REPORT

Asset Management Plan

Prepared for

City of Wichita

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245 North Waco Street
Suite 240
Wichita, KS 67202

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Acronyms and Abbreviations

AMP	Asset Management Plan
AMWA	Association of Metropolitan Water Agencies
BCE	business case evaluation
CAM	Comprehensive Asset Management
CH2M	CH2M HILL Engineers, Inc.
CH2M Team	CH2M HILL Engineers, Inc., Table Rock Capital, and Goldman Sachs
CIP	capital improvement program
City	City of Wichita
DST	Decision Support Tool
ISO	International Organization for Standardization
NACWA	National Association of Clean Water Agencies
NBP	National Biosolids Partnership
O&M	Operations and Maintenance
PAS 55	British Standard Institute Publicly Available Specification 55
PW&U	City of Wichita Public Works and Utilities Department hired
ROI	return-on-investment
SOP	standard operating procedures
SWOT	Strengths, Weaknesses, Opportunities, Threats

SECTION 1

Purpose and Benefits Asset Management

1.1 Introduction

Throughout the United States, aging infrastructure, financial constraints, and increasingly strict regulatory requirements have created challenges for cities and utility managers to meet the expectations of their customers. To provide reliable and high-quality service to customers, cities must be willing to adequately invest in improvements to facilities, as well as the operations and maintenance (O&M) of those facilities. Asset management has become increasingly popular as cities seek more effective ways to determine investment priorities. Asset management generates a rigorous decision-making process based on quantifiable risk, which can result in more sustainable and consistent decisions about investment and maintenance procedures. Proper application of asset management can lead to better management of utilities, including lowering life-cycle costs, improving levels of service, and reducing risk.

Proper asset management involves sufficiently identifying the condition of assets, determining levels of service that need to be achieved, and financially planning for improvement projects using decision frameworks and business case analyses; it also involves assessing assets, evaluating organizational goals, and prioritizing investment decisions based on defendable and objective data. Defining levels of service helps to establish the overarching goals of the organization and may include regulatory compliance, public and employee health and safety, and economic sustainability. By identifying levels of service that align the needs of the customer with those of the utility, cities can establish practices that achieve the levels of service in a way that encourages improvement and public confidence.

Comprehensive asset management programs have enabled other leading water and wastewater utilities, governmental agencies, and private sector companies around the world to better manage their assets, reduce cost, and introduce innovative methods and technologies into their organizations. The City of Wichita (the City) Public Works and Utilities Department (PW&U) hired CH2M HILL Engineers, Inc. (CH2M) to assist with evaluating risk, asset, and staffing management of their water and sewer utilities in order to establish a long-term investment strategy.

Our goals are to provide the PW&U with an asset management plan (AMP) that positions them as a world-class utility and includes the following:

- Proven methods and tools successfully applied at comparable water and wastewater utilities and other market sectors worldwide for better business and investment decision-making
- Improvements in prioritizing capital expenditures by applying a risk-based approach and a business case evaluation process using triple bottom line principles
- A business management approach that minimizes life-cycle asset costs at acceptable levels of risk
- Organizational change management methods to ensure adequate staffing, staff development, and knowledge retention
- Improved performance measurement, reporting, and management processes and tools to track benefits that can be shared with staff and key stakeholders

We have compiled our report so that it remains a living document, whereas each appendix can be removed and updated as necessary. This AMP report provides a high-level overview of asset management vision, goals, benefits and tools and methodologies. The appendixes describe the current state of the City utilities, the data collected, and recommendations for asset management

implementation. These appendixes should be revisited and updated with some regularity to ensure the effectiveness of the report; they include the following:

- Appendix A Current Utility Situational Analysis
- Appendix B Asset Condition Assessment and Capital Improvement Program
- Appendix C Operations and Maintenance Report
- Appendix D Financial Report
- Appendix E Northwest Water Treatment Business Case Evaluation
- Appendix F Northwest Water Treatment Plant Value for Money Analysis
- Appendix G Wastewater Treatment Business Case Evaluation
- Appendix H Decision Support Tool Report
- Appendix I Management Proposal

