

Process Benchmarking Drives WWTP Maintenance Optimization within the National Water and Wastewater Benchmarking Initiative: City of Calgary and the Regional District of Nanaimo Demonstrate that Business Process Design Must Precede Technology

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Abstract

This case study highlights how advanced metric benchmarking can be used as a tool to prioritize and initiate detailed process benchmarking. Process benchmarking should be used specifically to guide overall performance improvement. In this case study, process benchmarking was used to improve maintenance management practices within a group of a dozen advanced water and wastewater utilities within the National Water and Wastewater Benchmarking Initiative in Canada. This technical paper describes how the process benchmarking was undertaken and displays some of the results through case studies from the City of Calgary and the Regional District of Nanaimo.

Keywords

Benchmarking, Maintenance Management, Process Mapping, Performance Improvement

Introduction

The problem with metric benchmarking is that taken in isolation, it is of limited use. It can be used to demonstrate where a water/wastewater utility compares in relation to other utilities within the same benchmarking program (where the same suite of performance indicators are being used) and in some cases, it can be used to assess success in meeting certain levels of service. Even if a program is seen as successful in the above achievements, pure metric benchmarking will lose the interest of participants quickly unless tangible benefits can be identified and captured in a reasonable time frame.

One of the industry- prescribed routes to accrue tangible benefits is to use metric benchmarking as a means to prioritize areas that can be enhanced with process benchmarking. That is to say, metric benchmarking should be used to quantify and rank the best opportunities to conduct performance improvement. Process benchmarking can be a highly effective tool to assist with performance improvement. While this makes intuitive sense, it is hard in practice to implement and sustain.

This case study will demonstrate how metric benchmarking was used within the well-established Canadian National Water and Wastewater Benchmarking Initiative (NWWBI) to identify a

potentially enormous opportunity to deploy process benchmarking. The preliminary results of benchmarking suggested that the Canadian water sector in general was not conducting water and wastewater treatment plant maintenance according to well established maintenance management best practices even though most utilities were equipped with modern computerized maintenance management systems (CMMS), and well trained and educated maintenance staff. Plant maintenance was excessively reactive and therefore inefficient. Since too many maintenance resources were being expended on reactive maintenance, many plants were not able to complete their required Preventive Maintenance program each year, which causes assets to deteriorate prematurely.

An interesting feature of this case study was not that the original performance indicator (PI) was successful in quantifying the magnitude of the opportunity, but that the PI was investigated because the entire membership of the NWWBI had misinterpreted a seemingly basic performance indicator, and was instead reporting conflicting data over a significant number of years. By getting to the root of the poor ability to report on a vital performance indicator, it was possible to design a process to improve plant maintenance practices throughout the Canadian benchmarking partnership.

The National Water and Wastewater Benchmarking Initiative

The National Water and Wastewater Benchmarking Initiative (NWWBI) was established in 1998 to provide tangible statistical feedback to participating utilities to help them guide strategic performance improvement. The NWWBI includes approximately 75 different Performance Indicators to measure attainment of seven core objectives that reflect the overall mandate of 45 of Canada's most advanced water and wastewater utilities. The seven core utility objectives are presented below:

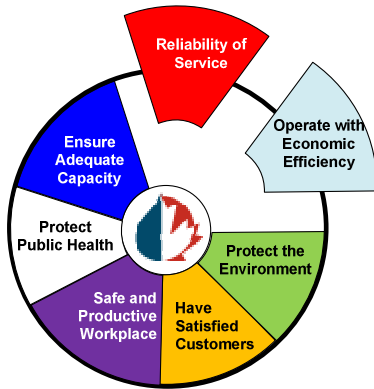


1. Provide Service Reliability
2. Provide Sufficient Service Capacity
3. Meet Service Requirements with Economic Efficiency
4. Protect Public Health and Safety
5. Provide a Safe and Productive Workplace
6. Have Satisfied and Informed Customers
7. Protect the Environment (Water, Land, and Air)

The first few years of this partnership were dedicated to stabilizing the performance indicators, testing the methodology, and then optimizing the data collection processes in each of the participating utilities. Once this was accomplished, the NWWBI began focusing efforts on process benchmarking in functional areas where the need was the greatest and where significant operational improvements were attainable. More information on the NWWBI can be found at www.nationalbenchmarking.ca

Improving Treatment Plant Maintenance Identified as a Priority Strategy

As part of a general industry-wide directive to “do more with less”, all water and wastewater utilities in Canada are being pushed to enhance system reliability while keeping costs down. Efficient treatment plant maintenance planning was identified as a priority strategy in this regard.



Optimized maintenance planning should result in improvements in at least two of the core utility objectives:

- 1) Improve plant reliability
- 2) Operate with greater economic efficiency

The first step in implementing such a strategy is to determine where you are before you decide where you need to go. This is where metric benchmarking is valuable. The Performance Indicator (PI) that was selected as a high level measure of treatment plant maintenance effectiveness is presented below:

$$\text{Reactive Maintenance Ratio} = \frac{\text{Unplanned Maintenance Hours}}{\text{Total Maintenance Hours}}$$

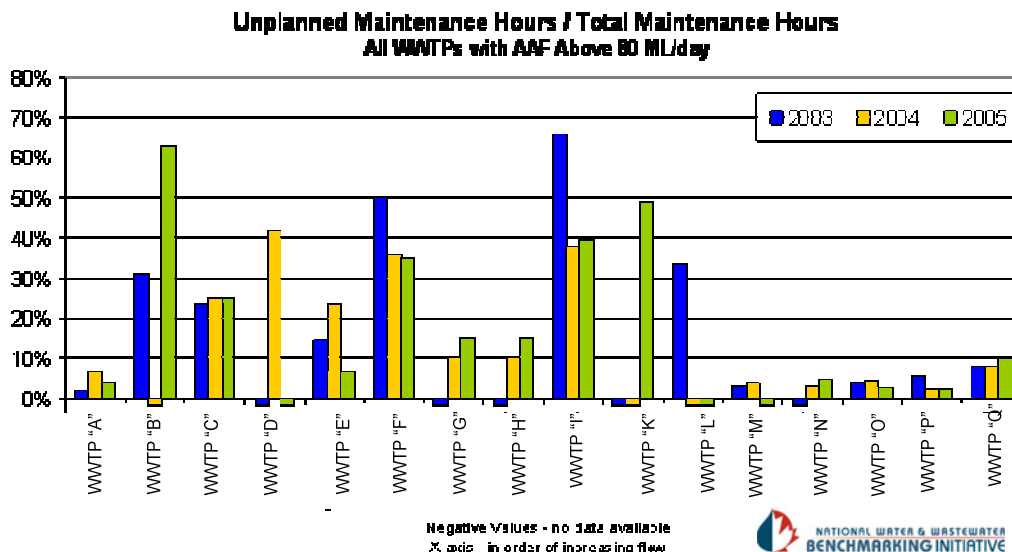
This PI was prioritized by the NWWBI in 1998, as it was recommended in the WERF Publication “Benchmarking Wastewater Operations” in 1996. This same performance indicator is presently included within the current AWWA QualServe Benchmarking program¹. The expectation was that a high ratio would be indicative of a reactive maintenance program, and possibly high volumes of urgent corrective work that demands immediate attention. Reactive work is presumed to be less efficient than proactive work.

