Technology and Cost Document for the Revised Total Coliform Rule

Disclaimer

Readers may use the information presented in this document to evaluate the available technologies, operational practices, and compliance activities available to PWSs in complying with the proposed revised Total Coliform Rule.

Information presented in this document serves as a foundation for making comparisons between regulatory alternatives developed by EPA, States, and other interested parties. This information is meant to be used for evaluation and comparison purposes at the national level only and not as direct input into system-specific design or budget preparation for non-EPA entities.

Mention of trade names or commercial products does not constitute an EPA endorsement.

CONTENTS

List of Acronyms/Abbreviations ____ *viii*

1 Introduction ____ *1-1*

1.1 Purpose of the Document ____ 1-1

1.2 Background of RTCR ____ 1-1

1.3 Document Organization ____ 1-2

2 Estimated Unit Costs of Labor ____ *2-1*

2.1 Water System Labor Rates ____ 2-1

2.2 State Drinking Water Program Personnel Labor Rates ____ 2-3

2.3 Escalated Labor Rates ____ 2-4

2.4 Labor Rates for RTCR Alternative Size Categories ____ 2-5

3 Estimated Unit Costs of TCR Monitoring Requirements ____ *3-1*

3.1 Introduction ____ 3-1

3.2 Sample Collection and Delivery ____ 3-1

3.2.1 Sample Collection ____ 3-2

3.2.1.1 Sample Collection Labor Burden ____ 3-2

3.2.1.2 Unit Sample Collection Costs ____ 3-2

3.2.2 Sample Delivery ____ 3-3

3.3 Sample Analysis ____ 3-6

3.3.1 Available Analytical Methods ____ 3-6

3.3.2 Sample Analysis Cost ____ 3-7

3.3.2.1 Contractor Labs ____ 3-7

3.3.2.2 In-house Analysis ____ 3-8

3.4 Estimated Average Unit Monitoring Costs ____ 3-9

4 Estimated Unit Costs of Assessments ____ *4-1*

4.1 Overview of Assessments ____ 4-1

4.1.1 Level 1 Assessments ____ 4-2

4.1.2 Level 2 Assessments ____ 4-2

4.2 Elements of Assessments ____ 4-3

4.2.1 Notification Element ____ 4-5

4.2.2 System Specific Element ____ 4-5

4.2.3 Sample Analytical Element ____ 4-5

4.2.4 Sample Methodology Element ____ 4-5

4.2.5 Event Situational Element ____ 4-6

4.2.6 Operational Data Element ____ 4-6

4.2.7 Historical Trend Element ____ 4-6

4.2.8 Sample Tap Element ____ 4-7

4.2.9 Sample Site Element ____ 4-7

4.2.10 Sample Area Element ____ 4-7

4.2.11 Third Party Element ____ 4-7

4.2.12 Report Element ____ 4-7

4.3 Unit Cost Estimates of Assessments ____ 4-7

4.3.1 Methodology ____ 4-7

4.3.2 Assumptions 4-13

5 Estimated Unit Costs of Corrective Actions 5-1

5.1 Flushing 5-3
5.1.1 Scheduled / Routine Flushing 5-3
5.1.2 Unscheduled / Spot Flushing 5-5

5.2 Sampler Training 5-7

5.3 Replacement / Repair of Distribution System Components 5-7
5.3.1 Valves 5-8
5.3.2 Water Mains 5-8
5.3.3 Fittings 5-9
5.3.4 Hydrants 5-10
5.3.5 Meters 5-11
5.3.6 Dedicated Sample Taps 5-12

5.4 Maintenance of Adequate Pressure 5-15
5.4.1 Booster Pumping Station 5-15
5.4.2 Modify or Replace Existing Pumps 5-17
5.4.3 Install Variable Frequency Drives 5-17
5.4.4 Elevated Storage Facility 5-18
5.4.5 Install Surge Relief Valve 5-19
5.4.6 Install Surge Tanks 5-19

5.5 Maintenance of Appropriate Hydraulic Residence Time 5-21
5.5.1 Loop Dead Ends 5-21
5.5.2 Install Appropriate Main Sizes 5-22
5.5.3 Install Automated Flushing Devices 5-22
5.5.4 Storage Facility Modifications 5-23
5.5.4.1 Modify Inlet/Outlet Piping 5-23
5.5.4.2 Install Mixing Devices 5-24
5.5.4.3 Modify Storage Operation 5-25
5.5.4.4 Decommission Storage 5-26

5.6 Storage Facility Maintenance 5-27
5.6.1 Inspecting/Cleaning of Tanks 5-27
5.6.2 Lining of Storage Tanks 5-28
5.6.3 Vent/Hatch Repair 5-28
5.6.4 Tank Repair 5-29

5.7 Booster Disinfection 5-30
5.7.1 Chlorine System 5-31
5.7.1.1 Permanent System 5-31
5.7.1.2 Temporary System 5-31
5.7.2 Chloramine System 5-34
5.7.2.1 Permanent System 5-34
5.7.2.2 Temporary System 5-34

5.8 Cross-connection Control and Backflow Prevention Program 5-38
5.8.1 Backflow Prevention Assemblies and Devices 5-38
5.8.2 Program Administration 5-39

5.9 Addition or Upgrade of On-line Monitoring and Control 5-40
5.9.1 Water Quality Monitoring and Control 5-41
5.9.1.1 Chlorinated Systems 5-41
5.9.1.2 Chloraminated Systems 5-42
5.9.2 Pressure Monitoring and Control 5-43

5.10 Addition of Security Measures _____ **5-44**

5.11 Development and Implementation of an Operations Plan _____ **5-45**

5.11.1 Operation and Maintenance Standard Operating Procedure (SOP) Training _____ 5-46

5.11.2 Operation and Maintenance Plan Revision _____ 5-47

References _____ ***R-1***

Appendix A _____ ***A-1***

List of Exhibits

Exhibit 2-1: Water System Labor Rates by System Size (2003$) 2-3
Exhibit 2-2: State Program Wage Rates (2003$) 2-4
Exhibit 2-3: Water System Wage Rates by System Size (2007$) 2-4
Exhibit 2-4: State Program Personnel Wage Rates (2007$) 2-5
Exhibit 2-5: Comparison of the Number of Systems in each System Size Category for the GWR EA and the Proposed RTCR 2-5
Exhibit 2-6: Water System Labor Rates by TCRDSAC TWG System Size Categories (2007$) 2-6
Exhibit 3-1: Estimated Travel and Sample Time by PWS Population Served 3-2
Exhibit 3-2: Estimated Sampling Collection Cost (2007$) 3-3
Exhibit 3-3: Estimated Sample Delivery Cost Per Shipment (2007$) 3-3
Exhibit 3-4: Estimated Per-Sample Delivery Cost (2007$) 3-4
Exhibit 3-5: Estimated Cost for Sample Self-Delivery[1] (2007$) 3-4
Exhibit 3-6: Per Sample Cost Estimate for Sample Self-Delivery (2007$) 3-4
Exhibit 3-7: Estimated Percentages[1] of Systems Using Each Type of Sample Delivery 3-5
Exhibit 3-8: Estimated Per Sample Shipping/Delivery Cost as a Function of System Size (2007$) 3-6
Exhibit 3-9: Common TC and *E. coli* Analytical Methods and their Average Contractor Lab Analytical Fee (2007$)[1] 3-8
Exhibit 3-10: Estimated Sample Cost for In-House Analysis (2007$) 3-9
Exhibit 3-12: Estimated Average Unit Cost of Monitoring (2007$) 3-10
Exhibit 4-2: Categories for which cost estimates are developed 4-8
Exhibit 4-3: Violations and triggers leading to assessments 4-8
Exhibit 4-4: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 1,001-4,100 4-9
Exhibit 4-6: Estimated Labor Burden Associated with Assessments (hours) 4-12
Exhibit 4-7: Estimated Labor Burden Associated with Assessments (2007$) 4-12
Exhibit 5-1: Summary of Corrective Actions 5-1
Exhibit 5-2: Estimated Costs for Routine Flushing 5-4
Exhibit 5-3: Estimated Costs for Spot Flushing 5-6
Exhibit 5-4: Estimated Costs Operator Training/Certification 5-7
Exhibit 5-5: Estimated Costs to Replace Valve 5-8
Exhibit 5-6: Estimated Costs to Replace Ductile Iron Pipe 5-9
Exhibit 5-7: Estimated Costs to Replace Fittings 5-10
Exhibit 5-8: Estimated Costs to Replace Hydrants 5-11
Exhibit 5-9: Estimated Costs to Replace Meters 5-12
Exhibit 5-10: Dedicated Sampling Station Schematic 5-13
Exhibit 5-11: Dedicated Sampling Station 5-14
Exhibit 5-12: Estimated Costs of Installing a Dedicated Sampling Tap 5-14
Exhibit 5-13: Estimated Costs to Install a New Booster Pump Station 5-16
Exhibit 5-14: Estimated Costs to Replace Existing Pump 5-17
Exhibit 5-15: Estimated Costs to Install a Variable Frequency Drive 5-18
Exhibit 5-16: Estimated Costs to Install a New Elevated Storage Tank 5-19
Exhibit 5-17: Estimated Costs to Install a Surge Relief Valve 5-19
Exhibit 5-18: Estimated Costs to Install a Surge Control Tank 5-21
Exhibit 5-19: Estimated Costs to Install Automated Flushing Devices 5-22
Exhibit 5-20: Estimated Costs to Modify Inlet/Outlet Piping 5-24
Exhibit 5-21: Estimated Costs to Install Mixing Devices 5-25
Exhibit 5-22: Estimated Costs to Modify Storage Operation 5-26
Exhibit 5-23: Estimated Costs to Decommission Storage 5-26
Exhibit 5-24: Estimated Costs for the Inspection and Cleaning of Storage Tanks 5-27
Exhibit 5-25: Estimated Costs for the Lining of Storage Tanks 5-28
Exhibit 5-26: Estimated Costs for the Repair/Replacement of a Storage Tank Vent 5-29
Exhibit 5-27: Estimated Costs for the Repair/Replacement of a Storage Tank Hatch 5-29
Exhibit 5-28: Estimated Costs for the Repair of Storage Tanks 5-30
Exhibit 5-29: Estimated Costs to Install a Permanent Chlorine Booster Disinfection Station 5-32
Exhibit 5-30: Estimated Costs to Install a Temporary Chlorine Booster Disinfection Station 5-33
Exhibit 5-31: Estimated Costs to Install a Permanent Chloramines Booster Disinfection Station 5-35

Exhibit 5-32: Estimated Costs to Install a Temporary Chloramine Booster Disinfection Station 5-37
Exhibit 5-33: Estimated Costs for a Backflow Prevention Assembly 5-39
Exhibit 5-34: Cost Components of Program Administration for a Cross-Connection Control and Backflow Prevention Program 5-40
Exhibit 5-35: Estimated Costs for Online Chlorine Monitoring and Programming 5-42
Exhibit 5-36: Estimated Costs for Online Chloramine Monitoring and Programming 5-43
Exhibit 5-37: Estimated Costs for Online Pressure Monitoring and Programming 5-44
Exhibit 5-38: Estimated Costs for Installation of Security Measures 5-45
Exhibit 5-39: Estimated Costs to Develop and Implement an Operations Plan 5-46
Exhibit 5-40: Estimated Costs for Operator Training/Certification 5-47
Exhibit 5-41: Estimated Costs to Maintain an Operations Plan 5-48
Exhibit A-1.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by NCWSs serving <= 1,000 1
Exhibit A-2.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by NCWSs serving 1,001 - 4,100 3
Exhibit A-3.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving <= 100 5
Exhibit A-4.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 101 -500 7
Exhibit A-5.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 501 - 1,000 9
Exhibit A-6.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 1,001 - 4,100 11
Exhibit A-7.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 4,001 - 33,000 13
Exhibit A-8.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 33,001 - 96,000 15
Exhibit A-9.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving > 96,000 17

List of Acronyms/Abbreviations

Acronym/Abbreviation	Agency/Organization/Definition
AIP	Agreement in Principle
ASDWA	Association of State Drinking Water Administrators
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BLS	U.S. Bureau of Labor Statistics
CA	California
CCCBFP	cross connection control and backflow prevention program
CO	Colorado
cy	cubic yard
CWS	Community Water System
DBP	disinfection byproduct
DC	District of Columbia
EA	Economic Analysis
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
FED	Federal
FR	Federal Register
ft	Feet
FTE	full time equivalent
GIS	Geographic Information Systems
GPCD	gallons per capita per day
GPM	Gallons per Minute
GSA	U.S. General Services Administration
GWR	Ground Water Rule
GWR EA	Economic Analysis for the Ground Water Rule
HRT	Hydraulic residence time
HVAC	heating, ventilation, air conditioning
ID	Idaho
IN	Indiana
in	Inches
kgal	Thousand gallons
KY	Kentucky
gpm	gallons per minute
MA	Massachusetts
MCL	Maximum Contaminant Level
MGD	million gallons per day
mg/L	milligrams per liter
MI	Michigan
MMO/MUG	minimal medium o-nitrophenyl-beta-D-galactopyranoside
NCS	National Compensation Survey
NCWS	non-community water system
NOM	natural organic matter
NPDWR	National Primary Drinking Water Regulations

NRWA	National Rural Water Association
O&M	operations and maintenance
OES	Occupational Employment Survey
OH	Ohio
PA	Pennsylvania
psi	pounds per square inch
PWS	Public Water System
QA/QC	Quality Assurance/Quality Control
RTCR	Revised Total Coliform Rule
SCADA	supervisory control and data acquisition
SDWA	Safe Drinking Water Act
SDWIS/FED	Safe Drinking Water Information System/Federal Version
sf	square feet
SIC	Standard Industrial Classification
SM	Standard Methods
SOP	Standard Operating Procedures
TC	Total Coliform
TCR	Total Coliform Rule
TCRDSAC	Total Coliform Rule Distribution System Advisory Committee
TWG	Technical Work Group
US	United States
USA	United States of America
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VFD	variable frequency drive
WV	West Virginia

1 Introduction

1.1 Purpose of the Document

This Technologies and Cost document is one of several technical documents developed in support of the proposed Revised Total Coliform Rule (RTCR). It describes available technologies, operational practices, and compliance activities that would be performed by public water systems (PWSs) in compliance with the proposed rule. The document also provides estimated unit costs associated with these technologies, operational practices, and compliance activities and descriptions of approaches used in developing estimates.

1.2 Background of RTCR

The U.S. Environmental Protection Agency (EPA) is required to review existing national primary drinking water regulations every six years. In 2003, EPA completed its review of the Total Coliform Rule (TCR) and 68 National Primary Drinking Water Regulations (NPDWRs) for chemicals that were established prior to 1997. The purpose of the review was to identify current health risk assessments, changes in technology, and other factors that would provide a health or technological basis to support a regulatory revision that would maintain or improve public health protection. In the Six-Year Review determination published in July 2003, EPA noticed its intent to revise the TCR.

In June 2007, EPA established a federal advisory committee, the Total Coliform Rule Distribution System Advisory Committee (TCRDSAC), under the Federal Advisory Committee Act (FACA). One of the goals of convening the TCRDSAC was to make recommendations to EPA on revisions to the TCR promulgated in 1989 (54 FR 27565, June 29, 1989).

The TCRDSAC included organizational members selected by EPA based on the diverse perspectives, expertise, and experience needed to provide balanced recommendations to EPA on issues related to the TCR and issues related to distribution systems. From July 2007 through September 2008, the committee met 13 times in Washington, DC. The TCRDSAC considered the technical and policy issues involved in the monitoring, assessment, and corresponding corrective actions of problems in the distribution systems to better understand and address public health impacts from degradation of drinking water quality due to sanitary defects in the distribution system. This RTCR applies to all PWSs nationwide.

The goal of the TCRDSAC in making recommendations on revisions to the TCR is to achieve the objectives of the 1989 TCR more effectively and efficiently, taking into account the changes in the regulatory framework for implementing the Safe Drinking Water Act (SDWA) over the past 20 years and the knowledge gained throughout implementation of the 1989 TCR. The TCRDSAC drew on a variety of data sources to capture experience with the existing TCR, on analyses conducted for TCRDSAC, and on the collective experience of the member organizations.

In concert with other rules promulgated by EPA under SDWA, the revised rule construct will better address the TCR objectives and enhance the multiple barrier approach to protecting public health, especially with respect to smaller groundwater systems. The RTCR paradigm is designed to trigger systems with positive total coliform (TC)/*E. coli* monitoring results to do an

assessment, to identify whether any sanitary defects are present, and to correct such defects accordingly. This is an improvement over the current TCR framework in that it takes a more proactive approach to identifying and fixing problems that affect or may affect public health.

The follow-up actions described in the proposed RTCR also will improve the cost-effectiveness of the rule as investigations and corrective actions provide an opportunity to improve public health. In addition to the corrective actions that might be directly related to total coliform positive samples in the distribution system, water systems may decide to undertake a variety of advanced projects to optimize distribution system water quality. These would generally require cooperation of multiple departments, including operations, laboratory, water quality, production, distribution and engineering staff. Programmatic efforts to optimize distribution system water quality could include asset management, work-order management and tracking, mapping and data management using GIS and related databases, hydraulic modeling, pressure transient modeling, and advanced distribution system monitoring. Infrastructure programs such as condition assessment and leak detection could also play a role in a water quality management effort. These types of projects require extensive investment in hardware, software and expertise and often take several years to develop and fully implement. These advanced distribution system technologies are not specifically addressed in this document.

For more information on the RTCR including its background, please see the preamble to the proposed RCTR, provisions and rationale, summary of national costs and benefits, and other information.

1.3 Document Organization

This document is divided into six chapters and one appendix:

Chapter 1 – Introduction

This chapter provides an overview of the RTCR development process, as well as a detailed summary of each chapter found in this document.

Chapter 2 – Estimated Unit Cost of Labor

This chapter presents the estimated unit cost of the labor rate.

Chapter 3 – Estimated Unit Costs of TCR Monitoring Requirements

This chapter describes the monitoring requirements under the RTCR based upon system characterization. This chapter is not intended to provide guidance for PWS compliance with the RTCR but rather to provide background information relevant to derivation of unit monitoring cost.

Chapter 4 – Estimated Unit Costs of Assessments

This chapter describes the estimated cost of realistic examples of specific elements of a public water distribution system assessment resulting from compliance with the RTCR. Specific assessments required under the RTCR will be determined by the primacy

agency.

Chapter 5 – Estimated Unit Costs of Corrective Actions

This chapter provides examples of corrective actions and the associated costs that could result from deficiencies or sanitary defects as determined by the required assessments under the proposed RTCR.

References

This section lists the references for the citations used in this document.

Appendix A – RTCR Labor Burden for Assessments

The appendix contains tables with labor burden estimates for performing various assessments. Tables are broken out by system type i.e. community vs. non-community and by the population served.

2 Estimated Unit Costs of Labor

Much of the burden associated with the proposed RTCR is due to the labor that would be required to comply with the provisions of the rule including collecting routine and repeat samples, conducting assessments, and taking follow-up and corrective actions. The following labor classes are used to estimate the costs associated with compliance activities:

- Water system technical staff
- Water system management staff
- State field engineering staff
- State program office staff

Other chapters of this document provide estimates of the labor time (burden) that PWS staff will expend in implementing these management and operational improvements. This chapter presents the estimated unit cost of this labor burden in terms of a loaded wage rate that incorporates both what systems and States pay their staff and an estimate of the dollar value of benefits associated with their employment.

2.1 Water System Labor Rates

The unit cost of labor is the wage per unit of time expended in performing compliance activities. This section presents estimated labor rates for the labor categories identified above.

National Analysis of Labor Rates. EPA performed an analysis of available data sources to derive a nationally representative set of labor rates corresponding to the primary labor categories involved in SDWA compliance activities. The results of this study, *Labor Costs for National Drinking Water Rules* (USEPA 2003), have been used in the development of the economic analyses of several NPDWRs including the Ground Water Rule (USEPA, 2006). These documents serve as the basis for the summary of the national labor rates below. The national labor rates were used by the TCRDSAC in support of the Agreement in Principle (AIP) signed for the proposed RTCR and consequently will be used to further analyze the national economic impact of the proposed RTCR.

The EPA identified several data sources for water industry-specific labor rates:

- Bureau of Labor Statistics, Occupational Employment Survey (OES)
- Bureau of Labor Statistics, National Compensation Survey (NCS)
- U.S. Census Bureau, 1997 U.S. Economic Census
- American Water Works Association (AWWA), Utility Compensation Survey (2001)

These national databases were supplemented with information provided in two EPA Drinking Water Program databases: the Safe Drinking Water Information System and the 2000 Community Water System Survey.

The OES tracked compensation by Standard Industrial Classification (SIC). Wage data from two industry classes were particularly relevant to this analysis: SIC 494 – Water Supply, which contained privately-owned drinking water systems, and SIC 903 – Local Government, which contained publicly-owned systems (USEPA, 2003). The NCS collects mean hourly

earnings data not by industry but by occupation using a national survey of private and public establishments. The 2000 NCS sampled 15,840 private sector establishments (including 1,158 establishments in transportation and public utilities) with one or more employees, and 2,489 state and local governments with 50 or more employees (USEPA, 2003). The NCS provided an occupational subgroup, comprised of water and sewer treatment plant operators, that was used to derive labor rates for technical labor. Other NCS occupational categories provided data for managerial, clerical, and administrative labor rates.

The 1997 Economic Census provided total payroll figures, but did not provide hourly wage rate or sufficient additional information required to estimate labor rates. The AWWA's Utility Compensation Survey provided annual salaries for 44 occupational categories. From these occupational categories, EPA was able to build hourly wage rates using the corresponding category salaries and assumptions regarding the number of hours per year worked per employee in these categories. Wage rates were derived for managerial, technical, and clerical positions using the occupational category descriptions in the AWWA database. EPA determined, based on further analysis and response rates, that the AWWA survey database is biased towards the larger water system size categories. Therefore, the AWWA-based wage rates were determined to be less accurate for smaller sized water systems.

EPA considered several factors in evaluating whether these data sources provided an accurate estimate of labor rates. Given the analytical needs of EPA's national regulatory cost models and data quality considerations, EPA selected the OES-based labor rates as nationally representative for use in national economic impact analyses.

Fringe Benefit Rates. In developing the unit labor costs, EPA also considered the additional indirect labor costs associated with fringe benefits paid to water system employees. The NCS reported fringe benefits on a per hour basis for select occupational categories. However, there was not a specific fringe benefit rate corresponding to water industry occupations. EPA identified fringe benefit rates for suitable occupational categories related to technical and managerial labor. These fringe benefit multipliers ranged from 1.3 to 1.5 times direct labor dollar across the establishment size and occupational categories considered. These rates were applied to the OES-based wage rates to produce fully-loaded labor rates which are presented in Exhibit 2-1.

National Labor Rates. Exhibit 2-1 presents unit labor costs for Technical and Managerial labor categories in 2003$ corresponding to the original EPA labor rate analysis (USEPA 2003).

Exhibit 2-1: Water System Labor Rates by System Size (2003$)

Labor Category/Rates	System Size (Population Served)					
	25-100	101-500	501-3,300	3,301-10k	10,001-100k	>100k
Fringe Benefit Rate[1]	1.3	1.4	1.5	1.5	1.5	1.5
Technical Wage Rate	$ 21.44	$ 23.09	$ 24.74	$ 25.34	$ 26.05	$ 31.26
Managerial Wage Rate	$ 44.36	$ 47.78	$ 51.20	$ 51.20	$ 51.20	$ 51.20
Weighted Labor Rate[2]	$ 21.44	$ 23.09	$ 24.74	$ 30.51	$ 31.08	$ 35.25

[1] Figures represent loaded rates that include a fringe benefit multiplier ranging from 1.3 to 1.5 across size categories.
[2] EPA estimates that systems with population served greater than 3,300 use a combination of operators (technical) and engineers (managerial), with an 80/20 ratio between the two, respectively. EPA also estimates that systems serving 3,300 or less use 100% (technical) labor.

Source: Economic Analysis for the Final Ground Water Rule (USEPA, 2006), the Stage 2 Disinfectants and Disinfection Byproducts Rule (USEPA-1996), and the Long Term 2 Enhanced Surface Water Treatment Rule (USEPA-1996).

These labor rates were applied to each of the economic analyses supporting the Ground Water Rule (USEPA-2006), the Stage 2 Disinfectants and Disinfection Byproducts Rule (USEPA-1996), and the Long Term 2 Enhanced Surface Water Treatment Rule (USEPA-1996). Systems serving 3,300 people or fewer are assumed by EPA to use only technical labor to perform RTCR activities (the same assumption that was made for the other rules). Therefore the technical rate shown in Exhibit 2-1 applies to these smaller water systems. For systems serving more than 3,300 people, EPA assumes a ratio of 80 percent technical labor to 20 percent managerial labor to arrive at a labor cost, or weighted labor rate, of $30.51 for systems serving 3,301-10,000 people, $31.08 for systems serving 10,001-100,000 people, and $35.25 for systems serving greater than 100,000 people. Exhibit 2-1 also presents these weighted labor rates.

2.2 State Drinking Water Program Personnel Labor Rates

The unit labor cost for State staff performing administrative tasks were estimated based on data from the 2001 State Drinking Water Needs Analysis (ASDWA, 2001). EPA estimated an average annual full time equivalent (FTE) labor cost, including overhead and fringe benefits, of $70,132 (2003$) which was converted to an hourly rate of $33.60 assuming an FTE is equivalent to one person working 2,080 hours per year. EPA used R.S. Means (1998) data to establish a wage rate of $31.00 for a field engineer. A 60 percent loading factor was also assumed to account for the cost of fringe benefits. When escalated to 2003$, the loaded wage rate for State field engineering staff was $37.34 per hour. Exhibit 2-2 presents the State Program personnel loaded labor rates in 2003$.

