Water Resource Efficiency Strategy Report

**FORSCOM Installation Characterization
and Ranking for Water Efficiency
Improvement**

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Preface

The goal of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) is to facilitate energy-efficiency improvements at federal facilities. This is accomplished by a balanced program of technology development, facility assessment, and use of cost-sharing procurement mechanisms. Technology development focuses upon the tools, software, and procedures used to identify and evaluate energy-efficiency technologies and improvements. For facility assessment, FEMP provides metering equipment and trained analysts to federal agencies exhibiting a commitment to improve energy use efficiency. To assist in procurement of energy-efficiency measures, FEMP helps federal agencies devise and implement performance contracting and utility demand-side management strategies.

Pacific Northwest Laboratory (PNL)^(a) supports the FEMP mission of energy systems modernization. Under this charter, the Laboratory and its contractors work with federal facility energy managers to assess and implement energy-efficiency improvements at federal facilities nationwide.

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Executive Summary

In response to the requirements of Executive Order 12902 - *Energy Efficiency and Water Conservation at Federal Facilities*, the U.S. Army Forces Command (FORSCOM) commissioned Pacific Northwest Laboratory (PNL) to perform a study of the water savings potential at each of its major installations. Section 302 of the Executive Order calls for energy and water prioritization surveys of federal facilities. These initial surveys are used to establish priorities for conducting comprehensive facility audits.

This report provides an assessment of the water and sewer savings potential at ten of the major FORSCOM installations. This assessment is a "first pass" estimate of the water savings potential, and will assist FORSCOM in prioritizing its installations for comprehensive water audits. In addition, the end uses (toilets, sinks, showerheads, irrigation, etc.) with the greatest savings potential are identified at each installation.

Table S.1 provides a summary of the study results and includes the current water consumption, sewer flow, costs associated with water, estimated water savings, wastewater treatment savings, and total cost savings. The savings analysis was based on current water and sewer usage and cost data.

The FORSCOM installations can be ranked by water and sewer volume reduction potential (kilogallons) or by cost savings potential. When the FORSCOM installations are ranked by the water and sewer volume reduction potential, the order is as follows:

Fort Hood
Fort Bragg
Fort Lewis
Fort Polk
Fort Sam Houston
Fort Carson
Fort Dix
Fort Stewart
Fort Campbell
Fort Drum

When ranked by cost savings resulting from water, sewer, and energy reductions, the order is as follows:

Fort Dix
Fort Polk
Fort Carson
Fort Sam Houston
Fort Hood
Fort Bragg
Fort Lewis
Fort Drum
Fort Stewart
Fort Campbell

This assessment indicates that FORSCOM should begin to look at specific installations in more detail and identify cost-effective projects that reduce water and sewer costs. Using the cost savings potential as a guide, Fort Dix, Fort Polk, and Fort Carson appear to be the best locations to start. These three installations had a significantly higher cost savings potential than the other seven, primarily due to the high cost of their water and sewer services. Detailed audits of these facilities would identify specific life-cycle, cost-effective projects and facilitate the identification of similar projects at the remaining FORSCOM installations.

Table S.1. Installation Summary

Installation	Current Water Use (KGal)	Potential Ave. Water Savings (KGal)	Potential Overall Water Savings (%)	Current Sewer (KGal)	Potential Ave. Sewer Savings (KGal)	Potential Sewer Savings (%)	Current Total Cost (\$)	Potential Total Cost Savings (\$)	Potential Overall Cost Savings (%)
Fort Bragg	2,211,338	631,413	29	1,784,353	467,691	26	1,968,881	567,948	29
Fort Campbell	1,704,527	197,854	12	1,123,933	197,854	18	1,861,583	340,344	18
Fort Carson	1,035,028	315,718	31	585,794	207,500	35	3,136,978	999,366	32
Fort Dix	702,000	218,682	35	642,132	202,682	32	3,584,421	1,061,396	30
Fort Drum	736,092	177,786	24	596,556	169,786	28	923,987	413,738	45
Fort Hood	2,270,074	684,856	30	1,466,900	496,133	34	1,829,475	580,715	32
Fort Lewis	2,192,404	484,059	22	932,200	271,188	29	1,294,414	485,302	31
Fort Polk	1,830,561	419,792	23	1,251,816	317,054	25	4,007,822	1,056,354	26
Fort Sam Houston	1,241,167	400,029	32	738,494	180,249	24	2,126,670	661,986	31
Fort Stewart	1,134,803	209,029	21	864,102	170,155	20	1,306,261	349,093	27

Contents

Preface	iii
Executive Summary	v
1.0 Introduction	1.1
2.0 Background	2.1
3.0 Technical Approach	3.1
3.1 Literature Review and Basic Research	3.1
3.2 Collect Data from the Selected FORSCOM Installations	3.1
3.3 Develop the Spreadsheet Program	3.3
3.3.1 Real Properties List (RPL) Module	3.3
3.3.2 Facilities Water Use Breakdown Module	3.4
3.3.3 Disaggregated End-Use Module	3.4
3.3.4 Water Resource Opportunity (WRO) Module	3.5
3.3.5 Hot Water Savings Module	3.5
3.3.6 End-Use Savings Module	3.6
3.3.7 Usage and Cost Savings Module	3.6
3.4 Prepare Summary Statements	3.7
4.0 Summary of Results	4.1
5.0 Strategy	5.1
6.0 Recommendations	6.1
7.0 References	7.1

Appendix A - Installation Summaries	A.1
A.1 Table and Figure Descriptions	A.1
A.2 Fort Bragg Army Installation	A.2
A.3 Fort Campbell Army Installation	A.7
A.4 Fort Carson Army Installation	A.11
A.5 Fort Drum Army Installation	A.16
A.6 Fort Hood Army Installation	A.21
A.7 Fort Lewis Army Installation	A.25
A.8 Fort Polk Army Installation	A.30
A.9 Fort Sam Houston Army Installation	A.34
A.10 Fort Stewart Army Installation	A.38
A.11 Fort Dix Army Installation	A.43
Appendix B - Water Use Indexes	B.1
Appendix C - Disaggregated End Use Pie Charts	C.1
Appendix D - Water Resource Opportunities List	D.1
Appendix E - Assumptions	E.1
Appendix F - FORSCOM Water Data Questionnaire	F.1
Appendix G - Bibliography	G.1
Appendix H - Special Issues	H.1

Figures

3.1 Water Usage and Cost Savings Potential Spreadsheet Program Flow Diagram	3.2
4.1 Water and Cost Savings	4.4

Tables

4.1 Installation Summary - Annual Data	4.2
4.2 Water Purchase/Production and Sewer Rate A Cost	4.3
4.3 Unaccounted Water Losses	4.3

1.0 Introduction

On March 11, 1994, President Clinton signed Executive Order 12902 - *Energy Efficiency and Water Conservation at Federal Facilities*. Section 302 of the Executive Order calls for energy and water prioritization surveys of federal facilities to be conducted. The surveys will be used to establish priorities for conducting comprehensive facility audits. In response to the requirements of the Executive Order, the U.S. Army Forces Command (FORSCOM) has tasked Pacific Northwest Laboratory (PNL) to initiate a broad study of the water savings potential at each of its major installations.

This report provides an assessment of the water, sewer, energy (for hot water production and pumping), and associated cost savings potential at ten of the major FORSCOM installations. This assessment is meant to be a "first pass" estimate of the water savings potential, to assist FORSCOM in prioritizing installations for detailed water audits and potential water efficient retrofits. In addition, the end uses (toilets, sinks, showerheads, irrigation, etc.) with the greatest water savings potential are identified at each installation.

This report is organized in the following manner. Following this Introduction, Section 2 provides important background information pertaining to the water analysis. Section 3 describes the methodology employed in the analysis, and Section 4 summarizes the study results. Section 5 prioritizes the installations based on both water/sewer savings and cost associated with water, sewer, and energy savings. Section 6 provides recommendations on where to start detailed water audits, as well as other recommendations. References are listed in Section 7. The appendices provide specific information on the analysis results and methodology, along with a discussion of special issues.

2.0 Background

PNL has significant experience working at FORSCOM installations performing integrated energy assessments using the Facility Energy Decision Screening (FEDS) analysis approach. The FEDS process provides a comprehensive, top-down approach to integrated resource (energy) planning and acquisition. This approach is being extended to include water and wastewater in the resource assessment. The methodology for that extension is being developed through this activity with FORSCOM.

Information on water and sewer usage was originally requested from 17 FORSCOM installations, as follows:

Fort Bragg
Fort Buchanan
Fort Campbell
Fort Carson
Fort Dix
Fort Drum
Fort Hood
Fort Indiantown Gap
Fort Irwin

Fort Lewis
Fort McPherson
Fort Polk
Fort Riley
Fort Sam Houston
Fort Stewart
Hunter Army Airfield
Yakima Firing Range

Because of time and resource limitations, the top ten water users of these 17 were selected for analysis. All ten responded with sufficient information to complete the analysis. (Fort Irwin was originally chosen as one of the top ten sites, but was unable to supply the needed information due to time and budget constraints.) The ten installations included in this study are:

Fort Bragg
Fort Campbell
Fort Carson
Fort Dix
Fort Drum
Fort Hood

Fort Lewis
Fort Polk
Fort Sam Houston
Fort Stewart

The primary goal of this study is to identify the water savings potential and quantify the associated cost savings at each installation. This information will be used to rank the installations in an order of priority for conducting detailed water audits.

3.0 Technical Approach

The principal objective of this study is to estimate the cost savings potential (associated with water, sewer, and energy savings) achievable through efficiency improvements in the end-use systems at the major FORSCOM installations and to prioritize these installations based on savings potential. This prioritization will give direction for an in-depth study of the installation(s) with the highest savings potential. The technical approach employed by PNL to accomplish this objective consists of the following steps:

- perform a literature review and develop the technical approach
- collect data from the selected FORSCOM installations
- develop a spreadsheet program to perform numerical analysis
- prepare summary statements.

PNL developed a spreadsheet program to accommodate the large volume of data and data processing requirements of the analysis. The spreadsheet program consists of several interlinked modules, as illustrated in Figure 3.1. Details on the spreadsheet program and each step of the technical approach are provided in this section.

3.1 Literature Review and Basic Research

The literature review and research provided information on water conservation techniques and technologies, water audits, and relevant case studies. Contributors and sources of information include: The American Water Works Association (AWWA), the U.S. Army Corps of Engineers' Institute for Water Resources and the Construction Engineering Research Laboratory, the Rocky Mountain Institute (RMI), the City of San Jose Environmental Services Department, the U.S. General Services Administration (GSA), the U.S. Army Center for Public Works (CPW) Department, and the Electric Power Research Institutes' Community Environmental Center (CEC). These sources are listed in Section 7, with a more complete bibliography sorted by category provided in Appendix G.

3.2 Collect Data from the Selected FORSCOM Installations

A questionnaire was developed by PNL and distributed by the FORSCOM Energy Branch to the utility managers at each installation. The analysis team at PNL followed-up the distribution of the questionnaire with telephone interviews. The general information requested included: total monthly

Figure 3.1. Water Usage and Cost Savings Potential Spreadsheet Program Flow Diagram

water and sewer purchased and/or production volume and cost, monthly population data, and information on metered or estimated reimbursable water use. More specific information was also requested such as central heating and cooling plant water-use logs, information on landscape irrigation practices, and water conservation measure penetration rates.

Information on Rate A for water and sewer was also requested from the installations. Rate A, the rate charged to reimbursable government water users, represents all production or purchased water costs to include electrical costs for pumping and all filtration and treatment costs of water and wastewater.

To determine fuel use and fuel cost savings attributable to end uses which consume hot water, a description of hot water fuel sources was also requested. A copy of the complete questionnaire appears in Appendix F - FORSCOM Water Data Questionnaire.

3.3 Develop the Spreadsheet Program

PNL used database and spreadsheet software to perform the analysis. The spreadsheet was formatted to easily handle the data and perform the analysis. The spreadsheet program consists of several modules, as illustrated in Figure 3.1.

The modules are linked so that as data is entered, the resultant computations lead to processed results useful in the subsequent modules. A description of the function and utility of each module of the spreadsheet program follows.

3.3.1 Real Properties List (RPL) Module

The RPL database, which is a component of the Integrated Facilities System Mini/Micro (IFS-M) program, was provided to PNL in electronic form by the US Army CPW. For several years PNL has made extensive use of the RPL database in its integrated energy assessments at FORSCOM installations and other DoD sites. The RPL database contains installation-specific information on building square footage, age, use, capacity, and utility connections (water, sewer, electrical, etc.).

For each FORSCOM installation, the buildings that are listed in the RPL database were categorized into twenty facility types. Each facility type has unique water use characteristics based on end-use equipment and fixtures, hours of operation, and occupancy. The facility types are:

Administration	Lab/Clinic
Barracks	Laundry
Chapels	Plant
Commissary	Pool
Detached Restrooms	Process
Dining	Recreation
Education	Shop
Family Housing	Utility Building
Hospital	Vehicle Wash
Irrigation	Warehouse

As mentioned above, the RPL database provides details for individual buildings in each facility category. PNL performed a screening process to correct or eliminate useless or obviously errant entries in the database (e.g., buildings with a construction date of 1776 are corrected to indicate a vintage of

1976). The remaining "clean" list of buildings is summed to determine the total square footage in each facility type. This summary information is fed into the Facilities Water Use Breakdown module.

3.3.2 Facilities Water Use Breakdown Module

In this module, the aggregate water use for each facility category is determined. Whenever possible, metered data was used to estimate water use in each facility type. When metered data was not available, calculations were performed to estimate water usage. Calculations relied on water use indexes (WUI) identified in the literature. The largest single source of WUI was found in a software program developed for the USCOE Institute for Water Resources by Planning and Management Consultants Ltd., "Installation Water Resources Analysis and Planning System" (IWRAPS), to forecast water consumption at military installations. IWRAPS (1994) used metered data from military installations to develop water use indexes that estimate water consumption in building types on an area basis (e.g., gallons/square foot). These WUIs cross-checked with the other sources found in literature. These WUIs and real property list building areas were used to calculate the facility type water consumption. A complete list of the WUIs used in the analysis can be found in Appendix B - Water Use Indexes.

In addition to calculating facility water use, total metered water supply data and sewer data were analyzed to estimate the percentage of water losses and the percentage of total attributable to landscape irrigation. Estimates of water losses are crosschecked with values found in the literature or with estimates by personnel at the installation. A chart of each installation's annual water supply and sewer data can be found in the corresponding section of Appendix A.

The facility water use at each installation was summed and reconciled to the actual water supply from the installation. Percentages of water use at each facility type were calculated to determine the largest consumers of water for each installation. The end uses for the facilities with the largest water use were analyzed in the disaggregated end-use module.

