Bridging the Gap:

An Educational Primer on Sustainable Water Infrastructure Asset Management

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Civil and Environmental Engineering

Municipal Water & Wastewater Infrastructure

Asset Management Primer

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NOTE FROM EDITOR

The Department of Civil and Environmental Engineering at the Pennsylvania State University is pleased to present this "Asset Management Primer." This primer is part of the project "Bridging the Gap: An Educational Primer on Sustainable Water Infrastructure Asset Management," funded by United States Environmental Protection Agency (U.S. EPA). The goal of this primer is to raise awareness of the role of water and wastewater infrastructure asset management for agencies, municipalities, associations, academics, and the general public.

An extensive list of resources related to this topic is available at the Web site's reference library. Within this PDF document, hyperlinks to some of these resources provide instant access.

The information contained in this "Asset Management Primer" is believed to be correct and appropriate for "Bridging the Gap" project. We strongly believe that this primer will help promote best asset management practices for water and wastewater infrastructure systems in the United States and around the world.

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ABOUT THIS PROJECT: "BRIDGING THE GAP"

Participant in the "Bridging the Gap: An Educational Primer on Sustainable Water Infrastructure Asset Management," project will able to access the site through USEPA Asset Management website. The USEPA site contains information about the project and a link to public page on the Penn State website. The entire project website is organized in the following five sections:

1. **Welcome:** Welcome to the Bridging the Gap: An Educational Primer on Sustainable Water Infrastructure Asset Management. As interest in water and wastewater asset management among utilities has grown over the past decade, a number of professional and government organizations have attempted to define asset management and develop strategic plans in an effort to focus the practice and implementation of asset management. This site synthesizes these initiatives to develop an educational primer for water and wastewater utility infrastructure asset management.
2. **Module 1:** This module is designed to help users understand key principles of asset management and its components. Furthermore, it is hoped that this module will inspire municipal officials to become "stewards" of water and wastewater infrastructure asset management through perspectives on building the case for asset management, getting people on board, and managing change.
3. **Module 2:** This module is more technical in focus, examining current and best practices for water and wastewater infrastructure asset management. Overall, it provides users with an overview of implementing an asset management plan including case studies in asset management from the Seattle Public Utility, Atlanta Utility, Pittsburgh Water and Sewer Authority, and Benton-Nicholson (PA) Sewer Authority.
4. **Module 3:** This module is designed to provide answers to common research and education questions from leading experts in the field of municipal infrastructure asset management. In addition, this module provides several international perspectives on municipal infrastructure asset management.
5. **Reference:** This online reference library on asset management combines rich and scholarly resources with quick-reference coverage of the extensive spectrum of water and wastewater infrastructure asset management. It offers a wide range of additional material such as videos, biographies, presentation slides, articles, books, summary, case studies, and reports.

ABOUT THIS PRIMER: "ASSET MANAGEMENT"

This Asset Management Primer is a part of project "Bridging the Gap: An Educational Primer on Sustainable Water Infrastructure Asset Management." Asset Management, as described later in this document, is a business process and a decision-support framework that:

1. Covers the extended service life of an asset.
2. Draws from business economics, finance, public policy, as well as various disciplines of science and engineering.
3. Considers a broad range of assets and a system approach.

The following sections outline a number of efforts related to sustainable infrastructure asset management system.

National Asset Management Steering (NAMS) Group

The Institute of Public Works Engineering Australia and the New Zealand National Asset Management Steering (NAMS) Group have jointly developed an International Infrastructure Management Manual. Manual is divided into five sections [1]:

Section One - Introduction: It introduces the concepts of Total Asset Management (asset management as an integrated part of all organizations' activities) and Lifecycle Asset Management (decisions are made based on costs associated with all stages of an asset's life).

Section Two - Implementing Asset Management: This section describes the principles and processes for successfully implementing asset management planning. It is designed to help asset managers to progress quickly through the steps of developing meaningful asset management plans and establishing a framework for the ongoing enhancement of asset management plans to meet real business needs.

Section Three - Implementing Techniques: Section three contains details of asset management standards, guidelines, techniques and references together with examples of key asset management activities.

Section Four - Asset Management Information Systems: This section advises how to evaluate and implement information systems to support good asset management planning and decision-making.

Section Five - Country Specific Information: This section provides separate country specific information for Australia and New Zealand outlining the current context of infrastructure asset management planning practices in each country.

Federal Highway Administration (FHWA)

To assist States, FHWA and the American Association of State Highway and Transportation Officials (AASHTO) are developing a guidebook that will offer advice on applying asset management principles and provide examples of best practices already underway in some of the States. AASHTO [2] has also set up an Asset Management Task Force to guide this effort.

"Transportation agencies have undergone a fundamental change," says Mary E. Peters, director of the Arizona Department of Transportation and head of the AASHTO task force. "Nationally our priorities are moving to focus on more efficient and effective management, operation, and preservation of transportation systems, rather than placing a primary emphasis on adding capacity. Yet, for the most part, we are still operating our agencies with management information systems that focus more on how many miles of highway we have built or maintained rather than how those systems are performing. We can tell you how many ribbons we cut last year, but not a rate of return on investment."

One example of an asset management technique that is helping States better evaluate their existing assets and calculate the return on investments in roadways is the use of a pavement management system (PMS). This software tool is used in the collection and monitoring of information on current pavement conditions, forecasting future conditions, and evaluating and prioritizing alternative reconstruction, rehabilitation, and maintenance strategies. The evaluation, forecasting, and prioritization are done in order to maintain the system at a steady level of performance. The alternative rehabilitation and maintenance strategies analyzed by the PMS might include shutting down a road completely for repair work, rather than putting the public through months or years of work zones and detours. States such as Virginia and Washington have chosen this option with great success. In the long run, the shutdowns saved the public time, money, and aggravation and were preferable to a protracted series of backups. Some States are also using bridge management system (BMS) software called PONTIS to help determine the best program of bridge investments to pursue over a certain time period, given particular funding levels. PONTIS [3] supports the entire bridge asset management. Ideally, a BMS should identify current and future deficiencies, estimate the backlog of investment requirements, and project future requirements. Another powerful software tool that is currently being tested by States is a modified version of FHWA's Highway Economic Requirements System [4] program, which provides benchmark estimates of future highway system requirements, given some user-defined criteria.

FHWA has initiated several programs to address the issues of infrastructure and asset management. In 1999, FHWA established the Office of Asset Management. It is one of four offices within FHWA's Office of Infrastructure. Its mission is to bring state-of-art management system technology and best practices to US States and local agencies and to provide leadership and expertise in the management of highway infrastructure assets. The Office has three key responsibilities [5]:

• provide national leadership in asset management for the highway programs;

• develop asset management policies for pavement and bridge systems; and

• partner with the American Association of State Highway and Transportation Officials (AASHTO) and others to conduct nationwide programs.

FHWA has published a number of primers on infrastructure asset management (5), life cycle cost analysis (6), and data integration (7).

Governmental Accounting Standards Board (GASB)

The US Governmental Accounting Standards Board is a private, non-profit organization that defines "generally accepted accounting principles" for state and local governments. In June 1999, the GASB approved new financial reporting requirements that will encourage state and local agencies to become better stewards of their infrastructure. GASB Statement No. 34: *Basic Financial Statements—and Management's Discussion and Analysis—for State and Local Governments,* requires municipal, local, and state governments to account for their assets and to identify them in their annual financial statements [8]. Statement 34 established and improved "standards of state and local governmental accounting and financial reporting that will result in useful information for users of financial reports and guide and educate the public, including issuers, auditors, and users of those financial reports". GASB 34 also requires state and local governments to value infrastructure either by depreciating it or by reporting on the cost and consequences of preserving it. Statement 34 provides two methods for reporting the infrastructure owned by governmental authorities: (1) straight depreciation method (traditional), referred to as the Standard Reporting Approach, and (2) the Modified Approach (preservation). The traditional approach to reporting the annual cost of using capital assets involves the operating, maintenance and repair costs, as well as depreciation costs. The Modified Approach provides information on the current physical condition and long-term maintenance needs of government's infrastructure assets. In the Modified Approach, infrastructure assets do not have to be depreciated if: (1) an asset management system is used, and (2) assets are maintained at a pre-established condition.

