Abstract
Most utilities have prepared water and wastewater system master plans and update these plans on a regular basis. Traditionally, the primary goal of these master plans has been to identify facility and infrastructure improvements that will be needed to provide adequate hydraulic capacity under existing and future projected system demand/flow conditions. System improvements recommended from the master plan were then incorporated into the utility’s capital improvement plan (CIP). In parallel to master planning activities, utilities have traditionally conducted various operations and maintenance (O&M) activities to maintain the system in an acceptable condition and operating at an acceptable level of performance. System repair, rehabilitation, and replacement improvements required from these O&M activities were also incorporated into the utility’s CIP. These parallel, but separate, system planning and O&M activities provided many coordination challenges and often resulted in CIPs that were not optimized.

With the continued aging of our nation’s water and wastewater systems, more and more system facilities and infrastructure are nearing the end of their useful service lives. A new approach to system planning, operations, and maintenance is needed to better coordinate these activities and manage system assets. This paper presents an asset management approach to water and wastewater master planning that better coordinates system planning and O&M activities and addresses rehabilitation and replacement needs of facilities and infrastructure that are nearing the end of their useful service lives.

An asset management approach to master planning is a holistic, integrated approach that considers the levels of service provided to customers, is risk based, and assesses the whole-life cycle costs of system improvements. Information on system condition and performance is used to assess the risks of failing to provide the required levels of service and to estimate expected remaining service life. Identified system improvements are then optimized so that they provide the required service levels for the least whole-life cost at a level of risk acceptable to the utility. A prioritized CIP is developed from the optimized system improvements to meet the different needs (growth, regulatory requirements, and asset renewal) at a price that is affordable to the utility’s customers.

Keywords
Asset Management, Infrastructure Prioritization, Capital Improvements Planning

Introduction
Utility managers face a conflicting set of priorities in today’s economic environment. On the one hand, aging infrastructure poses ever-increasing risk of catastrophic failures, which requires major capital outlays to replace and rehabilitate. On the other hand, capital and O&M budgets have been slashed as sales and revenue have dropped and rate increases are denied or delayed. Effectively balancing these risks while planning for future growth presents challenges for utility planning across the nation.

In many cases, the challenge is exacerbated by organizational structure, planning processes that have evolved over time, and lack of communication between disparate groups in the utility.
**Typical Planning Process**
There are as many planning processes as there are utilities. There is no typical process, but there is typically some level of dysfunction. One of the more common issues that limits effective planning and asset management is the separation, and more importantly the breakdown in communication, between engineering and operations functions.

Typically, engineering departments have prepared water and wastewater system master plans and update these plans on a regular basis. Traditionally, the primary goal of these master plans has been to identify facility and infrastructure improvements that will be needed to provide adequate hydraulic capacity under existing and future projected system demand/flow conditions. System improvements recommended from the master plan are then incorporated into the utility’s capital improvement plan (CIP). Frequently, the operations department has little knowledge of the hydraulic model(s) and their capabilities, system studies or the underlying data they contain, and proposed improvements or the rationale for implementing them. As such, there can be distrust or lack of acceptance of projects identified by the engineering department.

In parallel to master planning activities by engineering departments, operations departments have traditionally conducted O&M activities to maintain the system in an acceptable condition and operating at an acceptable level of performance. Proactive operations departments conduct condition assessments to provide a basis for prioritizing system repair, rehabilitation, and replacement improvements, which can be done with operational budgets or by inclusion into the CIP. Frequently, the engineering department does not have access to key data in the maintenance management system or the condition assessments, and the information is ignored in the planning process.

**Project Drivers**
Part of the problem is related to the drivers that require a capital project in the first place. Figure 1 presents some of the most common drivers. The distinction between types can be blurred and often depends on how the utility wishes to portray the budget. Multiple drivers can influence the need for and decisions in a project.

*Figure 1. Key Drivers in Planning Capital Projects*
The typical master planning process is best geared to identify and resolve problems resulting from capacity constraints, regulatory change, and growth.

The typical operations department is best geared to identify and resolve projects resulting from deterioration.

Efficiency-based projects are a special case that requires holistic coordination to identify opportunities to improve service, improve processes, reduce unnecessary activities, etc. These are often neglected completely unless there is a strong advocate for change.

By focusing on particular areas of interest and not communicating effectively, suboptimal solutions are not uncommon. These projects frequently require additional corrective action sooner than expected.