1.2 Project Background and Need

Wichita is the largest city in the state of Kansas and has a population of approximately 385,000 and a metropolitan area population of approximately 635,000. As Wichita continues to grow, utility infrastructure performance and operations becomes increasingly important to successfully meet its mission of providing an environment to protect the health, safety, and well-being of all who live and work in the community and maintain opportunities for business development, improve the quality of life, and protect the environment. The PW&U, as with all utilities, is responsible for providing high-quality, reliable, and responsive service to its customers. Fulfilling these responsibilities, at an acceptable level of risk, has become increasingly difficult with the ongoing business challenges of aging infrastructure, more stringent regulatory requirements, a shortage of an experienced workforce, and financial constraints.

In an analysis conducted by Black and Veatch in 2012-2013 (Black and Veatch, 2014), Wichita was shown to have the tenth-lowest combined water and sewer rates when compared with the 50 largest cities in the United States. The balance between low rates and the need for infrastructure improvements has resulted in a backlog of water and sewer system maintenance needs. As the list of deferred maintenance grows, the risk of a large system failure increases. Other potential risks to the City include failure to meet regulatory requirements and the inability to respond appropriately to emergency conditions.

PW&U hired CH2M and its subconsultants—Table Rock Capital and Goldman Sachs (CH2M Team)—to assist with evaluating risk exposure, asset, and staffing management within their water and sewer utilities. The project involves developing an AMP that includes a risk analysis of existing infrastructure and recommendations on how to proceed with capital improvement program (CIP) projects. The PW&U sought to use an asset management approach that focuses on proactive maintenance as opposed to reactive maintenance. The PW&U also wanted to create a plan that leads to optimal utility staffing and to identify alternative capital financing sources that may be more advantageous than traditional financing through issuance of revenue bonds.

The CH2M Team has created a long-term implementation plan that will improve PW&U O&M procedures so it can invest wisely in capital projects in the future. The goals of the AMP include optimizing staffing levels, identifying repair and replacement projects that will minimize risk and O&M costs, and creating a funding plan that minimizes impact to rate payers.

SECTION 2

Asset Management Foundation and Vision

2.1 Approach to Asset Management

According to *Implementing Asset Management: A Practical Guide,* (National Association of Clean Water Agencies [NACWA], 2007) asset management stems from and is defined to be "an integrated set of processes to minimize the life cycle costs of infrastructure assets, at an acceptable level of risk, while continuously delivering established levels of service." To achieve sustainable asset management, four key elements must be considered: strategy, managing assets, people effectiveness, and business processes (Figure-3-1). These "building blocks" must be in balance to consistently meet service levels and minimize overall cost of asset ownership:

- **Strategy—**Set the vision, mission, and roadmap for the organization.
- **Managing Assets—**Minimize total cost of ownership, increase reliability, and meet performance standards in a safe and environmentally conscious manner.
- **People Effectiveness—**Make good choices in organizational design, people resources, and corporate knowledge retention.
- **Business Processes—**Design and implement streamlined and effective processes with value-added steps.

Figure 3-1. Comprehensive Asset Management

Comprehensive Asset Management (CAM) is achieved when all four building blocks are in balance and CAM is essential for optimal business performance. When these elements are in balance, the PW&U will consistently improve performance with the investments in its assets, minimize life-cycle costs, manage risks, and ensure continuity of levels of service in the face of changing business drivers.

2.2 Path to a Mature Asset Management organization

The path to a robust, phased six-step implementation process includes the following steps:

- Step 1—Education
- Step 2—Current Situation Review and Analysis
- Step 3—Visioning
- Step 4—Design
- Step 5—Implementation (Pilot and Rollout)
- Step 6—Continuous Improvement

The PW&U organization is already quickly moving up the maturity levels, with staff having been exposed to a common view of leading asset management practices and participating in our approach and implementation methodologies.

