South	Phosphate Chemical Feed South UFC	Treatment Plant	1700-Production	Chemical Feed	False	BIF/Lutz-Jesco	1272-21-9210A	73733-8
Chevy Colorado	2012 Chevrolet Colorado	Treatment Plant	1700-Production	Vehicle	True			
CHLORINE BULK #1	CHLORINE BULK TANK WEST	Treatment Plant Chlorine	1700-Production	Chemical Feed	False			
CHLORINE BULK #2	CHLORINE BULK TANK EAST	Treatment Plant Chlorine	1700-Production	Chemical Feed	False			
CL17 Grundy RW Pit	Grundy Rural Water Pit Chlorine Analyzer	Rural Water Pit Grundy	1750-Distribution	Monitoring	False	Hach	CL17	
CL17 North RW Pit	North Rural Water Pit Chlorine Analyzer	North Rural Water Pit	1750-Distribution	Monitoring	False	Hach	CL17	
CL17 Plant	Treatment Plant Chlorine Analyzer	Treatment Plant HSP Room	1700-Production	Monitoring	False			
CLT10 Booster Station	Chlorine and pH Monitor Booster Station	Booster Station	1750-Distribution	Monitoring	False	Hach	CLT10 #2981500	
CLT10 South RW Pit	Chlorine and pH Monitor South Rural Water Pit	Rural Water Pit South	1750-Distribution	Monitoring	False	Hach	CLT10 #2981500	
CLT10 West RW Pit	Chlorine and pH Monitor West Rural Water Pit	Rural Water Pit West	1750-Distribution	Monitoring	False			
CO2 Feeder North	North UFC CO2 Feeder	Treatment Plant Chlorine	1700-Production	Process	False			
CO2 Feeder South	South UFC CO2 Feeder	Treatment Plant Chlorine	1700-Production	Process	False			
CO2 Feeder Supernatant	Supernatant CO2 Feeder	Treatment Plant Garage	1700-Production	Process	False			
CO2 Tank	CO2 Storage Tank	Treatment Plant	1700-Production	Chemical Feed	False	TOMCO	PROJECT CODE WT-	
Compressed Air Dryer	Plant Air Dryer	Treatment Plant Mech. Room	1700-Production	Process	False			
Dehumidifier Booster	Booster Station Dehumidifier	Booster Station	1750-Distribution	HVAC	False			
Dehumidifier HSP	HSP Room Dehumidifier	Treatment Plant HSP Room	1700-Production	HVAC	False			
Diesel Tank Monitor	Monitoring System for Diesel Storage Tank	Treatment Plant	1700-Production	Process	False	Franklin Fueling Syst		
DR5000 Lab Spectrophotometer	Hach DR5000 Lab Spectrophotometer	Laboratory	1700-Production	Monitoring	False	Hach	DR5000 UV-Vis	1166539
Drinking Fountain	Plant Drinking Water Fountain	Treatment Plant	1700-Production	Process	False			
Dust Collector North	Dust Collector and Fill Pipe North Lime Bin	Treatment Plant Roof	1700-Production	Chemical Feed	False			
Dust Collector South	Dust Collector and Fill Pipe South Lime Bin	Treatment Plant Roof	1700-Production	Chemical Feed	False			
Emergency Preparedness	Emergency Equipment Checklist	Multiple	1700-Production	Multiple	False			
Exhaust Fans	Treatment Plant Exhaust Fans	Treatment Plant	1700-Production	HVAC	False			
Filter #1	Treatment Plant Filter #1	Treatment Plant	1700-Production	Process	False			
Filter #2	Treatment Plant Filter #2	Treatment Plant	1700-Production	Process	False			
Filter #3	Treatment Plant Filter #3	Treatment Plant	1700-Production	Process	False			
Filter #4	Treatment Plant Filter #4	Treatment Plant	1700-Production	Process	False			
Filter #5	Treatment Plant Filter #5	Treatment Plant	1700-Production	Process	False			
Filter #6	Treatment Plant Filter #6	Treatment Plant	1700-Production	Process	False			

Figure 9 MWW - Screen shot of asset inventory in the CMMS

Equipment records, O&M manuals and other documentation have been digitized, and this is now starting to pay dividends as access to information has improved and scheduling maintenance is much more efficient. Each asset has a preventive maintenance schedule assigned to it based on the manufacturer's recommendations. Currently, paper work orders are produced for maintenance staff, but MWW is looking to make them electronic. Corrective maintenance is also tracked in the CMMS.

Everything that is above ground, including pumps, pipes, and tanks, are all inspected frequently by MWW staff. There is also a schedule for professional third party inspection. Inspection information and condition assessments are stored in the CMMS, and there is now enough data for analysis to inform predictive maintenance and to prioritize maintenance activities. Time and cost for corrective and preventive maintenance is captured, which is beneficial to MWW's CIP and O&M budgeting. MWW does not have a formal scoring system for condition; replacement decisions are made based on the age of the asset and the amount of preventive and corrective maintenance that is required to keep the asset operational.

BENEFITS

Implementing these asset management practices has enabled MWW to better prioritize the maintenance and replacement of assets, and equipment life expectancy has improved due to more effective maintenance. A specific example can be found in some chemical feed equipment (lime slakers) at the treatment plant, which is nearly 40 years old. The abrasive and corrosive nature of their work makes for a challenging maintenance environment. The CMMS has allowed MWW to better track and take care of this equipment. The slakers are being replaced this year as part of a major plant improvement project, but the increased amount of preventive and predictive maintenance that has been performed over the last several years has kept the corrective and emergency repairs to a minimum which has really helped to get this equipment “over the finish line.” Tracking the equipment a little more closely, it was easy to see that if MWW remained consistent and vigilant in taking care of it, and in some cases performing tasks ahead of schedule or shortening the maintenance intervals, they could make it last until replacement.

The measured approach to implementing asset management has provided tangible benefits; using the entire staff to gather data and assess asset condition has been a good team building exercise, providing everyone with a better understanding of what MWW is doing.

Tim Wilson has this advice for small utilities attempting to improve their asset management practices: *“don’t be intimidated by asset management. Slow adoption of some of the practices is way more beneficial than no adoption at all. You do not have to formalize and implement an entire asset management plan all at once; pick and choose. Get those quick wins that can deliver the greatest return on your investment and remember that your investment is not only capital but also time related, and that each of them has a value. The quick wins will help your buy in, from both management and staff, and use those wins to learn how best to proceed and expand your program. There is always room for improvement. Data collection can be tedious, but don’t be complacent, and monitor complacency in yourself and your staff closely. Stay focused on where you are and what you are trying to do. The more you do the easier it gets.”*

Hastings Utilities

Leading Practice – Current State of Assets

BACKGROUND

Hastings Utilities supplies potable water to residents of the City of Hastings and surrounding communities, a total population of about 30,000 directly from the Ogallala Aquifer. Hastings currently has no water treatment facility or storage tanks, but extracts water from 23 operational community wells. There are a total of 35 wells but 12 are inoperable due to either age or contaminants.

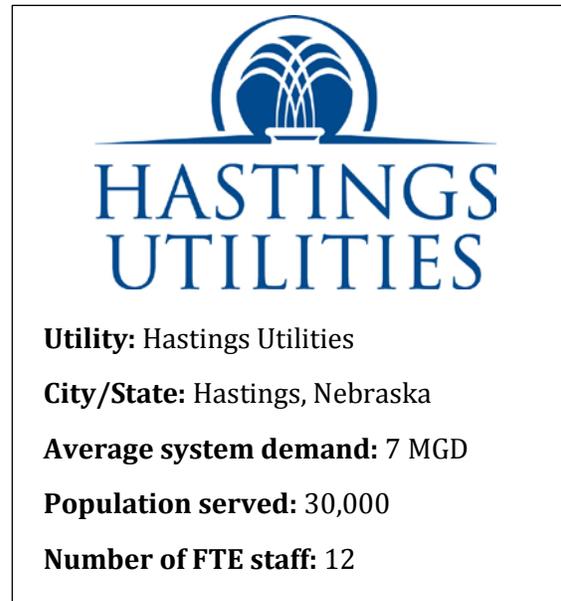
Water is supplied through a water distribution system that has a total length of 327 miles.

The utility also provides wastewater, electric, gas and street lighting services.

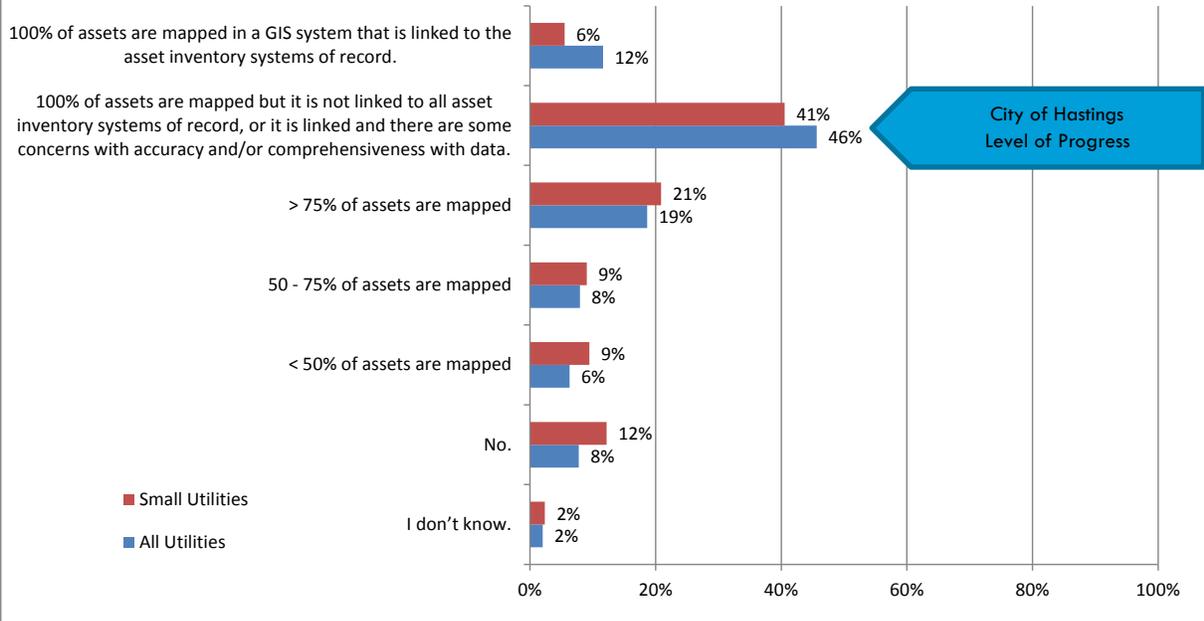
Hastings Utilities does not have a formal asset management program, but have identified certain priorities for improving asset management. This has initially focused on data collection and improving data quality, and prioritizing water main replacements.

SURVEY RESULTS

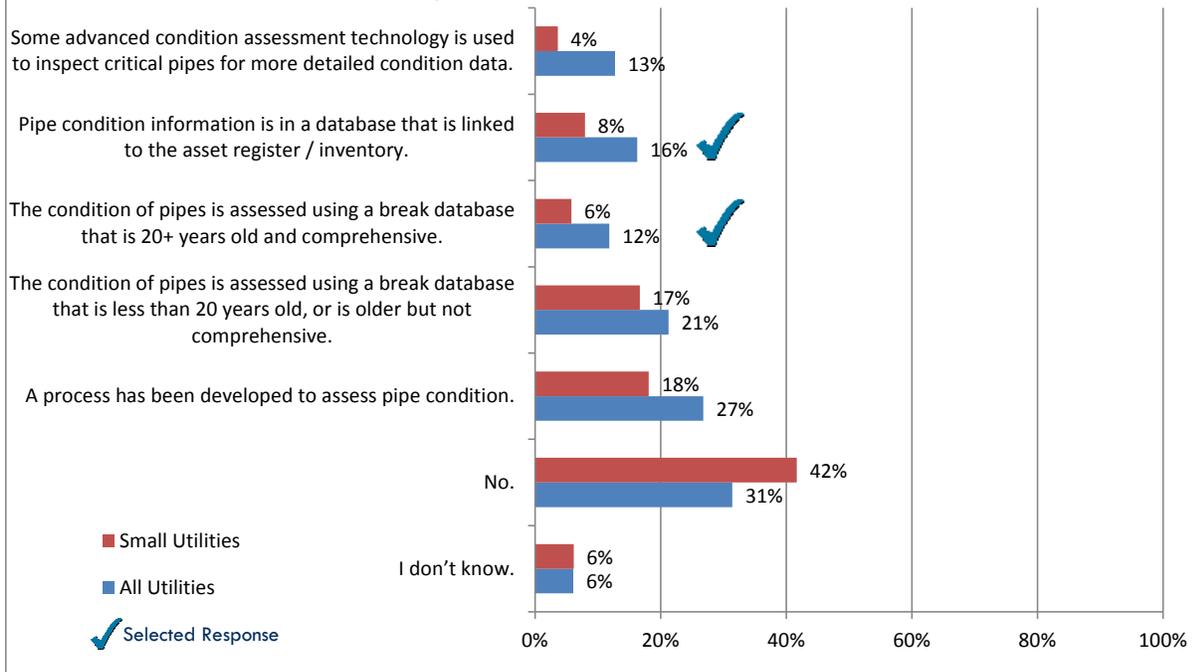
Hastings Utilities ranked high in the Current State leading practice compared with other small utilities in the case study focus areas of GIS and condition assessment. Hastings Utilities' responses are shown in the following graphs. The graphs also show the responses from all the other participating utilities and the responses for the small utilities.

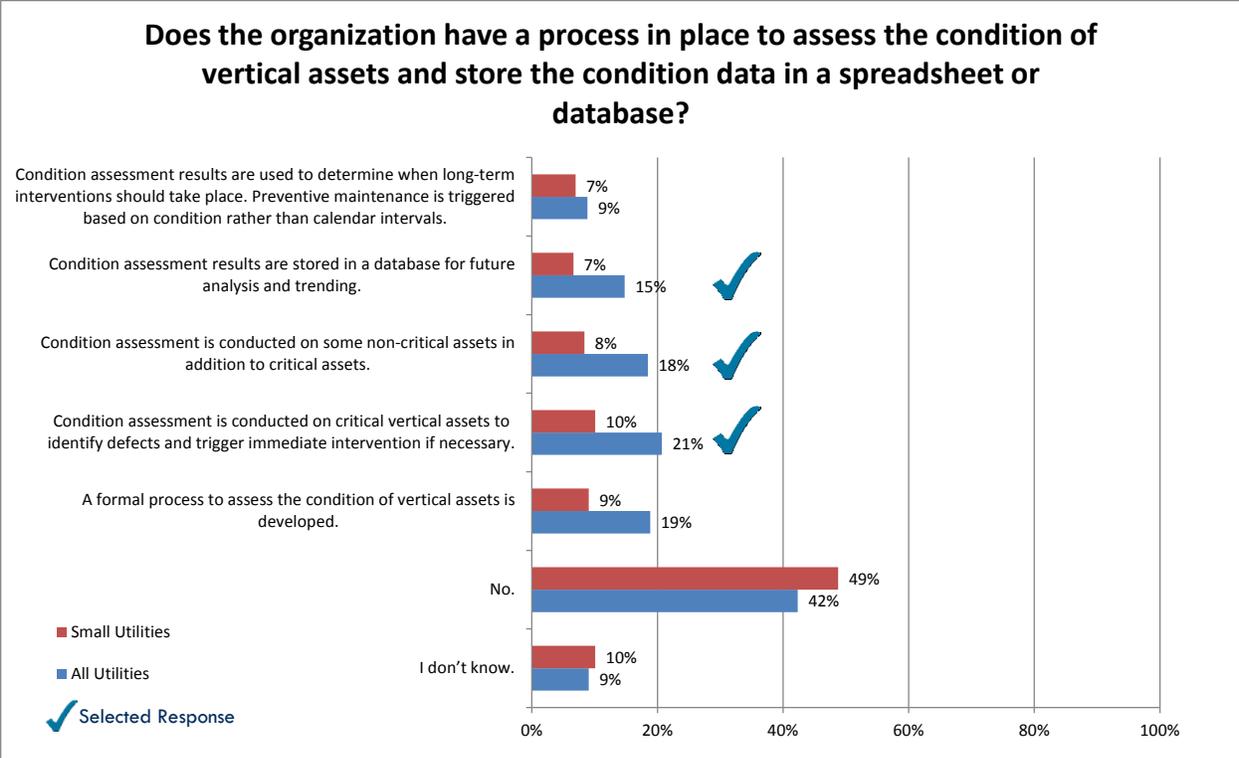


Does the organization have a map or a geographic information system (GIS) with both linear assets (pipes) and vertical asset locations?



Does the organization have a process in place to assess the condition of linear assets and store the condition data in a spreadsheet or database?





ASSET INVENTORY AND GIS

Hastings has had a GIS in place for about six years. Prior to the GIS paper maps were used by field crews in their trucks (referred to as “Truck Maps”); these maps divided the service area into quadrants and were produced by hand. It was difficult to keep these maps up to date and they were typically 1-2 years out of date, but there was no good way of tracking changes. When Hastings started to use CAD it decided to put the “Truck Maps” into the CAD format, which then led to the use of GIS. The use of GIS was implemented to provide for timely update of system and truck maps for not only the water system but for the sewer, gas, and electric systems operated by Hastings Utilities.

In implementing the GIS, Hastings identified all its existing record drawings and reviewed the quality of the information. In doing so, it was realized that there was only one copy of the record drawings, water service cards, water valve and hydrant cards, and other utility maps so the drawings were scanned for archiving. All the scanned drawings are linked to the GIS so they can be viewed.

The data attributes in the GIS include pipe diameter, length, material, year installed and who originally paid for it. Overall data coverage is around 99% complete, with some specific gaps for the pipes laid in the period 1900 – 1920. Figure 10 shows an example of the distribution main attributes in the GIS.

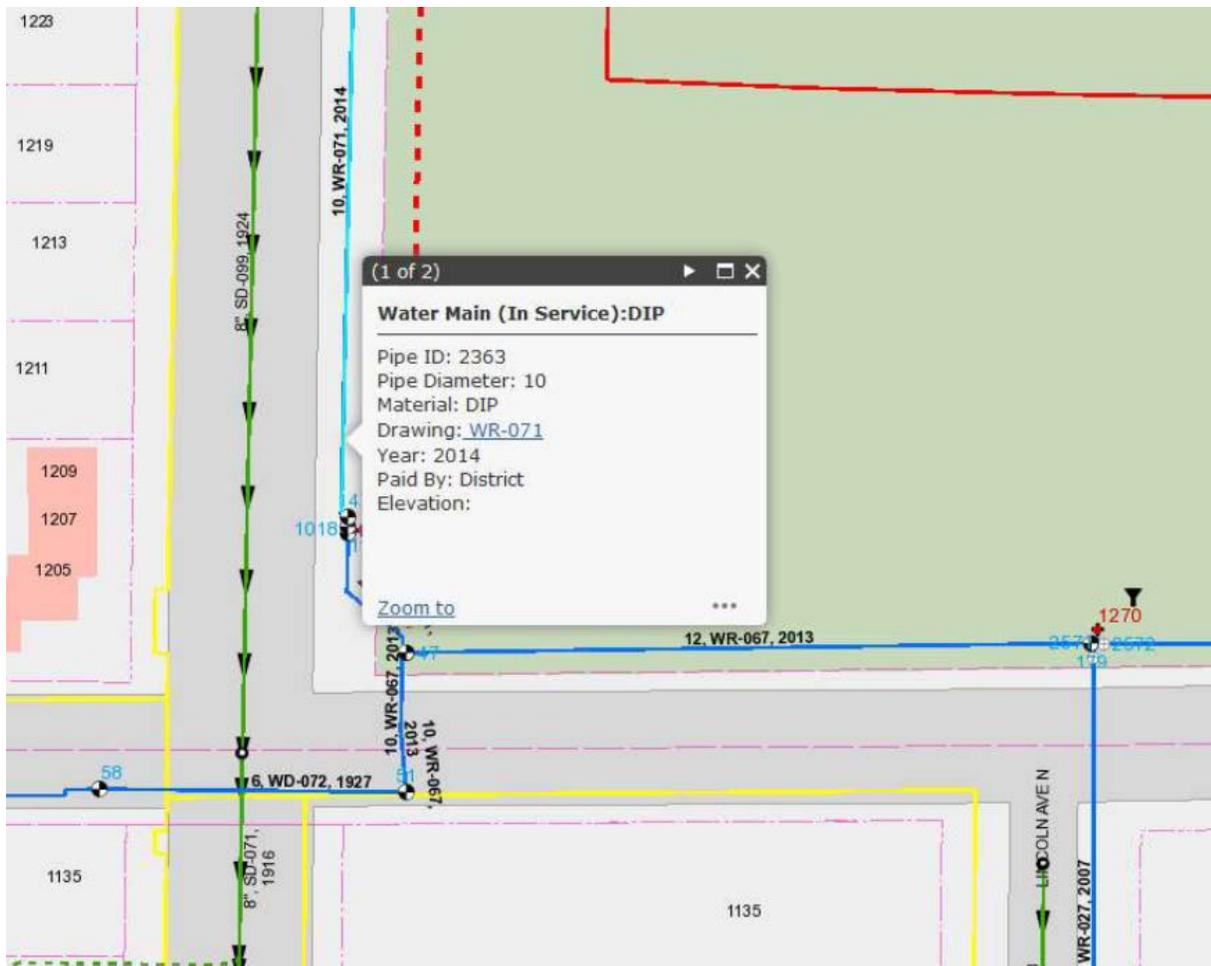


Figure 10 Hastings Utilities - Screenshot of GIS with data attributes for a distribution main

There is one GIS specialist who is responsible for managing the GIS, and the Utility provides some support from its IT department. Additional GIS resources are provided by the City and County. There is good coordination to provide support and share data. Requests are received from members of the public, realtors, and insurance companies for information on utility locations; the GIS specialist is able to provide the information easily and it is available on the City's website as well.

All of the staff has access to the GIS, but some people still like paper copies and they have maps printed periodically. As-built drawings are provided to the GIS specialist to update in GIS. Since Hastings Utilities also has a wastewater collection and treatment system, gas distribution system and electric production and distribution facilities, it has a large engineering department that does design and inspection in-house, including the provision of as-built drawings. Field staff will markup drawings with any corrections they identify on the ground for the GIS specialist to update.

The GIS is now the basis for planning and provides the foundation for monitoring performance and maintenance, and main breaks. Analysis can now be performed using the available data (such as analyzing the relationships between age and number of breaks) to facilitate water main rehabilitation and replacement planning.

WATER MAIN REPLACEMENT PRIORITIZATION

Water mains are prioritized for replacement using the following criteria:

1. Fire flow need
2. Breaks on the main
3. Age of the main
4. Location of the main (e.g. old mains might be located under buildings where there can be a greater risk of damaging a building and multiple buildings if there is a main break).

Fire flow is analyzed using a hydraulic model in combination with hydrant testing to calibrate and identify available fire flows. Flows can be predicted based on the size of pipe and whether it is a one or two-way feed. Currently high population centers like churches, schools, shopping malls, and industrial areas are provided with sufficient fire flow. However, residential areas where there are still a large number 4" mains is a problem as it is difficult to achieve the desired 1500 gallons per minute everywhere. If fire flow is less than 750 gallons per minute, then it becomes a priority for replacing. Hastings does not now allow any pipe less than 8-inch to be installed in the system.

Hastings typically has 8-10 main breaks and 40-50 service line leaks per year. When a break or leak is reported operations staff will attend to resolve the issue and try to identify the cause. A form is used to record information about the main break including the type of break and information on the strength and condition of the pipe, and a sample of the main is taken for inspection. The size and age of main is also noted as well as the materials used to make the repair and this information is then entered into the GIS.

Information on the main break is used as part of the analysis to prioritize water main replacement. Information on soil type is overlaid in GIS to assess any correlation between breaks and soil type, as well as age of the main and any third-party activity to identify problem areas in the system. As part of the analysis, it was identified that some ductile iron pipes installed in the 1970s were failing at a higher rate due to problems with the mechanical joints.

Hastings also includes the location of the main in the assessment to assess the impacts of a main break. An example of a recent project was the replacement of 1920s era mains built under a major highway. There had not been any failures of the main but the impact of a failure would be severe, so a proactive main replacement project was developed as a priority.

Water main replacements are coordinated with the City's street rehabilitation projects to minimize disruptions and some water main replacement may be advanced even if they have a lower priority.

BENEFITS

The main benefit from improving asset inventory information is having the data to be able to prioritize water main capital improvements to target the areas that need it most. With the GIS, it is much easier to analyze the main break information and coordinate replacements with the City's street projects and to determine whether to replace a main or extend its life. Improved information and analysis on fire flow has enabled Hastings to implement a replacement strategy that has resulted in big improvements in the performance of the system.

One of the lessons learned was that there are more factors to determining how long a main will last than just age. Hastings has developed a better understanding of how long mains with different

characteristics may last and is able to make better decisions on when to replace mains in conjunction with the City's streets program.

The field crews now have much better and more up-to-date information available to them with the GIS, which makes it easier for them to resolve incidents in the system, and the utility locate technician is better able to identify and confirm the location of water mains. The data collection process also identified where valves had been covered over which enabled them to be uncovered and made functional.

Hastings Utilities' Environmental Supervisor Marty Stange, believes that other small utilities would benefit from digitizing drawings and implementing GIS: *"Talking to other communities of similar size to Hastings we realized that they had similar problems, with many still relying on paper records. This may work now with experienced staff in place who are familiar with the existing assets, but it will soon become problematic once they retire and that knowledge is lost."*

San Diego County Water Authority

Leading Practice – Current State of Assets, Risk Management

BACKGROUND

The San Diego County Water Authority (Water Authority) is a public agency serving the San Diego region as a wholesale supplier of water from the Colorado River and Northern California and local desalinated water. The Water Authority's mission is to provide a safe and reliable supply of water to its 24 member agencies serving the San Diego region.

The San Diego County Water Authority operates and maintains the San Diego region's aqueduct delivery system, which consists of approximately 300 miles of large-diameter pipelines, including welded steel pipe, prestressed concrete cylinder pipe (PCCP), bar-wrapped concrete cylinder pipe, and reinforced concrete cylinder (and non-cylinder) pipe. Additionally, there are more than 1,400 aqueduct-related structures and over 100 flow-control facilities. These facilities occupy approximately 1,400 acres within the Water Authority's right of way, and deliver water for over 3 million residents. Figure 11 provides an overview of the system.



Utility: San Diego County Water Authority

City/State: San Diego, California

Average system demand: 200 MGD

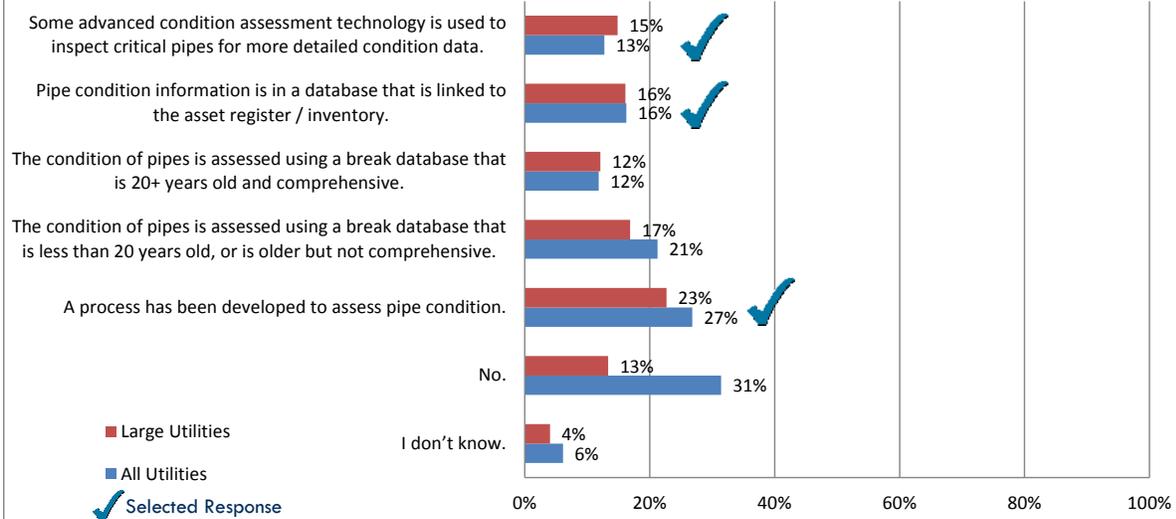
Population served: 3,000,000

Number of FTE staff: 253

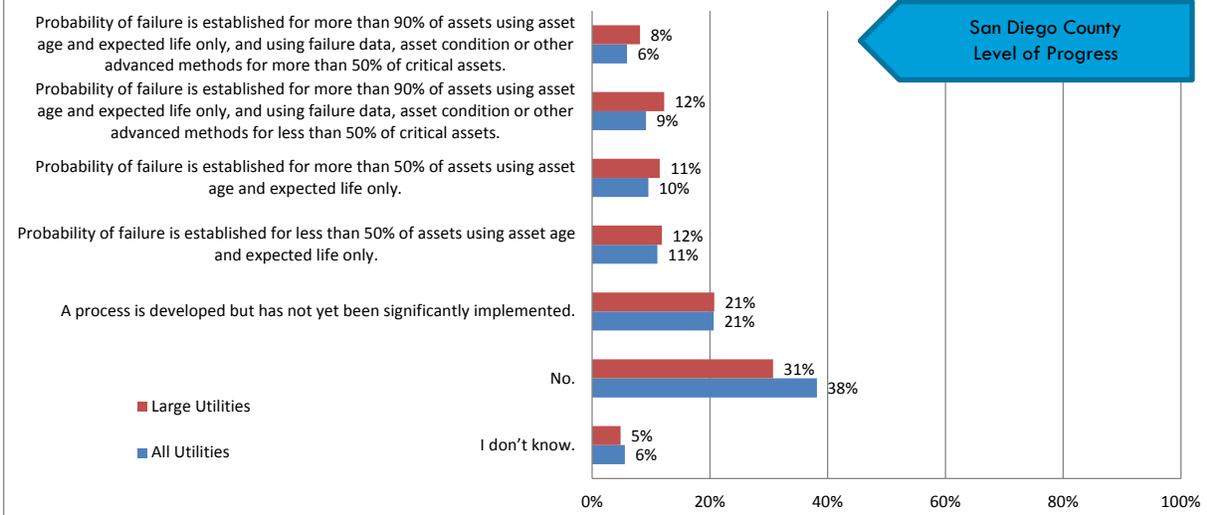
SURVEY RESULTS

The Water Authority ranked highest in the Current State and Risk Management leading practices, with a focus on linear asset condition assessment and proactive pipeline replacement. The Water Authority's responses are shown in the following graphs. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.