The problems in coordinating are exacerbated by timing of the planning processes – master plan updates are rarely conducted more frequently than every five years, and sometimes comprehensive updates may wait 20 years or more. These plans rarely include life cycle costs of operating and maintaining assets over the planning period.

Meanwhile, operations budgets are more frequently conducted on an annual basis, and it is not uncommon to implement stop-gap measures while waiting for a proposed capital project in the master plan. Even more commonly, the operations budget may identify the need to rehabilitate or replace major equipment not identified in the planning process.

**Typical Master Planning Process**

The master planning process has in many ways become a standardized process to investigate population projections, growth, and regulatory drivers to determine available or needed existing and future capacity, followed by an alternatives analysis and recommendations to meet the needed future capacity. A missing link in this process is the impact of asset condition and performance on the available capacity – whether a reduction in performance over time may reduce capacity, or if the asset will be completely unusable at some time in the future. In these analyses, there is an inherent assumption that facilities will be maintained, replaced, or rehabilitated to meet their existing performance, unless such considerations are explicitly included in the alternatives analysis.

**Master Planning Process**

- Population Projections & Growth
- Regulatory Drivers
- Model Update and Calibration
- Capacity Analysis
- Alternatives Analysis
- Recommended Capital Improvements

5, 10, 20 Year Capital Planning Update Cycle
Typical "Asset Management" Process

Asset Management can mean many things to many people – ranging from a holistic description of utility management to a simplistic risk-based prioritization of annual spending. For the purposes of this section, we are referring to asset management as the process of identifying the condition and performance of various assets and allocating funding to replace or rehabilitate appropriate assets at an appropriate time – a methodology described in the WERF SIMPLE documentation and EPA training and often erroneously conceived as the endpoint of asset management. In reality, the entire scope of this paper, including the master planning process, could and should be considered asset management.

Analysis and Prioritization Methodology

Perhaps the most common prioritization methodology in the United States is that laid out in the Water Environment Research Foundation (WERF) Sustainable Infrastructure Management Program Learning Environment (SIMPLE). This methodology, which includes assigning condition, reliability, consequence, and various other scores to each asset to enable calculation of a likelihood and consequence of failure, and ultimately a Business Risk Exposure (BRE), has become a primary means of allocating maintenance and capital funding in a number of utilities. The data collected and generated by the assessment and prioritization process process is used by utility staff to support prioritization of equipment repair and replacement needs and to develop long-term service condition and risk information for these assets. The underlying foundation of an effective process is reliable condition and performance data, which are obtained by regular assessments of the assets or a sampling of assets.

Business Risk Exposure

The BRE score, which is the product of the Probability of Failure (PoF) and the Consequence of Failure (CoF), is used to rank assets based on a variety of factors including the likelihood that the asset will fail, and the consequence that may result from the failure of the asset. The BRE for each asset provides a simple score for ranking and focusing on more detailed risks for particular assets and allows comparison between assets in an equitable manner. By ranking assets based on BRE score, a maintenance and replacement priority list of all assets that are currently in need of replacement can be generated. This allows for rapid filtering and better accuracy in the replacement of truly critical equipment and results in improved annual budgeting for the repair and replacement of critical infrastructure. Figure 2 shows calculated BRE scores within a matrix of PoF and CoF scores.
The prioritization tool is most commonly in a spreadsheet, which is often developed individually for each facility or system. Over time, as systems experience capacity expansions, process improvements, and other changes, the spreadsheets must be modified. The addition of structures and equipment assets and the removal of some assets from service often results in large and cumbersome spreadsheets that require significant staff time to track and maintain service condition and cost histories. Furthermore, the spreadsheet-based system is difficult to automatically update with links to maintenance databases, and it is prone to modification, corruption, and multiple versions when numerous staff members are involved in the process. This can lead to headaches and significant investments of staff time to reconcile the data with each budget update. This can make the information difficult to share in the planning process, and when it is shared, there can be a healthy skepticism of the reliability of the process.