United State Environmental Protection Agency (USEPA)

USEPA is working closely with utilities and others to provide technical assistance and training materials to assist utilities as they work to implement comprehensive asset management. Each utility is responsible for making sure that its system stays in good working order-regardless of the age of components or the availability of additional funds. Asset management programs with long-range planning, life-cycle costing, proactive operations and maintenance, and capital replacement plans based on cost-benefit analyses can be the most efficient method of meeting this challenge. As part of the EPA's Sustainable Infrastructure Initiative, the Office of Water works in collaboration with partner organizations to hosts and co-sponsor training sessions and facilitate discussions on best practice in Advanced Asset Management.[9]

1. INTRODUCTION

Clean and safe water is critical for human and ecosystem health. Wastewater collection systems perform the critical task of collecting sewage and other wastewater from places where people live, work, and recreate, and transport it to the treatment facility for proper treatment and disposal. These systems are essential for protecting public health and the environment. Most cities and towns started building sewer collection systems over 100 years ago and many of these systems have not received adequate upgrades, maintenance, repair, and rehabilitation over time. Cities have used a wide variety of materials, designs, and installation practices. The U.S. Environmental Protection Agency estimates that there are at least 40,000 overflows of sanitary sewers each year [10]. The untreated sewage from these overflows can contaminate our waters, causing serious water quality problems and threatening drinking water supplies and fish and shellfish. It can also back up into basements, causing property damage and creating threats to public health for those who come in contact with the untreated sewage. Sanitary sewer overflows that discharge to surface waters have been prohibited under the Clean Water Act since 1972 [11].

Today, municipal governments are facing an infrastructure crisis requiring costly renewal beyond their capacity. There has been a steady decline in the state of our wastewater infrastructure over the past two decades, and a growing concern is that these facilities may be inadequate both for current requirements and projected future growth [12]. Funding for these needs is limited, and a deferred maintenance, out-of-sight, out-of-mind philosophy still prevails in many regions. Recently, for example, the American

Society of Civil Engineering (ASCE) in its [2005] assessment of the nation's infrastructure assigned the grade 'D' and estimated a five-year investment needs to be in excess of $1.3 trillion [13]. It is estimated that the cost of replacing all water mains in the United States would run to $348 billion [14]. Although the federal government has spent more than $71 billion on wastewater treatment programs since 1973, the nation's 19,000 wastewater systems still face enormous infrastructure funding needs in the next 20 years to replace pipes and other constructed facilities that have exceeded their design life [15]. With billions being spent yearly for water infrastructure, the systems face a shortfall of at least $21 billion annually to replace aging facilities and comply with existing and future federal water regulations [16]. Monetary investment alone will not resolve this dilemma; it must be met with a new approach to sustainable water infrastructure engineering and management.

The enormity of the problem of deteriorating water infrastructure is apparent. Since rebuilding the entire system is not financially realistic, municipal engineers require the capacity to monitor and maintain the condition of water infrastructure systems. Thus, a reliable assessment and management system is necessary so that municipal engineers can develop long-term cost effective renewal programs [17]. These programs are necessary to ensure that critical pipeline sections are repaired or replaced before they fail. Data is central to managing civil infrastructure effectively [18]. At a minimum, a facility inventory and information about facility condition are essential. But what kind of condition information is necessary? At what level of detail – temporally and spatially – should data be collected? What level of accuracy is acceptable? The answers to these and similar questions determine how resources can most effectively be applied to gathering the information needed to make cost-effective decisions about infrastructure maintenance, repair, and rehabilitation [19]. Many decision-making processes used by municipalities lack the comprehensive integration of environmental impacts and technology solutions required to balance development and environmental well being. Additional research is needed in how to address the renewal of infrastructure through the application of a holistic, system approach that includes issues of system behavior, assessment, deterioration, and renewal [20]. The development, integration, and deployment of state-of-the-art research and technology are needed to maintain and renew the infrastructure more effectively.

The civil engineering curriculum must be altered through a contemporary focus on training a new breed of engineers who are well versed in the multi-disciplinary needs of asset management and maintenance, repair, rehabilitation, and renewal programs.

2. WHAT IS ASSET MANAGEMENT?

What is an infrastructure asset?

The EPA defines an infrastructure asset as “any long-lived capital asset that is operated as a system or network, such as a sewer collection system.” [21] Steve Albee incorporates the idea of “service” in his definition: “Physical facility or component of a physical facility that has a value that enables a service to be provided.” [22]

Figure 1. Infrastructure Assets [23]

Civil Infrastructure assets include bridges, highways, municipality’s assets i.e. water and wastewater infrastructure assets and other publicly owned assets. Only the last types of infrastructure assets are of the interest of this primer.

One of the important objectives of a utility is to maintain an asset’s level of service (LOS) at a desired level, making a comprehensive managerial program is an inevitable part of any utility. An asset management program implemented in the city of Wellington, New Zealand, provides a good case study example.[1]

[1] To download this document please visit USEPA Web site at: http://cfpub.epa.gov/npdes/sso/featuredinfo.cfm

Who is an asset manager?

An asset manager is responsible for conducting and managing the maintenance, repair, and infrastructure renewal program. Optimizing expenditures and maximizing the value of an asset during its life cycle are responsibilities of an asset manager, who must possess business and information management skills.

Figure 2. Asset Managers [24]

Infrastructure asset management

Employing a combination of financial, managerial, technical, and operational skills, asset management is becoming an important part of many utilities' efforts to provide a constant desired level of service while being cost-effective in the long term.

As a terminology, "asset management" may sound new, but its elements have long been employed by U.S. utilities. What is new, however, is how AM unifies, consolidates, and correlates these elements, which we'll examine in this primer.

Federal Highway Administration (FHWA)

The FHWA is one of the leading organizations conducting Transportation Infrastructure Asset Management from its separate office of Asset Management, with branches in each state. The office defines its function in this way:

> Asset management is a business process and a decision-making framework that covers an extended time horizon, draws from economics as well as engineering, and considers a broad range of assets. The asset management approach incorporates the economic assessment of trade-offs among alternative investment options and uses this information to help make cost-effective investment decisions.

This office works in areas of asset management, system preservation, pavement management and analysis, bridge management and inspection, and construction and maintenance activities, as well as technology development, outreach, and partnering

initiatives. It also conducts case studies[2] and training sessions. To date, 11 case studies have been done in several states on different aspects of Transportation Asset Management, e.g., bridge management, data integration, economics, highway economic requirement systems, and life cycle cost analysis. Training sessions are offered as workshops or courses.

High demand, shortage in resources and budget, and continual aging of assets are some of the reasons asset management is essential for this organization. To explore these issues more deeply, see the *Asset Management Primer* [5].

In July 2006 the FHWA office of Asset Management signed a Memorandum of Understanding (MOU) with the United States Environmental Protection Agency's (USEPA) Office of Water Works to exchange technology and increase the collaboration and communication between the two parties to provide better service for the nation's critical infrastructure assets.

2.1- USEPA

EPA: Definitions of Asset Management

"For wastewater management utilities, asset management can be defined as managing infrastructure capital assets to minimize the total cost of owning and operating them, while delivering the service levels customer's desire." [21]

"…a continuous process that guides the acquisition, use, and disposal of infrastructure assets to optimize service delivery and minimize costs over the asset's entire life." [21]

As part of the EPA's Sustainable Infrastructure Initiative, the Office of Water Works is collaborating with partner organizations to host and co-sponsor training sessions and facilitate discussions on best practice in Advanced Asset Management. The need for such training is imperative since each utility is responsible for maintaining its system in good working order, regardless of the age of components or the availability of

[2] To download the PDF version of these case studies please visit: http://www.fhwa.dot.gov/infrastructure/asstmgmt/casestudies.cfm

additional funds. The most efficient method of meeting this challenge can be through asset management programs with long-range planning, life-cycle costing, proactive operations and maintenance, and capital replacement plans based on cost-benefit analyses.