3.3.3 Disaggregated End-Use Module

Information on typical end-use distributions for many of the facility types was found in the literature. This information was used to disaggregate the end-uses for each of the facility types. These estimates are not based on military facilities because this information was not found in the literature. See Appendix C for a complete set of pie charts illustrating the end-use breakdown for each facility type analyzed.

By disaggregating the water use to the end-use level, water resource opportunities can be identified and directly applied to determine water savings by end-use type. This is accomplished in the end-use savings module discussed the Section 3.3.6.

3.3.4 Water Resource Opportunity (WRO) Module

A list of water efficient technologies and techniques was compiled to determine the water savings potential for each end use. This compilation is referred to as the Water Resource Opportunity (WRO) list. For use in the WRO module, the WRO list is broken down by end use (e.g., toilet, urinal, landscape irrigation) and provides several efficiency opportunities for each end use, including conservation retrofit and replacement options. The savings associated with technologies were identified in case studies and manufacturers' data. Savings estimates for some technologies, such as irrigation and cooling processes, are estimated based on engineering estimates.

The major categories included in the WRO list are plumbing, processes, and irrigation and landscaping. A complete list of the WROs and details on each end-use savings potential can be found in Appendix D.

3.3.5 Hot Water Savings Module

The installation of some water-flow-reducing devices, such as low-flow showerheads, has the additional benefit of savings energy for water heating. The amount of energy savings attributable to these types of measures are calculated in this module.

To determine the energy savings, the amount of hot water used in each end use was calculated by performing a mass-temperature balance on each end use (representative hot water temperatures found in ASHRAE Handbook, HVAC Applications, 1991) (ASHRAE 1991). The following table shows the percentage of cold and hot water for each end use.

End Use	Cold	Hot
Dishwashing	0%	100%
Laundry	25%	75%
Showers	28%	72%
Sinks	35%	65%

Penetration rates of efficient technologies were estimated on a site-by-site basis. A penetration rate represents the percentage of an end use that has been retrofitted by a water-efficient technology. A default penetration rate of 30% was used for showers and sinks if no specific site information was available. For dishwashing and laundry, a 0% penetration rate was used as a default value because the installation contacts identified that these end uses had not been retrofitted or replaced with high-efficiency units.

3.3.6 End-Use Savings Module

Water use for each facility type was determined in the facility water use breakdown module. In the disaggregated end-use module, the water use of specific end uses was estimated. In this module, water savings are calculated for those end uses.

The water savings are determined by applying the WRO percent savings potential to each water end use. Low, high, and average savings are calculated to represent the range of savings that exist with different water-efficient technologies. A complete list of the end-use savings potential can be found in Appendix D - WRO List.

The amount of water savings potential depends on the age of particular building, and whether the fixtures have been retrofitted by water-efficient technologies. To account for these factors, pre-1980 and post-1980 percentages and penetration rates have been applied to the savings calculations. The pre-1980 and post-1980 data reflects changes in federal, state and local building codes requiring more efficient domestic plumbing fixtures. For example, pre-1980 toilets usually use 5 gallons per flush while post-1980 toilets use 3.5 gallons per flush.

The questionnaires mailed to the FORSCOM installations requested information on penetration rates of water-efficient technologies, or water/energy conservation programs that led to the installation of water-conserving devices. The most prominent of these programs is usually for the installation of "low-flow" showerheads. FORSCOM installations have self-help outlets that sell or distribute these and other related devices. If information on penetration rates was not provided or if water conservation programs were never implemented at the installation, a penetration rate of 30% was assumed for sinks and showers. This means that of the pre-1980 and post-1980 buildings, 30% have upgraded their sinks with aerators and low-flow showerheads or flow restrictors. In this analysis, 100% implementation of water efficient technologies was assumed. Although this assumption yields the maximum savings potential at each installation, it provides consistent results for purpose of comparison.

This water savings data is used to calculate associated cost savings, as described in the section below.

3.3.7 Usage and Cost Savings Module

The cost savings associated with reduced water, sewer, and energy use are determined in this module of the spreadsheet.

Cost savings for water and sewer are derived using the price for water established by Rate A, the rate charged to reimbursable government water users. Rate A, given in the unit of \$/Kgal, has two major components: Unit Cost Purchase/Production and Unit Cost Maintenance. Cost of Purchase includes the purchase cost of water (if water service is provided by a municipal water utility or other outside water agency) and any pumping energy/costs for distribution that occur at the installation. Production costs include costs associated with pumping the water from onsite wells or surface waters

and with operating the water filtration and treatment plant(s). It is not uncommon for a FORSCOM installation to both purchase and produce water. The Unit Cost Purchase/Production of Rate A for both water and sewer is used directly to establish cost savings in this analysis. The Cost of Maintenance is not included in this analysis because determining the savings associated with reduced run-time of pumps and subsequent reduction in maintenance requirements would require an in-depth analysis of current maintenance practices, which is beyond the scope of this study.

Energy savings data are imported from the Hot Water Savings module and incorporated into the totals.

It should be noted that saving water can have a savings "domino-effect" as shown in the following example.

Installing an aerator in a sink to reduce excess water flow will reduce:

- pumping power to extract water from wells
- pumping power for distributing the water to the end use
- chemical, filtration, and maintenance costs associated with treating and purifying the water
- energy use associated with hot water production
- pumping power and associated costs to transport the water to the sewage treatment plant
- pumping power, chemical, and maintenance costs associated with sewage treatment
- costs associated with discharging the treated sewer water to a river or stream.

3.4 Prepare Summary Statements

The last step of the technical approach is to prepare summary statements for each installation evaluated. These statements contain a description of the installation's water and sewer sources and costs, a description of the information provided by the installation in response to the questionnaire and telephone inquiries, tables and graphs illustrating water and sewer use and costs, and the total savings potential by end use and facility type. Appendix A includes summary statements for the ten FORSCOM installations analyzed.

4.0 Summary of Results

This section summarizes pertinent information calculated on each installation in the analysis. This summary information is used to develop a strategy for prioritizing the sites based on highest savings potential. Table 4.1 summarizes the following information for each installation: current water consumption, sewer flow, costs associated with water, estimated water savings, wastewater treatment savings, and cost savings. The savings analysis was based on annual water, sewer, and cost figures. Please note, 100% implementation of water efficient technologies was assumed. Although this assumption yields the maximum savings potential at each installation, it provides consistent results for purpose of comparison. The following is a description of each component of Table 4.1.

The Current Water Use is the total annual water consumption of the installation. The Average Water Savings represents the sum of the average savings calculated in the end-use savings module. (see Section 3.3 for details on the calculation). The Percent Overall Water Savings is the average savings divided by the total annual water consumption of the installation.

The Current Sewer column shows the total annual installation treated water in kilogallons. The Average Sewer Savings represents the savings associated with decreasing the sewer flow by reducing water consumption. This figure includes savings for all end uses that contribute to sewer flow. The Percent Sewer Savings column is the average savings divided by the total annual sewer flow of the installation.

The Current Total Cost column shows the total annual cost associated with water (purchased/production), sewer, and energy required to heat water. The Total Cost Savings represents the reduction in cost due to applying the average water savings, average sewer savings, and hot water energy savings. The Percent Overall Cost Savings is the current total cost divided by the total cost savings.

The installation with the greatest water savings potential does not necessarily have the greatest cost savings potential. This disparity is the result of different water rates at each installation. Table 4.2 summarizes the purchase/production Rate A cost for water and sewer for each installation to assist in revealing the differences in savings.

Table 4.3 shows the percentage of unaccounted water losses for each installation. The installations with high unaccounted water losses tend to have low overall water savings. This is due in part because leak detection was not investigated in this project. Leak detection requires an in-depth onsite study to determine location and extent of leakage; therefore, it is beyond the scope of this initial study. (See Appendix G, Special Issues, for more details.)

Installations that have large penetration rates of water efficient technologies may have lower water savings opportunities because the installation has taken steps to conserve water. For example, Fort Campbell has both a high penetration rate of low flush toilets and a high unaccounted water loss percentage; thus the opportunity for savings is greatly reduced.

Table 4.1. Installation Summary - Annual Data

<i>Installation</i>	<i>Current Water Use (KGal)</i>	<i>Potential Ave. Water Savings (KGal)</i>	<i>Potential Overall Water Savings (%)</i>	<i>Current Sewer (KGal)</i>	<i>Potential Ave. Sewer Savings (KGal)</i>	<i>Potential Sewer Savings (%)</i>	<i>Current Total Cost (\$)</i>	<i>Potential Total Cost Savings (\$)</i>	<i>Potential Overall Cost Savings (%)</i>
Fort Bragg	2,211,338	631,413	29	1,784,353	467,691	26	1,968,881	567,948	29
Fort Campbell	1,704,527	197,854	12	1,123,933	197,854	18	1,861,583	340,344	18
Fort Carson	1,035,028	315,718	31	585,794	207,500	35	3,136,978	999,366	32
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Fort Hood	2,270,074	684,856	30	1,466,900	496,133	34	1,829,475	580,715	32
Fort Lewis	2,192,404	484,059	22	932,200	271,188	29	1,294,414	485,302	31
Fort Polk	1,830,561	419,792	23	1,251,816	317,054	25	4,007,822	1,056,354	26
Fort Sam Houston	1,241,167	400,029	32	738,494	180,249	24	2,126,670	661,986	31
Fort Stewart	1,134,803	209,029	21	864,102	170,155	20	1,306,261	349,093	27

Table 4.2. Water Purchase/Production and Sewer Rate A Cost

<u>Installation</u>	<u>Water Purchase/Production Rate A (\$/KGal)</u>	<u>Sewer Purchase/Production Rate A (\$/Kgal)</u>
Fort Bragg	0.3422	0.2118
Fort Campbell	0.4301	0.5407
Fort Carson	1.8180	1.4226
Fort Dix	1.8091	2.5340
Fort Drum	0.3436	1.1249
Fort Hood	0.2700	0.3200
Fort Lewis	0.2322	0.4472
Fort Polk	0.9177	0.9124
Fort Sam Houston	0.3435	1.4188
Fort Stewart	0.144	0.436

Table 4.3. Unaccounted Water Losses

<u>Installation</u>	<u>Unaccounted Water Losses (%)</u>
Fort Bragg	1
Fort Campbell	34
Fort Carson	9
Fort Dix	5
Fort Drum	10
Fort Hood	15
Fort Lewis	33
Fort Polk	24
Fort Sam Houston	15
Fort Stewart	3

Figure 4.1 shows the average annual water savings and associated cost savings for the sites. This graph illustrates the relationship between water and cost savings. For example, an installation with large water savings may not have high cost savings as a result of a low water cost.

Figure 4.1. Water and Cost Savings

5.0 Strategy

So what does this all mean for FORSCOM? The results of this water assessment of FORSCOM installations gives a mixed picture as to the priorities for future work. This first pass gives a quantitative measurement of the water and sewer savings potential in gallons, and the cost savings associated with water, sewer, and energy reduction. Looking at the installations by the conservation potential (water/sewer) results in one rank order, while looking at them strictly based on cost savings results in a different order. What is the right way to look at FORSCOM sites? The answer is really none of the above. A complete life-cycle cost analysis of the water and sewer opportunities needs to be made to determine the magnitude of cost-effective savings at each installation. That is the next step and requires more detailed information on the buildings, occupancy schedules, and water end uses at each site. However, this initial assessment can be used to focus this subsequent analysis on the installations and end uses of greatest potential.

If the FORSCOM installations are ranked by their water plus sewer volume reduction potential (kilogallons), the ranking would be as follows:

- Fort Hood
- Fort Bragg
- Fort Lewis
- Fort Polk
- Fort Sam Houston
- Fort Carson
- Fort Dix
- Fort Stewart
- Fort Campbell
- Fort Drum

Forts Hood and Bragg have the greatest water conservation potential by a wide margin over the remaining sites.

If the FORSCOM installations are ranked by the cost savings resulting from the water, sewer, and energy reductions, the ranking would be as follows:

- Fort Dix
- Fort Polk
- Fort Carson
- Fort Sam Houston
- Fort Hood
- Fort Bragg
- Fort Lewis
- Fort Drum
- Fort Stewart
- Fort Campbell

Similarly, Forts Dix, Polk, and Carson have the greatest cost savings potential by a wide margin over the remaining sites. These three installations also have the highest cost (\$/kilogallon) for water and sewer.

Given that the primary driver for water/sewer reduction should be cost savings, and that EO 12902 has no specific quantitative goals for water reduction at the agency or installation levels, the second priority list is more appropriate for FORSCOM. This list would maximize the cost savings to FORSCOM providing that most of the projects that were identified meet the LCC requirements. Forts Dix, Polk, and Carson have some of the highest water and sewer rates within FORSCOM, and this would increase the likelihood that the projects would be cost-effective.

In addition to the installations with the greatest cost savings potential, this analysis also revealed which end uses have the greatest potential for water reduction. In almost all cases these end uses were toilets and irrigation. Replacing toilets with ultra low flush models will only be cost-effective in locations with relatively high water and sewer rates. Forts Dix, Polk, Carson, Sam Houston, and Drum are installations where the rates may be high enough. Irrigation improvements may take a lot of different forms including timers, moisture detectors, drip systems, xeriscaping, etc. Several of the installations appear to use 25% to 50% of their water for irrigation, and would benefit greatly from some of these improvements. The benefits from a leak detection program were not addressed in this assessment, but based on the significant amount of unaccounted water losses, this should be a part of any water reduction program at FORSCOM installations.

6.0 Recommendations

This assessment indicates that FORSCOM should begin to look at specific installations in more detail and identify cost-effective projects that reduce water and sewer costs. Using the cost savings potential as a guide, Forts Dix, Polk, and Carson appear to be the best locations to start. These installations had a significantly higher cost savings potential than the other seven, primarily due to the high cost of their water and sewer services. Fort Dix, for example, has the highest Rate A water/purchase production component of any of the installations that produce their own water. These installations could serve as models in doing detailed water audits that could then be applied to the other installations. The detailed audits would identify cost-effective projects that could be implemented over several years to make a significant reduction in water and sewer costs.

Other recommendations include:

- Data should be collected on the remaining FORSCOM installations (particularly Fort Irwin) to see if there are other locations that would have similar savings potential to the ten in this initial assessment.
- A leak detection program should be instituted at all FORSCOM installations. Personnel should be trained in leak detection methods (possibly by CERL), and initial surveys should be done to identify major sources of water loss.
- Simple histograms should be developed to indicate if water technologies would be cost-effective at a given location. These histograms would be similar to the ones developed for the Federal Relighting Initiative to quickly assess the life-cycle cost-effectiveness of lighting technologies. The water histograms would vary the cost of water, sewer, and energy for each technology and show how much water would have to be saved in order to be cost-effective.

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Appendix A

Installation Summaries

Appendix A

Installation Summaries

This appendix details the results from analysis performed on each installation. Each installation has four tables and one figure to summarize the results of the analysis. The tables and figures that appear in each installation summary are described below, followed by the installation summaries.