An interesting feature of this case study was not that the original performance indicator was successful in quantifying the proportion of reactive maintenance work. The PI was investigated because the entire membership of the NWWBI had misinterpreted or misunderstood a seemingly well defined Performance Indicator. This was evidenced by conflicting data reported over a significant number of years. Figure 1 displays the results of the Performance Indicator “Unplanned Maintenance Hours/Total Maintenance Hours” from 16 large and advanced wastewater treatment plants during the years 2003 to 2005 (before the process benchmarking was initiated). All of the treatment plants had modern computerized maintenance management

¹ Benchmarking Performance Indicators for Water and Wastewater Utilities: Survey Data and Analyses Report; Lafferty and Laur, AWWA, 2005

systems in place, and were well equipped to conduct a complete program of corrective and preventative maintenance.

Figure 1: Maintenance Efficiency Benchmarking Results for Selected WWTPs



Note: Negative values in the above graph report that data was not available.

Taking the First Step: Acting on PI Results

An important foundation for productive metric benchmarking is that if a PI does not result in useful information, it should be investigated or alternatively, deleted from further use. NWWBI participants were not able to make any useful conclusions from the data reported in Figure 1. Detailed discussions about this data demonstrated that there were significant misunderstandings in the PI definition, and that the data needed to populate this PI was not reportable from any of the plant CMMS systems. The reported values were estimates and even guess-work in some cases. Once this issue was recognized as an important gap in vital utility management information, a methodology for Maintenance Management Process Benchmarking was initiated with a Process Definition workshop in 2007 that included the NWWBI Project Manager (AECOM), and eight utility partners to represent the full NWWBI membership.

Establishment of a Process Improvement Task Force: Implementation of Best Practice-based Maintenance Management within Water and Wastewater Treatment Plants

The first function of the Process Improvement Task Force was to establish terms of reference and objectives. The objectives of the Task Force were agreed as follows:

1. Confirm the objectives of “maintenance planning” as it pertains to treatment plants.
2. Confirm what constitutes “success” in maintenance planning, and then advance processes that can result in success

3. Compare the basic maintenance activities, work priorities, and associated performance targets that exist amongst Canadian municipalities.
4. Design reports to measure the attainment of maintenance objectives, isolate and identify maintenance “problem” areas, and to improve the management of maintenance.
5. Identify and share maintenance related best practices.

Working to the objectives, the Task Force developed a milestone-based series of activities that would move the group (who were all in different phases of their own local program implementation) on a similar path to achieve the objectives. Milestones were identified as follows:

1. Agree on a high level business model for maintenance management so that all benchmarking participants can conduct their own evaluation regarding their current gaps and deficiencies within the overall business model;
2. Standardized the maintenance Work Order prioritization scheme to fully define “reactive” work;
3. Agree on a common maintenance management business process design that is based on generally accepted maintenance management best practices;
4. Adoption of a suite of common Maintenance Management Key Performance Indicators (KPIs) and standardized Management Reports targeted to provide factual input to improve maintenance operations, and
5. Advance a peer to peer community of maintenance management practitioners to collaborate and share results in a planned sequence of Best Practice implementations.

Confirm a Common Business Model for Maintenance Management

To achieve success in managing the “business” of maintenance, a well defined business model is essential. While the installation of a CMMS is an important step in assisting a “maintenance management” philosophy, the major productivity and efficiency improvement opportunities lie outside the area of computerization. Computerization must be associated with a complete process management system (with regard to people, processes, and technology). In general terms, the process of organizing a maintenance management system is similar to organizing any management system (and is in keeping with general quality management).

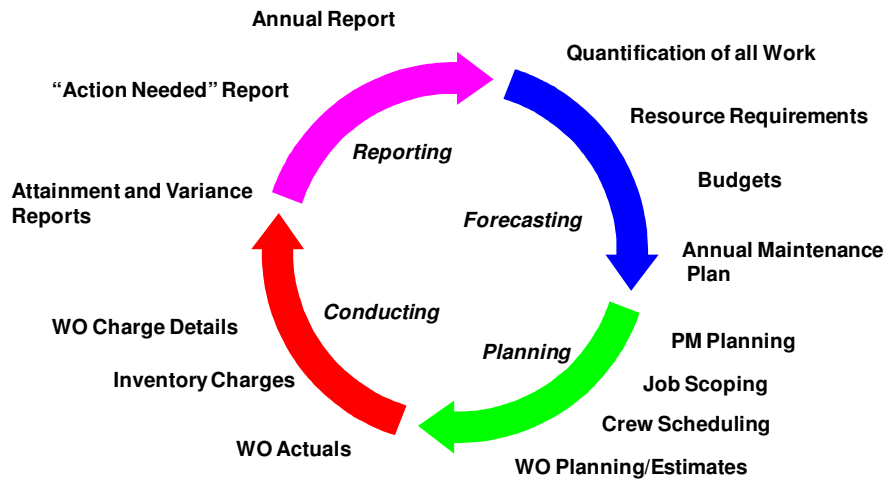
As pictured in Figure 2 below, there needs to be a continuous and systematic information loop that provides the right information at the right time in order to achieve the correct outcomes and actions. This loop must close on itself so that the system can “learn” from the previous cycle, and be used to improve the next iteration.