2.3 Defining Utility Asset Management Goals—What makes a world-class utility?

Identifying "world-class" status is not an easy task. In the water sector, recognition for best practice is typically associated with national recognition such as NACWA's Peak Performance Award, NACWA's Excellence-in-Management Award and Association of Metropolitan Water Agencies' (AMWA's) Utility Performance Award, along with the National Biosolids Partnership (NBP) certification. Also, the Stockholm Water Prize is awarded for outstanding global achievements in water-related activities, but there remains no specific award for asset management. Nevertheless, in the past decade, the British Standard Institute's Publicly Available Specification 55 (PAS 55), has become the "standard" for asset management best practice for water utilities and other public and private sectors in the United Kingdom, Canada, and several other countries. The Institute of Asset Management in the United Kingdom provides a third-party audit and certification program to document compliance with the principles and practices of PAS 55. International Organization for Standardization (ISO) 55000 is a new standard developed based on PAS-55 as with other ISO standards (most notably to the water sector ISO 9000 and ISO 14000); third-party audit and certification is available to those entities that meet the ISO 55000 standard and seek to become certified.

Each utility has its own unique challenges, vision, and goals, and therefore, defining what makes a world-class utility can vary. Typically, the qualities include an emphasis on sustainability and environmental stewardship, optimized costs for rate-payers, energy efficiency, good asset management, safety, regulatory compliance, and reduced impacts on the public. Some utilities are very focused on taking an integrated water resources approach, new and more efficient technologies, and water reuse.

The CH2M Team performed a "strengths, weaknesses, opportunities, and threats" (SWOT) analysis and conducted interviews to identify PW&U's challenges, goals, and vision and rank its needs and goals; these are summarized in Appendix A.

SECTION 3

Asset Management Implementation Strategies

3.1 Developing Levels of Service Goals

Defining levels of service is a foundational element in building a strategic asset management program, because they can ensure an integrated approach from the corporate performance vision, down to day-to-day asset management decision-making. Levels of service typically address the overarching goals of the asset management mission and represent how infrastructure assets will achieve the goals related to customer service, environmental protection, regulatory compliance, economic sustainability and public and employee health and safety. City staff and CH2M collaboratively defines level of service goals for the PW&U in Appendix B.

Establishing level of service measures ensures that a clear relationship is identified between business objectives and asset-focused objectives which enables the utility to move towards budgets based on achieving a set of level of service and/or being able to communicate a reduction or improvement in level of service associated with a reduction or increase in available budgets.

3.2 Asset Condition Assessments

3.2.1 Developing the Asset Hierarchy

An asset hierarchy represents the relationships between a utility's infrastructure assets. The hierarchy is arranged in a parent-child format, similar to a family tree: it starts at the top with the utility system, then to the facility, followed by facility components. The hierarchy can be developed using physical location or by function (see Figure 4-1).