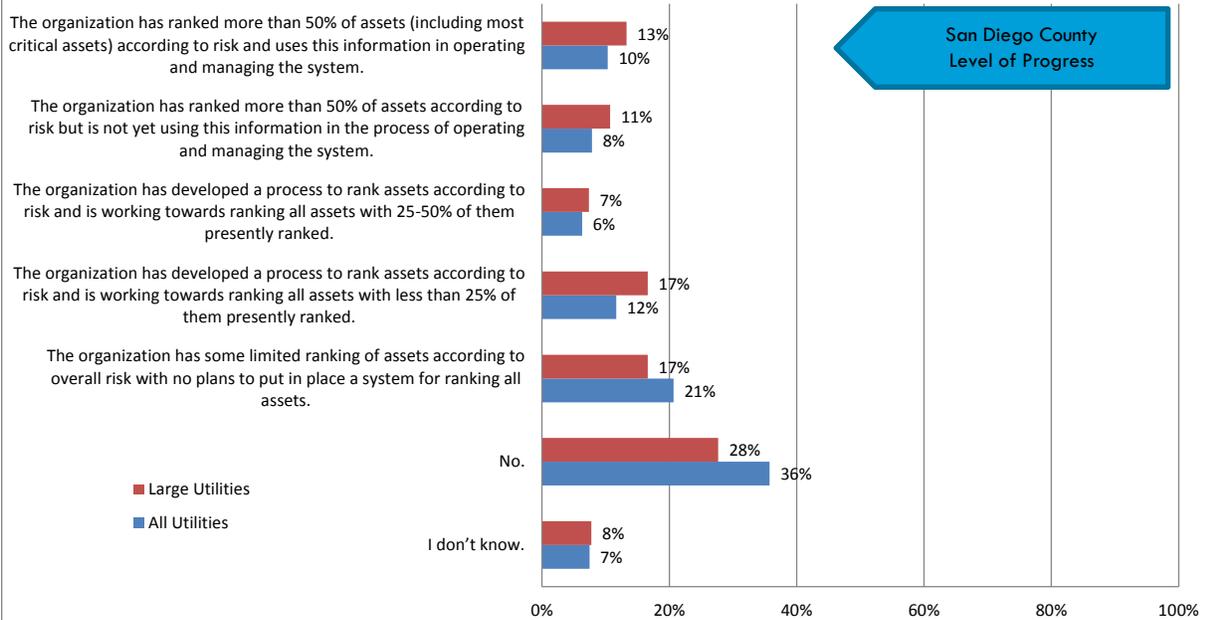
Does the organization have a process in place to assess the condition of linear assets (distribution system pipes) and store the condition data in a spreadsheet or database?



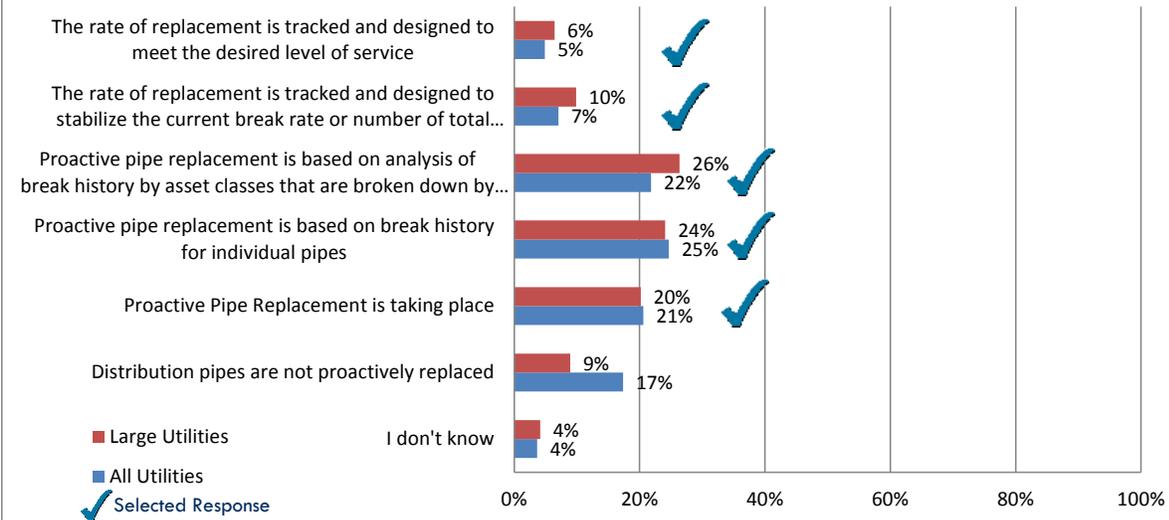
Does the organization have a process to assess the probability (or likelihood) of failure of assets?



Does the organization have a process to rank assets according to overall risk (the product of likelihood and consequences of asset failure)?



How advanced is the organization in predicting when water distribution pipe assets should be proactively replaced?



ASSET MANAGEMENT PROGRAM

Prior to 2009, the Water Authority did not have a formal asset management program. It had been managing its critical assets through several existing programs that identified specific replacement priorities based on condition assessment factors such as age, maintenance cost, risk of failure, and level of service. In 2008, the Water Authority's Board of Directors presented a strategic plan that provided guidance in setting policies over the next 25 years and provided the groundwork for the approval of the Asset Management Plan in January 2009.

The intent of the Asset Management Program is to systematically assess and monitor all of the Water Authority's existing water conveyance assets to prioritize and administer rehabilitation or replacement projects and ensure continued cost-effective service.

Two guidelines help to define the scope of the program:

- The program is intended to target significantly aged or defective assets, which the utility would be unable to maintain or extend the useful life using regular maintenance techniques alone.
- The program does not set out to change the function of an asset, as this situation would warrant a broader planning investigation. For example, an aging flow control facility in poor condition would be a good candidate for replacement in the program, but if a new hydro-electric component was desired in the facility, a separate planning study would be needed.

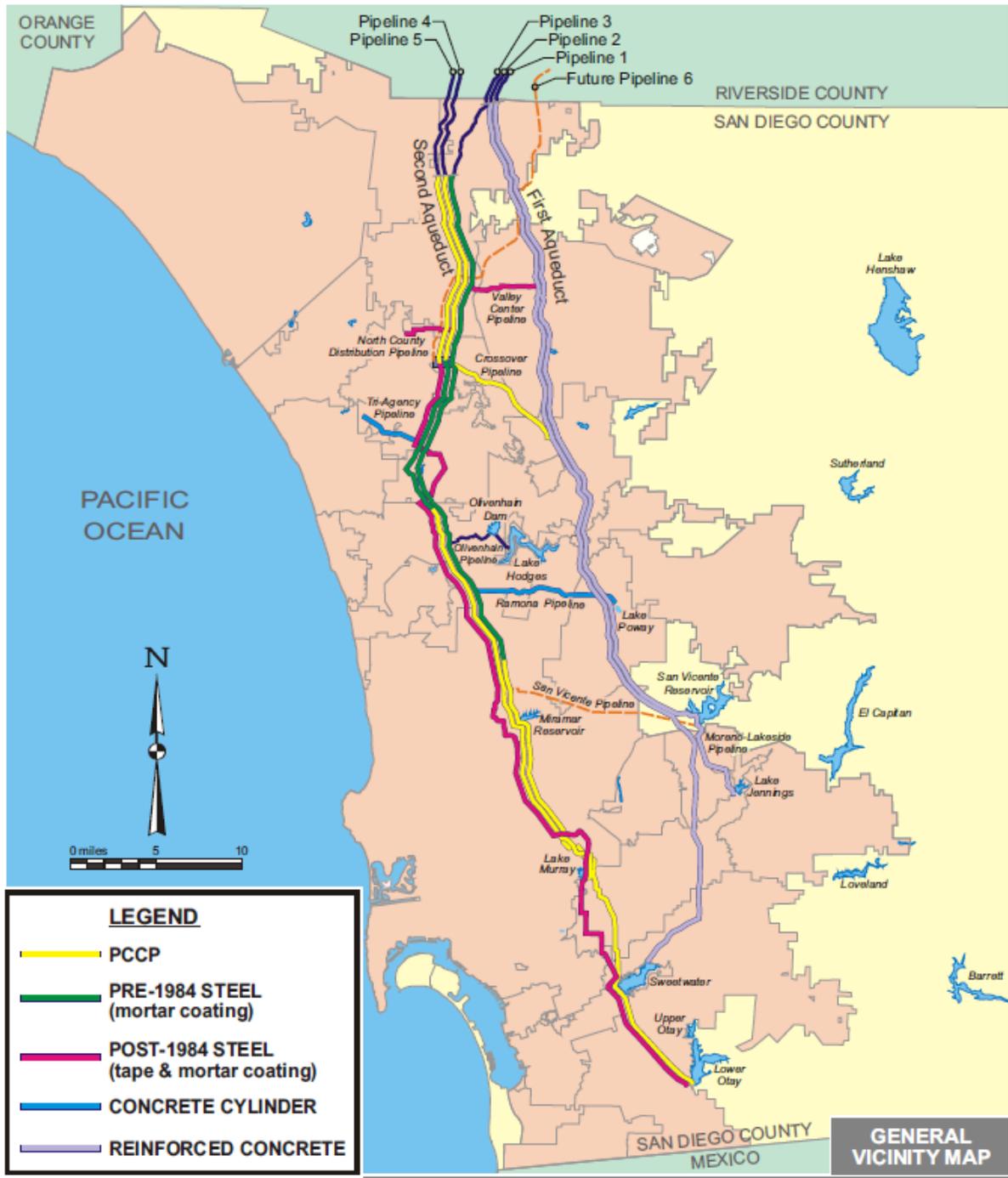


Figure 11 San Diego County Water Authority Aqueducts

APPROACH TO CONDITION ASSESSMENT

Over the past 50 years, the Water Authority has experienced nine major pipe failures. These failures occurred on pipes ranging from 48-inches in diameter to 96-inches in diameter and had significant consequences. With this experience and the recognition that the Water Authority's first pipelines

and facilities were constructed in 1947, it was recognized that a significant proportion of its infrastructure may be approaching the end of its useful life. This provided the impetus for a robust condition assessment plan to define inspection activities and increase knowledge and confidence regarding the condition of pipeline and facility assets.

The condition assessment and monitoring function is performed by a group of specialists to determine the rate of deterioration. Tools in regular use include:

- Visual inspections
- Sounding
- Ultrasonic testing
- Remote Field Eddy Current (RFEC)
- Acoustic Fiber Optic Monitoring
- Magnetic Flux Leakage (MFL)

As the Water Authority's asset management program developed, it was recognized that a consistent methodology and structure was needed to organize, visualize, and analyze the large amounts of data that were collected in various condition assessment efforts. This resulted in a dynamic geovisualization approach that overlaid two-dimensional graphs and charts over perspective aerial photos, allowing rapid understanding of the complete situation for each pipe. This was found to be much more effective at interpreting and communicating potential concerns than typical spreadsheets.

The visualization approach developed in stages as multiple assessments and methodologies were used to assess pipes. It was established in particular for PCCP pipes, which were identified to have the highest risk of failure. Figure 12 shows an example of the visualization, which compiles data from assessments and monitoring.

- The baseline assessment involved an RFEC inspection, which provides a summary of wire breaks along the length of the pipe. The height and color coding of the vertical bars along the length of the pipe corresponds to the number of wires broken on a per-stick of pipe basis. This provides a very easy-to-understand visualization of the problem areas for the pipe.
- Following the RFEC assessment, acoustic detection systems were installed to provide continuous monitoring capability. This is reflected graphically by adding presentation of acoustically detected breaks. Although these could be represented by increasing the height of the vertical bars in Figure 12, this would miss the critical element of timing. Therefore, this data is presented with the addition of reference lines and a plot of acoustic data above the plotted bars.

In Figure 12, the horizontal reference lines represent timelines for 2005, 2010, and 2015, respectively. The red dots represent single acoustic events – wire breaks – plotted according to the horizontal location along the pipeline and vertically according to the date and time they occurred. This provides not only a static 'snap-shot' of pipeline status, but also an interpretation of rate-of-change as time progresses.

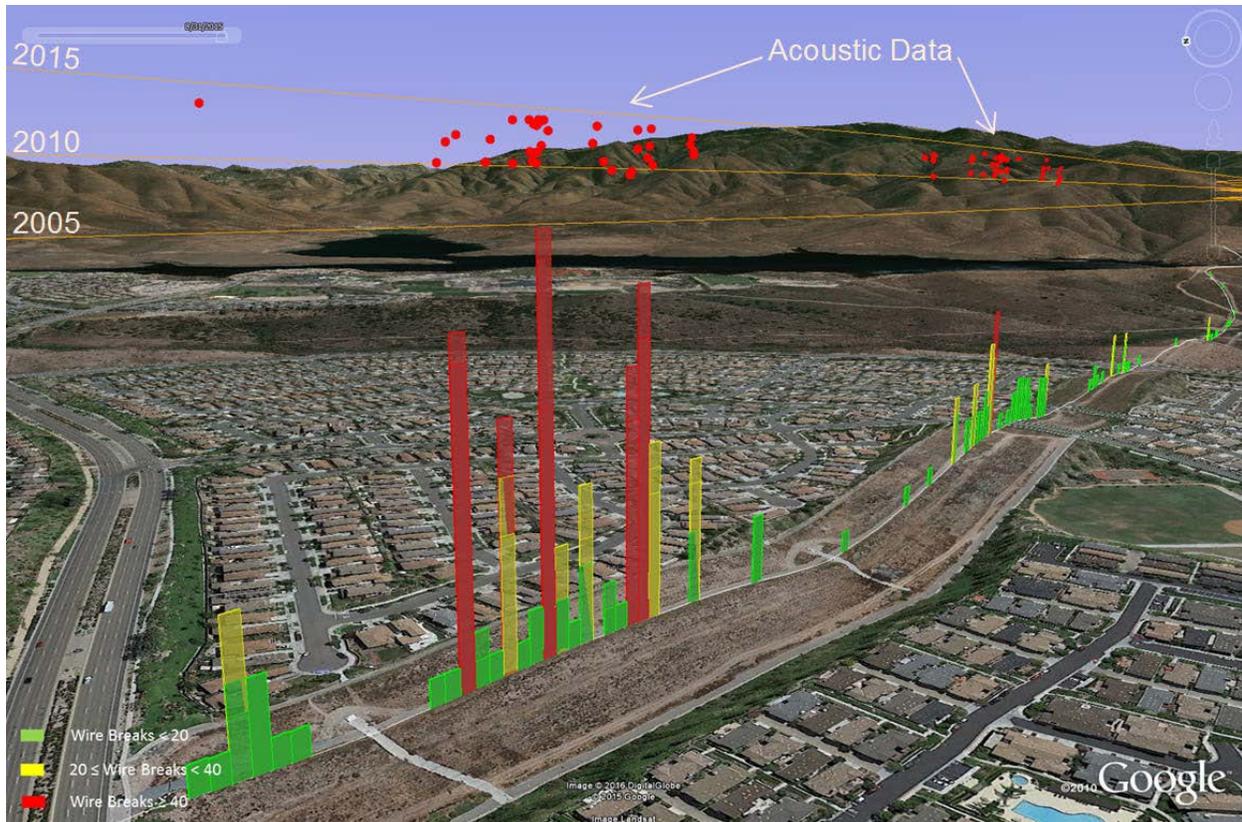


Figure 12 San Diego County Water Authority - Geovisualization of Wire Break Data

The Water Authority uses a similar methodology for other condition assessment approaches as well. For example, Figure 13 presents the Magnetic Flux Leakage (MFL) data in a way that permits the visualization of anomaly orientation. The area in question indicates a pipeline running within a few feet of an embankment belonging to a plant nursery. Corrosion pitting was identified along the spring line of the pipe on the side facing the embankment. Pitting was confirmed in subsequent testing, and external investigation was planned in the future to confirm suspicion that earth moving equipment from the nursery may have damaged the pipe.

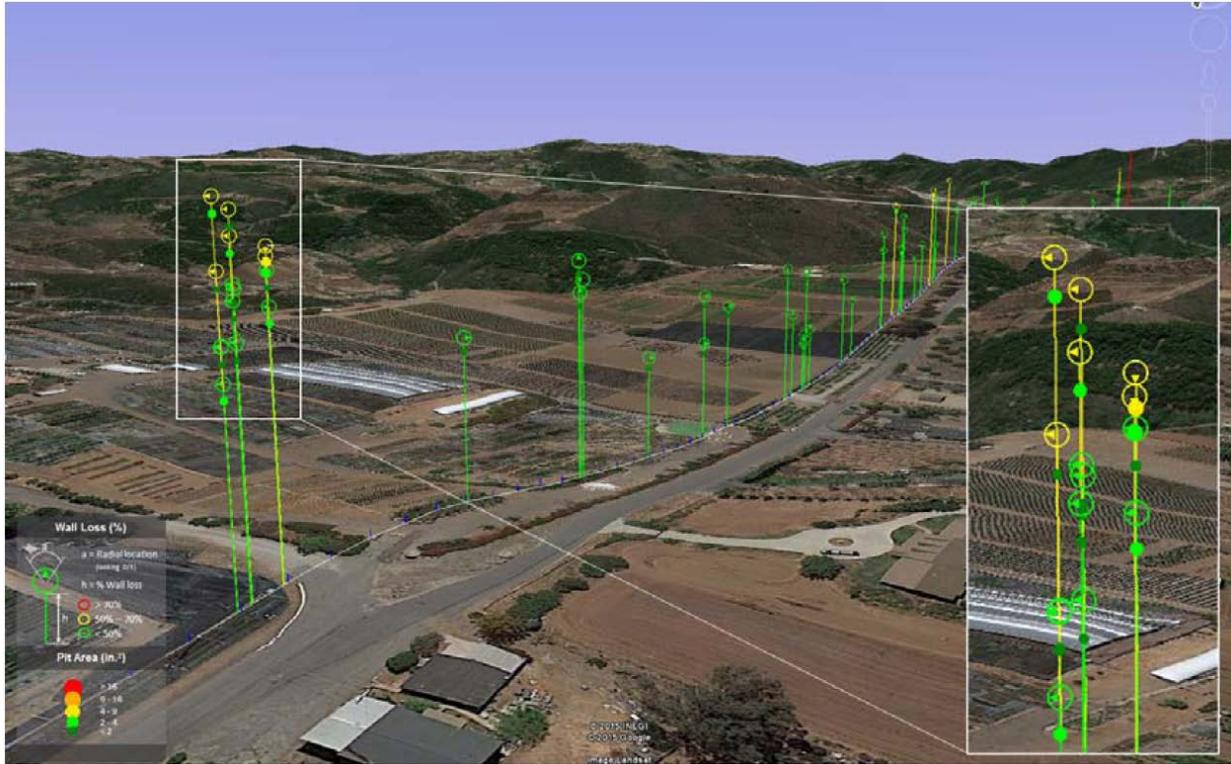


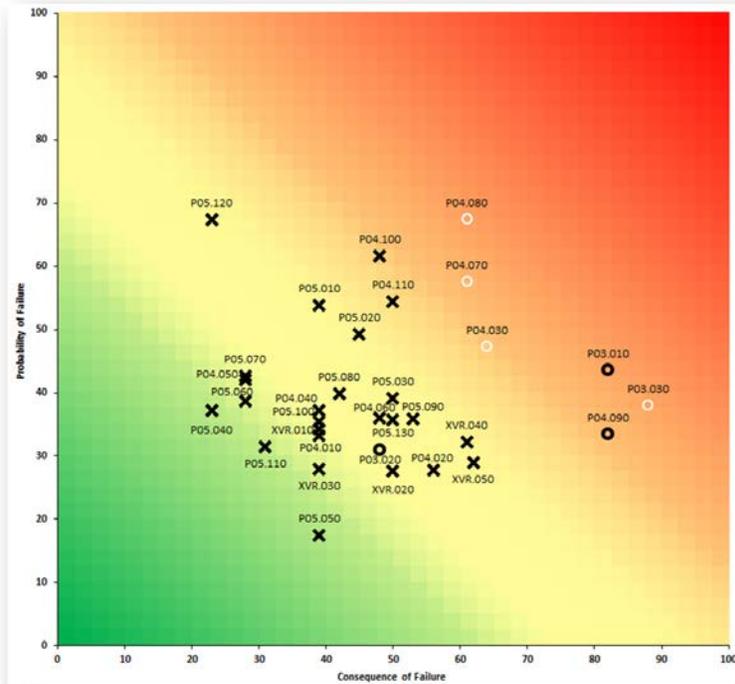
Figure 13 San Diego County Water Authority - Geovisualization of Magnetic Flux Leakage Data

APPROACH TO RISK MANAGEMENT

Risk assessment is conducted to address the probability of failure and the consequence of failure on scales of 0 to 100. This may be done for individual assets or components of assets, as applicable. Criteria used in the evaluation include (but are not limited to):

- Probability of Failure: Asset age, visual condition, non-destructive testing (NDT) condition assessment, monitoring activity, wire breaks, design features, construction practices, modes of operation, maintenance procedures, and external environmental factors.
- Consequence of Failure: Loss of functionality, limits to water supply, damage to property, risk to other assets, buried utilities, Member Agency service, system redundancy, and function.

The risk results are then presented in a common format risk matrix, as shown in Figure 14.



Example Risk Matrix

Figure 14 San Diego County Water Authority - Example Risk Matrix

Using the risk matrix, the priority for repair or replacement would be those projects within the most critical red sector (top right), and those within the yellow sector with notably high probabilities or consequences of failure. Within the same asset class, the highest priorities would be those with the highest combined scores; however, these need to be assessed with respect to other asset classes as there may exist the potential for efficiencies in packaging of projects.

When developing projects, the Authority goes through an exercise of picking priority sectors on a pipeline, based on reaches of pipeline where they have data. Relining a whole section could fix areas with multiple wire breaks. The size of each reach to be analyzed and improved is dictated largely by the rehabilitation methods. In the latest iteration, they had rate of change data on the PCCP pipe, in 66 priority sectors, which were then analyzed with other data in a spreadsheet. Categories such as maximum number of breaks, percent of distressed pipe sticks (with 1 or more wire breaks), rate of change (qualitative score 1 to 5), and pressure (as % of maximum on prestressed) were used to assess and prioritize the pipe.

The risk-based approach has been used not only to identify rehabilitation and replacement needs, but to identify inspection and assessment needs on an iterative basis. Based on their analyses, they originally identified the materials and locations that were most likely to fail, and this information helped them develop monitoring plans for pipes that were not yet been assessed or that require continuing assessment. The current status of the monitoring/inspection approach for the materials most likely to fail is as follows:

- PCCP – was identified as a very critical material. Major portions of the system have been relined, and everything that has not been relined (42 miles) is being actively monitored.

- Welded Steel Pipe – everything received a level 1, high level inspection. Approximately one-third of the pipe was followed up with MFL inspection. In the analyses, they identified that the primary mode of failure is localized corrosion that is dealt with immediately and proactively after inspection. Since the areas of concern were fixed and the inspections do not yield a rate of change, the trigger for doing additional condition assessments is based on age, when it first reaches 50 years. The remaining uninspected pipe is newer, so it will be inspected at 50 years, when it reaches 50% of the expected life. This approach is subject to modification if a problem arises, but based on the current information, the remaining pipe that has not been inspected was identified to be lower risk.

For consequence of failure, numerical scores were assigned based on factors such as proximity of gas lines, utilities, and roads. Shapefiles from various sources were plotted with the alignments on Google Earth, providing a 1-5 rating for each category, with weighting factors. However, because the Water Authority's system is a transmission system, all pipes are inherently high consequence pipes. As a result, the risk tolerance of the Water Authority is very low, and their goal is not to have a single failure.

OBSERVATIONS FOR THOSE GETTING STARTED

The Water Authority's overall approach has been phased in over a number of years, and they strongly recommend that approach for those getting started. There is no need to create everything from scratch all at once. They relate this as a "Journey to Confidence." In the beginning, the data and information may not be perfect, but the imperfections can help guide future data collection. Especially in the beginning, the answers and priorities from the process may be obvious, but even then, it is useful to be able to communicate a logical path to get there.

When considering prioritization approaches, they offer the following advice:

- Although age may initially be a primary factor in determining the risk of failure, as a utility matures, age should be less and less of a consideration, since there will be a better understanding of individual assets.
- Data is used extensively in decision making, but flexibility must be designed into the process to take site-specific considerations into account and to allow for adjustments in the prioritization of work.
- Their current approach, which is built on a strong base of condition data, is to make decisions based on the rate of change in condition in order to provide the best estimate of when an asset needs to be replaced. To achieve this, multiple assessments are needed, and old assessments should be kept for comparison.

BENEFITS

As noted above, the Water Authority relates its asset management program as a Journey to Confidence. When they started, they were surprised by significant failures of critical mains. Now, they have reviewed their critical inventory and have a high level of confidence in the condition and remaining life of their assets. Because of their large number of critical assets, their aim is to prevent any failure. Their program has given them confidence in achieving this goal.

Leading Practice – Levels of Service

The mission of a water utility is to provide service to its customers, and asset management includes the practice of setting service level goals and monitoring performance. In addition to addressing customer service level expectations, utilities must also anticipate and address any future changes in system demands, such that the capacity of their infrastructure is sufficient.

The following questions were asked in the *Level of Progress in Utility Asset Management* survey:

- *Has the organization documented Levels of Service across the organization and are they contained in a Level of Service agreement or another similar document?*
- *Which of the following apply to the organization's clearly defined Level of Service targets?*
 - *All levels of service have targets*
 - *Targets are well known throughout the organization*
 - *Performance is measured and progress in relation targets is communicated regularly (e.g. monthly)*
- *Does the organization analyze current and anticipated customer demands, including planning for future growth or population decline, and plan infrastructure investments to meet future demands?*

The following utilities ranked very high or high in their responses to these questions on the leading practice Levels of Service, and case studies describing their approaches are included in the following sections:

- Portland Water Bureau (also covers Risk Management and Asset Management Planning)
- Brunswick & Topsham Water District (also covers Asset Management Planning)

Portland Water Bureau

Leading Practice – Risk Management, Asset Management Planning

BACKGROUND

Portland Water Bureau provides drinking water to around 960,000 people in Portland, Oregon. Water is sourced primarily from the Bull Run Watershed, and is delivered to customers through a distribution system that consists of 2,330 miles of pipe, 41 pump stations and 66 tanks and covered reservoirs. The estimated replacement value of all the Bureau's assets is \$8.0 billion.

The Bureau created its Asset Management Branch (AMB) in 2004 following a reorganization of its engineering department, and an Asset Management Steering Committee (AMSC) was

created to oversee the implementation of the asset management program. The Bureau participated in the Water Services Association of Australia (WSAA) benchmarking project multiple times, starting in 2006, which included visits to water utilities in Melbourne and Sydney to learn about some of the leading asset management practices used by Australian utilities. This focused the Bureau's efforts on establishing levels of service, developing a risk management approach and a business case evaluation process.

The Bureau's risk management methodology was implemented in 2007 and asset management plans (AMPs) were developed for some asset groups. In 2010, the AMSC identified AMP development for all asset classes as a priority, and since then the Bureau has developed AMPs for more than 90% of its assets.

This case study describes the Bureau's approach to risk management, business case evaluation and the development of asset management plans.

SURVEY RESULTS

The Bureau ranked very high in the Levels of Service, Risk Management and Asset Management Planning leading practices, and four of the AWWA Level of Progress Survey questions apply to the Bureau's case study focus area.

The Bureau's responses are shown in the following graphs, and the utility is in the most advanced category, in all cases. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.



Utility: Portland Water Bureau

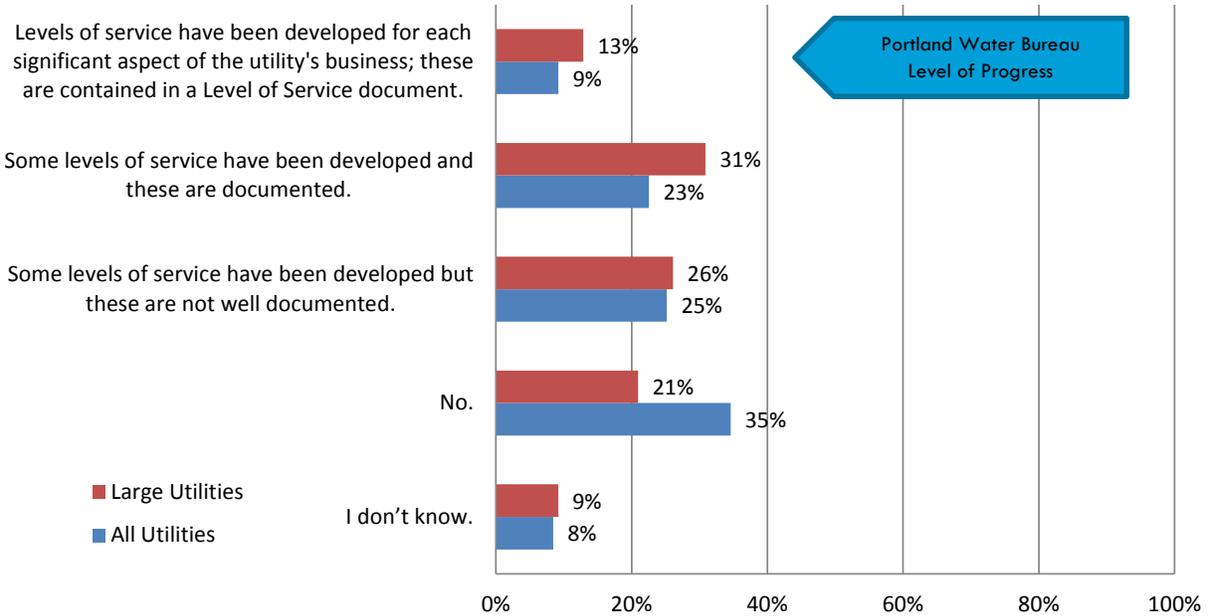
City/State: Portland, OR

Average system demand: 100 MGD

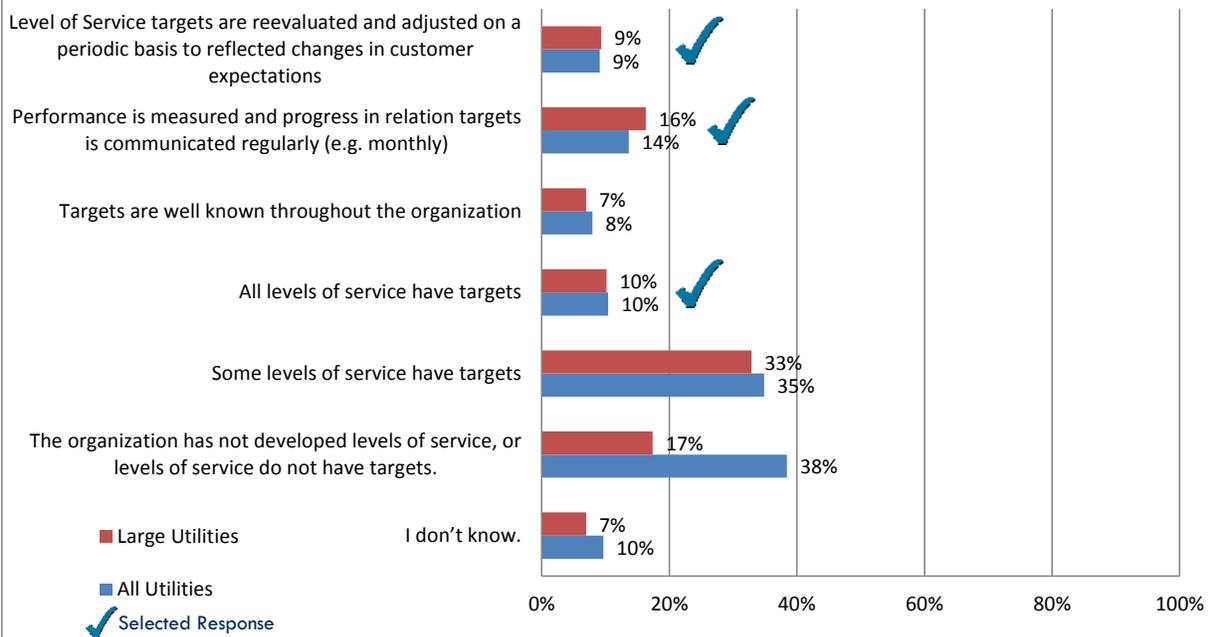
Population served: 960,000

Number of FTE staff: 570

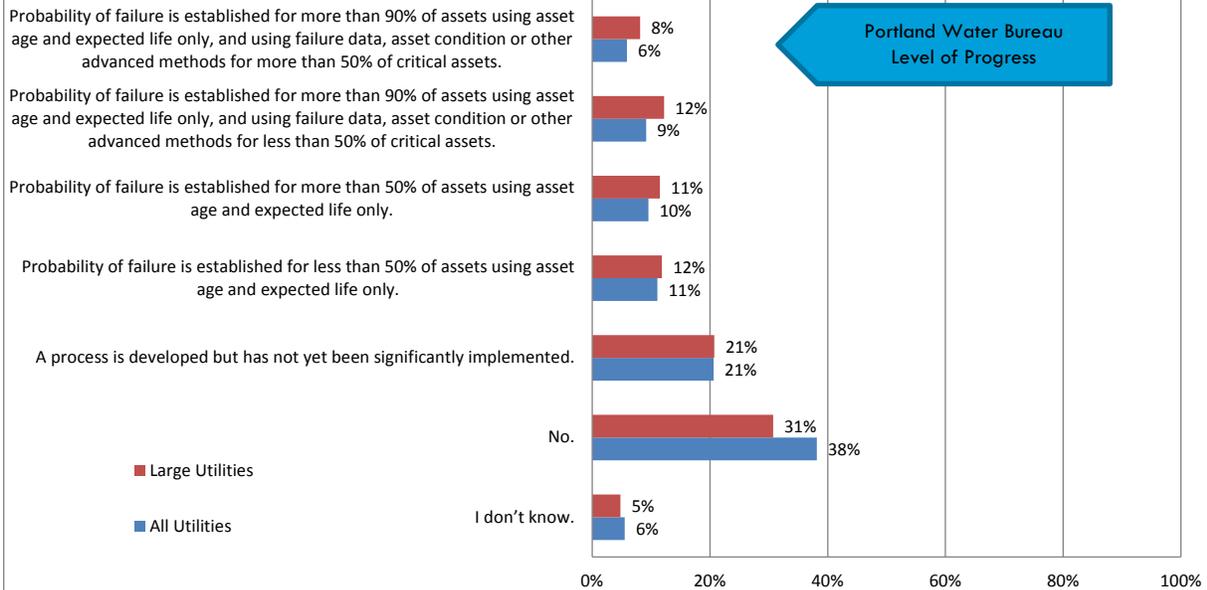
Has the organization documented Levels of Service across the organization and are they contained in a Level of Service agreement or other similar document?