**Pitfalls of a Split Process**

A couple examples highlight the value of considering asset management and master planning in parallel:

A distribution system in California recently did a criticality assessment of its water infrastructure using historic main break data, with the intent of developing a capital improvements program as well as a long term rate justification. In this analysis, the most critical pipe was found to be the 36-inch backbone of the system. Although the pipe itself has not failed, failures of smaller diameter pipes of the same material and vintage have caused concern, warranting a planned inspection. This conclusion was corroborated by staff concerns about the pipeline and its critical nature. As such, the pipe is now planned for inspection to confirm its condition and suitability for rehabilitation. However, if the inspection finds that rehabilitation is recommended, simple rehabilitation may not be the best solution. Instead, a planning analysis is recommended to determine if the pipe is the appropriate size, the system has adequate redundancy, and growth areas in town are effectively supplied.
One southern city highlights the similar issue for a collection system, when O&M rehabilitation decisions are made independently of a master plan. The City collection system has been inadequately funded for decades and is influenced by a high water table, with the result that the system is now inundated with more flow than the system was originally designed to handle. Although the City has undertaken localized flow monitoring and planning studies, it has been more than 20 years since the City undertook a comprehensive update of its master plan, so there is not a strong overarching strategy for the collection system. In the face of a sewer overflow problem and an impending consent decree, the City has started a master planning process and would simultaneously like to show progress by rehabilitating one of the most problematic interceptors in the system, and the pumping station has already been rehabilitated. The weakness of this approach is that it is being done in the absence of a plan – it is possible, indeed likely, that the resulting improvements will be undersized for the amount of flow in the system. This will in-turn force the City to implement aggressive I/I reduction efforts that may not have the desired effect given the high groundwater conditions, so the City runs the risk of implementing very costly improvements without solving the problem at hand.

Solutions

Integration of analysis
Tools and models are continually getting more sophisticated. Great advances have been made in improving communication and sharing of data and results between applications. This permits access to and inclusion of data heretofore considered impossible. Prioritization models have remarkable flexibility to include new data and information with modest changes in the calculation algorithm. While these tools can dramatically improve the efficiency of the planning process, full communication is required for them to be fully accepted – people may not believe they are using all available information, or they may not trust the methods used to calculate a solution.
• A key element in integration is the real-time (i.e. up-to-date) maintenance of condition and reliability data in a central database, such as the computerized maintenance management system or enterprise asset management system, which is accessible by multiple departments, not just the operations group. By having this data available, the information can be integrated into the master planning process and inform the initial development of alternatives, as opposed to an after-the-fact adjustment.

• Likewise, the operations group should have access to up-to-date plans, model results, and geographic information system databases. This is key information to effectively maintaining the system and making coordinated decisions with engineering, but all too often, it is not readily accessible. Modern software packages are remarkably adept at providing functionality for operations staff to view this data in the platform (e.g. CMMS) that they are used to or in a similar interface.

Conversion to Database
In the absence of a more sophisticated CMMS, one approach is to update the prioritization tool from a spreadsheet to a multi-user database, with tools to automatically update the asset inventory, information, maintenance history, condition, and reliability data with direct linkages to their CMMS. A centralized database can be designed to receive condition and reliability data directly from the CMMS and to calculate business risk exposure (BRE) scores for prioritization of each asset. Based on the BRE scores and anticipated replacement years, basic budgeting calculations are performed and formatted to export for further budgeting and CIP development. After downloading up-to-date CMMS condition assessment information and performing automated updates, the database engine allows the users to analyze and refine the prioritization, as well as to prepare summary reports and charts to make business-case justifications for the capital improvements program budget. The GIS can directly link to the calculated prioritization for mapping and analysis. By having an up-to-date automatic calculation, the information can be more readily incorporated into a planning process or compared with planning projects when considering rehabilitation.

Communication
Sometimes the solution can be as easy as increasing communication. One way this can be achieved is by implementing a business case analysis for projects to provide a unified method of evaluation. The business cases would then be reviewed and compared by an asset management committee with representatives from both operations and engineering. In the process of comparing and discussing project drivers, it is more likely that opportunities for further improvement may be identified.

Work process alignment
The fundamental problem described here is that disparate groups are working on essentially the same process. Namely, both groups are simultaneously attempting to implement optimal life-cycle decisions without key information on different aspects of the life cycle. By re-aligning the process into a single life-cycle based process, it is possible to bring the key information to light and better identify optimal solutions.

Conclusion
An asset management approach to master planning is a holistic, integrated approach that considers the levels of service provided to customers, is risk based, and assesses the whole-life cycle costs of system improvements. Information on system condition and performance is used to assess the risks of failing to provide the required levels of service and to estimate expected remaining service life. Identified system improvements are then optimized so that they provide the required service levels for the least whole-life cost at a level of risk acceptable to the utility. A prioritized CIP is developed from the optimized system improvements to meet the different needs (growth, regulatory requirements, and asset renewal) at a price that is affordable to the utility’s customers.