Exhibit 2-2: State Program Wage Rates (2003$)

State Labor Category	Labor Cost
Field Engineer	$37.34
Administrative	$33.60

Source: Economic Analysis for the Final Ground Water Rule (USEPA, 2006), the Stage 2 Disinfectants and Disinfection Byproducts Rule (USEPA-1996), and the Long Term 2 Enhanced Surface Water Treatment Rule (USEPA-1996).

2.3 Escalated Labor Rates

The Agency continues to improve the basis from which it estimates the cost of its rules. Newer data from EPA's own national surveys, updated U.S. Bureau of Labor Statistics (BLS) data, and other industry surveys are currently under evaluation and are not yet ready to be incorporated into the Economic Analysis for the proposed RTCR. EPA intends to use these more recent data sources for the final RTCR. To ensure these labor rates are presented consistently with other cost analyses and to present results that reflect current values, EPA has adjusted the water system and State Program labor rates to 2007$ using an appropriate labor price index. At the time this document was prepared, 2007 was the latest year that a complete price index was available.

Water system technical and managerial labor rates were escalated from 2003$ to 2007$ using a BLS Employment Cost Index – Series Index CIU2014400000000I (B), Total Compensation; Utilities. An escalation rate was computed using the price index for 4th Quarter 2003 (90.2) and 4th Quarter 2007 (105.2) as follows: 105.2 ÷ 90.2 = 1.17. The escalation rate was applied to the 2003 labor rates to derive the corresponding 2007 labor rate values. Exhibit 2-3 presents the escalated labor rates for water system labor categories.

Exhibit 2-3: Water System Wage Rates by System Size (2007$)

	System Size (Population Served)					
Loaded Wage Rate (2007$)	25-100	101-500	501-3,300	3,301 -10k	10,001-100k	>100k
Technical Wage Rate	$25.10	$27.03	$28.96	$29.67	$30.50	$36.60
Managerial Wage Rate	$51.93	$55.94	$59.94	$59.94	$59.94	$59.94
Weighted Labor Rate	$25.10	$27.03	$28.96	$35.72	$36.39	$41.27

Notes:
1. Figures represent loaded rates that include a fringe benefit multiplier ranging from 1.3 to 1.5 across size categories.
2. EPA estimates that systems with population greater than 3,300 use a combination of operators (technical) and engineers (managerial), with an 80/20 ratio between the two, respectively. EPA also estimates that systems serving 3,300 or less use 100% (technical) labor.
3. Labor costs adjusted from 2003 to 2007 dollars using BLS Employment Cost Index, Series Index CIU2014400000000I (B), Total Compensation; Utilities.

Source: Economic Analysis for the Final Ground Water Rule (USEPA, 2006), the Stage 2 Disinfectants and Disinfection Byproducts Rule (USEPA-1996), and the Long Term 2 Enhanced Surface Water Treatment Rule (USEPA-1996).

State program administrative and field engineering staff labor rates were escalated from $2003 to 2007$ using BLS Employment Cost Index CIS3010000000000I (B) – Total Compensation, State and Local Government. An escalation rate was computed using the price index for 4th Quarter 2003 (92.7) and 4th Quarter 2007 (108.2) as follows: 108.2 ÷ 92.7 = 1.17. The escalation rate was applied to the 2003 labor rates to derive the corresponding 2007 labor rate values. Exhibit 2-4 presents the escalated labor rates for the State labor categories.

Exhibit 2-4: State Program Personnel Wage Rates (2007$)

State Labor Category	Labor Cost
Field Engineer	$43.58
Administrative	$39.22

Notes: Labor rates escalated using the BLS Employment Cost Index – Total Compensation State and Local Government, CIS3010000000000I (B).

Source: Economic Analysis for the Final Ground Water Rule (USEPA, 2006), the Stage 2 Disinfectants and Disinfection Byproducts Rule (USEPA-1996), and the Long Term 2 Enhanced Surface Water Treatment Rule (USEPA-1996).

2.4 Labor Rates for RTCR Alternative Size Categories

The TCRDSAC Technical Working Group (TWG) analyzed the impact on PWSs using a modified set of system sizes based on the requirements of the proposed RTCR. This is because certain rule provisions differ for systems above or below different population breaks (e.g., those serving more or less than 1,000, 4,100, or 33,000 people). Exhibit 2-5 presents the number of systems in each system size category for both the Economic Analysis for the Ground Water Rule (GWR EA) and the proposed RTCR.

Exhibit 2-5: Comparison of the Number of Systems in each System Size Category for the GWR EA and the Proposed RTCR

GWR EA Categories (population served)	Number of Systems according to GWR EA Categories	Alternative Size Categories for RTCR (population served)	Number of Systems according to RTCR Alternative Size Categories
≤100	83,746	≤100	83,746
101-500	42,692	101-500	42,692
501-3,300	19,204	a) 501-1,000 b) 1,001-4,100	a) 9,498 b) 10,952
3,301-10,000	5,069	a) 1,001-4,100 b) 4,101-33,000	a) 10,952 b) 6,498
10,001-100,000	3,761	a) 4101-33,000 b) 33,001-96,000 c) >96,000	a) 6,498 b) 1,063 c) 430
>100,000	407	>96,000	430

Source: 4th quarter freeze from Safe Drinking Water Information System/Federal Version (SDWIS/Fed).

Exhibit 2-6 presents the water system labor rates using these alternative system size classifications. These were developed from the weighted labor rates presented in Exhibit 2-3 and reclassified into the system sizes presented below by weighing the labor rates by the numbers of systems in each size category outlined in Exhibit 2-5 above.

Exhibit 2-6: Water System Labor Rates by TCRDSAC TWG System Size Categories (2007$)

Loaded Wage Rate (2007$)	System Size (Population Served)						
	≤100	101 - 500	501 - 1,000	1,001 - 4,100	4,101 – 33,000	33,001 – 96,000	>96,000
Weighted Labor Rate	$25.10	$27.03	$28.96	$29.73	$36.00	$36.39	$41.01

3 Estimated Unit Costs of TCR Monitoring Requirements

3.1 Introduction

The current TCR requires PWSs to test for the presence of total coliforms and either *E. coli* or fecal coliform at designated frequencies and locations in the distribution system as part of the routine, repeat, and additional routine monitoring provisions of the rule. The proposed RTCR would remove fecal coliforms as an indicator, but the general framework of monitoring would remain the same.

This chapter presents the methodology, data, and assumptions used in developing estimates of the unit costs of compliance monitoring for both the current TCR and for the RTCR. The general approach used to develop these estimates was developed by the TCRDSAC TWG during the federal advisory committee process in order to approximate relative costs of different rule options. EPA further refined this approach to develop the final unit costs presented in this document. Any assumptions that differ from those made by the TCRDSAC TWG are highlighted. The unit costs and the approach to develop them are presented below.

The costs presented in this chapter serve as a foundation for making comparisons between regulatory alternatives developed by EPA. They are meant to capture national averages of unit costs and not the unit costs of any particular system. Some components of monitoring costs, such as the purchase and wear-and-tear of vehicles, were discussed but not quantified here because of either limited data or inability to attribute these costs directly to the TCR or RTCR. Thus, the unit costs presented in this document may over- or under-estimate the unit costs of any particular system. The information is meant to be used for evaluation and comparison purposes at the national level only and not as direct input for system-specific design or budget preparation for non-EPA entities.

The following sections of this chapter present unit cost estimates for each component of monitoring costs under the RTCR. A concluding section presents a weighted average unit cost of monitoring. These sections are:

- Sample Collection and Delivery
- Sample Analysis
- Estimated Average Unit Monitoring Costs

3.2 Sample Collection and Delivery

Sample collection and delivery unit costs are determined by the labor burden, or estimated staff time, to collect samples and the cost to deliver the samples to contracted laboratories (where applicable). For systems that use in-house labs, no additional delivery cost is applied. Approved sampling procedures for TC/*E. coli* require very short hold times: not more than 30 hours from the time the sample is collected to the time the sample analysis begins. Delivery to a contracted laboratory, therefore, requires rapid response on the part of system staff or lab courier service. The TCRDSAC TWG discussed sample collection and delivery in detail during the proceedings of the TCRDSAC. A variety of delivery methods were discussed, each with a different cost. The TWG used available data along with best professional judgment in assuming the proportions of systems using each delivery method and developing the unit cost estimates.

3.2.1 Sample Collection

Sample collection unit costs include all activities and the time to execute such activities in the collection of all routine, repeat, and additional routine samples by water system staff. Proper procedures must be followed to ensure the sample is representative of the distribution system water quality and is not contaminated during sampling and subsequent handling. There are 12 approved methods under the TCR. All methods generally require that the same sample collection procedure is followed. The TCRDSAC TWG used best professional judgment to estimate the labor burden for system staff to take a single sample for compliance with the TCR. For costing purposes, a simplifying assumption was made that systems collect their own samples (as opposed to contracting sample collection).

3.2.1.1 Sample Collection Labor Burden

The TCRDSAC TWG estimated the time (in hours) to collect a single sample based upon approved collection procedures and practices, including: gaining access to the sampling site, disinfection of the sampling tap, sample collection, completion of requisite forms and associated paperwork, and travel to and from the sampling site. Per-sample labor burden estimates were informed both by best professional judgment and by estimating the time required for collecting the total number of samples over a period of time. For example, a PWS may take 100 TC samples per month with an estimated total sample collection time for the entire month of 75 hours which would be equivalent to a per-sample burden of 0.75 hours. Per-sample labor burden was estimated by water system size and included travel and sample collection time based on approved sample collection procedures. Larger systems would likely have longer travel times between sampling sites compared to smaller systems and therefore greater estimated costs.

Exhibit 3-1 presents the estimated average sample collection labor burden for three PWS population size categories.

Exhibit 3-1: Estimated Travel and Sample Time by PWS Population Served

Population Served	Time (hours) required per sample[1]
≤500	0.5
501 – 96,000	0.75
>96,000	1.0

[1]Developed by TCRDSAC TWG based on experience and best professional judgment of TWG members.

3.2.1.2 Unit Sample Collection Costs

Exhibit 3-2 presents the unit cost per sample collected. These costs, which represent a total labor cost per sample, were derived by multiplying the labor burden estimates in Exhibit 3-1 and the appropriate staff labor rate for each PWS size category. The labor rates presented in Exhibit 3-2 represent technical wage rates originally reported in the *Economic Analysis for the Final Ground Water Rule* -USEPA, October 2006. See chapter 2 for a detailed description of how these labor rates were derived.

Exhibit 3-2: Estimated Sampling Collection Cost (2007$)

System Size	Labor Rate[1]	Sampling Time (hours)[2]	Total Labor Cost
A	B	C	D=B*C
≤100	$25.10	0.5	$12.55
101-500	$27.03	0.5	$13.52
501-1,000	$28.96	0.75	$21.72
1,001-4,100	$29.73	0.75	$22.30
4,100-33,000	$36.00	0.75	$27.00
33,001-96,000	$36.39	0.75	$27.29
>96,000	$41.01	1.0	$41.01

[1]Includes travel time between sites and sample collection
[2]Estimated by TCRDSAC TWG

3.2.2 Sample Delivery

EPA considered the various options that PWSs have for delivery of proposed RTCR compliance monitoring samples to approved laboratories for analysis. These delivery methods included using a contract lab's courier service or ground next day, standard next day, and priority overnight shipping options through private delivery companies such as FedEx. Given the constraint of sample hold times (no more than 30 hours from time sample is drawn to analysis) and the requirement for a national delivery route, FedEx was deemed to be a reasonable cost basis. The derived costs are based on the delivery rates for delivering a package a distance of 100 miles, a distance based on experience of members of TCRDSAC TWG. The delivery package is assumed to be a cooler with dimensions of 17" x 12" x 15" sufficient to contain between one and five samples with ice packs at a single price per shipment (except ground next day service which varies with package weight). Exhibit 3-3 presents the estimated unit cost for sample delivery.

Exhibit 3-3: Estimated Sample Delivery Cost Per Shipment (2007$)

Type of Delivery	1 sample	2 samples	3 samples	4 samples	5 samples
Lab Courier Service	$3.50	$3.50	$3.50	$3.50	$3.50
Ground Next Day[1]	$6.65	$6.77	$6.88	$7.00	$7.12
Standard Next Day[1]	$38.48	$38.48	$38.48	$38.48	$38.48
Priority Overnight[1]	$45.12	$45.12	$45.12	$45.12	$45.12

[1]Source of Cost Quotes: FedEx

Exhibit 3-4 below presents the shipping cost on a per-sample basis which is applied to those systems that are permitted to take all of their samples on the same day and to those systems required to take repeat samples or additional routine samples (and would thus be taking and delivering multiple samples at the same time). The effect on cost of taking multiple samples diminishes as the number of samples shipped or delivered simultaneously increases. Thus, the estimated delivery costs for systems taking more than five samples simultaneously or grouped together was assumed to be the same as the costs of shipping or delivering five samples.

Exhibit 3-4: Estimated Per-Sample Delivery Cost (2007$)

Type of Delivery	Number of Samples Shipped or Delivered Simultaneously				
	1	2	3	4	5
Lab Courier Service	$3.50	$1.75	$1.17	$0.88	$0.70
Ground Next Day	$6.65	$3.39	$2.29	$1.75	$1.42
Standard Next Day	$38.48	$19.24	$12.83	$9.62	$7.70
Priority Overnight	$45.12	$22.56	$15.04	$11.28	$9.02

Note: Per-sample delivery cost is calculated by dividing the delivery cost per shipment in the previous exhibit by the number of samples shipped or delivered simultaneously.

Some systems deliver samples to contract laboratories themselves, sometimes driving long distances. The cost to these systems to self-deliver will vary based on the distance driven and the labor rate of the employee delivering the samples. The TCRDSAC TWG discussed the wide range of distances that are driven by different systems when self-delivering samples by personally owned vehicles to labs. Based on best professional judgment and discussions with industry, EPA estimates that when a system employee delivers the samples to a lab in a personally owned vehicle, the employee will drive, on average, 15 miles (30 miles round trip). The estimated costs for sample self-delivery by personally owned vehicle are presented in Exhibit 3-5.

Exhibit 3-5: Estimated Cost for Sample Self-Delivery[1] (2007$)

System Size	Labor Rate	Drive Time (hours)[1]	Total Labor Cost	Personal Vehicle Use Reimbursement[2]	Total Delivery Cost
A	B	C	D=B*C	E	F=D+E
≤100	$25.10	0.5	$12.55	$15.15	$27.70
101-500	$27.03	0.5	$13.52	$15.15	$28.67
501-1,000	$28.96	0.5	$14.48	$15.15	$29.63
1,001-4,100	$29.73	0.5	$14.87	$15.15	$30.02
4,100-33,000	$36.00	0.5	$18.00	$15.15	$33.15
33,001-96,000	$36.39	0.5	$18.20	$15.15	$33.35
>96,000	$41.01	0.5	$20.51	$15.15	$35.66

[1]Distance of 15 miles (30 miles roundtrip) and average speed of 60 mph.
[2]Estimated 3/19/2008 using the U.S. General Services Administration (GSA) rate at that time of $0.505 per mile.

Consistent with the use of a courier or parcel delivery service, the unit cost of self-delivery of samples decreases as the number of samples per shipment increases. These bulk shipment unit costs are presented in Exhibit 3-6.

Exhibit 3-6: Per Sample Cost Estimate for Sample Self-Delivery (2007$)

System Size	Number of Samples Shipped or Delivered Simultaneously				
	1	2	3	4	5
≤100	$27.70	$13.85	$9.23	$6.93	$5.54
101-500	$28.67	$14.33	$9.56	$7.17	$5.73
501-1,000	$29.63	$14.82	$9.88	$7.41	$5.93
1,001-4,100	$30.02	$15.01	$10.01	$7.51	$6.00
4,100-33,000	$33.15	$16.58	$11.05	$8.29	$6.63
33,001-96,000	$33.35	$16.68	$11.12	$8.34	$6.67
>96,000	$35.66	$17.83	$11.89	$8.92	$7.13

Note: Per sample cost delivery cost is calculated by dividing the total delivery cost from the previous exhibit by the number of samples being driven simultaneously.

The TCRDSAC TWG developed estimates of the percentage of systems using the different types of sample delivery methods based on its best professional judgment. These percentages are provided as Exhibit 3-7. These percentages were used along with the other unit costs above to derive a weighted average unit cost of sample delivery among those systems that deliver or ship samples to a certified laboratory. The same delivery process was used for all system sizes that deliver or ship samples.

Exhibit 3-7: Estimated Percentages[1] of Systems Using Each Type of Sample Delivery

Delivery Type	Percentage of Systems
Lab Courier Service Pick-up	20%
Ground Next Day	50%
Standard Next Day	12.5%
Priority Overnight	12.5%
Self-Delivery by Car	5%

[1]Based on best professional judgment of TCRDSAC TWG

Exhibit 3-8 shows the weighted average unit delivery costs by PWS size category. As an example calculation to demonstrate how the preceding exhibits come together to form the values in Exhibit 3-8, consider the average cost to a system serving ≤100 people to ship one sample. The cost is calculated as follows:

(0.2 * $3.50) + (0.5 * $6.65) + (0.125 * $38.48) + (0.125 * $45.12) + (0.05* $27.70) = $15.86

The percentages (0.2, 0.5, 0.125, 0.125, and 0.05) were obtained from Exhibit 3-7. The dollar values for all delivery methods, except for self-delivery by vehicle, were obtained from the first column of Exhibit 3-4. The first column is used because, in this example, it is specified that only one sample is being delivered. The dollar value for self-delivery by vehicle was obtained from the first row and first column of Exhibit 3-6, corresponding to the smallest sized system shipping only one sample. The dollar values are multiplied by their corresponding percentages to derive the weighted average delivery cost of $15.86.

As another example, consider the average per-sample cost incurred by a system serving 101-500 persons. The cost is calculated as follows:

(0.2 * $1.75) + (0.5 * $3.39) + (0.125 * $19.24) + (0.125 * $22.56) + (0.05 * $14.33) = $7.98.

In this example, the per-sample costs are drawn from the second columns of Exhibits 3-4 and 3-6 which corresponds to two samples shipped at the same time and resulting in a lower weighted average per-sample shipping/delivery cost.

Exhibit 3-8: Estimated Per Sample Shipping/Delivery Cost as a Function of System Size (2007$)

System Size	Number of Samples Shipped or Delivered Simultaneously				
	1	2	3	4	5
≤100	$15.86	$7.96	$5.33	$4.01	$3.22
101-500	$15.91	$7.98	$5.34	$4.02	$3.23
501-1,000	$15.96	$8.01	$5.36	$4.03	$3.24
1,001-4,100	$15.98	$8.02	$5.36	$4.04	$3.24
4,100-33,000	$16.13	$8.10	$5.42	$4.08	$3.27
33,001-96,000	$16.14	$8.10	$5.42	$4.08	$3.28
>96,000	$16.26	$8.16	$5.46	$4.11	$3.30

3.3 Sample Analysis

This section briefly describes two analytical methods for simultaneous sample analysis of TC and *E.coli*: SM 9223-B (most common) and SM 9222-D membrane filtration (most labor intensive) and presents an approach for estimating the average unit cost of sample analysis. The unit costs of sample analysis are presented in two ways: (1) the cost for those systems that send out the analysis to a certified contract laboratory and (2) the cost for those systems that perform the analysis using in-house staff and laboratories.

Sample analysis costs for systems that contract the services are derived from the analytical fees charged by certified laboratories. Systems that perform the sample analyses in-house are assumed to incur both labor and operations and maintenance (O&M) costs. O&M costs are those expenses associated with operating a laboratory and performing an approved analytical method in-house. They include the laboratory facility, equipment and maintenance, supplies such as reagents, glassware and sample containers, as well as lab certification fees. In the final section of this chapter, a weighted average sample analysis unit cost is calculated based upon the percentages of systems conducting sample analysis in-house versus sending samples out to contract labs.

3.3.1 Available Analytical Methods

Several common analytical methods exist that provide for simultaneous detection of TC and *E. coli* in single samples. Simultaneous detection is often preferred because it reduces the total time required for analysis of *E. coli*, as non-simultaneous methods can require an additional 24- to 48-hour incubation time for *E. coli* detection.

A commonly-used analytical method for simultaneous TC and *E. coli* analysis utilizes enzyme substrate technology. Various commercially available formulations are available in disposable tubes for the multiple tube procedure, in disposable multi-wells or in containers that will hold 100-ml samples for presence-absence determination. This type of method can typically utilize various nutrient indicators to produce a chromogenic or fluorogenic reaction with natural enzyme substrates (i.e., β-galactosidase for TC and β-glucorinidase for *E.coli*).

Another common simultaneous method utilizes an enriched lactose growth media and an incubation temperature of 44.5ºC ± 0.2 ºC for selectivity. This method requires membrane filtration of the bacteria with subsequent differentiation of *E.coli*. *E. coli* bacteria are detected by transferring the membrane after the TC test to a 4-methyl umbelliferyl β-D glucuronide (MUG) nutrient agar substrate. *E. coli* bacteria are detected by observing any coliform colonies with a

fluorescent blue periphery. The colony forming units counted on each membrane are added together for a reportable result as number per 100 ml.

The preamble to the proposed RTCR provides a complete discussion on analytical methods for detection of total coliforms and *E. coli* utilized under this proposed rule.

3.3.2 Sample Analysis Cost

The cost of sample analysis is one of the key components of the overall unit cost of monitoring. The cost of sample analysis will vary depending on whether a system contracts the analysis to a certified laboratory or conducts the analytical methods in-house. The following sections discuss the approach for determining sample analysis cost for contractor labs versus in-house labs.

3.3.2.1 Contractor Labs

Any laboratory that performs analyses for a PWS that is not performing sample analysis for itself under the TCR is considered to be a contractor laboratory. Typically contract laboratories are commercial laboratories holding certification in one or more States to perform sample analysis by approved methods under the TCR. Some larger PWSs also perform contract sample analysis typically for smaller systems. Some States also provide analytical support services to PWSs.

Contract laboratories normally bid on annual contracts to perform compliance sample analysis for PWSs. Purchasing requirements typically include state or primacy agency certification and sample analysis unit cost for each contracted method. Sample analysis fees may also include sample pick-up. Contractor laboratory fees include direct labor and overhead as well as O&M. Therefore, no estimates of direct labor or O&M are required to determine the direct cost to a PWS for contracted sample analysis.

Information for sample analysis costs for each of the two commonly performed methods described previously for simultaneous analysis of TC and *E. coli* was reviewed to estimate average contractor lab analytical fees. This data is presented below in Exhibit 3-9.

Based on the best professional judgment and experience of the TCRDSAC TWG and EPA, the majority of systems employ substrate methods (e.g., SM 9223 B) rather than membrane filtration methods (e.g., 9222 D). Thus, the estimated unit costs of monitoring presented at the end of this chapter assume the use of substrate methods. However, the contractor lab fees for both SM 9223 B and SM 9222 D are presented in Exhibit 3-9 to allow the reader to compare costs between the two methods. The data were derived from an informal survey of nine commercial laboratories in April 2008. Only four of the laboratories contacted were certified to perform both methods. As a simplifying assumption the TCRDSAC TWG assumed the analytical pricing was equivalent to 2007 costs.

Although not explicitly discussed here, contracted lab fees may also include the cost of reporting to the primacy agency. Certain States require the laboratory performing the analysis to also perform the reporting function.

Exhibit 3-9: Common TC and *E. coli* Analytical Methods and their Average Contractor Lab Analytical Fee (2007$)[1]

Lab (Location)	Analytical Method	
	SM 9223 B	*SM 9222 D*
CA	$18.00	$27.75
KY	$25.00	$35.00
OH	$15.00	$25.00
IN	$25.00	$30.50
CA	$20.00	
NY	$25.00	
MI	$30.00	
NY	$18.00	
WV	$23.25	
Average	$22.13	$29.56

[1]Based on 2008 data from nine laboratories across the United States.

3.3.2.2 In-house Analysis

Water systems serving a population greater than 33,000 persons typically perform sample analysis in-house. Larger systems are more likely to have the staff, equipment, and facilities required to hold certifications and perform analysis for one or more of the approved methods under the TCR. The cost of sample analysis performed in-house should also account for O&M costs which can include equipment and maintenance such as incubators, UV lights, glassware, miscellaneous lab equipment and supplies, as well as perishables including reagents, sampling containers, etc. Certification fees must also be included in O&M costs. Certification fees can be highly variable and may range from a few hundred dollars to several thousand dollars a year. Some States, Indiana for example, do not have laboratory certification fees. Certification fees are typically based upon specific methods performed or by analyte groups such as inorganics, organics, or microbiology. Certification requirements are also specific with regard to facilities, equipment, and staff. Laboratory work stations must be properly maintained with adequate facilities, be of an adequate size, and possess safety equipment including safety showers, eyewash stations, and hoods. All of these items must be included in O&M costs.

For purposes of this document, EPA is applying the same estimate for O&M costs ($8.95) that was used in the GWR EA escalated to 2007 dollar values ($10.09). In addition to O&M, labor burden was considered a key criterion for estimating cost for sample analysis performed in-house. The TCRDSAC TWG agreed that 0.5 hours per sample was a reasonable estimate for labor burden. The site-specific technical labor rate was also considered as a key component to the estimation of sample analysis cost. Again, the TWG agreed to use the labor rates from the GWR EA adjusted to 2007 dollars. Exhibit 3-10 demonstrates the estimated sample cost for analysis performed in-house.