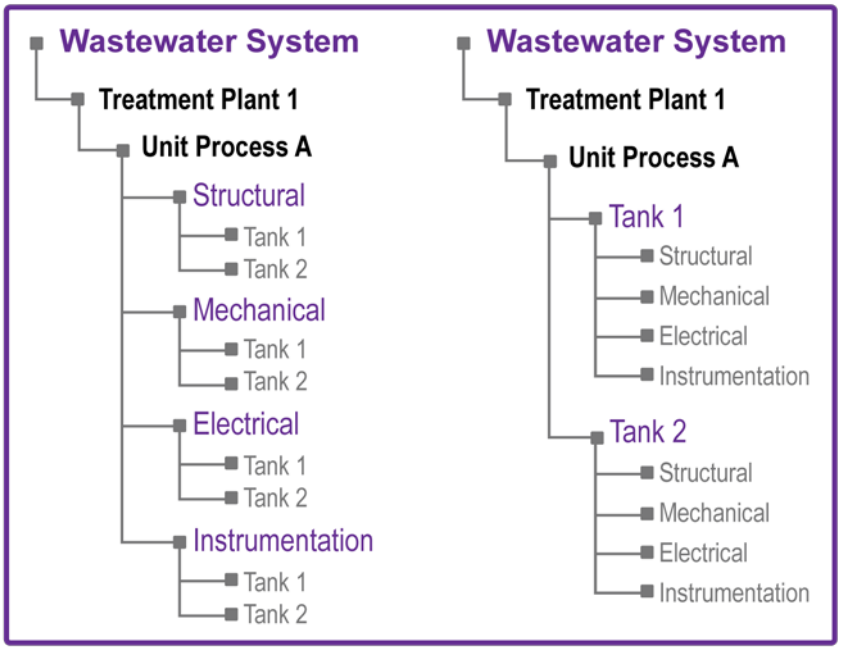

Figure 4-1. Example of an Asset Hierarchy

Asset hierarchies can be developed with the top-down approach, which involves starting with an entire system and breaking it down into plants or piping systems and then into components (see Figure 4-2). The assets belonging to a component should be grouped into a higher level parent asset for evaluation. Once the hierarchy has been established, the highest priority or highest-risk parent group at any particular level can be investigated more thoroughly.

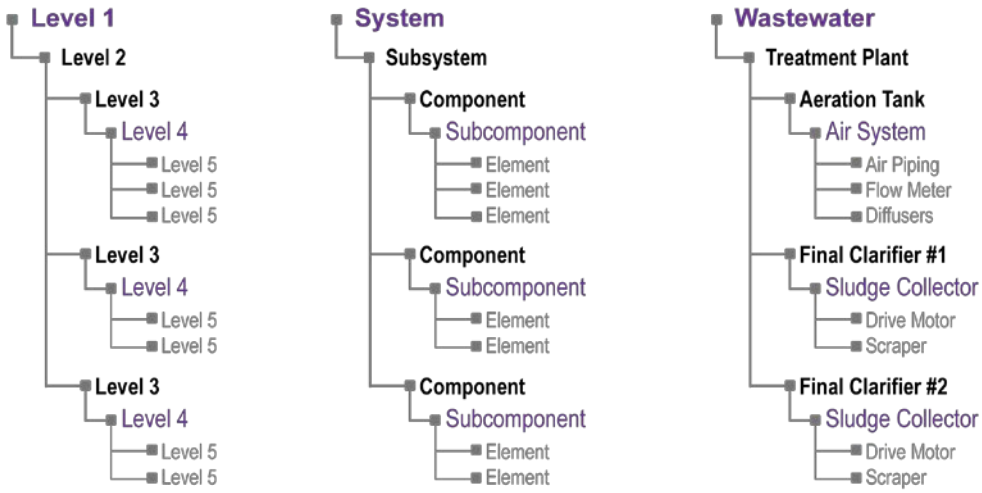

Figure 4-2. Example of a Top-Down Format of an Asset Hierarchy

3.2.2 Developing the Risk Framework

For infrastructure asset management, risk refers to the risk of asset failure:

Risk = Consequence x Likelihood

Consequence is the impact of asset failure on established levels of service. Consequence may be economic, such as direct cost associated with a failure or health and safety impacts to employees; it may also include noneconomic consequences, such as failure to meet regulatory requirements or loss of public confidence. As shown in Table 4-1, quantifying consequence involves developing categories of level of service and the associated consequences of not meeting the level of service. Each asset can be scored based on the matrix to determine the severity level of the assets failure. The example shown in Table 4-1 briefly describes possible level of service categories and associated consequences.