Figure 2: Generic Business Planning Model Loop



The first step of the NWWBI process benchmarking analysis was to adapt this well understood general business model to maintenance management. This was conducted through a review of Maintenance Management best practice literature and then augmenting this with a range of general municipal management practices and standards. After a number of draft iterations, the following was agreed as a general “Best Practice” business planning process for both water and wastewater treatment maintenance management:

Figure 3: Proposed Best Practice-Based Maintenance Business Model



Each of the quadrants is briefly described below:

Forecasting:

A forecast is a method for developing accurate longer-range plans. It predicts the total amount of work to be done. A forecast must combine past volume trends with current data and market trends to provide reliable predictions as to what will happen. For example: If we want to forecast the number of corrective and emergency Work Orders (WOs) to expect in the coming year, we need to know:

1. How many corrective and emergency WOs did we receive and process last year? (And the year before if available)
2. Are there any seasonal variations in the number of WOs received /processed?
3. Are there new or existing Capital works planned or in progress, which might affect the number of WOs received /processed?
4. Should certain assets be replaced instead of being repaired?
5. Are there any new level of service conditions that might have an impact on work requirements?
6. Do we have any regulatory factors that might impact work or resources?

A forecast must be used to improve its own predictability through a comparison of “forecast to actual”. In other words, the actual volume of work conducted must be compared to the forecasted volume on a regular basis in order to revise and optimize the future forecasts as necessary.

Planning

A plan breaks down a long-range forecast into smaller increments (daily or weekly, for example) and addresses work volume, labour, materials, and equipment. A plan is an orderly way of organizing the future. It is something that every business and every person does in one way or another. A plan must be realistic and related to your capacities. That is, if you have a maintenance staff complement of ten tradespersons, each capable of working no more that 35 hours per week on maintenance Work Orders, then you obviously cannot expect to complete a weekly plan that requires an estimate of 400 hours of total work.

When we make a plan, we have to know the following:

1. How much work (volume) has to be completed?
2. When do we need to have it done? (What is the time sequence for completing the work?)
3. What steps or activities are necessary to complete the work?
4. How long should-each activity take? How long should the combined activities take? (What are the standards and/or estimates for each activity or group of activities?)

Results of a good plan include:

1. A good plan allows us to have better control over the work flow (input and output). A plan establishes a daily goal against which we can measure our progress during the day.
2. A good plan adds a dimension of predictability to the daily work.
3. A good plan minimizes over and under resourcing.

Conducting and Follow -Up

Conducting is the process of carrying out the plan (and completing the Work Orders) in such a way that we are constantly aware of our position in relation to the plan. Effective

short-interval follow-up allows us to adjust through corrective action in cases where the Work Order is not proceeding as planned and scheduled. If off-schedule conditions are quickly identified, it is often possible to remedy a problem at an early stage before it becomes costly or inconvenient to correct.

Reporting/Evaluating

Reporting determines the focus for management follow-up. It provides a summary of facts that can be used to improve overall performance and to assist in ensuring that resourcing appropriately corresponds to the projected volume of upcoming work. Reporting is an important communication process for dissecting past activities and performance so that processes, procedures, and resourcing can be modified for future requirements.

Reporting tells us what we actually accomplished against the planned objectives. Reporting documents are “actual results” which in turn enhance our ability to further forecast and plan. Through the evaluation of past events (performance, attainment, quality indicators), we can improve our prediction of future volume requirements. Through proper evaluation, reporting documents can be used to teach us where and how we can better focus our attention to maximize results.

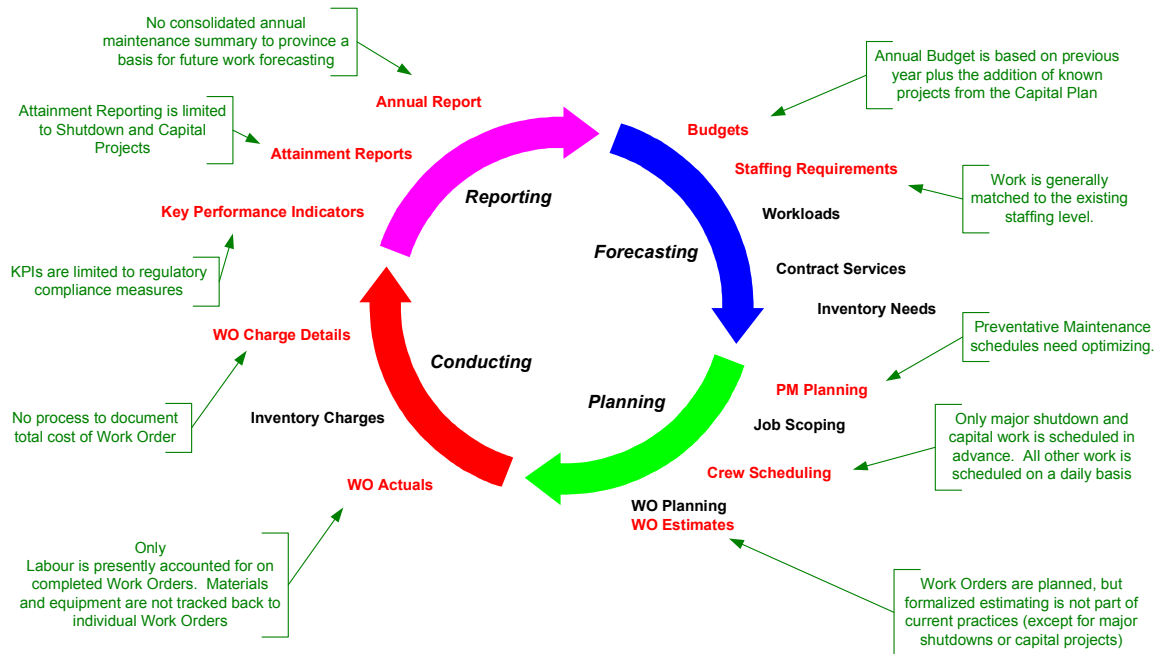
Once the generic business model was agreed upon, it was used by the process benchmarking participants as the backdrop to conduct a high level process gap analysis. The objective is to first identify the key process gaps within the model, and then to prioritize where detailed process improvement actions are required.

Example Gap Assessments: City of Calgary and the Regional District of Nanaimo

Two case studies from the Process Improvement Task Force are described to illustrate the progression of the Best Practices. The first case study is from the City of Calgary. The City of Calgary Water Services serves a population of more than 1 million and operates three large complex wastewater treatment plants and two large water plants. According to data collected through the National Water and Wastewater Benchmarking Initiative, the City of Calgary had an opportunity make improvements to the maintenance management program at their water and wastewater treatment plants. This was based on the NWWBI performance indicator that measures the amount of maintenance work that is unscheduled in comparison to total maintenance work. It was also generally recognized that both the water and wastewater treatment maintenance sections were driven primarily by reactive maintenance. The underlying assumption is that reactive maintenance (which includes both emergency and non-emergency corrective maintenance) is less efficient and more expensive than optimized preventative and scheduled maintenance.