Exhibit 3-10: Estimated Sample Cost for In-House Analysis (2007$)

System Size	Labor Rate	Labor Burden (hours)	O&M	Total Labor Cost
A	B	C	D	E=B*C+D
≤100	$25.10	0.5	$10.09	$22.64
101-500	$27.03	0.5	$10.09	$23.61
501-1,000	$28.96	0.5	$10.09	$24.57
1,001-4,100	$29.73	0.5	$10.09	$24.96
4,100-33,000	$36.00	0.5	$10.09	$28.09
33,001-96,000	$36.39	0.5	$10.09	$28.29
>96,000	$41.01	0.5	$10.09	$30.60

3.4 Estimated Average Unit Monitoring Costs

This chapter has presented the methodology, data, and assumptions used in developing estimates of the unit costs of compliance monitoring for both the current TCR and for the proposed RTCR based on whether the system uses a contract lab or tests samples in-house. The general approach used to develop these estimates is the same that was used by TCRDSAC TWG during the federal advisory committee process in order to approximate relative costs of different rule options. The components of unit monitoring costs are as follows:

For in-house sample analysis:

- Sample collection
- Sample analysis

For contract lab sample analysis:

- Sample collection
- Shipping/delivery
- Lab fee

Unit costs were derived for both of these monitoring approaches and for each of the different system size categories. A weighted average for sample analysis cost incorporating both in-house and contractor sample analysis cost is presented. This weighted average is based on the estimated percentage of systems using in-house versus contractor labs and is shown in Exhibit 3-11. Large systems typically have the staff, facilities and equipment required to obtain certifications and perform one or more of the approved analytical methods. Small systems typically contract a certified laboratory to perform the sample analysis. The assumptions presented in Exhibit 3-11 demonstrate that systems serving 33,000 persons or less contract 100 percent of their sample analysis to a certified laboratory. Systems serving between 33,001 and 96,000 persons are equally divided between using in-house labs and using contractor labs. For the largest systems, those serving >96,000 persons, 90 percent are assumed to use an in-house laboratory and 10 percent to use contract labs. These percentages were used to derive the weighted average unit monitoring cost of in-house and contract labs for the different size categories presented in Exhibit 3-12.

Exhibit 3-11: Percentage of Systems Using In-House vs. Contracted Laboratories

System Size	Percent Using In-House Laboratory	Percent Using Contract Laboratory
≤100	0%	100%
101-500	0%	100%
501-1,000	0%	100%
1,001-4,100	0%	100%
4,100-33,000	0%	100%
33,001-96,000	50%	50%
>96,000	90%	10%

[1]Developed by TCRDSAC TWG based on the experience of the group and best professional judgment.

An example calculation is presented below to demonstrate the source of the data presented in Exhibit 3-12. Consider a system serving 33,001-96,000 persons that takes five samples simultaneously. As presented in Exhibit 3-12, the estimated average unit cost of monitoring (per sample cost) is $54.14.

$$0.5 * \underbrace{(\$27.29 + \$28.29)}_{\text{Unit cost for in-house}} + 0.5 * \overbrace{(\$27.29 + \$3.28 + \$22.13)}^{\text{Unit cost for contract lab}} = \$54.14$$

0.5 =	Percentage of systems in this size category using in-house labs and percentage of systems in this size category using contract labs (from Exhibit 3-11)
$27.29 =	Sampling cost (from Exhibit 3-2)
$28.29 =	In-house analytical cost (labor + O&M) (from Exhibit 3-10)
$3.28 =	Average per-sample shipping cost for a system in this system size when collecting 5 samples at once (from Exhibit 3-8)
$22.13 =	Average lab fee to test one sample for TC/*E. coli* using substrate method (from Exhibit 3-9)

Exhibit 3-12: Estimated Average Unit Cost of Monitoring (2007$)

System Size	Number of Samples Taken Simultaneously				
	1	2	3	4	5
≤100	$50.54	$42.64	$40.01	$38.69	$37.90
101-500	$51.55	$43.63	$40.99	$39.67	$38.87
501-1,000	$59.81	$51.86	$49.21	$47.88	$47.09
1,001-4,100	$60.40	$52.45	$49.79	$48.47	$47.67
4,100-33,000	$65.26	$57.23	$54.55	$53.21	$52.40
33,001-96,000	$60.57	$56.55	$55.21	$54.54	$54.14
>96,000	$72.38	$71.57	$71.30	$71.17	$71.09

4 Estimated Unit Costs of Assessments

The current federal requirements of the TCR do not include assessments of PWSs following nonacute violations or acute violations. However, under the current TCR, as it is actually implemented, many systems are either conducting some level of assessments themselves or receiving some level of assessments from States following Maximum Contaminant Level (MCL) violations. This chapter estimates the level of effort currently incurred by systems to conduct assessments following TCR MCL violations under the current TCR, as implemented. In addition, the chapter provides an overview of the assessment provisions proposed as part of RTCR and their associated costs for drinking water systems. The cost estimates presented in this chapter were informed by input from States and industry received during the proceedings of the TCRDSAC. They are described in more detail later in the chapter. State costs associated with assessments are included in the RTCR Economic Analysis.

This chapter is organized into three sections. Each section builds on the previous section to describe how the unit costs incurred by systems to perform assessments were estimated. The three sections are as follows:

1. Overview of Assessments
2. Elements of Assessments
3. Unit Cost Estimates of Assessments

4.1 Overview of Assessments

The purpose of performing assessments is to proactively enhance public health protection by identifying the presence of "sanitary defects" and defects in distribution system coliform monitoring practices. EPA believes that assessments will strengthen the drinking water system's capacity to ensure that barriers to intrusion or contamination are in place and effective. The proposed assessment triggers represent a significant improvement over the current TCR paradigm in that sampling results will trigger an assessment to take a closer look at the system and to identify whether one or more sanitary defects are present. This is a more proactive approach than the current TCR and will lead to the identification and correction of problems that may compromise public health. The RTCR includes two levels of assessments: Level 1 and Level 2. For either Level 1 or 2 assessments, the PWS will complete the assessment as soon as practicable after notification of their monitoring results. The PWS will provide the primacy agency a complete Level 1 or 2 assessment report within 30 days after notification of exceeding the trigger.

EPA proposes that minimum elements of both Level 1 and 2 assessments should include a review and identification of the following:

1. Inadequacies in sample sites, sampling protocol, and sample processing

2. Atypical events that may have affected distributed water quality or indicate that distributed water quality was impaired

3. Changes in distribution system maintenance and operation that may have affected or are affecting distributed water quality including water storage

4. An evaluation of source water quality and treatment changes or conditions that may affect distributed water quality, where appropriate (e.g., small ground water systems)

5. Existing water quality monitoring data

Appendix X of the AIP contains forms that serve as examples of Level 1 and 2 assessments. These forms are intended as conceptual examples to describe practical expectations for the level of resources committed to undertaking a Level 1 or 2 assessments. Assessments conducted under the RTCR should reflect the substance and effect of the elements of these example Level 1 and 2 assessment checklists. The following two sections describe the Level 1 and Level 2 assessments in more detail.

4.1.1 Level 1 Assessments

The Level 1 assessment will consist of a simple examination of the system and relevant operational practices. The Level 1 assessment is intended as a self-assessment (EPA anticipates that these will be completed by the PWS and reviewed by the primacy agency). If the primacy agency determines the assessment report insufficient, it will consult with the PWS.

A Level 1 assessment is triggered if sampling results in one of the following:

1. For systems collecting 40 or more samples per month, the PWS exceeds 5.0% TC positive samples for the month; or

2. For systems collecting fewer than 40 samples per month, the PWS has two or more TC-positive samples in the same monitoring period; or

3. Failure to collect every required repeat sample after a single TC-positive sample.

The assessment report will identify sanitary defects detected, corrective actions completed, and a timetable for any corrective actions not already completed. The assessment report may also note that no sanitary defects were identified. Upon completion and submission of the assessment report by the PWS, the primacy agency will determine if the system has identified a likely cause for the Level 1 trigger and establish whether the system has corrected the problem.

4.1.2 Level 2 Assessments

A Level 2 assessment is a more detailed examination of the system, its monitoring program and results, and its operational practices. It is comprised essentially of the same elements as a Level 1 assessment, but each element is investigated in greater detail. The level of effort and resources required to implement the Level 2 assessments will be commensurate with a more comprehensive investigation, a higher level review of available information, and may involve the engagement of additional parties and expertise.

A Level 2 assessment is triggered if sampling results in any of the following:

1. An acute violation as determined by an *E. coli* MCL violation; or

2. An *E. coli* monitoring violation (defined as failing within 24 hours to collect repeat samples following an *E. coli*-positive sample); or

3. A second Level 1 trigger, within a rolling 12 month period, unless the primacy agency has determined a likely reason that the initial Level 1 samples were TC-positive and establishes that the system has corrected the problem; or

4. For systems with approved reduced annual monitoring, a Level 1 trigger in two consecutive years.

EPA anticipates that the system burden incurred by conducting Level 2 assessments following triggers associated with the presence of *E. coli* (referred to later in this document as Level 2 [acute]) may be higher than the system burden incurred by conducting Level 2 assessments following triggers in which there is not *E. coli* (referred to later in this document as Level 2 [nonacute]).

Level 2 assessments will be conducted by the PWS, where the system has staff or management with the certification or qualifications specified below, unless otherwise directed or approved by the primacy agency:

1. A certified operator with a minimum of two (2) years of experience as a certified operator in systems requiring similar or more extensive certification requirements, or

2. Individuals with equivalent training or experience as approved by the primacy agency.

As with the Level 1 assessment report, the Level 2 assessment report will identify sanitary defects detected, corrective actions completed, and a timetable for any corrective actions not already completed. The assessment report may also note that no sanitary defects were identified. Upon completion and submission of the assessment report by the PWS, the primacy agency will determine if the system has identified a likely cause for the Level 2 trigger and establish whether the system has corrected the problem. If the primacy agency determines that the Level 2 assessment report is insufficient, it will consult with the PWS and, if necessary, provide assistance or require appropriate action.

The cost associated with the State conducting the assessment will be considered in the economic analysis in addition to other State implementation costs. In this document, only the costs incurred by systems are considered.

4.2 Elements of Assessments

The TCRDSAC TWG discussed the various elements that assessments would likely encompass including those that are currently implemented by some systems and States under the existing TCR. This list of elements was based on the collective experience and best professional judgment of TCRDSAC TWG members and their colleagues. They are summarized in Exhibit

4-1 below and described further in the sections that follow. The list is not intended to represent required elements of an assessment and should not be interpreted as such. Rather, the list is an interpretation by the TCRDSAC TWG of both what is occurring under the existing TCR and of what is anticipated to occur under the revised TCR and is meant to provide estimates of system labor burden associated with assessments. The different types of assessments are made up of the same elements, but the degree to which the elements are implemented varies. Because of differences among systems and States, EPA anticipates that primacy agencies will tailor specific assessment elements to the size and type of a water system and that PWSs will adapt their assessment activities based on the characteristics of the distribution system. The actual assessment costs will be highly dependent upon the specific system characteristics and the primacy agency requirements.

Exhibit 4-1: Summary of TCRDSAC TWG Investigative Spreadsheet Assessment Elements

Element	Description
Notification Element	Notification of the state authority. Includes time for the system to review sample data, notify superiors, and contact state authority.
System Specific Element	Includes time for personnel to gather system specific information (system ID, size, active sources, sample site plan, etc.) if necessary.
Sample Analytical Element	Evaluate Lab Quality Assurance/Quality Control (QA/QC). Includes time for systems with labs to evaluate QA/QC procedures or for systems without labs to call contract lab with questions.
Sample Methodology Element	Includes time for personnel to evaluate whether proper sampling and sampling handling techniques were used and to identify and note any deviations.
Event Situational Element	Includes time for personnel to review and evaluate any significant system events that may have influenced the sample(s) (main breaks, main repair, pressure events, treatment problems, source water changes, weather events, etc.).
Operational Data Element	Includes time for personnel to compile other data that may be important to the event (such as chlorine residual, other water quality parameters, treatment parameters), if available.
Historical Trend Element	Includes time for personnel to review the history of samples in the system and at the site in question.
Sample Tap Element	Includes time to inspect and evaluate the condition of the sampling tap(s).
Sample Site Element	Includes time to inspect and evaluate the facility in which the sample was taken.
Sample Area Element	Includes time to inspect and evaluate other positive follow-up samples (if applicable) away from the original site.
Third Party Element	Includes time for contracting with a third party consultant.
Report Element	Includes time for the personnel to complete the report and provide the results to state authority.

The sections that follow describe the elements in more detail and include some of the assumptions discussed by the TCRDSAC TWG that helped to inform that cost estimates associated with each one. These elements differ in some respects with the elements contained in the example assessment forms provided in Appendix X of the AIP. However, most of the elements are equivalent or contain significant overlap, and while the investigations spreadsheet was developed to provide a basis for the cost estimate developed by the TCRDSAC TWG to

perform Level 1 and 2 assessments, the assessment forms found in Appendix X of the AIP are intended to be used as investigation concept examples for performing assessments.

4.2.1 Notification Element

The Notification Element involves notification of monitoring results to the state authority. Cost estimates are based on the time for sample data review, notification of superiors, state authority contact, and external advisor contact for guidance. Sample data review includes preparing information relevant to recent monitoring and the violation for dialog with the State, and a review of state code and guidance for the situation. Notification of superiors assumes contact within the chain of command extending to a local government entity. State authority contact assumes the State maintains a 24-hour call center or accepts email or fax communication. Under external advisor contact, after determining that a threshold has been exceeded, it is assumed that the system manager will contact a contract engineer, a colleague, National Rural Water Association (NRWA) Rider, or state employee to assess the implication or significance of the violation.

Normally, notification is limited to monthly filing of RTCR routine monitoring report and information related to the triggering of a Level 1 or 2 assessment would be provided by the system to the State in the routine monitoring report.

4.2.2 System Specific Element

The System Specific Element includes personnel time to gather system specific information, such as system ID, size, active sources, a description of the sample site plan, etc. Cost estimates assume that this information is available and that if it is not compiled yet, some time will be spent gathering the information and checking against previous permits and submissions to state authorities. Subsequent reporting will require minimal time to fulfill this element. Systems serving at least 4,100 customers will usually spend more time gathering information for this element because they typically have more complex community water system (CWS) identification assignments, retail and wholesale relationships, etc., which will need to be reviewed to properly associate positive sample sites to CWS identifiers.

4.2.3 Sample Analytical Element

The main purpose of the Sample Analytical Element is to document and evaluate laboratory QA/QC. Cost estimation assumes the State will provide this information for systems serving 1,000 or fewer customers. The estimated time burden for larger systems may include evaluating QA/QC procedures, or for systems without a laboratory, time to contact contract laboratories to obtain QA/QC information.

4.2.4 Sample Methodology Element

The Sample Methodology Element includes the time to evaluate whether proper sampling techniques were used and whether proper sample handling procedures were followed. Any deviations are identified, documented, and corrected. Cost estimates for systems serving 1,000

customers or fewer are based on time spent contacting an external advisor to evaluate the situation and to determine or receive confirmation on the steps to follow, as well as time for a review of procedures and equipment. Cost estimates for systems serving more than 1,000 customers include time for communication between a technician and a manager to evaluate whether proper sampling techniques were used, time for a review of proper procedures, and will likely involve time for a discussion with external advisors, such as a laboratory and the State. Adherence to proper sample handling techniques is also evaluated, so this step could occur concurrently with the initial evaluation. Some additional time will be devoted towards preparing handouts to guide and support the discussion, such as current sample handling, Standard Operating Procedures (SOPs), and methods (such as Standard Methods or EPA methods). Time will also be needed to identify and correct any deviations from established sampling and sample handling protocol.

4.2.5 Event Situational Element

Event Situational Elements include a review of any significant system events that may have influenced the samples. These may include main breaks, main repairs, pressure events, treatment problems, source water changes, power outages, distribution system operations (such as flushing), weather events, or vandalism. Cost estimation was based on the time needed to match specific sampling dates with specific event dates. In addition, this review may require interacting with non-water system personnel, such as construction crews. Time required will increase with increasing size and complexity of the system (multiple sources, larger distribution systems, etc.). For systems serving 4,100 customers and larger, additional time was allotted to evaluate the information collected through the review process and to evaluate the significance of this information.

4.2.6 Operational Data Element

The Operational Data Element involves collecting other data that may have influenced the sample, such as chlorine residual, other water quality parameters, and treatment parameters. The information collected is evaluated through a review process to determine whether it may have affected water quality at the time and location of sampling. Time estimates consider that the review is taking place at the end of the month and therefore specific data collected will have to be matched to specific sampling events. Aside from those associated with a significant effect on operations, treatment problems will likely not be recognized without reviewing available data from wells or treatment facilities to link changes in performance to specific results of collected samples. Cost estimates for this element also assume some time spent evaluating the significance of the data collected through a review process.

4.2.7 Historical Trend Element

The Historical Trend Element includes time for personnel to review the history of samples in the system, and a review of the history of samples at the site in question. Each of these review phases is further subdivided into three phases for time estimation purposes: data compilation, summarization, and evaluation. Data compilation includes compiling data

associated with collected TC samples for trend analysis, such as sources in production, tank release patterns, and water quality parameters.

4.2.8 Sample Tap Element

The Sample Tap Element involves an inspection and evaluation of the condition of the sampling tap. In addition, some time is allotted to evaluate the condition of the sampling taps. These time estimates were consistent across all trigger levels.

4.2.9 Sample Site Element

The Sample Site Element includes the time for an inspection and evaluation of the facility in which the sample was collected. For most utilities, there will likely be limited opportunities to make any changes to the facility where the sample tap is located. Therefore, the focus will be on the sample tap and associated plumbing.

4.2.10 Sample Area Element

The Sample Area Element is included if positive follow-up samples are present at other locations away from the original sample site. This assessment may include some or all of the above elements (such as Sample Tap and Sample Site Elements), and also includes inspection of valves and tanks.

4.2.11 Third Party Element

This element includes time for contracting with a third party consultant: identification of contractor options, drafting a scope, procurement review, management review, governing board approval, proposal distribution, proposal review, management review of proposals, drafting a contract, financial and legal review, dialog with State, and governing board approval. With increasing system size, some additional time is devoted towards management review of proposals and the financial and legal review.

4.2.12 Report Element

A report of the results of the assessment performed by the PWS in response to a trigger will need to be completed and submitted to the state authority. The cost estimate is based on time to complete the report, a chain of command review, and possibly a legal review and briefing.

4.3 Unit Cost Estimates of Assessments

4.3.1 Methodology

The cost estimates presented in this chapter were informed by input from States and industry received during the proceedings of the TCRDSAC and the associated TCRDSAC TWG meetings. Specific cost estimates are provided for each system type, either a CWS or non-

community water system (NCWS), on the size categories presented in Exhibit 4-2 and for the triggers listed in Exhibit 4-3. For each of the elements presented in Exhibit 4-1, an estimate is made for: (1) the percentages of systems that currently spend time on that element (under the existing TCR, as implemented) or the percentage of systems that are anticipated to spend time on that element (under the RTCR) and (2) the number of hours that are currently spent on that element (under the existing TCR, as implemented) or the number of hours that are anticipated to be spent on that element (under the RTCR). The product of (1) and (2) is taken for each element and these products are summed to calculate the estimated average labor burden incurred by a given system type/size for a given type of assessment. This approach recognizes the differences in responses to the various triggers and system size/type categories and the differences between what is happening under the existing TCR, as implemented, and what is anticipated to happen under the RTCR.

Exhibit 4-2: Categories for which cost estimates are developed

NCWS ≤1,000
NCWS 1,001-4,100
NCWS 4,101-33,000
NCWS 33,001-96,000
NCWS >96,000
CWS ≤100
CWS 101-500
CWS 501-1,000
CWS 1,001-4,100
CWS 4,100-33,000
CWS 33,001-96,000
CWS >96,000

Exhibit 4-3: Violations and triggers leading to assessments

Current TCR, as implemented
Nonacute MCL Violation
Acute MCL Violation
RTCR
Level 1 Trigger
Level 2 Trigger (Nonacute)
Level 2 Trigger (Acute)

As an example, consider the labor burden estimates for the existing TCR, as implemented, incurred by CWSs serving between 1,001 and 4,100 people. Exhibit 4-4 includes the elements that might make up an assessment and how the percentages of systems implementing those elements and the labor hours associated with those elements vary depending on the type of MCL violation. The exhibit indicates that, on average, under the existing TCR as it is implanted now, 22 system labor hours are spent on assessment activities following a nonacute MCL violation and 29 system labor hours are spent on assessment activities following

an acute MCL violation. Some systems spend more time that this on assessments and some spend less. This methodology is meant to capture the average for the purposes of developing national cost estimates for the comparison of rule options.

Exhibit 4-4: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 1,001-4,100

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems performing Element	Estimated Hours Associated with performing Element	Average Burden Associated with Element (hrs)	Percentage of Systems performing Element	Estimated Hours Associated with performing Element	Average Burden Associated with Element (hrs)
	A	B	C = A* B	D	E	F = D * E
Notification Element	100%	3	3	100%	3	3
System Specific Element	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0
Sample Methodology Element	80%	3	2.4	80%	3	2.4
Event Situational Element	10%	5.5	0.55	100%	5.5	5.5
Operational Data Element	60%	4	2.4	60%	4	2.4
Historical Trend Element	100%	3	3	100%	3	3
Sample Tap Element	80%	1.5	1.2	100%	2	2
Sample Site Element	5%	2	0.1	100%	2	2
Sample Area Element	30%	4	1.2	5%	3	0.15
Third Party Consulting Element	0%	0	0	0%	0	0
Report Element	100%	7.5	7.5	100%	7.5	7.5
Total			22.35			28.95

As a second example, consider NCWSs serving ≤ 1,000 conducting assessments under the RTCR. The elements and estimates of percentages of systems implementing the elements and labor hours associated with implementing the elements are presented in Exhibit 4-5. The exhibit indicates that, on average, 7, 9, and 21 system labor hours are anticipated to be spent on Level 1, Level 2 (nonacute), and Level 2 (acute) assessments, respectively. Recall that for the purposes of this document, a Level 2 (acute) assessment refers to a Level 2 assessment that is associated with the presence of *E. coli* while a Level 2 (nonacute) assessment is not associated with the presence of *E. coli.* Based on input from industry and States, EPA believes that the system burden associated with conducting a Level 2 assessment will likely vary depending on whether there is *E. coli* present.

Exhibit 4-5: RTCR Labor Burden Estimate for Assessments done by NCWSs serving ≤1,000

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element (hrs)	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element (hrs)	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element (hrs)
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	0	0	100%	0.5	0.5	100%	2	2
System Specific Element	0%	0	0	100%	0.3	0.3	100%	1	1
Sample Analytical Element	0%	0	0	100%	0	0	100%	1	1
Sample Methodology Element	50%	1	0.5	100%	0.5	0.5	100%	1	1
Event Situational Element	100%	1	1	100%	2	2	100%	2	2
Operational Data Element	60%	0.3	0.18	40%	0.5	0.2	40%	1	0.4
Historical Trend Element	100%	0.5	0.5	100%	0.5	0.5	5%	4	0.2
Sample Tap Element	100%	1	1	100%	1	1	100%	1	1
Sample Site Element	100%	1	1	100%	1	1	100%	1	1
Sample Area Element	100%	1	1	100%	1	1	20%	7	1.4
Third Party Element	0%	0	0	0%	0	0	50%	16	8
Report Element	100%	2	2	100%	2	2	100%	2	2
Total			7.18			9			21

Exhibit 4-6 summarizes the labor burden associated with conducting assessments for all of the system categories and types of triggers, both under the existing TCR and the proposed RTCR. Exhibit 4-7 presents the monetary burden. Labor hours in Exhibit 4-6 are multiplied with the hourly labor rates presented in chapter 2 of this document to calculate the monetary burden in Exhibit 4-7. Appendix A includes detailed tables with the elements of assessments, percentages, and hours (similar to Exhibit 4-4 and 4-5) for all system type/size categories.

Exhibit 4-6: Estimated Labor Burden Associated with Assessments (hours)

	Current TCR, as implemented		Proposed RTCR		
System Type/Size	Nonacute MCL Violation	Acute MCL Violation	Level 1 Trigger	Level 2 Trigger (nonacute)	Level 2 Trigger (Acute)
NCWS ≤1,000	4	6	7	9	21
NCWS 1,001-4,100	4	6	8	10	29
NCWS 4,101-33,000	30	36	41	69	71
NCWS 33,001-96,000	59	75	68	116	121
NCWS >96,000	108	117	159	238	252
CWS ≤100	11	14	19	22	23
CWS 101-500	11	14	19	22	23
CWS 501-1,000	13	15	20	23	24
CWS 1,001-4,100	22	29	31	46	48
CWS 4,100-33,000	30	36	41	69	71
CWS 33,001-96,000	59	75	68	116	121
CWS >96,000	108	117	159	238	252

Exhibit 4-7: Estimated Labor Burden Associated with Assessments (2007$)

	Current TCR, as implemented		Proposed RTCR		
System Type/Size	Nonacute MCL Violation	Acute MCL Violation	Level 1 Trigger	Level 2 Trigger (nonacute)	Level 2 Trigger (Acute)
NCWS ≤100	$100.40	$150.60	$175.70	$225.90	$527.10
NCWS 101-500	$108.12	$162.18	$189.21	$243.27	$567.63
NCWS 501-1,000	$115.84	$173.76	$202.72	$260.64	$608.16
NCWS 1,001-4,100	$118.92	$178.38	$237.84	$297.30	$862.17
NCWS 4,101-33,000	$1,080.00	1,296.00	$1,476.00	$2,484.00	$2,556.00
NCWS 33,001-96,000	$2,147.01	2,729.25	$2,474.52	$4,221.24	$4,403.19
NCWS >96,000	$4,429.08	4,798.17	$6,520.59	$9,760.38	10,334.52
CWS ≤100	$276.10	$351.40	$476.90	$552.20	$577.30
CWS 101-500	$297.33	$378.42	$513.57	$594.66	$621.69
CWS 501-1,000	$376.48	$434.40	$579.20	$666.08	$695.04
CWS 1,001-4,100	$654.06	$862.17	$921.63	$1,367.58	$1,427.04
CWS 4,100-33,000	$1,080.00	1,296.00	$1,476.00	$2,484.00	$2,556.00
CWS 33,001-96,000	$2,147.01	2,729.25	$2,474.52	$4,221.24	$4,403.19
CWS >96;000	$4,429.08	,798.17	$6,520.59	$9,760.38	10,334.52

4.3.2 Assumptions

Several underlying assumptions were made for the cost estimation development as follows:

- The costs estimates presented in this chapter and the assumptions that support those estimates were informed by input from States and industry received during the proceedings of the TCRDSAC and the associated TCRDSAC TWG meetings.