Likelihood is the possibility that an asset will physically fail or otherwise fail to meet its purpose. A matrix is developed for likelihood to quantify the factors that can contribute to an assets likelihood of failure (Table 4-2). The categories may include physical condition, performance, and reliability. The matrix should be developed so that it can be widely applied to different kinds of assets, and the scoring is as objective as possible. In assessing risk, consequence and likelihood are defined and quantified separately, then combined to calculate the risk.

3.2.3 Field Condition Assessments

We conducted condition assessments as noted in Appendix B. Future condition assessments can be performed by City staff and operators in the field and should be a part of daily operations procedures. By maintaining condition assessments, the City can achieve a more thorough understanding of their assets and more readily identify projects for improvement. When performing daily operations, a staff member or operator should take note of the physical condition of an asset, as well as the ability of the asset to meet performance needs. If an asset is failing in some way, the failure should be documented immediately and the source of failure should be identified.

Table 4-1. Consequence Matrix and Scoring System

Level of Service Category	Weight (percent)	Negligible = 1	Low = 2	Moderate = 4	High = 7	Severe = 10
Regulatory Compliance	30.0	No permit violations	Violation of permit with no formal enforcement action	Permit violation with enforcement action and potential fines of less than $100,000	Violations with enforcement action and fines of $100,000 to $500,000 or Violation of existing consent order	Violations with enforcement action, fines more than $500,000 or Moratorium or Additional consent order or reopening of existing consent order
Environmental and Public Health Impact	15.0	No environmental impacts and No waterborne disease and No release of toxic gas	Minor short-term reversible impacts on the environment; no remediation required but No waterborne disease	Major short-term reversible impacts on the environment; minor remediation efforts required but No waterborne disease	Major long-term reversible impacts on the environment; moderate remediation efforts required or Localized waterborne disease possible	Irreversible environmental impacts if major remediation is not performed or serious long-term or permanent impacts
System Reliability	30.0	No loss of treatment or system effectiveness	No loss of treatment or system effectiveness but need to use redundant systems	Loss of treatment or system effectiveness if action is not taken promptly	Will immediately result in loss of treatment or system effectiveness if action is not taken promptly or Widespread moderate property damage (25 to 100 structures backup)	Immediate loss of treatment or system effectiveness that cannot be easily reversed or Widespread major property damage (100 or more structures backup)

Table 4-1. Consequence Matrix and Scoring System

Level of Service Category	Weight (percent)	Negligible = 1	Low = 2	Moderate = 4	High = 7	Severe = 10
Employee Health and Safety	15.0	No injuries and Routine work not requiring rapid response	Routine work requiring rapid response	Possible unsafe conditions (e.g., confined space, 480 volts, more than 20 feet above ground)	Possible multiple unsafe conditions (e.g., two or more conditions such as confined space, 480 volts, more than 20 feet above ground, moderate concentrations of hydrogen sulfide)	Extreme unsafe condition requiring long-term treatment (e.g., more than 4,160 volts, chlorine gas, very high concentrations of hydrogen sulfide)
Fiscal Impacts	5.0	Expenditure within adopted budget line item	Expenditure within budget by may require line item transfer	Expenditure requiring director approval	Expenditure requiring city manager approval	Expenditure requiring council approval
Public Confidence	5.0	No adverse impact on community	Limited adverse impact on businesses	Localized adverse impact on businesses but no critical customers affected	Localized adverse impact on businesses, including one critical customers	Widespread adverse impact on multiple businesses, with two or more critical customers affected

Table 4-2. Likelihood Matrix and Scoring System

Category	1	2	4	7	10
Assumed Probability	Less than 3 percent in any given year	3 to 10 percent in any given year	10 to 25 percent in any given year	25 to 50 percent In any given year	50 or more percent in any given year

Assets are assessed for their condition and performance and their ability to meet associated levels of service. Maintaining a schedule of condition assessments and understanding the relationship between physical condition, performance, and causes for changes in condition status of assets are important. By updating the conditions of assets, preventive maintenance can be scheduled. In some cases, adequate preventive maintenance can offset corrective maintenance costs or even improve the anticipated useful life.