A.1 Table and Figure Descriptions

The first table for each installation (starting with Table A.1 and all other equivalent tables) shows the water and sewer savings (in kilogallons [Kgal]). The first section of the table shows the savings potential of the ten facility types with the largest water consumption. The water consumption of all other facility types represents less than 2% of the total water use and therefore is not included in the table. A low, high, and average savings is given for each category with the corresponding percent savings. These values are totaled in the row labeled "Supply Water Total." This row shows the savings potential (absolute and percent savings) for the sum of the top ten facility types only (it does not include the facility types which were not analyzed). Total sewer flow and savings potential (absolute savings and percent savings) is shown directly below the supply water savings. The water that is unaccounted for or lost in the system is also shown. This value is the difference between the baseline water consumption and the wastewater flow.

At the bottom of this first table (Table A.1 and all other equivalent tables), the overall percent water savings at the installation is shown. It is important to distinguish this value from the percent savings shown above in the top ten facility total. The overall water savings is based on the average total savings (of the facility types that were analyzed) divided by the *total* water use of the installation given in the metered data. There may be a significant drop in savings compared to the savings potential shown for the top ten facilities because the unaccounted water losses may be high.

The second table for each installation (Table A.2 and all other equivalent tables) shows the total cost savings associated with each facility type. A low, high, and average cost savings is given for the top ten facility types, showing both the total dollar savings potential, and the corresponding percent savings. The unit cost of water and sewer is shown that is the purchase/production component of Rate A at the installation. (Rate A is the rate used to charge all DoD customers for water or sewer, which includes all costs associated with supply water and wastewater treatment.)

A summary of cost savings is also given in these tables. This section details the total water supply savings, the total sewer savings, and the total hot water cost savings (the total hot water cost savings is associated with the reduction in energy due to the decrease in hot water usage; see Table A.3 and all other equivalent tables). At the bottom of the table, the overall percent cost savings potential at the installation is shown. This number is based on the total savings divided by the total cost of supply water production, wastewater treatment, and hot water energy costs at the installation.

The third table for each installation (Table A.3 and all other equivalent tables) shows a summary of the energy and cost savings associated with reduction in energy due to decrease in hot water usage. The table details the energy savings and cost of each fuel type associated with hot water production. The table, for some installations, have hot water production broken into residential and non-residential water use. A grand total in the cost savings potential is given at the bottom of the table. The fourth table for each installation (Table A.4 and all other equivalent tables) describes the water savings potential of each end-use given in kilogallons.

The figure given for each installation (Figure A.1 and all other equivalent figures) is a plot of the annual metered water use and sewer flows on a monthly basis.

For more details on the procedure used to calculate water consumption and savings that are shown in the following tables, see the information provided on water use indexes (Appendix B), disaggregated end-use (Appendix C), water resource opportunities (Appendix D), and other general assumptions (Appendix E) used in the calculations.

A.2 Fort Bragg Army Installation

Fort Bragg pumps water from the Little River, which is filtered and treated on-site. The average annual water consumption is 2,200 million gallons. It is estimated that the facility types with the largest water consumption are barracks (25%), irrigation (19%), family housing (16%), dining (8%), shops (7%), and administration (5%). The unaccounted/losses category at the site was estimated at less than 1% of the total annual water consumption, which can be attributed to a very low water loss rate in the distribution system, and/or infiltration of water into the system.

Sewage is treated on-site at Fort Bragg. The average annual volume of wastewater treatment is 1,780 million gallons.

Fort Bragg was one base under study in a US Army Corps of Engineers report for water distribution at Fixed Army Installations (US Army Corps of Engineers 1983). This report was used as a reference when water use was disaggregated into various facility categories. The method used in the report for disaggregating the water use into facility categories, however, is different than the method used in this study. For example, family housing in the CERL report includes irrigation of family housing grounds, but irrigation is treated separately in this study. Thus, the values in the CERL report are not representative of those determined in this study.

Table A.1. Water Savings - Fort Bragg

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	120,738	24,073	54,383	39,228	20%	45%	32%
BARRACKS	543,000	123,192	297,045	210,118	23%	55%	39%
DINING	180,996	27,738	42,181	34,959	15%	23%	19%
EDUCATION	7,711	1,537	3,421	2,479	20%	44%	32%
FAMILY HOUSING	364,000	76,110	195,582	135,846	21%	54%	37%
HOSPITAL	25,575	4,334	11,528	8,230	17%	45%	32%
IRRIGATION	409,304	81,861	245,583	163,722	20%	60%	40%
LAB/CLINIC	10,139	1,335	3,332	2,376	13%	33%	23%
LAUNDRY	27,992	7,558	17,635	12,596	27%	63%	45%
SHOPS	146,404	12,868	29,836	21,858	9%	20%	15%
SUPPLY WATER TOTAL	1,835,859	360,606	900,525	631,413	20%	49%	34%
SEWER TOTAL	1,784,353	278,745	654,943	467,691	16%	37%	26%
				1%			
				29%			

The estimated, average annual savings potential at Fort Bragg is 631 million gallons of water, which is 29% of the overall water consumption of the installation. The associated total cost savings is \$567,948, which is a 29% overall savings (costs associated with supply water, sewer, and hot water energy costs).

The following list details the data that Fort Bragg sent upon request from PNL.

- Completed questionnaire with references.
- Monthly water supply data for October 1991 through July 1994.
- Monthly wastewater treatment data for October 1991 through July 1994.
- Monthly reimbursable customers' metered water consumption and billing data for FY 1991 (family housing only).
- Water and sewer rate data.
- Water Plant records for June 1992 through July 1994.
- Population estimates for FY 1993.

Table A.2. Cost Savings - Fort Bragg

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$8,238	\$18,610	\$13,424	20%	45%	32%
BARRACKS	\$42,156	\$101,649	\$71,902	23%	55%	39%
DINING	\$9,492	\$14,434	\$11,963	15%	23%	19%
EDUCATION	\$526	\$1,171	\$848	20%	44%	32%
FAMILY HOUSING	\$26,045	\$66,928	\$46,487	21%	54%	37%
HOSPITAL	\$1,483	\$3,945	\$2,816	17%	45%	32%
IRRIGATION	\$28,013	\$84,038	\$56,026	20%	60%	40%
LAB/CLINIC	\$457	\$1,140	\$813	13%	33%	23%
LAUNDRY	\$2,586	\$6,035	\$4,310	27%	63%	45%
SHOPS	\$4,403	\$10,210	\$7,480	9%	20%	15%
SUPPLY WATER TOTAL	\$123,399	\$308,160	\$216,070	20%	49%	34%
SEWER TOTAL	\$59,038	\$138,717	\$99,057	16%	37%	26%
Unit Cost Water (Rate A - Purch/Prod) \$/Kgal 0.3422						
Unit Cost Sewer (Rate A - Purch/Prod) \$/Kga 0.2118						
SAVINGS						
Water Supply Cost Savings		\$216,070				
Sewer Cost Savings		\$99,057				
Hot Water Cost Savings		\$252,821				
TOTAL \$ SAVINGS		\$567,948				
OVERALL COST SAVINGS (%) 29%						

Table A.3. Hot Water - Energy and Cost Savings - Fort Bragg

Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
0	\$0	894,943	\$252,821	0	\$0
Grand Total		\$252,821			

Table A.4. End-Use Savings - Fort Bragg

End-use	Savings (Kgal)
Toilets	175,148
Irrigation	163,722
Showers	75,071
Sinks	42,235
Urinals	39,108
Laundry	38,076
Dishwasher	9,487
Vehicle Wash	8,983
Icemaker	5,068

Site-specific assumptions:

- Monthly water consumption is based on an average of data from 1991 to 1994.
- Monthly wastewater treatment is based on an average of data from 1991 to 1994.
- Metered data used to estimate water consumption for family housing building category.
- Baseline use calculated from average of water consumption in winter months (October - April).
- Unaccounted water losses estimated from difference between monthly baseline and sewer figures. Some months show negative loss due to infiltration into sewer system. Ft. Bragg study estimates 5% line losses. (US Army Corps of Engineers 1983)
- Irrigation estimated from difference between total monthly water consumption and monthly baseline figures. Assumed no irrigation in winter months.
- Vehicle washing water use is embedded in shops category, as no metered data were available for vehicle wash facilities.
- Central vehicle wash facility filters and reuses water, so an estimated 80% penetration rate is applied to vehicle wash end-use within the shops facility category.
- Estimated cooling tower make-up water to be the same as Fort Carson, as no site-specific data was available for Fort Bragg, and size and climates of sites are similar.
- 30% of all shower heads have been retrofitted with low flow heads.
- 30% of all sinks have been retrofitted with aerators.

Figure A.1. Fort Bragg Average Monthly Water and Sewer

A.3 Fort Campbell Army Installation

Fort Campbell is supplied with water from an artisan spring. An additional source of water is the Colorado River. The Colorado is used as a backup when the spring is low, which only occurs about twenty days a year. Fort Campbell's annual water consumption is 1,700 million gallons. It is estimated that the facility types with the largest water consumption are family housing (20%), barracks (6%), hospitals (5%), shops (4%), and dining (3%). The unaccounted/losses category is estimated at 34%. Some of this unaccounted water may fall in the irrigation category for individual buildings, but it was provided in the questionnaire that no water for irrigation is used at Fort Campbell. This high percentage may also be attributed to losses in the distribution system or additional cooling loads in warmer months.

The wastewater treatment plant is on-site, with an average of 1,100 million gallons treated annually. The treatment plant uses an ultra-violet process for treatment.

The estimated, average annual savings potential at Ft. Campbell is 198 million gallons of water, which is 12% of the overall water consumption of the installation. The associated total cost savings is \$340,605, which is an 18% overall savings (costs associated with supply water, sewer, and hot water energy costs).

Table A.5. Water Savings - Fort Campbell

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	31,650	6,310	14,858	10,584	20%	47%	33%
BARRACKS	100,263	20,182	48,727	34,455	20%	49%	34%
DINING	58,016	8,891	13,346	11,118	15%	23%	19%
EDUCATION	6,814	1,359	3,364	2,361	20%	49%	35%
FAMILY HOUSING	347,897	71,297	182,745	127,021	20%	53%	37%
HOSPITAL	92,044	15,281	-	-	17%	0%	0%
IRRIGATION	-	-	-	-	0%	0%	0%
LAB/CLINIC	3,823	503	1,323	929	13%	35%	24%
LAUNDRY	-	-	-	-	0%	0%	0%
SHOPS	81,319	7,147	15,623	11,385	9%	19%	14%
SUPPLY WATER TOTAL	721,826	130,971	279,985	197,854	18%	39%	27%
SEWER TOTAL	1,123,933	130,971	279,985	197,854	12%	25%	18%
UNACCOUNTED/LOSSES				34%			
OVERALL WATER SAVINGS (%)				12%			

Table A.6. Cost Savings - Fort Campbell

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$2,714	\$6,390	\$4,552	20%	47%	33%
BARRACKS	\$8,680	\$20,958	\$14,819	20%	49%	34%
DINING	\$3,824	\$5,740	\$4,782	15%	23%	19%
EDUCATION	\$584	\$1,447	\$1,016	20%	49%	35%
FAMILY HOUSING	\$30,665	\$78,599	\$54,632	20%	53%	37%
HOSPITAL	\$6,572	\$0	\$0	17%	0%	0%
IRRIGATION	\$0	\$0	\$0	0%	0%	0%
LAB/CLINIC	\$217	\$569	\$400	13%	35%	24%
LAUNDRY	\$0	\$0	\$0	0%	0%	0%
SHOPS	\$3,074	\$6,719	\$4,897	9%	19%	14%
SUPPLY WATER TOTAL	\$56,331	\$120,422	\$85,097	18%	39%	27%
SEWER TOTAL	\$70,815	\$151,385	\$106,978	12%	25%	18%
Unit Cost Water (Rate A - Purch/Prod) \$/Kgal 0.4301						
Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal 0.54069						
SAVINGS						
Water Supply Cost Savings	\$85,097					
Sewer Cost Savings	\$106,978					
Hot Water Cost Savings	\$148,531					
TOTAL \$ SAVINGS	\$340,605					
OVERALL COST SAVINGS (%) 18%						

Table A.7. Hot Water - Energy and Cost Savings - Fort Campbell

Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
0	\$0	371,327	\$148,531	0	\$0
Grand Total		\$148,531			

Table A.8. End-Use Savings - Fort Campbell

End-use	Savings (Kgal)
Toilets	102,845
Showers	32,067
Laundry	24,353
Sinks	23,316
Urinals	14,349
Vehicle Wash	5,757
Dishwasher	5,060
Icemaker	1,624
Irrigation	0

The following list details the data which Ft. Campbell sent upon request from PNL.

- Completed questionnaire with references.
- Monthly water supply data for October 1991 through July 1994.
- Monthly wastewater treatment data for October 1991 through July 1994.
- Monthly reimbursable customers' metered water consumption and billing data for October 1991 through July 1994.
- Water and sewer rate data.
- Estimate costs of chemicals for treatment of water supply and wastewater treatment.
- Energy study for pump station generators.

Site-specific assumptions:

- Monthly water consumption is based on an average of data from 1991 to 1994.
- Monthly wastewater treatment is based on an average of data from 1991 to 1994.
- Metered data used to estimate water consumption for education and hospital building categories.
- Baseline use is assumed to be the same as total water consumption, as there is no irrigation done at Fort Campbell.

Figure A.2. Fort Campbell Average Monthly Water and Sewer

- Unaccounted/Losses estimated from difference between monthly baseline and monthly sewer figures.
- Water consumption for plant is based on water consumption for boiler plant only (there is no central cooling plant at Fort Campbell). The monthly consumption is based on 2,500 gallons per day per plant of makeup water.
- Vehicle washing water use is embedded in shops category, as no metered data was available for vehicle wash facilities.
- Central vehicle wash facility filters and reuses water, so an estimated 80% penetration rate is applied to vehicle wash end-use within the shops facility category.
- Plant facility category water use includes makeup water for central boiler plant. Used estimated 2500 gallons per day of makeup water from Fort Lewis reference.
- 40% of all shower heads and toilets have been retrofitted with low flow heads in barracks.
- 30% of all shower heads have been retrofitted with low flow heads in building types other than barracks.
- 30% of all sinks have been retrofitted with aerators.

A.4 Fort Carson Army Installation

Fort Carson is supplied with treated water from the City of Colorado Springs. A small portion of water is also pumped from wells on-site. The average annual water consumption is 1,035 million gallons. It is estimated that the facility types with the largest water consumption are irrigation (26%), family housing (26%), barracks (11%), shops (11%), administration (5%), and hospital (4%). The unaccounted/losses category is estimated at 9% of the total annual water consumption, which was determined in a CERL report on water use distribution at Fort Carson. This percentage of water consumption can be attributed to line losses in the distribution system.