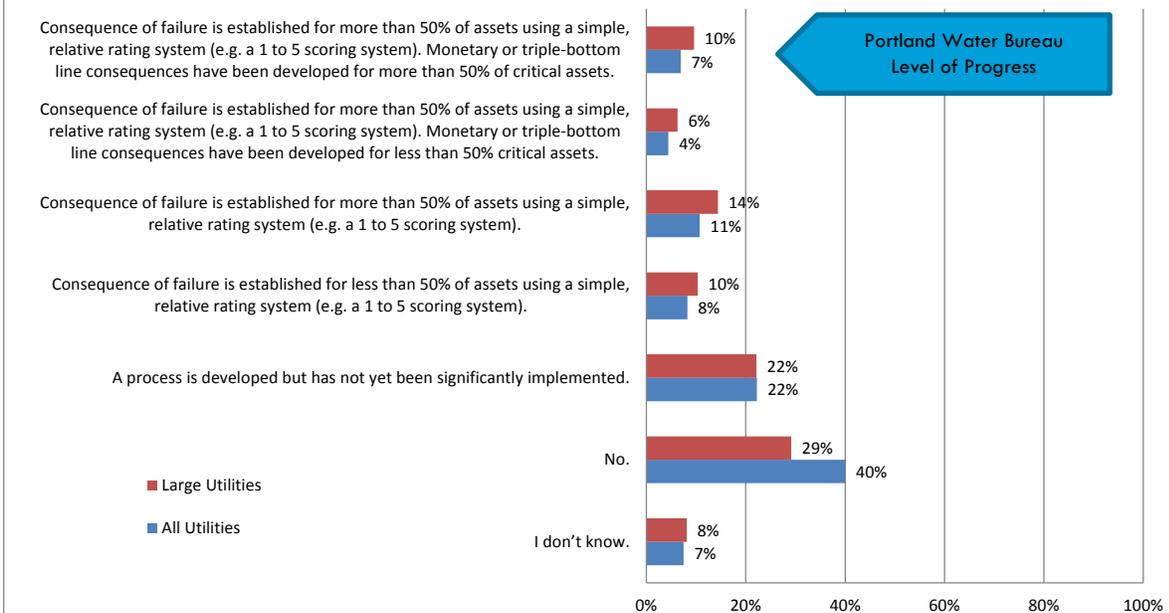
Which of the following apply to the organization's clearly defined Level of Service targets?



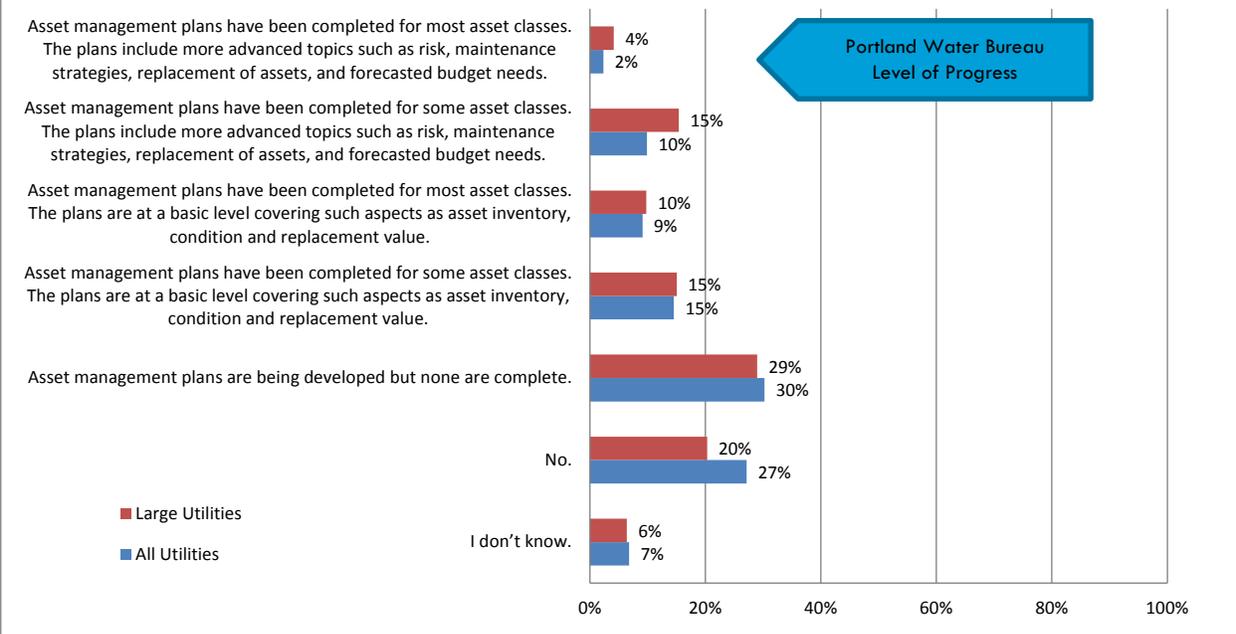
Does the organization have a process to assess the probability (or likelihood) of failure of assets?



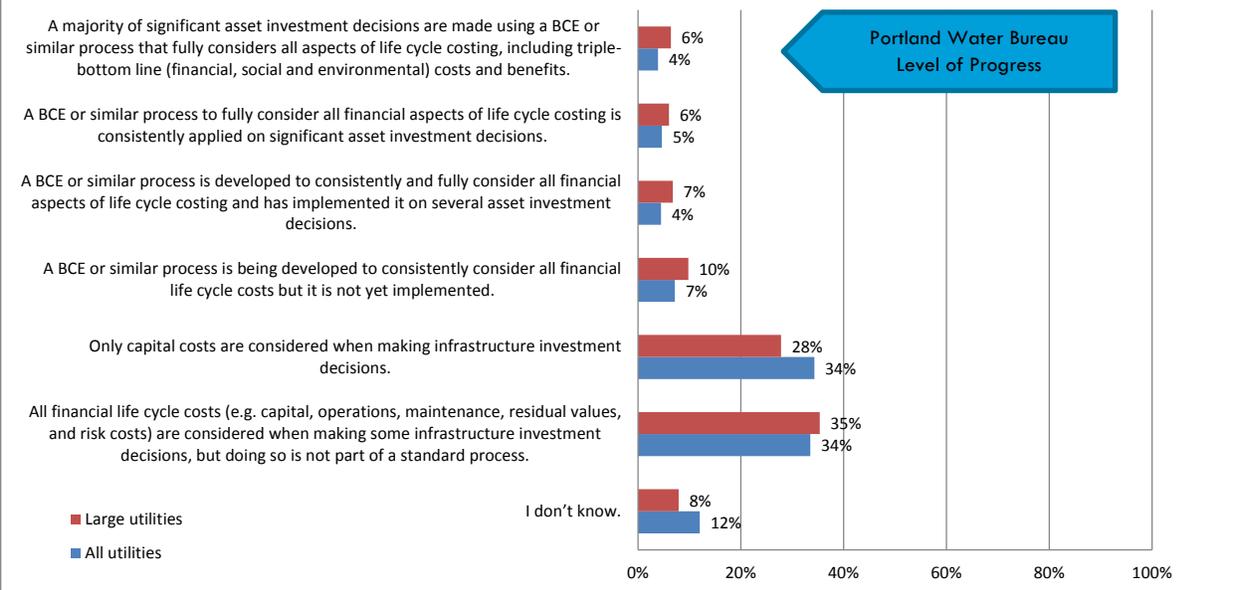
Does the organization have a process to assess the consequence of asset failure?



Has the organization developed asset management plans for its various asset classes?



Does the organization require business case evaluations (BCE's) when making infrastructure investment decisions?



LEVELS OF SERVICE

Key Service Levels

In 2008 the Bureau established 27 Key Service Levels to track its performance (Table 2). The service levels provide targets for the Bureau’s goals and objectives; Programmatic Service Levels and Workload Measures measure performance in more detail. Performance has been measured and reported since 2008, with performance on Key and Programmatic Service Levels reported in the Bureau’s internal semi-annual budget reports.

Table 2 Portland Water Bureau Key Service Levels

CATEGORY	KEY SERVICE LEVEL
Water Quality	A.1 100% compliance with water quality regulations A.2 Adequate pressure, more than 20 psi 99% of time A.3 Fewer than 7 water quality complaints per 1000 customers A.4 Chlorine is 0.5–4.0 in 95% of samples
Customer Service	B.1 High or Very High rating for quality of water service, at least 75% of customers B.2 Respond to 95% of customer inquiries in less than 5 days B.3 Answer 80% of calls within 60 seconds B.4 Use of preferred payment methods C.1 Less than 5% of customers out of water more than 8 hours a year C.2 No one out of water more than 3 times in a year C.3 90% of service installs completed in 15 days C.4 Working hydrants within 500 feet of all services C.5 90% of valves tested worked
Financial Health	D.1 Aaa bond rating D.2 Debt service coverage 1.9/1.75
Infrastructure Management	E.1 CIP projects on schedule E.2 Maintenance improvement E.3 Manage risks, 80% of risk standards met E.4 Benefit cost analysis for new projects
Workforce and Workplace Excellence	F.1 50% of employees engaged F.2 OSHA SHARP certification F.3 Promotion of internal candidates 60–80% F.4 Workforce diversity
Conservation and Sustainability	G.1 Per capita water use steady or declining G.2 25% water savings from technical assistance G.3 Carbon emissions less than 2007 levels G.4 % Renewable energy up from 2007

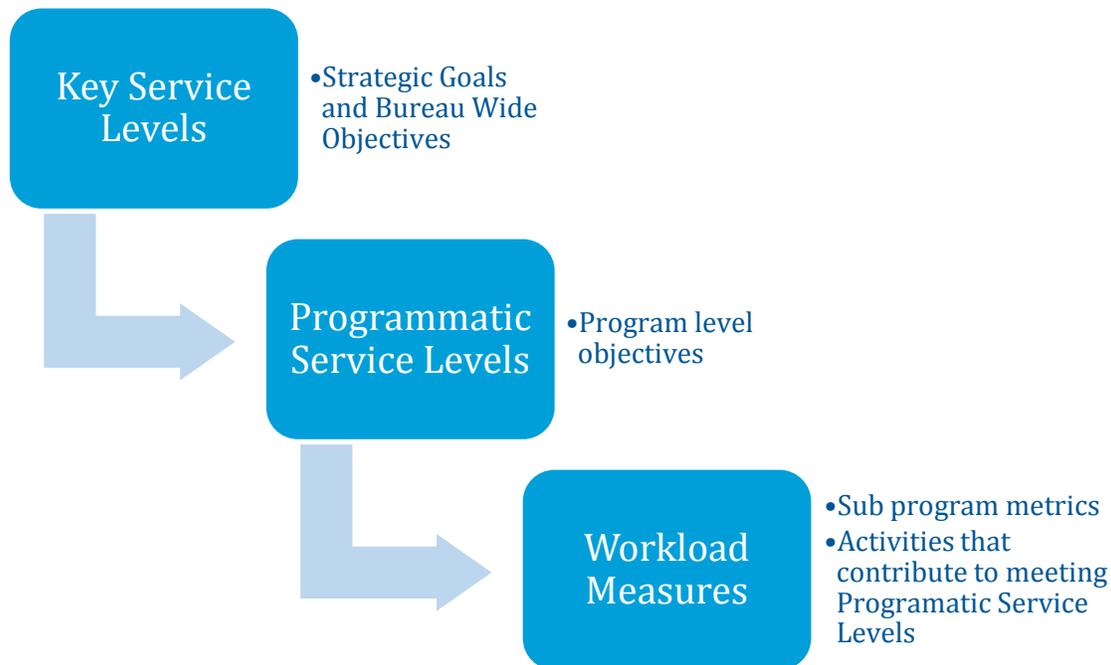


Figure 15 Portland Water Bureau - Service Level Hierarchy

Currently, each budget program is associated with certain service levels, and these are reflected in the asset management plans. The following is an example for the valve program based on the hierarchy shown in Figure 15:

- Key Service Level - C.5 90% of valves tested worked
- Programmatic Service Level – 90% of valves operating and less than 5% of customers experiencing a cumulative outage of water for more than 8 hours in a year
- Workload Measures - inspect and exercise all 2000 large valves annually

The asset management plans include recommendations for additional service levels to be considered.

Key Performance Measures

Since 2016, all City of Portland Bureaus are required to report on Key Performance Measures (KPMs). The Bureau identified six targets for KPMs:

- complying with 100% of drinking water quality regulations,
- maintaining average call holding times of 2 minutes or less,
- addressing at least 80% of high-risk assets by an established deadline,
- having 2 or fewer unplanned events leading to outages that last more than 8 hours,
- maintaining an Aaa bond credit rating, and

- complying with 100% of environmental regulations.

The Bureau reports on these KPMs each year in a dashboard as part of the Bureau budget. The dashboard will indicate whether Bureau performance remains the same, improves, or declines compared to the baseline period. At the same time, the Bureau will retain its list of 27 Key Service Levels and will continue to report on them in a process parallel to the reporting on the KPMs.

The KPMs have some overlap with the existing service levels. The Bureau is planning to align Key Service Levels more closely with KPMs following its consultation with customers in the first half of 2016.

Customer Consultation

The 2016 Customer Survey was conducted by Survey Research Lab at Portland State University, with the purpose to collect data on customer's opinions and attitudes in order to help the Bureau improve customer service and plan future investments.

The survey form included a range of questions about customers' experiences of the water service, their preferences for service expectations and the Bureau's investments, and their water drinking behavior. Responses were provided as multiple choice and open ended options for respondents to select. Question topics included:

- Overall satisfaction with the Bureau's services
- Impression of average 2-minute call hold time (whether it is reasonable or too long)
- Reasonableness of advance notice for most recent water outage and preferred methods of advance notification
- Reasonableness of an 8-hour unplanned water outage, and what would be an acceptable length of time to be without water
- Importance of the Bureau investing customer dollars in water-system improvements to prepare for a major earthquake

A random selection of the Bureau's customers were invited to participate and were sent an invitation letter with instructions on how to complete the survey on a secure website or using a paper form. In addition to English, the survey was also provided in Spanish, Russian, Chinese, and Vietnamese to allow for the range of cultural background of the Bureau's customers. To incentivize participation, there was the option of entering a random drawing to win one of two \$50 gift cards. The overall response rate was 15.6% with a sampling error of 3.3%, which indicated that the survey findings are representative.

The results of the survey are being analyzed by the Bureau to determine whether any of the Key Service Levels of Key Performance Measures will need to be adjusted.

RISK MANAGEMENT

The AMG worked with a wide range of stakeholders across the Bureau to develop and reach consensus on the risk criteria. The likelihood of failure (LoF) uses a rating scale of 1 to 5 (1 is in excellent or new condition, 5 is in very poor condition); the ratings are defined as follows:

LIKELIHOOD RATING	RECURRENCE INTERVAL FOR A SINGLE ASSET FAILURE	FAILURE RATE OF A POPULATION
5	<= 5 years	0.3
4	5 - 20 years	0.1
3	20 - 50 years	0.03
2	50 - 100 years	0.013
1	>> 100 years	<.01

Figure 16 Portland Water Bureau – Likelihood of Failure Criteria

Consequence of failure (CoF) is also scored on a 1-5 scale. There are a number of CoF categories and definitions have been developed for each of these categories. Consequence categories include:

- Water supply
- Supply continuity
- Social consequences, health and safety
- Environmental
- Loss of revenue
- Customer service

Business Risk Exposure (BRE) is calculated based on the likelihood and consequence scores. The Bureau developed an approach to risk that is referred to as the Consequence and Likelihood Evaluation Methodology (CLEM). A risk matrix that rates the BRE of an asset and the identified possible failure using five levels of ranking from “Very Low” to “Extreme” is shown in Figure 17.

Likelihood	Consequences				
	1 Very low	2 Low	3 Moderate	4 High	5 Very high
Very low (1)	VL	VL	L	M	M
Low (2)	VL	VL	M	M	H
Moderate (3)	L	L	H	H	E
High (4)	L	M	H	E	E
Very high (5)	L	M	H	E	E

Where: VL = Very Low M = Medium
 L = Low H = High
 M = Medium E = Extreme

Figure 17 Portland Water Bureau - Risk Matrix

The Bureau assesses risk on two levels: at the asset or program level (how important is a single asset within its class), and at the Bureau level (how important is a single asset to the Bureau). The program risk assessment is only used if having a separate, asset program specific BRE will help in developing maintenance and replacement strategies.

An example of an asset program is the meter replacement program. A large meter failure is considered highly consequential to the Meter Shop and the meter program if that meter measures a large volume of water. However, the failure of the large meter may only pose a medium or low risk to the overall Bureau risk exposure. A separate risk scoring criteria was used for meters, as shown in the following figures.

Likelihood	Consequences				
	1	2	3	4	5
Very Low (1)	2,082	995	173	20	24
Low (2)	85	936	327	56	67
Moderate (3)	0	141	147	25	26
Moderately-High (4)	0	22	54	12	12
High (5)	465	304	256	60	121

Figure 18 Portland Water Bureau - Count of meters in each BRE category based on the meter program risk criteria

Likelihood	Consequences				
	1	2	3	4	5
Very Low (1)	3,088	240	16		
Low (2)	1,184	700	8		
Moderate (3)	758	414	2		
Moderately-High (4)					
High (5)					

Figure 19 Portland Water Bureau - Count of meters in each BRE category based on the Bureau CLEM risk criteria

The Bureau identifies and records specific risks in a risk register (Table 3), which is used to determine mitigation measures and monitor risks. The AMB is responsible for tracking risks and provides a risk report to the Steering Committee twice a year; any high or extreme risks that are identified are automatically reported to the Steering Committee.

Table 3 Portland Water Bureau - Examples from the risk register

ASSET	FAILURE MODE	LOF	COF	RISK RATING	NEXT STEPS
GW Transformer and Automatic Circuit Breaker	Failure of GW Transformer or Automatic Circuit Breaker during a 10 Day Turbidity Event	3 - Likely happen within the next 50 years	5 - New transformer or circuit breaker has a long lead time. City would not have water or would have to serve turbid water	5 – Extreme	Forward to Planning for more detailed evaluation
NW Yeon - NW Nicolai to NW Kittridge bypass bridge	Multiple leaks from corrosion pitting	4 - Pipe has had 6 leaks in past 20 years, despite adding cathodic protection in 1986. System is shorted and needs to be fixed.	3 - If the main is out of service north of NW 35th Avenue, supply to the St. Helen's Rd Industrial area from Washington Park would be reduced. These three lines feed a 24" and 16" to Saltzman, Linwit and Willalatin.	4 – High	Fix shorts and isolation so that cathodic protection system works again
Willamette Heights Tank	Loss of supply main on Thurman St. bridge	3 - 50 year event. Bridge is considered to be in poor shape and if it fails main could be unavailable for several days to several weeks.	4 - 250-1000 customers out of water for 72 hours or more. Damages/additional costs >5 million, major environmental damage probable.	4 – High	Forward to Planning for more detailed evaluation

Risk is now well embedded in the organization, and risk assessments are carried out as part of the AMP development and for all engineering planning studies. The City includes risk management as an infrastructure-related service level measure for the Bureau - “percent of identified high risk assets addressed”, and it is reported in the City’s key performance measure dashboard.

BUSINESS CASE EVALUATION

Once a risk mitigation measure is identified as a potential project a business case evaluation (BCE) is performed. The Bureau developed a BCE process in 2009 that incorporates a methodology for benefit cost analysis (BCA) using benefit cost (B/C) ratios and net present value (NPV), as well as triple bottom line analysis that includes not only financial impacts but also social and environmental impacts. The AMB has an economist on its staff who developed the approach and a business case guidance document and provided training so that other Bureau staff would be able to develop business cases.

Developing a business case is essentially making a case for a project or program to ratepayers and other decision makers. The BCE process forms part of the Bureau’s project planning process and is used to justify projects for the five-year CIP, which is updated annually. A process is in place for the review and approval of the business cases.

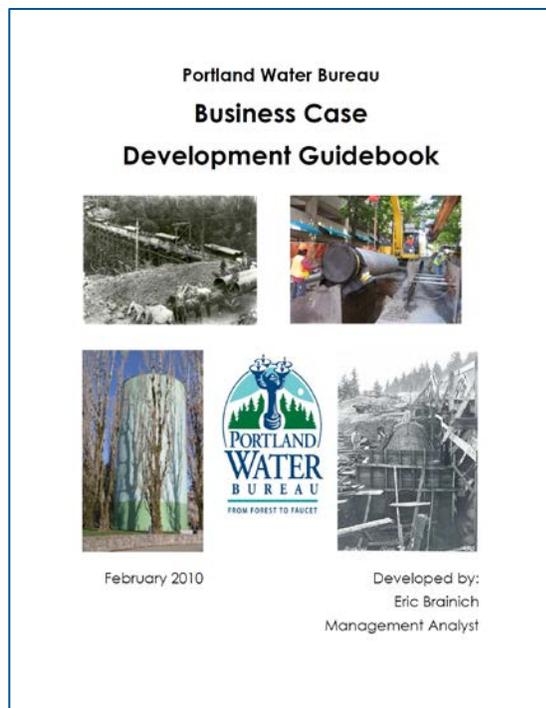
BCE Process

The initial steps in developing a business case include defining the purpose of the project or program, identifying the issues to be addressed, and defining the set of available alternatives. In most cases, there will be a “no action” alternative (sometimes called the status quo).

Objectives are defined that are the quantifiable or measurable outputs of a project. Examples of objectives include increasing fire flow within a service area, improving service reliability, and reducing costs by changing program strategies or processes.

Alternatives are evaluated to assess the different costs and benefits associated with different options. The business case defines the outputs of each alternative and measures how much of the intended service objective will be provided under each alternative. The life cycle costs are estimated for each alternative: costs for construction, engineering, permits, project management, contractor fees, operations and maintenance, fleet, labor and labor overhead. Project future maintenance, renewal, and replacement costs are also considered if they fall within the project life cycle. If operations costs also change they are reflected in the analysis.

Triple bottom line analysis is used to monetize the impacts of the project. Financial impacts include avoided costs or increased revenue which are considered benefits, and impacts on customer financial status. Social impacts can include traffic disruption, service outages and public safety. The Bureau has monetized these impacts using a range of assumptions including the cost of a fatality using a U.S. Department of Transportation figure (approval from the elected official who oversees the Bureau was obtained to include this). Some environmental impact costs are also monetized.



A business case development guidance document was created and training provided

Once benefits and costs have been determined, the B/C ratio is calculated for each alternative ($B/C \text{ ratio} = \text{present value of benefits} / \text{present value of costs}$). Some sensitivity analysis is performed to assess the impact on the B/C ratio using different costs or assumptions. The extent to which a B/C ratio exceeds 1.0 shows the relative attractiveness of an investment alternative. B/C ratios that are well below or above 1.0 present a stronger case to reject or accept an option.

Business cases have helped inform decision making on investments in major assets. In one example a business case showed a low B/C ratio of replacing a water tank and a higher B/C ratio for relying on pressure in adjacent pressure zones to provide service to the area. As a result, the Bureau decided not to replace the tank which resulted in avoided costs of \$600,000 for the capital cost of the tank in addition to savings on the annual operation and maintenance costs.

ASSET MANAGEMENT PLANS

The Bureau developed the draft of its first AMP in 2005 for distribution system mains. By 2008, three AMPs (distribution system mains, valves and hydrants) had been written. The production of these early AMPs helped refine the process for creating the larger body of AMPs. The effort to gather data for these early AMPs revealed gaps between data sources and in some of the data sets. The early AMP analysis efforts pointed to the need for a standardized approach.

Between 2008 and 2010 the AMG developed a template and guidance document for developing AMPs. Co-leads with subject matter expertise gathered information, conducted analyses and drafted sections of the AMPs. A key effort for some assets was gathering information on asset status and condition, which required mining data, extrapolating information from multiple sources, and interviewing expert stakeholders.

All of the Bureau's AMPs follow the same structure: an introduction followed by sections on levels of service; asset inventory and replacement value; condition and utilization; failure modes; business risk exposure; maintenance, repair and replacement; budget forecasting; performance tracking; and an improvement plan. The following describes each of the sections:

Section 1 – Introduction

The introduction provides a clear description of the asset's purpose (how it contributes to the Bureau's goals and delivers water to customers) and scope of the asset class (including which assets are excluded).

Section 2 – Levels of Service

This section links the key service levels articulated in the Bureau's strategic plan to program service levels and subprogram workload targets for each asset. This may include recommendations from asset managers and stakeholders for improvements to the specific measurable program service levels arising from the analyses and information gathered during the AMP's development.

Information on asset performance is also included. This is taken from the Bureau's Budget Program Results reports and includes trends in asset performance where data is available.

Section 3 – Asset Inventory and Valuation

This section provides a detailed description of the asset and its replacement value based on information from multiple sources. Assets with limited numbers are listed (e.g. pump stations or tanks) while assets that are too numerous to list individually are grouped by size, material or other characteristics (e.g. distribution mains or meters). An age profile of the assets is included; age of an asset is important to understanding condition which is often based on a deterioration curve with age as the independent variable.

An asset's replacement value is based on estimated averages of all costs to plan, design, and construct the asset. Estimated costs may reflect past construction records adjusted for inflation, industry averages, or a combination of the two.

Section 4 – Asset Condition and Utilization

As the majority of the Bureau's assets are underground or in places that are difficult to access, asset condition (and in some cases utilization) must be estimated. Asset condition for some buried assets

(such as pipes and valves) may be estimated from the asset age combined with other factors. For many assets, utilization data are provided through the Bureau's supervisory control and data acquisition (SCADA) system. Asset condition is used to estimate the likelihood of failure as part of the risk assessment.

A summary of the current condition of the assets is included in the AMP, either using a chart or table, and assets that are in poor condition are identified. The proposed condition assessment approach is described in the plan. The utilization of the assets (e.g. flow, energy use, hours run) is also reported where applicable.

The Bureau uses condition to forecast when various assets will require rehabilitation or replacement. Deterioration curves have been developed for some asset classes and are used to forecast asset deterioration. These are included in the AMP where appropriate.

Section 5 – Failure Modes and Asset Life

This section provides a detailed discussion of the failure modes and expected life of each asset. The AMPs describe failure modes for critical subcomponents and the asset overall. In many cases, factors that influence failure modes include asset material, use, and location. The failure modes are discussed in terms of capacity, failure to meet service levels, obsolescence, and physical mortality. For some assets, the trend in physical mortality of the Bureau's assets is compared to trends for similar assets in the water industry.

For assets, such as water mains, average known pipe failure rates are analyzed to make estimates about the expected useful life for pipes of similar material and manufacture (referred to as pipe cohorts). These analyses are especially helpful for buried assets for which little actual condition data are available. The Bureau has performed some Weibull analysis of pipe failure rates to predict Mean time to failure and estimate expected useful life (see Figure 20).