3.2.4 Identifying Assets that Need Investment

Often, an asset is identified for investment when it is beyond its useful life or when it somehow fails to meet its assigned level of service. The level of service may not be met due to capacity, performance measures, or other criteria that can affect system reliability or incur a higher cost to the City. If adequate field condition assessments are sustained, then the identification process becomes much easier. Priority can be based on the assets with a higher risk of failure.

3.3 Operations and Maintenance Assessment

The CH2M Team evaluated PW&U's O&M practices, including standard operating procedures (SOPs); this evaluation involved SOPs that cover preventive maintenance and corrective maintenance. Our assessment includes updates required or gaps in SOPs and recommendations for efficiencies; the O&M assessment is located in Appendix C.

An effective SOP typically provides step-by-step details along with the skills and tools necessary to perform a task. The goal is to provide an established level of service efficiently and within regulatory compliance. Preventive maintenance differs based on the system to which it is applied. In vertical systems, performing preventive maintenance can extend the life of an asset or ensure that the asset will perform adequately through its expected useful life. While preventive maintenance may not directly extend the life of linear assets—for example, diligent closed-circuit television and flushing—can help identify areas of improvement before an asset fails. When properly implemented, preventive maintenance can significantly reduce life-cycle costs and can prevent emergency repair situations from arising.

Corrective maintenance refers to the repairs and reactive maintenance required to retain the performance of an asset. Corrective maintenance is based on the asset's age and condition, and well as the kind of asset that is being maintained. Corrective maintenance increases as an asset ages and increases significantly after an asset has passed the end of its estimated useful life. **An effective utility should place emphasis on performing preventive maintenance rather than corrective maintenance where possible.**

3.4 Financial Assessment

The City's finances are a critical part of planning for future capital improvements and understanding tradeoffs between capital investment, maintenance, and revenue requirements. Existing finances for fiscal years 2015-2016 and 2016-2017 were used as a basis for future projections. The CH2M Team analyzed revenue, expenses, and existing debt, as well as available debt instruments and funding mechanisms.

The CH2M Team developed a financial decision support tool (DST) to support PW&U's CIP alternatives analysis. Appendix D describes the methodology used for developing the tool and offers guidance its functionality and use. Existing finances are also discussed as the basis for the model's methodology.

SECTION 4

Developing an Optimized Capital Improvement Program

This AMP will inform an optimized CIP that prioritizes PW&U projects based on risk reduction, providing a favorable return-on-investment (ROI) or other aspects, such as anticipating regulatory requirements. The CIP created by the DST is developed by estimating the year of failure for any given asset.

4.1 Decision Support Tool

4.1.1 Asset and Operations and Maintenance Decision Support Tools

The CH2M Team developed a DST that combines several management aspects into a comprehensive analytical tool to create a strategic long-term AMP. The City's water utility is organized within the DST into vertical assets, such as pump stations or plants, and the linear distribution system assets. The sewer utility is split into vertical assets and the linear collection system. By diligently updating the asset conditions and the list of existing assets, the PW&U can use the DST to model their expected expenditures over 40 years of improvements and maintenance.

The vertical asset DSTs are constructed such that they estimate a required CIP schedule and budget for each year that can replace assets that are predicted to fail. This schedule is created while estimating necessary preventive and corrective maintenance costs. Each DST considers four scenarios and provides an estimated budget for each: contracted O&M, current City procedures, and two adjustable scenarios. Users are able to adjust their expected budget, and the asset DST will estimate the capability to replace assets at or before failure, show the impact of large CIP projects on asset replacement schedules, and describe yearly expenditures on O&M. The preventive maintenance materials cost and labor for a vertical asset is based on the equipment type; it is unchanging each year, with the only exceptions being that preventive maintenance labor hours and cost may change if the associated asset is removed permanently or a new asset is added. Corrective maintenance is calculated based on the age of the asset, with cost and labor increasing as the asset nears the end of its useful life. If the asset exceeds its useful life before being replaced in the CIP, the corrective maintenance increases more dramatically until the asset reaches 200 percent of its useful life.