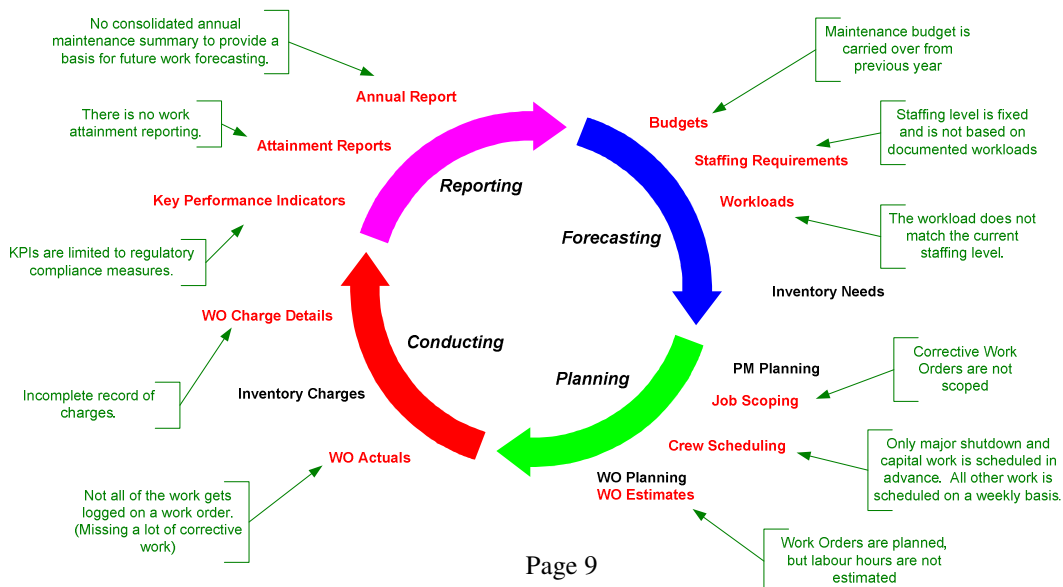
Each of the business model quadrants were reviewed and customized to the requirements of the maintenance function of Calgary’s water and wastewater treatment plants. Following the review, process gaps or inconsistencies were noted for follow up. A summary of the individual process gaps is shown in Figure 4 below:

Figure 4: City of Calgary WWTTP Business Model Gap Assessment



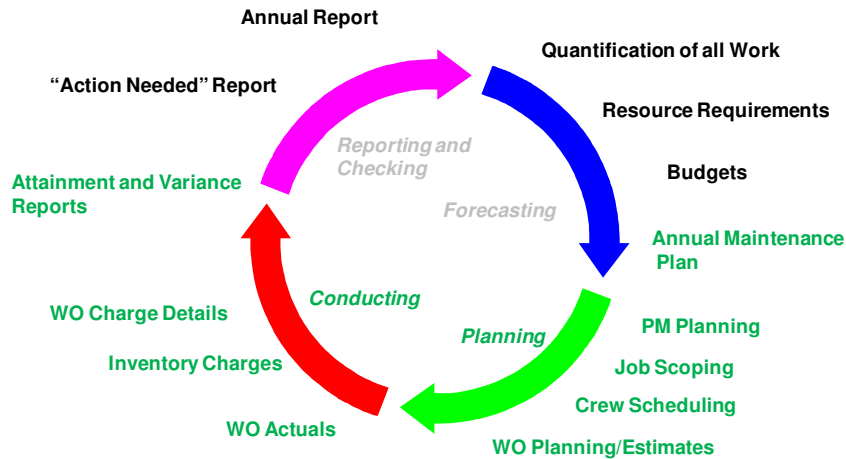
This gap assessment procedure is equally effective in assessing the maintenance business model within smaller communities. The Regional District of Nanaimo (RDN) provides wastewater treatment through four wastewater treatment plants for a service population of about 120,000. Its wastewater treatment plants are smaller, and they do not have a dedicated maintenance crew. Mechanical maintenance is conducted by operators, and electrical maintenance is contracted out. Like Calgary, the RDN recognized that its maintenance functions were driven primarily by reactive needs. Figure 5 show the results of the business modal gap assessment that was conducted at the RDN before they commenced their maintenance optimization process.

Figure 5: Regional District of Nanaimo WWTTP Business Model Gap Assessment



The gap assessments from the individual benchmarking participants were an important starting point to determine where the group could work collectively as compared with where each individual participant were better off improving their own local processes individually. Following a review of each of the gap assessments, the Process Benchmarking exercise narrowed its scope to the lower half of the business model as shown in Figure 6.

Figure 6: Scope of Process Benchmarking



With a focused scope, the Process Improvement Task force was able to advance a progressive sequence of Best Practices that could move the utility gradually out of the reactive mode of maintenance planning and into a process that support high levels of proactive planning.

Best Practice 1: Identify, Quantify, and Manage Reactive Maintenance Work

One of the primary objectives of maintenance improvement plan is to improve the ratio of proactive maintenance work to reactive work. The aim should be to minimize reactive work, but when it occurs, it needs to be carefully managed. One of the misconceptions within the benchmarking participants about reactive work concerned a presumption that there was an industry standard for the volume of reactive work that was tolerable. 20 % reactive work seemed to be a common presumption for acceptable reactive work. This was proven to incorrect. Factors that influence the actual volume of reactive maintenance work include:

- Age and condition of plant assets: Older assets are subject to more failures and breakdowns;
- Extent of process redundancy. Multiple layers of redundancy can generally eliminate the possibility of reactive work, but requires a greater capital cost;
- Poor maintenance work planning. It was found that a lot of reactive work occurred due to poor planning practices. This presented a large opportunity for maintenance productivity and efficiency improvements.

Only after a review of all of the above factors is it possible to identify and forecast the expected volume of appropriate reactive work that is particular to each facility. In virtually no case was it

a reasonable expectation to entirely eliminate reactive work (except on particular assets that are deemed as critical from a risk perspective.) In order to appropriately identify reactive work, the following Work Order priority classification scheme was adopted as a Best Practice.