- Estimated percentage of systems undertaking actions is a function of estimated value, expertise at different system sizes, and available resources.

- As system size increases, there is an increasing level of expertise, and there are also increasing levels of potential complexity, greater numbers of positive samples required to trigger investigation, larger numbers of individuals engaged in aspects of investigation, and increased levels of management and supervisory involvement.

- At very small system sizes, State direction will dominate what actions systems tend to focus on in the investigation process.

- As system size increases, there is greater automation of data systems but a parallel increase in the complexity of interpreting any data.

- Separate estimates were not developed for NCWSs serving >4,100. Rather, the burden estimates for these larger NCWSs are assumed to be the same as similarly sized CWSs.

- For all levels of investigation, it is assumed that a "toolbox" type of approach is used such that not all systems will necessarily conduct all elements of the investigation. Systems may stop conducting assessments once they have found the apparent cause of the problem.

5 Estimated Unit Costs of Corrective Actions

This chapter discusses various examples of corrective actions that can help mitigate or eliminate sources of coliform contamination that may occur during operation and maintenance of a treatment process or a water system. Exhibit 5-1 provides a summary of those corrective actions, and the purpose or type of water quality problem addressed by each action.

Exhibit 5-1: Summary of Corrective Actions

Action	Purpose
Flushing – Section 5.1 Scheduled / Routine Flushing (Section 5.1.1) Unscheduled / Spot Flushing (Section 5.1.2)	· Keep system clean and free of sediment · Reduce disinfectant demand of pipe surfaces · Remove stagnant, untreated, or contaminated water · Address water quality deterioration at dead-ends
Sampler Training – Section 5.2	· Reinforces proper sampling and sample handling procedures to obtain uncontaminated samples
Replacement / Repair of Distribution System Components – Section 5.3 Valves (Section 5.3.1) Water Mains (Section 5.3.2) Fittings (Section 5.3.3) Hydrants (Section 5.3.4) Meters (Section 5.3.5) Dedicated Sample Taps (Section 5.3.6)	· Reduce potential sources / pathways of contamination from improper installation or material degradation
Maintenance of Adequate Pressure – Section 5.4 Booster Pumping Stations (Section 5.4.1) Pump Modifications or Replacement (Section 5.4.2) Variable Frequency Drives (Section 5.4.3) Elevated Storage Facilities (Section 5.4.4) Surge Relief Valves (Section 5.4.5) Surge Tanks (Section 5.4.6)	· Minimize sudden changes in water velocity which impact system pressure · Reduce risk of backflow and intrusion contamination resulting from low pressures · Reduce risk of hydraulic disturbances to pipe surface biofilm
Maintenance of Appropriate Hydraulic Residence Time – Section 5.5 Looping Dead Ends (Section 5.5.1) Installing Appropriate Main Sizes (Section 5.5.2) Automated Flushing Devices (Section 5.5.3) Storage Facility Modifications (Section 5.5.4)	· Mitigate water quality problems associated with increased water age (e.g. higher DBP formation, reduced disinfectant residual, increased microbial activity, nitrification, and taste-and-odor problems)
Storage Facility Maintenance – Section 5.6 Inspecting / Cleaning of Tanks (Section 5.6.1) Lining of Storage Tanks (Section 5.6.2) Vent / Hatch Repair (Section 5.6.3) Tank Repair (Section 5.6.4)	· Remove contamination from birds and insects · Remove accumulated sediment · Protect against tank wall corrosion
Booster Disinfection – Section 5.7 Chlorine (Section 5.7.1) Chloramine (Section 5.7.2)	· Improve or maintain disinfectant residual in the distribution system

Action	Purpose
Cross Connection Control and Backflow Prevention Program – Section 5.8 Backflow Prevention Devices (Section 5.8.1) Program Administration (Section 5.8.2)	· Prevent flow of non-potable substances into the distribution system
Addition or Upgrade of On-line Monitoring and Control – Section 5.9 Water Quality Monitoring & Control (Section 5.9.1) Pressure Monitoring & Control (Section 5.9.2)	· Automatically control and monitor disinfectant dosages and water quality parameters (other than total coliform) · Monitor pressure levels to identify physical problems in the system (e.g. pipe breaks, leaking valves, etc.)
Addition of Security Measures – Section 5.10	· Monitor potential locations for vandalism or security breaches that could lead to water contamination · Increase public confidence in protection of their drinking water
Development and Implementation of an Operations Plan – Section 5.11 O&M SOP Training (Section 5.11.1) O&M Plan Revision (Section 5.11.2)	· Integrate all operations and maintenance functions to meet the goals of flow, pressure, and water quality · Establish a routine distribution system sampling plan · Implement an inspections and maintenance program · Define an emergency response plan for the distribution system

The costs incurred for implementing each of these corrective actions is described in detail in the following sections. The costs represent a typical estimate for each type of corrective action. However, system specific characteristics such as system configuration, climate, soil conditions, local construction practices and requirements, and labor rates may impact the final cost for a particular water utility to implement a corrective action.

The costs provided in this chapter were obtained from equipment price lists and quotes, cost estimates from similar projects, best practices from public water systems, and from engineering cost data sources (R.S. Means). Where appropriate, the costs are separated into categories of public water systems (PWS) based on the population size that each system serves. The labor wage rates used in this chapter are described in Chapter 2 of this document. Assumptions regarding labor burden, including number of employees and shift hours, were based on best professional judgment and typical practices from public water systems and are described in each of the following sub-sections. All labor costs are assumed to include basic items that would be part of normal operations for a water system such as tools, field equipment, vehicle access and incidentals.

All costs are presented in 2007 dollars; however, some estimates were obtained from vendors in 2008 and 2009 and were subsequently adjusted to 2007 using construction cost indices (R.S. Means, 2009). For some items, installed costs were not available so installation was assumed to be a percentage of the capital cost based on public water system information and project experience.

Wherever it was assumed that a contractor would execute the work to implement any of the corrective actions, a 22.5% factor for overhead and profit was applied (R.S. Means, 2009). This overhead factor includes items such as insurance, permits, field offices, temporary facilities, storage, mobilization and demobilization, barricades, signs, and security measures for the contractors.

5.1 Flushing

A water main flushing program helps to keep the system clean and free of sediment, can reduce the disinfectant demand of pipe surfaces, and removes stagnant water and any untreated or contaminated water that may have entered the system (Kirmeyer et al. 2000b). Flushing can also be used to address water quality deterioration at dead-ends. The following sections discuss scheduled system-wide flushing, and periodic unscheduled (or "spot") flushing which can be used to address isolated water quality problems, including total coliform positive samples.

The volume of water flushed is related to the length of flushing time and flow rate from the hydrant. Typically, water systems flush until a disinfectant residual can be measured or other water quality target is reached. These practices are similar for all types of disinfectants and would also hold true for undisinfected systems.

5.1.1 Scheduled / Routine Flushing

Minimum elements of a flushing program are outlined in the AWWA G200 Standard (AWWA 2004) and include: (1) a preventive approach to address local problems or customer concerns and routine flushing to avoid water quality problems; (2) use of an appropriate flushing velocity to address water quality concerns; and (3) written procedures for all elements of the flushing program including water quality monitoring, regulatory requirements and specific flushing procedures.

Exhibit 5-2 summarizes the estimated annual cost for routine flushing a complete water distribution system (at a rate of once per year). These costs include estimates of labor, cost of lost water, and cost of treatment (dechlorination) prior to disposal. In smaller systems, maintenance of a routine flushing program may be only one aspect of an operator's duties; however, in larger systems one or more full-time employees may be entirely dedicated to this program. Column D presents the estimated percent commitment of operators to a routine flushing program, based on PWS size. Estimates of the volume of water flushed are based on mid-point population of each PWS category, water usage rate of 100 gallons per person per day (GPCD), and 0.47% average percentage of water flushed per water produced, as obtained from *Cost and Benefit Analysis of Flushing* (Hasit, 2004). Value of lost water is based on an average billing rate of $3.00 per thousand gallons (kgal), also obtained from *Cost and Benefit Analysis of Flushing*, and adjusted to 2007 dollars. Dechlorination costs were estimated based on chemical consumption of dechlorinating agents per gallon of water flushed. However, treatment requirements for discharge of flushing water will vary according to locality and should be examined on a case-by-case basis. Public notification costs were not included in this estimate.

Exhibit 5-2: Estimated Costs for Routine Flushing

System Size	Average System Population	Labor Rate[1]	Number of employees involved in flushing program	Percent time Committed to Flushing[2]	Total Labor (hours per year)	Total Labor Cost	Flushed Water Volume[3,4] (kgal/yr)	Value of Water Flushed per year[5]	Cost of Disposal of Flushed Water per year[6,7,8]	Total Annual Cost[9] (2007$)
A	B	**C**	**D**	**E**	**F=D*E*2080**	**G=C*F**	**H=0.0047*B *100*365 /1000**	**I=H*$3.00**	**J=H*$3.00 /8.5**	**K=G+I+J**
< 500	250	$25.75 *	1	2-3%	48	$1,240	50	150	20	$1,410
501 - 1,000	1,400	$28.96	1	3-4%	72	$2,090	250	750	90	$2,930
1,001 - 4,100	6,650	$29.73	1	4-5%	96	$2,860	1,150	3,450	410	$6,720
4,101 - 33,000	30,000	$36.00	1	18-20%	384	$13,830	5,150	15,450	1,820	$31,100
33,001 - 96,000	75,000	$36.39	1	80-90%	1920	$69,870	12,870	38,610	4,550	$113,030
96,001 - 500,000	300,000	$41.01	2	100%	4160	$170,610	51,470	154,410	18,170	$343,190
500,001 - 1,000,000	750,000	$41.01	3	100%	6240	$255,910	128,670	386,010	45,420	$687,340
> 1,000,001	1,500,000	$41.01	6	100%	12480	$511,810	257,330	771,990	90,830	$1,374,630

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*. *Note: A weighted labor rate was used for system size serving < 500 based on the number of systems serving < 100 and 101 – 500 – see exhibit 2-5 for the number of systems in each population size category. The weighted labor rate for system size < 500 was calculated as follows ((83,746 x $25.10) + (42,692 x $27.03)/(83,746 + 42,690) = $25.75 .

[2] Estimate based on typical PWS practices.

[3] Average ratio of water flushed per water produced = 0.47%, as reported in *Cost and Benefit Analysis of Flushing* (Hasit, 2004).

[4] Water produced based on mid-point population of each PWS category, and average usage rate of 100 GPCD.

[5] Value based on average price that PWSs charge for water, as reported in *Cost and Benefit Analysis of Flushing* (Hasit, 2004) and adjusted to 2007 dollars ($3.00 / kgal).

[6] Assumes that dechlorinator attachments are part of typical equipment already owned by the PWS.

[7] Cost per dechlorination tablet obtained from USA Bluebook catalog, 2008 and adjusted to 2007 dollars ($3.00 / tablet)

[8] Each dechlorination tablet neutralizes 8,500 gallons of water with 1ppm of chlorine according to manufacturer recommendations.

[9] Estimates rounded up to the nearest $10

5.1.2 Unscheduled / Spot Flushing

Upon obtaining a positive sample for total coliform (TC), a common response is to flush the area near the sample site to draw in fresh water and remove any contaminated water that may be present. This unscheduled spot flushing is different than a routine flushing program in that the flushing only occurs when triggered by a water quality measurement, customer complaint, or similar event.

Exhibit 5-3 summarizes the estimated cost for a single unscheduled / spot flushing event. As in Section 5.1.1, these costs include estimates of labor, cost of lost water, and cost of treatment (dechlorination) prior to disposal. Labor estimates were based on half-day flushing events, with 1 or 2 person crews depending on system size. Flushed water volumes were based on a single hydrant flushing event, size of the hydrant and maximum discharge flows, and an assumed 1-hour flush time. Duration was based on the assumption that it takes longer to achieve a reasonable disinfectant residual when spot flushing problem areas than it takes when performing routine flushing in a healthy system. According to *Cost and Benefit Analysis of Flushing*, routine flushing is normally maintained for 5 to 40 minutes (with 15 minutes being the most common); however, actual durations are based on time it takes for water quality to improve, water color to clear, or both.

Exhibit 5-3: Estimated Costs for Spot Flushing

System Size	Labor Rate[1]	Shift Hours[2]	Total Labor Cost	Average Hydrant Size	Maximum Flushing Flow (GPM)	Flushed Water Volume (kgal)[3]	Value of Water Flushed[4]	Cost of Disposal of Flushed Water[5,6,7]	Total Cost[8] (2007$)
A	B	C	D=B*C	E	F	G=F*60/1000	H=G*$3.00	I=H*$3.00 / 8.5	J=D+H+I
< 500	$25.75	4	$110	4	500	30	90	20	220
501 - 1,000	$28.96	4	$120	4	500	30	90	20	230
1,001 - 4,100	$29.73	4	$120	6	750	45	135	20	280
4,101 - 33,000	$36.00	8	$290	6	750	45	135	20	450
33,001 - 96,000	$36.39	8	$300	6	750	45	135	20	460
96,001 - 500,000	$41.01	8	$330	8	1000	60	180	30	540
500,001 - 1,000,000	$41.01	8	$330	8	1000	60	180	30	540
> 1,000,001	$41.01	8	$330	8	1000	60	180	30	540

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Shift hours for systems serving < 500 to 4,100 assume 1-person crew, and half-day flushing event. Systems serving > 4,100 assume 2-person crew and half-day flushing event.

[3] Flushed water volume based on 1-hour flushing event.

[4] Value based on average price that PWSs charge for water, as reported in *Cost and Benefit Analysis of Flushing* (Hasit, 2004) and adjusted to 2007 dollars ($3.00 / kgal).

[5] Assumes that dechlorinator attachments are part of typical equipment already owned by the PWS.

[6] Cost per dechlorination tablet obtained from USA Bluebook catalog, 2008 and adjusted to 2007 dollars ($3.00 / tablet).

[7] Each dechlorination tablet neutralizes 8,500 gallons of water with 1ppm of chlorine according to manufacturer recommendations.

[8] Estimates rounded up to the nearest $10.

5.2 Sampler Training

EPA establishes sampling requirements to determine if a distribution system is in compliance with regulatory requirements. Implementation of a sampler training program provides guidelines for procedures that samplers must follow to collect valid, uncontaminated samples for analysis of total coliform in the distribution system. Training sessions for operators reinforce proper sampling and sample handling procedures to obtain uncontaminated samples.

The costs for sampler training assume that the operator/sampler attends an external, 8-hour training class. The costs include travel costs, training fees, and the operator labor costs associated with the time spent at the training session. Exhibit 5-4 summarizes the cost for sampler training.

Exhibit 5-4: Estimated Costs Operator Training/Certification

System Size	Labor Rate[1]	Course Time (hours)[2]	Total Labor Cost	Travel[3]	Training/ Certification Fees[4]	Total (2007$)[5]
A	B	C	D = B*C	E	F	G = D + E + F
< 500	$25.75	8	$210	$31	$125	$370
501 - 1,000	$28.96	8	$240	$31	$125	$400
1,001 - 4,100	$29.73	8	$240	$31	$125	$400
4,101 - 33,000	$36.00	8	$290	$31	$125	$450
33,001 - 96,000	$36.39	8	$300	$31	$125	$460
96,001 - 500,000	$41.01	8	$330	$31	$125	$490
500,001 - 1,000,000	$41.01	8	$330	$31	$125	$490
> 1,000,001	$41.01	8	$330	$31	$125	$490

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*..

[2] Assumes an 8-hour training/certification course

[3] Assumes 60 miles of round-trip driving distance at $0.52/mi.

[4] Assumes a $125 training fee for members based on costs from the National Rural Water Association.

[5] Estimates rounded up to the nearest $10.

5.3 Replacement / Repair of Distribution System Components

Distribution system components and appurtenances such as valves, pipe, fittings, hydrants, meters, and sample taps are integral parts of a water system. These components are also potential sources of contamination if improper installation or material degradation allows leaks or other entry points for coliforms into a distribution system.

These individual components are described in the following sections and costs for the repair or replacement of these components are presented. In general, a three-person labor crew was assumed for replacement / repair of underground facilities (which require digging, replacement of pavement or turf, trench safety considerations, maintenance of traffic, etc.) and a two-person crew was assumed for above-ground / exposed facilities. All activities were assumed to take a full 8-hour day, based on the need to mobilize equipment, perform the necessary excavation, setup, and restore the surface condition after replacement / repair. Where appropriate, assumptions on component size were made based on the population range served by a distribution system. The most common pipe diameters are 6 and 8 inches, even for large

systems, from the TCR Issue Paper: *Distribution System Inventory, Integrity, and Water Quality* (EPA 2007).

5.3.1 Valves

Valves are located throughout a distribution system to isolate portions of the system as needed. Leaks at the connection points between the valve and the adjacent pipe, as well as a valve seat or valve body, can create a pathway for contamination.

Prior to replacing or repairing a valve, it should be identified as the cause of the leak. Some isolation valves throughout the distribution system are located below grade, making a leak difficult to locate. A number of technologies, discussed in Chapter 7, have been developed to locate leaks below grade.

As butterfly valves are typically the most common type of valve encountered in a water distribution system, this type of valve was used as the basis for the cost estimation presented in Exhibit 5-5. Costs are presented on a per valve basis. Labor estimates are based on an 8-hour shift and 3-person crew.

Exhibit 5-5: Estimated Costs to Replace Valve

System Size	Labor Rate[1]	Shift Time (hours)[2]	Total Labor Cost[3]	Valve Size (in.)[4]	Valve Cost[5,6]	Total Cost (2007$)[7]
A	B	C	D=B*C*3	E	F	G=D+F
< 500	$25.75	8	$620	4	$385	$1,010
501 - 1,000	$28.96	8	$700	4	$385	$1,090
1,001 - 4,100	$29.73	8	$720	6	$565	$1,290
4,101 - 33,000	$36.00	8	$870	6	$565	$1,440
33,001 - 96,000	$36.39	8	$880	6	$565	$1,450
96,001 - 500,000	$41.01	8	$990	8	$785	$1,780
500,001 - 1,000,000	$41.01	8	$990	8	$785	$1,780
> 1,000,001	$41.01	8	$990	8	$785	$1,780

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.
[2] Shift time assumes 8 hours needed for mobilization, setup, and cleanup of site.
[3] Labor cost assumes a three-person crew needed for underground valve replacement.
[4] Based on commonly-occurring valve sizes in similarly-sized systems (EPA, 2007).
[5] Valve cost assumed a cast iron, mechanical joint, butterfly valve with box.
[6] Valve costs obtained from R.S. Means, 2007.
[7] Estimates rounded up to the nearest $10.

5.3.2 Water Mains

The condition of distribution system piping can be vital to the quality of water being conveyed to a community. Contaminants may enter through holes, breaks, cracks or joints in the piping. The condition of a pipe can vary based on type, age, and location of the pipe. Depending on the condition of the pipe, the water main can be replaced or repaired to stop infiltration into the system.

Prior to replacing or repairing a water main, the location of the break or leak must be determined. Since most of the distribution system is below grade, locating a leak can be difficult. A number of technologies have been developed to evaluate the condition of below grade piping to locate leaks.

Costs presented in Exhibit 5-6 are based on replacement of a 20-foot pipe segment, which is the nominal laying length of standard ductile iron pipe. Labor estimates are based on an 8-hour shift and 3-person crew.

Exhibit 5-6: Estimated Costs to Replace Ductile Iron Pipe

System Size	Labor Rate[1]	Shift Time (hours)[2]	Total Labor Cost[3]	Pipe Size (in.)[4]	Pipe Cost[5,6,7] (per 20 ft.)	Total Cost (2007$)[8]
A	B	C	D=B*C*3	E	F	G=D+F
< 500	$25.75	8	$620	4	$167	$790
501 - 1,000	$28.96	8	$700	4	$167	$860
1,001 - 4,100	$29.73	8	$720	6	$196	$910
4,101 - 33,000	$36.00	8	$870	6	$196	$1,060
33,001 - 96,000	$36.39	8	$880	6	$196	$1,070
96,001 - 500,000	$41.01	8	$990	8	$265	$1,250
500,001 - 1,000,000	$41.01	8	$990	8	$265	$1,250
> 1,000,001	$41.01	8	$990	8	$265	$1,250

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Shift time assumes 8 hours needed for mobilization, setup, and cleanup of site.

[3] Labor cost assumes a three-person crew needed for underground pipe replacement.

[4] Based on commonly-occurring valve sizes in similarly-sized systems (EPA, 2007).

[5] Pipe cost assumed cement lined, ductile iron, push-on joint pipe.

[6] Pipe cost based on 20 feet segments, as standard nominal pipe laying lengths are 20 feet (American Pipe Manual, 18th Edition, 2004).

[7] Pipe costs obtained from R.S. Means, 2007.

[8] Estimates rounded up to the nearest $10.

5.3.3 Fittings

There are many types of fittings located throughout a distribution system. The most common type of distribution system fitting is a cross. A cross has four connections; therefore making it more susceptible to leaks. Leaks can occur because of a crack on the fitting or through the gasket between the fitting and another appurtenance, e.g. valve, cap, or pipe.

Once a leak is located and it is confirmed that the fitting is the cause of the leak, it can be replaced or repaired depending on the condition of the fitting. A portion of the distribution system will be placed out of service as this work is performed; therefore, interrupting water service.

Costs are presented in Exhibit 5-7 and are calculated based on material costs and labor, assuming an 8-hour shift and 3-person work crew.

Exhibit 5-7: Estimated Costs to Replace Fittings

System Size	Labor Rate[1]	Shift Time (hours)[2]	Total Labor Cost[3]	Fitting Size (in.)[4]	Fitting Cost[5,6,7]	Total Cost (2007$)[8]
A	B	C	D=B*C*3	E	F	G=D+F
< 500	$25.75	8	$620	4 x 4	$368	$990
501 - 1,000	$28.96	8	$700	4 x 4	$368	$1,070
1,001 - 4,100	$29.73	8	$720	6 x 6	$480	$1,200
4,101 - 33,000	$36.00	8	$870	6 x 6	$480	$1,350
33,001 - 96,000	$36.39	8	$880	6 x 6	$480	$1,360
96,001 - 500,000	$41.01	8	$990	8 x 8	$686	$1,680
500,001 - 1,000,000	$41.01	8	$990	8 x 8	$686	$1,680
> 1,000,001	$41.01	8	$990	8 x 8	$686	$1,680

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Shift time assumes 8 hours needed for mobilization, setup, and cleanup of site.

[3] Labor cost assumes a three-person crew needed for replacement of underground fittings.

[4] Based on commonly-occurring fitting sizes in similarly-sized systems.

[5] Fitting cost assumed cement lined, ductile iron, and mechanical joint cross, with gaskets.

[6] Fitting costs obtained from R.S. Means, 2007, by multiplying the tee cost by the ratio of the weight of a cross and a tee.

[7] Fitting weights obtain from American Pipe Manual, 19th Edition.

[8] Estimates rounded up to the nearest $10.

5.3.4 Hydrants

Hydrants are located throughout a distribution system to provide potable water at required fire flow pressures for emergency situations. Hydrant connections are tapped off the distribution system; therefore, these connections can be possible locations for coliform contamination to enter a distribution system.

Replacing a damaged or faulty fire hydrant can help eliminate sources of contamination into the distribution system as it eliminates a pathway for contamination. The costs included to replace a fire hydrant are presented in Exhibit 5-8. Costs are calculated based on labor rate data per population range, assumptions on the number of workers and the time required, as well as material costs.

Exhibit 5-8: Estimated Costs to Replace Hydrants

System Size	Labor Rate[1]	Shift Time (hours)[2]	Total Labor Cost[3]	Hydrant Cost[4,5]	Total Cost (2007$)[6]
A	B	C	D=B*C*2	E	F=D+E
< 500	$25.75	8	$420	$1,225	$1,645
501 - 1,000	$28.96	8	$470	$1,225	$1,700
1,001 - 4,100	$29.73	8	$480	$1,225	$1,710
4,101 - 33,000	$36.00	8	$580	$1,225	$1,810
33,001 - 96,000	$36.39	8	$590	$1,225	$1,820
96,001 - 500,000	$41.01	8	$660	$1,225	$1,890
500,001 - 1,000,000	$41.01	8	$660	$1,225	$1,890
> 1,000,001	$41.01	8	$660	$1,225	$1,890

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Shift time assumes 8 hours needed for mobilization, setup, and cleanup of site.

[3] Labor cost assumes a two-person crew needed for replacement of partially-exposed hydrants.

[4] Hydrant cost assumes a two-way, 4-1/2 inch valve size, hydrant, partially excavated at a depth of 3 feet.

[5] Hydrant costs obtained from R.S. Means, 2007.

[6] Estimates rounded up to the nearest $10.

5.3.5 Meters

Meters are located at entry points to commercial, residential, and industrial facilities to measure the amount of water that is consumed at a particular location. Sizes for each of the meters will vary based on the type and usage requirements of a facility. Contamination may enter through the connection points of the meter and the distribution system. Replacing a meter can help prevent contamination into the distribution system through leaks, as it eliminates a pathway for contamination.

Costs presented in Exhibit 5-9 are based on the standard meter size for a commercial/ industrial user (such as a farm or food processing plant), as these users would likely have a much higher potential for coliform contamination. Costs are calculated based on an 8-hour shift and 2-person crew.

Exhibit 5-9: Estimated Costs to Replace Meters

System Size	Labor Rate[1]	Shift Time (hours)[2]	Total Labor Cost[3]	Meter Cost[4,5]	Total Cost (2007$)[6]
A	B	C	D=B*C*2	E	F=D+E
< 500	$25.75	8	$420	$330	$750
501 - 1,000	$28.96	8	$470	$330	$800
1,001 - 4,100	$29.73	8	$480	$330	$810
4,101 - 33,000	$36.00	8	$580	$330	$910
33,001 - 96,000	$36.39	8	$590	$330	$920
96,001 - 500,000	$41.01	8	$660	$330	$990
500,001 - 1,000,000	$41.01	8	$660	$330	$990
> 1,000,001	$41.01	8	$660	$330	$990

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Shift time assumes 8 hours needed for mobilization, setup, and cleanup of site.