Through a macro written in Microsoft Excel's Visual Basic applications, the four maintenance strategies can be adjusted and measured. When changes are made to the assets, monetized consequences, or user inputs that affect all of the strategies, the macro should be run for all strategies to accurately model the change in cost or system value. In addition to the CIP, the macro creates a summary page that shows the estimated preventive and corrective maintenance labor, preventive and corrective maintenance materials cost, CIP costs of projects performed, unused funding, monetized consequences, and system value for 40 years. The summary sheet is included to give a platform for comparing the maintenance strategies over time, as well as the total expenditures of each strategy.

The operations DST is based on the current budget provided by the City and escalates the cost over 40 years. The City can adjust the level of investment and observe the effect on the budget. The benefit of the DST is its ability to very specifically change parts of the operations budget. For example, the City may choose to invest in providing training and theoretically could improve their efficiency in their O&M. Every line item of the operations budget can be adjusted to determine the most desirable blend of funding, and alternative funding can be considered in the model as well.

4.1.2 Financial Decision Support Tools

The financial DST is discussed in detail in Appendix D. Asset and O&M scenarios were developed in separate DSTs that produce outputs based on both need (a function of asset condition scores and risk) and budget. Those data are then copied and pasted as values into the financial DST to examine how different budgets impact required maintenance and monetized risk exposure. Annual asset investment, preventive and corrective maintenance, monetized consequence exposure, system value, and operational expenses are taken from the asset DSTs and input into the financial DST.

Results from the financial DST are taken as an input back into the asset DSTs. The asset DST will use the available budget for vertical and linear assets determined by the financial DST and calculate a new corrective maintenance cost.

The financial DST works iteratively with the four asset DSTs and the operations DST to determine the optimal allocation of funding between water treatment, wastewater treatment, water distribution, and sewage collection improvement projects. The process will include many manual aspects, as well as override capabilities because the situations may be contingent on factors other than directly budgetary constraints, such as schedule or regulatory requirements. PW&U will also be able to control their expected revenue and revenue increases through the financial DST.

4.2 Capital Improvement Program Prioritization

The CIP is prioritized by the year of replacement and the monetized consequence to replacement cost ratio. Each year, the CIP can be prioritized based on the greatest reduction in monetized consequence per dollar spent. All four DSTs also account for the presence of projects that must be funded before other assets, and those projects are marked manually by users. If the project is a 'must fund,' then the total monetized consequence is used in place of the monetized consequence to replacement cost ratio. This typically brings the must-fund projects to the highest priority. Prioritizing must-fund projects is especially important for the budget restrained CIP.

To develop the optimized budget-based CIP, users first populates the anticipated budget over 40 years on the Excel Input tab. The Calculation tab lists assets that will need to be replaced within the 40 years and prioritizes them by risk and replacement cost. The Calculation tab also groups the assets that will be replaced more than once. Each year, the top priorities that can be funded are replaced, and their useful life is reset. If the asset is not replaced with the given budget in the expected year, then the asset continues to age and is reprioritized the next year. The actual year of replacement is recorded, creating the budget based CIP. If unused budget remains, then the option exists to roll the budget to the next year, adding it to the anticipated budget for that year.

The CIP created also considers the escalation of project costs over time, providing a more realistic cost estimate of projects that may not occur for several years. By providing an escalation factor, the budget for CIP projects can be realistically estimated, and the chances for underestimating project cost can be reduced.