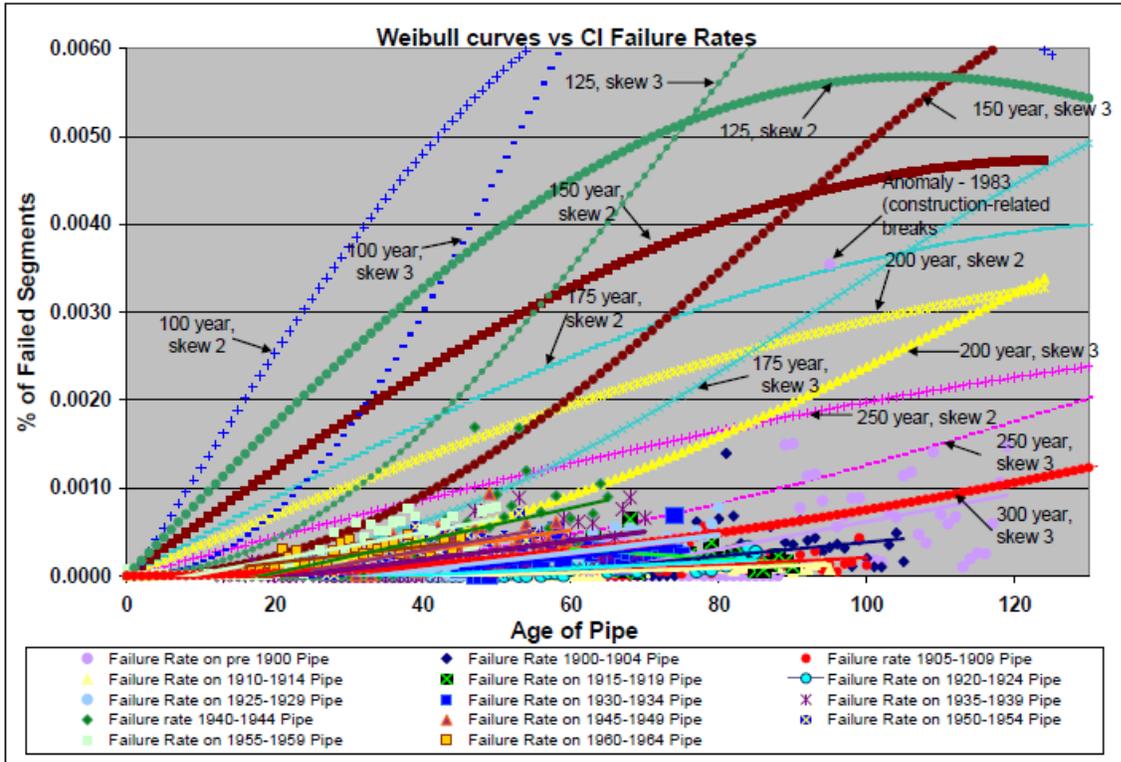


Figure 20 Portland Water Bureau - Weibull graph showing failure rates of Cast Iron pipe vs age of Pipes

Section 6 – Business Risk Exposure

The level of business risk the asset poses is analyzed using the Bureau-wide CLEM risk assessment methodology. As described in the earlier section on risk, in some cases risks are assessed at the asset level using alternative risk criteria and scoring.

The business risk exposure of each asset is calculated with regard to similar assets and then again in comparison to the entire Bureau’s water system assets. In many cases, the asset-level risk rankings are higher than the asset risk rankings at the Bureau level. In asset-level rankings the risk of one asset (a large valve for example) might be high compared to other valves. However, the same large valve may not be rated highly when compared with assets across the Bureau. A key pump station or large main may receive a higher rating on the Bureau-wide scale because it represents greater business risk exposure than the risks of a large valve failure

Section 7 – Maintenance, Repair and Replacement Strategies

This section provides a snapshot of current maintenance, repair, and replacement strategies and proposes new strategies that save resources, reduce risk, and optimize processes. The strategies focus on assets with a high consequence of failure. An introduction describes the current state of condition-assessment activities, the types of preventive and predictive maintenance performed, and the various reactive maintenance activities that have been recorded. Descriptions can be organized to align with computerized maintenance management systems (CMMSs).

Many of the recommendations focus on strategies to revise, replace or add to current operations strategies. Other strategies provide information to help the Bureau as it makes plans to replace

aging infrastructure. These recommended strategies are at the heart of the AMP. All recommendations enumerate the desired outcomes and benefits of the strategies and preliminary estimates of the levels of effort required to implement the strategies. An example of recommended strategies from an AMP is shown in Figure 21.

Table 3. Strategies Selected by the Recommended Strategies Subcommittee of the Asset Management Steering Committee in 2015

Asset Group	AMP Strategy Number	Strategy Description
Conduits	2.5	Visually inspect and repair leaks identified in leak testing on high risk mains w/ in 6 mos.
Conduits	2.15	Clean and seal exposed external piping, particularly at transitions, as appropriate. Assume every 10 yrs or as required during inspections.
Conduits	2.17	Clean and seal exposed piping in vaults.
Conduits	4.3	Evaluate if CP should be added to specific sections of Conduit to extend useful life.
Distribution Mains	2.6	Complete additional inspections on mains ranked as high risk based on CIPS surveys, prior leak history, consequence scores, or other means to determine best locations and methods for inspection. May be exterior (exposed or excavated) or interior inspection. May occur when other project work allows.

Figure 21 Portland Water Bureau - Example of selected strategies

Section 8 – Budget Forecasting

Estimates of the resources needed to implement the current and proposed maintenance, repair, and replacement activities are provided in this section. Cost projections are based on best available knowledge but not estimates based on engineering analyses and studies, which would be implemented during a formal planning and design process. Estimates are provided in labor hours multiplied by direct costs for Bureau staff plus any materials and known capital costs derived from a five-year capital improvement project budget.

Some AMPs provide separate cost estimates for work on critical or replacement projects and forecasting. Other AMPs estimate future repair and replacement costs beyond the five-year CIP horizon. Many AMPs provide a long-term projection of Bureau expenditures for repair or replacement using the current set of strategies.

Section 9 – Performance Tracking

The Bureau tracks and reports on service levels, budget program targets, accomplishments, and expenditures. The Performance Tracking section of the AMP describes the Bureau’s approach to performance tracking, including the responsible staff, the measurements or targets, and the sources

of the performance data. Most AMPs recommend concentrating data and data tracking functions in CMMS. Final subsections recommend additional failure modes or risk evaluations that should be tracked for the asset.

Section 10 – Improvement Plan

The last section of the AMP provides a road map for improving the asset management effort overall. Recommendations for changes to service levels, approaches to condition assessment, analysis of failure modes, and evaluations of risk, maintenance, repair, or replacement strategies are listed here. This section provides a gap analysis of data that should be collected or data that should be centralized or normalized to be useful for analysis.

BENEFITS

Since 2005, the asset management program has generated many work products and processes. Over 400 specific strategies have been recommended that will provide direction and reference points for asset information in the foreseeable future. Business case evaluations, risk assessments, and a life-cycle management approach provide frameworks for evaluating the benefits and costs of projects and plans.

Business cases have been particularly valuable to assess the benefits and costs of replacement for the many assets that are at or approaching the end of their useful lives. The risk management approach has been an invaluable tool for refining priorities among the many assets that the Bureau manages, and has helped the Bureau identify assets that pose higher than acceptable risks and projects to mitigate risks.

Life-cycle management has also helped Bureau managers and operators make better informed repair and replacement decisions. For example, in the past, meter replacement was based strictly on the age of the meter. Using an asset management approach, stakeholders developed an algorithm to determine the longest useful life before replacement for meters based on age and on the consumption measured. The new method is now standard practice for meters.

Jeff Leighton, Asset Management Coordinator for the Portland Water Bureau stated *“Applying asset management practices has been very beneficial to our organization. By demonstrating benefits such as avoiding high consequence asset failures, performing more maintenance on high consequence assets and less on low consequence ones, and selecting alternatives that have the lowest life cycle cost, asset management as a way of doing business has become very popular with upper management and elected officials.”*

The Bureau has attempted to quantify the benefits of its approach using asset management leading practices. The following table presents some of the results; these examples are representative of the range of decisions that have been made, based on an asset management approach.

Table 4 Portland Water Bureau - Benefits of the asset management approach

ASSET ISSUE	ORIGINAL APPROACH	ASSET MANAGEMENT APPROACH	NET BENEFIT
Overhauls of hydrants	Increase rate of overhauls at annual cost of \$500,000	Eliminate overhauls with resulting annual increase in repairs of \$100,000	\$400,000 a year less cost
Pump station replacement	Replace pump station at cost of \$6 million	Replace only obsolete electrical system. New more efficient pumps not justified. \$1 million project	\$5 million less cost
Back-up water supply	Use supply as needed	Operate annually if not needed for supply to extend life of motors and provide training	Quantified net benefit to limited annual pumping
Tank replacement	Replace tank at a cost of \$600,000	For next 25 years, use emergency connection to adjacent pressure zone. Install bypass and pressure regulator for \$100,000	Avoided \$500,000 cost for 25 years
Pipe hanging under bridge – out of alignment	Not inspected	Inspection of high consequence pipes on bridges. Imminent failure identified; potential impacts similar to 1985 and 2010 failures.	Avoided a potential \$10 million cost of pipe failure (includes social costs)
Pipe hanging under bridge – corroded	Not inspected	Inspection of high consequence pipes on bridges. Imminent failure identified; potential impacts similar to 1985 failure	Avoided a potential \$5 million cost of pipe failure (includes social costs)
Recurring slides on to watershed road	Continue with periodic clean up	Rock scaling and debris clearing avoids risk to staff to clean up near cliff during/following storm events	Avoids millions of dollars in risk cost for potential injuries or fatality considered likely in next 20 years
Corroded tank in public park	Continue to use	Taken out of service to avoid risks, without impact to supply	Avoids safety risk considered likely in next 20 years
Insufficient fire flow in service area	Pump station and piping improvements to achieve full fire flow	Pump station and piping improvements to reach reduced fire flow that impacts fire fighting only marginally – acceptable to Fire Bureau	\$500,000 cost reduction

ASSET ISSUE	ORIGINAL APPROACH	ASSET MANAGEMENT APPROACH	NET BENEFIT
Pump maintenance	Oil analysis and motor starter p.m. same for all pumps	Reduced oil analysis and motor starter p.m. on redundant pumps	\$20,000 annual savings
Fall hazards in tanks and vaults	No improvements implemented (to date)	Risk cost justification for improvements	Risk cost of potential for worker disability in next 20-50 years far exceeds upgrade costs
Electrical system hazards in confined space	No improvements implemented (to date)	Risk cost justification for improvements	Risk cost of potential for worker electrocution in next 50-100 years exceeds upgrade costs
Large meter maintenance	Test and repair meters on schedule as determined by size, per AWWA guidelines	Meters with higher annual consumption and poorer condition (determined by total consumption through meter and previous test accuracies) tested and repaired on a more frequent basis, newer meters and/or with lower annual consumption tested less frequently	Meters most likely to degrade and with higher usage to be tested and repaired more frequently thus reducing the amount of unrecorded water, increasing revenues in the short-run and improving customer equity in the long-run

The Bureau has developed an Asset Management Tactical Plan that sets out activities to improve asset management over the next two years. Fifteen tactical areas are described, including AMP strategy implementation, managing risk of asset failure, implementation of reliability-centered maintenance, forecasting asset replacement needs, and developing asset management competency.

An annual progress report on asset management implementation is also prepared.

Jeff Leighton has this advice for utilities looking to advance their asset management practices: *“There are many ways to advance in asset management. You can’t do it all but you can pick one or two key practices and make good progress. Our early efforts demonstrated the value of doing asset management and this created support from upper management to invest in the program.”*

Brunswick & Topsham Water District

Leading Practice – Levels of Service, Asset Management Planning

BACKGROUND

The Brunswick and Topsham Water District (the District) has been providing water to the communities of Brunswick and Topsham since 1903. There are around 7,000 service connections which are mainly residential, and the water distribution system is a total of 115 miles long. Water is treated at three water treatment plants.

The District developed an asset management implementation plan (referred to as the Asset Management Plan) in 2009 which focused on improving the asset inventory, developing asset management information systems, setting levels of service and assessing the state of the assets. The plan was developed by the District staff to help the Board and staff develop a long-term plan.

The asset management implementation plan covers ten years from 2010 to 2020, but resource constraints have meant it has taken longer for the District to implement the plan. The current focus is on asset data collection and populating data in the GIS and CMMS.

SURVEY RESULTS

The District ranked high in the Levels of Service leading practice compared with other small utilities, having developed levels of service for each significant aspect of the utility's business. It also ranks very high in the Asset Management Planning leading practice in the area of business case evaluation. The District's responses are shown in the following graphs. The graphs also show the responses from all the other participating utilities and the responses for the small utilities.



Utility: Brunswick and Topsham Water District

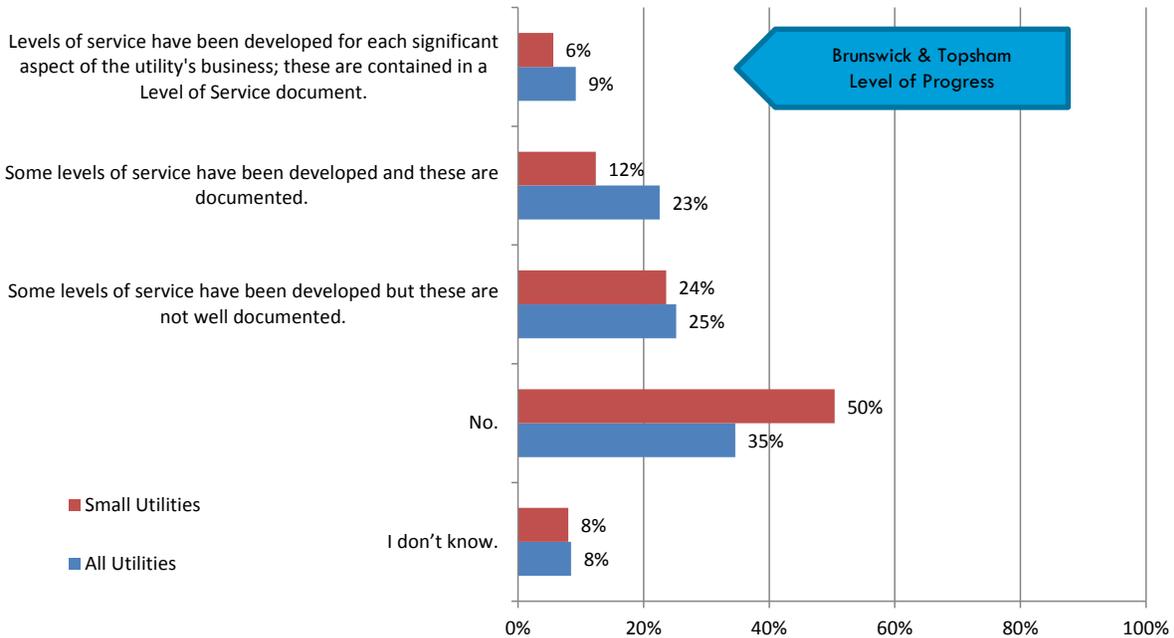
City/State: Topsham, ME

Average system demand: 1.6 MGD

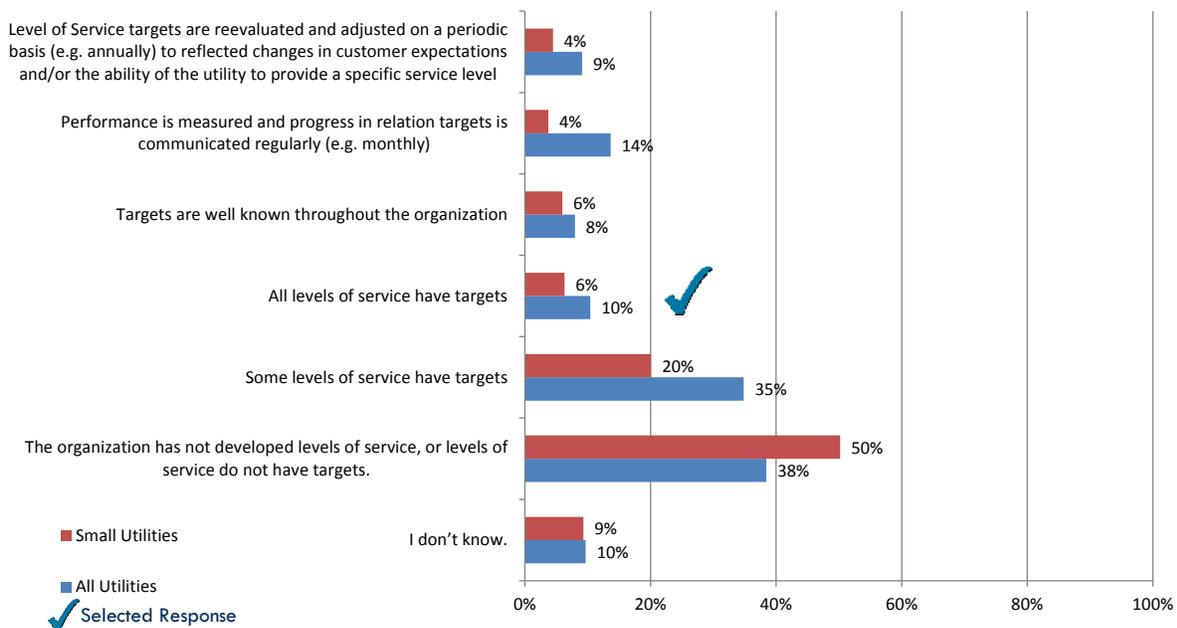
Population served: 30,000

Number of FTE staff: 21

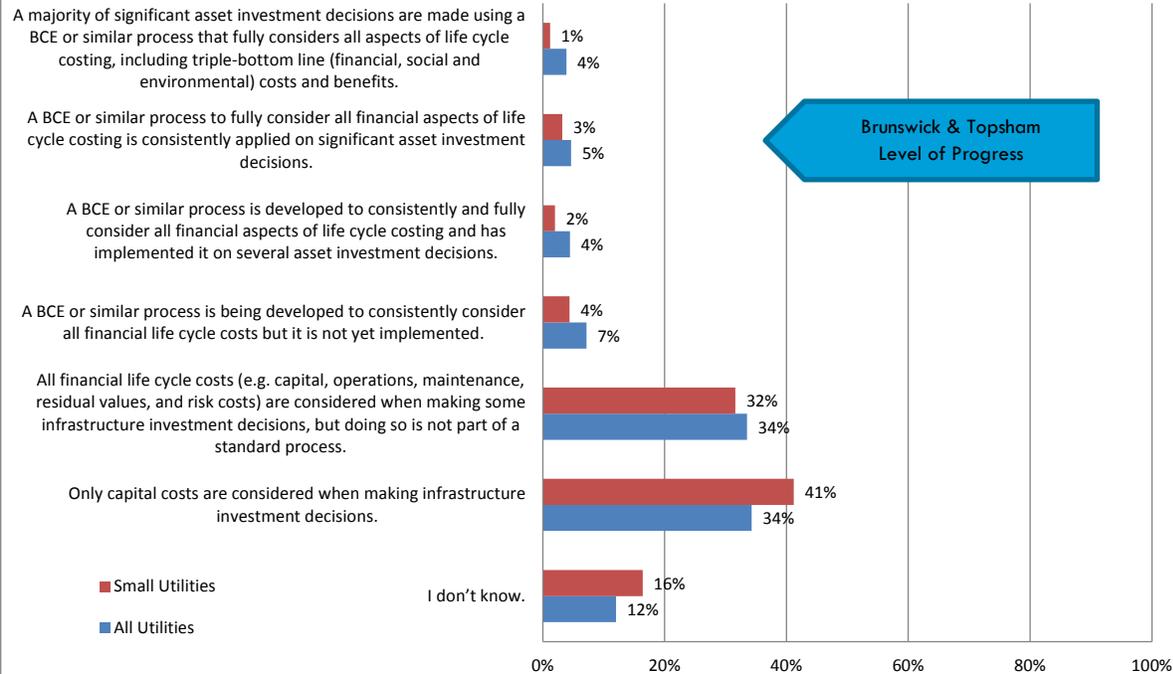
Has the organization documented Levels of Service across the organization and are they contained in a Level of Service agreement?



Which of the following apply to the organization's clearly defined Level of Service targets?



Does the organization require business case evaluations (BCE's) when making infrastructure investment decisions?



LEVELS OF SERVICE

In developing the District's Asset Management Plan, the District recognized the need to set levels of service as a key component of its approach to asset management, defining the way in which the District wants its system to perform over the long term. The District wanted its levels of service to:

- Provide a means of assessing overall system performance
- Provide a direct link between costs and service
- Communicate the system's operation to the customers
- Serve as an internal guide for system management and operations staff

District managers, including the Treatment Manager, Distribution Manager, District Engineer and Finance Manager, worked together to identify what metrics were required to monitor and report their most important activities. They identified the core service areas that the District is responsible for serving, and for each of these service areas benchmarks have been identified as the target level of service that the District is striving to achieve. The core service areas are:

- Water System Operations
- Water Resource Management
- Business Principles
- Workplace Environment

The levels of service and targets for water operations are shown in Table 5 below. For the District the most important levels of service are the compliance with regulations, the water mains breaks and the renewal of frozen services. There is a focus on the level of service for mains breaks, and GIS is being used to identify hot spots of mains breaks and to prioritize mains replacements. The level of service target is used as justification for the replacement projects.

Table 5 Brunswick and Topsham Water District - Water system operations levels of service

LEVEL OF SERVICE	TARGET
Compliance with Safe Drinking Water Rules and Regulations	No violations
Compliance with Taylor Discharge Permit	No violations
Compliance with USEPA secondary water quality standards	No events in exceedance
Maintain assets to a service level where there will be less than 1 break per 25 miles	<5 per year
Repair detected leaks within 24 hours	>90% of leaks detected
Renew frozen services the following construction season	100% Obtained
Maintain full redundancy for all pumping and treatment equipment on stand-by or on the shelf	100%
Maintain a full inventory of parts on hand for the repair of main breaks	100%
Maintain stand-by power at all stations in the event of a power outage	100%
The District will upgrade the system mains as they need to be replaced to meet the latest ISO standards.	Meet ISO standards
The District will prioritize projects that improve redundancy and reliability for the system as identified in the asset management plan.	Improve system reliability/redundancy

Table 6 shows water resource management levels of service. The District is currently installing AMI which will help identify where in the system water is being lost. The land purchase target is part of an aquifer protection program.

Table 6 Brunswick and Topsham Water District - Water Resource Management Levels of Service

LEVEL OF SERVICE	TARGET
Minimize unaccounted for water	<10% of water pumped
Engage in acquiring ownership of and protecting the land over the 250-day travel zones, as it becomes available for purchase.	100% Ownership

Table 7 shows the specific levels of service for water rates, debt coverage, and complaints. The District does not have any control over the target of zero PUC (Public Utility Council) complaints as anyone can make complaint, and is looking at alternative target or metric. Table 8 shows the safety related levels of service.

Table 7 Brunswick and Topsham Water District Business Principles Levels of Service

LEVEL OF SERVICE	TARGET
The District will comply with all PUC rules and regulations and perform an annual audit.	0 PUC complaints
The District will strive to keep water rates in the lower half of all water utilities in the state.	Rates < 50% of water utilities
The District will keep the debt coverage ratio above 125%	Debt coverage ratio > 125%

Table 8 Brunswick and Topsham Water District - Workplace Environment Levels of Service

LEVEL OF SERVICE	TARGET
Maintain a safety committee and strive to operate in the safest manner possible	8 meetings/year
Personnel related to the operation of system will maintain an appropriate grade license	100%
Training hours per licensed operator	24 hours

Customer service metrics have also been established, shown in Table 9 below.

Table 9 Brunswick and Topsham Water District - Customer Service Levels of Service

LEVEL OF SERVICE	TARGET
Respond to a customer by the next business day of receiving an inquiry	>95% of customer inquiries
Respond to a water quality or pressure service complaint within 4 hours	>95% of customer complaints
Planned Service interruptions will be less than 8 hours or temporary services will be provided.	100% of interruptions

The performance against each of the levels of service is reported on an annual basis as a report card. The District is in the process of reviewing the metrics and targets, and has plans to update them.

BUSINESS CASE EVALUATION

The District undertakes a business case evaluation for significant investment projects, including lifecycle cost analysis. An example was the current AMI project that the District is implementing. In the initial feasibility stage a business case evaluation was performed, but the Return on Investment (ROI) indicated that the investment was not affordable. So, alternative solutions were evaluated and the vendors came back with lower cost proposals which resulted in a positive ROI and approval for the project. The District has now deployed AMI for 50% of its system.

Another example of the application of a business case evaluation was for a replacement lagoon at the treatment plant which was built to handle coagulated backwash which was failing and presented a risk to the treatment process. There was a plan to build a new treatment process in eight years' time, so the decision had to be made whether to replace the lagoon now, and then potentially have to replace it again in eight years, or whether there was another option. A consultant was employed to evaluate alternative solutions and provide cost estimates. The District then undertook the business case evaluation.



A business case evaluation was performed for a replacement lagoon

The business case evaluated three options: Option 1 – Redundant Infiltration Lagoons, similar to the current design but modified to meet current engineering practices (\$413,000); Option 2 – A solids separating Lagoon Followed by an Earthen Infiltration Lagoon (\$518,000); and Option 3 – Construct a solids separation decant process with Supernatant Recycle (\$713,000). Each option was evaluated for permitting, siting constraints, storage volume, hydraulics, water efficiency, operational complexity, operational flexibility, and cost considerations.

By evaluating the business case for the lagoon the District was able to commit the money to Option 2 which represented more operational

flexibility to meet potential changes that could be introduced by a new treatment scheme. The District avoided the cost of Option 3 because the business case detailed that the water efficiency and additional land required for the District to construct Option 2 would not be limiting factors for the District.

BENEFITS

The District has found that defining the levels of service, combined with other initiatives to collect data and implement information management systems has led to better data to support business decisions. The business case evaluation process has enabled the District to justify investments that might not otherwise have been approved.

Craig Douglas, the Assistant General Manager commented: *“As we have implemented our asset management plan we have been able to provide information to more people in the organization, and*

as we have adopted key asset management principles the knowledge base has increased. It is easier to get new staff up to speed and explain our goals from level of service report card.”

The District plans to review the asset management implementation plan and update it. There are plans to improve the information management systems and how work orders are managed, and the District has discussed adding a maintenance management module to the information system. Data improvement needs have been identified; the District is replacing the treatment facility in seven years and would like to set up process to capture the relevant asset information, and improved data is required for water audits.

Craig has this advice for other utilities that are looking to develop levels of service. *“You will likely be surprised how many of these goals are already integrated into your business; the trick is to recognize and document this excellent work that you already do. Our ‘aha moment’ was with frozen services. It was during an operations meeting when we were discussing renewal of a frozen service, when we all looked at each other and realized this activity is the exact kind of service we already provide that we should be documenting for our annual report card.”*

“Start collecting data now, 5-6 years down the road you can do a lot with the data. And with technology adoption, make sure it is making your job easier and not harder. I have seen a lot of examples of technology making workflows longer, not shorter, and it is difficult to adopt if it is making workflows harder.”

Leading Practice – Risk Management

Risk management has been considered, by many, as the most important concept related to the management of water utility assets. Risk is made up of two parts: the probability, or likelihood, of failure of assets, and the consequence of asset failure.

The following questions were asked in the *Level of Progress in Utility Asset Management* survey:

- *Does the organization have a process to assess the probability (or likelihood) of failure of assets?*
- *Does the organization have a process to assess the consequence of asset failure?*
- *Does the organization have a process to rank assets according to overall risk (the product of likelihood and consequences of asset failure)?*
- *How advanced is the organization in predicting when water distribution pipe assets should be proactively replaced?*

Four utilities ranked very high or high in their responses to these questions on the leading practice Risk Management. Case studies describing the approaches for two utilities are included in the following sections:

- City of Annapolis
- Washington Suburban Sanitary Commission (case study also covers Asset Management Planning)

Case studies for the other two utilities have already been presented:

- San Diego County Water Authority (case study included under Current State of Assets)
- Portland Water Bureau (case study included under Levels of Service)

City of Annapolis

Leading Practice – Risk Management

BACKGROUND

The City of Annapolis Department of Public Works (the Department) provides water and wastewater services to approximately 36,000 people through 12,000 water and sewer connections, which includes a significant number of businesses and government institutions.

Water is extracted from three aquifers using eight groundwater wells and is treated at a single water treatment plant. Water is distributed through a distribution system that comprises 140 miles of water main, 2900 valves, 1240 hydrants and five elevated water storage tanks. The wastewater

collection systems comprised of 129 miles of pipe and 25 lift stations, and wastewater is treated at a treatment plant that is operated and maintained by a neighboring county.

The City is required to develop a comprehensive 10-year plan for its water and sewer assets, and the Department decided that the approach to planning would incorporate asset management. The driver for this was that the Rate Study required assumptions for future asset repair and replacement, and this was being estimated based on financial terms and not based on asset management principles such as risk and performance. The Department employed a consultant to develop the plan and the risk assessment methodology, as well as reviewing the asset inventory, performing a desktop condition assessment and developing strategies to manage the assets.

SURVEY RESULTS

The City ranked very high in the Risk Management leading practice compared with other small utilities, having developed a risk assessment methodology and applied it. The City's responses are shown in the following graphs. The graphs also show the responses from all the other participating utilities and the responses for the small utilities.