[3] Labor cost assumes a two-person crew needed for replacement of exposed meters.

[4] Meter costs assume a standard 1-1/2 inch bronze commercial meter, which is typically the same, regardless of system size.

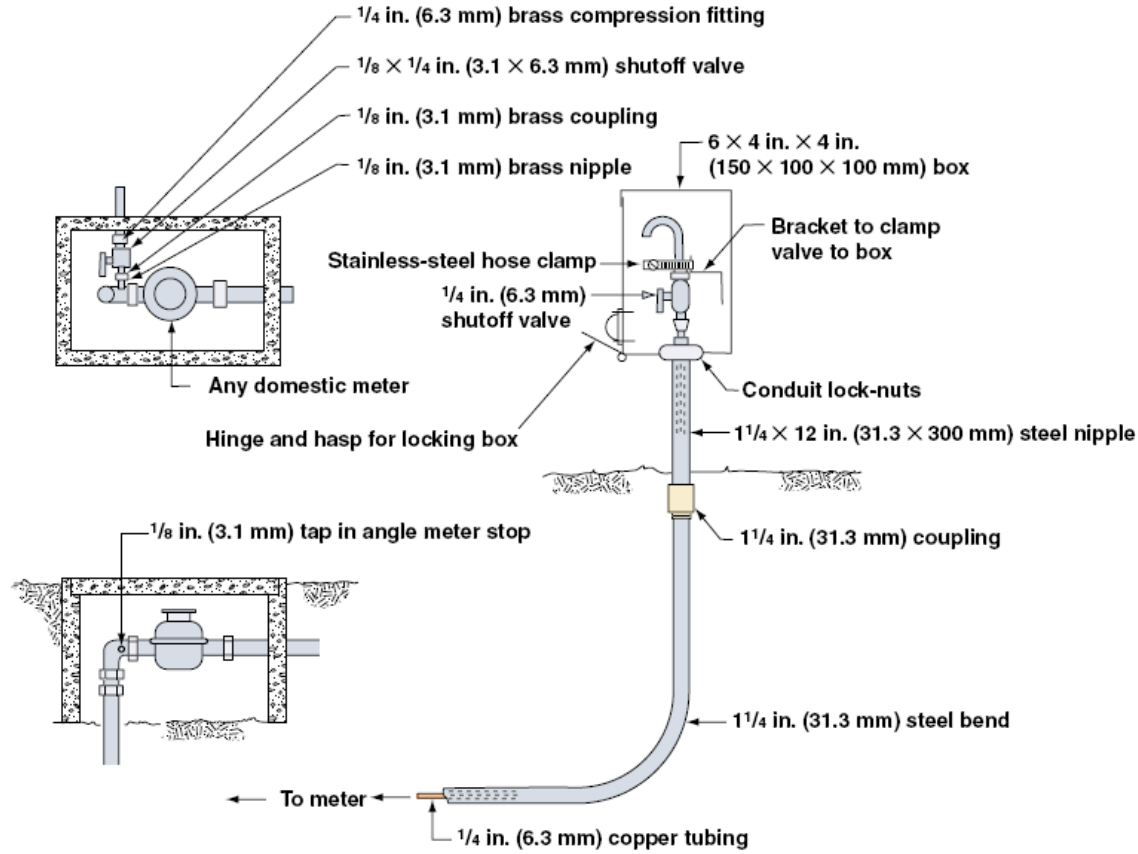
[5] Meter costs obtained from R.S. Means, 2007.

[6] Estimates rounded up to the nearest $10.

5.3.6 Dedicated Sample Taps

The TCRDSAC recommends that routine and repeat sample siting plans should ensure that the quality of the water is representative of the distribution system, and further recommends such samples could be drawn from a dedicated sampling station, or sampling tap, among other locations. A dedicated sampling station is a device that is plumbed directly into a distribution system line to provide "improved access to the distribution system water and provide reproducible samples that are representative of water quality at the customer's meter" (Kirmeyer -AWWARF, 2000). Dedicated sampling stations should be metal construction and have unthreaded nozzles or an approved design and should be located so as to be representative of the water in the distribution system. They are typically covered to protect them from birds, insects, dirt and other sources of outside contamination. Exhibit 5-10 is a graphic schematic detailing the components of a dedicated sampling station. Exhibit 5-11 is a photograph of an actual dedicated sampling station.

Exhibit 5-10: Dedicated Sampling Station Schematic



Box should be located near a stationary object, such as a power pole, for protection, or place sufficient concrete around riser below ground.

Source: Water Distribution System Operation and Maintenance, A Field Study Training Program. USEPA Office of Drinking Water and California Department of Health Services, Sanitary Engineering Branch. Hornet Foundation Inc., Sacramento, Calif. (1989, 2nd ed.).

Exhibit 5-11: Dedicated Sampling Station

Source: With permission courtesy of Koraleen Enterprises.

The cost of a new sampling station will vary depending on site conditions including cold weather vs. warm weather installation. Exhibit 5-12 provides unit cost estimates for installation of new sampling stations. Actual cost will vary depending on whether an existing meter service could be tapped into, or whether a new service line must be installed from the main line. For the purposes of this estimate, it has been assumed that an existing meter service could be tapped into, and that a 2-person crew can achieve installation in one 8-hour shift.

Exhibit 5-12: Estimated Costs of Installing a Dedicated Sampling Tap

System Size	Labor Rate[1]	Shift Time (hours)[2]	Total Labor Cost[3]	Sampling Tap Cost[4]	Total Cost (2007$)[5]
A	B	C	D=B*C*2	E	F=D+E
< 500	$25.75	8	$420	$600	$1,020
501 - 1,000	$28.96	8	$470	$600	$1,070
1,001 - 4,100	$29.73	8	$480	$600	$1,080
4,101 - 33,000	$36.00	8	$580	$600	$1,180
33,001 - 96,000	$36.39	8	$590	$600	$1,190
96,001 - 500,000	$41.01	8	$660	$600	$1,260
500,001-1,000,000	$41.01	8	$660	$600	$1,260
> 1,000,001	$41.01	8	$660	$600	$1,260

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Shift time assumes 8 hours needed for mobilization, setup, and cleanup of site.

[3] Labor cost assumes a two-person crew needed for installation / replacement of exposed sample taps.

[4] Material cost assumes Koraleen Enterprises cold weather station, provided by manufacturer / distributor and adjusted to 2007 dollars.

[5] Estimates rounded up to the nearest $10.

5.4 Maintenance of Adequate Pressure

Pressure losses can occur in the distribution system as a result of events such as flushing, main breaks, power outages, service line breaks, and fires. Pressure transients (also called pressure surges or water hammer) can occur when an abrupt change in water velocity occurs due to a sudden valve closure, pump shutdown or loss of power. The resulting pressure wave, with alternating low and high pressures, travels back and forth through the distribution system until the pressure is stabilized. Low pressure conditions in the distribution system can allow a flow reversal or backflow of non-potable water to enter the system from a cross connection or other source. Pressure transients can also create hydraulic disturbances that allow biofilm material on pipe surfaces to enter the bulk water. Industry guidelines suggest that system pressure should be maintained within the range of 35 to 100 psi at all points in the distribution system (AWWA 1996). The AWWA G200 standard indicates that the minimum residual pressure at the service connection under all operating conditions should be > 20 psi (AWWA 2004). Written standard operating procedures for pump, hydrant and valve operation under routine and emergency conditions can help minimize sudden changes in water velocity that impact system pressure.

Other actions that can help to maintain an adequate pressure in the distribution system include building new booster pump stations and elevated storage facilities, modifying existing high services pumps, and installing surge relief valves and surge tanks. The following sections discuss costs associated with each of these options.

5.4.1 Booster Pumping Station

Booster pumping stations are used in the distribution systems to move water from lower pressure zones to higher pressure zones and to maintain pressure at desirable levels. As the water system grows and changes, existing booster pump stations may no longer be able to maintain the desired pressure across the distribution system. In those cases, the construction of a new booster station may be required.

Exhibit 5-13 presents the estimated cost for the installation of a new booster pump station including equipment, required piping and appurtenances, electrical and instrumentation equipment, a building, installation, and overhead and profit.

Exhibit 5-13: Estimated Costs to Install a New Booster Pump Station

Cost Component[1]		Population Size Category							
		<500	501 to 1,000	1,001 to 4,100	4,101 to 33,000	33,001 to 96,000	96,001 to 500,000	500,001 to 1,000,000	>1,000,001
Pump Station Size (MGD)	A	0.03	0.08	0.09	0.6	2.2	3.0	7.5	15
Number of Pumps	B	1 duty 1 stand-by	1 duty 1 stand-by	1 duty 1 stand-by	1 duty 1 stand-by	2 duty 1 stand-by	2 duty 1 stand-by	2 duty 1 stand-by	2 duty 1 stand-by
Pump Size (gpm)	C	17	52	59	429	747	1,042	2,604	5,208
Pump & Motor Cost	D	$1,960	$2,140	$2,140	$15,280	$26,520	$36,780	$92,440	$184,860
Pipes and related materials	E	$1,930	$5,130	$5,770	$38,460	$141,000	$192,280	$480,690	$961,370
Equipment Installation[2]	F=0.3*(D+E)	$1,170	$2,190	$2,380	$16,130	$50,260	$68,720	$171,940	$343,870
Total Cost of Installed Equipment	G=D+E+F	$5,060	$9,460	$10,290	$69,870	$217,780	$297,780	$745,070	$1,490,100
Building Size (sf)	H	72	72	72	167	264	366	920	1,841
Building Cost[3]	I	$3,940	$3,940	$3,940	$9,120	$14,420	$19,980	$50,260	$100,510
Slab-on-grade Cost[4,5]	J	$230	$230	$230	$530	$830	$1,140	$2,870	$5,730
Electrical and Instrumentation[6]	K=0.2*G	$1,020	$1,900	$2,060	$13,980	$43,560	$59,560	$149,020	$298,020
Total Cost (2007$)[7,8]	L=1.225*(G+I+J+K)	$12,560	$19,030	$20,240	$114,540	$338,830	$463,620	$1,160,350	$2,320,600

[1] All costs on a per pump station basis.

[2] Assumes 30% of pump, motor, pipes and related materials total cost.

[3] Assumes the median cost ($60/sf) of a Warehouse & Storage Building type (includes site work, masonry, plumbing, electrical, HVAC & labor). Source: R.S. Means, 2009 (adjusted to 2007 dollars).

[4] Assumes $184.43/cubic yard. Source: R.S. Means, 2009.

[5] Assumes a 6-inch slab.

[6] Assumes 20% of the total installed equipment.

[7] Cost rounded up to the nearest $10.

[8] Includes 22.5% overhead and profit, based on R.S. Means (2009).

5.4.2 Modify or Replace Existing Pumps

The construction of a completely new booster pump station is not always required to maintain an appropriate pressure in a water system. There may be situations where a modification or replacement of an existing pump is sufficient.

Exhibit 5-14 presents the estimated cost for replacing a new booster pump including equipment, required piping and appurtenances, installation, and overhead and profit. For smaller systems, the pump and motor were provided in a package cost estimate; however for pumps greater than 59 GPM, the pump and motor were quoted separately and summed in Row D.

Exhibit 5-14: Estimated Costs to Replace Existing Pump

Cost Component [1]		Population Size Category							
		<500	50 to 1,000	1,001 to 4,100	4,100 to 33,000	33,001 to 96,000	96,001 to 500,000	500,001 to 1,000,000	>1,000,001
Pump Size (gpm)	A	17	52	59	429	747	1035	2604	5208
Pump Cost	B	-	-	-	$4,390	$7,620	$10,560	$26,550	$53,100
Motor Cost	C	-	-	-	$3,250	$5,640	$7,830	$19,670	$39,330
Pump & Motor Cost	D=B+C	$980	$1,070	$1,070	$7,640	$13,260	$18,390	$46,220	$92,430
Related Pump Equipment[2]	E=0.3*D	$300	$330	$330	$2,300	$3,980	$5,520	$13,870	$27,730
Installation[3]	F=0.2*(D+E)	$260	$280	$280	$1,990	$3,450	$4,790	$12,020	$24,040
Total Cost (2007$)[4,5]	G=1.225* (D+E+F)	$1,890	$2,060	$2,060	$14,620	$25,350	$35,160	$88,340	$176,650

[1] All costs on a per pump basis. Source: USABlueBook Catalog, 2008 (adjusted to 2007 dollars).

[2] Assumes 30% of the pump and motor cost.

[3] Assumes 20% of the pump, motor and related equipment cost.

[4] Cost rounded up to the nearest $10.

[5] Includes 22.5% overhead and profit, based on R.S. Means (2009).

5.4.3 Install Variable Frequency Drives

A variable frequency drive (VFD), also called a variable speed drive, allows a booster pump to supply the required amount of flow based on system demand with a pressure set point to maintain constant system discharge pressure, controlled to within a few psi of an operator–adjustable system pressure set point. VFDs work with a system pressure transmitter to control the system pressure set point.

Exhibit 5-15 presents the estimated cost to install a VFD, including installation, overhead and profit.

Exhibit 5-15: Estimated Costs to Install a Variable Frequency Drive

System Size	Pump Size (gpm)	VFD Cost[1]	Total Cost (2007$)[2,3]
A	B	C	D=C*1.225
< 500	17	$1,150	$1,410
501 - 1,000	52	$3,440	$4,220
1,001 - 4,100	59	$3,900	$4,780
4,101 - 33,000	429	$28,340	$34,720
33,001 - 96,000	747	$49,260	$60,350
96,001 - 500,000	1,042	$68,730	$84,200
500,001 - 1,000,000	2,604	$171,830	$210,500
> 1,000,001	5,208	$343,650	$420,980

[1] Based on installed cost, per equipment vendor quotes and adjusted to 2007 dollars.

[2] Cost rounded up to the nearest $10

[3] Includes 22.5% overhead and profit, based on R.S. Means (2009).

5.4.4 Elevated Storage Facility

Elevated storage is provided within the distribution system to supply peak demand rates and equalize system pressures. In certain systems, elevated storage is more effective and economical than ground storage because by nature of the elevated supply, pumping requirements may be reduced, and the storage can serve as a source of emergency supply since system pressure requirements can still be met temporarily when pumps are out of service.

Elevated storage tanks are often sited in areas having the lowest system pressures during intervals of high water use. These areas are often those of greatest water demand or those farthest from pump stations. Elevated tanks are generally located at some distance from the pump station serving a distribution pressure level, but ideally are not placed outside of boundaries of the service area unless the facility can be located on a nearby hill. Elevated tanks are built on the highest available ground so as to minimize the required construction cost and the height requirements.

Exhibit 5-16 presents the estimated costs to install a new elevated storage tank. These costs are per tank and include the installed tank cost, the foundation, pipe and related materials costs, installation and profit and overhead.

Exhibit 5-16: Estimated Costs to Install a New Elevated Storage Tank

System Size	Tank Size (gal)	Tank Cost[1]	Foundation Cost[2,3]	Piping & Related Materials Cost[4]	Total Cost (2007$)[5]
A	B	C	D=0.15*C	E=0.3*(C+D)	F=(C+D+E)*1.225
< 500	50,000	$202,240	$30,340	$69,770	$370,380
501 - 1,000	100,000	$278,770	$41,820	$96,180	$510,550
1,001 - 4,100	250,000	$384,440	$57,670	$132,630	$704,060
4,101 - 33,000	500,000	$620,390	$93,060	$214,040	$1,136,180
33,001 - 96,000	1,000,000	$859,980	$129,000	$296,690	$1,574,950
96,001 - 500,000	1,000,000	$859,980	$129,000	$296,690	$1,574,950
500,001 - 1,000,000	2,000,000	$1,719,970	$258,000	$593,390	$3,149,920
> 1,000,001	2,000,000	$1,719,970	$258,000	$593,390	$3,149,920

[1] Assumes installed cost. Source: R.S. Means (2009), adjusted to 2007 dollars.
[2] Assumes 15% of tank cost, based on project experience.
[3] Foundation cost depends on soil conditions, good soil conditions assumed.
[4] Assumes 30% of tank and foundation combined cost.
[5] Includes 22.5% overhead and profit, based on R.S. Means (2009).

5.4.5 Install Surge Relief Valve

Surge relief valves provide pressure management by ejecting water out of a side orifice to prevent excessive high-pressure surges and can also be triggered to open on a downsurge in pressure in anticipation of an upsurge to follow. Surge relief valves must always be used with caution for they can make low-pressure conditions in a line worse than they would be without the valve.

Exhibit 5-17 presents the estimated costs to install a surge relief valve.

Exhibit 5-17: Estimated Costs to Install a Surge Relief Valve

System Size	Valve Size (in)	Surge Relief Valve Cost[1]	Total Cost[2] (2007$)
A	B	C	D = C*1.225
< 500	4	$4,040	$4,950
501 - 1,000	4	$4,040	$4,950
1,001 - 4,100	6	$5,920	$7,250
4,101 - 33,000	10	$15,510	$19,000
33,001 - 96,000	12	$23,590	$28,900
96,001 - 500,000	20	$41,830	$51,240
500,001 - 1,000,000	24	$51,040	$62,520
> 1,000,001	24	$51,040	$62,520

[1] Assumes installed cost. Source: Apollo Valves catalog, 2008.
[2] Includes 22.5% overhead and profit, based on R.S. Means (2009).

5.4.6 Install Surge Tanks

The four common types of surge tanks include pneumatic or closed tanks, open standpipes (or air chambers), one-way surge tanks (allows water to flow only from the tank into the pipeline) and two-way surge tanks (allows flow to and from the tank). If water is stored in

these tanks for long periods of time, the water may lose its disinfectant residual and microbial growth and other water quality problems may results. Proper operations and maintenance of surge tanks is required to prevent poor quality or contaminated water from entering the distribution system.

Hydropneumatic tank systems are a popular way to provide pressure control and stabilization in smaller water distribution systems; however, they are not typically used in larger systems (serving > 500,000 customers). A hydropneumatic tank system allows for fluctuations in water distribution system pressure, and a potential cushion against water hammer. The system also minimizes booster pump on-off cycles.

The pressure tank uses a compressed air head-space to maintain system pressure. As water system demand increases, water in the pressure tank discharges into the system and reduces the pressure tank's water level, which expands the air cushion above the water and decreases the tank air pressure. When the air reaches a determined set point, the air compressor comes on to recharge the air space and cycles off when the high pressure set point is met. If the water demand continues to increase, the booster pumps will cycle on at the low water level and replenish the water level in the pressure tank. The pressure tank must be sized correctly, because its size determines the frequency of pump cycling.

Exhibit 5-18 presents the estimated cost to install a hydropneumatic tank system. The hydropneumatic tank system consists of a hydropneumatic pressure tank, and air compressor and associated piping and controls. The cost of the slab-on-grade where the tank will be installed on is also included in this estimated cost as well as installation and overhead and profit costs.

Exhibit 5-18: Estimated Costs to Install a Surge Control Tank

System Size	Tank Size (gal)	Tank Cost[1,2]	Tank Control & Accessories[3]	Slab-on-grade[4,5]	Installation[6]	Total Cost (2007$)[7,8]
A	B	C	D= C*0.4	E	F=(C+D+E)* 0.2	G=(C+D+E+ F)*1.225
< 500	500	$6,650	$2,660	$1,180	$2,100	$15,430
501 - 1,000	1,000	$9,020	$3,610	$1,640	$2,850	$20,980
1,001 - 4,100	2,000	$12,660	$5,070	$2,100	$3,970	$29,160
4,101 - 33,000	7,500	$29,790	$11,920	$4,010	$9,140	$67,210
33,001 - 96,000	10,000	$34,980	$14,000	$5,280	$10,850	$79,760
96,001 - 500,000	12,000	$39,630	$15,860	$6,290	$12,360	$90,830
500,001 - 1,000,000[9]	NA	NA	NA	NA	NA	NA
> 1,000,001[9]	NA	NA	NA	NA	NA	NA

[1] Assumes standard horizontal tanks for 100 psi working pressure including standard fittings and freight.
[2] Cost estimates obtained from USABlueBook Catalog (2008) adjusted to 2007 dollars.
[3] Assumes 40% of the Tank Cost.
[4] Assumes a 4-inch slab.
[5] Assumes $184.43/cubic yard. Source: R.S. Means, 2009.
[6] Assumes 20% of the total cost of the tank, tank control and accessories, and slab-on-grade.
[7] Includes 22.5% overhead and profit, based on R.S. Means (2009).
[8] Estimates rounded up to the nearest $10.
[9] Surge control tanks not typically used in larger systems (serving >500,000 customers).

5.5 Maintenance of Appropriate Hydraulic Residence Time

As water travels through the distribution system, chlorine continues to react with natural organic matter (NOM) to form disinfection by-products (DBPs). Thus, increased water age can lead to higher DBP concentrations. Other water quality problems associated with increased water age include reduced disinfectant residual, increased microbial activity, nitrification, and/or taste and odor problems. Water systems should develop an overall strategy to manage the water age in their distribution systems. Establishing a water age goal is system-specific depending on system design and operation, water demands, and water quality (e.g. DBP formation potential). In the US, the average distribution system retention time is 1.3 days and the average maximum retention time is 3.0 days based on a survey of 800 medium and large water utilities (AWWA and AwwaRF 1992). Water age can be controlled through a variety of techniques including management of finished water storage facilities, looping of dead-ends, and re-routing of water by changing valve settings. Additional guidance is provided in the AwwaRF report, Managing Distribution System Retention Time to Improve Water Quality (Brandt et al. 2004).

5.5.1 Loop Dead Ends

Dead end pipes often result in stagnant water conditions where water age increases, which can cause water quality problems. One of the solutions to address the stagnant water issue is looping of dead ends. However, looping should be evaluated carefully on a case-by-case basis as it may not actually reduce the long detention times present in those areas.

The cost associated with installing loops to eliminate dead ends is the same as to replace or repair ductile iron pipe lines presented in Exhibit 5-6.

5.5.2 Install Appropriate Main Sizes

Most distribution systems have been designed to meet a minimum hydraulic capacity. Additional capacity is generally included at the design stage to accommodate for future growth or to allow more flexibility in the configuration of a distribution system network. A PWS may also have a policy to limit the number of different pipe diameters within the system in order to simplify construction and maintenance. Consequently network pipes tend to be larger than is necessary to meet the daily demand from the network leading to increased retention time. Hence, there can be an option to replace mains with smaller diameter pipes but still maintain the required hydraulic capacity.

The cost associated with installing appropriate water main sizes is the same as to replace or repair ductile iron pipe lines presented in Exhibit 5-6.

5.5.3 Install Automated Flushing Devices

Automated flushing devices are used to purge accumulated sediments at low spots and dead-ends of pipelines at regular intervals and for draining pipelines for repairs, maintenance, and inspection. These devices are best suited to rural networks in which security of the units and disposal of the water flushed is less problematic. An additional drawback of installing these devices is the volume and value of the wasted water may be unacceptable. However, in networks with long pipe runs terminating in dead ends, there may be few viable alternatives to flushing for controlling retention time.

Exhibit 5-19 presents the cost of installing automatic flushing devices, including the material cost and in-house labor, assuming an 8-hour shift and 2-person work crew are required for installation of an above-ground flushing device.

Exhibit 5-19: Estimated Costs to Install Automated Flushing Devices

System Size	Labor Rate[1]	Shift Time (hours)	Total Labor Cost[2]	Automated Flushing Device Cost[3,4]	Total Cost (2007$)[5]
A	B	C	D=B*C*2	E	F=D+E
< 500	$25.75	8	$420	$3,190	$3,610
501 - 1,000	$28.96	8	$470	$3,190	$3,660
1,001 - 4,100	$29.73	8	$480	$3,190	$3,670
4,101 - 33,000	$36.00	8	$580	$3,190	$3,770
33,001 - 96,000	$36.39	8	$590	$3,190	$3,780
96,001 - 500,000	$41.01	8	$660	$3,190	$3,850
500,001 - 1,000,000	$41.01	8	$660	$3,190	$3,850
> 1,000,001	$41.01	8	$660	$3,190	$3,850

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*..

[2] Labor cost assumes a two person crew working for a total of 8 hours each.

[3] Assumes a long-neck standard unit, installed at a depth of 3 feet.

[4] Automated flushing device costs obtained from Hydro Guard® catalog, 2008.

[5] Estimates rounded up to the nearest $10.

5.5.4 Storage Facility Modifications

Most storage facilities have been designed focusing more on quantity, cost, service life, appearance and shape than on maintaining water quality. Water quality in storage facilities is affected by the mixing patterns that occur primarily during the filling cycle, the long term residence time, and the interaction between these two phenomena.

Increasing volume turnover reduces the average hydraulic residence time (HRT) in finished water storage facilities, thereby reducing DBP formation, loss of disinfectant and microbial growth. Kirmeyer et al. (2000b) recommend complete turnover every three to five days but suggest that water systems establish their own turnover goal based on system-specific needs and goals.

Improving mixing in finished water storage facilities can help eliminate stagnant zones. Old water in stagnant zones can often have very high DBPs and no or low disinfectant residual. This water can be released into the system during periods of high demand. Mixing can be improved by increasing inlet momentum, changing the inlet configuration, increasing the fill time, and by installing mixing devices within the storage facility.

5.5.4.1 Modify Inlet/Outlet Piping

Inlet/outlet configuration is critical in the development of proper mixing in a finished water storage facility. The inlet/outlet structure should be located and sized to disperse the jet into the storage facility as well as to maintain a jet sufficient for mixing. In particular, the location and orientation of the inlet pipe relative to the tank walls can have a significant impact on mixing characteristics, while the outflow characteristics do not significantly influence mixing. The physical modifications to the inlet pipe for improving mixing within the tanks include:

- Changing the orientation of the inlet pipe and/or
- Decreasing the inlet diameter to increase the jetting action.