Strategic Municipal Asset Management

The Strategic Municipal Asset Management* report examines international expertise and practices in strategic municipal asset management, with a particular focus on the evaluation of asset management in Australia and New Zealand, and provides an analysis of asset management methodologies, outlined in its best practices below:

Best Practices in Asset Management

To achieve best practices in asset management, organizations must be able to demonstrate:

Figure 3. Best Practices [25]

1. Knowledge of levels of service required by customers
2. Ability to predict future demands for service
3. Knowledge of ownership of existing assets
4. Knowledge of physical condition of assets
5. Knowledge of asset performance and reliability
6. Knowledge of asset utilization and capacity
7. Ability to predict the failure modes and estimated time of failure for assets
8. Ability to analyze alternative treatment options
9. Ability to rank works based on economic analysis
10. Ability to prioritize works to suit the available budget
11. Ability to develop and revise strategic objectives for each asset
12. Ability to optimize operations and maintenance activities

2.2- International Infrastructure Management Manual

The International Infrastructure Management Manual (IIMM) [1] was first introduced by the NAMS Group in 2000 with the second edition coming out in 2002. The new IIMM 2006 edition contains the latest concepts in asset management and more practices and case studies from different infrastructure sectors, presented in a very user-friendly format, which makes it easier and more pleasing to use, especially for those new to this area. To date, it is the most comprehensive manual in covering general Infrastructure management topics and is highly recommended to agencies and people interested in gaining more knowledge on getting the most out of their infrastructure assets. To see the table of content of this manual please click here.

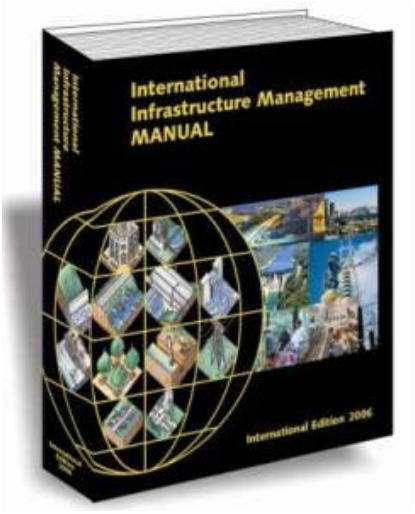

Figure 4. International Infrastructure Management Manual [26]

This manual includes five sections, beginning with the "Introduction," which outlines the benefits that infrastructure managers will gain from using the techniques described. Also briefly introduced are the concepts of Total Asset Management and Lifecycle Asset Management.

Section two, "Implementing Asset Management," describes the principles and processes for successfully implementing asset management planning. It is designed to help asset manager progress quickly through the steps of developing meaningful asset management plans and establishing a framework for the ongoing enhancement of asset management plans to meet real business needs.

Section three, "Implementation Techniques," talks more in details of asset management standards, guidelines, techniques and references, together with examples of key asset management activities such as:

- Developing and consulting

- Optimized decision-making on service levels
- Maintenance planning
- Demand forecasting
- Risk management methods and management.

Section 4, "Asset Management Information System and Data Management"
"… advises how to evaluate and implement information systems to support good asset management planning and decision-making. The section includes guidelines for good data capture and ongoing data management processes." [1]

Section 5, "Country Specific Information," "…provides separate country specific information for Australia and New Zealand outlining the current context of infrastructure asset management planning practices in each country, the relevant drivers, legislation, regulations and related documents that support this Manual." [1]

The New Zealand Asset Valuation and Depreciation Guidelines was also issued by NAMS later in 2001 as a companion for IIMM.

To see the content of this manual please click here.

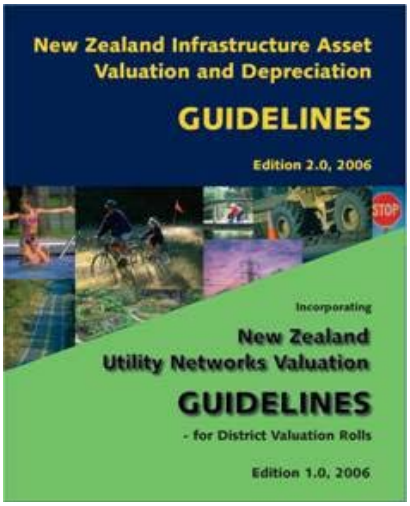

Figure 5. The New Zealand Asset Valuation and Depreciation Guidelines [27]

3. WHY ASSET MANAGEMENT?

According to the Board on Infrastructure and the Constructed Environment (BICE) [28]:

"The United States spends an enormous amount of money annually to replace or repair deteriorated equipment, machines and other components of the infrastructure. In the next several decades, a significant percentage of the country's transportation, communications, environmental, and power system infrastructure, as well as public buildings and facilities, will have to be renewed or replaced."

The concept of asset management has drawn much attention from those responsible for and interested in civil infrastructure systems. Motivated by rising public expectation, changing capital allocation requirements, and increasing resource constraints, many public agencies and enterprises in the United States have begun promoting and coordinating efforts to develop frameworks and decision support systems for infrastructure asset management [29].

3.1- System Demands

- Water and Wastewater assets include water or sewer pipes, treatment plant facilities, pumps, manholes, and so on. Buried underground and thus out of sight, water and wastewater pipes typically are considered less than other assets. Maintenance of many buried assets follows a reactive model, noticed only when deteriorated or, even worse, when a disaster occurs.

- As cities continue to develop and population grows, users are increasing. Some cities like Gelendale, Arizona, had a population of 36,000 in 1970 and 148,000 in 1990, triple its growth, and is estimated to be 300,000 in 2020 [30]. But what of the utility's capacity? Are these utilities adequately controlled? Are the levels of asset service measured and at desired levels?

- Geological conditions such as settling, earth movements, or corrosive soil and tree root intrusion are some of the disturbances that over time can cause deterioration of pipes lines, especially

waste water collection systems, which are usually metal, PVC, or concrete pipes.

3.2- Budget Demands

- An enormous amount of money is spent annually to rehabilitate or replace deteriorated infrastructure assets including facilities and pipelines. This trend does not stop and will continue in coming years and decades, as you cannot stop buried pipes from aging. According to the USEPA estimate, drinking water facilities will need $154 to $446 billion invested in future programs for upgrading aging infrastructure assets.

- The nonlinearity of assets' deterioration rate makes estimating and predicting necessary funds for maintenance and rehabilitation programs complicated.

- Allocating budgets for each city's infrastructure assets is another issue. Major funding sources for these budgets come from the Federal government, taxes, or consumers. Though these are the current providers, we nonetheless should ask: who should be funding these budgets? Federal money always has its constraints, and relying on it is not the wisest choice.

4. ASSET MANAGEMENT FRAMEWORK

- Asset management is a systematic process of maintaining, upgrading, and operating physical assets cost effectively.
- Asset management combines sound business practices, economic theory, and engineering to facilitate a more organized, logical approach to decision-making.
- Asset management provides a framework for handling short- and long-range planning.

Figure 1 shows some of the basic elements of sustainable municipal infrastructure asset management and how the elements build on and complement each other to form an integrated asset management system.