Sewage flow is an average of 586 million gallons per year. The treatment plant is located on-site.

Fort Carson was one base under study in a CERL report for water distribution at Fixed Army Installations. This report was used as a reference when water use was disaggregated into various facility categories.

Table A.9. Water Savings - Fort Carson

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	54,049	10,776	25,981	18,379	20%	48%	34%
BARRACKS	111,430	25,280	64,412	44,846	23%	58%	40%
DINING	39,333	6,028	8,883	7,455	15%	23%	19%
EDUCATION	4,910	979	2,304	1,641	20%	47%	33%
FAMILY HOUSING	268,602	56,163	144,373	100,268	21%	54%	37%
HOSPITAL	46,823	7,935	15,687	12,183	17%	34%	26%
IRRIGATION	270,544	54,109	162,327	108,218	20%	60%	40%
LAB/CLINIC	9,907	1,305	3,320	2,354	13%	34%	24%
LAUNDRY	7,324	1,977	4,614	3,296	27%	63%	45%
SHOPS	108,904	9,572	23,830	17,078	9%	22%	16%
SUPPLY WATER TOTAL	921,825	174,124	455,730	315,718	19%	49%	34%
SEWER TOTAL	585,794	120,015	293,404	207,500	20%	50%	35%
UNACCOUNTED/LOSSES					9%		
OVERALL WATER SAVINGS (%)					31%		

The estimated, average annual savings potential at Fort Carson is 316 million gallons of water, which is 31% of the overall water consumption of the installation. The associated total cost savings is \$999,366, which is a 32% overall savings (costs associated with supply water, sewer, and hot water energy costs).

The following list details the data which Ft. Carson sent upon request from PNL.

- Completed questionnaire with references.
- Monthly water supply data for October 1991 through September 1993.
- Monthly wastewater treatment data for October 1991 through September 1993.
- Monthly reimbursable customers' metered water consumption and billing data for October 1991 through April 1994.
- Water and sewer rate data.
- Population estimates for FY 1993.
- Supply pump flow capacities.

Table A.10. Cost Savings - Fort Carson

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$19,592	\$47,233	\$33,412	20%	48%	34%
BARRACKS	\$45,960	\$117,101	\$81,531	23%	58%	40%
DINING	\$10,959	\$16,149	\$13,554	15%	23%	19%
EDUCATION	\$1,780	\$4,189	\$2,984	20%	47%	33%
FAMILY HOUSING	\$102,104	\$262,471	\$182,288	21%	54%	37%
HOSPITAL	\$14,426	\$28,519	\$22,148	17%	34%	26%
IRRIGATION	\$98,370	\$295,110	\$196,740	20%	60%	40%
LAB/CLINIC	\$2,372	\$6,036	\$4,280	13%	34%	24%
LAUNDRY	\$3,595	\$8,388	\$5,992	27%	63%	45%
SHOPS	\$17,402	\$43,322	\$31,047	9%	22%	16%
SUPPLY WATER TOTAL	\$316,558	\$828,518	\$573,975	19%	49%	34%
SEWER TOTAL	\$170,734	\$417,396	\$295,190	20%	50%	35%
<div>Unit Cost Water (Rate A - Purch/Prod) \$/Kgal1.818</div> <div>Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal1.4226</div>						
SAVINGS						
Water Supply Cost Savings	\$573,975					
Sewer Cost Savings	\$295,190					
Hot Water Cost Savings	\$130,201					
TOTAL \$ SAVINGS	\$999,366					
OVERALL COST SAVINGS (%)			32%			

Table A.11. Hot Water - Energy and Cost Savings - Fort Carson

Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
0	\$0	340,127	\$130,201	0	\$0
Grand Total		\$130,201			

Table A.12. End-Use Savings - Fort Carson

End-use	Savings (Kgal)
Irrigation	108,218
Toilets	94,487
Showers	28,806
Laundry	22,098
Sinks	20,993
Urinals	15,663
Vehicle Wash	7,710
Dishwasher	4,469
Icemaker	1,101

- Graywater data for golf course irrigation.
- Cooling tower makeup water data.

Site-specific assumptions:

- Monthly water consumption is based on an average of data from 1991 to 1993.
- Monthly wastewater treatment is based on an average of data from 1991 to 1993.
- Metered data used to estimate water consumption for family housing, lab/clinic, and hospital building categories.
- Baseline use calculated from average of water consumption in winter months.
- Unaccounted/Losses estimated at 9% of total water consumption from CERL Fort Carson study report.
- Irrigation estimated from difference between total monthly water consumption and monthly baseline figures. Assumed no irrigation in winter months.
- Vehicle washing water use is embedded in shops category, as no metered data was available for vehicle wash facilities.
- Central vehicle wash facility filters and reuses water, so an estimated 80% penetration rate is applied to vehicle wash end-use within the shops facility category.

Figure A.3. Fort Carson Average Monthly Water and Sewer

- Estimated plant building category use for cooling tower makeup water. Literature reference states that 3 gpm/100 tons cooling is used for makeup water. Estimated Fort Carson uses 1200 tons of cooling in winter months and 2400 tons of cooling in summer months. Makeup water for boiler plant is negligible in comparison to cooling tower makeup water.
- 30% of all shower heads have been retrofitted with low flow heads.
- 30% of all sinks have been retrofitted with aerators.

A.5 Fort Drum Army Installation

Fort Drum, located in upstate New York, purchases water and sewer services and also produces its own water with a system of 11 wells located in the area around the intersection of the New Post, Old Post, and new airfield. The aggregate capacity of the well pumps is 2,000 gpm. The aggregate connected load of the pump motors is about 100 kW. Water is pumped to the Old Post water tower where a portion is diverted to the New Post water tower, situated a couple of miles to the north.

Table A.13. Water Savings - Fort Drum

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	38,574	7,691	14,496	11,094	20%	38%	29%
BARRACKS	138,468	31,415	67,264	49,339	23%	49%	36%
DINING	26,957	7,150	8,554	7,852	27%	32%	29%
EDUCATION	4,796	956	2,157	1,557	20%	45%	32%
FAMILY HOUSING	300,000	62,728	107,147	84,938	21%	36%	28%
HOSPITAL	6,479	1,249	1,958	1,604	0%	0%	0%
IRRIGATION	20,000	4,000	12,000	8,000	20%	60%	40%
LAB/CLINIC	3,554	468	1,028	763	13%	29%	21%
SHOPS	95,979	8,436	16,178	12,639	9%	17%	13%
SUPPLY WATER TOTAL	634,807	124,093	230,784	177,786	20%	36%	28%
SEWER TOTAL	596,556	120,093	218,784	169,786	20%	37%	28%
UNACCOUNTED/LOSSES				10%			
OVERALL WATER SAVINGS (%)				24%			

Table A.14. Cost Savings - Fort Drum

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$2,643	\$4,981	\$3,812	20%	38%	29%
BARRACKS	\$10,794	\$23,112	\$16,953	23%	49%	36%
DINING	\$2,457	\$2,939	\$2,698	27%	32%	29%
EDUCATION	\$329	\$741	\$535	20%	45%	32%
FAMILY HOUSING	\$21,553	\$36,816	\$29,185	21%	36%	28%
HOSPITAL	\$429	\$673	\$551	0%	0%	0%
IRRIGATION	\$1,374	\$4,123	\$2,749	20%	60%	40%
LAB/CLINIC	\$161	\$353	\$262	13%	29%	21%
SHOPS	\$2,899	\$5,559	\$4,343	9%	17%	13%
SUPPLY WATER TOTAL	\$42,638	\$79,297	\$61,087	20%	36%	28%
SEWER TOTAL	\$135,093	\$246,110	\$190,992	25%	46%	36%
Unit Cost Water (Rate A - Purch/Prod) \$/Kgal		0.3436				
Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal		1.1249				
SAVINGS						
Water Supply Cost Savings	\$42,813					
Sewer Cost Savings	\$190,992					
Hot Water Cost Savings	\$179,933					
TOTAL \$ SAVINGS	\$413,738					
OVERALL COST SAVINGS (%)			45%			

Table A.15. Hot Water - Energy and Cost Savings - Fort Drum

Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)	HTHW Savings (MBtu)	HTHW Savings (\$)	Propane Savings (MBtu)	Propane Savings (\$)
133,201	81,252	8,880	43,766	9,563	41,074	2,391	13,841
Grand Total		\$179,933					

Table A.16. End-Use Savings - Fort Drum

End-use	Savings (Kgal)
Toilets	68,677
Showers	21,284
Laundry	21,000
Sinks	20,523
Urinals	11,012
Irrigation	8,000
Vehicle Wash	6,795
Icemaker	3,774
Dishwasher	2,970

In July 1991, delivery of water from a new source, the Development Authority of North County (DANC), commenced. The DANC system includes three 150-hp, 2000-gpm pumps owned by DANC but powered from the Old Post substation. This system is used to feed water into the Old Post water tower. The site is under contract to purchase 550 million gallons of DANC water per year, which corresponds to an average flow rate of 1,050 gpm, or 1.5 million gpd. The contract Fort Drum has with DANC for water is a take-or-pay type agreement. Initially, there was concern on the part of PNL's research team that this type of agreement could nullify cost savings from water conservation efforts. However, Fort Drum still produces approximately 25% of its water from the on-site wells and this volume exceeds the projected savings available at Drum. However, if Fort Drum is considering taking more DANC water in the future and relying less on production from wells, the potential disincentive of the contractual arrangement might be taken into consideration.

The average annual water consumption is 736 million gallons. It is estimated that the facility types with the largest water consumption are family housing (41%), barracks (19%), shops (13%), administration (5%), and dining (4%). The unaccounted/losses category at the site was estimated at 10% from the CERL study of water use at Fixed Army Installations.

Fort Drum's sewage is treated off-post by DANC. The average annual volume of wastewater treatment is 600 million gallons.

The estimated, average annual savings potential at Fort Drum is 177 million gallons of water, which is 24% of the overall water consumption of the installation. However, Fort Drum pumps an average of 125 million gallons annually from its wells. Cost savings may be applied only to the portion of water Fort Drum pumps, as the cost of DANC water is fixed (approximately \$2,862,000 annually). The rate used to calculate water cost savings for Fort Drum is Rate A for production water only. The associated total cost savings is \$413,738, which is a 45% overall savings (costs associated with supply water, sewer, and hot water energy costs).

—○— Water Supply (KGal) —△— Sewer Treatment (KGal)

Figure A.4. Fort Drum Average Monthly Water and Sewer

Calculations were performed to estimate how much savings would be incurred if Fort Drum could decrease the amount of water purchased from DANC, not just the water produced on-site. Using Rate A for purchased water only, these calculations yielded a cost savings of \$550,488, for a 39% overall percentage savings. However, this calculation was based on the assumption that the ratio of cost savings to water savings is linear, which may not actually be the case. As noted above, the actual savings that may be incurred depends on the contractual agreement between Fort Drum and DANC.

Fort Drum uses a telemetering system to track water consumption. The system may be of benefit to a more detailed water management assessment.

The following list details the data which Ft. Drum sent upon request from PNL.

- Completed questionnaire with references.
- Monthly water supply data for June 1991 through April 1994.
- Monthly wastewater treatment data for June 1991 through April 1994.
- Monthly reimbursable customers' metered water consumption and billing data for FY 1991 (family housing only).
- Water and sewer rate data.

Site-specific assumptions:

- Monthly water consumption is based on an average of data from 1991 to 1994.
- Monthly wastewater treatment is based on an average of data from 1991 to 1994.
- Metered data used to estimate water consumption for family housing building category.
- Irrigation was estimated at an average of 10,000 Kgal/month for the summer months of July and August.
- Unaccounted/Losses were estimated at 10% of the total monthly water consumption from a CERL study of water use distribution at Fort Drum.
- Vehicle washing water use is embedded in shops category, as no metered data was available for vehicle wash facilities.
- 30% of all shower heads have been retrofitted with low flow heads.

- 30% of all sinks have been retrofitted with aerators.

The non-maintenance component of Rate A for water and sewer at Fort Drum is \$0.3436/Kgal and \$1.1249 Kgal, respectively. It should be noted that Fort Drum pays a large capital cost to DANC for water and sewer services. However, these costs will not be impacted by water use reductions and therefore are not considered in this analysis.

A.6 Fort Hood Army Installation

Fort Hood is supplied with water by two sources. North Fort Hood's supply is from the City of Gatesville, and South Fort Hood's supply is from Bell County Water Control and Improvement District. The total annual water consumption is 2,270 million gallons. It is estimated that the facility types with the largest water consumption are family housing (32%), irrigation (21%), barracks (12%), shops (11%), administration (5%), and dining (3%). The unaccounted/losses category is an estimated 15% of the total water consumption.

North Fort Hood sewage is treated on-site, while South Fort Hood sewage is treated off-site by the City of Killeen. Sewage flow is estimated at 1,800 million gallons per year for the combined sewage treatment.

The estimated, average annual savings potential at Fort Hood is 685 million gallons of water, which is 30% of the overall water consumption of the installation. The associated total cost savings is \$580,715, which is a 32% overall savings (costs associated with supply water, sewer, and hot water energy costs).

Table A.17. Water Savings - Fort Hood

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	111,014	22,134	51,966	37,050	20%	47%	33%
BARRACKS	265,041	60,130	153,137	106,634	23%	58%	40%
DINING	61,705	9,456	14,278	11,867	15%	23%	19%
EDUCATION	45,532	9,078	21,681	15,379	20%	48%	34%
FAMILY HOUSING	721,234	150,806	382,424	266,615	21%	53%	37%
HOSPITAL	31,181	5,284	14,032	10,021	17%	45%	32%
IRRIGATION	471,807	94,361	283,084	188,723	20%	60%	40%
LAB/CLINIC	9,342	1,230	2,822	2,065	13%	30%	22%
LAUNDRY	26,063	7,037	16,420	11,728	27%	63%	45%
SHOPS	240,884	21,172	46,708	34,773	9%	19%	14%
SUPPLY WATER TOTAL	1,983,803	380,690	986,551	684,856	19%	50%	35%
SEWER TOTAL	1,466,900	286,328	703,467	496,133	20%	48%	34%
UNACCOUNTED/LOSSES				15%			
OVERALL WATER SAVINGS (%)				30%			

Table A.18. Cost Savings - Fort Hood

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$5,976	\$14,031	\$10,004	20%	47%	33%
BARRACKS	\$16,235	\$41,347	\$28,791	23%	58%	40%
DINING	\$2,553	\$3,855	\$3,204	15%	23%	19%
EDUCATION	\$2,451	\$5,854	\$4,152	20%	48%	34%
FAMILY HOUSING	\$40,718	\$103,255	\$71,986	21%	53%	37%
HOSPITAL	\$1,427	\$3,789	\$2,706	17%	45%	32%
IRRIGATION	\$25,478	\$76,433	\$50,955	20%	60%	40%
LAB/CLINIC	\$332	\$762	\$558	13%	30%	22%
LAUNDRY	\$1,900	\$4,433	\$3,167	27%	63%	45%
SHOPS	\$5,716	\$12,611	\$9,389	9%	19%	14%
SUPPLY WATER TOTAL	\$102,786	\$266,369	\$184,911	19%	50%	35%
SEWER TOTAL	\$91,625	\$225,109	\$158,763	20%	48%	34%
<div> Unit Cost Water (Rate A - Purch/Prod) \$/Kgal 0.27 Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal 0.32 </div>						
SAVINGS						
Water Supply Cost Savings	\$184,911					
Sewer Cost Savings	\$158,763					
Hot Water Cost Savings	\$237,042					
TOTAL \$ SAVINGS	\$580,715					
OVERALL COST SAVINGS (%)			32%			

Table A.19. Hot Water - Energy and Cost Savings - Fort Hood

Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
0	\$0	817,385	\$237,042	0	\$0
Grand Total		\$237,042			

Table A.20. End-Use Savings - Fort Hood

End-use	Savings (Kgal)
Toilets	229,202
Irrigation	188,723
Showers	70,378
Laundry	62,215
Sinks	50,777
Urinals	33,488
Vehicle Wash	17,055
Dishwasher	7,509
Icemaker	1,728

The following list details the data which Ft. Hood sent upon request from PNL.