Table 1: Work Order Priorities Classification

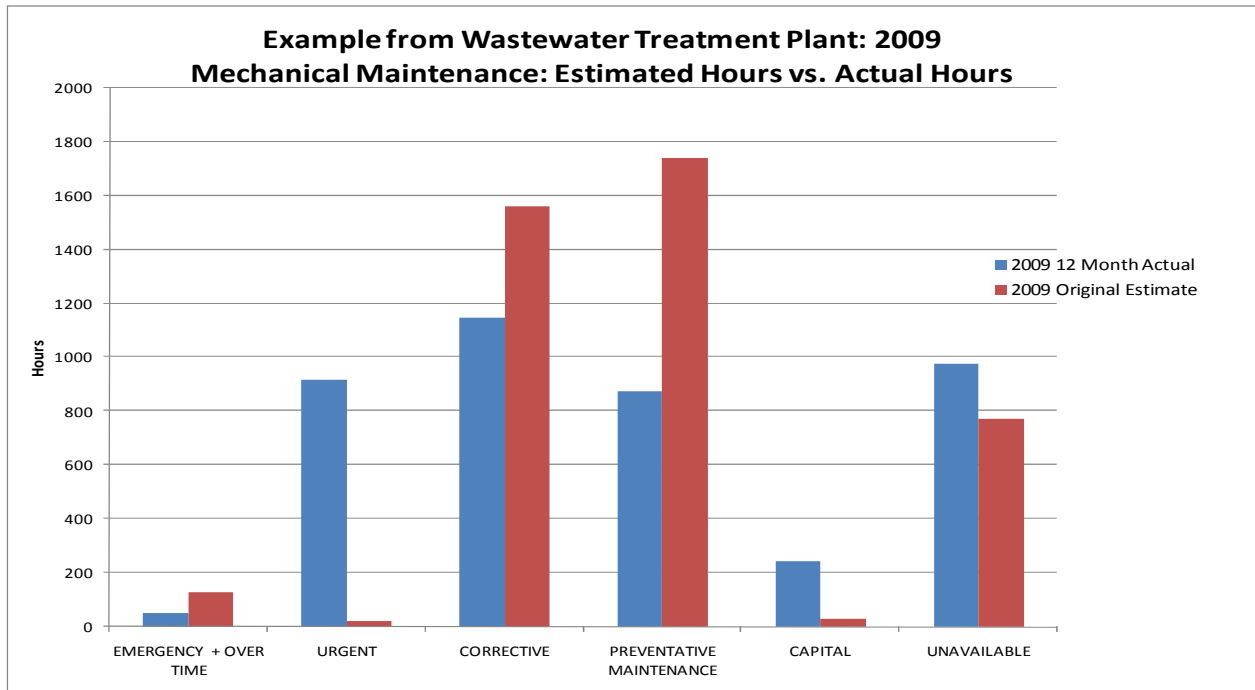
Type	Detail	Result	Impact
Reactive: Emergency Corrective	Breakdown that may result in loss of service or other severe detriment to the utility (e.g.; spill, safety, etc.)	Deploy maintenance as soon as possible, including call outs	Disrupts maintenance schedules, incur overtime, and high costs
Reactive: Urgent Corrective	Breakdown, but may not result in loss of service, or is protected by equipment redundancy	Deploy maintenance at earliest convenience (eg: next shift)	May disrupt scheduled maintenance, but costs can be managed
Proactive: Routine Corrective (Including Shutdowns)	Various maintenance tasks as identified through observation, etc.	Planned and scheduled maintenance	None: Planning and scheduling can occur
Proactive: Preventive Maintenance	Regularly scheduled and periodic preventive maintenance	Planned and scheduled maintenance	None: Planning and scheduling can occur
Proactive: Capital/Construction	Work assistance provided to capital programs	Planned and scheduled but not true maintenance	Important work but takes resources away for maintenance work.
Non Scheduled Event	Minor, low priority tasks that can be assigned during slow periods	Assigned when resources are available	Used to eliminate non-productive time
Unavailable for Work	Vacation, sick time, training time, etc.	Time that is paid but not available for conducting work	Used to forecast resource availability

This type of prioritization scheme facilitates the following:

- Alerts for high priority emergency maintenance work, where there might be severe consequences for slow response;
- Projects the anticipated required volume of Preventive Maintenance work
- Allows for effective scheduling of most work;
- Allows for the development of good management reports concerning the reliability of equipment, cost of emergency service, and overall maintenance productivity;
- Provides an inventory of low priority work backlog to fill times where work is slow;
- Enables future forecasting of resource availability once unavailable time is factored in.

This prioritization scheme enables a utility to forecast, manage, and report on large volumes of work over any time interval in an understandable manner. The graphed report in Figure 7 was recommended as an important milestone within the Task Force. This is known as a Work Attainment report.

Figure 7: Example Work Attainment Report based on Standardized Priority Classifications.



Using the Work Attainment report pictured above as an example, the following observations can be made to assist future planning in the reported facility:

- This facility was not able to complete its PM program, at least in 2009
- This facility experienced far more “urgent” work than was expected. Urgent work is “reactive” and thus more expensive to conduct.
- This facility lost maintenance time due to higher unavailable and capital time in 2009.

Implementing this Best Practice in Calgary and Nanaimo

One of the most challenging issues that both Calgary and the RDN had to respond to was the fact that the Computerized Maintenance Management Systems (CMMS) in both of these utilities had not yet been configured to accurately report Work Order results using the recommended Best Practice work classifications shown in Table 1. Waiting until the job of reconfiguring the CMMS system was done, and then for data to back fill the required reports would cause a frustratingly long time delay. (At least more than two years). The draft Work Attainment reports were instead produced manually with data support from the CMMS as a temporary work-around until such time that the CMMS was reconfigured and accurate data becomes available to generate the desired reports automatically. Examples of the manually derived Work Attainment report from Calgary’s Fish Creek Wastewater Treatment Plant and from RDN’s French Creek Pollution Control Centre are shown below:

Figure 8: Calgary Fish Creek WWTP Draft Attainment Report (2009)