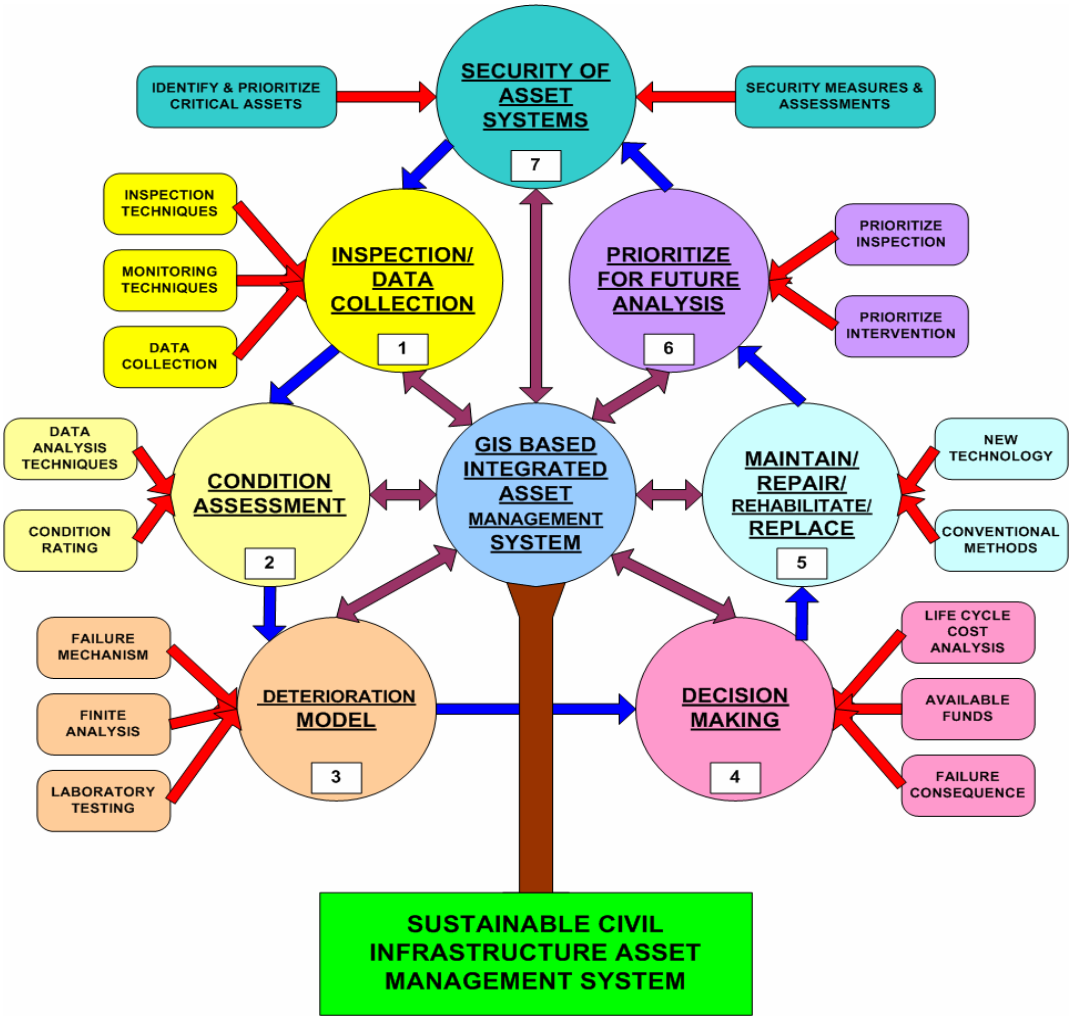

Figure 6. Elements of Sustainable Municipal Infrastructure Asset Management [31]

4.1- Asset Identification

Asset identification is the process of documenting existing assets. Assigning a code or an ID to each component of an infrastructure system lets you link all its related data, making it easy for the operator to locate and access the asset. These data include financial, technical, economic, and management use. Information needed for identification of a component includes location, burial depth, length, slope, size, material, and age.

4.2- Asset Valuation

It is essential to establish the service life of assets to establish the cost of capital renewal and the current asset value.

GASB 34

The Governmental Accounting Standards Board (GASB) was formed in 1984 by the Financial Accounting Foundation to establish standards of financial reporting for state and local governmental entities. GASB 34 refers to the Governmental Accounting Standards Board (GASB) and its Statement 34 (June 1999): ‘‘Basic Financial Statements—and Management’s Discussion and Analysis—for State and Local Governments.’’ The statement establishes a new financial reporting model for state and local governments and introduces the biggest change in history to public sector accounting. GASB developed the new requirements to make annual reports more comprehensive and easier to understand and use.

GASB Perspective:
“Once a community has made the transition to GASB 34 reporting, any collection system components that are acquired, rehabilitated, or significantly improved should be recorded as new assets on the financial statement for the same fiscal year. “ [21]

Community Perspective:
“GASB 34 is a mandate of sorts that is not given to us by the federal government, but by the Federal Accounting Standards Board, which can hold the ‘‘clean audit’’ over our heads if we do not comply.”[32]

GASB 34 requires that financial statements are made available to the public to disclose how funds were budgeted and money spent. In this way, the public will understand how the budget drives asset management and provided services and may then support tax increases if needed to match their expectations. Public review of financial statements and distribution of funding also helps to shape community expectation of service. Likewise, employees gain needed pubic feedback as well as recognition for their efforts.

GASB 34 provides two options for filing the required annual reports: modified or straight-line depreciation methods. Both methods have benefits and drawbacks, as described by Chris Yarnell, author of "Asset Management GASB 34":

Straight-line depreciation

The benefit of straight-line depreciation is the ease of reporting and tracking. Once the initial information or database is developed, it is easily maintained. As time marches on, the asset depreciates at a rate that is established at the onset. The largest drawback to straight-line depreciation is that, for all the effort a department must put forth to develop the database, there is no required maintenance of the database so that it can be used in the end to help make maintenance-funding decisions to benefit the traveling public. [32]

Modified approach

The drawback to the modified approach is the continuous effort it takes to maintain the database. A well-maintained database can be used in return by a department to help make justifiable maintenance decisions that can be shown to be good, justifiable, and defendable expenditures of the taxpayers' money. Thus a significant benefit of the modified approach is that it reflects the actual state of the asset, taking into account actual wear and tear of the asset and the funds put back into its upkeep, as well as major improvements to the asset [32].

Finally, reaction to GASB 34 to date has been spotty. Forward thinking utilities have understood the advantages of implementing GASB 34 recommendations and have grasped the advantages of undertaking the Modified Approach. In essence, well run utilities are already doing the tasks under the Modified Approach so adhering to GASB 34 recommendations is not difficult. However, those utility managers without the luxury of sufficient staff or resources to implement AM practices have a more difficult time in using the Modified Approach. Many utilities assume that their current accounting practices meet the GASB 34 recommendations for depreciating network assets and that they can safely ignore GASB 34. Unfortunately, these utilities are missing an opportunity to realize the real benefits of an asset management program. [33]

4.3- Inspection/Data Collection

- To collect data regarding the condition of an asset, an inspection must be performed. Depending on the type, size, and location of an asset, either crews or machines are used. Closed-circuit TV (CCTV), sonar/CCTV, and static camera are the most common machine-based inspections methods used for inspecting collection systems.

- To conduct a thorough inspection program, utilities must be assured that all assets have been identified and none overlooked. Complete inspection is an expensive and time-consuming undertaking that must be done with perfect planning and scheduling to best support the goals of asset management in different ways.

- Inspection of an asset is based on the prioritized scheduling derived from decisions considering the condition of the asset, to be discussed later.

- For utilities beginning to apply asset management, program scheduling for inspection is of high importance. Inspecting all assets after identification

may take as long as 20 years, while some may need most frequent inspection. The question to ask: are all the assets at the same level of risk and importance? The answer is “no.” Some pipes are in much higher risk of deterioration due to corrosive surrounding soil, differences in loading and earth movement, as well as the capacity of the asset.

4.4- Condition Assessment

- The outputs of inspections are raw data that need to be translated into information. For example, different colors in a video taken by the CCTV method represent different degrees of infection and condition of the asset. By analyzing the data, the condition of the asset is obtained. To predict future behavior of an asset, either a linear deterioration rate is used or a deterioration model (discussed in the next part).