Utility: Department of Public Works, City of Annapolis

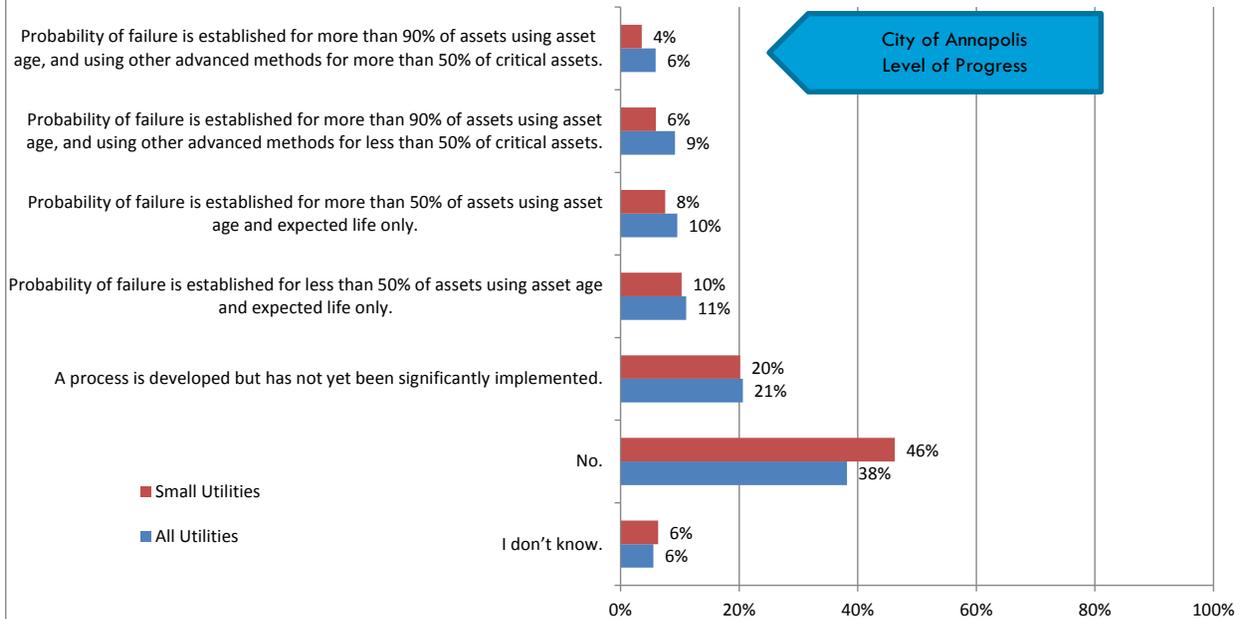
City/State: Annapolis, Maryland

Average system demand: 4 MGD

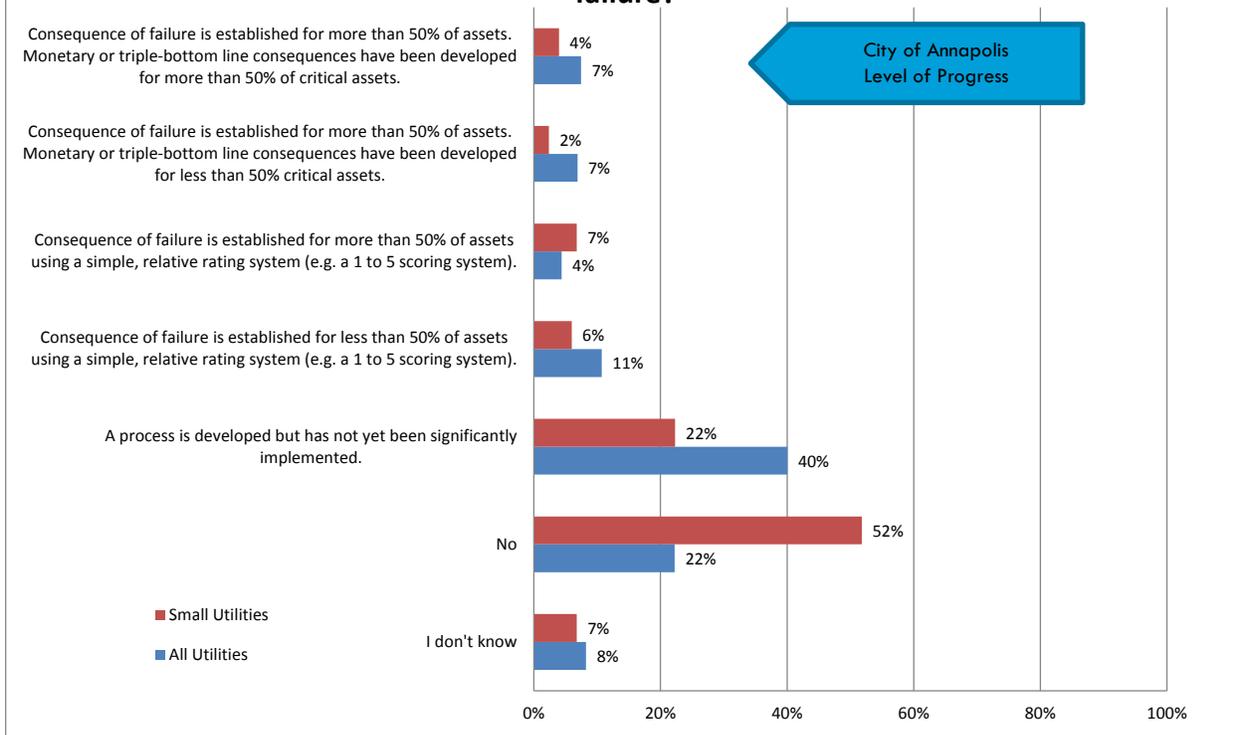
Population served: 36,000

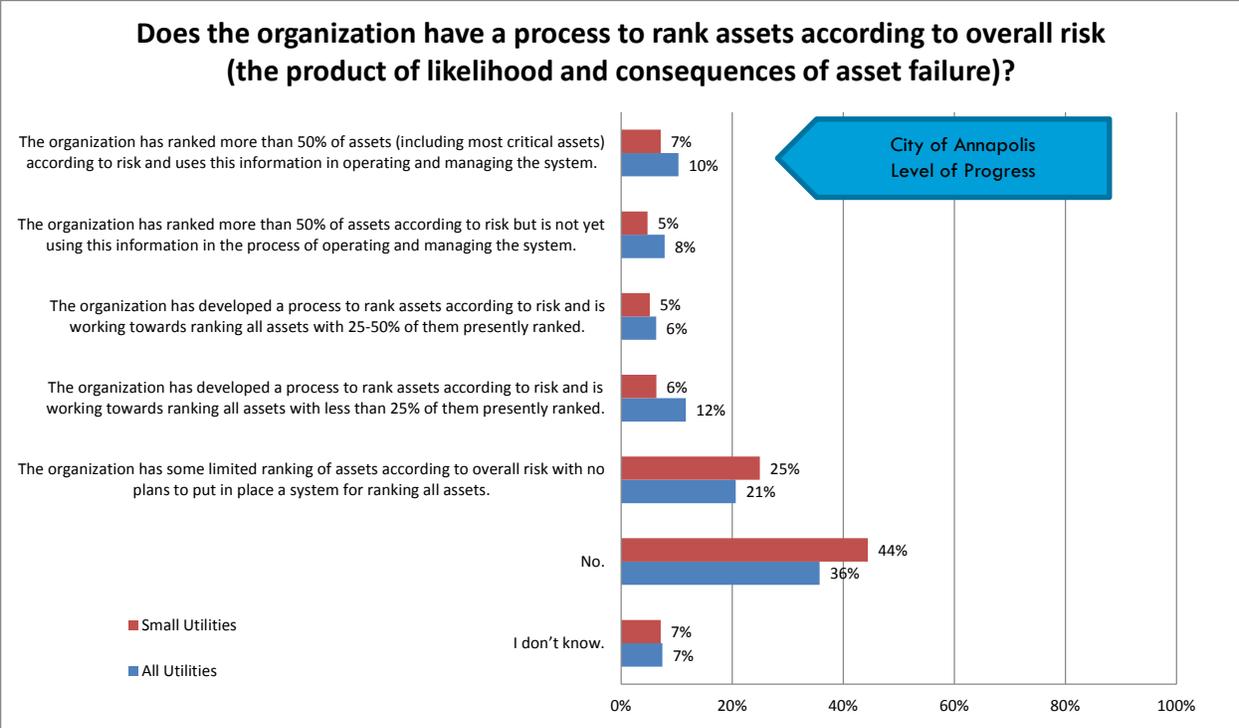
Number of FTE staff: 31

Does the organization have a process to assess the probability (or likelihood) of failure of assets?



Does the organization have a process to assess the consequence of asset failure?





RISK ASSESSMENT APPROACH

The risk assessment methodology was developed for water mains and sewers. The consultant used the EPA 5-step process to develop the plan which is based on the following questions:

- What is the current state of my assets?
- What is the required level of service?
- Which assets are critical?
- What are the best O&M and CIP strategies?
- What is the best funding strategy?

The plan development started with a review of available records on asset inventory and performance data. Though physical condition assessment data is not currently available, the Department has good asset inventory data in its GIS, and a work order system with good data, including information on water main breaks. The mains breaks were referenced to addresses, so some analysis was performed in GIS to correlate the historical break information with the asset inventory, to assign breaks to specific pipes.

The available work order data and inventory data on asset age and material was used to perform a desktop condition assessment. The Department has carried out some sewer CCTV inspection but the data is not completed and there are no sewer condition scores. Soil corrosivity data from USDA was used to develop a spatial link between pipes and soil corrosivity; soil corrosivity changes the rate of decay of pipe wall thickness thereby decreasing the asset life expectancy. Using the parameters of age, material, performance, soil corrosivity and asset life expectancy, a condition score between 1 and 5 was assigned to each asset, where a score of 1 is good condition and a score

of 5 is poor condition. If there was no history of failure but the age of the asset shows it at the end of its life, the score was capped at 4. The results from the desktop assessment are shown in Figure 22.

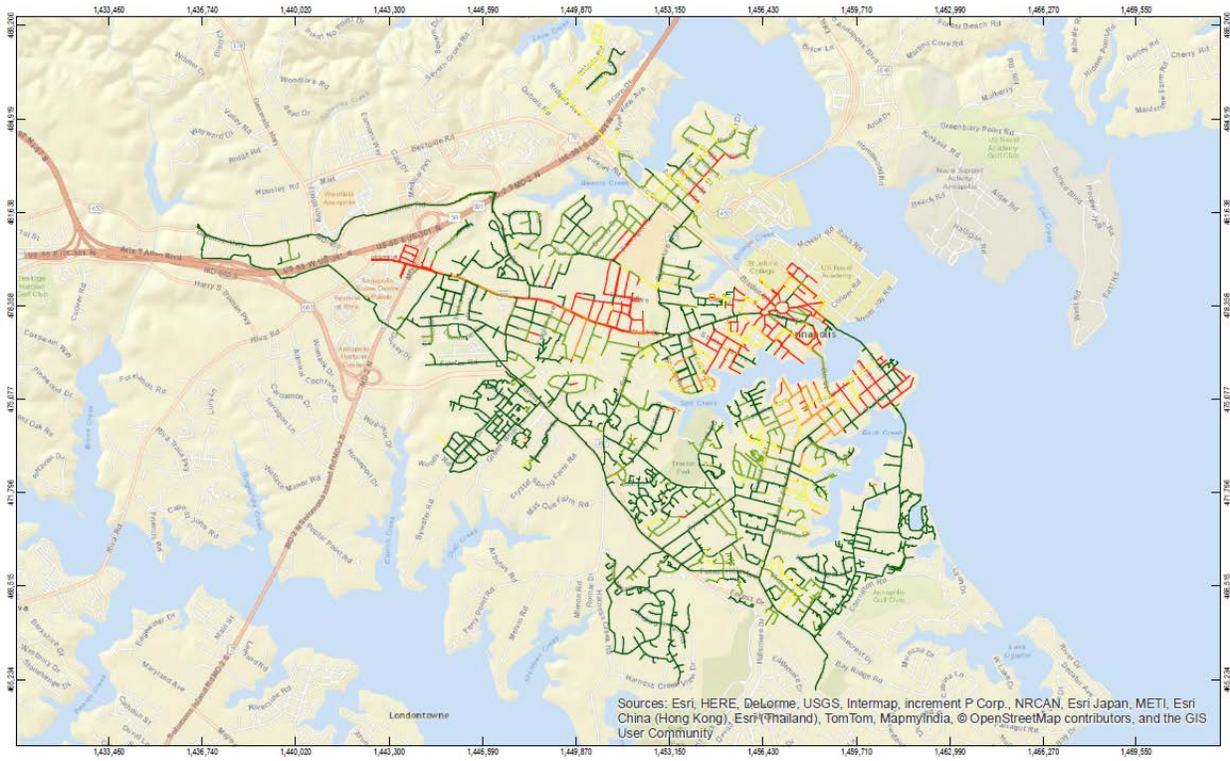


Figure 22 City of Annapolis - Results of desktop condition assessment for water mains

Consequence of failure criteria were developed using the Triple Bottom Line of Environmental, Social and Economic impacts to align the criteria (see Table 10). The criteria are scored on a scale of 0 to 5 where 0 is no impact and 5 is major impact, and definitions were developed for each of the criteria and scores. GIS analysis was used to assess the proximity of the assets to roads, buildings and environmentally sensitive areas, along with pipe size in order to score some of the consequence criteria.

Table 10 City of Annapolis - Consequence of failure criteria

CONSEQUENCE CRITERIA	DESCRIPTION
Loss of service impact	Number of customer hours without service and number of critical customers affected
Integrity and dependability	Impact on public image, media coverage, concern from politicians
Public health and safety	Potential sickness, minor or major injuries, death
Fiscal	Direct and indirect costs of a failure
Resource and operational impact	Number of resource hours required to correct failure
Environment	Environmental impact and regulatory sanctions

The likelihood of failure score was calculated based on the condition score, converting to a scale of 1 to 10. The consequence of failure score was calculated by adding the consequence of failure scores for each of the six criteria to give an overall score between 0 and 30. No weighting factors were applied. The Business Risk Exposure (BRE) was calculated for each asset by multiplying its likelihood and consequence scores. The results are shown in the figure below.

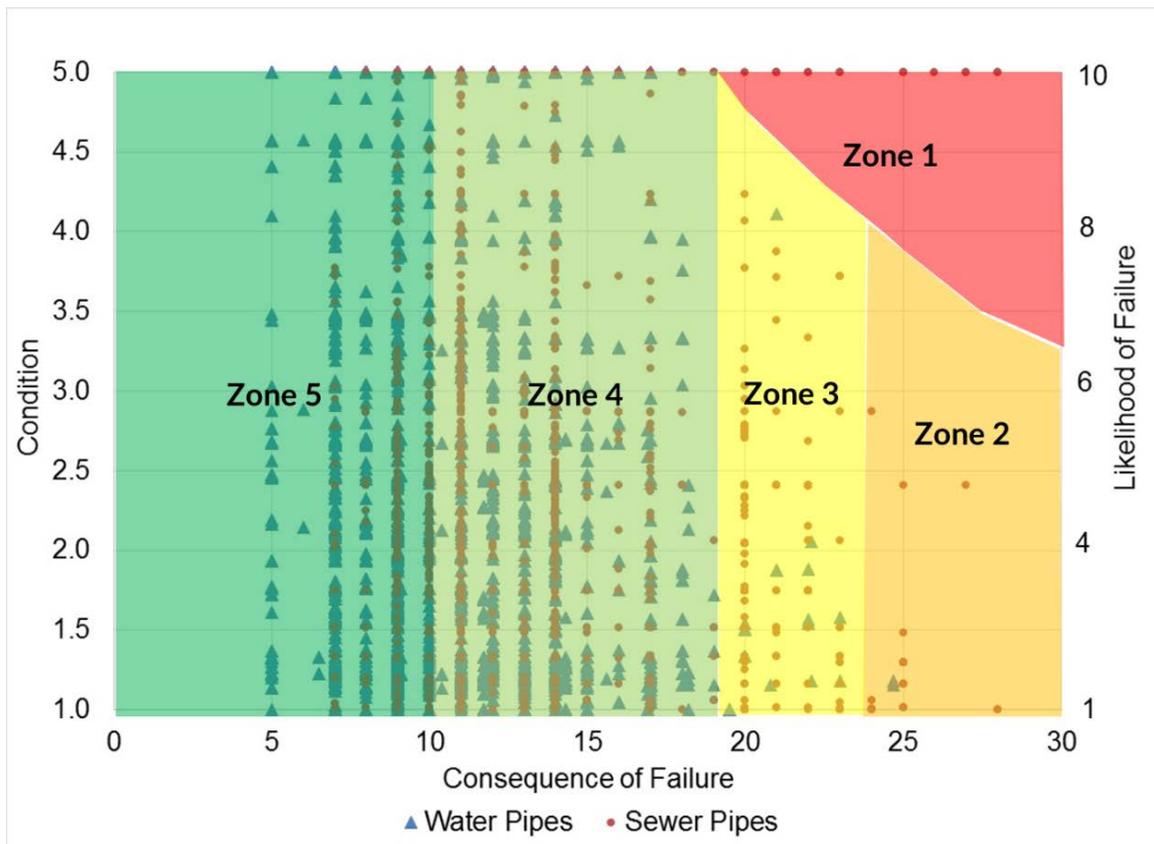


Figure 23 City of Annapolis - Risk Exposure Plot

Zones of risk tolerance have been created to evaluate the BRE results and will be used to assign asset management strategies. Zone 1 is intolerable risk and any assets in this zone will require risk mitigation, and assets in Zone 5 will be run to failure.

Asset management strategies have been developed based on the results of the risk assessment to mitigate some of the risks identified, and some projects have been identified for immediate execution. Strategies include leak detection, valve exercising and inspection, priority pipe replacements, and sewer CCTV inspections on critical sewers identified from the risk assessment. Resource needs were assessed for each of the strategies to determine which activities would be performed by City staff and which ones by a contractor.

The costs of the water and sewer asset management strategies have been forecast for a period of 15 years and priority projects have been identified, and the Department will incorporate these strategies and projects in the CIP.

The intent is to develop more resources and capabilities in-house, with less reliance on consultants. Currently the department has a small staff who will be provided training in the risk model by the consultant. The staff has been engaged in the process and have bought into the approach. The consultant is currently acting as program managers to assist with initiating implementation of the strategies and further asset management improvements.

BENEFITS

This is a good example of what you can do with limited data. Analysis can be performed to correlate data and assumptions can be made to fill data gaps, so having limited data does not prevent a utility from performing a risk assessment. As long as you are aware of the uncertainties and some of the limitations, a risk-based approach to planning can provide justification for projects and provide focus for areas of improvement.

The asset management strategies include data collection, and the Department wants to move beyond desktop condition assessments and commence physical condition assessments to collect comprehensive condition data for the system.

Thora Burkhardt, the Water and Sewer Program Manager for the City of Annapolis, stated *“The consequence of failure analysis was an eye-opener for us and identified that we could run some pipes to failure. The risk assessment now enables us to justify projects; in the past, we had a hard time explaining why we needed to implement a project.”*

Washington Suburban Sanitary Commission

Leading Practice –Asset Management Planning and Risk Management

BACKGROUND

Established in 1918, Washington Suburban Sanitary Commission (WSSC) is among the largest water and wastewater utilities in the nation. The service area spans nearly 1,000 square miles in Prince George’s and Montgomery counties, serving 1.8 million residents through approximately 460,000 customer accounts. WSSC drinking water has always met or exceeded federal standards.

WSSC operates and maintains the following assets:

- Three reservoirs – Triadelphia, Rocky Gorge, and Little Seneca, have a total holding capacity of 14 billion gallons.
- Two water filtration plants – The Patuxent (max 56 MGD) and the Potomac (max 285 MGD) plants produce an average of 167 MGD of safe drinking water.
- Six wastewater treatment plants – Western Branch, Piscataway, Parkway, Seneca, Damascus, and Hyattstown with a total capacity to handle 71.08 MGD.
- The Blue Plains Advanced Wastewater Treatment Plant, operated by DC Water, handles as much as an additional 169 MGD under a cost sharing agreement with the WSSC, treating on average approximately 65% of the Commission’s wastewater annually.
- Over 5,650 miles of water main lines and more than 5,686 miles of sewer main lines are maintained.

WSSC’s vision is to be among the top tier of the best-managed water and wastewater utilities in the world.

SURVEY RESULTS

WSSC ranked very high in the Risk Management and Asset Management Planning leading practices. WSSC’s responses are shown in the following graphs. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.



Utility: Washington Suburban Sanitation Commission

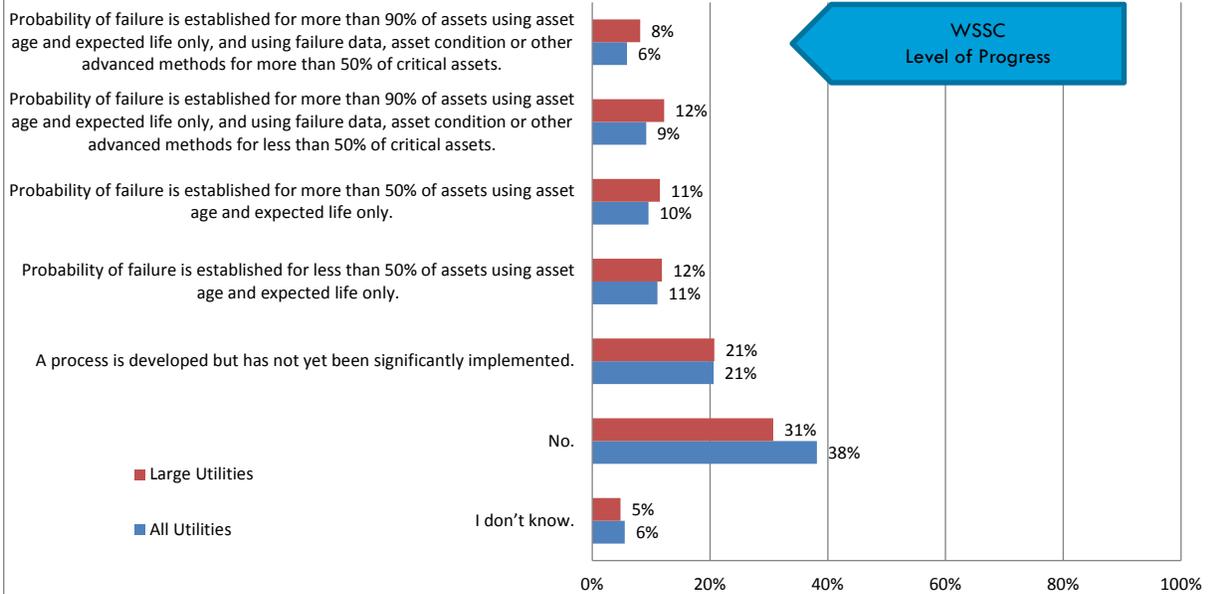
Location: Prince Georges and Montgomery Counties, MD

Average system demand: 167 MGD

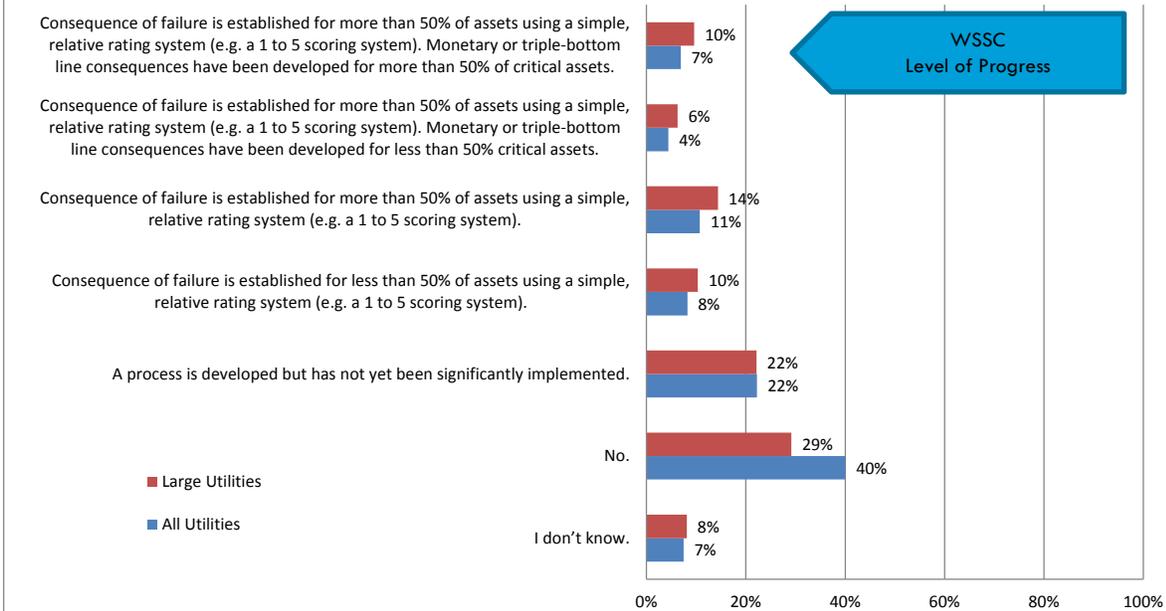
Customers: 1,800,000 residents

Number of FTE Staff: 1700

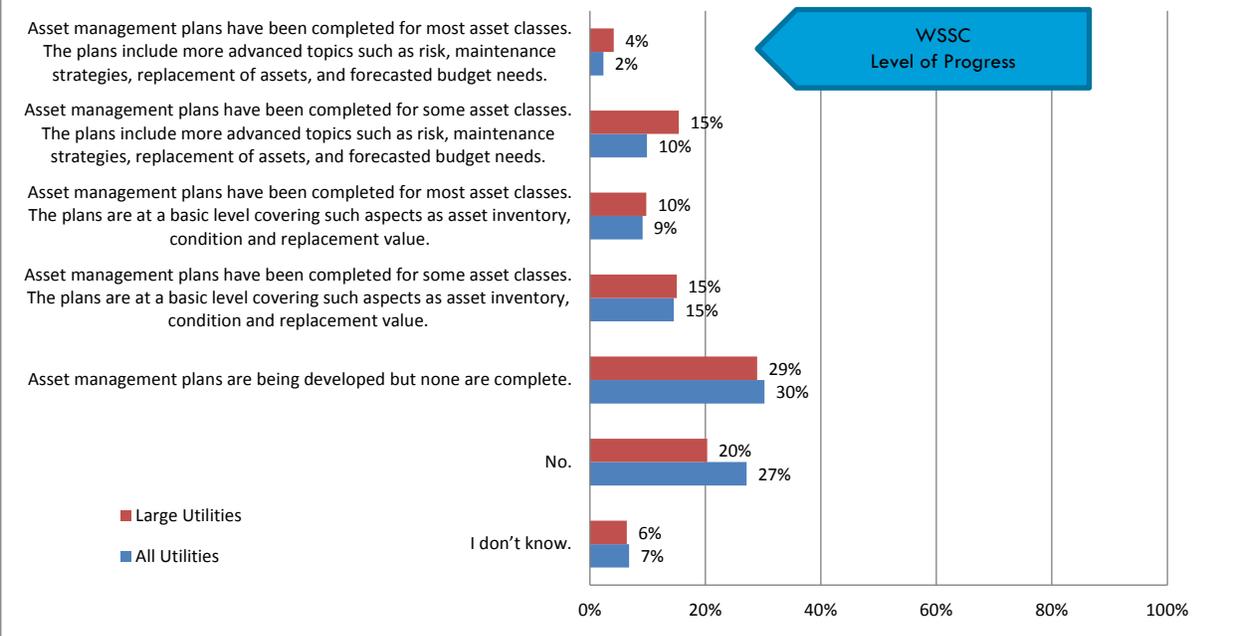
Does the organization have a process to assess the probability (or likelihood) of failure of assets?



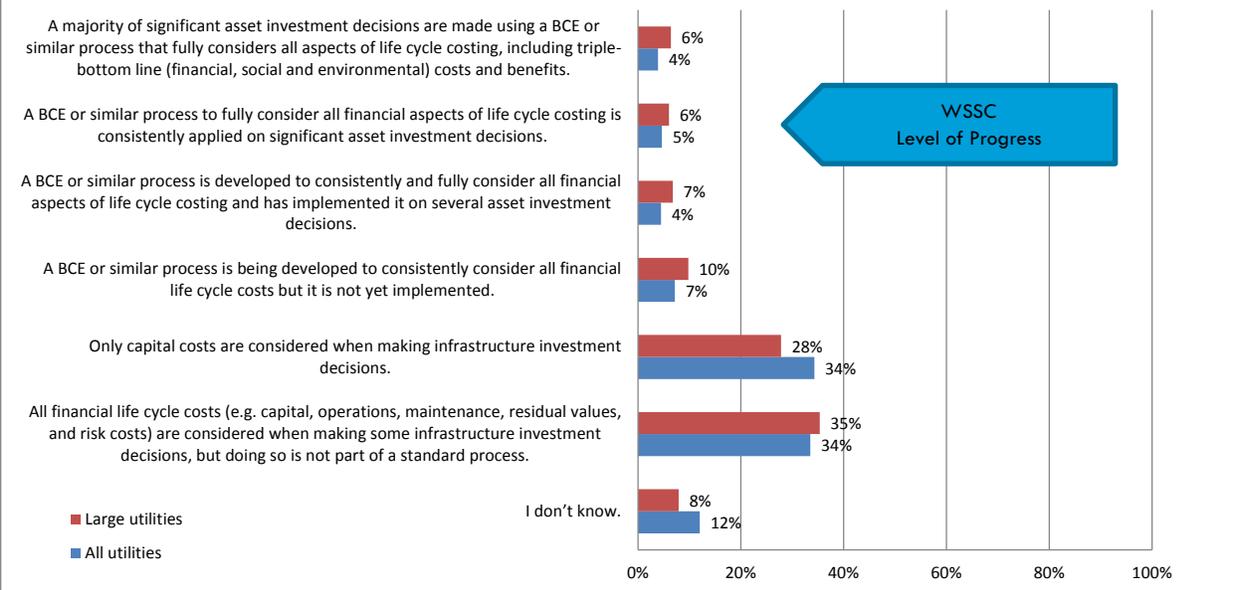
Does the organization have a process to assess the consequence of asset failure?



Has the organization developed asset management plans for its various asset classes?



Does the organization require business case evaluations (BCE's) when making infrastructure investment decisions?



ASSET MANAGEMENT PROGRAM

In April 2007, WSSC began work on a Utility Master Plan (UMP) project to apply asset management principles as the basis for future investment decision making and management of its water, wastewater, communications, and buildings and grounds infrastructure. Early in that project, WSSC focused its attention on more holistic approach embracing asset management principles.

The initial output of the UMP was completed in July 2007 and provided a high-level analysis of the capital and renewal/replacement investment needs for WSSC infrastructure. This was considered the first Enterprise Asset Management Plan. The next steps involved

- Refinement of the asset hierarchy;
- Creation of a roadmap for the development of Asset Management (AM) Plans over the future phases; and
- Definition of the structure and content of the proposed AM Plans for networks, systems, sub-systems, and facilities.

AM Program Charter

To drive the implementation of the Asset Management Program, WSSC established an Asset Management Program Charter that provided the vision, goals, and objectives of the program, as well as many other factors, risks, and milestones for consideration. Following are the Vision, Mission and Goals defined in the Charter:

- **Vision:** The Asset Management Program will:
 - Identify infrastructure needs (existing and future) for the next 30 years;
 - Develop and implement an asset management strategy to strengthen current asset management practices for optimal investment decision making; and
 - Help WSSC advance its Infrastructure Asset Management Core Strategy.
- **Mission:** The Asset Management Program will implement an asset management strategy to strengthen current asset management practices and develop an Enterprise Asset Management Plan which identifies the infrastructure needs for a 30-year planning period, and can be used in the development of the ten-year Fiscal Plan.
- **Goals:**
 - To Identify the infrastructure needs (existing and future capacity, regulatory, rehabilitation/repair/replacement, and O&M of the water and wastewater, support services, and communications networks) for the next 30 years; and
 - Establish and institutionalize an asset management program within the organization that:
 - Ensures our workforce implements asset management principles for better decision-making and provides opportunities for knowledge transfer.
 - Applies innovative asset management techniques, tools and practices.
 - Collaborates with peers in the water and wastewater industry to foster a strong asset management knowledge community.

The vision and goals received further definition with the development of Asset Management Policies, shown in the figure below.



ASSET MANAGEMENT POLICIES
Washington Suburban Sanitary Commission

Effective planning, design, construction, operation, maintenance and renewal of infrastructure assets are the primary means by which we meet our obligations to stakeholders and rate-payers.