4.3 Business Case Evaluation of Asset Investment Alternatives

4.3.1 Business Case Evaluation Process

The CH2M Team developed a business case evaluation (BCE) template (presented in Appendices E and G) that can be used for making balanced decisions related to important capital investments regarding asset rehabilitation, renewal, or replacement options. The BCE process provides a framework for

evaluating alternative solutions for every capital project(s) and evaluates those solutions against financial, environmental, and community and social values and benefits. The goal of the BCE process is to make consistent and defendable decisions regarding capital investment that meet the PW&U's strategic plan and are in the best interest of its customers. Once the BCE process is completed, for a given capital investment, the project stakeholders will present the BCE recommendations to PW&U management and possibly Wichita City Council for approval. The BCE recommendations would then be implemented according to the CIP budget and schedule.

The BCE process is adaptive, and when utilized, there is enough flexibility to allow considerations for changing situations. Regulatory changes could require a change in procedure while forming a project, and a second BCE can help determine alternatives when the path forward is unclear. Similarly, a change in the scope of a project or a dramatic change in cost may elicit the need for a new BCE.

An example where the PW&U could have benefited from the BCE process in the past includes when it decided to build a new wastewater treatment plant rather than adding an additional pipeline to the Tyler Road force main in order to address wastewater capacity issues. PW&U proceeded with the wastewater treatment plant construction; however, as the project progressed, moving the location of the plant onto airport property became necessary, dramatically increasing construction cost. Because the project cost changed, and the construction had not yet begun, PW&U may have benefited from reemploying the BCE process. The BCE may have revealed that the new cost outweighed the potential benefit of constructing the new plant, especially when considering the O&M cost of maintaining a plant compared with the low cost of maintaining a pipeline.

4.3.2 Business Case Evaluation and Value for Money Template

The BCE provides background of the project or asset being considered for rehabilitation, renewal, or replacement. The background includes asset age and condition and the O&M procedures. The background also explores the purpose of the asset, the level of service provided by the asset, and its current capabilities to meet levels of service. Once the project's history and purpose have been established, the BCE will identify the problem facing the asset. The problem will include details about why the asset is being repaired or replaced and usually refer to the failure to meet a desired level of service and/or the condition of the asset.

Once the problem is identified, alternatives are established for how to solve the problem at hand. While considering the cost of design and construction is important, it is not sufficient to end cost analysis of alternatives here. Improvement alternatives should be fully developed based on background information, life-cycle costs, O&M requirements of each alternative, and the planning periods for improvements. The final costs of the project depend on many variable factors, and the BCE should attempt to account for most of these variances. However, in some cases it is not possible to accurately represent all possible variables, and if the scope or cost of the original plan changes significantly, then it may be necessary to perform a second BCE.

Once the improvement strategies have been identified, the strategies can be compared against one another to determine relative benefit of each project. The alternatives should also be analyzed by looking at the relative benefit-to-cost ratio so that identifying the amount of benefit received per dollar spent is easy. Using the risk framework above, the BCE should also identify the risk reduction of each alternative and per dollar spent.

Finally, the BCE gives a recommendation to the intended audience about which improvement strategy to pursue. The recommendation is defendable from the data collected and analyzed throughout the BCE. Sometimes the decision is not entirely based on the project cost. It may be that the benefit or the risk reduction is of much greater value to the City than the cost of the project.

SECTION 5

References

Black and Veatch. 2014. *Operations and Maintenance*. Available at http://www.saws.org/who_we_are/community/RAC/docs/2014/50-largest-cities-brochure-water-wastewater-rate-survey.pdf.

National Association of Clean Water Agencies (NACWA). 2007. Implementing Asset Management: A Practical Guide. Water Environment Federation. Published in cooperation with Association of Metropolitan Water Agencies, American Water Works Association, and Water Environment Federation.

U.S. General Accounting Office (GAO). 2004. *Water Infrastructure: Comprehensive Asset Management Has Potential to Help Utilities Better Identify Needs and Plan Future Investments*. GAO-04-461. Report to the Ranking Minority Member, Committee on Environment and Public Works, U.S. Senate. Available at http://www.gao.gov/products/GAO-04-461. March.