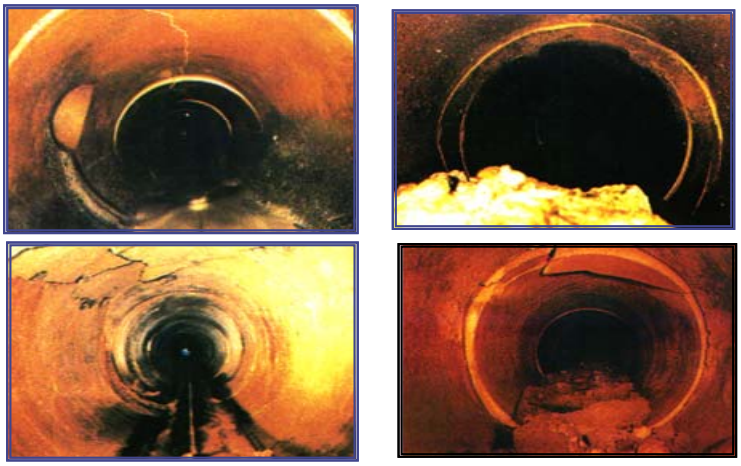

Figure 7. Typical CCTV images from a sewer pipe [34]

- Software is used to assist operators with condition assessment. Some asset management software applications are more advanced and capable of automatically evaluating the condition of assets, identifying the location and level of defects, and assigning a condition rating, while others need a specialist to assign the ratings manually. The key point in this process is to convert the data to accurate and useful information.

Deterioration Model

- Inspection is a costly and time-consuming process, which is inevitably required to predict the behavior and condition of an asset over time. How will the condition of that asset change? Is it possible to predict it?

- Deterioration modeling is the tool used today for predicting future behavior of pipes based on the data collected from inspection. Other information used to develop the model includes material and depth of the pipe, type of the soil, level of water table, and so on.

4.5- Decision Making

"Water Infrastructure: Comprehensive Asset Management Has Potential to Help Utilities Better Identify Needs and Plan Future Investments," a report by the U.S. General Accounting Office (GAO) (March 2004), outlines some benefits of AM for making more efficient future investments. Another benefit includes using information more effectively to coordinate across departments.

Life cycle cost analysis

- Assets follow a cycle of behavior after construction. As the condition of an asset approaches its least acceptable condition, rehabilitation activities are required.

- Usually the rate of deterioration derived from deterioration models dictates the timing of the next action, which can be either maintenance and rehabilitation or replacement.
- LCCA provides decision makers with the most economical strategies to maintain the public assets while satisfying their needs. In an LCCA process, only those costs, which are different for alternatives, need to be considered. This is an important distinction as it may considerably simplify the analytical process and reduce the required information.

- *Optimized Decision Making Guidelines* is another manual by NAMS. It provides step-by-step guide for making optimized decisions for infrastructure acquisition, renewal, operations and maintenance. To learn more about the content if this manual please click here.

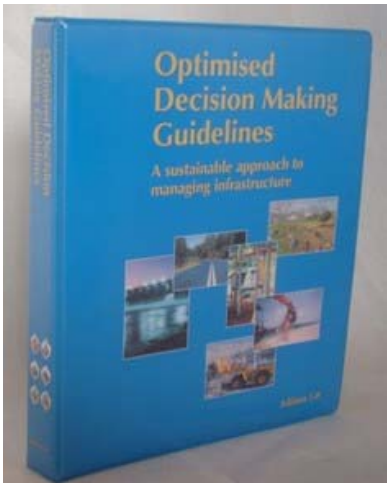

Figure 8. *Optimized Decision Making Guidelines*
Management Manual [35]

4.6- Maintenance and Rehabilitation Planning and Implementation

- More rehabilitation and maintenance programs exist today due to growing awareness that proper periodic rehabilitation and maintenance arrests deterioration. Still many cities take no action to maintain and rehabilitate the municipalities' assets until a failure occurs. In such an emergency, cost will be manifold. Maintenance programs prevent failure of the asset before major deterioration occurs. It is a proactive approach, which tackles problems before they are born. In the case of storm water utilities, such a program saves money by reducing the likelihood of a breakdown; likewise saving money that would have been spent on cleanup. Finally, field staff can provide feedback on the viability of different maintenance and rehabilitation strategies in case mid-course corrections are necessary.

Trenchless Techniques for Sewer rehabilitation

- In traditional dig-and-replace techniques, an additional parallel or a replacement pipe will be placed by digging all along the length of the

existing one. In trenchless techniques, the existing pipe is used as a host to a new pipe or liner, while in dig-and-replace the existing (old) pipe is removed.

- Traditional dig-and-replace methods cannot be used to rehabilitate sewer pipes everywhere, especially in urban environments where this method can cause disruption to traffic and the transportation system. In some instances, pipes are buried underneath a tree or even beneath a recently constructed building. In such cases trenchless techniques are valuable. Spot repairs and manhole-to-manhole lining are other benefits

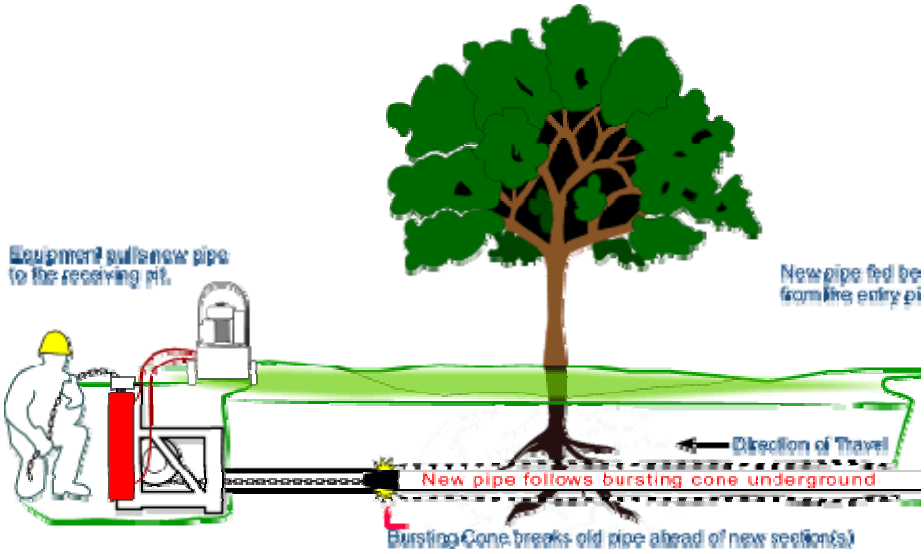

Figure 9. An Illustration of simple Trenchless technique [36]

- Installation time is a critical issue and plays an important role in choosing between traditional and trenchless techniques. City officials may dictate a certain time length, which is usually short, for shutting the line. In such cases, the available time may not accommodate the dig-and-replace method, whereas trenchless techniques can overcome such time constraints.
- Another very important issue is the effect of dig and replace technique on traffic. Most of the pipe lines are along the streets and traffic routes.

Imagine what would happen if you want to use this technique to replace a pipe at a conjunction. Figure 7.a shows a conjunction with the traffic flow. Figure 7.b shows the same conjunction while using dig-and-replace technique while figure 7.c shows the same conjunctions using trenchless technique. Traffic congestion is the first effect accompanying with many other social effects.

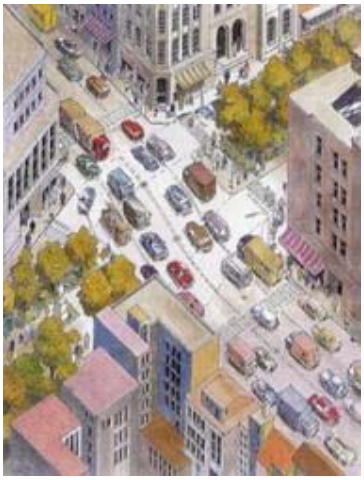

Figure 10.a.Normal traffic [37]

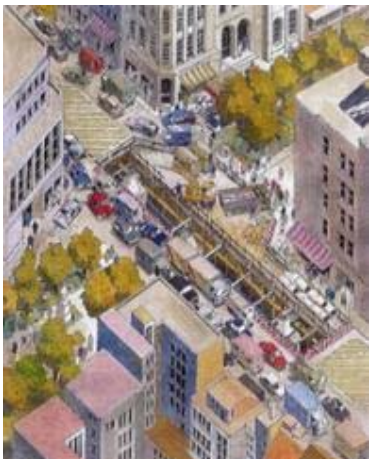

Figure 10.b. Using dig-and-replace technique (Congestion is observed) [37]