When the inlet/outlet is a common pipe, the ability to reduce the inlet diameter to achieve a higher inflow velocity and better jetting action will be constrained by the need to maintain an outflow capacity adequate to satisfy system operational and fire flow requirements. For this reason, it is recommended to eliminate the common inlet/outlet pipe.

Exhibit 5-20 presents the cost of modifying the inlet/outlet configuration, including the pipes and related materials (e.g. valves), installation, and profit and overhead costs. Because these modifications are very site-specific and based on tank geometry, materials costs were estimated as 10% of the piping and related materials cost associated with installation of a new elevated storage tank, as identified in Exhibit 5-16 (column E). Installation was estimated as 20% of the materials cost based on similar experience at several PWSs. Note that this estimate does not include the cost of designing the new inlet/outlet configuration.

Exhibit 5-20: Estimated Costs to Modify Inlet/Outlet Piping

System Size	Tank Size (gal)	Pipe & Related Materials Cost[1]	Installation Cost[2]	Total Cost (2007$)[3,4]
A	B	C	D=0.2*C	E=(C+D)*1.225
< 500	50,000	$6,980	$1,400	$10,270
501 - 1,000	100,000	$9,620	$1,930	$14,150
1,001 - 4,100	250,000	$13,260	$2,660	$19,500
4,101 - 33,000	500,000	$21,400	$4,280	$31,460
33,001 - 96,000	1,000,000	$29,670	$5,940	$43,620
96,001 - 500,000	1,000,000	$29,670	$5,940	$43,620
500,001 - 1,000,000	2,000,000	$59,340	$11,870	$87,230
> 1,000,001	2,000,000	$59,340	$11,870	$87,230

[1] Assumes 10% of the Piping & Related Materials Cost of installing a new storage tank presented in Exhibit 5-16, column E.

[2] Assumes installation equal to 20% of the materials cost.

[3] Estimates rounded up to the nearest $10.

[4] Assumes and includes a 22.5% Overhead and Profit cost, based on R.S. Means (2009).

5.5.4.2 Install Mixing Devices

Mixing the storage facility contents to reduce stagnant zones can also be accomplished by installing mixing devices. Special precautions are needed with mechanical mixing devices because of potential contamination to finished water by the mixer mechanism lubrication system. Multiple mixing devices may be needed and the PWS should consider the increased maintenance requirements inside the storage facility.

Exhibit 5-21 presents the cost of installing mixing devices in the storage facilities, including the mixing device, the pipes and related materials (e.g. valves) and installation costs. Mixing system costs were obtained from vendor quotes, while piping and related materials costs were assumed to be 10% of the piping and related materials costs associated with installation of a new elevated storage tank, as identified in Exhibit 5-16 (column E). Installation was estimated as 20% of the total equipment and materials cost based on similar experience at several PWSs.

Exhibit 5-21: Estimated Costs to Install Mixing Devices

System Size	Tank Size (gal)	Mixing System Cost[1]	Pipes & Related Materials Cost[2]	Installation Cost[3]	Total Cost[4] (2007$)
A	B	C	D	E=0.2*(C+D)	F=1.225*(C+D+E)
< 500	50,000	$1,650	$6,980	$1,730	$12,690
501 - 1,000	100,000	$3,290	$9,620	$2,590	$18,990
1,001 - 4,100	250,000	$8,230	$13,260	$4,300	$31,590
4,101 - 33,000	500,000	$16,450	$21,400	$7,570	$55,640
33,001 - 96,000	1,000,000	$32,900	$29,670	$12,520	$91,990
96,001 - 500,000	1,000,000	$32,900	$29,670	$12,520	$91,990
500,001 - 1,000,000	2,000,000	$65,800	$59,340	$25,030	$183,960
> 1,000,001	2,000,000	$65,800	$59,340	$25,030	$183,960

[1] Assumes a mixing system by TideFlex Technologies (Carnegie, PA).

[2] Assumes 10% of the Piping & Related Materials Cost of installing a new storage tank presented in Exhibit 5-16, column E.

[3] Assumes installation equal to 20% of the total equipment and materials cost.

[4] Assumes and includes a 22.5% Overhead and Profit cost, based on R.S. Means (2009).

5.5.4.3 Modify Storage Operation

As mentioned earlier in this section, increasing the volume turnover reduces the average HRT in the storage tank. Turnover can be accomplished by making operational modifications to the storage tank such as increasing the water level fluctuation or drawdown between fill and draw cycles. The water level should be lowered in one continuous operation not small incremental drops throughout the day.

Operational modifications may be limited by the following considerations:

- Control of flow rates during tank filling may be needed to minimize the potential for low pressure in the distribution system;
- Changes in operating protocol for booster stations and other tanks to achieve turnover while maintaining adequate pressure system-wide.

Exhibit 5-22 presents the costs associated with modifying a storage operation. The costs included in this action are the operator labor costs associated with the time spent analyzing the different storage operation alternatives, selecting the most appropriate for their system and implementing it. For PWSs serving more than 1,001 customers, it was assumed that it would also be necessary to reprogram the Supervisory Control and Data Acquisition SCADA system and therefore there is an additional cost for the programmer time. In many systems, a SCADA system is used to automatically control pumps, and the system would need to be reprogrammed to incorporate any changes to the control logic.

Exhibit 5-22: Estimated Costs to Modify Storage Operation

System Size	Labor Rate[1]	Labor Time (hours)[2]	Programmer Rate[3,4]	Programming Time (hours)	Total Cost (2007$)
A	B	C	D	E	F=B*C+D*E
< 500	$25.75	8	NA	NA	$210
501 - 1,000	$28.96	8	NA	NA	$240
1,001 - 4,100	$29.73	8	$120	8	$1,200
4,101 - 33,000	$36.00	8	$120	8	$1,250
33,001 - 96,000	$36.39	8	$120	8	$1,260
96,001 - 500,000	$41.01	8	$120	8	$1,290
500,001 - 1,000,000	$41.01	8	$120	8	$1,290
> 1,000,001	$41.01	8	$120	8	$1,290

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Assumes 8 hours of operator time to analyze operational changes.

[3] Assumes average programmer rate of $120 per hour (in 2007 dollars), which is independent of system size.

[4] Assumes systems serving <1,000 do not use SCADA systems and therefore require no programming time.

5.5.4.4 Decommission Storage

Decommissioning storage facilities may be an appropriate strategy to reduce water age if existing facilities are oversized and not needed for emergency conditions, fire protection, or for maintaining system pressure. A professional engineer should review system needs, system design, and operation to determine if the existing storage capacity is appropriate.

Exhibit 5-23 presents the cost associated with the decommissioning of a storage tank, including the labor hours of in-house staff to drain the storage tank, close valves and oversee the work of the outside company that will clean the tank.

Exhibit 5-23: Estimated Costs to Decommission Storage

System Size	Tank Size (gal)	Labor Rate[1]	Time (hours)	Total Labor Cost[2]	Tank Cleaning Cost[3]	Total Cost (2007$)[4]
A	B	C	D	E=C*D*2	F	G=E+F
< 500	50,000	$25.75	8	$420	$1,510	$1,930
501 - 1,000	100,000	$28.96	8	$470	$1,830	$2,300
1,001 - 4,100	250,000	$29.73	8	$480	$3,190	$3,670
4,101 - 33,000	500,000	$36.00	8	$580	$5,020	$5,600
33,001 - 96,000	1,000,000	$36.39	8	$590	$7,750	$8,340
96,001 - 500,000	1,000,000	$41.01	8	$660	$7,750	$8,410
500,001 - 1,000,000	2,000,000	$41.01	8	$660	$9,110	$9,770
> 1,000,001	2,000,000	$41.01	8	$660	$9,110	$9,770

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Labor cost assumes a two-person crew and 8-hour shift.

[3] Includes cost of tank cleaning, as presented in Exhibit 5-24.

[4] Estimates rounded up to the nearest $10.

5.6 Storage Facility Maintenance

Finished water storage tanks are an important component of a PWS's distribution system. Tanks are usually designed for three purposes: reduce pressure fluctuations in the distribution system, equalize water demands, and provide water reserves for emergencies such as fires and power outages.

The two main categories of water storage tanks include ground storage tanks and elevated storage tanks. Ground storage tanks can be below grade, partially below grade, or at ground level in a distribution system and are usually constructed of a variety of materials, including steel, concrete, and fiberglass reinforced plastic. Elevated storage tanks are typically constructed of steel.

Contamination from birds and insects can be a source of microbial contamination in the distribution system. Maintenance to a storage tank can significantly reduce the possibility of contamination. Some actions include inspecting and cleaning, lining the interior of the tank, repairing vents and/or hatches, and repairing the tank itself.

5.6.1 Inspecting/Cleaning of Tanks

Tank inspections can provide useful information on the physical condition of the exterior and interior of the tank, identifying potential sources of microbial contamination. Inspections can also identify the accumulation of sediment within storage tanks due to particle settling in the tank or the dissolving of cementitious materials of a concrete tank from soft, low alkalinity, low pH waters. There are several water quality issues associated with sediment buildup in a storage tank, including increased disinfection demand, microbial growth, disinfection by-product formation, and increased turbidity.

Exhibit 5-24 presents the costs associated with inspecting and cleaning various sized finished water storage tanks. Assumptions regarding tank size were made based on population served. All tanks were assumed as elevated; ground storage tanks may have slightly lower costs as they are easier to access. The costs include inspection, cleaning, labor, equipment, and insurance costs.

Exhibit 5-24: Estimated Costs for the Inspection and Cleaning of Storage Tanks

System Size	Tank Size (gal)	Tank Type	Total Cost[1,2] (2007$)
A	B	C	D
< 500	50,000	Elevated	$1,510
501 - 1,000	100,000	Elevated	$1,830
1,001 - 4,100	250,000	Elevated	$3,190
4,101 – 33,000	500,000	Elevated	$5,020
33,001 - 96,000	1,000,000	Elevated	$7,750
96,001 - 500,000	1,000,000	Elevated	$7,750
500,001 - 1,000,000	2,000,000	Elevated	$9,110
> 1,000,001	2,000,000	Elevated	$9,110

[1] Cost includes inspection, labor, equipment, and insurance.

[2] Costs obtained from Pittsburg Tank & Tower Maintenance Co., Inc.

5.6.2 Lining of Storage Tanks

Lining the interior of a water storage tank is another action that can be taken to reduce the potential for coliform contamination of a distribution system. Corrosion and corrosion product buildup from excessive interior corrosion can also result in water quality issues such as increased disinfection demand, microbial growth, and increased turbidity.

The costs associated with lining the interior of various sized water storage tanks are presented in Exhibit 5-25. The tank sizes and types presented were assumed to be present in a distribution system serving the associated population range. The costs include material, labor, equipment, and insurance costs, and assume an existing layer is required to be stripped from the tank's interior surface.

Exhibit 5-25: Estimated Costs for the Lining of Storage Tanks

System Size	Tank Size (gal)	Tank Type	Total Cost (2007$)[1,2]
A	B	C	D
< 500	50,000	Elevated	$28,380
501 - 1,000	100,000	Elevated	$35,530
1,001 - 4,100	250,000	Elevated	$63,770
4,101 – 33,000	500,000	Elevated	$88,830
33,001 - 96,000	1,000,000	Elevated	$150,320
96,001 - 500,000	1,000,000	Elevated	$150,320
500,001 - 1,000,000	2,000,000	Elevated	$200,420
> 1,000,001	2,000,000	Elevated	$200,420

[1] Cost includes stripping existing coating, material, labor, equipment, and insurance

[2] Costs obtained from Pittsburg Tank & Tower Maintenance Co., Inc

5.6.3 Vent/Hatch Repair

One of the most common sources of contamination in a water storage tank is the improper design and maintenance of vents and roof hatches. These accessories can provide entry points for debris as well as microbial contamination from birds and insects.

Exhibit 5-26 presents the costs associated with replacing a storage tank's vent screen. Costs are presented on a per vent screen basis. Labor costs were calculated based on a two-person crew and two hours for installation. Exhibit 5-27 presents similar installed costs of repair or replacement of a storage tank hatch.

Exhibit 5-26: Estimated Costs for the Repair/Replacement of a Storage Tank Vent

System Size	Labor Rate[1]	Shift Time (hours)	Total Labor Cost[2]	Vent Screen Cost[3]	Total Cost (2007$)
A	C	D	E=C*D*2	F	G=E+F
< 500	$25.75	2	$110	$50	$160
501 - 1,000	$28.96	2	$120	$50	$170
1,001 - 4,100	$29.73	2	$120	$50	$170
4,101 – 33,000	$36.00	2	$150	$50	$200
33,001 - 96,000	$36.39	2	$150	$50	$200
96,001 - 500,000	$41.01	2	$170	$50	$220
500,001 - 1,000,000	$41.01	2	$170	$50	$220
> 1,000,001	$41.01	2	$170	$50	$220

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*

[2] Labor cost assumes a two-person crew working for a total of 2 hours

[3] Assumes 2-inch wide steel screen frame, 12-inch vent diameter, 6.9 lb/ft2 area weight, $1.37/lb frame cost and $45 screen cost

Exhibit 5-27: Estimated Costs for the Repair/Replacement of a Storage Tank Hatch

Item	Total Cost (2007$)[1,2]
A	B
6 ft. x 6 ft. Hatch	$3,190

[1] Hatch cost assumed 6 ft. by 6 ft. fiberglass hatch, including materials, labor, and mobilization.

[2] Hatch costs obtained from The Crom Corporation.

5.6.4 Tank Repair

Aging water storage tanks with damaged tank covers can also be a source of microbial contamination. Exhibit 5-28 presents estimated costs for repairing water storage tank covers for various tank sizes and types assumed to be present in a distribution system serving the associated population range. These cost estimates assume a repair cost equal to 20% of the installed cost of a new tank, which includes material, labor, overhead, and profit.

Exhibit 5-28: Estimated Costs for the Repair of Storage Tanks

System Size	Tank Size (gal)	Tank Type	New Tank Cost[1]	Total Cost[2] (2007$)
A	B	C	D	E=0.2*D
< 500	50,000	Elevated	$202,240	$40,448
501 - 1,000	100,000	Elevated	$278,770	$55,754
1,001 - 4,100	250,000	Elevated	$384,440	$76,888
4,101 – 33,000	500,000	Elevated	$620,390	$124,078
33,001 - 96,000	1,000,000	Elevated	$859,980	$171,996
96,001 - 500,000	1,000,000	Elevated	$859,980	$171,996
500,001 - 1,000,000	2,000,000	Elevated	$1,719,970	$343,994
> 1,000,001	2,000,000	Elevated	$1,719,970	$343,994

[1] Assumes installed cost of a new elevated storage tank, as presented in Exhibit 5-16.

[2] Tank repair costs estimated at 20% of new tank costs.

5.7 Booster Disinfection

Booster disinfection facilities located throughout a distribution system can provide additional chemical treatment in the system. Booster disinfection can improve or maintain disinfectant residual levels in a distribution system. Prior to discharge into the system, potable water from a treatment facility must have a certain disinfectant residual level to minimize microbial growth. These levels are defined by state and government regulations. Organics and reduced metals in the water also consume disinfectant residuals; therefore, it is vital to maintain an appropriate disinfectant residual level in the system in order to avoid increased levels of total coliform in the system.

The following sections present costs associated with installation of both chlorine and chloramines booster disinfection facilities. The booster disinfection facilities were sized based on the system size, type of chemical treatment, and permanent or temporary system. Permanent systems were assumed to be operating all year round and providing 30 days of chemical storage. It is assumed that an operator would visit the facility for one hour each day. These systems are assumed to constantly maintain disinfectant residual levels in a system. They would be placed in locations that typically had low disinfectant residual levels. Temporary systems were assumed to operate one day and provide one day of chemical storage. It is assumed that an operator would visit the facility for two hours for the day the system was in operation. These systems are assumed to operate at times when disinfectant residuals levels were low for a distribution system; however, these distribution systems would only experience low residuals at various times of the year. Some systems experience higher levels of organic growth at certain times of the year, particularly the summer months. Therefore, the booster disinfection facilities are not required to operate all year round.

The capital costs of the facilities include feed equipment, storage, required piping and appurtenances, electrical and instrumentation equipment, a building, and installation. Buildings were sized to provide adequate spacing between the chemical feed equipment. Yearly operation and maintenance costs include labor, chemical, and parts and maintenance costs.

5.7.1 Chlorine System

Most systems currently use chlorine as their main disinfectant. Exhibits 5-29 and 5-30 show various chlorine facility sizes. Based on the facility size, either a tablet chlorinator or a liquid hypochlorite system was provided. It was assumed that these systems would provide a 1.0 mg/L chlorine dosage.

The tablet chlorinator systems used calcium hypochlorite tablets. These tablets are placed in a chlorinator where water from the main line is introduced at a controlled rate to erode the tablets. A pump then injects the chlorinated solution back into the main line. These facilities did not require a storage container. The manufacturer provided the tablets in large buckets. Liquid hypochlorite systems consisted of solenoid diaphragm feed pumps and chemical storage.

5.7.1.1 Permanent System

For permanent systems, it is assumed that either one tablet chlorinator system was provided or two feed pumps were provided depending on the system size. Two feed pumps were provided to have one pump in operation and one on standby. It is assumed that polyethylene storage tanks were provided for liquid sodium hypochlorite storage. The number of tanks varied depending on the system size. Exhibit 5-29 presents the estimated cost for the installation of a permanent chlorine disinfection booster station. Costs to rehabilitate an existing chlorine booster station are assumed to be equal to the total cost of equipment for a new station, as presented in Exhibit 5-29, Row K.

5.7.1.2 Temporary System

For temporary systems, it was assumed that each of the facilities would have liquid hypochlorite systems; therefore, each facility was equipped with a single feed pump. There was no permanent chemical storage at these facilities. Exhibit 5-30 presents the estimated cost for the installation of a temporary chlorine disinfection booster station.

Exhibit 5-29: Estimated Costs to Install a Permanent Chlorine Booster Disinfection Station

Cost Component		Population Size Category							
		<500	501 to 1,000	1,001 to 4,100	4,100 to 33,000	33,001 to 96,000	96,001 to 500,000	500,001 to 1,000,000	>1,000,001
Tablet Chlorinator System[1]									
Usage Rate (lb/hr)	A	0.01	0.01	0.04	-	-	-	-	-
System Size (lb/hr)	B	0.5	0.5	0.5	-	-	-	-	-
System Cost[2]	C	$6,840	$6,840	$6,840	-	-	-	-	-
Liquid Hypochlorite System[1]									
Usage Rate (gal/hr)	D	-	-	-	0.32	1.12	1.55	3.91	7.82
Pump Size (gal/hr)	E	-	-	-	0.55	1.9	1.9	5	8.4
Total Pump Cost (two pumps)[3]	F	-	-	-	$1,100	$1,190	$1,190	$1,190	$1,640
Storage Requirement[4] (gal)	G	-	-	-	300	900	1,200	2,900	5,700
Storage Tank Cost[3]	H	-	-	-	$640	$1,190	$1,010	$2,010	$6,930
Cost of Piping and Appurtenances[5]	I	$250	$250	$250	$270	$360	$330	$480	$1,290
Cost of Instrumentation and Electrical[5]	J	$250	$250	$250	$270	$360	$330	$480	$1,290
Total Cost of Equipment	**K=C+F+H+I+J**	**$7,340**	**$7,340**	**$7,340**	**$2,280**	**$3,100**	**$2,860**	**$4,160**	**$11,150**
Total Structure Cost[6]	L	$4,200	$4,200	$4,200	$9,660	$9,660	$12,940	$23,780	$26,060
Cost of Installation[7]	M=0.15*(K+L)	$1,740	$1,740	$1,740	$1,800	$1,920	$2,370	$4,200	$5,590
Total Capital Cost (2007$)[8]	**N=K+L+M**	**$16,270**	**$16,270**	**$16,270**	**$16,840**	**$17,990**	**$22,260**	**$39,380**	**$52,430**
Labor Cost ($/year)[9]	O	$9,400	$10,800	$10,800	$13,200	$13,200	$14,400	$14,400	$14,400
Chemical Cost ($/year)[10]	P	$1,200	$1,200	$1,200	$6,000	$15,600	$20,400	$48,000	$92,400
Parts and Maintenance Cost ($/year)[11]	Q=0.1*K	$740	$740	$740	$230	$310	$290	$420	$1,120
Yearly Operation and Maintenance Cost	**R=O+P+Q**	**$11,540**	**$12,740**	**$12,740**	**$19,430**	**$29,110**	**$35,090**	**$62,820**	**$107,920**

1 Tablet chlorinator systems assumed for system sizes 10,000 and less; liquid hypochlorite systems assumed for system sizes 10,001 and greater
2 Table chlorinator system cost obtained from vendor.
3 Pump and tank cost per Cole Palmer catalog (2008), adjusted to 2007 dollars. Pumps are solenoid diaphragm metering pumps and tanks are polyethylene tanks.
4 Storage requirements based on providing approximately 30 days of chemical storage.
5 Assumes 15% of chemical system and storage costs.
6 Structure cost includes building and slab per R.S. Means (2009), adjusted to 2007 dollars.
7 Assumes 15% of equipment and structure costs.
8 Includes 22.5% overhead and profit, based on R.S. Means (2009).
9 Assumes one hour of maintenance a day and labor rates presented in Exhibit 2-6 of Section 2. Estimated Unit Costs of Labor.
10 Chemical cost per chemical supplier ($2.50 per lb of chlorine tablets and $1.35 per gallon of hypochlorite).
11 Assumes 10% of equipment cost.

Exhibit 5-30: Estimated Costs to Install a Temporary Chlorine Booster Disinfection Station

Cost Component		Population Size Category							
		<500	501 to 1,000	1,001 to 4,100	4,100 to 33,000	33,001 to 96,000	96,001 to 500,000	500,001 to 1,000,000	>1,000,001
Usage Rate (gal/hr)	A	0.01	0.04	0.04	0.32	1.12	1.55	3.91	7.82
Pump Size (gal/hr)	B	0.19	0.19	0.19	0.55	1.9	1.9	5	8.4
Total Pump Cost (one pump)[1]	C	$540	$540	$540	$560	$640	$640	$730	$820
Storage Requirement (gal)	D	10	10	10	10	30	40	100	190
Type of Storage Container[2]	E	Carboy	Carboy	Carboy	Drum	Drum	Drum	Drum	Tote
Cost of Piping and Appurtenances[3]	F=0.15*C	$90	$90	$90	$90	$100	$100	$110	$130
Cost of Instrumentation and Electrical[3]	G=0.15*C	$90	$90	$90	$90	$100	$100	$110	$130
Total Cost of Equipment	H=C+F+G	$720	$720	$720	$740	$840	$840	$950	$1,080
Total Structure Cost[4]	I	$930	$1,000	$1,000	$1,460	$1,660	$1,660	$2,100	$4,190
Cost of Installation[5]	J=0.15*(H+I)	$250	$260	$260	$330	$380	$380	$460	$800
Total Capital Cost (2007$)[6]	**K=H+I+J**	**$1,900**	**$1,980**	**$1,980**	**$2,530**	**$2,880**	**$2,880**	**$3,510**	**$6,070**
Labor Cost ($/year)[7]	L	$60	$60	$60	$80	$80	$90	$90	$90
Chemical Cost($/year)[8]	M	$90	$90	$90	$90	$90	$90	$170	$450
Parts and Maintenance Cost ($/year)[9]	N=0.1*H	$80	$80	$80	$80	$90	$90	$100	$110
Yearly Operation and Maintenance Cost	**O=L+M+N**	**$230**	**$230**	**$240**	**$250**	**$260**	**$270**	**$360**	**$650**

[1] Pump cost per Cole Palmer catalog (2008), adjusted to 2007 dollars. Pumps are solenoid diaphragm metering pumps.
[2] Assumes storage containers obtained from chemical supplier, and returned for refund of any applicable deposit.
[3] Assumes 15% of pump costs.
[4] Structure cost includes building and slab per R.S. Means, 2009.
[5] Assume 15% of equipment and structure costs.
[6] Assume two hours of maintenance a day based on labor rates presented in Exhibit 2-6 of Section 2. *Estimated Unit Costs of Labor*
[7] Includes 22.5% overhead and profit, based on R.S. Means, 2009.
[8] Chemical cost based on minimum chemical delivery volume per chemical vendor.
[9] Assumes 10% of equipment cost.

5.7.2 Chloramine System

Some utilities use combined chlorine, or chloramine, as a secondary disinfectant. For these systems to provide residual boosting, an aqua ammonia feed is required in addition to a chlorine feed system. Exhibits 5-31 and 5-32 outline costs for a chloramine feed system similar to the permanent and temporary systems that were previously described for free chlorine. It was assumed that these systems would provide a 1.0 mg/L total chlorine dosage. In addition to the chlorine system, an aqua ammonia feed system was provided in order to produce chloramines. It was assumed that these systems would provide a 0.2 mg/L of ammonia dosage.

5.7.2.1 Permanent System

For permanent systems, the aqua ammonia feed system included two solenoid pumps, one in operation and one on standby. Chemical storage varied depending on the required amount of ammonia. It was assumed that systems requiring 500 gallons or greater of storage would install stainless steel storage tanks. Systems that required less would either obtain a 250 gallon tote or 55 gallon drum from the chemical supplier depending on the required amount of ammonia. Exhibit 5-31 presents the estimated cost for the installation of a permanent chloramine booster station. Estimated costs to rehabilitate an existing chloramine booster station are assumed to be equal to the total cost of equipment for a new station, as presented in Exhibit 5-31, Row P.

5.7.2.2 Temporary System

For temporary systems, it was assumed each was equipped with a single feed pump. There was no permanent chemical storage at these facilities. Exhibit 5-32 presents the estimated cost for the installation of a temporary chloramine booster station.