We are committed to an asset management program that ensures our staff and management will:

1. Train, as needed, in all relevant aspects of asset management including best practices/processes, resource managing tools, knowledge retention and individual skills improvement.
2. Know what assets we own and for which assets we have responsibility or legal liability. We will record these assets in one register down to a maintenance-managed item (MMI level).
3. Apply best appropriate life cycle processes and practices to our assets. We will acquire and maintain the necessary data and knowledge these processes and practices require. We will store our data and knowledge in suitable enterprise-wide information systems that support our asset management responsibilities.
4. Monitor the condition, performance, use and cost of infrastructure assets down to the appropriate level (part, item, asset, etc.) and against prescribed service levels and regulatory requirements.
5. Understand those infrastructure assets that are critical to our service levels and prioritize their management to ensure they don't fail. (This is not to imply that non-critical assets are ignored).
6. Understand and record the current levels of service with which we provide our customers. We will understand the likely future levels of service required in order to continue to serve our customers.
7. Know the future level of service options available and their associated costs. We will publish future level of service options periodically through our asset management plans and associated funding strategies. We will use future level of service options in our public/customer outreach programs.
8. Link our level of service with our stakeholder expectations, through customer outreach, at a cost that our customers are willing to pay.
9. Understand customer expectations including the non-regulatory aspects of our business (e.g., noise, customer service, appearance, cleanliness, customer outreach).
10. Identify, understand, and manage the risks associated with running our business.
11. Understand the total cost of service delivery including the total cost of asset renewal.
12. Understand the real growth of our business and the way service demands will change in the future. We will systematically project long term (>20 years) funding needs to meet business requirements in both capital and recurrent (operation, maintenance and renewal) investment.

WSSC Asset Management Policies Page 1 of 2
Revision Date: March 3, 2008



13. Develop pricing and funding strategies that balance the needs of the Sanitary District to ensure our sustainability. We will monitor and report in triple bottom line terms (financial, environmental, social/community/organizational).
14. Link our strategic goals to our asset related investments and action plans.
15. Implement systematic validation processes to evaluate all planned investment in capital projects, maintenance programs, operations and associated support services, as well as their impact on rates.
16. Work with other agencies to leverage asset investment when cost effective.
17. Prepare and execute an enterprise-wide Asset Management Plan so that all stakeholders know the Commission's asset management strategy. Prepare system, facility, and sub-system asset management plans.
18. Review our progress to continuously improve our asset management performance.
19. Recommend that adequate resources be allocated to assure the continued development and implementation of an asset management program.

Figure 24 WSSC Asset Management Policies

WSSC determined that implementation of the Asset Management Program would be a ten-year process to be conducted over three phases as follows.

Phase 1: Assessment

In 2007-08, a gap assessment was used to assess WSSC's existing AM practices. They used the results to develop a Roadmap, identify processes and practices that needed to be developed, and create an asset hierarchy. The hierarchy was structured to categorize assets at different levels, which provided a basis to determine and prioritize what AM plans needed to be developed at each level. The hierarchy included anything related with water and sewer services and support facilities, such as administration buildings, depots, and warehouses. It did not include fleet, but it included fixed assets in the support facilities.

This resulted in a hierarchy with levels defined as follows:

- Enterprise AM Plan
 - Network AM Plan
 - System AM Plan
 - Facility AM Plan
 - Sub-system AM Plan

Using the established hierarchy, WSSC identified 185 AM plans to be developed, and prepared a prioritized Roadmap to complete AM plans by December 2018.

Also in phase 1, WSSC performed a review of utility functions, to determine which functions would be impacted by asset management, and these impacts were used to identify stakeholders to be included as part of a program/project team. WSSC identified 13 processes that needed

improvement. These were prioritized and resulted in the process and procedures update timetable shown in Table A below.

Table 11 WSSC - Asset Management Process and Procedures

PROCESSES (AT VARIOUS LEVELS OF THE AM PROGRAM HIERARCHY)	TIMEFRAME			
	Facility or Sub-system	System	Network	Enterprise
AM Plan Organizational Structure	2011	2011	2011	2011
Business Risk Exposure Policies & Guidelines	2011	2015	2017	2017
Levels of Services Management Procedures	2011	2015	2017	2017
Capital and Financial Management Procedures	2011	2015	2017	2017
Condition Assessment Procedures	2011	2015	2017	2017
Confidence Level Service Procedures	2011	2016	2017	2018
Asset Management System Functionality and Business Logic	2011	2015	2017	2018
Maintenance Strategies and Procedures	2011	2016	2017	2018
Asset Commissioning and Decommissioning Procedures	2011	2015	2015	2015
Document Management & Document Change Management Procedure	2011	2015	2017	2018
Training Plan	2011	2015	2017	2018

Phase 2: Implementation

To implement the roadmap, WSSC needed knowledge transfer to build its staff knowledge until they achieved self-sufficiency. Therefore, it engaged a consultant working with them to commence AM program. Initial plans were identified to serve as templates for subsequent ones, so WSSC tried to select a representative range of asset types: a wastewater pump station, a collection system sub-basin, and a wastewater treatment plant, all part of same network. The intent of analyzing assets in the same network was to see how they could associate information and decisions for same network. Water and distribution system pipes were also selected.

Also in phase 2, one of the processes was to look at the organizational structure and identify needed changes to effectively implement asset management in the organization. This review led to the development of an immediate structure and a longer-term structure that included more positions and more processes. WSSC has been following this plan with some changes to the planned long term structure, and are currently approaching being fully staffed.

Phase 3: Implementation under ownership of in-house staff

WSSC are presently in stage three, which is the continuing process of developing the remaining AM plans, updating existing plans, and developing and updating asset management processes. All plans are anticipated to be complete in 2018.

BUSINESS RISK EXPOSURE

WSSC assesses the risk of its assets based on its Business Risk Exposure (BRE) measure. The BRE measure is based on a variety of factors, including how each asset affects WSSC's ability to deliver service to its customers, how each asset affects WSSC's goal of offering affordable services, how each asset might impact the environment, and how WSSC is managing each of its assets.

The BRE measure is used for a variety of purposes by WSSC within the context of its AM Plans. The principal purpose of the BRE measure is to quantify the level of risk exposure to WSSC from a particular asset. The BRE measure is also used to monitor assets, identify needs, prioritize projects, optimize capital investments, and assess the level of risk exposure to WSSC at the sub-system, system, network, and enterprise levels.

There are three components to the BRE measure, the probability of failure (POF), the consequence of failure (COF), and the mitigation factor (MF). The formula for the BRE measure is as follows:

$$\text{BRE} = \text{POF} \times \text{COF} \times \text{MF}$$

The first component of the BRE measure is the probability of failure, which measures the physical mortality of an asset based upon its current age, condition, and/or work order history. Table 12 below shows the generic enterprise-wide table used by WSSC for determining POF based on the condition score for the asset.

Table 12 WSSC - Probability of Failure Criteria

CONDITION SCORE	DESCRIPTION	POF
1	New or Excellent	0.10
2	Minor Defects Only	0.31
3	Moderate Deterioration	0.51
4	Significant Deterioration	0.71
5	Virtually Unserviceable	1.00

The POF component of the BRE measure is also important with regard to WSSC's risk management efforts. One of the strategies available to WSSC to manage its risk is to reduce the POF of its assets. If the POF of an asset is reduced, then its BRE score is also reduced. Therefore, efforts to improve the condition of WSSC's assets through maintenance, rehabilitation, and replacement activities are important parts of WSSC's risk management planning.

The second component of the BRE measure, consequence of failure, is used to determine the risk posed to WSSC from the failure of an asset. WSSC assesses the COF on a triple-bottom-line ("TBL") basis. The TBL method assesses the social, economic, and environmental impacts resulting from an

asset failure. WSSC recently updated its methodology for assigning a monetized COF value to each COF numeric score. The COF factors and example criteria are shown in the following tables.

Table 13 WSSC - Consequence of Failure Factors

TBL	COF FACTOR	DESCRIPTION
Social, Community, and Organizational Consequences of Failure	Loss of Service Impact	Flow impacts; loss of treatment capabilities; operational flow rate; reduced firefighting ability; number of customers and critical customers connected to the segment
	Public Health & Safety	Regulatory compliance; proximity to roads, railroads, and water transmission mains; health and safety of public and WSSC employees
	WSSC's Credibility	Media coverage
Economic and Financial Consequences of Failure	Total Cost of Failure	Direct cost to remedy failure; damage to WSSC and non- WSSC assets; value of lost production; legal cost; fines
	Indirect Costs for Resource and Operational Impacts	Resource and operational impacts associated with remedying failure
Environmental Consequences of Failure	Environmental Impacts	Intangible costs

Table 14 WSSC - Loss of Service Impact

COF SCORE	DESCRIPTION	COF VALUE
1	Can be out of service for up to a year	\$1
3	Can be down for a month; disruption of 10 people for one day	\$1,000
4	Minor loss of revenue; minor service outage no greater than one week; disruption of 100 people for one day	\$10,000
7	Minor loss of revenue; service outage no greater than one day; disruption of 1,000 people for one day	\$50,000
9	Moderate loss of revenue; major service function outage of 12 hours; disruption of 10,000 people for one day	\$600,000
10	Major loss of revenue; major service function outage of two days; disruption of 100,000 people for two days	\$6,500,000

The third component of the BRE measure is the mitigation factor, which measures the degree to which the COF of an asset has been lessened through mitigation activities. Mitigation of the COF of an asset failure is another strategy available to WSSC for managing the raw risk posed by an asset. If the COF of an asset is lessened when a failure occurs due to the effects of mitigation efforts, then its BRE score is also reduced. Therefore, efforts to reduce the impact of asset failure through redundancy, emergency response plans, or other mitigation methods are important parts of WSSC's risk management planning. Mitigation factors are shown in Table 15.

Table 15 WSSC - Examples of Mitigation Approaches and Mitigation Factors

MITIGATION APPROACH	DESCRIPTION	MF
No Backup	All Capacity Lost	1.00
20% Backup	20% of Capacity Available After Failure of the Asset	0.80
Spares on Site	Equivalent to 25% Backup	0.75
50% Backup	50% of Capacity Available After Failure of the Asset	0.50
100% Backup	One Complete Redundant System	0.10

WSSC organizes its assets into groups that are referred to as BRE zones. Each asset is assigned a zone based upon the BRE score for that particular asset. The assets are grouped into BRE zones in order to better identify those assets that pose a high or significant risk to the organization as a whole. The identification of high and significant risk assets is important to risk reduction efforts, as it points out which assets need more individualized risk management endeavors. The BRE zones (see Table 16) also allow WSSC to track its risk reduction efforts.

Table 16 WSSC - BRE Zones

ZONE	RISK LEVEL	LOWER BOUNDARY	% OF MAX BRE SCORE	UPPER BOUNDARY	% OF MAX BRE SCORE
Zone 5	Low	BRE > \$0	0.0%	BRE < \$6.20 Million	10.0%
Zone 4	Mild	BRE >= \$6.20 Million	10.0%	BRE < \$9.30 Million	15.0%
Zone 3	Moderate	BRE >= \$9.30 Million	15.0%	BRE < \$15.50 Million	25.0%
Zone 2	High	BRE >= \$15.50 Million	25.0%	BRE < \$31.00 Million	50.0%
Zone 1	Significant	BRE >= \$31.00 Million	50.0%	BRE <= \$62.00 Million	100.0%

WSSC also organizes its assets into groups that are referred to as COF bands, using the same boundaries as used for the BRE zones. Each asset is assigned a band based upon the COF value for that particular asset. By grouping the assets into COF bands, WSSC is able to better identify those assets that could pose a high or significant risk to the organization (even if the current BRE scores of the assets do not fall within the high or significant risk BRE zones). Additionally, the use of COF bands allows WSSC to track the results of its risk reduction efforts. COF bands are shown in Table 17 below.

Table 17 WSSC - Consequence of Failure Bands

COF BAND	CONSEQUENCE	LOWER BOUNDARY	UPPER BOUNDARY
Band 5	Low	COF > \$0	COF < \$6.20 Million
Band 4	Mild	COF >= \$6.20 Million	COF < \$9.30 Million
Band 3	Moderate	COF >= \$9.30 Million	COF < \$15.50 Million
Band 2	High	COF >= \$15.50 Million	COF < \$31.00 Million
Band 1	Significant	COF >= \$31.00 Million	COF <= \$62.00 Million

By grouping the assets into BRE zones and COF bands, WSSC is able to compare the operating risk of an asset (i.e., its BRE score) with the criticality of an asset (i.e., its COF value). This comparison shows how WSSC is managing the risk of its asset, through its efforts to keep the assets in good condition (i.e., POF) and its efforts to mitigate the risks posed by the assets (i.e., MF). Table 18 below shows the effects of WSSC’s risk reduction efforts. For example, out of the 942 assets that are in COF Band 1, only 83 fall into BRE Zone 1. This means that the risk of the remaining 859 assets is being reduced to levels that fall into the lower zones through WSSC’s risk management efforts.

Table 18 WSSC - Risk Reduction Efforts, Number of Assets in Each BRE Zone by COF Band

		BRE ZONE					
		Zone 5	Zone 4	Zone 3	Zone 2	Zone 1	Total
COF BAND	Band 1	86	72	97	604	83	942
	Band 2	5,680	3,123	1,008	93	-	9,904
	Band 3	5,939	1,028	173	-	-	7,140
	Band 4	1,092	4	-	-	-	1,096
	Band 5	564,724	-	-	-	-	564,724
Total		577,521	4,227	1,278	697	83	583,806

ASSET MANAGEMENT PLANS

After AM Plans are developed, they are updated on an annual basis thereafter. The plans are used to feed into the CIP process and the budget process, and there is a well-defined schedule for implementation and update in July through April. Review of the CIP starts in May, so AM Plans need to be completed before that. All System AM Plans need to be completed and transferred each December to the Asset Management Office, where the information and recommendations are reviewed and used to develop the Network AM Plans and ultimately the Enterprise AM Plan

To support the planning process, WSSC has implemented a decision support system, which links to the computerized maintenance management system and GIS. Using this tool, WSSC can forecast the asset needs for the next 30 years and produce reports for each facility. As the process was developed, one of the lessons learned by WSSC was that there wasn’t value in having separate AM Plans for many facilities (e.g. each pumping station) and determined it would be very repetitive. Instead of producing separate plans, WSSC now summarize the information in the corresponding System AM Plan and provide reports for each of the facilities as part of the appendices. The decision support system is programmed to calculate replacement cost and remaining life, as well as planning repair, rehabilitation and replacement costs for the next 30 years.

The AM Plans summarize the number of assets, overall condition, overall risk, pre-and post mitigated risk. They have monetized risk values to provide consistency between different assets and risk types.

The Five Questions Template

WSSC’s AM Plans are based on the five questions that were developed as part of the Environmental Protection Agency (EPA) training on asset management. These are the fundamental questions that

all managers of infrastructure should be constantly posing to their management teams. Following are the questions, which are also used as the structure (table of contents) of their asset management plans.

Question 1. What is the current state of my assets?

- What do I own?
- Where is it?
- What condition is it in? How is it performing?
- What is its remaining useful life?
- What is its remaining economic value?

Question 2. What is my required level of service?

- What is the demand for my services by my stakeholders?
- What do regulators require?
- What is my actual performance?

Question 3. Which assets are critical to sustained performance?

- How does it fail? How can it fail?
- What is the likelihood of failure?
- What does it cost to repair?
- What are the consequences of failure?

Question 4. What are my best O&M and CIP investment strategies?

- What alternative management options exist?
- Which are the most feasible for my organization?

Question 5. What is my best long-term funding strategy?

Additionally, WSSC has included a sixth question: What business processes need to be improved?

BUSINESS CASE EVALUATION

To follow through on the AM Plans and develop projects for inclusion in the CIP, there is a project needs validation process that is managed by AM strategy managers. This is a formal process that is tracked in one of the many tools WSSC uses for program management. In these tools, the requester can track where the request is. Every month, a project needs planning committee reviews requests and makes approvals, and in this process, determine whether a business case is needed.

If a business case is required, it is referred to two project managers and an economic analyst, who are supported by two consultants assigned to business case development. The business case development is managed as a regular project. Alternatives are developed and screened; lifecycle costs are analyzed in conjunction with risk reduction; and there is a cost-benefit analysis on projects that might have a societal impact not included in the lifecycle cost analysis. Based on this analysis, the project team makes a recommendation, which is then prioritized for inclusion in CIP

and goes to committee for approval. Below is a diagram that shows WSSC's Business Case Evaluation Process.



Introduction to WSSC's Business Case Evaluation Process



Figure 25 WSSC's Business Case Evaluation Process

BENEFITS

WSSC has recognized a number of important benefits from the asset management planning process:

- There is now a system in place that allows WSSC to identify the infrastructure needs at the asset level every year for a 30-year time period. The list of the needs is then prioritized and funding requirements determined and discussed as part of the yearly CIP and budget development processes.
- Risk is monetized and WSSC can evaluate risk reduction per dollar spent at the asset level, and show how mitigation strategies help reduce risk.
- WSSC can track expected risk reduction and evaluate performance by comparing to observed trends over time.
- An enhanced analysis of buried assets has allowed WSSC to identify and defend future spending needs. With the aid of this analysis 55 miles of main replacement per year has been achieved.
- With the business cases, WSSC has a process to determine the best solution to address needs, evaluate efficiency and support continual improvement.
- Across the organization, WSSC has a better understanding of risk and condition of the assets.
- WSSC has accomplished a lot, but efforts are ongoing, including organizational acceptance of the asset management approach.

Leading Practice – Maintenance and Reliability

Advanced maintenance practices include finding the right balance between the amount of planned versus reactive maintenance, and conducting more predictive maintenance on vertical or facility assets. Because the ability to detect defects and/or predict asset failures is based on experience, data and the use of predictive technologies has improved with time, improved maintenance for many utilities means becoming more proactive and less reactive.

The following questions were asked in the *Level of Progress in Utility Asset Management* survey:

- *Is the organization moving from reactive (corrective and emergency) maintenance to planned (predictive and preventive) maintenance?*
- *How advanced has the organization become in applying predictive maintenance to its vertical assets (mechanical, electrical, HVAC, and other asset types associated with facilities)?*
- *Does the organization utilize a computerized maintenance management system (CMMS)?*

The following utilities ranked very high or high in their responses to these questions on the leading practice Maintenance and Reliability, and case studies describing their approaches are included in the following sections:

- Fairfax Water
- Des Moines Water Works
- Livingston County Water & Sewer Authority

Fairfax Water

Leading Practice – Maintenance and Reliability

BACKGROUND

Founded in 1957 by the Virginia State Corporation Commission as a public, non-profit water utility, Fairfax Water is Virginia’s largest water utility and one of the 25 largest water utilities in the country. Fairfax Water serves nearly two million people in the Northern Virginia communities of Fairfax, Loudoun, Prince William, Fort Belvoir, Herndon, Dulles, Vienna, Alexandria, Falls Church, and Fairfax City.

Fairfax Water has an average daily water production rate of 163 million gallons and maximum production capacity of 376 million gallons per day. Supplying water from four different locations, the utility owns and operates the two largest water treatment plants in the state of Virginia. This includes the James J. Corbalis Jr. treatment plant at the northern tip of Fairfax County and the Frederick P. Griffith Jr. treatment plant on the southern border of Fairfax County.

Fairfax Water draws raw water from two primary sources: the Potomac River and the Occoquan Reservoir, which is fed by the Occoquan River. The four treatment facilities feed an interconnected distribution system that includes 3,971 miles of water mains, 28,827 fire hydrants, and 97,683 valves.

SURVEY RESULTS

Fairfax Water ranked very high in the Maintenance and Reliability leading practice, and three of the AWWA Level of Progress Survey questions apply to the case study’s focus area.

Fairfax Water’s responses are shown in the following graphs, and the utility is in the most advanced category, in all cases. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.



Utility: Fairfax Water

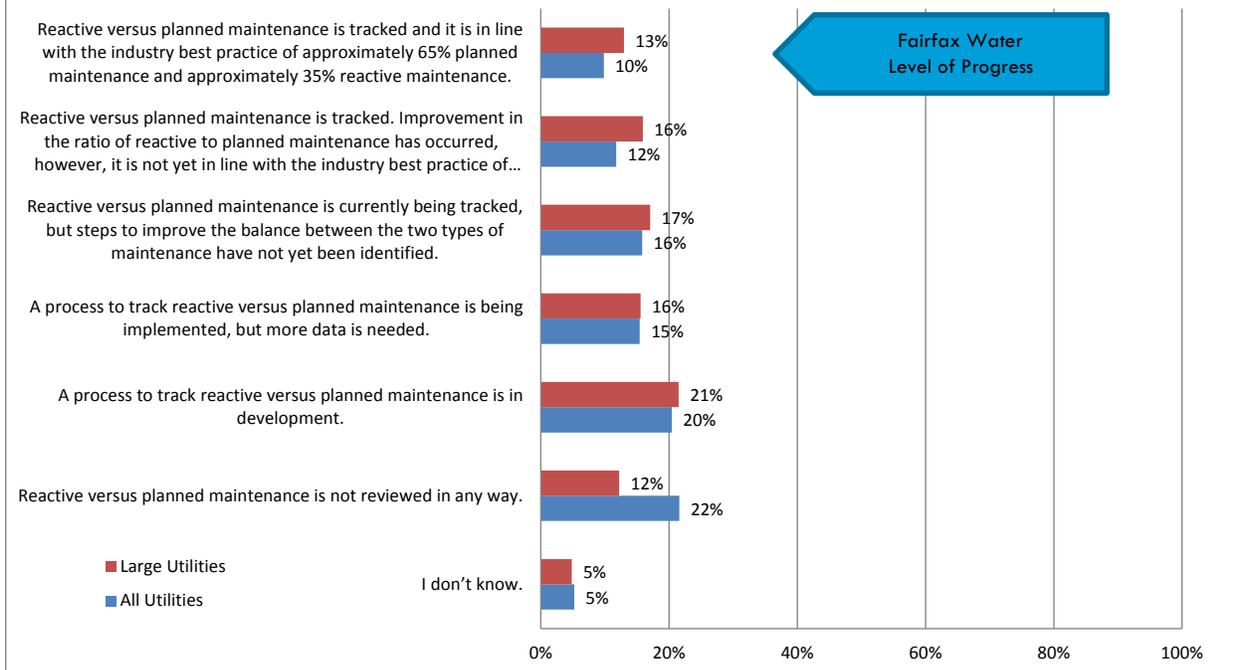
City/State: Fairfax County, VA

Average system demand: 163 MGD

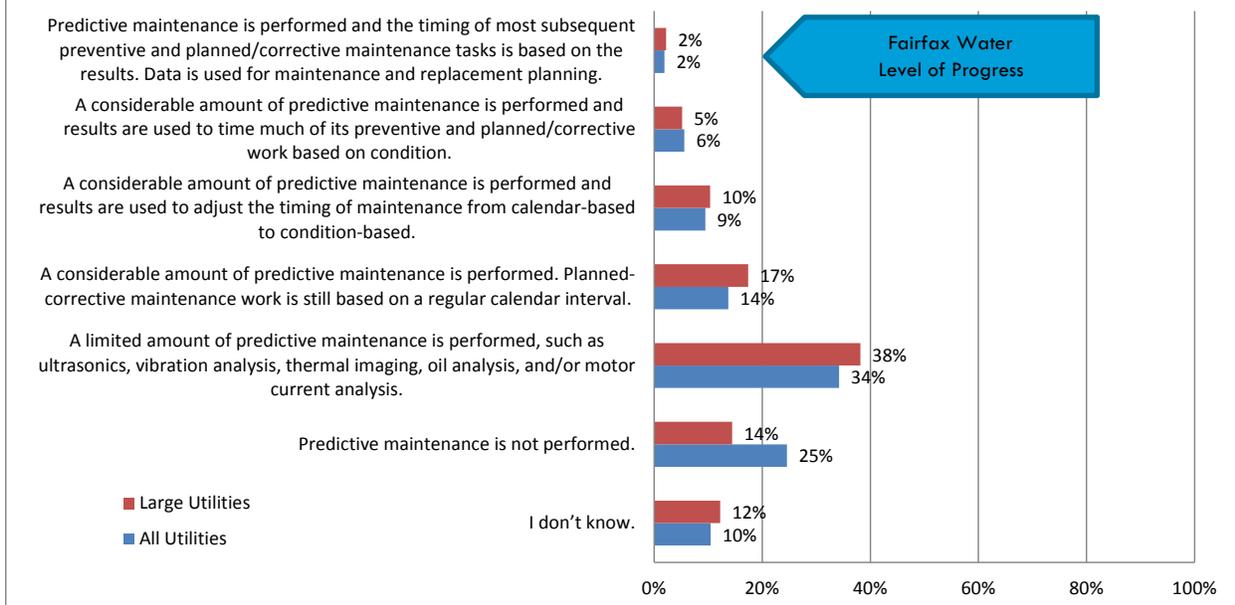
Population served: 1,800,000

Number of FTE staff: 475

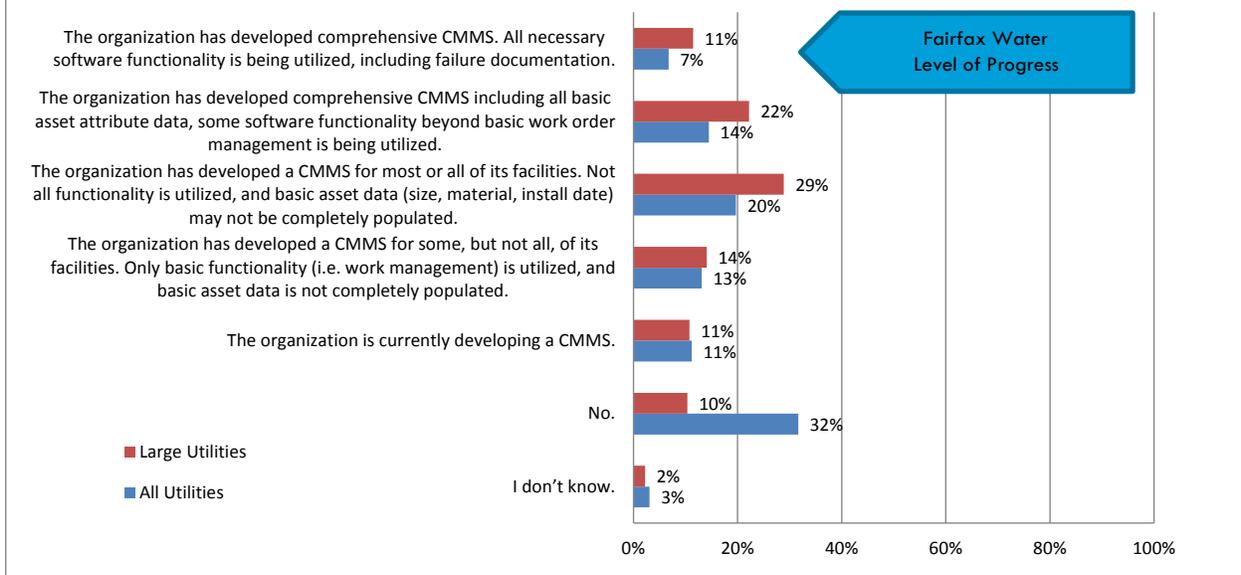
Is the organization moving from reactive (corrective and emergency) maintenance to planned (predictive and preventive) maintenance?



How advanced has the organization become in applying predictive maintenance to its vertical assets?



Does the organization use a computerized maintenance management system (CMMS)?



MAINTENANCE PROGRAM

Fairfax Water’s maintenance program is built on the foundation of good asset information stored within and accessed from a CMMS and the application of good maintenance strategies utilizing a wide variety of maintenance practices and tools.

Computerized Maintenance Management System (CMMS)

Fairfax Water currently uses an enterprise resource planning (ERP) platform which includes a robust maintenance module as its CMMS. Utilizing an ERP suite allows for tight integration between finance, human resources, customer service and utility billing. The system was originally implemented for Customer Service, where a costly system upgrade was needed for the legacy system, and after doing a study, the utility elected to move to the current software platform instead. Subsequent similar studies for the human resources information system resulted in standardization on the current platform. Implementation of additional system modules was completed in 2009 which included maintenance management and finance. With this completion, Fairfax Water has been able to more easily capture the costs of maintaining its assets.

The CMMS implementation started on the above ground (or vertical) assets. Therefore, that implementation is more mature than the distribution system implementation. Assets are labelled with a CMMS asset ID for easy reference in field. The initial implementation was a challenge, specifically related to data collection and entry. Efforts began with the most critical assets based on staff’s knowledge of criticality. Ongoing checks during data entry on the completeness and quality of data resulted in a high degree of confidence in reporting outputs. Not all assets have been entered into the system at this time. However, collecting the remaining information is facilitated by having a standard task in the preventive maintenance (PM) work orders to collect nameplate data for assets missing this information in the system.

All maintenance staff use the CMMS and enter information directly into CMMS to execute and close work orders, and to order parts and equipment. Planners and schedulers run reports on the data to track key performance indicators (KPIs), bad actor reports, cost analysis, and other needed information. There are numerous examples of weekly, monthly, and annual reports as shown in Figure 26.

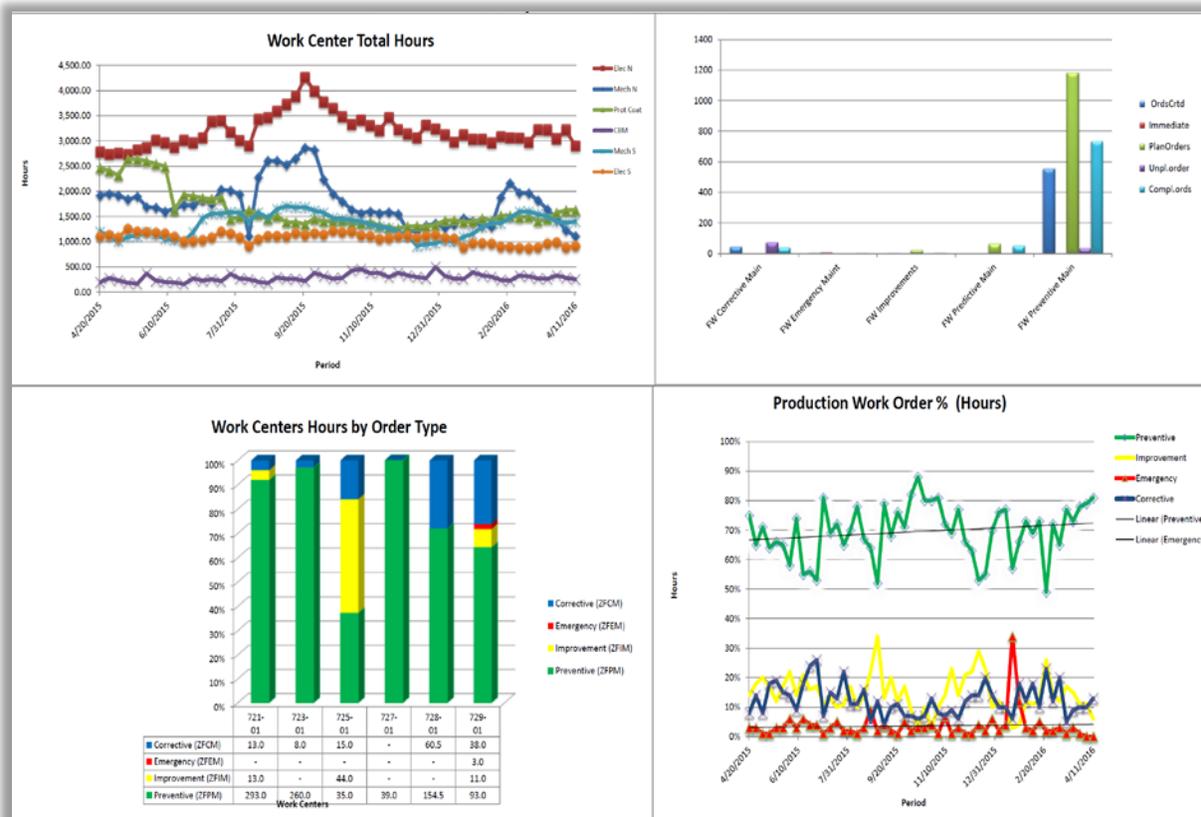


Figure 26 Fairfax Water - Example CMMS Reports

Maintenance Practices

Fairfax Water has established maintenance plans for all equipment. The first work plans were based on manufacturers' recommendations as a starting point, but as information was further developed through completion of PMs, staff were able to adjust the maintenance frequency based on observed needs. The objective is to adjust schedules such that staff are not overdoing or underdoing maintenance, particularly after the warranty period has expired on an asset. Manufacturer's recommendations are generally considered to be conservative but are required during the warranty period.