- Completed questionnaire with references.
- South Fort Hood monthly water supply data for October 1991 through July 1994.
- North Fort Hood monthly water supply data for October 1992 through July 1994.
- South Fort Hood monthly wastewater treatment data for October 1992 through July 1994.
- Water and sewer rate data.
- Monthly reimbursable customers' metered water consumption and billing data for October 1989 through October 1993.
- Population figures for October 1991 through June 1994.
- Main Water Pump Station KWH consumption.

Site-specific assumptions:

- Metered data was used to estimate water consumption for dining, education, and family housing building categories.
- Monthly water consumption is based on average of data from 1992 to 1994.
- North Fort Hood Monthly sewer flow is based on extrapolation of South Fort Hood metered data.

Figure A.5. Fort Hood Average Monthly Water and Sewer

- Baseline use calculated from average of water consumption in winter months (December - March).
- Losses/Unaccounted estimated from difference between monthly baseline and monthly sewer figures.
- Irrigation estimated from difference between monthly total water consumption and monthly baseline figures. No irrigation assumed between the months of December and March.
- Vehicle washing water use is embedded in shops category, as no metered data was available for vehicle wash facilities.
- Four central vehicle wash facilities filter and reuse water, so an estimated 80% penetration rate is applied to vehicle wash end-use within the shops facility category.
- Water consumption for plant is based on water consumption for boiler plant only (there are no cooling towers at Fort Hood). The monthly consumption is based on 2,500 gallons per day per plant of makeup water.
- 30% of all shower heads have been retrofitted with low flow heads.
- 30% of all sinks have been retrofitted with aerators.

A.7 Fort Lewis Army Installation

Fort Lewis Army Installation is supplied with water from one spring and eleven wells. The spring is used virtually year around, and the wells are used based on supply demands. The annual water consumption is 2,200 million gallons. It is estimated that the facility types with the largest water consumption are irrigation (24%), family housing (21%), shops (5%), barracks (5%), and administration (4%).

Ft. Lewis has a wastewater treatment plant on-site. Sewage flow is 930 million gallons per year. The water is initially treated with a chlorination, fluorination, and poly-phosphate process. Ft. Lewis has a wastewater plant on-site with chlorination process to treat the effluent. Ft. Lewis has no unit cost for water. The only costs associated with water are for treatment (purchase of chemicals), pumping, operation and maintenance, and permits.

Unaccounted water losses is estimated to be 33% of the total consumption. Unaccounted water losses is the difference between the baseline water use and the sewer flow. Ft. Lewis informed PNL that the meter at the wastewater treatment facility is faulty, which may cause the sewer flows to appear lower than the actual flow. This may be the cause of the high, unaccounted water losses.

Table A.21. Water Savings - Fort Lewis

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	96,266	19,196	45,880	32,538	20%	48%	34%
BARRACKS	112,547	19,986	48,803	34,394	18%	43%	31%
DINING	42,171	11,186	14,481	12,833	27%	34%	30%
EDUCATION	12,126	2,418	6,003	4,210	20%	50%	35%
FAMILY HOUSING	457,532	83,307	207,696	145,501	18%	45%	32%
HOSPITAL	38,810	6,066	13,276	10,011	16%	34%	26%
IRRIGATION	532,179	106,436	319,307	212,871	20%	60%	40%
LAB/CLINIC	17,964	2,366	6,327	4,422	13%	35%	25%
LAUNDRY	26,139	7,057	16,467	11,762	27%	63%	45%
SHOPS	50,730	10,021	19,468	15,515	20%	38%	31%
SUPPLY WATER TOTAL	1,386,462	268,039	697,708	484,059	19%	50%	35%
SEWER TOTAL	932,200	161,603	378,401	271,188	17%	41%	29%
UNACCOUNTED/LOSSES				33%			
OVERALL WATER SAVINGS (%)				22%			

The estimated, average annual savings potential at Ft. Lewis is 484 million gallons of water, which is 22% of the overall water consumption of the installation. The associated total cost savings is \$485,302, which is a 37% overall savings (costs associated with supply water, sewer, and hot water energy costs).

The following list details the data which Ft. Lewis sent upon request from PNL.

- Monthly water consumption data from January of 1992 to April of 1994.
- Monthly sewer flow data from January of 1992 to April of 1994.
- Monthly rainfall data from January of 1992 to April of 1994.
- Monthly water consumption data from off post customers from January of 1992 to April of 1994.
- Population data from 1989 to 1994.
- Estimate costs of chemicals for supply and wastewater treatment.
- Supply pump flow capacities.

Table A.22. Cost Savings - Fort Lewis

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$4,457	\$10,653	\$7,555	20%	48%	34%
BARRACKS	\$4,641	\$11,332	\$7,986	18%	43%	31%
DINING	\$2,597	\$3,362	\$2,980	27%	34%	30%
EDUCATION	\$561	\$1,394	\$978	20%	50%	35%
FAMILY HOUSING	\$19,344	\$48,227	\$33,785	18%	45%	32%
HOSPITAL	\$1,409	\$3,083	\$2,325	16%	34%	26%
IRRIGATION	\$24,714	\$74,143	\$49,429	20%	60%	40%
LAB/CLINIC	\$549	\$1,469	\$1,027	13%	35%	25%
LAUNDRY	\$1,639	\$3,824	\$2,731	27%	63%	45%
SHOPS	\$2,327	\$4,520	\$3,603	20%	38%	31%
SUPPLY WATER TOTAL	\$62,239	\$162,008	\$112,399	19%	50%	35%
SEWER TOTAL	\$72,269	\$169,221	\$121,275	17%	41%	29%
Unit Cost Water (Rate A - Purch/Prod) \$/Kgal		0.2322				
Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal		0.4472				
SAVINGS						
Water Supply Cost Savings	\$112,399					
Sewer Cost Savings	\$121,275					
Hot Water Cost Savings	\$251,628					
TOTAL \$ SAVINGS	\$485,302					
OVERALL COST SAVINGS (%)			37%			

Table A.23. Hot Water - Energy and Cost Savings - Fort Lewis

AREA	Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
Non Residential	594,995	\$14,577	101,512	\$29,439	8,121	\$56,847
Residential	3,963,599	\$97,108	110,656	\$53,657	0	\$0
TOTAL		\$111,686		\$83,095		\$56,847
Grand Total			\$251,628			

Table A.24. End-Use Savings - Fort Lewis

End-use	Savings (Kgal)
Irrigation	212,871
Toilets	101,341
Laundry	35,151
Sinks	25,875
Urinals	7,687
Icemaker	5,904
Showers	2,996
Dishwasher	2,745

Site-specific assumptions:

- 95% of all shower heads have been retrofitted with low flow heads (information was provided by Ft. Lewis).
- 30% penetration rate for aerators was assumed.
- Monthly water consumption is based on average of data from 1992 to 1994 (or from 1991 to 1993 when 1994 data was unavailable).
- Monthly sewer flow is based on average of data from 1992 to 1994 (or from 1991 to 1993 when 1994 data was unavailable).
- Vehicle washing water consumption is based on numbers of washed vehicles and 450 gallons of water per vehicle (based on 30 gpm flow rate, 15 minute wash time).
- Number of vehicles for Ft. Lewis was found in CERL report, *Analysis of Usage Data for Central Vehicle Wash Facilities at Three Army Installations*, where the number of washed vehicles at Ft. Lewis were collected during 1986-1987.
- Water consumption for Plant category is based on water consumption for central heating plant only (there is no central cooling at Ft. Lewis). The monthly consumption is based on 2,500 gallons per day per plant of makeup water.

Figure A.6. Fort Lewis Average Monthly Water and Sewer

A.8 Fort Polk Army Installation

Fort Polk is supplied with water from wells on-site. UDS Management Corporation supplies water to the Toledo Bend Recreation Site, located off-post. For this study, the recreation site was not accounted for as part of the total water usage, as it attributed minimally to the total consumption. The annual water consumption is 1,800 million gallons. It is estimated that the facility types with the largest water consumption are family housing (35%), irrigation (14%), barracks (8%), shops (6%), and administration (3%). The unaccounted/losses category is an estimated 25% of the total water consumption.

Sewage treatment for Fort Polk is on-site; one plant is located on the North Fort and another located on the South Fort. Sewage flow is 1,250 million gallons per year.

The estimated, average annual savings potential at Fort Polk is 587 million gallons of water, which is 23% of the overall water consumption of the installation. The associated total cost savings is \$1,056,354, which is a 26% overall savings (costs associated with supply water, sewer, and hot water energy costs).

Table A.25. Water Savings - Fort Polk

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	51,614	10,291	22,473	16,382	20%	44%	32%
BARRACKS	141,896	32,192	77,310	54,751	23%	54%	39%
DINING	28,972	4,440	6,596	5,518	15%	23%	19%
EDUCATION	6,937	1,383	2,853	2,118	20%	41%	31%
FAMILY HOUSING	628,879	131,495	281,212	206,353	21%	45%	33%
HOSPITAL	22,508	3,814	6,529	5,319	17%	29%	24%
IRRIGATION	256,843	51,369	154,106	102,737	20%	60%	40%
LAB/CLINIC	4,702	619	1,326	992	13%	28%	21%
LAUNDRY	24,103	6,508	15,185	10,846	27%	63%	45%
SHOPS	103,884	9,131	19,698	14,774	9%	19%	14%
SUPPLY WATER TOTAL	1,270,337	251,241	587,288	419,792	20%	46%	33%
SEWER TOTAL	1,251,816	199,873	433,182	317,054	16%	35%	25%
UNACCOUNTED/LOSSES				24%			
OVERALL WATER SAVINGS (%)				23%			

Table A.26. Cost Savings - Fort Polk

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$9,444	\$20,624	\$15,034	20%	44%	32%
BARRACKS	\$29,543	\$70,948	\$50,245	23%	54%	39%
DINING	\$4,075	\$6,053	\$5,064	15%	23%	19%
EDUCATION	\$1,269	\$2,618	\$1,944	20%	41%	31%
FAMILY HOUSING	\$120,673	\$258,069	\$189,371	21%	45%	33%
HOSPITAL	\$3,500	\$5,991	\$4,882	17%	29%	24%
IRRIGATION	\$47,141	\$141,423	\$94,282	20%	60%	40%
LAB/CLINIC	\$568	\$1,217	\$911	13%	28%	21%
LAUNDRY	\$5,972	\$13,935	\$9,954	27%	63%	45%
SHOPS	\$8,379	\$18,077	\$13,558	9%	19%	14%
SUPPLY WATER TOTAL	\$230,565	\$538,956	\$385,244	20%	46%	33%
SEWER TOTAL	\$182,373	\$395,256	\$289,295	15%	32%	23%
Unit Cost Water (Rate A - Purch/Prod) \$/Kgal 0.917703						
Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal 0.912447						
SAVINGS						
Water Supply Cost Savings	\$385,244					
Sewer Cost Savings	\$289,295					
Hot Water Cost Savings	\$381,814					
TOTAL \$ SAVINGS	\$1,056,354					
OVERALL COST SAVINGS (%) 26%						

Table A.27. Hot Water - Energy and Cost Savings - Fort Polk

Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
3,516,927	\$219,808	480,018	\$162,006	0	\$0
Grand Total		\$381,814			

Table A.28. End-Use Savings - Fort Polk

End-use	Savings (Kgal)
Toilets	141,278
Irrigation	102,737
Laundry	54,868
Showers	42,485
Vehicle Wash	36,775
Sinks	35,569
Urinals	14,201
Dishwasher	5,509
Icemaker	811

The following list details the data which Ft. Polk sent upon request from PNL.

- Completed questionnaire and references.
- Monthly water supply data for October 1989 through September 1990.
- Monthly wastewater treatment data for October 1989 through September 1990.
- Monthly reimbursable customers' metered water consumption and billing data for family housing from July 1991 through July 1994.
- Population estimates for 1989 through 1994.

Site-specific assumptions:

- Monthly water consumption is based on average of data from 1989 to 1990.
- Monthly sewer flow is based on average of data from 1989 to 1990.
- Monthly family housing water consumption is based on average of metered data from July 1991 to July 1994.
- Baseline use calculated from average of water consumption in winter months (September - April).
- Unaccounted/Losses estimated from difference between monthly baseline and monthly sewer figures.
- Vehicle washing water use is embedded in shops category, as no metered data was available for vehicle wash facilities.

Figure A.7. Fort Polk Average Monthly Water and Sewer

- Family housing irrigation calculated from difference between winter baseline from total family housing water consumption figures.
- Estimated cooling load water use to be the same as Fort Carson, as no site-specific data was available for Fort Polk, and size and climates of sites are similar.
- 30% of all shower heads have been retrofitted with low flow heads.
- 30% of all sinks have been retrofitted with aerators.

A.9 Fort Sam Houston Army Installation

Water is supplied to three main areas at Fort Sam Houston: the main base, Camp Bullis, and Canyon Lake. Ft. Sam Houston is supplied with water from five wells, Camp Bullis is supplied water from 2 well, and Canyon Lake receives water from one well. The total annual water consumption of these three areas is 1,240 million gallons. It is estimated that the top five facility types with the largest water consumptions are irrigation (44%), family housing (16%), barracks (8%), administration (4%), and hospital (3%).