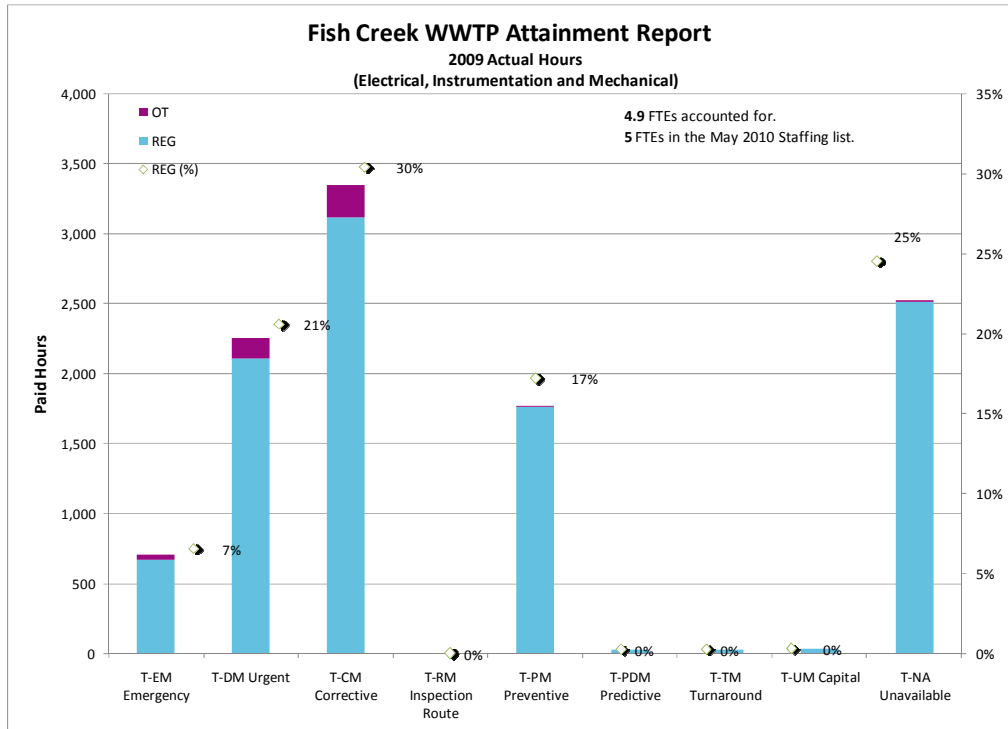
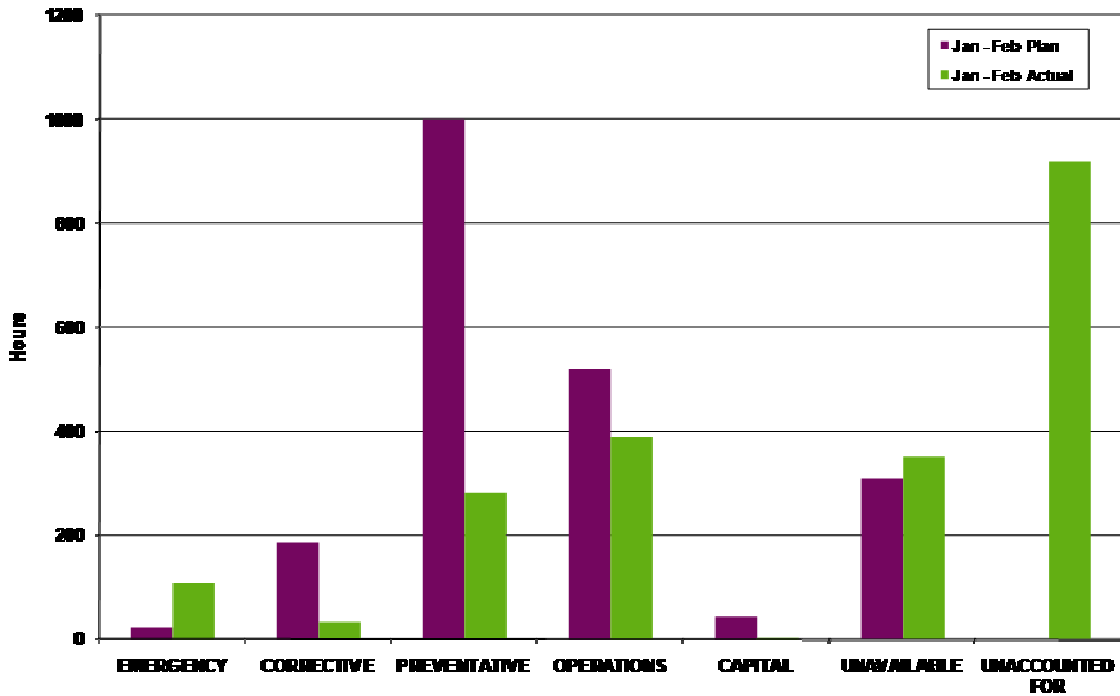


Figure 9: RDN French Creek PCC Draft Attainment Report (January February 2009)



Interestingly, the draft results from both of the case study facilities show that there was a considerable amount of time that could not be accounted for under closed Work Orders during the period. This is not to say that the time was wasted or to spend idly, but rather, a large amount of time was not charged to valid work orders and then stored within the CMMS records. This observation leads directly into the next Best Practice recommendation.

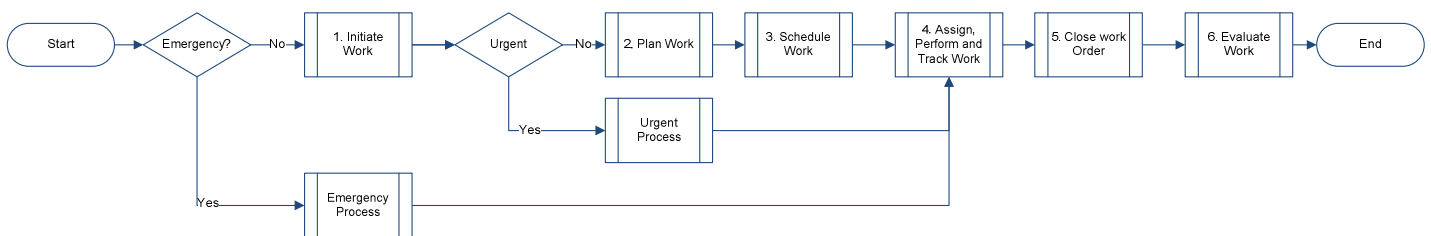
Best Practice 2: Define Business Process for Conducting Maintenance

The most significant gap in most of the CMMS implementations within the Process Task Force surrounded the issue that the business process for conducting maintenance was not adequately aligned to the way in which the CMMS was implemented to support maintenance.

Once the Task Force had a common understanding of the differing nature of maintenance work that was aggregated under each of the priority classes (Table 1), two distinct types of maintenance work was recognized; preventive maintenance and corrective maintenance. Some utilities were struggling to incorporate both within a single business process and workflow within the CMMS. Once the Task Force separated preventive and corrective maintenance, a well defined sequence of recommendations was developed to advance each utility into conformance with Best Practices. As a starting point, corrective and preventive maintenance benefited from a well defined business process to ensure it was conducted productively and efficiently.