- Reactive versus planned maintenance is tracked and is broken down with approximately 65% planned maintenance, 15% improvement maintenance, and approximately 20% corrective and emergency maintenance.
- Predictive maintenance is performed and the timing of most subsequent preventive and planned/corrective maintenance tasks is based on the results. Predictive maintenance

data is stored and analyzed for asset condition trending to be used in maintenance and replacement planning.

Catastrophic failures are very rare, but if they occur, a root cause analysis is performed. A particular focus of the root cause analysis is to identify whether PMs could be modified to avert future failures. Although a formal root cause analysis process is not followed, in-house expertise is utilized to figure out what went wrong and if there is a way to prevent it. Usually issues are caught long before an asset fails.

Condition Assessment and Condition Monitoring

Fairfax Water has an extensive condition-based maintenance group that is certified by the Vibration Institute. Staff use a variety of technologies to assess equipment including:

- Vibration Analysis: used mainly for rotating equipment. The organization has in-house data collection and analysis capabilities. A specialist is assigned to vibration analysis to provide consistency, and with that expertise, they are able to identify problems on new pieces of equipment. Issues are identified up to a year ahead of time.
- Laser alignments: used for precise repairs.
- Tribology: oil analysis is used for large quantity oil users. This is used in the establishment of thresholds before changing oil.
- Thermography: bearing temperatures are recorded and analyzed for trends and discrepancies.
- Ultrasonics: staff investigated the use of ultrasonics but found that systems were too expensive and that vibration data was more reliable. Although ultrasonics is viewed as not needed at this time, staff will continue to consider it in the future for identifying different types of failure.

BENEFITS

The implementation effort was supported from the top by management and pushed from the bottom by staff, which has helped with the success of the program. However, change has resistance, as CMMS systems are not necessarily intuitive, particularly to new users. These systems can be difficult to learn and require staff training and commitment to be successful, and to become proficient, staff needed to use it regularly. It took some buy-in, but staff has become familiar with the system and complaints have significantly reduced.

Key to acceptance and support of the system was demonstrating that it is being used and reviewed by management at multiple levels. Once staff saw that others were utilizing the data they collected, running reports, and asking questions about the assets and information, they realized it is important and useful to use the system.

Joel Thompson, Director of Production at Fairfax Water, stated *“Defining benefits is difficult and not all benefits are easily quantifiable. The general feeling is that the maintenance process has gotten better; we have fewer failures with a lower cost of maintenance. Emergency call-outs have reduced significantly. Critical equipment has been identified and it has been years since there has been a catastrophic failure”*.

Joel has this advice for other utilities: *“The biggest key is to just get started. Get the data in the system and start by developing PM schedules and work orders. Work on getting more detail, including nameplate data, into the system and continue refining the work plans; these can always be adjusted. Investment in a condition-based approach to maintenance is highly recommended, even if assistance from an outside contractor is required.”*

Des Moines Water Works

Leading Practice – Maintenance and Reliability

BACKGROUND

Founded in 1871, Des Moines Water Works (DMWW) provides drinking water to approximately 500,000 customers serving the city of Des Moines as well as providing wholesale water outside the city limits. DMWW operates three water treatment plants: Fleur Drive, L. D. McMullen Treatment Plant at Maffitt Reservoir and Saylorville Water Treatment Plant with the oldest plant (Fleur Drive) dating back to 1921. DMWW tracks a total of approximately 147,000 assets, including the distribution system assets which encompass over 1,360 miles of buried water mains and appurtenances. The water production assets number approximately 7,000.



Utility: Des Moines Water Works

City/State: Des Moines, IA

Average system demand: 45 MGD

Population served: 500,000

Length of Pipe: 1,360 miles

Number of FTE staff: 230

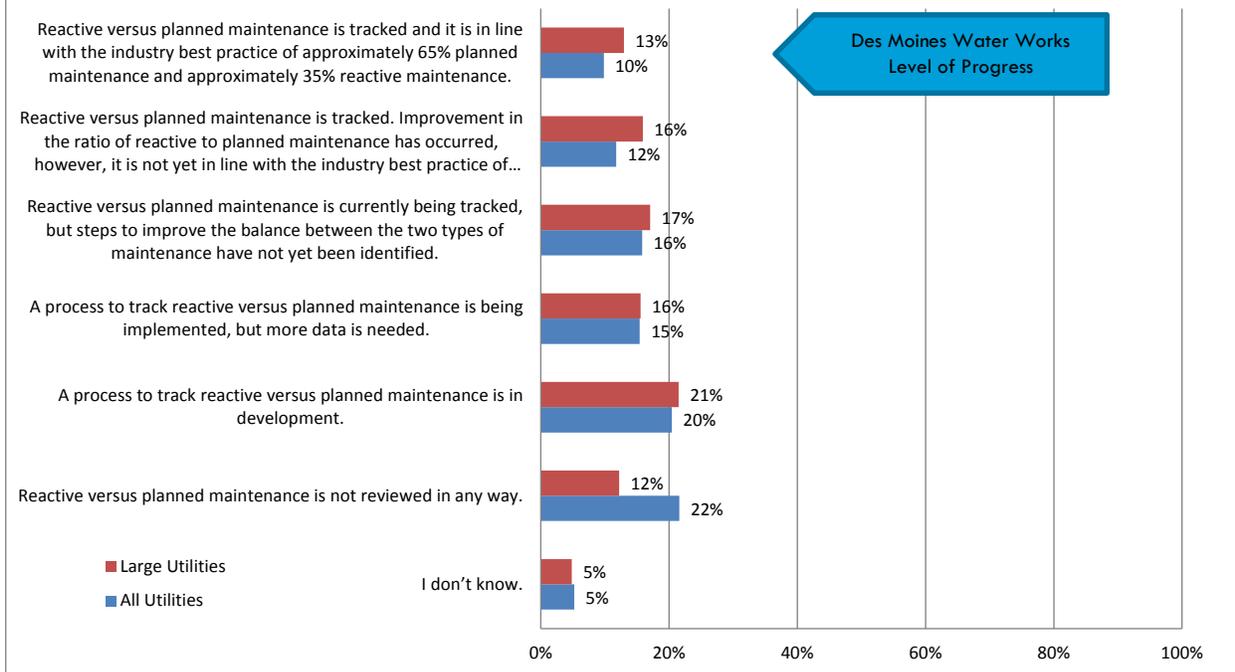
Leading practice: Maintenance

SURVEY RESULTS

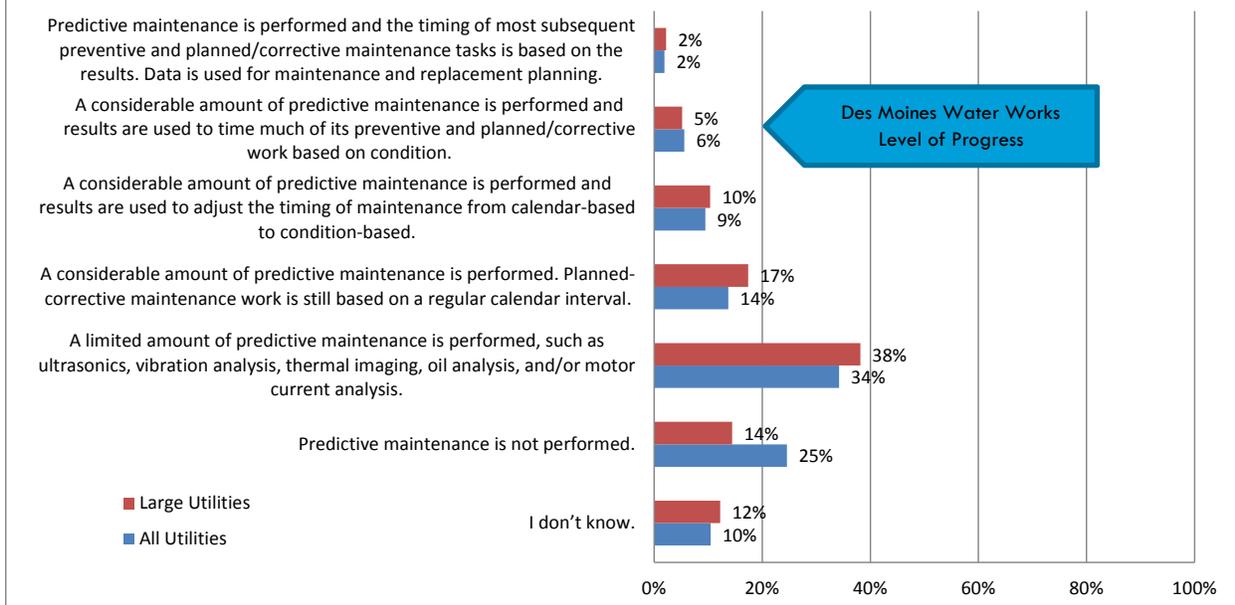
DMWW ranked very high in the Maintenance and Reliability leading practice, and three of the AWWA Level of Progress Survey questions apply to the case study's focus area.

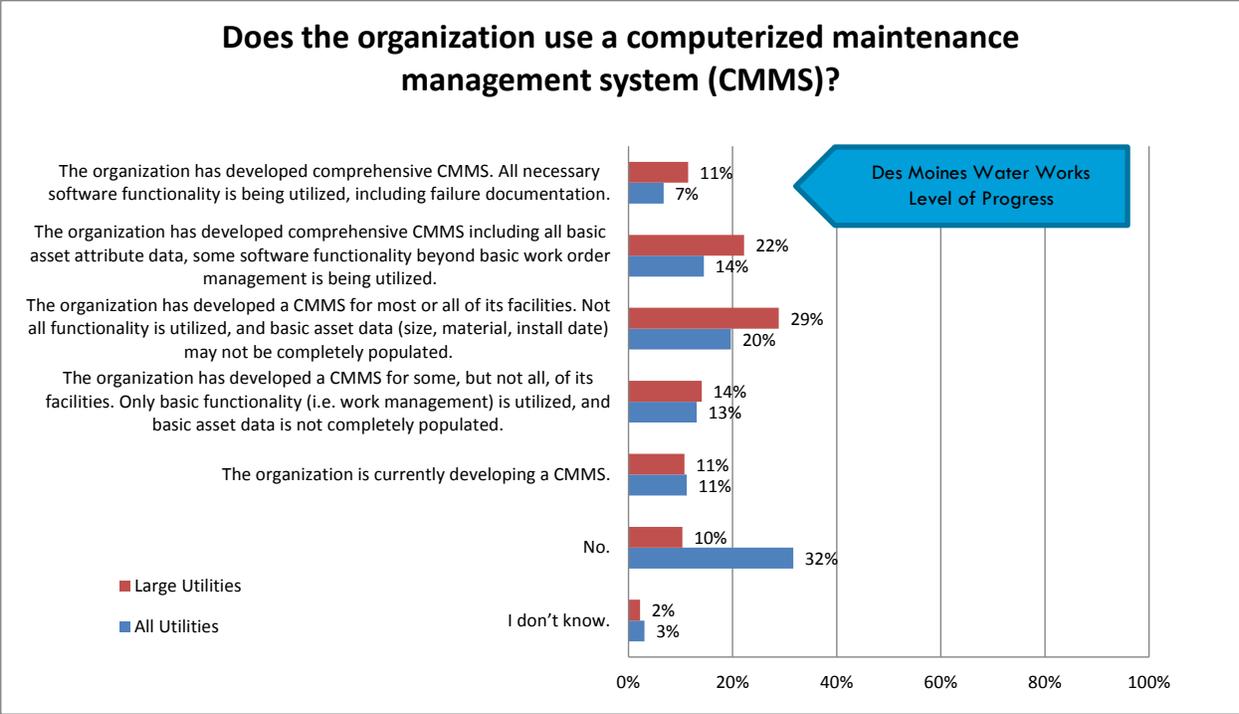
DMWW's responses are shown in the following graphs, and the utility is in the most advanced in two of the categories. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.

Is the organization moving from reactive (corrective and emergency) maintenance to planned (predictive and preventive) maintenance?



How advanced has the organization become in applying predictive maintenance to its vertical assets?





ASSET MANAGEMENT PROGRAM

DMWW has a full-time enterprise asset project manager. In addition, a senior applications developer and application support analyst are available as needed.

The asset management work plan was developed in 2010 and continues today. The work plan, centered on the Enterprise Asset Management System (EAM) includes implementing all purchasing, inventory, work orders, asset records, and projects into EAM. The EAM is used for purchasing, inventory, and warehousing. The EAM is integrated with the finance system allowing for transactions recorded in the EAM to be transferred to the finance system via an automated process. A similar process is used for payroll.

Although the entire organization uses EAM for purchasing and inventory, two departments have yet to fully implement EAM: Engineering and Fleet/Fabrication. Both are scheduled to implement EAM by the end of 2017.

One hundred percent of the linear assets are mapped with details in GIS and linked to the asset record in EAM. One hundred percent of vertical locations are mapped. Details (such as the assets in place at each location along with nameplate and other information) are recorded in EAM.

Asset management program KPIs are tracked in the EAM and provided to managers in their “start centers” (Figure 27) so they can manage the program on a real-time basis.

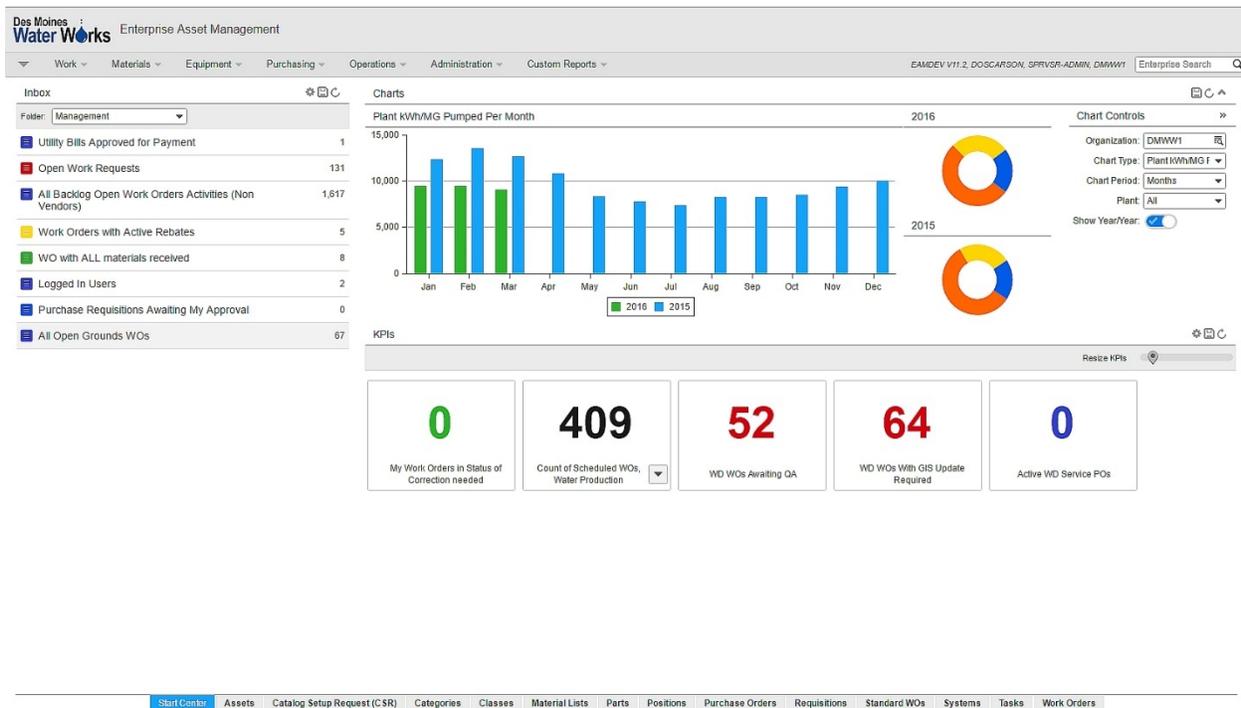


Figure 27 DMWW - Example of an EAM Start Center

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM (CMMS)

DMWW has an established history using CMMS. The Production group (Water Treatment) started with a CMMS in the late 1990s. On the distribution side, another CMMS was implemented along with a GIS resulting in three parallel systems in concurrent operation. When all these were near the end of their useful life in 2010, DMWW decided to upgrade with a more cohesive and integrated system. A decision was made to implement a single CMMS for Production and Distribution and to utilize a new GIS platform. The implementation was done in two phases: Phase 1 implementation for Production, followed by Phase 2 implementation for Distribution.

Phase 1 EAM Implementation: Water production

Production was previously fully invested in the CMMS. Staff were fully dependent on it for daily operations because it was complete, including spare parts and operations and maintenance documentation. The update to the new platform was relatively smooth because an import routine was available to pull in existing asset and condition data. Historical work order data was not transferred because it was a more involved and expensive process.

In the prior CMMS system, supervisors were the power users, and they printed and passed out work orders for completion to O&M staff. In the transition to the new system, the organization made the decision to go electronic to reduce paperwork and increase efficiency. This required providing laptops and tablets, as well as adding 4G routers to vehicles. Both desktop and mobile versions are available to end users, but the full enterprise version is available wherever they go. For some operators less skilled with computers, the mobile application was found to be easier to use because of its focused, scaled down functionality. However, not all functions are available. A key to the success of the implementation was that the IT director led the project, oversaw procurement of equipment and made sure the program was well supplied for sustainable use/application. Overall,

the transition went well, in no small part because the technicians had been requesting access to the CMMS for some time, so they were ready to start using the system.

Phase 2: Water Distribution

The transition for Water Distribution was more complicated than for Production. They had been using two systems: GIS and CMMS. However, the systems were not integrated. The CMMS was used for work management and was largely a manual process. Duplicate data entry for the GIS and CMMS reduced efficiency and led to some conflicting data. In this environment, the Distribution staff never had to use computers; they used paper work orders and work packets.

The transition to an electronic environment was difficult for many staff that needed training in basic computer operation. This was a significant struggle, but it was also found that many younger and computer savvy staff loved the new system and were able to assist staff less comfortable with technology. One strong element in the transition was that DMWW made a point of including a cross section of the department on the implementation team, and as a team, they made a significant investment to configure their workflows. EAM was configured to closely match existing workflows which, while making the implementation effort more complicated, resulted in a more user friendly and familiar adoption of the new system. For example, a work order could extend from initial permitting all the way through to restoration (repair and patching). This required a process to track complete costs, since one work order might extend over several months.

To aid the transition, DMWW used parallel paper and EAM systems for a month during initial go-live. Once staff became familiar with the EAM system the paper system was phased out. The EAM system has been in use for about a year and the transition and acceptance has been good. Originally, there were approximately 10-12 calls per day for the help desk to answer system questions. That is down to one per week now.

The implementation has progressively included increased functionality and now the system is very advanced. Following are some examples of features that DMWW has implemented in its EAM.

- **SCADA:** DMWW's SCADA system integrates with EAM. When SCADA sees anomalies in equipment operating parameters (such as current imbalance, pressure out of range, flow out of range, etc.) an alarm is issued to the operators and a work request is automatically generated against that asset in EAM to investigate. The figure below provides an example of a phase imbalance that triggered a corrective work order.
- **Metering:** Run-time meters within SCADA automatically populate meter fields on asset records in EAM for scheduling maintenance activities. Electric sub-meters on all significant energy users feed data into SCADA that is used to continuously calculate wire-to-water pump efficiency and flag anomalies for work requests.
- **Energy Management:** The electric sub-meter data is used to balance utility bills. EAM audits the utility bills before payment. Bills that fail the audit are sent to staff for further analysis before payment is issued. To assist staff in managing this audit process and results, the EAM Start Center has a number of charts and KPIs that help management track progress.
- **Rebates:** DMWW does several projects each year that are eligible for rebates from the utility company. Work orders with outstanding rebates are flagged and kept in an EAM Start

Center Inbox until the rebate is received. Currently, they are tracking over \$90,000 in outstanding rebates.

- **Start Center KPIs & Charts:** Currently, 131 KPIs and 48 charts are available for staff to track performance. The KPIs and charts are updated automatically from data imported from various sources as well as live EAM data.
- **Mobile connectivity:** Most field feet vehicles have 4G routers used to VPN into the company network. The routers have a 600' radius Wi-Fi as well. Field vehicles have laptops so they run the same enterprise software as office personnel.
- **Mobile application:** The asset management system has a mobile application that runs on tablets and smartphones. Currently, 15 iPads and 10 smartphones are running the mobile application.
- **Notifications:** Automatic notifications are set up in the EAM for various events, e.g. if a work order is created that includes a water outage, an email is sent to distribution managers. Emergency work orders in Water Production generate an email and text messages to operations and maintenance managers.

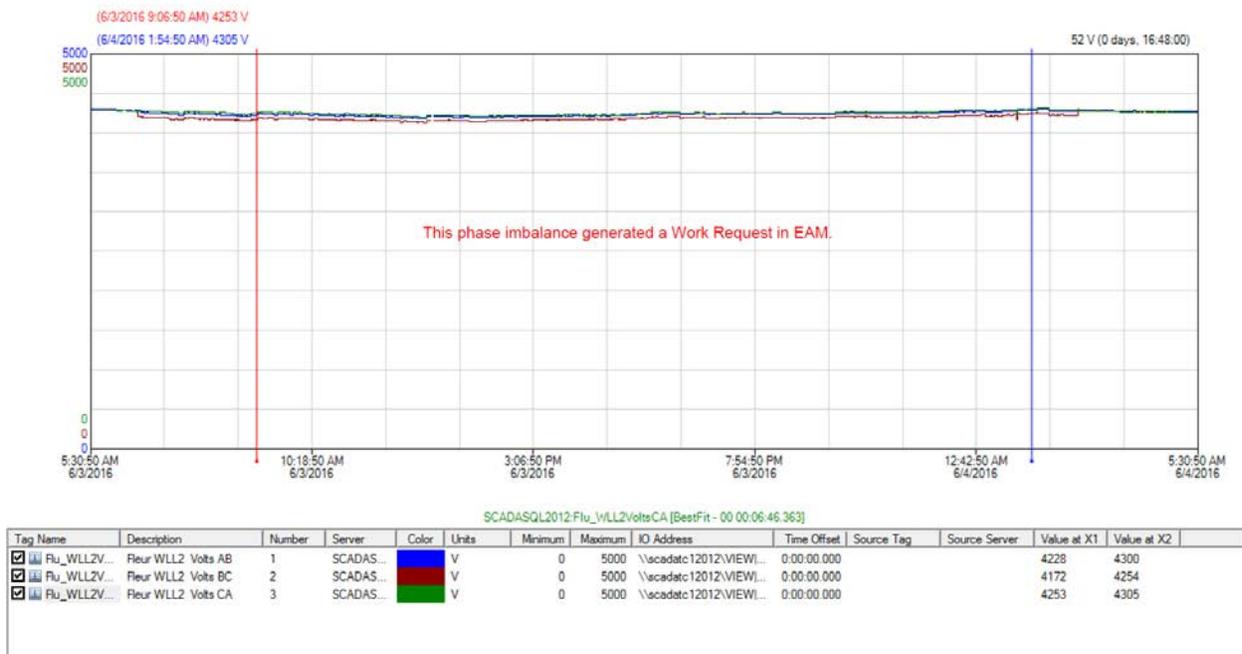


Figure 28 DMWW - The SCADA system is integrated with the EAM and used to trigger work orders based on operational anomalies.

MAINTENANCE PRACTICES

DMWW has had an active predictive maintenance program for some time. The EAM system is used to support the process and schedule follow-up maintenance routines. A planner reviews preventive maintenance data and uses that information to adjust the schedules for maintenance accordingly.

The SCADA integration is actively used to support maintenance. It provides detailed measurement of electrical, flow and suction pressure data, so DMWW can analyze that data and create automated work requests in EAM based on anomalies in operation. They can also do trending to see exactly what was going on.

RISK MANAGEMENT

Consequence of failure is defined by the Calculated Priority and is determined by multiplying the Equipment Criticality Code and the value associated with the Work Order Class. Calculated Work Order Priorities further improve sorting, grouping and prioritization of the Work Order Backlog. The EAM System is configured to automatically calculate this value. Figure 29 below shows how the priority is calculated, with the Work Order Class on the horizontal axis and the Equipment Criticality Code on the vertical axis.

		Cosmetic	Spares rebuild	Efficiency Improvement	Quality Improvement	Safety Improvement	PM & Inspections	Repair from PM & Inspections	Breakdown repair	Risk of Environmental violation	Risk of Safety violation
		1	2	3	4	5	6	7	8	9	10
Safety protection equipment	10	10	20	30	40	50	60	70	80	90	100
Environmental protection equipment	9	9	18	27	36	45	54	63	72	90	100
Plant Utility	8	8	16	24	32	40	48	56	64	90	100
Process equipment non-spared	7	7	14	21	28	35	42	49	56	90	100
Process equipment spared	6	6	12	18	24	30	36	42	48	90	100
Support equipment non-spared	5	5	10	15	20	25	30	35	40	90	100
Support equipment spared	4	4	8	12	16	20	24	28	32	90	100
Plant facilities - non-process	3	3	6	9	14	15	18	21	24	90	100
Administrative facilities	2	2	4	6	8	10	12	14	16	90	100
Grounds	1	1	2	3	4	5	6	7	8	90	100

Figure 29 DMWW - Maintenance Priority Matrix

CONDITION ASSESSMENT

Integration of condition assessment data and information into the EAM is ongoing. DMWW recently adopted a new condition assessment/reliability system and are currently in the process of implementation. The first step was to attach a nameplate photograph to the asset record. They are now in the process of completing inspections on assets using the new system. Some data is entered in the asset records themselves.

Predictive condition assessment tools include the following:

- Thermography
- Vibration analysis
- Oil analysis
- Ultrasonic (mostly used for compressed gas survey/leak detection)

- VLF (very low frequency – used to benchmark/test medium voltage cable and motor windings)

The results of condition assessments are used to schedule repairs and preventive maintenance.

BENEFITS

DMWW has identified numerous benefits from its asset management and EAM system, across their organization, from management, to field staff, to supervisors.

Management

The main benefit is having accurate financial and labor information. There is a project accounting system with projects and activities, which aligns well with the EAM structure. Staff are now able to enter hours as they go, since they book time on the work order, rather than waiting for the end of the two-week period to book. Before, time was charged to a general number; now it is specific. EAM is integrated with the payroll system, so all work booked on work orders is synchronized with payroll. This has increased the accuracy by nearly 35% over double entry. With the increased accuracy, budgeting accuracy has improved.

Another benefit involves the asset cost rollup for systems in the hierarchy. Because DMWW can now roll-up costs, much more detailed information is available now than before. This is good for asset replacement planning.



Figure 30 DMWW - Asset cost hierarchy

Field user perspective

Field users have indicated a variety of benefits from the EAM system, including:

- Spare parts: they can easily identify the right equipment and its availability. Even from the truck, they can look up work orders and spare parts. Once identified, they place a request, and it will be waiting at the counter at central stores when they arrive.
- Documents: all documents associated with asset are part of the work order. It is easy to reference and check asset history, including who did recent work, if someone else was working on it recently.
- Lesson learned: some staff have been hesitant to embrace the new system. DMWW has found it takes about one year for most staff to fully embrace EAM as a useful tool.

Supervisor perspective

Supervisors have reported additional benefits of the system, including:

- When planning a job, the spare parts list is readily available, and they can identify parts that need to be purchased. They can create the purchase requisition directly from the work order. When the parts are all received, then the work order moves to an "all parts ready" inbox. There is no need to track parts availability separately which makes it easier to schedule work.

- The Start Center allows drill down of work order backlog for work planning. The level of detail in start centers is dependent on role. The KPIs eventually drill the user down to the work orders that are at issue.
- DMWW is able to track work orders with active rebates. Work orders don't get closed until the rebate is issued.

Livingston County Water & Sewer Authority

Leading Practice – Maintenance and Reliability

BACKGROUND

The Livingston County Water & Sewer Authority (LCWSA) was established in 1995 to finance, construct, operate and maintain the water and sewage facilities for the benefit of the residents of Livingston County, New York. LCWSA is a public benefit corporation organized under the Public Authorities Law of the State of New York and is self-governed by a seven-member board that is appointed by the County's Board of Supervisors.

Although established in 1995, LCWSA is responsible for the operations and maintenance of water and sewer infrastructure that dates to 1950's in terms of original construction. This includes 65 miles of water distribution and transmission mains, 11 water storage tanks, 17 operating valves, 6 water pump stations (with back-up power generation) and 5 re-chlorination stations.

In addition to water services, LCWSA also provides sewer services encompassing two sewage treatment plants. One plant operates at an average of 500,000-600,000 gallons per day. The second plant is much smaller at an average of 20,000 gallons per day. Also, included in the sewer system are approximately 50 miles of sewer collection system, and 46 sewer pump stations (also with back-up power generation).

Although the asset management program is not formally documented, LCWSA has established several key foundational components of an asset management program. The program includes the development of an asset register, identifying some levels of service, establishing a method for highlighting high risk assets. The program also includes identification of probability and consequence of failure, and development of a Computerized Maintenance Management System (CMMS) for the recording and planning of maintenance activities against water and sewer assets.

SURVEY RESULTS

LCWSA ranked high in the Maintenance and Reliability leading practice compared with other small utilities in the case study focus areas of predictive maintenance and use of CMMS. LCWSA's responses are shown in the following graphs. The graphs also show the responses from all the other participating utilities and the responses for the small utilities.