Table A.29. Water Savings - Fort Sam Houston

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	48,530	9,677	23,529	16,603	20%	48%	34%
BARRACKS	99,851	22,653	55,540	39,097	23%	56%	39%
DINING	22,287	5,912	7,567	6,739	27%	34%	30%
EDUCATION	10,640	2,121	5,049	3,585	20%	47%	34%
FAMILY HOUSING	196,446	41,076	105,590	73,333	21%	54%	37%
HOSPITAL	41,484	7,413	17,269	12,342	18%	42%	30%
IRRIGATION	549,452	109,890	329,671	219,781	20%	60%	40%
LAB/CLINIC	7,790	1,026	2,372	1,699	13%	30%	22%
LAUNDRY	27,726	7,486	17,467	12,477	27%	63%	45%
SHOPS	33,985	7,286	18,194	12,741	21%	54%	37%
SUPPLY WATER TOTAL	1,038,191	214,540	582,247	398,397	21%	56%	38%
SEWER TOTAL	738,494	104,650	252,576	178,616	14%	34%	24%
UNACCOUNTED/LOSSES				15%			
OVERALL WATER SAVINGS (%)				32%			

Table A.30. Cost Savings - Fort Sam Houston

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$3,324	\$8,081	\$5,702	20%	48%	34%
BARRACKS	\$7,780	\$19,075	\$13,428	23%	56%	39%
DINING	\$2,030	\$2,599	\$2,315	27%	34%	30%
EDUCATION	\$729	\$1,734	\$1,231	20%	47%	34%
FAMILY HOUSING	\$14,107	\$36,265	\$25,186	21%	54%	37%
HOSPITAL	\$2,546	\$5,931	\$4,239	18%	42%	30%
IRRIGATION	\$37,742	\$113,226	\$75,484	20%	60%	40%
LAB/CLINIC	\$352	\$815	\$584	13%	30%	22%
LAUNDRY	\$2,571	\$5,999	\$4,285	27%	63%	45%
SHOPS	\$2,502	\$6,249	\$4,376	21%	54%	37%
SUPPLY WATER TOTAL	\$73,684	\$199,973	\$136,829	21%	56%	38%
SEWER TOTAL	\$148,477	\$358,354	\$253,420	14%	34%	24%
<div> Unit Cost Water (Rate A - Purch/Prod) \$/Kgal <div>0.34345</div> </div> <div> Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal <div>1.4188</div> </div>						
SAVINGS						
Water Supply Cost Savings	\$136,829					
Sewer Cost Savings	\$253,420					
Hot Water Cost Savings	\$263,243					
TOTAL \$ SAVINGS	\$653,492					
OVERALL COST SAVINGS (%)			31%			

Table A.31. Hot Water - Energy and Cost Savings - Fort Sam Houston

Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (MBtu)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
0	\$0	60,396	263,243	0	\$0
Grand Total		\$263,243			

Table A.32. End-Use Savings - Fort Sam Houston

End-use	Savings (Kgal)
Irrigation	219,781
Toilets	75,717
Laundry	44,006
Showers	23,947
Sinks	16,244
Urinals	13,956
Vehicle Wash	12,301
Icemaker	3,120
Dishwasher	1,981

Ft. Sam Houston's wastewater is treated by the San Antonio Sanitary Sewer Plant. This flow is not metered by the city of San Antonio; however, Ft. Sam Houston is billed for 59.9% of its water consumption. The estimated flow for sewer is 738 million gallons per year.

Unaccounted water losses is estimated to be 15% of the total consumption. Because sewer flow is not metered by the city of San Antonio for Ft. Sam Houston, this percentage cannot be calculated. 15% is considered to be the average loss for military bases determined in the IWRAPS program.

The estimated, average savings potential at Ft. Sam Houston is 484 million gallons of water, which is 22% of the overall water consumption of the installation. The associated total cost savings is \$661,986, which is a 31% overall savings (costs associated with supply water, sewer, and hot water energy costs). Ft. Sam Houston does address Regulation 11-27 (irrigation and water conservation requirements).

The following list details the data which Ft. Lewis sent upon request from PNL.

- Monthly water consumption data from Ft. Sam Houston, Camp Bullis, and Canyon Lake January of 1980 to May of 1994.
- Monthly sewer data from Camp Bullis and Canyon Lake from January 1984 to May of 1994.
- Monthly rainfall data for 1993.
- Standards and procedures for water conservation.
- Population data from FY 82 to FY 93.

Site-specific assumptions:

- 30% penetration rate is used for low-flow showerheads and aerators.

Figure A.8. Fort Sam Houston Average Monthly Water and Sewer

- Monthly water consumption is based on average of data from 1991 to 1994 (or from 1991 to 1993 when 1994 data was unavailable). The data between this time period appeared to be most representative of the existing water consumption.
- Accounted for or lost water is assumed to be 15%.
- Ft. Sam Houston irrigates year-round - assume a reduction of 70% during winter months (November through February).
- Estimate winter baseline by subtracting winter irrigation.
- Because there is no centralized vehicle wash station, vehicle wash water consumption is included in shops water consumption.

A.10 Fort Stewart Army Installation

Fort Stewart Army Installation produces all its own water. The annual water consumption is 975 million gallons. It is estimated that the facility types with the largest water consumption are family housing (30%), irrigation (10%); barracks (7%), shops (5%), and administration (4.6%).

Table A.33. Water Savings - Fort Stewart

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	45,160	9,004	20,687	14,845	20%	46%	33%
BARRACKS	72,880	16,535	40,133	28,334	23%	55%	39%
DINING	33,925	8,220	10,588	9,404	24%	31%	28%
EDUCATION	6,400	1,276	2,866	2,071	20%	45%	32%
FAMILY HOUSING	288,003	60,220	144,092	102,156	21%	50%	35%
HOSPITAL	22,571	4,034	-	-	18%	0%	0%
IRRIGATION	97,185	19,437	58,311	38,874	20%	60%	40%
LAB/CLINIC	2,575	339	787	574	13%	31%	22%
LAUNDRY	13,911	3,756	8,764	6,260	27%	63%	45%
SHOPS	49,266	4,330	8,351	6,511	9%	17%	13%
SUPPLY WATER TOTAL	631,876	127,150	294,578	209,029	20%	47%	33%
SEWER TOTAL	864,102	107,713	236,268	170,155	12%	27%	20%
UNACCOUNTED WATER LOSSES				3%			
OVERALL WATER SAVINGS (%)				21%			

Table A.34. Cost Savings - Fort Stewart

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	\$1,297	\$2,979	\$2,138	20%	46%	33%
BARRACKS	\$2,381	\$5,779	\$4,080	23%	55%	39%
DINING	\$1,184	\$1,525	\$1,354	24%	31%	28%
EDUCATION	\$184	\$413	\$298	20%	45%	32%
FAMILY HOUSING	\$8,672	\$20,749	\$14,710	21%	50%	35%
HOSPITAL	\$581	\$0	\$0	18%	0%	0%
IRRIGATION	\$2,799	\$8,397	\$5,598	20%	60%	40%
LAB/CLINIC	\$49	\$113	\$83	13%	31%	22%
LAUNDRY	\$541	\$1,262	\$901	27%	63%	45%
SHOPS	\$624	\$1,203	\$938	9%	17%	13%
SUPPLY WATER TOTAL	\$18,310	\$42,419	\$30,100	20%	47%	33%
SEWER TOTAL	\$46,963	\$103,013	\$74,188	12%	27%	20%
<div> Unit Cost Water (Rate A - Purch/Prod) \$/Kgal <div>0.144</div> Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal <div>0.436</div> </div>						
SAVINGS						
Water Supply Cost Savings	\$30,100					
Sewer Cost Savings	\$74,188					
Hot Water Cost Savings	\$244,805					
TOTAL \$ SAVINGS	\$349,093					
OVERALL COST SAVINGS (%)				27%		

Table A.35. Hot Water - Energy and Cost Savings - Fort Stewart

AREA	Electricity Savings (kWh)	Electricity Savings (\$)	Natural gas Savings (therms)	Natural gas Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)
Non Residential	372,783	\$18,639	63,600	\$24,168	5,088	\$29,438
Residential	2,847,108	\$142,355	79,486	\$30,205	0	\$0
TOTAL		\$160,995		\$54,373		\$29,438
Grand Total			\$244,805			

Table A.36. End-Use Savings - Fort Stewart

End-use	Savings (Kgal)
Irrigation	120,000
Toilets	78,234
Laundry	26,420
Showers	23,678
Sinks	18,763
Vehicle Wash	17,440
Urinals	9,532
Icemaker	3,895
Dishwasher	3,644

Fort Stewart wastewater is treated by city of Hinesville, Georgia, sewer treatment plant. The city of Hinesville meters the sewer flows, where the total annual sewer flow is approximately 864 million gallons.

Unaccounted water losses is estimated to be only 3% of the total consumption. Unaccounted water losses is the difference between the baseline water use and the sewer flow. The unaccounted water losses may be so low because the sewer flows actually exceed the water flow during the winter months, as shown in the Ft. Stewart water and sewer consumption chart. Rainfall during the winter probably flows into the distribution system and is treated as effluent.

The total water consumption (sum of end-use water consumption), including unaccounted water losses, only reconciled to 75% of the total water. The data was received very late in the analysis from Ft. Stewart; therefore it was difficult to uncover the 25% unknown water consumption, which may be accounted for due to an unknown end-use with a large water use or recent growth of the base.

The estimated, average annual savings potential at Ft. Stewart is 218 million gallons of water, which is 21% of the overall water consumption of the installation (average water savings divided by the total meter water use). The percent average water savings of the top ten facilities is 33% (average water savings divided by the associated facility types). Because the total water use of the facility types only reconciled to approximately 75% of the total metered data, the overall water savings is low when compared to the average.

The associated total cost savings is \$398,963, which is a 27% overall savings (costs associated with supply water, sewer, and hot water energy costs).

Figure A.9. Fort Stewart Average Monthly Water and Sewer

The following list details the data which Ft. Stewart sent upon request from PNL.

- Monthly water consumption data from January of 1987 to July of 1994.
- Monthly sewer flow data from July of 1992 to July of 1994.
- Monthly operating logs form central energy plant and laundry facility.

Site-specific assumptions:

- 30% penetration rate for aerators and showerheads was assumed.
- Monthly water consumption is based on average of data from 1991 to 1994 (or from 1991 to 1993 when 1994 data was unavailable). The water consumption during this time frame seemed most representative of the current water use.
- Monthly sewer flow is based on average of data from 1992 to 1994 (or from 1991 to 1993 when 1994 data was unavailable).
- Vehicle washing water consumption was included in the shop water consumption.
- Plant water consumption was taken from central plant makeup water operating logs, averaged from 1993 to 1994 (where 1994 data was available).

A.11 Fort Dix Army Installation

Fort Dix Army Installation produces all its own water from a surface water source and from five wells. Fort Dix is mandated to use surface water before using the groundwater sources, and typically 20 to 30% of the water produced comes from the surface water source. The installation's annual water consumption is approximately 750 million gallons. It is estimated that the facility types with the largest water consumption are family housing (46%), barracks (21%), irrigation (7%), administration (6%), and dining (4%).

Fort Dix sewage water is treated on site. A new contractor-operated wastewater treatment facility came on line in August of 1994. The total annual sewer flow for Fort Dix is approximately 650 million gallons. This does not include the effluent processed for McGuire AFB.

Table A.37. Water Savings - Fort Dix

Facility Type	Usage (Kgal)	Low Savings (Kgal)	High Savings (Kgal)	Average Savings (Kgal)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	39,355	8,560	20,116	14,338	22%	51%	36%
BARRACKS	145,914	37,488	95,227	66,358	26%	65%	45%
DINING	27,782	10,811	13,127	11,969	39%	47%	43%
EDUCATION	7,274	1,487	3,308	2,398	20%	45%	33%
FAMILY HOUSING	322,334	58,769	127,360	93,065	18%	40%	29%
HOSPITAL	21,149	4,078	9,534	6,806	19%	45%	32%
IRRIGATION	40,000	8,000	24,000	16,000	20%	60%	40%
LAB/CLINIC	1,898	264	655	459	14%	34%	24%
LAUNDRY	10,930	2,951	6,886	4,918	27%	63%	45%
SHOPS	16,479	1,460	3,284	2,372	9%	20%	14%
SUPPLY WATER TOTAL	633,115	133,866	303,498	218,682	21%	48%	35%
SEWER TOTAL	642,132	125,866	279,498	202,682	20%	44%	32%
UNACCOUNTED FOR WATER LOSSES				5%			
OVERALL WATER SAVINGS (%)				31%			

Table A.38. Cost Savings - Fort Dix

Facility Type	Low Savings (\$)	High Savings (\$)	Average Savings (\$)	Low Savings (%)	High Savings (%)	Average Savings (%)
ADMIN	15,486	36,393	25,939	22 %	51 %	36 %
BARRACKS	67,819	172,276	120,048	26 %	65 %	45 %
DINING	19,558	23,747	21,652	39 %	47 %	43 %
EDUCATION	2,689	5,985	4,337	20 %	45 %	33 %
FAMILY HOUSING	106,319	230,408	168,363	18 %	40 %	29 %
HOSPITAL	7,377	17,247	12,312	19 %	45 %	32 %
IRRIGATION	14,473	43,418	28,946	20 %	60 %	40 %
LAB/CLINIC	477	1,185	831	14 %	34 %	24 %
LAUNDRY	5,339	12,457	8,898	27 %	63 %	45 %
SHOPS	2,641	5,942	4,291	9 %	20 %	14 %
SUPPLY WATER TOTAL	242,177	549,058	395,618	21 %	48 %	35 %
SEWER TOTAL	318,944	708,248	513,596	20 %	44 %	32 %
Unit Cost Water (Rate A - Purch/Prod) \$/Kgal			1.81			
Unit Cost Sewer (Rate A - Purch/Prod) \$/Kgal			2.53			
SAVINGS						
Water Supply Cost Savings	\$	395,618				
Sewer Cost Savings	\$	513,596				
Hot Water Cost Savings	\$	152,182				
TOTAL \$ SAVINGS	\$	1,061,396				
OVERALL COST SAVINGS (%)				30%		

Table A.38. Hot Water - Energy and Cost Savings - Fort Dix

Electricity Savings (kWh)	Electricity Savings (\$)	Fuel Oil Savings (MBtu)	Fuel Oil Savings (\$)	Natural Gas Savings (MBtu)	Natural Gas Savings (\$)
152,022	\$13,287	20,754	\$114,146	4,670	\$24,749
Grand Total		\$152,182			

Table A.39. End-Use Savings - Fort Dix

End-use	Savings (Kgal)
Toilets	82,665
Urinals	11,087
Sinks	9,805
Showers	43,397
Laundry	38,326
Icemakers	9,229
Irrigation	16,000
Vehicle Wash	4,259

Fort Dix wastewater is treated on site. A new contractor operated wastewater treatment facility came on line in August of 1994. The total annual sewer flow for Fort Dix is approximately 650 million gallons. This does not include the effluent processed for McGuire AFB.