Corrective Maintenance: Corrective maintenance responds to all types of repair work and is much more complicated than preventive maintenance. Emergency repairs will be deployed immediately and without the benefit of advance planning, but all other non urgent work can benefit by optimized planning and scheduling to ensure that the work is completed in an effective and efficient manner. The following high level work process flow chart was endorsed by the Task Force and now provides a guide to assist individual implementation efforts:

Figure 10: Agreed Corrective Maintenance Business Process



Based on this high level view (that is in conformance with generally accepted maintenance management best practices), individual facilities can migrate to increasing levels of detail, and implement appropriate technology with a greater confidence of success. The Task Force members all agreed the “Plan Work” and “Schedule Work” tasks were weaknesses in virtually all of the Task Force participants. In fact, true work order scheduling was almost entirely absent. Work order planning was often left to the trade foreman or even the trades person to do once the work order was assigned. Without good planning, the work becomes reactive, and subject to

numerous delay possibilities. The Task Force agreed that enhanced planning and scheduling offered the highest potential for productivity and efficiency returns. Tangible productivity returns of 30% or higher is possible.

The other important observation regarding corrective work is that vital asset and work order post mortem data should be collected in the field during corrective maintenance work and then entered into the CMMS as part of the permanent record. This includes:

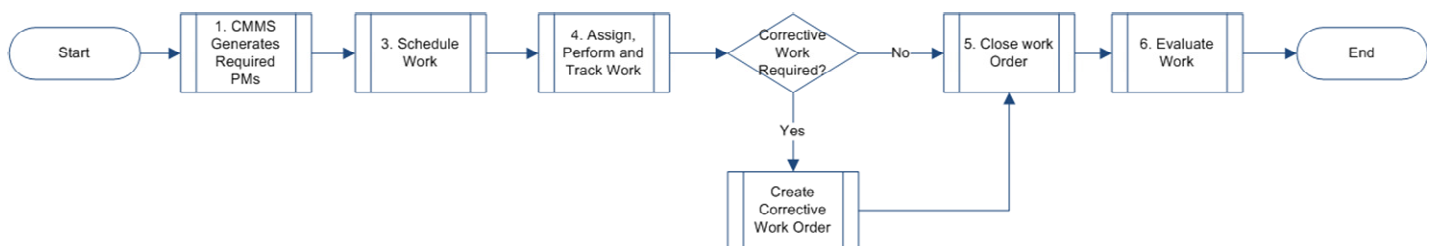
- Cause of failure (through the use of a dedicated failure code);
- Cause of any unanticipated delay in completing the work order (through the use of a dedicated delay code);
- Magnitude of the delay;
- Focused notes that could assist trades persons on future work orders should be added to the asset record for reference;
- Required asset register changes to keep the CMMS asset record up to date.

The requirements of the above drove a number of recommended changes to the standard Corrective CMMS work order form. Once this type of information begins to accumulate in the CMMS, important asset management processes such as enhanced reliability engineering can truly begin.

Preventive Maintenance (PM)²: Preventive maintenance is regular and periodic maintenance work that is preplanned at the master work order level and scheduled in advance. PM work is required to ensure asset reliability and to ensure that the utility maximizes its return from the asset over a complete expected life cycle. Many utilities found that the PM work program was the first to suffer during difficult or overly busy times. As a result, most utilities were rarely able to complete their annual PM workload which ultimately results in higher levels of breakdown and reactive corrective maintenance work in the future. Over time, the utility becomes more and more reactive and the PM backlog begins to grow to an unmanageable volume.

Since PM work orders are planned at the master level and are never reactive in nature, the business process is simplified.

Figure 11: Agreed Preventive Maintenance Business Process



² This includes inspection routes and predictive maintenance.

In terms of improving productivity within the PM program, the objective is to optimize the total PM program so that only essential PM activities are being conducted on each asset based on a criterion of risk assessment that includes impact and frequency of asset failure. Methodologies such as Failure Modes and Effects Analysis (FMEA) are useful here, and some of the Task Force participants are now ready to conduct FMEA or similar processes successfully. A challenge remains however, that once the overall annual PM workload is agreed as correct, it MUST be completed regularly and reliably.

Implementing this Best Practice in Calgary and Nanaimo

The business process analysis outlined in Best Practice 2 has been a highly effective tool to enable each of the case study examples to develop an individual program to for overall performance improvement. Both the City of Calgary and the Regional District of Nanaimo have developed detailed work management business process maps that identify ALL of the tasks that are required in the overall business process. The process maps are also used to assign the individuals who are responsible for completing the tasks. This ensures that everyone has a common understanding of the process. It also provides a reference for staff training. Example detailed business process flow charts from both Calgary and RDN are presented below.