Exhibit 5-31: Estimated Costs to Install a Permanent Chloramines Booster Disinfection Station

Cost Component		Population Size Category							
		<500	501 to 1,000	1,001 to 4,100	4,100 to 33,000	33,001 to 96,000	96,001 to 500,000	500,001 to 1,000,000	>1,000,001
Tablet Chlorinator System[1]									
Usage Rate (lb/hr)	A	0.01	0.01	0.04	-	-	-	-	-
System Size (lb/hr)	B	0.5	0.5	0.5	-	-	-	-	-
System Cost[2]	C	$6,840	$6,840	$6,840	-	-	-	-	-
Liquid Hypochlorite System[1]									
Usage Rate (gal/hr)	D	-	-	-	0.32	1.12	1.55	3.91	7.82
Pump Size (gal/hr)	E	-	-	-	0.55	1.9	1.9	5	8.4
Pump Cost[3]	F	-	-	-	$1,100	$1,190	$1,190	$1,190	$1,640
Storage Requirement (gal)[4]	G	-	-	-	300	900	1200	2900	5700
Storage Tank Cost[3]	H	-	-	-	$640	$1,190	$1,010	$2,010	$6,930
Aqua Ammonia System									
Usage Rate (gal/hr)	I	0.002	0.002	0.007	0.049	0.169	0.235	0.591	1.183
Pump Size (gal/hr)	J	0.19	0.19	0.19	0.19	0.29	0.29	1.10	1.90
Pump Cost[3]	K	$1,100	$1,100	$1,100	$1,100	$1,100	$1,100	$1,190	$1,640
Storage Requirement(gal)[4]	L	10	10	10	40	130	170	430	860
Storage Tank Cost[3]	M	-	-	-	-	-	-	$18,220	$20,780
Cost of Piping and Appurtenances[5]	N=0.15*(C+F+H+K+M)	$420	$420	$420	$430	$530	$500	$3,400	$4,650
Cost of Instrumentation and Electrical[5]	O=0.15*(C+F+H+K+M)	$420	$420	$420	$430	$530	$500	$3,400	$4,650
Total Cost of Equipment	**P=C+F+H+K+M+N+O**	**$8,780**	**$8,780**	**$8,780**	**$3,700**	**$4,540**	**$4,300**	**$29,410**	**$40,290**
Total Structure Cost($/year)[6]	Q	$7,870	$7,930	$7,930	$15,580	$15,580	$19,590	$37,450	$41,910
Cost of Installation[7]	R=0.15*(P+Q)	$2,500	$2,510	$2,510	$2,900	$3,020	$3,590	$10,030	$12,330
Total Capital Cost (2007$)[8]	**S=P+Q+R**	**$23,460**	**$23,550**	**$23,550**	**$27,180**	**$28,350**	**$33,670**	**$94,200**	**$115,800**

Cost Component		Population Size Category							
		<500	501 to 1,000	1,001 to 4,100	4,100 to 33,000	33,001 to 96,000	96,001 to 500,000	500,001 to 1,000,000	>1,000,001
Operations & Maintenance Costs									
Labor Cost($/year)[9]	T	$9,400	$10,800	$10,800	$13,200	$13,200	$14,400	$14,400	$14,400
Chemical Cost($/year)[10]	U	$2,400	$2,400	$2,400	$7,200	$19,200	$24,000	$54,000	$103,200
Parts and Maintenance Cost ($/year)[11]	V=0.1*P	$880	$880	$880	$370	$460	$430	$2,950	$4,030
Yearly O&M Cost	**W=T+U+V**	**$15,780**	**$17,250**	**$17,250**	**$25,450**	**$40,260**	**$47,570**	**$87,410**	**$149,000**

[1] Tablet chlorinator systems assumed for system sizes 10,000 and less; liquid hypochlorite system assumed for system sizes 10,001 and greater.

[2] Table chlorinator system cost obtained from vendor.

[3] Pump and tank cost per Cole Palmer catalog (2008), adjusted to 2007 dollars. Pumps are solenoid diaphragm metering pumps and tanks are polyethylene tanks.

[4] Storage requirements based on providing approximately 30 days of chemical storage.

[5] Assume 15% of chemical system and storage costs

[6] Structure cost includes building and slab per R.S. Means 2009

[7] Assume 15% of equipment and structure costs

[8] Includes 22.5% overhead and profit, based on R.S. Means

[9] Assumes one hour of maintenance a day based on labor rates presented in Exhibit 2-6 of Section 2. *Estimated Unit Costs of Labor.*

[10] Chemical cost per chemical supplier in 2009. ($2.50 per lb of chlorine tablets, $1.35 per gallon of hypochlorite, and $0.99 per gallon of aqua ammonia).

[11] Assumes 10% of equipment cost.

Exhibit 5-32: Estimated Costs to Install a Temporary Chloramine Booster Disinfection Station

Cost Component[1]		Population Size Category							
		<500	501 to 1,000	1,001 to 4,100	4,100 to 33,000	33,001 to 96,000	96,001 to 500,000	500,001 to 1,000,000	>1,000,001
Liquid Hypochlorite System									
Usage Rate (gal/hr)	A	0.01	0.01	0.04	0.32	1.12	1.55	3.91	7.82
Pump Size (gal/hr)	B	0.19	0.19	0.19	0.55	1.90	1.90	5.00	8.40
Pump Cost[1]	C	$540	$540	$540	$560	$560	$560	$560	$820
Storage Requirement (gal)	D	10	10	10	10	30	40	100	190
Type of Storage Container[2]	E	Carboy	Carboy	Carboy	Drum	Drum	Drum	Drum	Tote
Aqua Ammonia System									
Usage Rate (gal/hr)	F	0.002	0.002	0.007	0.049	0.169	0.235	0.591	1.183
Pump Size (gal/hr)	G	0.19	0.19	0.19	0.19	0.29	0.29	1.10	1.90
Pump Cost[1]	H	$540	$540	$540	$540	$540	$540	$560	$820
Storage Requirement (gal)	I	10	10	10	10	10	10	20	30
Type of Storage Container[2]	J	Carboy	Carboy	Carboy	Carboy	Carboy	Carboy	Drum	Drum
Cost of Piping and Appurtenances[3]	K=0.15*(C+H)	$170	$170	$170	$170	$170	$170	$170	$250
Cost of Instrumentation and Electrical[3]	L=0.15*(C+H)	$170	$170	$170	$170	$170	$170	$170	$250
Total Cost of Equipment	**M=C+H+K+L**	**$1,420**	**$1,420**	**$1,420**	**$1,440**	**$1,440**	**$1,440**	**$1,460**	**$2,140**
Total Structure Cost[4]	N	$1,920	$1,920	$1,920	$2,920	$2,920	$2,920	$3,560	$6,020
Cost of Installation[5]	O=0.15*(M+N)	$510	$510	$510	$660	$660	$660	$760	$1,230
Total Capital Cost (2009$)[6]	**P**	**$4,720**	**$4,720**	**$4,720**	**$6,150**	**$6,150**	**$6,150**	**$7,090**	**$11,510**
Labor Cost[7]	Q	$60	$60	$60	$80	$80	$90	$90	$90
Chemical Cost[8]	R	$150	$150	$150	$150	$150	$150	$230	$510
Parts and Maintenance Cost[9]	S	$150	$150	$150	$150	$150	$150	$150	$220
Yearly Operation and Maintenance Cost	**T**	**$370**	**$370**	**$370**	**$390**	**$390**	**$400**	**$490**	**$840**

[1] Pump cost per Cole Palmer catalog. Pumps are solenoid diaphragm metering pumps.
[2] Assumes storage containers obtained from chemical supplier, and returned for refund of any applicable deposit.
[3] Assume 15% of chemical systems costs
[4] Structure cost includes building and slab per R.S. Means 2009
[5] Assume 15% of equipment and structure costs
[6] Includes 22.5% overhead and profit, based on R.S. Means
[7] Assume two hours of maintenance a day based on labor rates presented in Exhibit 2-6 of Section 2. *Estimated Unit Costs of Labor*
[8] Chemical cost based on minimum chemical delivery volume (For hypochlorite a 55 gallon drum is $82.50 and a 300 gallon tote is $450.00, and for ammonia a 55 gallon drum is $54.45)
[9] Assumes 10% of equipment cost.

5.8 Cross-connection Control and Backflow Prevention Program

Implementing a Cross-Connection Control and Backflow Prevention (CCCBFP) Program, including the installation of backflow prevention assemblies and devices, can prevent the flow of non-potable substances into the distribution system. When implementing the CCCBFP Program, the drinking water system should adhere to applicable state and/or local criteria, codes, and/or regulations. Some codes or regulations may include documenting installation procedures and the periodic testing of backflow prevention assemblies.

CCCBFP can prevent the introduction of non-potable substances into the public water supply due to backsiphonage or backpressure. The cost components of a cross-connection control and backflow prevention program can be broadly classified as:

- Cost of Backflow Prevention Assemblies and Devices, and
- Cost of Program Administration. This can be further classified as program organization, system survey, record keeping costs, and enforcement.

The relative cost of program administration is usually more significant for small systems (i.e., typically systems serving populations less than or equal to 10,000) as these systems have limited personnel performing many duties at once. For large systems, the costs of the backflow devices and assemblies' costs are usually more significant than the program administration costs. This section provides the costs of installing a backflow prevention device and describes the items included under program administration.

5.8.1 Backflow Prevention Assemblies and Devices

Exhibit 5-33 presents the costs of installing a backflow prevention assembly (i.e., a reduced pressure flanged iron assembly). This is usually the most expensive assembly and is used in situations of highest hazard when backpressure and backsiphonage are both possible. More information can be found at (www.usc.edu/dept/fccchr).

Systems should install above-grade housing with drainage and heat to protect the equipment from freezing where systems cannot install valves indoors. Installation costs do not include costs for this housing, or costs for engineering/construction. Maintenance of these assemblies includes a minimum of annual testing and inspection. In addition, the frequency for performance monitoring and internal inspections (dismantling, cleaning, and repairs) should occur based on local water quality conditions, the probability of contamination due to potential backflow, and manufacturers' recommendations for the specific backflow prevention assembly.

Backflow prevention equipment installation and maintenance is generally the consumer's responsibility. However, depending on how a system implements the cross-connection control and backflow prevention program, the customer and the PWS can share costs for the equipment and equipment installation, inspection, testing, and maintenance. The PWS, on the other hand, is primarily responsible for the administration of cross-connection control and backflow prevention and the inspection, review, and approval of all backflow prevention assemblies and devices. Labor costs assume a three-person crew is required to dig a new vault and install the backflow prevention device.

Exhibit 5-33: Estimated Costs for a Backflow Prevention Assembly

System Size	Labor Rate[1]	Shift Time (hours)	Total Labor Cost[2]	Backflow Preventer Pipe Size (in.)	Backflow Preventer Cost[3,4]	Total Cost (2007$)[5]
A	B	C	D=B*C*3	E	F	G+D+F
< 500	$25.75	8	$620	2.5	$2,825	$3,450
501 - 1,000	$28.96	8	$700	2.5	$2,825	$3,530
1,001 - 4,100	$29.73	8	$720	2.5	$2,825	$3,550
4,101 - 33,000	$36.00	8	$870	3	$2,950	$3,820
33,001 - 96,000	$36.39	8	$880	3	$2,950	$3,830
96,001 - 500,000	$41.01	8	$990	4	$3,725	$4,720
500,001 - 1,000,000	$41.01	8	$990	6	$5,375	$6,370
> 1,000,001	$41.01	8	$990	6	$5,375	$6,370

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*

[2] Labor cost assumes a three-person crew working for a total of 8 hours.

[3] Backflow preventer cost assumed a reduced pressure principle, flanged, including valves, four test cocks, and corrosion resistant.

[4] Costs do not include design or permit costs.

[5] Estimates rounded up to the nearest $10

5.8.2 Program Administration

The administration of a CCCBPP is typically the responsibility of the PWS. Costs for program administration depend on the system size (population served and area covered), system demographics (number of industrial, residential, and institutional customers), available staffing resources, maintenance, record keeping, and specific code and regulatory requirements. Another factor in the administrative costs, in some cases, is overcoming political resistance. The Cross-Connection Control Manual provides additional guidance on program administration (USEPA, 1989c). Program administration will require availability of technical and administrative staff. If sufficient staff is available, appropriate division of program oversight duties may apply. Otherwise, these tasks may require additional staff or temporary help. In some cases, program administration is contracted out. The Program Administration costs can be classified under three headings:

- Program Organization: It involves establishing the legal foundation for the plan, establishing responsibilities and chain of command, conducting employee and consumer education programs, implementing required codes and regulations for enforcing the program, and monitoring the progress of the program.
- System Survey: It involves surveying the system for potential cross-connections and identifying and prioritizing hazardous connections.
- Record Keeping: It involves updating and maintaining records that are pertinent to the implementation of the CCCBPP.

Exhibit 5-34 summarizes the activities included under each of the three components of Program Administration.

Exhibit 5-34: Cost Components of Program Administration for a Cross-Connection Control and Backflow Prevention Program

Cost Component	Specific Items Included
Program Organization	• Consulting with relevant local and State administrations • Establishing responsibilities and authorities for required program activities (inspections, maintenance, reporting, etc.) • Notifying and educating employees and consumers of program and implications • Developing and implementing a local ordinance • Program enforcement by the PWS
System Survey	• Recording number and sites of connections Identifying potential hazardous connections • Prioritizing hazardous connections • Developing inspection schedules and records
Record Keeping	• Inspection records • Installation, repair, and maintenance of records • Customer correspondence records • Ordinance development records • Assembly test records

In addition to the other items presented in this section, a successful cross connection control program will require development of testing and enforcement programs to ensure proper operation and compliance. Such programs represent additional costs that would typically be handled by a department other than then PWS (e.g. writing notices of violation, issuing fines, preparing litigation); therefore these costs have not been included.

5.9 Addition or Upgrade of On-line Monitoring and Control

Currently, monitoring of total coliform is performed through grab samples at the treatment plant and throughout the distribution system. These grab samples are then analyzed in a laboratory to determine whether TC is present or not in the grab sample.

To ensure sufficient treatment has been provided, grab samples, disinfectant dosages, and certain water quality parameters, such as disinfectant residual levels, can be correlated. Since automatic monitoring is not available for TC, communities can control and monitor disinfectant dosages and water quality parameters.

Controlling and monitoring disinfectant dosages and water quality parameters through the SCADA system performed at a treatment facility is relatively easily. Disinfectant dosing equipment can be monitored and analyzers can be placed in the treatment process to monitor water quality parameters.

Monitoring water quality parameters via SCADA in a distribution system is possible; however, it can be costly. Determining the number and location of the analyzers is challenging and highly dependent upon the system size. Typically, analyzer equipment will draw samples from an above grade pipe or a sample tap to an analyzer that is placed in a building. Sample locations will require analyzer equipment, a building, electric power, and, in the case of some systems, integration to the PWS's existing SCADA system.

In addition to water quality monitoring, a PWS can monitor pressure levels throughout the distribution system to determine if there are any physical problems in the system, e.g., a crack in a pipe, a leaking valve, etc., that cause changes to the water quality of the system. Similar to the water quality monitoring, determining the number of pressure monitors and their locations is dependent upon the system size. Pressure monitoring locations will also require the same equipment as water quality sampling locations.

On-line distribution system monitoring through the SCADA system can alert operators if there are possible issues with the distribution system; however, monitoring the water quality or pressure will not identify the source of the contamination nor will it necessarily identify the location of the contamination.

The following sections provide costs for on-line monitoring equipment. Costs provided are for the installation of a single analyzer into an existing building; therefore, costs of a building and electrical and instrumentation equipment are not included.

5.9.1 Water Quality Monitoring and Control

The ability of a PWS to monitor water quality parameters, particularly disinfectant residuals, in the distribution system can allow the PWS to determine if there is an area of possible contamination or an area that requires additional treatment. Low levels of disinfectant residuals in a system can be caused by an increase of organics in a system, which consume disinfectant residuals, or insufficient disinfectant dosages at the treatment facility. Maintenance of sufficient disinfectant residual levels in a distribution system is important in maintaining minimal levels of TC in the system.

5.9.1.1 Chlorinated Systems

Most systems currently utilize chlorine as the main disinfectant. There are a number of chlorine-based treatment technologies available: chlorine gas, hypochlorite, chlorine dioxide, and anodic oxidation.

Exhibit 5-35 presents the costs associated with incorporating a chlorine residual analyzer in the distribution system. The costs below include a chlorine residual analyzer, installation of the analyzer based on system size, required piping and appurtenances, and programming costs.

Exhibit 5-35: Estimated Costs for Online Chlorine Monitoring and Programming

System Size	Labor Rate[1]	Labor Time (hours)[2]	Programmer Rate[3]	Program. Time (hours)[4]	Total Labor & Program. Cost[2]	Chlorine Analyzer Cost[5]	Piping and related[6]	Total Cost[7,8] (2007$)
A	B	C	D	E	F=B*C*2+D*E	G	H	I=F+G+H
< 500	$25.75	24	$120	8	$2,200	$2,770	$460	$5,430
501 -1,000	$28.96	24	$120	8	$2,360	$2,770	$460	$5,590
1,001 -4,100	$29.73	24	$120	8	$2,390	$2,770	$460	$5,620
4,101 - 33,000	$36.00	24	$120	8	$2,690	$2,770	$460	$5,920
33,001 - 96,000	$36.39	24	$120	8	$2,710	$2,770	$460	$5,940
96,001 - 500,000	$41.01	24	$120	8	$2,930	$2,770	$460	$6,160
500,001 - 1,000,000	$41.01	24	$120	8	$2,930	$2,770	$460	$6,160
> 1,000,001	$41.01	24	$120	8	$2,930	$2,770	$460	$6,160

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Assumes a two-person crew required over a three-day period to install chlorine monitoring device and associated equipment (electrical wiring, installing a sample drain, etc.).

[3] Assumes average programmer rate of $120 per hour (in 2007 dollars), which is independent of system size.

[4] Programming time includes integration of analyzer signals into a SCADA system.

[5] Chlorine analyzer cost per vendor research

[6] Assume an additional $460 for sample lines.

[7] Estimates rounded up to the nearest $10.

[8] Costs assume that analyzer will be installed at an existing facility.

5.9.1.2 Chloraminated Systems

Exhibit 5-36 presents the costs associated with incorporating an ammonia and monochloramine analyzers in the distribution system. The costs below include an ammonia and monochloramine residual analyzer, installation of the analyzer based on system size, required piping and appurtenances, and programming costs.

Exhibit 5-36: Estimated Costs for Online Chloramine Monitoring and Programming

System Size	Labor Rate[1]	Labor Time (hours)[2]	Programmer Rate[3]	Program. Time (hours)[4]	Total Labor & Program. Cost[2]	Chloramines Analyzer Cost[5]	Piping and related[6]	Total Cost (2007$)[7,8]
A	B	C	D	E	F=B*C*2+D*E	G	H	I=F+G+H
< 500	$25.75	24	$120	8	$2,200	$11,230	$460	$13,890
501 - 1,000	$28.96	24	$120	8	$2,360	$11,230	$460	$14,050
1,001 -4,100	$29.73	24	$120	8	$2,390	$11,230	$460	$14,080
4,101 - 33,000	$36.00	24	$120	8	$2,690	$11,230	$460	$14,380
33,001 - 96,000	$36.39	24	$120	8	$2,710	$11,230	$460	$14,400
96,001 - 500,000	$41.01	24	$120	8	$2,930	$11,230	$460	$14,620
500,001 - 1,000,000	$41.01	24	$120	8	$2,930	$11,230	$460	$14,620
> 1,000,001	$41.01	24	$120	8	$2,930	$11,230	$460	$14,620

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Assumes a two-person crew required over a three-day period to install chloramine monitoring device and associated equipment (electrical wiring, installing a sample drain, etc.).

[3] Assumes average programmer rate of $120 per hour (in 2007 dollars), which is independent of system size.

[4] Programming time includes integration of analyzer signals into a SCADA system.

[5] Chloramine analyzer cost per vendor.

[6] Assume an additional $460 for sample lines.

[7] Estimates rounded up to the nearest $10.

[8] Costs assume that analyzer will be installed at an existing facility.

5.9.2 Pressure Monitoring and Control

The ability of a PWS to monitor pressure throughout its distribution system can provide useful information for responding to water quality events and ensuring that pressure maintenance is adequate. Pressure readings can also be used to help locate areas of deficiency in a distribution system.

Exhibit 5-37 presents the costs associated with incorporating pressure monitoring equipment in the distribution system. The costs below include pressure monitoring equipment, installation of a pressure transmitter based on system size, and programming costs.

Exhibit 5-37: Estimated Costs for Online Pressure Monitoring and Programming

System Size	Labor Rate[1]	Labor Time (hours)[2]	Programmer Rate[3]	Program. Time (hours)[4]	Total Labor & Programming Cost[2]	Pressure Transmitter Cost[5]	Total Cost[6,7] (2007$)
A	B	C	D	E	F=B*C*2+D*E	G	H=F+G
< 500	$25.75	16	$120	8	$1,790	$2,740	$4,530
501 - 1,000	$28.96	16	$120	8	$1,890	$2,740	$4,630
1,001 - 4,100	$29.73	16	$120	8	$1,920	$2,740	$4,660
4,101 - 33,000	$36.00	16	$120	8	$2,120	$2,740	$4,860
33,001 - 96,000	$36.39	16	$120	8	$2,130	$2,740	$4,870
96,001 - 500,000	$41.01	16	$120	8	$2,280	$2,740	$5,020
500,001 - 1,000,000	$41.01	16	$120	8	$2,280	$2,740	$5,020
> 1,000,001	$41.01	16	$120	8	$2,280	$2,740	$5,020

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*

[2] Assumes a two-person crew working for a total of two days to install analyzer.

[3] Assumes average programmer rate of $120 per hour (in 2007 dollars), which is independent of system size.

[4] Programming time includes integration of transmitter signals into a SCADA system.

[5] Pressure transmitter cost per vendor.

[6] Estimates rounded up to the nearest $10.

[7] Costs assumes that pressure transmitter will be installed at an existing facility.

5.10 Addition of Security Measures

Systems may need to install security measures in circumstances where the sanitary survey or onsite inspection reveals vandalism or security breaches that could lead to water contamination. Measures that a water system may take to correct security breaches include installing a fence or locking buildings to restrict access to the system. In addition, alarms and cameras may be used to detect security breaches.

Water systems should prioritize their security measures and concentrate on the most vulnerable parts of the system, such as unstaffed facilities (e.g., finished water storage tanks). An important implementation issue is determining the extent to which the water system needs to be secured. This would depend on how widely spread the system/facility is, the number and complexity of the treatment trains, the extent of the watershed, the distance of the treatment plant from the influent wells, accessibility of the distribution system, etc. Possible security measures include locked fence enclosures and employing a full time, on-site security staff.

Installing security measures can increase the public's confidence in the protection of their drinking water and indeed can provide substantial protection against vandalism that might result in contamination of the water. However, security measures are not always foolproof or absolute in combating vandalism or security breaches.

Exhibit 5-38 presents the cost components for installing fencing, gates, and security lighting for 0.5 and 1-acre lots. A site size of 0.5-acres was assumed for systems serving populations of 10,000 or fewer, and a 1-acre site size was assumed for systems serving populations greater than 10,000. Costs include materials, installation and overhead and profit.

Exhibit 5-38: Estimated Costs for Installation of Security Measures

System Size	Fence Cost[1,2,5]	Gate Cost[3,5]	Lighting Cost[4,5]	Security Capital Cost	Installation Cost[6]	Total Cost (2007$)[7,8]
A	B	C	D	E=B+C+D	F=0.3*E	G=(E+F)*1.225
< 500	$8,400	$795	$880	$10,075	$3,023	$13,100
501 - 1,000	$8,400	$795	$880	$10,075	$3,023	$13,100
1,001 - 4,100	$8,400	$795	$880	$10,075	$3,023	$13,100
4,101 - 33,000	$11,900	$795	$880	$13,575	$4,073	$17,650
33,001 - 96,000	$11,900	$795	$880	$13,575	$4,073	$17,650
96,001 - 500,000	$11,900	$795	$880	$13,575	$4,073	$17,650
500,001-1,000,000	$11,900	$795	$880	$13,575	$4,073	$17,650
> 1,000,001	$11,900	$795	$880	$13,575	$4,073	$17,650

[1] Fence cost assumed a 0.5 acre site (600 linear feet) for systems less than 10,000 and a 1.0 acre site (850 linear feet) for systems greater than 10,000.

[2] Fence cost assumed to be industrial chain link, three strands barbed wire, 2 inch posts, set in concrete, 6 feet high, with 9 ga. wire, galvanized steel.

[3] Gate cost assumed double swing gates, including posts and hardware, 6 feet high, 12 feet opening.

[4] Lighting cost assumed four wall-mounted, 35 watt, low pressure sodium fixtures per site.

[5] Cost obtained from R.S. Means, 2007.

[6] Installation costs assumed to be 30% of security capital cost based on project experience and assuming installation includes electrical work.

[7] Cost rounded up to the nearest $10

[8] Assumes and includes a 22.5% Overhead and Profit cost, from R.S. Means 2009.

5.11 Development and Implementation of an Operations Plan

A water system should develop a distribution system operations plan to integrate all operations and maintenance functions to meet the goals of flow, pressure and water quality. AWWA G200-04 standard describes the critical requirements for the effective operation and management of drinking water distribution systems. According to this standard, a water system should develop standard operating procedures (SOPs), comprehensive monitoring plans, routine inspections, and emergency response plans.

SOPs should be developed for each operation and maintenance function that affects system water quality (e.g. flushing programs, storage facility inspections). The water quality goals for both the distribution system and the particular function should be specified in the SOP. SOPs should be developed from information gathered from the various departments and crews involved in a given function. The SOPs should be written in terms that everybody will understand and they should include all activities needed to conduct the procedures, and describe the labor, equipment and materials needed to complete the activity.

The water system should establish a routine distribution system sampling plan that is representative of the entire distribution system. The sample sites shall include, at a minimum, sites required for regulatory compliance monitoring. Additional sites shall be sampled as necessary to provide a complete picture of the water quality in the system. All samples should be collected in accordance with latest edition of Standard Methods for the Examination of Water and Wastewater.