Unaccounted water loss is estimated by Fort Dix personnel to be 5% of the total consumption. The unaccounted water loss estimate may be low because the sewer flows actually exceed the water flow during the high rainfall months, as shown in the Ft. Dix water and sewer consumption chart. During these periods rainfall probably flows into the distribution system and is treated as effluent.

The estimated average annual savings potential at Ft. Dix is 219 million gallons of water, which is 31% of the overall water consumption of the installation (average water savings divided by the total meter water use). The associated total cost savings is \$1,061,396, which is a 30% overall savings (costs associated with supply water, sewer, and hot water energy costs).

Figure A.10. Fort Dix Average Monthly Water and Sewer

The following list details the data which Ft. Dix sent upon request from PNL.

- Monthly water consumption data from FY93 and FY94, including information from resale customers.
- Monthly sewer flow data from January 1993 through December 1994.
- Monthly operating logs from central heating plant and laundry facility.
- Water and sewer Rate A information.
- Data on fuel costs (electricity, natural gas, fuel oil).

Site-specific assumptions:

- 30% penetration rate for aerators and showerheads was assumed.
- Monthly water consumption and sewer flow is based on data for FY93.
- Vehicle washing water consumption was included in the shop water consumption.
- Plant water consumption was estimated from central plant makeup water operating logs provided for parts of FY93 and FY94.
- Water for domestic use is heated by 80% steam, 18% natural gas, and 2% electricity.

Appendix B

Water Use Indexes

Appendix B

Water Use Indexes

Water use indexes are used to calculate water consumption in facility types for which metered data was not available. PNL developed a list of WUIs for 19 different building types. A large portion of the WUIs were taken from the IWRAPS software (Institute for Water Resources by Planning and Management Consultants Ltd. 1994), because this data relied on metered data from Army installations. Others were derived from metered data obtained through the questionnaire PNL sent to each installation.

Table B.1 below lists the default WUIs used in water consumption calculations. A brief description is given for the source of each WUI.

Table B.1. Water Use Indexes

Building Category	WUI (gal/square foot/day)	Description of Sources
ADMIN	0.0874	IWRAPS WUI
BARRACKS	0.1561	IWRAPS WUI
CHAPELS	0.0382	Education IWRAPS WUI
DET-RR	0.0874	Administration IWRAPS WUI
DINING	0.2408	IWRAPS WUI
EDUCATION	0.0382	IWRAPS WUI
FAMILY HOUSING	0.2249	IWRAPS WUI
GROCERY	0.0477	IWRAPS WUI
HOSPITAL	0.1703	Calculated from selected metered data
LAB/CLINIC	0.1228	IWRAPS WUI
LAUNDRY	1.3021	IWRAPS WUI
PLANT	-	Calculated on a site-by-site basis
POOL	-	Calculated on a site-by-site basis
PROCESS	-	Calculated on a site-by-site basis
RECREATION	0.2227	IWRAPS WUI
SHOP	0.2170	Calculated from selected metered data
UTILITY BLDG	0.0111	Warehouse IWRAPS WUI
VEHICLE WASH	-	Calculated on a site-by-site basis
WAREHOUSE	0.0111	IWRAPS WUI

Appendix C

Disaggregated End Use Pie Charts

Appendix C

Disaggregated End Use Pie Charts

The following pie charts show each end-use breakdown for the facility types which were analyzed in the report. Each breakdown was determined by examining typical end-use breakdowns of similar building types found in the literature search. If there were more than one source of information, the breakdowns were averaged. The following list shows each facility type with the corresponding source of information that was used to disaggregate the end use:

- Administration: City of San Jose Environmental Services Department, *Water Conservation Guide for Office Buildings and Commercial Establishments*, 1992.
- Barracks: Conserv'93 Proceedings. December 1993. - apartment building and hotel, City of San Jose Environmental Services Department, *Water Conservation Guide for Hotels and Motels*, 1992.
- Dining: Conserv'93 Proceedings. December 1993. - restaurant, City of San Jose Environmental Services Department, *Water Conservation Guide for Restaurants*, 1992.
- Hospital: Conserv'93 Proceedings. December 1993. - hospital, City of San Jose Environmental Services Department, *Water Conservation Guide for Hospitals and Health Care Facilities*, 1992.
- Lab/Clinic: based on assumption from hospitals, eliminating showers and kitchen facilities.
- Shops: estimations and assumptions based on examining other building types water use breakdown (due to lack of information on shop water use).
- Family Housing: Mechanical and Electrical Equipment for Buildings (Stein, Benjamin Reynolds, John and McGuinness, William, 7th edition, New York, 1986) - residential indoor water use.

Laundry facilities, irrigation, and vehicle wash station were not included in end-use breakdown because it was assumed that 100% of the water use was used for the particular end use. Also, the breakdown for shops varied from site to site. For sites with no central wash station, vehicle wash was included in the shops category, representing 59% of the water use. The pie chart shown for shops, however, does not represent vehicle wash, but the other end uses.

The following pie charts represent the breakdown of each facility type.

Dining: Enduse Breakdown

Education: Enduse Breakdown

Family Housing: Enduse Breakdown

Hospital: Enduse Breakdown

Lab/Clinic: Enduse Breakdown

Shops: Enduse Breakdown

Appendix D

Water Resource Opportunities List

Appendix D

Water Resource Opportunities List

A list of water efficient technologies and techniques has been compiled to provide facility managers with resources that help decrease water consumption at their installations. This compilation is referred to as the Water Resource Opportunity (WRO) list. The WRO list is broken down by end use, providing several opportunities for each end use, including conservation techniques, retrofit, and replacement options. Corresponding water savings potential or flow rate reduction is shown, where appropriate. Exact savings are not associated with every option because of the complexity involved with particular technologies and techniques, such as climate variations and site-specific data. When available, savings potential recorded in case studies has been included. Also, included in the WRO list are general costs associated with some of the end uses where costs were available.

This information (technology options and costs) has been researched in several sources, mainly in the *Water Management, A Comprehensive Approach for GSA Facility Managers*, produced by Environmental Management & Research; *The Water Conservation Guides*, produced by the City of San Jose, Environmental Services Department; and *Water-Efficient Technologies*, Second Edition, 1991, produced by the Rocky Mountain Institute.

From the WRO list, a range of savings potential for each end use was determined. The savings potential was calculated by associating a percentage savings based on reduced water flow or consumption of the technology or technique. For most of the end uses, a low, high, and average savings was calculated to represent the variety of retrofit options. Rather than showing a range of savings for some of the end uses, simply an average savings was shown because a range of savings was not applicable.

The savings potential for toilets, urinals, and showers decrease in post-1980 buildings due to improvements in the building standards. Therefore, separate savings were attributed to these end uses for pre-1980 and post-1980 buildings (buildings were broken down on a percentage basis).

It is difficult to estimate savings for some technologies, such as irrigation and vehicle wash stations. Therefore, these estimates are based on information from similar case studies. Irrigation savings potential was referenced from several case studies documented in *Water-Efficient Technologies*, Second Edition, 1991, produced by the Rocky Mountain Institute. Vehicle wash savings potential was referenced from a case study detailed in Conserv 93 proceedings, *Commercial and Industrial Program Case Study*. Some end uses were not analyzed in this top-level screening, due to the complexity involved in determining a savings potential. These end uses include all cooling

processes, boiler and steam generators, and wastewater recycling and reuse systems. To accurately estimate the savings potential, these end uses must be studied in depth on a site-by-site basis.

Table D.1 shows each end use that was analyzed with the associated savings potential.

Table D.1. End use percent savings

End Use	% Low Savings	% High Savings	% Average Savings
Faucets	NA	NA	38%
Laundry	30%	70%	50%
Dishwasher	NA	NA	10%
Irrigation	20%	60%	40%
Vehicle Wash	NA	NA	60%
Icemaker	NA	NA	50%
Pre-1980			
Toilets	20%	68%	44%
Urinals	33%	67%	50%
Showers	22%	64%	43%
Post-1980			
Toilets	20%	38%	29%
Urinals	NA	NA	33%
Showers	22%	26%	24%

The following section details the water conservation technologies and techniques compiled in the Water Resource Opportunity List.

Water Resource Opportunity List

Plumbing

Toilets

Gravity Flow Toilets

Standard flow (pre-1980 standard) of 5 to 7 gallons per flush (gpf)

Retrofit Options

Technology	Flow Reduction (gpf)	Cost Range
Displacement Devices	0.75	~ \$20
Toilet Dams	0.5 to 1	~ \$20
Early Closure devices	1 to 2	~ \$20
Dual-flush adapters	0.6 to 1.2	~ \$20

Flush Valve Toilets (tankless toilet)

Standard flow (pre-1980 standard) of 5 gpf

Retrofit Options

Technology	Flow Reduction (gpf)	Cost Range
Insert or Valve Replacement	1	~ \$50
Electronic Sensors	not measurable	not available
Early Closure devices	1 to 2	~ \$20
Dual-flush adapters	0.6 to 1.2	~ \$20

Toilet Replacement Options

Technology	Gallons per Flush	Cost Range
Gravity Flush Toilets	1.6 - 1.2	\$100 - \$300
Pressurized-Tank Toilet	1 - 1.6	\$200 - \$600
Commercial Toilet: (siphon-jet)	1.6	
Air-assisted Toilet:	0.6	\$400 - \$600
Mechanically-assisted Toilet	0.6 - 0.7	~ \$700

~ PITFALLS to be aware of...

- Some low flush toilets are not readily retrofitted to current sewer system design (i.e., large diameter pipe). Flushing action may be affected by sewer pipe resulting in multiple flushes.

Urinals

Categories of Urinals

Washout and Washdown Urinals

Siphonic Jet Urinal

Blowout Urinal

Standard flows (post 1980 standard) of 1.5 to 3 gpf

Retrofit Options

Technology	Flow Reduction (gpf)	Cost Range
Flushometer Valves	1	\$75 - \$100
Flushing Timer or Sensor	not measurable	not available

Replacement Options

Technology	Gallons per Flush	Cost Range
Ultra Low Flush (ULF)	1	\$100 - \$400

Showerheads

Standard Flow 3-7 gal per min (gpm)

Retrofit Options

Technology	Flow Reduction (gpm)	Cost Range
Flow Restrictors	1	\$5
Temporary Cutoff Valves	not measurable	not available

Replacement Options

Technology	Gallons per minute	Cost Range (typically \$20)
Atomizer	2.5	\$3 - \$90
Pulsaters	2.5	\$3 - \$90
Aerators	2.5	\$3 - \$90

~ PITFALLS to be aware of...

- Corrosion in old showerhead is common which impedes water flow, therefore saving potential decreases when installing low-flow showerhead.
- Broken diverter valve will decrease savings potential.
- With water source from wells, effectiveness of low flow showerhead is reduced due to lower pressure.]

Faucets

Standard Flow - 3 to 5 gpm

Retrofit Options

Technology	Gallons per minute	Cost Range
Flow Restrictors	0.5 to 2.5	\$5
Aerators	0.5 to 2.5	\$5 - \$15

Replacement Options

Technology	Savings	Cost Range
Metering Valves	not measurable	\$50 - \$180
Self Closing	not measurable	\$50 - \$180
Electronic and Infrared Sensors	not measurable	\$380

Note: A "not measurable" in savings column denotes technologies which do not have an exact flow reduction associated with the use. These technologies have savings potential, but vary on the type of use.

Processes

Water Cooling Systems

Cooling Towers

Cooling towers provide a means of cooling down hot water from industrial processes. Hot water is finely sprayed through nozzles into a collection tank. A portion of this water evaporates into the air (as water vapor) which cools the remaining liquid water. There is virtually no potential to save water regarding the evaporation process. (Approximately 2.4 gallons per minute per 100 tons of cooling is lost due to evaporation (City of San Jose, Environmental Services Department 1992).

Another source of water loss in cooling towers is through blow-down. Blow-down is the release of circulating water to remove suspended and dissolved solids left as pure water evaporates from the system. Once blow-down has occurred, clean water is introduced back into the system, referred to as make-up water. The concentration ratio is the term that quantifies this make-up water. Essentially, the concentration ratio is the number of times the water is recycled in the cooling tower before it is discharged as blow-down.

Conservation Opportunities

The main opportunity for conserving water is increasing the concentration ratio. This will occur if water quality can be maintained. By working with a reliable chemical vendor, the concentration ratio can be optimized with proper amounts of chemicals. This can be done by specifying a minimum concentration ratio with the vendor. Another way of decreasing blow-down is with alternative water treatment techniques, discussed in the following section.

Alternate Forms of Treatment

Sidestream Filtration

- Removes suspended solids in recirculating water.
- Reduces scaling and fouling.
- Increases efficiency.
- Decreases operation and maintenance costs.

Sulfuric Acid Treatment

- Injection of sulfuric acid lowers pH to control scale build up.
- Produces higher cycles of concentration.
- Low initial capital cost.
- Reduces operating costs.

Ozonation

- Injected ozone (O_3) into cooling water kills microorganisms.
- Use and handling of chemicals are eliminated.
- Reduces operation costs due to the elimination of chemicals.
- Reduction in blow-down - case study shows reduction of 96% (EPRI 1992).
- Helps to control scale and corrosion.

Reclaiming Water

Reclaiming the water which is blown down from the system can provide a great opportunity for savings. This water can be reclaimed and filtered to be used directly in the system again. Also, other sources of reclaimed water, such as treated municipal effluent, can be sufficient for cooling tower make-up water. Phosphate buildup can be a problem due to the possibility of high phosphate ions in the effluent. Phosphate can be removed with a lime-softening treatment (City of Phoenix).

Single Pass Cooling

Single pass cooling is an open looped system where all process water is directly ejected at the end of one cycle. Single pass cooling is most commonly used in air conditioning, welding machines, hydraulic equipment, x-ray processes, air compressors, and vacuum pumps.

Conservation Opportunities

- Add a recirculating cooling system. Recirculate the cooling water through a cooling tower or chilled water system.
- Retrofit or replace single pass system to a closed-loop cooling system.
- Retrofit or replace single pass system to a air-cooled system.
- Reclaim water from equipment and reuse in another application (non-drinking), such as landscape watering and cooling tower make-up water.
- Insulate piping, chiller, and central storage tank to reduce energy consumption.

Evaporative Coolers

Evaporative coolers cool air by increasing the humidity of the air being drawn into the building. The evaporative cooler circulates water through fibrous material. The incoming air is blown across this material, absorbing water vapor. This process decreases the "dry bulb" air temperature (while the saturating "wet bulb" temperature remains the same). Evaporative coolers are obviously best used in dry climates (City of Phoenix).

Conservation Opportunities

- Make sure there is a recirculating pump to recirculate the cooling water.
- Ensure proper water quality to reduce blow-down (blow-down should be no greater than 3-4 gallons per hour. See description of blow-down in cooling tower section).

- Insulate piping, chiller, and central storage tank to reduce energy consumption.
- Check equipment for leaks.