Figure 12: City of Calgary Detailed Business Process

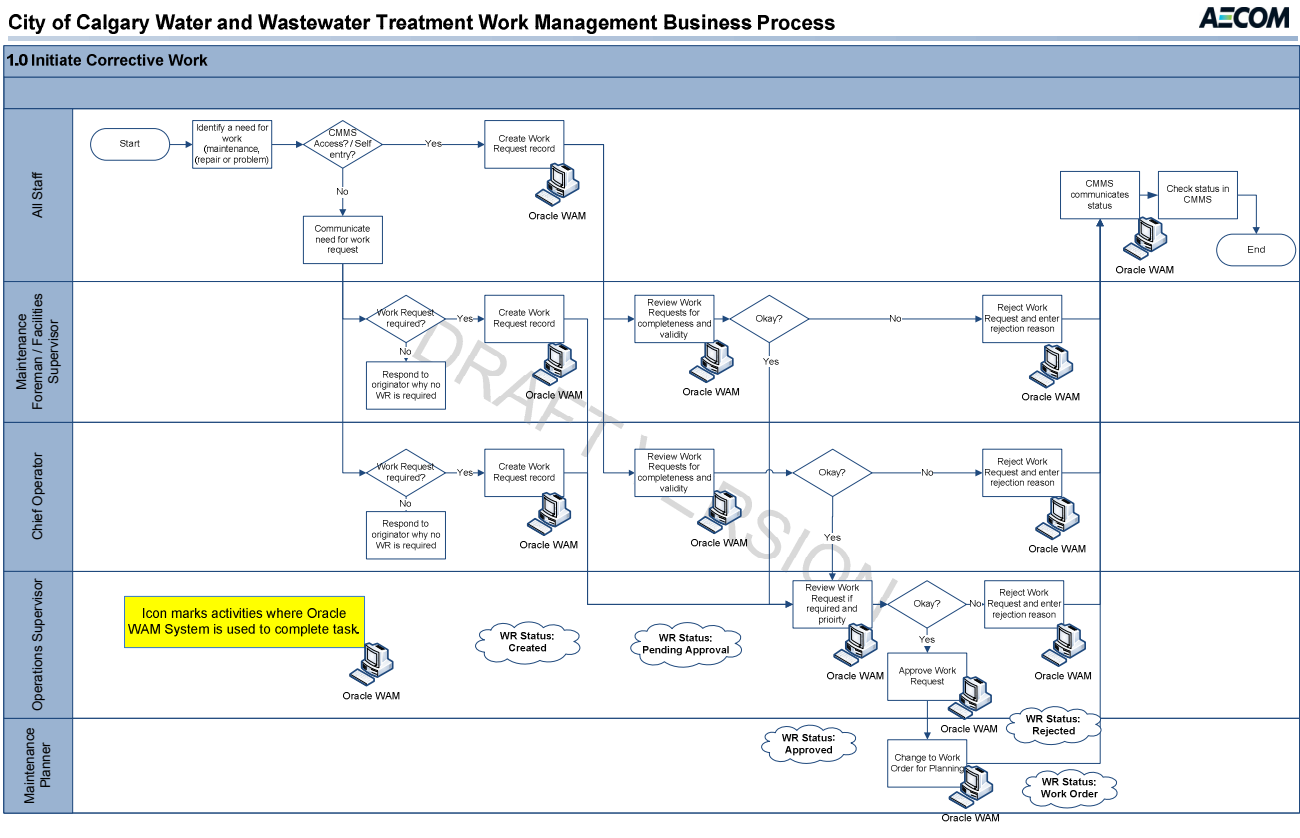
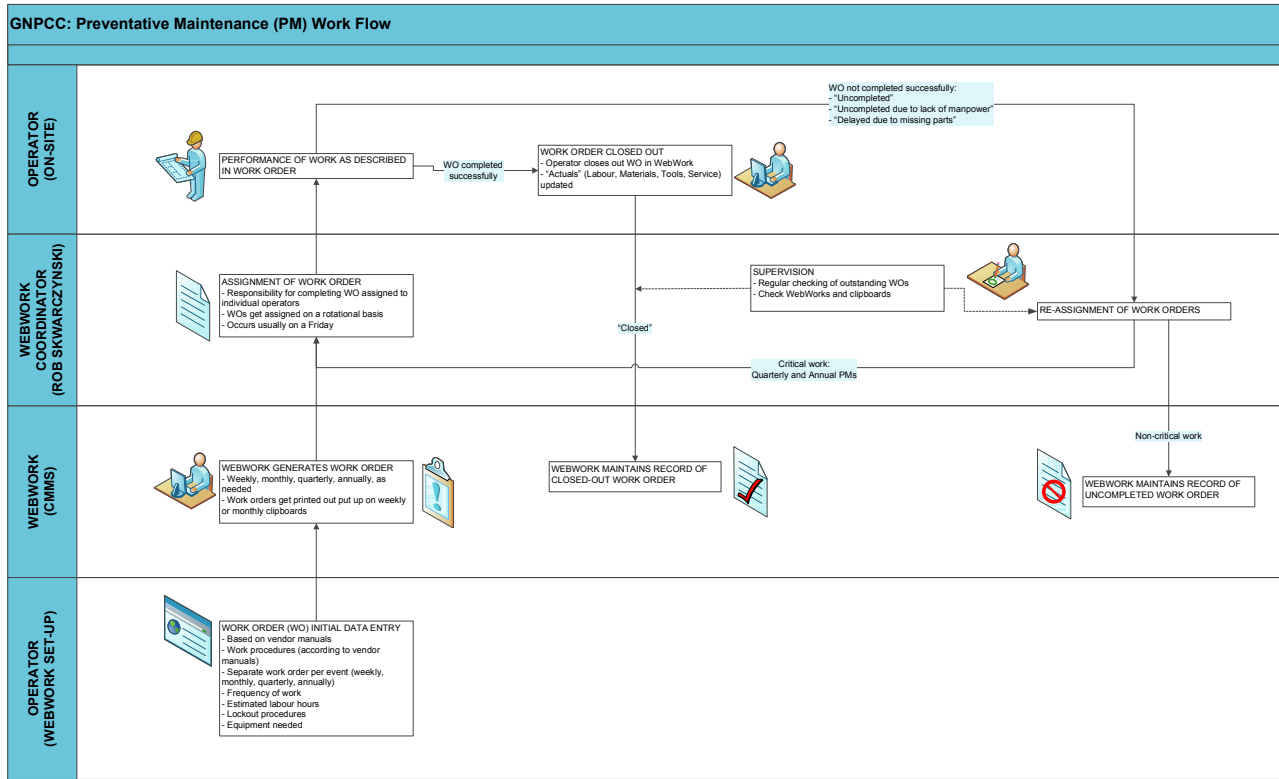


Figure 13: Regional District of Nanaimo Detailed Business Process



Once complete, these business process maps are also an excellent guide to assist Information Technology Planners with the optimization and implementation of the CMMS. Both Calgary and Nanaimo are now in the process of making changes to their CMMS that will result in a better tool for the managing and improving plant maintenance.

Conclusion: Benchmarking Requires Patience and Diligence:

The accomplishments of this Process Improvement Task Force are impressive, and it is easy to forget that this process began by recognizing that faulty data was being generated from the early benchmarking returns. The faulty data was not the fault of the benchmarking exercise, but served to highlight an important misunderstanding. It would have been easy to overlook this aberration without insightful analysis from the metric benchmarking perspective. While each participant will look closely at their own data, a well managed metric benchmark exercise is a proven tool to identify trends or factors that affect the group. A benchmarking collective such as the National Water and Wastewater Benchmarking Initiative is also well positioned to begin mobilizing individual participants to areas that have the potential to generate tangible benefits and Best Practice implementation strategies.

Once this maintenance optimization strategy was identified, the Process Improvement Task Force expanded to 12 utilities from eight in its second year of operation due to recognition that

optimizing maintenance within water and wastewater treatment plants presents substantial opportunities to realize significant tangible benefits; both in improved economies and in an increase to the reliability of the plant. This case study demonstrates that defining plant maintenance business processes in response to well articulated management needs is a vital first step to optimizing plant maintenance. Once the management objectives and business processes have been defined, technology (such as a CMMS, and advanced predictive maintenance techniques) can be successfully deployed to dramatically improve the effectiveness of the maintenance function. This procedure is not technically challenging, but it requires leadership, perseverance, dedication, and a very strong commitment to organizational communication.