Routine inspections of various distribution system components such as finished water storage facilities, water mains, pump stations, chemical storage facilities, valves, and fire

hydrants are necessary to ensure high-quality water. The water systems should implement inspection and maintenance programs of these components.

A written emergency response plan for the distribution system allows operating personnel to respond efficiently, effectively and rapidly to an emergency situation. Water quality system safety and reliability are improved if a water system has an emergency response plan. Exhibit 5-39 presents the estimated cost of developing and implementing an operations and maintenance plan. The estimated cost assumes that both technical and managerial staff will be involved in this task.

Exhibit 5-39: Estimated Costs to Develop and Implement an Operations Plan

System Size	Labor Rate[1]	Time (hours)[2]	Total Cost (2007$)[3]
A	B	C	D=B*C
< 500	$25.75	96	$2,480
501 - 1,000	$28.96	144	$4,170
1,001 - 4,100	$29.73	192	$5,710
4,101 - 33,000	$36.00	384	$13,820
33,001 - 96,000	$36.39	384	$13,970
96,001 - 500,000	$41.01	1152	$47,240
500,001-1,000,000	$41.01	1152	$47,240
> 1,000,001	$41.01	1152	$47,240

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*

[2] Time includes hours for both operator and managerial staff.

[3] Cost rounded up to the nearest $10.

5.11.1 Operation and Maintenance Standard Operating Procedure (SOP) Training

EPA established an operator certification program with minimum professional standards for the operation and maintenance of water systems. The EPA program issued guidelines that specify standards for certification and recertification of operators. States implement the minimum standards of the certification program guidelines. While the specific requirements vary from state to state, the goal of the program is to ensure that skilled professionals are overseeing the treatment and distribution of safe drinking water and compliance with the Safe Drinking Water Act.

Implementation of an operator certification and training program provides guidelines for the standards operators must uphold to operate and maintain a treatment facility or system. This is one component necessary for the protection of public health and the maintenance of a safe and reliable PWS. Training sessions for operators reinforce proper operation and maintenance of these facilities and systems. In addition, these sessions can help to educate PWS staff on emerging treatment technologies, regulatory requirements, and other advances in the drinking water industry.

The costs for operator training or certification include travel costs, training/certification fees, and the operator labor costs associated with the time spent at the training or certification session. Increased operator knowledge could potentially decrease the possibility of contamination within the distribution system. Exhibit 5-40 summarizes the cost for operator training and certification.

Exhibit 5-40: Estimated Costs for Operator Training/Certification

System Size	Labor Rate[1]	Course Time (hours)[2]	Total Labor Cost	Travel[3]	Training/ Certification Fees[4]	Total Cost (2007$)[5]
A	B	C	D=B*C	E	F	G=D+E+F
< 500	$25.75	8	$210	$31	$125	$370
501 - 1,000	$28.96	8	$240	$31	$125	$400
1,001 - 4,100	$29.73	8	$240	$31	$125	$400
4,101 - 33,000	$36.00	8	$290	$31	$125	$450
33,001 - 96,000	$36.39	8	$300	$31	$125	$460
96,001 - 500,000	$41.01	8	$330	$31	$125	$490
500,001 - 1,000,000	$41.01	8	$330	$31	$125	$490
> 1,000,001	$41.01	8	$330	$31	$125	$490

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*.

[2] Assumes an eight hour training/certification course

[3] Assumes 60 miles of round-trip driving distance at $0.52/mi.

[4] Assumes a $125 training/certification fee for members according to the National Rural Water Association.

[5] Estimates rounded up to the nearest $10.

5.11.2 Operation and Maintenance Plan Revision

The operations and maintenance programs described earlier in this section should be reviewed periodically and modified based on input from all affected groups so they remain accurate, beneficial, and easy to follow. AWWA Standard G200-04 outlines that the modified documents should be approved for adequacy prior to issue and the current revision status of documents should be identified. Following the approval of the modified documents a copy of the updated documents should be made available at the points of use.

Exhibit 5-41 presents the yearly estimated cost of maintaining an operations and maintenance plan. The estimated cost assumes that both technical and managerial staff will be involved in this task.

Exhibit 5-41: Estimated Costs to Maintain an Operations Plan

System Size	Labor Rate[1]	Time (hours)[2]	Total Cost (2007$)[3]
A	B	C	E=B*C
< 500	$25.75	14	$370
501 - 1,000	$28.96	29	$830
1,001 - 4,100	$29.73	29	$860
4,101 - 33,000	$36.00	48	$1,730
33,001 - 96,000	$36.39	48	$1,750
96,001 - 500,000	$41.01	48	$1,970
500,001-1,000,000	$41.01	96	$3,940
> 1,000,001	$41.01	96	$3,940

[1] See Exhibit 2-6 in Chapter 2. *Estimated Unit Costs of Labor*
[2] Assumes both technical and managerial time[3] Cost rounded up to the nearest $10
[3] Estimates rounded up to the nearest $10.

References

The references included in this section contain additional information for readers who wish to pursue in greater detail, the specific topics discussed in this document. Many of these references (especially the EPA references) are freely available on the internet. The references are listed alphabetically, based on the last name of the first author(s). In cases where there are two or more works by the same author (e.g. AWWA, AwwaRF, and EPA), the entries are listed by the year, with the most recent document listed first. The reverse chronological order makes it easy for the reader to look up the most recent publication first.

American Water Works Association (AWWA). 2001 Utility Compensation Survey. AWWA. October 2001.

American Water Works Association, 2004. AWWA G200 – AWWA Standard for *Distributions Systems Operation and Management*. Denver, CO: AWWA

Association of State Drinking Water Administrators (ASDWA). 2001. Drinking water program resource needs assessment. Version 9. November 27, 2001.

Brandt, M. J., Clement, J., Powell, J., Casey, R., Holt, D., Harris, N., and Ta, C.T. 2004. Managing Distribution System Retention Time to Improve Water Quality Denver, CO: AWWARF

Bureau of Labor Statistics, U.S. Department of Labor, Employment Cost Index, [www.bls.gov/news.release/eci.toc.htm].

Bureau of Labor Statistics, U.S. Department of Labor, National Compensation Survey, [www.bls.gov/ncs/].

Bureau of Labor Statistics, U.S. Department of Labor, Occupational Employment Statistics, [www.bls.gov/oes/].

Clesceri, Lenore & Greenberg, Arnold & Eaton, Andrew. Standard Methods for the Examination of Water and Wastewater, 20th Edition. Washington, DC: American Public Health Association, American Waterworks Association, Water Environment Federation; 1998: Pages 9-47 – 9-78.

Davis, G., Moraca, T. and O'Connell, S, 2008. *Get a Grip on Fluctuating Pressures and Flows*. Opflow Magazine. Denver, CO:AWWA

Hasit, Y.J. 2004. *Cost and Benefit Analysis on Flushing*. Denver, Co: AWWARF

Kirmeyer, G.J and Friedman M. 2000. *Guidance Manual for Maintaining Distribution System Water Quality*. Denver, CO: AWWARF and AWWA

Means, R.S. 2009 Building Construction Cost Data. 62nd Annual Edition. Kingston, MA Construction Publishers and Consultants

R.S. Means. 1998 Mechanical Cost Data. R.S. Means Company, Inc. Kingston, MA.

U.S. Bureau of the Census, Economic Census. Census Bureau. 1997. Available: http://www.census.gov/epcd/www/econ97.html [3 Mar 2006].

U.S. Environmental Protection Agency. 2007. Total Coliform Rule Issue Paper: *Distribution System Inventory, Integrity, and Water Quality*.

U.S. Environmental Protection Agency. 2006 *Technology and Cost Document for the Final Ground Water Rule*. EPA 815-R-06-014

U.S. Environmental Protection Agency. 2007. *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules* EPA 815-R-07-017

USEPA, Safe Drinking Water Act (SDWA). USEPA. Available: http://www.epa.gov/safewater/sdwa/ [17 Mar 2009].

USEPA, Safe Drinking Water Information System (SDWIS). USEPA. Available: http://www.epa.gov/enviro/html/sdwis/ [1 Feb 2008].

USEPA. 2009. Total Coliform Rule / Distribution Systems Advisory Committee Agreement in Principle. 74 FR 1683. January 13, 2009.

USEPA. 2007. Meeting of the Total Coliform Rule Distribution System Advisory Committee--Notice of Public Meeting. 72 FR 35870, June 29, 2007.

USEPA. 2006. National Primary Drinking Water Regulations: Stage 2 Disinfectants and Disinfection Byproducts Rule. 71 FR 388. January 4, 2006.

USEPA. 2006. Economic Analysis for the Final Ground Water Rule. October, 2006. EPA-815-R-06-014.

USEPA. 2006. National Primary Drinking Water Regulations: Ground Water Rule. 71 FR 65574. November 8, 2006.

USEPA. 2003. National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule. 68 FR 47739. August 11, 2003.

USEPA. 2003. National Primary Drinking Water Regulations; Announcement of Completion of EPA's Review of Existing Drinking Water Standards. 68 FR 42907, July 18, 2003.

USEPA. 2003. Consideration of Other Regulatory Revisions for Chemical Contaminants in Support of the Six-Year Review of National Primary Drinking Water Regulations. June, 2003. EPA 815-R-03-005.

USEPA. 2003. The Safe Drinking Water Information System - Federal Version (SDWIS/FED) data (4th quarter freeze year 2003 data).

USEPA. 2003. Labor Costs for National Drinking Water Rules.

USEPA. 2002. 2000 Community Water System (CWS) Survey. December, 2002. EPA 815-R-02-005A.

USEPA. 1989. National Primary Drinking Water Regulations; Total Coliforms (Including Fecal Coliforms and E. Coli); Final Rule. 54 FR 27544. June, 29, 1989.

U.S. General Services Administration (GSA). GSA. Available: http://www.gsa.gov/Portal/gsa/ep/contentView.do?programId=15580&channelId=-24651&ooid=10359&contentId=9646&pageTypeId=17113&contentType=GSA_BASIC&programPage=%2Fep%2Fprogram%2FgsaBasic.jsp&P=MTT [10 Feb 2009].

Appendix A

Exhibit A-1.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by NCWSs serving <= 1,000

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	1	1	100%	1.75	1.75
System Specific Element	100%	1	1	100%	0.5	0.5
Sample Analytical Element	0%	0	0	0%	0	0
Sample Methodology Element	0%	0	0	0%	0	0
Event Situational Element	0%	0	0	0%	0	0
Operational Data Element	0%	0	0	0%	0	0
Historical Trend Element	0%	0	0	0%	0	0
Sample Tap Element	0%	0	0	0%	0	0
Sample Site Element	0%	0	0	0%	0	0
Sample Area Element	0%	0	0	0%	0	0
Third Party Consulting Element	0%	0	0	0%	0	0
Report Element	100%	2	2	100%	4	4
Total			4			6.25

Exhibit A-1.2: RTCR Labor Burden Estimate for Assessments done by NCWSs serving <= 1,000

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	0	0	100%	0.5	0.5	100%	2	2
System Specific Element	0%	0	0	100%	0.3	0.3	100%	1	1
Sample Analytical Element	0%	0	0	100%	0	0	100%	1	1
Sample Methodology Element	50%	1	0.5	100%	0.5	0.5	100%	1	1
Event Situational Element	100%	1	1	100%	2	2	100%	2	2
Operational Data Element	60%	0.3	0.18	40%	0.5	0.2	40%	1	0.4
Historical Trend Element	100%	0.5	0.5	100%	0.5	0.5	5%	4	0.2
Sample Tap Element	100%	1	1	100%	1	1	100%	1	1
Sample Site Element	100%	1	1	100%	1	1	100%	1	1
Sample Area Element	100%	1	1	100%	1	1	20%	7	1.4
Third Party Element	0%	0	0	0%	0	0	50%	16	8
Report Element	100%	2	2	100%	2	2	100%	2	2
Total			7.18			9			21

Exhibit A-2.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by NCWSs serving 1,001 - 4,100

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	1	1	100%	1.8	1.8
System Specific Element	100%	1	1	100%	0.5	0.5
Sample Analytical Element	50%	0	0	0%	0	0
Sample Methodology Element	80%	0	0	0%	0	0
Event Situational Element	100%	0	0	0%	0	0
Operational Data Element	100%	0	0	0%	0	0
Historical Trend Element	100%	0	0	0%	0	0
Sample Tap Element	0%	0	0	0%	0	0
Sample Site Element	0%	0	0	0%	0	0
Sample Area Element	0%	0	0	0%	0	0
Third Party Consulting Element	0%	0	0	0%	0	0
Report Element	100%	2	2	100%	3.5	3.5
Total			4			5.8

Exhibit A-2.2: RTCR Labor Burden Estimate for Assessments done by NCWSs serving 1,001 - 4,100

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	0	0	100%	0.5	0.5	100%	2	2
System Specific Element	0%	0	0	100%	0.3	0.3	100%	1	1
Sample Analytical Element	0%	0	0	100%	0	0	100%	1	1
Sample Methodology Element	50%	1	0.5	100%	0.5	0.5	100%	1	1
Event Situational Element	100%	1	1	100%	2	2	100%	2	2
Operational Data Element	60%	0.3	0.18	40%	0.5	0.2	40%	1	0.4
Historical Trend Element	100%	0.5	0.5	100%	0.5	0.5	5%	4	0.2
Sample Tap Element	100%	1	1	100%	1	1	100%	1	1
Sample Site Element	100%	1	1	100%	1	1	100%	1	1
Sample Area Element	100%	2	2	100%	2	2	20%	7	1.4
Third Party Element	0%	0	0	0%	0	0	50%	16	8
Report Element	100%	2	2	100%	2	2	100%	2	2
Total			8.18			10			21

Exhibit A-3.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving <= 100

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	1	1	100%	1.5	1.5
System Specific Element	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0
Sample Methodology Element	80%	2	1.6	80%	2	1.6
Event Situational Element	10%	2	0.2	100%	2	2
Operational Data Element	60%	2	1.2	60%	2	1.2
Historical Trend Element	0%	0	0	10%	1	0.1
Sample Tap Element	80%	1	0.8	100%	1	1
Sample Site Element	5%	2	0.1	5%	2	0.1
Sample Area Element	0%	0	0	0%	0	0
Third Party Consulting Element			0	0%	0	0
Report Element	100%	5.5	5.5	100%	5.5	5.5
Total			11.4			14

Exhibit A-3.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving <= 100

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	2	2	100%	2	2	100%	2	2
System Specific Element	100%	1	1	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0	0%	0	0
Sample Methodology Element	100%	2	2	100%	2	2	100%	2	2
Event Situational Element	100%	2	2	100%	2	2	100%	2	2
Operational Data Element	60%0	2	1.2	60%	2	1.2	60%	2	1.2
Historical Trend Element	100%	2	2	100%	2	2	100%	2	2
Sample Tap Element	100%	1	1	100%	1	1	100%	1	1
Sample Site Element	5%	2	0.1	5%	2	0.1	100%	1	1
Sample Area Element	100%	2.5	2.5	100%	2.5	2.5	100%	2.5	2.5
Third Party Element						0			0
Report Element	100%	5.5	5.5	100%	8.5	8.5	100%	8.5	8.5
Total			19.3			22.3			23.2

Exhibit A-4.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 101 -500

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	1	1	100%	1.5	1.5
System Specific Element	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0
Sample Methodology Element	80%	2	1.6	80%	2	1.6
Event Situational Element	10%	2	0.2	100%	2	2
Operational Data Element	60%	2	1.2	60%	2	1.2
Historical Trend Element	0%	0	0	10%	1	0.1
Sample Tap Element	80%	1	0.8	100%	1	1
Sample Site Element	5%	2	0.1	5%	2	0.1
Sample Area Element	0%	0	0	5%	2	0.1
Third Party Consulting Element			0	0%	0	0
Report Element	100%	5.5	5.5	100%	5.5	5.5
Total			11.4			14.1

Exhibit A-4.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving 101 - 500

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	2	2	100%	2	2	100%	2	2
System Specific Element	100%	1	1	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0	0%	0	0
Sample Methodology Element	100%	2	2	100%	2	2	100%	2	2
Event Situational Element	100%	2	2	100%	2	2	100%	2	2
Operational Data Element	60%0	2	1.2	60%	2	1.2	60%	2	1.2
Historical Trend Element	100%	2	2	100%	2	2	100%	2	2
Sample Tap Element	100%	1	1	100%	1	1	100%	1	1
Sample Site Element	5%	2	0.1	5%	2	0.1	100%	1	1
Sample Area Element	100%	2.5	2.5	100%	2.5	2.5	100%	2.5	2.5
Third Party Element						0			0
Report Element	100%	5.5	5.5	100%	8.5	8.5	100%	8.5	8.5
Total			19.3			22.3			23.2

Exhibit A-5.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 501 - 1,000

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	2.5	2.5	100%	2.5	2.5
System Specific Element	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0
Sample Methodology Element	80%	2	1.6	80%	2	1.6
Event Situational Element	10%	2	0.2	100%	2	2
Operational Data Element	60%	2	1.2	60%	2	1.2
Historical Trend Element	0%	0	0	10%	1	0.1
Sample Tap Element	80%	1	0.8	100%	1	1
Sample Site Element	5%	2	0.1	5%	1	0.05
Sample Area Element	0%	0	0	5%	2	0.1
Third Party Consulting Element			0	0%	0	0
Report Element	100%	5.5	5.5	100%	5.5	5.5
Total			12.9			15.05

Exhibit A-5.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving 501 - 1,000

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	2.5	2.5	100%	2.5	2.5	100%	2.5	2.5
System Specific Element	100%	1	1	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0	0%	0	0
Sample Methodology Element	100%	2	2	100%	2	2	100%	2	2
Event Situational Element	100%	2	2	100%	2.5	2.5	100%	2	2
Operational Data Element	60%0	2	1.2	60%	2	1.2	60%	2	1.2
Historical Trend Element	100%	2	2	100%	2	2	100%	2	2
Sample Tap Element	100%	1	1	100%	1	1	100%	1	1
Sample Site Element	5%	2	0.1	5%	2	0.1	100%	1	1
Sample Area Element	100%	2.5	2.5	100%	2.5	2.5	100%	2.5	2.5
Third Party Element						0			0
Report Element	100%	5.5	5.5	100%	8.5	8.5	100%	8.5	8.5
Total			19.8			23.3			23.7

Exhibit A-6.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 1,001 - 4,100

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	3	3	100%	3	3
System Specific Element	100%	1	1	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0
Sample Methodology Element	80%	3	2.4	80%	3	2.4
Event Situational Element	10%	5.5	0.55	100%	5.5	5.5
Operational Data Element	60%	4	2.4	60%	4	2.4
Historical Trend Element	100%	3	3	100%	3	3
Sample Tap Element	80%	1.5	1.2	100%	2	2
Sample Site Element	5%	2	0.1	100%	2	2
Sample Area Element	30%	4	1.2	5%	3	0.15
Third Party Consulting Element			0	0%	0	0
Report Element	100%	7.5	7.5	100%	7.5	7.5
Total			22.35			28.95

Exhibit A-6.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving 1,001 - 4,100

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	2.5	2.5	100%	3	3	100%	3	3
System Specific Element	100%	1	1	100%	2.5	2.5	100%	1	1
Sample Analytical Element	0%	0	0	0%	0	0	0%	0	0
Sample Methodology Element	100%	2	2	100%	2	2	100%	2	2
Event Situational Element	100%	5.5	5.5	100%	2.5	2.5	100%	5.5	5.5
Operational Data Element	60%0	4	2.4	60%	4	2.4	60%	4	2.4
Historical Trend Element	100%	3	3	100%	3	3	100%	3	3
Sample Tap Element	100%	2	2	100%	2	2	100%	2	2
Sample Site Element	5%	2	0.1	5%	2	0.1	100%	1.5	1.5
Sample Area Element	100%	5	5	100%	7.5	7.5	100%	7.5	7.5
Third Party Element						0			0
Report Element	100%	7.5	7.5	100%	20.5	20.5	100%	20.5	20.5
Total			31			45.5			48.4

Exhibit A-7.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 4,001 - 33,000

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	3	3	100%	3	3
System Specific Element	100%	1.5	1.5	100%	1.5	1.5
Sample Analytical Element	0%	0	0	0%	0	0
Sample Methodology Element	80%	3	2.4	80%	3	2.4
Event Situational Element	10%	5.5	0.55	100%	5.5	5.5
Operational Data Element	75%	4	3	75%	4	3
Historical Trend Element	100%	9	9	100%	9	9
Sample Tap Element	100%	1.5	1.5	100%	2	2
Sample Site Element	5%	2	0.1	100%	2	2
Sample Area Element	30%	4	1.2	5%	3	0.15
Third Party Consulting Element			0	0%	0	0
Report Element	100%	7.5	7.5	100%	7.5	7.5
Total			29.75			36.05

Exhibit A-7.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving 4,100 - 33,000

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	3	3	100%	3	3	100%	3	3
System Specific Element	100%	1.5	1.5	100%	1.5	1.5	100%	1.5	1.5
Sample Analytical Element	0%	0	0	0%	0	0	0%	0	0
Sample Methodology Element	100%	3	3	100%	3	3	100%	3	3
Event Situational Element	100%	5.5	5.5	100%	7	7	100%	7	7
Operational Data Element	75%	4	3	75%	4	3	75%	4	3
Historical Trend Element	100%	9	9	100%	9	9	100%	9	9
Sample Tap Element	100%	2	2	100%	2	2	100%	2	2
Sample Site Element	5%	2	0.1	5%	2	0.1	100%	2	2
Sample Area Element	100%	5.5	5.5	100%	7	7	100%	7.5	7.5
Third Party Element				10%	109	10.9	10%	109	10.9
Report Element	100%	8.5	8.5	100%	22	22	100%	22	22
Total			41.1			68.5			70.9

Exhibit A-8.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving 33,001 - 96,000

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	6	6	100%	6	6
System Specific Element	100%	1.5	1.5	100%	1.5	1.5
Sample Analytical Element	50%	4	2	50%	4	2
Sample Methodology Element	90%	4	3.6	90%	4	3.6
Event Situational Element	10%	17	1.7	100%	9.5	9.5
Operational Data Element	90%	14	12.6	90%	14	12.6
Historical Trend Element	100%	11	11	100%	16	16
Sample Tap Element	100%	3.5	3.5	100%	3.5	3.5
Sample Site Element	10%	4	0.4	100%	4	4
Sample Area Element	30%	14	4.2	30%	14	4.2
Third Party Consulting Element			0	0%	0	0
Report Element	100%	12.5	12.5	100%	12.5	12.5
Total			59			75.4

Exhibit A-8.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving 33,001 - 96,000

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	6	6	100%	6	6	100%	6	6
System Specific Element	100%	1.5	1.5	100%	3.5	3.5	100%	3.5	3.5
Sample Analytical Element	50%	4	2	50%	4	2	50%	4	2
Sample Methodology Element	100%	4	4	100%	4	4	100%	4	4
Event Situational Element	100%	10	10	100%	10	10	100%	10	10
Operational Data Element	75%	14	10.5	75%	14	10.5	75%	14	10.5
Historical Trend Element	100%	11	11	100%	11	11	100%	16	16
Sample Tap Element	100%	3.5	3.5	100%	5	5	100%	5	5
Sample Site Element	10%	4	0.4	10%	5	0.5	10%	5	0.5
Sample Area Element	100%	7	7	100%	21	21	100%	21	21
Third Party Element	0%	0	0	10%	146	14.6	10%	146	14.6
Report Element	100%	12.5	12.5	100%	28	28	100%	28	28
Total			68.4			116.1			121.1

Exhibit A-8.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving > 96,000
Exhibit A-9.1: Current TCR (as implemented) Labor Burden Estimate for Assessments done by CWSs serving > 96,000

	Nonacute MCL Violation			Acute MCL Violation		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	A	B	C = A * B	D	E	F = D * E
Notification Element	100%	8	8	100%	8	8
System Specific Element	100%	1.5	1.5	100%	1.5	1.5
Sample Analytical Element	90%	6	5.4	90%	6	5.4
Sample Methodology Element	100%	5	5	100%	5	5
Event Situational Element	10%	24	2.4	100%	13	13
Operational Data Element	100%	14.5	14.5	100%	21	21
Historical Trend Element	100%	23.5	23.5	100%	23.5	23.5
Sample Tap Element	100%	9.5	9.5	100%	11.5	11.5
Sample Site Element	10%	10	1	100%	11.5	11.5
Sample Area Element	30%	47.5	14.25	30%	14	4.2
Third Party Consulting Element			0	0%	0	0
Report Element	100%	23	23	100%	12.5	12.5
Total			108.05			117.1

Exhibit A-8.2: RTCR Labor Burden Estimate for Assessments done by CWSs serving > 96,000

	Level 1 Assessment			Level 2 Assessment (nonacute)			Level 2 Assessment (acute)		
	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element	Percentage of Systems doing Element	Estimated Hours Associated with Element	Average Burden Associated with Element
	G	H	I = G * H	J	K	L = J * K	M	N	O = M * N
Notification Element	100%	8	8	100%	8	8	100%	8	8
System Specific Element	100%	1.5	1.5	100%	4	4	100%	4	4
Sample Analytical Element	90%	6	5.4	90%	6	5.4	90%	6	5.4
Sample Methodology Element	100%	5	5	100%	5	5	100%	6	6
Event Situational Element	100%	20	20	100%	20.5	20.5	100%	22	22
Operational Data Element	100%	14.5	14.5	75%	14.5	10.875	100%	21	21
Historical Trend Element	100%	23.5	23.5	100%	23.5	23.5	100%	23.5	23.5
Sample Tap Element	100%	9.5	9.5	100%	18.5	18.5	100%	18.5	18.5
Sample Site Element	10%	10	1	10%	23.5	2.35	10%	23.5	2.35
Sample Area Element	100%	47.5	47.5	100%	78	78	100%	78	78
Third Party Element	0%	0	0	10%	181	18.1	10%	192	19.2
Report Element	100%	23	23	100%	44	44	100%	44	44
Total			158.9			238.225			251.95