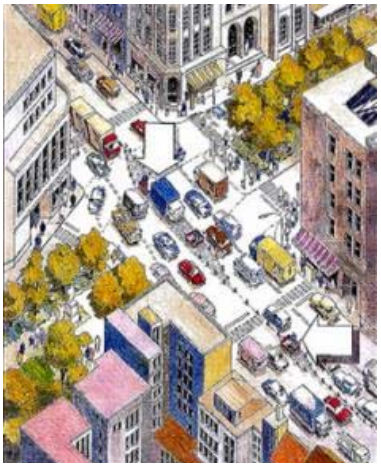

Figure 10.c. Using trenchless technique (The traffic still flows) [37]

- In short, trenchless techniques are mostly the appropriate choice for urban areas and are more beneficial both in time savings and convenience for citizens. [38]

4.7- Prioritization for the Future

- Financial Planning

"Financial forecasting should be performed over a period of 5 to 10 years and should be updated annually." [21]

4.8- Water Infrastructure Security

Security and Safety of Municipal Infrastructure Systems

The September 11, 2001, attacks on the World Trade Center and the Pentagon have drawn attention to the security of many institutions, facilities, and systems in the United States, including the nation's water supply and water quality infrastructure. These systems have long been recognized as being potentially vulnerable to terrorist attacks of various types, including physical disruption, bioterrorism/chemical contamination, and cyber attack. Damage or destruction by terrorist attack could disrupt the delivery of vital human services in this country, threatening public health and the environment, or possibly causing loss of life. Further, since most water infrastructure is government-owned, it may serve as a symbolic and political target for some. The Congressional Research Service (CRS) report (2005) for congress presents an overview of this large and diverse sector, describes security-related actions by the government and private sector since September 11, and discusses additional policy issues and responses, including congressional interest.

Figure 11. Water Security [39]

A bill entitled "Wastewater Treatment Works Security Act of 2003" was introduced in the Senate on May 12, 2003, that will provide grants for conducting vulnerability assessments (VA's) and implementing security enhancements. The VAs look at the following five plant assets: the physical plant, the people (employees), the knowledge base (plans, drawings, etc.), information technology, and customers.

5. ASSET DATA and INFORMATION MANAGEMENT

- A utility's information system plays an important role since it links all information, activities, and aspects of an asset management program. From the location and specification of a utility component or an asset, to scheduling a coming maintenance/rehabilitation program—all should be managed with an integrated information system.

- During excavation or construction work, especially in large cities, crews sometimes hit buried pipes, resulting in a system breakage that may have serious consequences. Such difficulties usually rise from a lack of cooperation between parties and accessibility to proper information. Maps and documents for pipes installed long ago may no longer exist and those that do may not be properly shared with those in charge.

- Another important issue, one relevant to even new asset, is the loss of information associated with the move or retirement of personnel. By organizing and properly documenting these vital components of asset management, accessing the information is much more convenient for new employees and decision makers.

- For a small utility a well-designed spreadsheet may be adequate; however larger scale utilities or municipalities may need more sophisticated and advanced asset management software.

Geographic Information Systems (GIS)

- Some software linked to a GIS database system, which allows the operator to, locates an asset on the map and provides instant access to edit the information. Some more complicated software are even equipped to programs that allows user to enter data taken from inspection to the appropriate sections and zones in the map and get instant analyze of the data. Thereby the data transforms to information used in decision-making process.

- GIS provides the utilities many feature especially having instant access to the assets and locating different component of the system like manholes, pipes, FireHydr and so on. If any problem occurs and the utility gets informed by phone, they can quickly locate the exact location of the problem by asking some basic question about the street names or other identical signs close to the location and dispatch their team at the earliest possible time. Using GIS system also provides utilities the opportunity to highlight critical zones, which need more frequent periodically inspection, to give more attention to crisis situations.

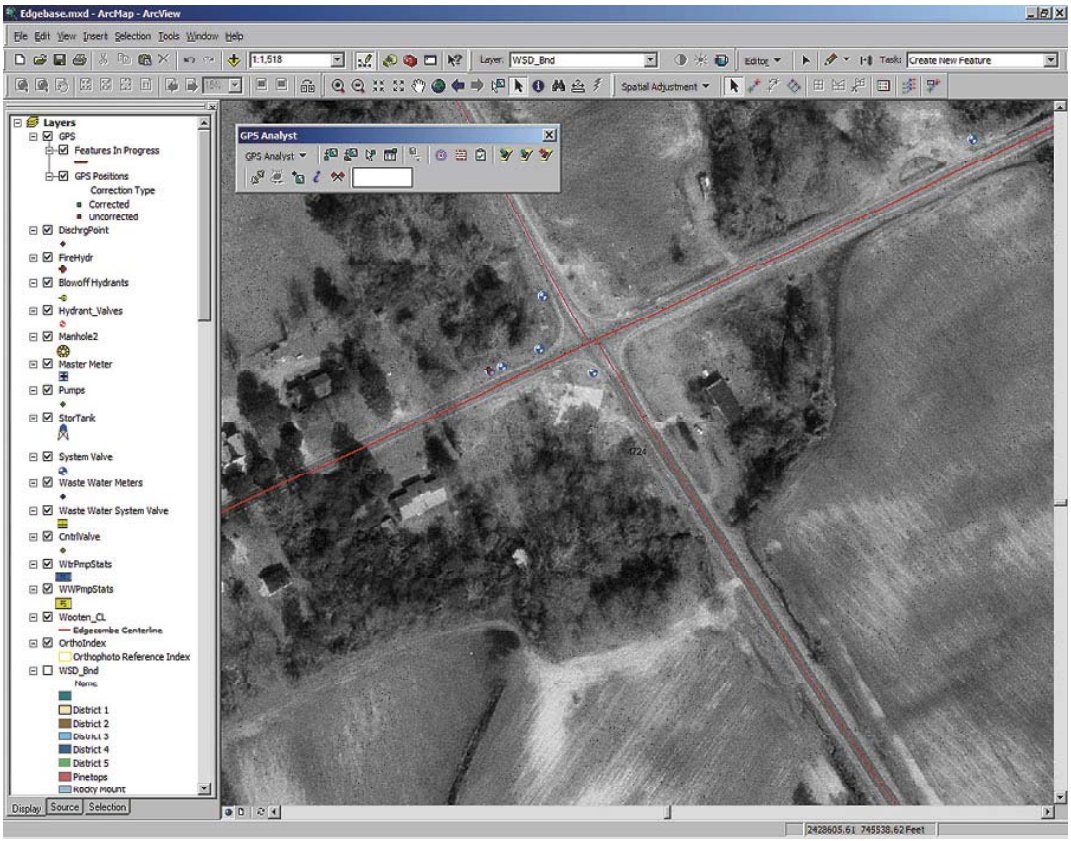

Figure 12. GIS database for a water/wastewater system [40]

- Although the cost of implementing a comprehensive GIS system is expensive especially for small communities and municipalities, the benefits gained for long term are considerable and worth it.

6. PERSPECTIVES ON ASSET MANAGEMENT

National Perspective on Municipal Infrastructure Asset Management

Leading organizations and agencies in water and wastewater are briefly introduced below, along with their activities related to asset management in the United States. (Descriptions within quotation marks have been quoted from sponsoring Web sites.)

6-1- Water Environment Federation (WEF)

WEF is a not-for-profit organization for technical and educational purposes, mainly focusing on water quality protection and wastewater treatment by the following services:

- Sponsoring conferences
- Providing technical training sessions and education workshops and seminars
- Technical publications (magazines and journals)
  - Water environment and technology
  - Water environment research
- Newsletter
- Reviewing, testifying, and making comments on environmental regulations and legislation
- Public information and education
-

WEFTEC® - The Water Quality Event

WEFTEC, as the largest technical exhibition and conference on water quality and wastewater treatment technology in North America, annually hosts 16,000 water quality experts from around the world. Infrastructure security and asset management are topics addressed in this conference.

Managing the Water and Wastewater Utility is one of the best books published by WEF in asset management.

Water Is Life, and Infrastructure Makes It Happen™ is a new public education program "designed to inform and motivate the public, ratepayers, and elected officials to invest in water and wastewater infrastructure." For more information about this organization, please visit http://www.wef.org.