LIVINGSTON COUNTY
WSA
WATER & SEWER AUTHORITY

Utility: Livingston County Water & Sewer Authority

City/State: Lakeville, NY

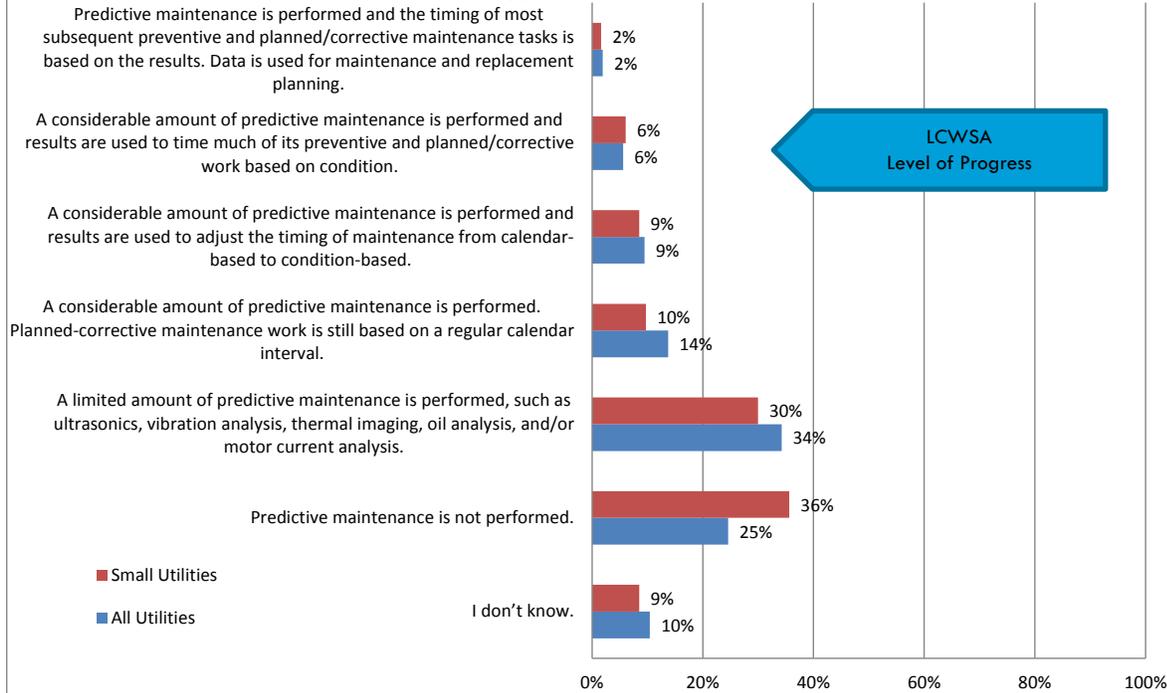
Average system demand: <5 MGD

Customers: 3,500

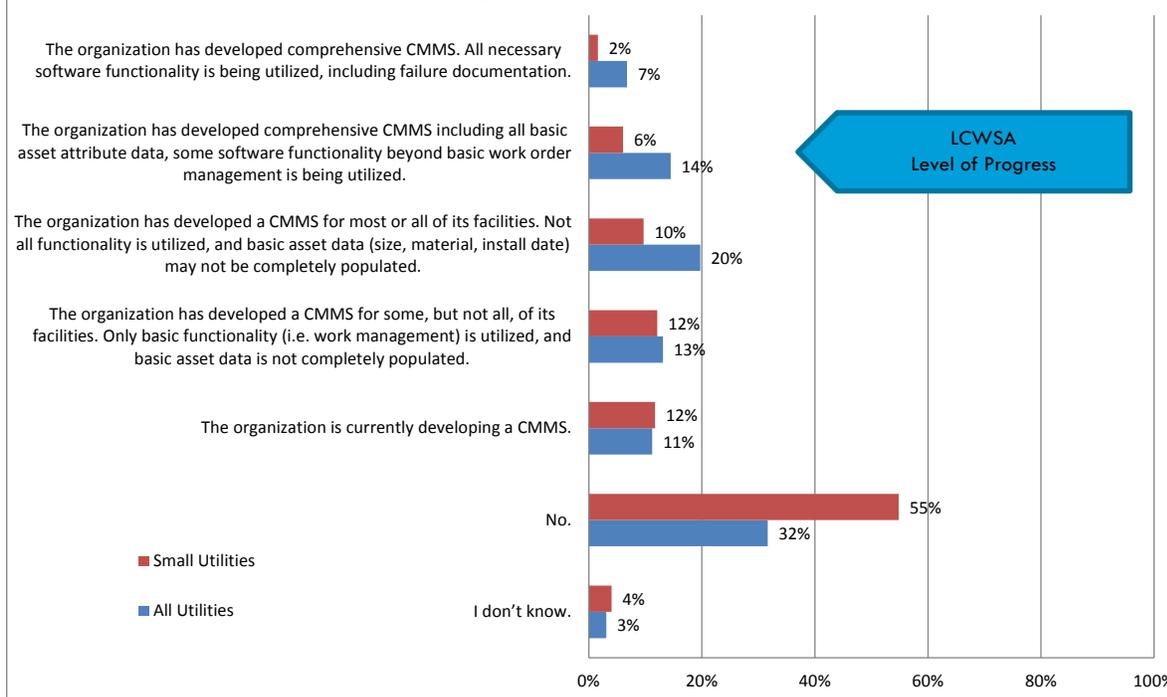
Population served: 10,000

Number of FTE staff: 11

How advanced has the organization become in applying predictive maintenance to its vertical assets (mechanical, electrical, HVAC, and other asset types associated with facilities)?



Does the organization utilize a computerized maintenance management system (CMMS)?



MAINTENANCE APPROACH

Computerized Maintenance Management System (CMMS)

LCWSA elected to develop an in-house CMMS based on the availability of in-house resources capable of architecting the system specific to LCWSA requirements. The system is accessible to staff both in the office and in the field via the use of mobile devices connected by cellular cards and/or hot spots. The CMMS houses both asset and maintenance history information.

The asset registry is complete for approximately 75% of all assets. Typical information collected for each asset includes a unique identifier, description, location, install date, size, material, etc. Asset locations are mapped for approximately 75% of the assets as well with ties back to the CMMS utilizing the same asset identifier.

Work orders are generated from the CMMS and are associated to each asset allowing for asset maintenance history to be viewed and reported. Work orders can include reactive maintenance, preventive maintenance (PM), and inspections of assets which, based on inspection findings, may result in the generation of follow-up work orders to address issues found during the inspection.

Maintenance Practices

The water distribution system has experienced very few main breaks, as the system is relatively new with the bulk of construction completed in the late 1980's and early 1990's. Through root cause analysis, the most recent main break was determined to be caused by corrosion from a defective run of pipe from the supplier. LCWSA has experienced the majority of its breaks or leaks on water service lines.

LCWSA has developed an extensive preventive maintenance program to ensure operation of the water and sewer system at required service levels. Staff monitors operations of pump stations and tanks daily, with performance monitored through data retrieved from the SCADA system. The majority of PM schedules are based on elapsed time rather than meter-based triggers (e.g. elapsed run-time meters). Hydrants and valves are exercised as part of the preventive maintenance program. This helps to identify leaky valves, as well as ensure operability of valves in case of emergency, and reduce non-revenue water loss. Every year, half of the water system is flushed and exercised with the exception of dead-end lines which are flushed on a more frequent basis. Figure 31 is an example of PM schedules for various assets configured in the CMMS.

Weekly, Monthly, Semiannual, and Annual staff inspection and maintenance questionnaires have been developed within the CMMS for LCWSA water and sewer facilities. Each inspection includes a series of detailed questions that, depending on the response by the maintenance staff, may result in identification of an issue to be forwarded to the Director of Operations. Figure 32 shows a list of questions for weekly inspections of a water pump station.

Action	TYPE OF MAINT.	FREQUENCY	LOCATION	LOCATION TYPE	LAST COMPLETED	NEXT DUE DATE
  	Automatic Valve maintenance	Bi-Yearly	Sliker Hill Rd 6022	WATER TANK	2/2/2016	2/1/2018
  	Calibration of chlorine analyzers	Semi-Annual	Sliker Hill Rd 6022	WATER TANK	4/29/2016	10/28/2016
  	Driveway maintenance - sealing	Bi-Yearly	Sliker Hill Rd 6022	WATER TANK	11/17/2015	11/16/2017
  	Electrical Maintenance	Every 3 Years	Sliker Hill Rd 6022	WATER TANK	4/11/2016	4/11/2019
  	Generator - anti freeze	Every 5 Years	Sliker Hill Rd 6022	WATER TANK	12/3/2015	12/1/2020
  	Generator Batteries and Block heater replacement	Every 5 Years	Sliker Hill Rd 6022	WATER TANK	3/4/2012	3/3/2017

Figure 31 LCWSA - Example of preventive maintenance schedule

Location	Type of Facility	PM	Questions	
 Big Tree 7650	water pump station	Weekly	1 Are all the locks/hinges functional? (Y/N)	Y
 Big Tree 7650	water pump station	Weekly	2 Is all the lighting functional? (Y/N)	Y
 Big Tree 7650	water pump station	Weekly	3 Is the chart recorder functioning properly? (Y/N)	Y
 Big Tree 7650	water pump station	Weekly	4 Did you change the Chart and bring back to office ? (Y/N)	Y
 Big Tree 7650	water pump station	Weekly	5 Is the pump oil full? (Y/N)	Y
 Big Tree 7650	water pump station	Weekly	6 Are there any unusual noise, vibration, leaks or overheating problems? (Y/N)	N
 Big Tree 7650	water pump station	Weekly	7 Any leaks or obvious issues? (Y/N)	n
 Big Tree 7650	water pump station	Weekly	8 Have you check for infestations and removed current infestations of rodents or insects from the equi	y
 Big Tree 7650	water pump station	Weekly	9 Is the site mowed properly?(Y/N)	y

Figure 32 LCWSA - Example of inspection and maintenance questionnaire

If staff identifies an issue or an item that is not functional, they are required to provide a response to the question. For example, if staff answered question one above as “N” then a box would pop up on the screen and they would be required to put an explanation such as – The lock on the front door is broken and needs a locksmith to repair. This message goes directly to the Director of Operations who then will review the inspection results and schedule corrective work orders accordingly.

LCWSA has identified that some assets are more efficiently maintained through the use of contract services. Water tank internal inspections, automatic valves, electrical systems and generators are maintained by contractors or professional engineers through maintenance agreements. Although regularly scheduled maintenance is conducted by manufacturers’ technicians, LCWSA staff is trained in the basic maintenance of these assets for purposes of emergency response. Maintenance of these assets is still tracked within the CMMS as preventive maintenance work orders.

LCWSA has begun implementation of some predictive maintenance practices. One example is the gauging of pumps. Gauging a pump provides information to determine if the pump is running under the most efficient set of design parameters. Gauging also leads to adjustments to bring pumps back into optimal running conditions. The LCWSA also conducts condition assessment and

monitoring of pipes, which then drive maintenance activities or capital replacement programs. Pipe condition information is stored in a separate database with linkages back to the CMMS. However, condition monitoring and assessment of pipes has been primarily focused on the wastewater collection system at this time.

BENEFITS

LCWSA has identified several benefits resulting from the current efforts to establish an asset management program. The most important benefit of the system is that maintenance is assured to be completed on a consistent and understood time frame. Preventive maintenance takes place on schedule and issues are corrected in a more efficient and timely manner. Also, the system has made historical records much more accessible. Previous maintenance activities were recorded on paper and to research maintenance history or conduct a root cause analysis on failure of an asset was a manual and sometimes time and labor-intensive process. By recording and making this information available digitally through the use of a CMMS, this information is more easily accessed and utilized by LCWSA to make informed decisions on the management of its assets.

Leading Practice – Asset Management Planning

Two advanced asset management practices, developing asset management plans and requiring formal business case evaluations (BCE) for major investments, were identified by the AWWA Asset Management Committee as important asset management concepts.

The following questions were asked in the *Level of Progress in Utility Asset Management* survey:

- *Has the organization developed management plans for its various asset classes (e.g., water distribution valve management plan), sometimes known as Asset Management Plans, or AMP's?*
- *Does the organization require business case evaluations (BCE's) or have a program to fully consider all aspects of life cycle costing when making infrastructure investment decisions?*

The following utilities ranked very high or high in their responses to these questions on the leading practice Asset Management Planning:

- Mount Pleasant Waterworks (case study included in the following section)
- Brunswick & Topsham Water District (case study included in Current State of Assets)
- Portland Water Bureau (case study included in Levels of Service)
- Washington Suburban Sanitary Commission (case study included in Risk Management)

Mount Pleasant Waterworks

Leading Practice –Asset Management Planning

BACKGROUND

Mount Pleasant Waterworks (MPW) began in 1935 with the establishment and operation of a water distribution system comprised of 3 wells, an elevated storage tank, steel storage tank, 5.8 miles of water mains, 21 fire hydrants, and 179 water meters. In 1942 the public wastewater system began operations with expansions to the system through the 1960's and construction of a 1.4 MGD primary treatment facility in 1969. Today MPW serves 37,000 water customers via four reverse osmosis water treatment plants and over 160 pump stations along with operation of a wastewater collection system including two wastewater treatment plants with a combined treatment capacity of 9.7 MGD.



Utility: Mount Pleasant Waterworks

City/State: Mount Pleasant, SC

Average system demand: 5-15 MGD

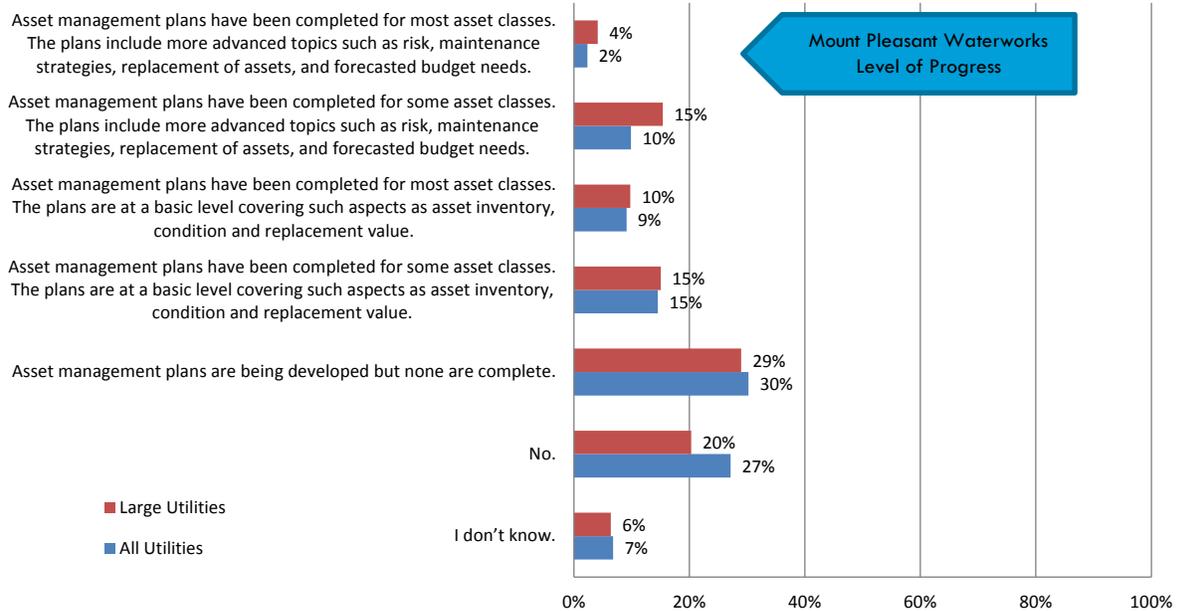
Population: 80,000

Number of FTE Staff: 123

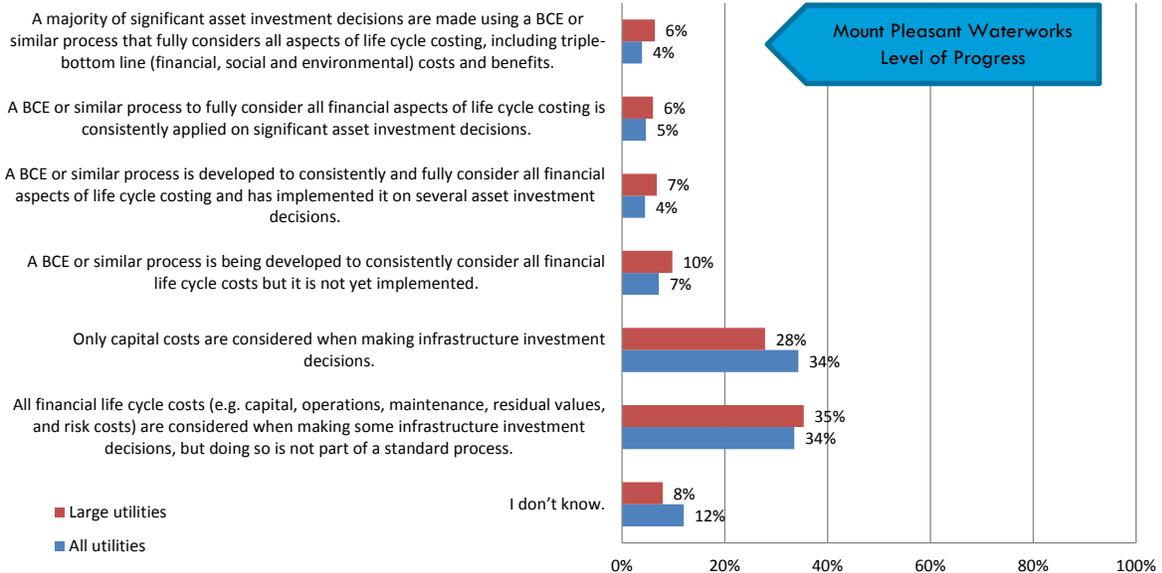
SURVEY RESULTS

MPW ranked very high in the Asset Management Planning leading practice. MWP's responses are shown in the following graphs, and the utility is in the most advanced category in all cases. The graphs also show the responses from all the other participating utilities and the responses for the large utilities.

Has the organization developed asset management plans for its various asset classes?



Does the organization require business case evaluations (BCE's) when making infrastructure investment decisions?



ASSET MANAGEMENT PROGRAM

The asset management program was initially begun in 2004 with assistance from an outside consultant. However, it was quickly realized that without some of the basic data and tools necessary to support the initiative that further development of the program would quickly become cumbersome. In 2007 efforts began to establish some of the foundational data and tools including implementation of a computerized maintenance management system (CMMS). Over a four-year period, Mount Pleasant established the asset hierarchy within the CMMS and began deployment to operations and maintenance personnel.

The collection of the asset and maintenance information within the CMMS provided the necessary data to begin development of the formal asset management program. This included development and distribution of the Asset Management Program manual documenting the overall strategy and framework for the program; establishing asset valuation, condition assessment and risk prioritization methodologies; asset management plan development for each asset class; and a formalized process for capital and rehabilitation and replacement project program definition.

To oversee the asset management program, Mount Pleasant has a full-time asset management coordinator and additional support staff. In addition, asset class engineers have been assigned (via five-year contracts) for each asset class and assist with the planning needs for each asset class accordingly.

Mount Pleasant has established an asset hierarchy for all of its assets. The hierarchy is broken out into three main categories of Water, Wastewater, and Administration. The high-level Water hierarchy organizes assets as follows:

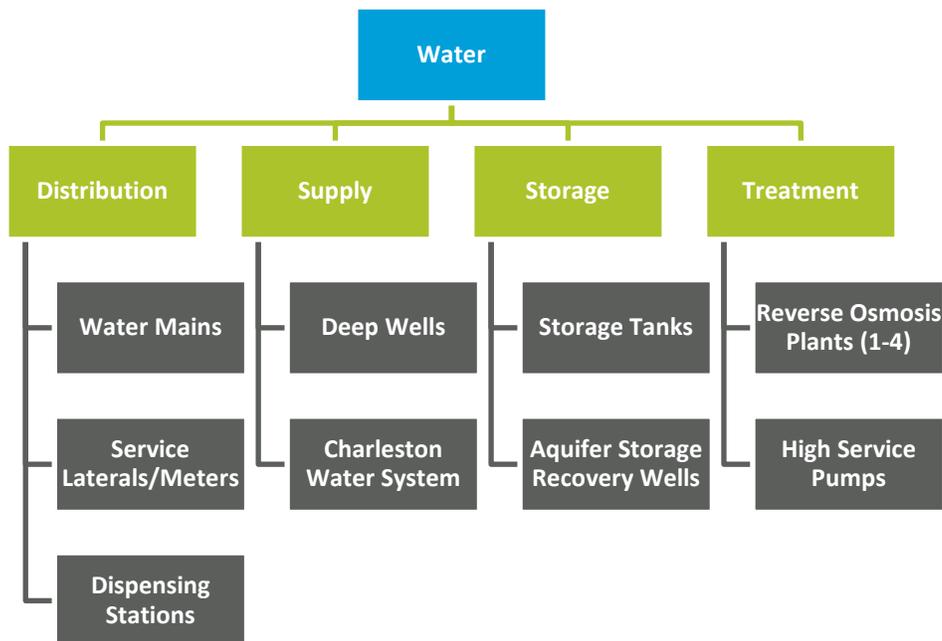


Figure 33 Mount Pleasant Waterworks – High level asset hierarchy

Both current year asset values and replacement costs in current year dollars have been defined for all assets within the asset hierarchy. For example, the Water hierarchy has a current asset

valuation of approximately \$142M, including depreciation, and replacement value in current year dollars of approximately \$284M.

Within the asset management plans, staff has defined the effective useful life and relevant failure modes (common methods of asset failure) for each asset class. This information is then utilized in the development of condition and risk calculations for each asset class.

For the distribution system assets, Mount Pleasant is leveraging a 20-year investment in GIS technology. One hundred percent of all distribution system assets are mapped in GIS and linked to the asset inventory record within the CMMS.

In addition to the Water and Wastewater system assets, Mount Pleasant also manages fleet/rolling equipment and administrative assets (such as network and software assets) within its asset management program.

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM (CMMS)

The implementation of the CMMS began in 2007 with implementation progressing over a four-year period. The CMMS is currently utilized to inventory all asset data including maintenance information for each asset. Although all assets are inventoried within the CMMS, some basic asset data (size, material, install date) may not be completely populated throughout the system. Staff has identified that not all available functionality is currently utilized and efforts are continually underway to more effectively and efficiently utilize the CMMS accordingly.

The CMMS is currently utilized to track reactive versus planned maintenance. However, Mount Pleasant recognizes this as an area for improvement and is taking steps to improve the balance between the two types of maintenance. A considerable amount of predictive maintenance is performed, particularly within the plant environments, and the results of the predictive maintenance efforts are used to determine preventive maintenance schedules (rather than utilizing strictly calendar-based preventive maintenance schedules).

CONDITION ASSESSMENT

Mount Pleasant has identified condition assessment protocols within the associated asset management plans for each asset class. Examples include field condition assessment and internal Remote Field Eddy Current (RFEC) inspection for water mains (based on technical and cost feasibility) and field condition assessment of fire hydrants, blow-offs and isolation valves within the distribution system.

RISK MANAGEMENT

Risk prioritization methodologies have been identified for each asset class and are documented within their respective asset management plans. This includes calculations for Condition (analogous to Probability of Failure or PoF) and Criticality (analogous to Consequence of Failure or CoF). Condition scores have been established for over 90% of assets and criticality scores have been established for approximately 50% of assets at this time. Overall Mount Pleasant has ranked more than 50% of assets according to risk and uses this information in the operation and maintenance of the system.

A set of criteria are identified for condition and criticality specific to each asset class with each criterion being scored and combined via a weighting method to determine an overall score. For example, water main condition is calculated utilizing specific criteria with each criterion being ranked on a 10-point scale and then combined with the other criteria using a weighted measure to result in an overall condition score for each asset: (criteria1 rank x criteria1 weight) + (criteria2 rank x criteria2 weight), etc. Water main condition criteria and weights include (weights in parentheses):

- Remaining Useful Life (5)
- Material (5)
- Number of Recorded Failures (10)
- Soil Type (2)
- Failure Type – Splits (10)

Criticality for each asset within an asset class is calculated in a similar fashion. Criteria are defined with an associated ranking system and then combined into an overall criticality score utilizing a weighting system for each criterion. Water main criticality criteria and weights include:

- Pipe Size (10)
- Urban Impact – i.e. proximity to major roads and critical customers (5)
- Meters Served (2)
- Anticipated Difficulty of Repair – i.e. depth, road type, impacted land use (8)
- Pipe Material (2)

Overall risk scores for each asset were determined by multiplying the condition score by the criticality score. Continuing with the example for water mains, risk scores were classified into High, Moderate, or Low Risk classifications with the following result.

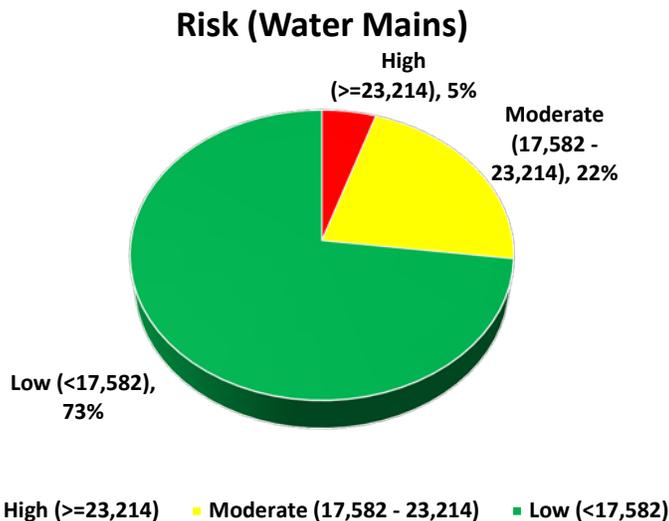


Figure 34 Mount Pleasant Waterworks – Risk Scoring for Water Mains

ASSET MANAGEMENT PLANS

MPW uses the information and analysis from the asset management program, including the CMMS and the risk management process, to develop asset management plans (AMPs) for each asset type. MPW has implemented a standard AMP format for each asset type, structured to answer the following questions and provide conclusions:

- What does it do for us?
- How much of it do we have?
- How much is it worth?
- How long does it last?
- How does it fail?
- How do we fix it?
- What condition is it in now?
- Knowledge Management
 - Identifies what asset data is needed, how the data will be collected and the method of analyzing the data to make informed decisions on the continued asset management needs.
- Program Strategy
 - Development of detailed plan, processes, and policies to best manage to the asset based on the collected data and upon life-cycle methodologies.
- Capital Funding Program
 - Details the current and long term asset budget funding strategies as well as projected financial impacts.

MPW has adopted a strategy of selected asset class consulting engineers for each asset class. These engineers help with developing the AMPs and identifying the needs for each asset class.

The wastewater collection system AMP is the most mature. It was built on studies that provided a system-wide review of inflow and infiltration, as well as a Capacity, Management, Operations, and Maintenance (CMOM) plan. Based on the AMP, MPW is currently implementing a \$16 million project for spot repairs and lateral work.

For the pump station AMPs, MPW has implemented a Reliability Centered Maintenance process on the highest priority pump stations. For these stations, run time information and condition information are collected to support the process. MPW is still building the database to support the process, and operational plans and recommendations are largely based on staff recommendations at this time.

CAPITAL PLANNING AND BUSINESS CASE EVALUATION

MPW's Capital Improvement Plan (CIP) consists of a two-year Capital Planning Process and operates on a two-year Capital Budget Cycle. The goal of the two-year Capital Planning Process is to allow for advanced planning, project justification and development of a Project Business Case if required. The two-year Capital Budget Cycle allows for actual project implementation and construction.

The Project Business case is a document that is used to assess the justification of a proposed project and to assess the options for a project that is seeking funding. If approved, it confirms the support and commitment to resourcing (outside services, internal labor, material, equipment) for the recommended course of action.

A project business case is developed to:

- Gain approval to proceed with a project,
- Obtain resources for a project,
- Document what the project will accomplish for the funding, and
- Gain agreement on the project scope.

A Project Business Case is required for any new project with a projected cost of over \$500,000. It may also be necessary if several alternatives are available to accomplish the goal of a project. A Project Business Case or smaller projects allows the alternatives to be compared and the most advantageous project to be selected. A template and guidance document for Project Business Case Development has been developed.

Risk information is a key component of the CIP process. The Project Business Case utilizes asset risk data along with anticipated project costs, anticipated benefits, analysis of options, ultimate recommendation of option for completion, and a ranking of each project within the overall capital project portfolio. This process is fully documented and executed on an annual basis to update the capital improvement program as follows:

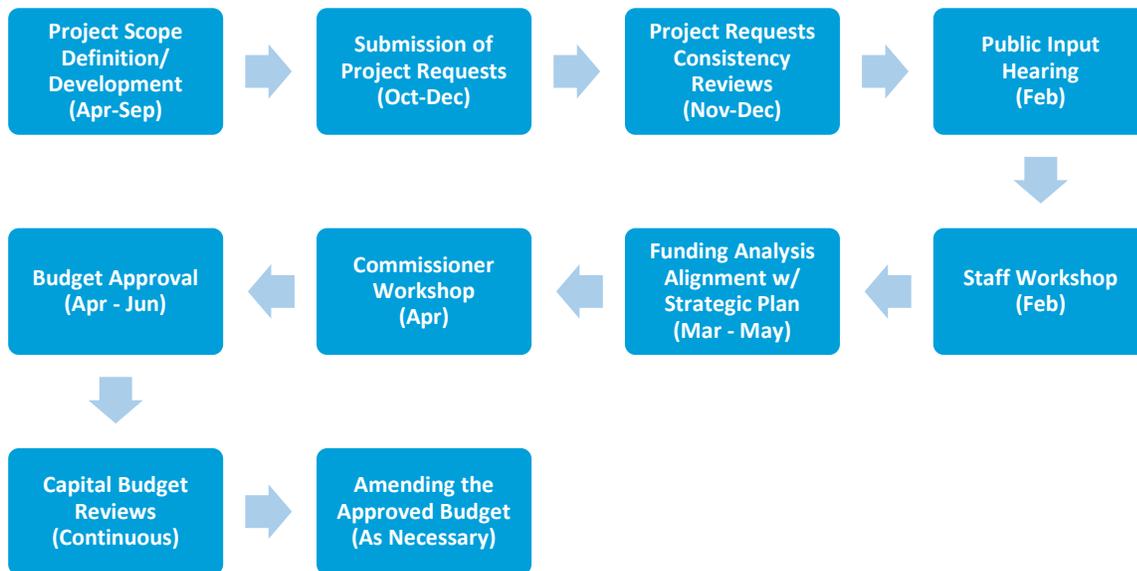


Figure 35 Mount Pleasant Waterworks – Capital Improvement Planning Process

BENEFITS

Implementation of the asset management program has provided a number of benefits. This includes an improved accountability and deeper understanding of the extent and effect of aging infrastructure and shortfalls in sustainable funding levels. Identification of assets that support core Mount Pleasant services are now monitored and maintained at levels that enable the organization to meet identified service levels at manageable risks and costs. This has yielded the following direct benefits:

- Mount Pleasant received a bond rating upgrade because of its planning capabilities, which allowed for stable revenue to support reliably identified capital improvements.
- The force main condition assessment program saved money by deferring replacement based on a better understanding of the remaining useful life and how much pipe needs to be replaced.
- Rates are the lowest in Charleston County.