6-2- Water Environment Research foundation (WERF)

As a not-for-profit organization in the water and wastewater industry, WERF seeks to promote the development and application of sound science to water quality management by providing nearly $7 million in new projects annually, mainly focusing on management decisions, science policy, and water quality topics.

Sustainable Infrastructure Management Program Learning Environment (SIMPLE):

"This web-based knowledge management tool assists wastewater treatment facilities in developing a proper life-cycle asset management system. By gathering asset management best practices and processes from around the world, SIMPLE offers users a look at state-of-the-art asset management programs and provides the tools they need to begin a program of their own." For more information about WERF's activities and products please visit the Web site at: www.werf.org

6-3- American Public Works Association (APWA)

APWA "is an international educational and professional association of public agencies, private sector companies, and individuals dedicated to providing high quality public works goods and services. . . . APWA provides a forum in which public works professionals can exchange ideas, improve professional competency, increase the performance of their agencies and companies, and bring important public works-related topics to public attention in local, state and federal arenas."

APWA's publications found in the bookstore webpage, include manuals, books, CD-ROMs, and others, cover many topics in public works such as "Facilities and Grounds," "Leadership, Management, and Administration," "Water Resources," and "Construction and Municipal Engineering." Some of selected APWA's publications in Asset Management are:

- Infrastructure Asset Management Manual
- GASB 34 Statement & Implementation Guide
- Managing Infrastructure Assets - Knowledge Product
- The Facility Management Handbook, 2nd Edition

6-4- The National Association of Clean Water Agencies (NACWA)

"NACWA represents the interests of the country's wastewater treatment agencies, true environmental practitioners that serve the majority of the population in the United States, and collectively treat and reclaim more than 18 billion gallons of wastewater each day. NACWA maintains a key role in the development of environmental legislation, and works closely with federal regulatory agencies in the implementation of environmental programs." [41]

Managing Public Infrastructure Assets to Minimize Cost and Maximize Performance (Asset Management Handbook) published by the **Association of Metropolitan Sewerage Agencies (AMSA)** is a useful handbook in water and wastewater.

6-5- The Water Infrastructure Network (WIN)

"The Water Infrastructure Network (WIN) is a broad-based coalition of local elected officials, drinking water and wastewater service providers, state environmental and health administrators, engineers and environmentalists dedicated to preserving and protecting the health, environmental and economic gains that America's drinking water and wastewater infrastructure provides." Two reports by WIN discussing water and wastewater infrastructure financing programs:

"Clean & Safe Water for the 21st Century" and "Water Infrastructure NOW: Recommendation for clean and safe Water in the 21st Century"

For more information please visit WIN's Web site at win-water.org.

6-6- American Water Work Association (AWWA)

Founded in 1881, AWWA is the largest organization of water supply professionals in the world dedicated to water quality and support's improvement as a non-profit scientific and educational society. AWWA is distinguished as "…the authoritative resource for knowledge, information, and advocacy to improve the quality and supply of water in North America and beyond." [42] Members of this society are "…treatment plant operators and managers, scientists, environmentalists, manufacturers, academicians, regulators, and others who hold genuine interest in water supply and public health."

Some of the activities of AWWA:

- Conferences
- Public Officials Program
- Seminars
- Teleconference
- E-Journal
- Forums

International Perspective on Infrastructure Asset Management

In a number of countries around the world, asset management programs have become a vital part of utilities; among these Australia, New Zealand, United Kingdom, and South Africa are the most experienced and successful.

6-7- International Infrastructure Management Manual

The Institute of Public Works Engineering Australia (formerly the Institute of Municipal Engineers Australia-IMEA) and the New Zealand National Asset Management Steering (NAMS) Group have jointly developed an *International Infrastructure Management Manual* [1]. This manual is divided into five sections: introduction, implementing asset management, implementing techniques, asset management information systems, and country specific information. The manual defines asset management; introduces the concepts of total asset management and life cycle asset management; shows the benefits provided by asset management techniques; outlines best practices; provides principles and processes of asset management implementation guidelines; shows how to evaluate and implement information systems to support good asset management planning and decision making; cites case studies, and includes an implementation plan.

6-8- Australian National Audit Office (ANAO)

The ANAO's *Asset Management Handbook* [43] helps asset managers implement asset management principles. The *Asset Management Handbook* provides an overview of asset management principles, instructions on the application of asset management principles and concepts, a selection of case studies, and a glossary of terms. The Australian National Audit Office found that:

- Most organizations can benefit from proper asset management strategies;
- Asset management strategies should integrate with other strategic planning processes;

- Alternatives should be considered when purchasing and replacing assets;
- Life-cycle costing analysis should be used;
- Improved asset management can occur from proper codification of costs of assets;
- Decisions about asset decommissioning should be made at a strategic level, and
- Regular inspection of the condition and performance of assets, combined with careful planning for replacement, can maximize the return on investment.

6-9- National Guide to Sustainable Municipal Infrastructure

The *National Guide to Sustainable Municipal Infrastructure* [44] is funded under the Infrastructure Canada Program (ICP) and managed by the Federation of Canadian Municipalities (FCM) in partnership with the National Research Council of Canada (NRC). The *Guide* provides a road map to the best available solutions (*Best Practices*) for addressing municipal infrastructure issues. It also serves as a focal point for the Canada-wide network of practitioners, researchers, and municipal governments focused on infrastructure operations and maintenance.

6-10- Municipal Infrastructure Investment Planning (MIIP)

The Municipal Infrastructure Investment Planning [45] project is a research initiative of the National Research Council Canada and a number of municipalities. Its objectives are:

- Evaluating existing tools and techniques to assist municipal infrastructure investment planning, and
- Developing prototype tools and techniques for asset managers to better manage their municipal infrastructure

Specific deliverables of the MIIP project include: evaluations of Information Technology (IT) tools, surveys of the use of asset management in practice, case studies of asset management, and guidelines and manuals on asset management [46].

7. IMPLEMENTING ASSET MANAGEMENT

- An asset management program is not only required for large utilities but also for small systems. Unfortunately there is no complete and comprehensive instruction on how to implement an asset management program for water and wastewater infrastructure assets; however, available manuals, books, and reports are valuable resources to help utilities achieve a proper AM program. An AM program needn't be complicated to be useful. For small utilities with budgeting constraints, applying a complex asset management program would be wasteful and not even useful. In such utilities, a basic program, like an excel sheet database, would be a good start. Then as the system grows and enhances more advanced programs can be used. A benefit of this strategy is that as the system develops, staff becomes more familiar and competent in applying asset management concepts. A useful document prepared by the EPA is *Asset Management: A Handbook for Small Water Systems*. It is recommended to the owner and operators of small utilities as a good reference for starting an AM program.[3]

- More advanced asset management technologies and programs are used for utilities at high-level risk of deterioration, those of high value with potentials of huge financial impact, and, finally, systems that have considerable complexity in terms of design, size, location, or importance.

- A mandate from Congress for utilities to develop a comprehensive AM program can be a good solution and policy.

- Today, ten times as many professionals are focusing on AM than last year, with their numbers increasing continuously because of the scale of challenge ahead.

[3] To download a free PDF copy of this document please visit: http://www.epa.gov/safewater/smallsys/pdfs/guide_smallsystems_asset_mgmnt.pdf

8. RESEARCH and EDUCATION in ASSET MANAGEMENT

Water (drinking water and wastewater) plays a critical role in every aspect of civilization: agriculture, industry, economy, environment, recreation, transportation, culture, and health. While clean water and sanitary conditions remain an elusive luxury in many parts of the world, we, as Americans, take them for granted. Much of America's drinking water and wastewater infrastructure, however, is old and deteriorating. A crisis looms as our demands on these systems increase. The costs associated with renewal of these eroding systems are staggering. There is a critical disconnect between the methodological remedies for infrastructure renewal problems and the current sequential or isolated manner of renewal analysis and execution. These disconnect manifests in the need for a holistic systems perspective to address the renewal problem. New tools are needed to provide the intellectual support for water infrastructure decisions necessary to sustain economic growth, environmental quality, and improved societal health.

Meeting the challenge for sustainability and intelligent infrastructure renewal will require a reevaluation of the purpose for infrastructure systems within a sustainable society, which in turn will require development of an understanding of the relationship between sustainable community development and the demands for efficient use of technology and materials associated with infrastructure systems. This requires the education of engineers, technological professionals, and decision/policy makers with an integrated view of technologies and their applications, and sensitivity to the complex and diversity of the cultural, natural, and societal environment [47]. In addition, students need to acquire the analytical tools to assess risks, to perform life-cycle analyses, and to solve technical problems, cognizant of and taking into consideration the economic, socio-political and environmental implications [48].

Education is critically needed in the areas of infrastructure failure, sensor technology, life-cycle cost analysis, and renewal and rehabilitation engineering to give both students and the professional engineering workforce the skills needed to revitalize and preserve our nation's municipal infrastructure system. The education plan should involve a systems approach to civil infrastructure management and disseminating the results to K-12 students, graduate and undergraduate courses and research, professional development offerings for engineers and researchers.

9. CONCLUSIONS

- Asset management of municipal infrastructure system can bring major benefits by ensuring that scarce resources are used in the most cost effective manner, thereby enhancing economic growth, improving living standards and improving environmental sustainability.

- The first step in implementing an Asset Management program is having enough understanding and knowledge about this important concept and its components, which requires skilled employees. Therefore hiring personnel with the appropriate skill or providing training sessions for current personnel is a must for municipalities or other agencies.

- Asset management is a systematic process of maintaining, upgrading and operating physical assets cost effectively.

- It combines sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making.

- Thus, asset management provides a framework for handling short- and long-range planning.

10. ACKNOWLEDGEMENT

The authors would like to thank a number of individuals who contributed either directly or indirectly to the development of this municipal infrastructure asset management primer.

11. REFERENCES

[1] IIMM, International Infrastructure Management Manual – Version 2.0, 2002.

[2] AASHTO (2003) American Association of State Highway and Transportation Officials www.aashto.org/aashto/home.nsf/FrontPage.

[3] PONTIS, Cambridge Systematics, Inc. Pontis Release 4 User's Manual, AASHTO, Washington, D.C., 2001.

[4] FHWA (2000), *Highway Economic Requirements System State Version, (HERS-ST)*, Office of Asset Management**),** Federal Highway Administration, US Department of Transportation, www.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.htm

[5] FHWA (1999) *Asset Management Primer*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, www.fhwa.dot.gov/infrastructure/asstmgmt/amprimer.pdf

[6] FHWA (2002) *Life-Cycle Cost Analysis Primer*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.htm

[7] FHWA (2001) *Data Integration Primer*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, http://www.fhwa.dot.gov/infrastructure/asstmgmt/difact.pdf

[8] GASB (2001) *Basic Financial Statements—and Management's Discussion and Analysis—for State and Local Governments*, Governmental Accounting Standards Board, Norwalk, CT.

[9] USEPA (2006), Office of Wastewater Management, Asset Management http://www.epa.gov/owm/assetmanage/index.htm

[10] United States Environmental Protection Agency (U.S. EPA), (2002). "*Asset Management for Sewer Collection Systems*," Washington D.C.

[11] United States Environmental Protection Agency (U.S. EPA), (1999). "*Protecting Sources of Drinking Water: Case Studies*," Washington D.C.

[12] U.S. Environmental Protection Agency (U.S. EPA), (2000). "*Liquid Assets*," Washington, D.C.

[13] American Society of Civil Engineers (ASCE), (2005). "*Report Card for America's Infrastructure*," Reston, VA.

[14] American Society of Civil Engineers (ASCE) Policy Statement 480, (2000a). "*Clean Water Infrastructure Financing*," Reston, VA.

[15] American Society of Civil Engineers (ASCE) Policy Statement 326, (2000b). "*Wastewater Facilities Construction Funding*," Reston, VA.

[16] Water Infrastructure Network (WIN), (2000). "*Clean and Safe Water for the 21st Century*," Washington, D.C.

[17] World Bank Group, (WBC), (2000). "*Strategic Municipal Asset Management*," Background Series in Municipal Finance, prepared by Worley International Limited, Washington, D.C.

[18] National Research Council (NRC), (1995). "*Measuring and Improving Infrastructure Performance*," National Academy Press, Washington, D.C.

[19] National Science Foundation (NSF), (1995). "*Civil Infrastructure Systems. An Integrative Research Program*," Washington, D.C., March.

[20] National Science Foundation (NSF), (1993). "*Civil Infrastructure Systems Research: Strategic Issues*," Report of the Civil Infrastructure Systems Task Group, Washington, D.C.

[21] U.S. Environmental Protection Agency (U.S. EPA), (2002). "*Asset Management for Sewer Collection Systems," Washington D.C.*

[22] Natalie Eddy, NESC, (2005). "*Asset Management from Theory to Reality."*

[23] http://www.gscc.org/Infrastructure/Infrastructurefiles/Infrastructure.gif

[24] http://www.irisfinancial.com/web/25/0/5/0.htm

[25] http://www3.best-in-class.com/beb

[26] http://www.nams.org.nz/International%20Infrastructure%20Management%20Manual

[27]http://www.nams.org.nz/Infrastructure%20Asset%20Valuation%20and%20Depreciation%20Guidelines%202006%20Edition

[28] BICE (1999), "*Research Agenda for Test Methods and Models to Simulate the Accelerated Aging of Infrastructure Materials*," National Academy Press, Washington, D.C.

[29] Garvin, M.J. (2001). "*Challenges of Infrastructure Asset Management*," www.icisnyu.org/admin/files/garvin.pdf

[30] William J. Thornton, CMC, (2001). "Asset Management in Prioritizing Water Distribution Capital Improvement Projects."

[31] Sinha, S.K. (2005). "*Civil Infrastructure Asset Management*," Graduate Course Materials in Civil & Environmental Engineering at the Pennsylvania State University.

[32] Chris Yarnell, P.E., (2004), *"Asset Management GASB 34, And the Local Entity Perspective,"* January.

[33] Henry R. (Kelly) Derr, P.E., "*Asset Management Is Much More Than an Annoying Buzzword"*

[34] NASSCO, 2001. "*Pipeline Assessment and Certification Program*," Version 3.0 Edition Reference Manual, Maryland.

[35] http://www.nams.org.nz/Optimised%20Decision%20Making%20Guidelines.

[36] http://www.alpha-plumbing.com/images/workers-in_pit-lg.gif

[37] http://www.istt.com/index.cfm?menuID=10

[38] U.S. Environmental Protection Agency (U.S. EPA), (2002).*"Collection Systems O&M Fact Sheet, Trenchless Sewer Rehabilitation," Washington D.C.*, September.

[39] http://www.uwm.edu/News/PR/03.06/images/water_security.jpg

[40] http://www.esri.com/news/arcnews/summer05articles/summer05gifs/p19p2-lg.jpg

[41] The National Associasion of Clean Water Agencies (NACWA), (2006), http://www.nacwa.org/about/

[42] American Water Works Associasion (NACWA), (2006), http://www.awwa.org/

[43] ANAO (1996) Asset Management Handbook, Australian National Audit Office, Canberra, Australia, www.anao.gov.au

[44] Guide (2003) National Guide to Sustainable Municipal Infrastructure www.infraguide.gc.ca

[45] MIIP (2003) Municipal Infrastructure Investment Planning Project www.nrc.ca/irc/uir/miip

[46] MIIP Report, (2004). "A Primer on Municipal Infrastructure Asset Management," National Research Council, Canada.

[47] Hudson, R., Haas, R., and Uddin, W., (1997). "Infrastructure Management," McGraw Hill Publication, N.Y.

[48] Grigg, N., (2000). "Demographics and Industry Employment of Civil Engineering Workforce," J. of Professional Issues in Engineering Education & Practice, ASCE, 126(3), pp. 116-124.

[49] Short, J.J., (1997). "Infrastructure Visionaries," Civil Engineering Magazine, ASCE, 67(8), pp. 63-64.