Boilers and Steam Generators

Conservation Opportunities

- Install Condensate Return
 - Reduction in water, energy, and chemical consumption.
 - May reduce operating costs by up to 50 -70% (City of San Jose, Environmental Services Department 1992).
 - Decrease energy costs.
- Limit blow-down to meet the required water quality (see cooling tower section for more details).
- Discharge blow-down into an expansion tank to allow for condensing and cooling.
- Check steam traps and lines for leaks.
- Insulate piping, chiller, and central storage tank.

Irrigation and Landscaping

Retrofit Options

- Install moisture sensor to avoid watering during rain.
- Install cathodic conditioner - reduces pressure which can save 25%-50% water (Enviro-Management and Research, Inc. 1994).
- Install soil tensiometer - gauges amount of water needed in the soil.
- Install flow restricting nozzle or sprayer.

Replacement Options

- Irrigation system using controls or sensors
- Trickle or subsurface drip irrigation system. Cost range \$0.20 to \$0.45 per foot of hosing.
 - Surface seam irrigation hose - water leaks from a seam, extending along the tubing's surface.
 - Subsurface soaker-hose - water leaks through porous walls of the hosing.
- Use rain runoff to irrigate - case study used 50 - 65% irrigation water with rain. (Anderson 1993)

Xeriscaping

- Use plants which are indigenous to your area.
- Do not mix high and low water plants together - turf areas should be kept separate from trees and shrubbery.
- Put plants with high water needs in lower areas so they intercept the runoff.
- Planting in beds helps to decrease watering needs.
- Add wood chips, mulch, or rock in beds to maintain moisture.
- Water deeply occasionally instead of lightly every day.

The exact savings potential associated with the above technologies and practices is difficult to estimate. Savings is mainly dependent on climate conditions. However, case studies show that employing these types of watering practices can save anywhere from 20% to 60% (Rocky Mountain Institute 1991).

Other Major Use Areas

Vehicle Washing Stations

Most installations have vehicle wash stations on-site, and there is usually a large, main facility. This main vehicle wash station provides a great opportunity for saving water. A water recycling system can provide high savings and is easy to implement. Usually, the water is collected in a pond

(which also collects rain water) and is filtered through a simple filtration system, to be reused again as vehicle wash water. Water is lost in a recycling system through evaporation, and fresh water is added periodically to maintain proper water quality.

Laundry Facilities

The most common washing machines are vertical axis (top-loading), horizontal axis (front-loading), and horizontal-axis (top-loading) washer. Horizontal axis washers only need to be filled about half full, instead of completely full like the vertical axis washers. Typical costs of a household horizontal axis is around \$500. A commercial front loader washer can cost up to \$50,000 for a maximum capacity of 200 lbs of laundry (Rocky Mountain Institute 1991).

Replacement/Retrofit Options

Technology	Savings Potential
Horizontal axis washer	50% (25 - 30 gallons/wash)
Computerized control	Case study shows 50% savings (Anderson 1993)
Recycle rinse water	not measurable

Pools

- Avoid excessive backwash and cover pool when unoccupied to avoid evaporation.

Dining Facilities

Ice Machines

- Retrofit to air cooled system instead of water cooled - Case study showed 70% savings with a low conversion cost of \$577 (City of San Jose Environmental Services Department 1992).
- Replace cube machine with flake machine (flake machine has no bleed off, where a ice cube machine has constant bleed off to eliminate minerals). Flake machines use up to 50% less water (Anderson 1993).

Wastewater

Water Recycle System

A recycling system filters graywater (graywater is water which has a low concentration of suspended particles), utilizing the filtered water in the same end-use.

End-Use Opportunities for Water Recycle System

- Cooling Towers Make-Up Water
- Industrial Laundries
- Vehicle and Aircraft Washing Stations - Case study used 80% recycled water (Anderson 1993).

Water Reuse - Onsite Recycling Systems

Wastewater is treated and stored for reuse in other end-uses

Conservation Opportunities

- Graywater System: Graywater is filtered (usually not chemically treated), and stored for reuse.
- Combined Wastewater Treatment - Collection and treatment of all wastewater.

End-Use Opportunities for Onsite Recycling Systems:

- Landscape Irrigation
- Flushwater for toilets and urinals

- Supply water for ornamental ponds
- Make-up Water for cooling towers
- Vehicle and Aircraft washing stations

Leak Detection Program

The following briefly describes the leak detection technologies that can be used to locate leaks in water distribution systems. The information was found in a CERL report (Maloney, S.W., Scholze, R. J., Bandy, J. T., US Army Corps of Engineers, *Preventing Water Losses in Water Distribution Systems: Money-Savings Leak Detection Programs* (AD-A167 556, technical report N-86/05), March 1986).

Technologies

Sonic Technology

Locate leaks by detecting sound of water escaping through leaks in the distribution system.

Mechanical Techniques

Geophone: sensors placed on the ground with stethoscope type attachment for listening. They are not directly connected to the distribution system, therefore there is background noise. Extensive knowledge of the distribution system is required. Equipment costs can cost around \$10.

Aquaphone: hand-held device which is place directly on distribution system at exposed points only, placed directly onto distribution system at fire hydrants, accessible valves. Equipment costs can cost around \$250.

Electronic Techniques

Sound amplification and noise filtration to help pin-point the leaks by keying in the frequency range characterized by leaks. This equipment includes technologies such as electronic amplifier, filter control, ground microphones. Equipment costs can cost range from \$500 - \$3000.

Probes, with radio transmitters, are placed into the distribution system, where the probe locates major leaks in the pipe. This technique is expensive and labor intensive.

Infrared Photography

This method is used when the ground water temperature is colder than the potable water. A major leak may change the temperature of the surrounding soil. Infrared photography, which senses heat sources, can detect temperature differences in the soil surrounding the pipes. This method is very expensive and can be unreliable because of interference with other heat sources.

Costs

General costs can range from \$60/mile to as high as \$1200/mile. This is based on the type of technology and associated labor costs.

Conclusion

The above list is intended to provide a brief summary of water conservation opportunities in common water end-uses. This can be utilized by facility managers as a resource of information on water efficient technologies and techniques. Each WRO has potential for savings, but some options have more attractive savings than others. For example, low flow showerheads are usually an inexpensive and reliable way to achieve a significant savings. Also, conservative outdoor watering practices can decrease water consumption without much initial investment. Other options have disadvantages which may limit the effectiveness, such as on-site recycling system which has a high capital cost and high maintenance. To properly determine the options which will provide significant savings and a reasonable pay back period, a site specific analysis is essential.

Appendix E

Assumptions

Appendix E

Assumptions

Assumptions

Real Property Data

- Used 1991 Real Property List from master Real Property Database from DEH Nine Track
- Categorized into 19 categories by facility type
- Removed buildings with no water utility hook-ups
- Removed functionally non-serviceable buildings, unless had additional information from installation on buildings condition

Facility Type Water Consumption Breakdown

- Grouped buildings together with similar water end-use type and hours of operation
- Irrigation for grounds of each particular building type is encompassed in irrigation category
- Vehicle washing is included as end-use in shops category unless specific information was available regarding centralized vehicle wash station.
- Laundry is a separate facility category (associated with the centralized laundry facility), though it is included as an end-use in barracks and family housing categories
- Centralized cooling and heating of buildings is encompassed in plant category
- Used metered water use data when available
- Used square footage of buildings in each facility type to estimate water use by applying a WUI (water use index)
- Used IWRAPS coefficients to calculate water use where metered data was not available

- Baseline use = non-seasonal (i.e., winter) water use
- Baseline use estimated by graphing total water use and extracting non-seasonal component
- Seasonal use = irrigation in warmer months
- Seasonal use estimated by graphing total water use, determining baseline use, and subtracting baseline use from total use
- Losses are estimated as (Baseline use - Sewer) if not provided
- Assumed 30 days/month use for buildings

End-Use Breakdown

- Breakdown percentages taken from literature references
- May not be all-encompassing, but is a general breakdown of water end-use in each facility type

Penetration Rates

- Default value of 30% penetration rate assumed for showers and aerators (only those water-savings devices that conserve energy) unless site-specific values are available
- Divided facilities into pre-1980 and post-1980 buildings to apply different savings potential values, as codes for certain devices changed at that time
- 100% implementation of water efficient technologies was assumed. Although this assumption yields the maximum savings potential at each installation, it provides consistent results for purpose of comparison.

Water and Sewer Savings Calculation

- Savings estimations were calculated for the facility types with the largest volume of water consumption only: Irrigation, Family Housing, Barracks, Administration, Hospitals, Shops, Dining, Education, Labs/Clinics, and Laundry (all others are minute consumers).
- Estimated sewer savings are calculated as the difference between total water savings and the irrigation savings.
- Savings are calculated for a range of savings potential for each end-use, shown as low, high,

and average (see details in WRO appendix [Appendix D] for explanation of each end-use)

- Plant water savings was not investigated in depth. This is due to the complexity of determining the water consumption at plants (cooling towers, boilers) at the individual installations. This issue should be addressed in a detailed study on a site-by-site basis.

Cost Calculations

- Applied "Rate A" cost of purchase/production to determine water cost savings
- Rate A includes pumping and treatment costs
- Cost savings associated with reduction in water consumption, pumping energy, wastewater treatment, and water heating.

Energy Savings Calculations

- Energy savings calculations (energy savings due to reduction in energy to heat water) were based on simple energy equation as follows in Equation (1):

$$E_{\text{savings}} = HW_{\text{savings}} \times v \times C_p \times (T_{\text{supply}} - T_{\text{ground}}) \quad (\text{Btu}) \quad (1)$$

Where E_{savings} = Energy Savings (Btu)

HW_{savings} = volume of hot water saved due to retrofits (ft³)

v = volumetric weight of water = 62.4 lbm/ft³

C_p = specific heat of water = 1.0 Btu/lbm-°F

T_{supply} = Hot water supply temperature = 130 °F

T_{ground} = Hot water ground temperature = 58 °F

- The amount of hot water used in each end-use was calculated by performing a mass-temperature balance on each end-use (representative hot water temperatures found in ASHRAE Handbook, HVAC Applications, 1991) (ASHRAE 1991). The following table shows the percentage of cold and hot water for each end-use.

End-Use	Cold	Hot
Dishwashing	0%	100%
Clothes Washer	25%	75%
Showers	28%	72%
Sinks	35%	65%

- Penetration rates of efficient technologies were estimated on a site-by-site basis (if no information was available, a penetration rate of 0% was applied). For water-efficient showers and sinks, a penetration rate of 30% was used as a default.
- Groundwater temperature was assumed to be 58°F.
- Supply water temperature was assumed to be 130°F.
- Total dollar savings was estimated on a site-by-site basis - the fuel and fuel cost varied from site to site.

Savings Comparison

- Comparison of cost savings was determined from water volume savings, energy savings associated with reducing pumping requirement, water heating requirement, and water treatment savings for both water supply and wastewater treatment.
- Savings were determined with assumed 100% implementation of water resource savings opportunities for non-penetrated fixtures and technologies.
- Cost savings, water savings, wastewater treatment savings, and energy savings are used as a means to compare the savings potential among sites, but are not intended to be used as actual savings.

Appendix F

FORSCOM Water Data Questionnaire

Appendix F

FORSCOM Water Data Questionnaire

Please provide the following information to Pacific Northwest Laboratory:

Part 1 - Water and Sewer Use Information

1. Water utility company name:

If you purchase water from a utility company, please send monthly usage data for as many years as are readily available. If you keep water use information on a spreadsheet or several spreadsheets please copy the information to a 3.5" or 4.25" floppy disk and forward to PNL.

2. Do you have wells or take water from a stream?

Please send data on volume of water taken from each source (monthly data is preferable). Please indicate if you do not meter your water supply.

3. "Other" water supply sources:

Please send data on volume of water taken from each other source (monthly data is preferable). Please indicate if you do not meter your water supply.

4. Sewage Treatment company name:

If your sewage is processed by a sewer utility company, please send monthly data on volume of sewage treated for as many years as are readily available.

5. Do you have a sewage treatment plant onsite?

Please send monthly meter data for as many years as are readily available.

- 5.a Is graywater used for any recycling purposes?

Please send monthly meter gray water data for as many years as are readily available.

6. Do you maintain usage information for reimbursibles or other submetered accounts?

Please send monthly meter data (or estimated usage) for as many years as are readily available. This information is especially important to the study.

7. Are there water and/or sewer accounts for off-post customers? If so, is the usage included above or are separate records maintained?

If separate records are maintained, please send monthly data for as many years as are readily available.

8. Is irrigation water taken from a separate source?

Please send monthly meter data for as many years as are readily available.

Part 2 - Population and Conservation Information

THE FOLLOWING INFORMATION IS VALUABLE BUT NOT NECESSARY - PLEASE FORWARD THE INFORMATION FROM PART 1 TO PNL IMMEDIATELY. PLEASE PROVIDE ANSWERS TO PART 2 OF THE SURVEY AS YOUR TIME PERMITS. THANK YOU VERY MUCH.

A. Population Profile

1. Do you have historic monthly population data available?

Please provide as many years of data as is readily available.

If you do not have ready access to population data, could you provide a point of contact for this information:

POC:

PHONE NUMBER:

B. Water Use and Conservation Information

1. Is there any recycling or reuse of water, such as recycling of vehicle wash water or use of graywater at your installation?

Part 2 - Population and Conservation Information Continued

2. Has a leak detection study been performed at your installation?

If so, was a repair program implemented?

If savings were quantified please provide a copy of the study or a summary of results.

C. Conservation Measures and Programs

1. Have conservation measures have been implemented on the base (water saving toilets, low flow showers, etc.)?

Please provide information on quantities installed, penetration rates, etc.

2. Do you have records of actual savings as a result of those conservation measures?

If savings were quantified please provide a copy of the study or a summary of results.

3. Does your water utility offer rebate programs?

Please include copies of brochures or name and phone number of utility representative.

4. Does your water utility offer incentive rate structures?

Please include copies of rate sheets or name and phone number of utility representative.

D. Irrigation Information

1. Are your sprinkler systems and irrigation controlled by programmable timeclocks or other control devises?
2. What strategy or strategies do you employ for watering?
3. Is xeriscaping used for water conservation?

Other information gathered via phone conversations from most of the installations:

- Purchase/production Rate A for water and sewer at each installation.
- Operating logs for central plant showing make-up water logs.
- Specific information about vehicle wash stations (if vehicle washing was performed in the shops or central facility)
- Fuel types and average cost for hot water production.

Appendix G

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Appendix G

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Appendix H

Special Issues

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H.1 Cost of Water and Sewer Services

Determining the actual cost of water services at a FORSCOM installation can be more difficult than determining the cost of electricity or natural gas. With electricity or natural gas, a utility company typically charges the FORSCOM installation for service based on a rate schedule that is approved by a regulating body such as a public utilities commission. In contrast to electrical and natural gas service, many FORSCOM installations produce their own water from onsite wells or surface water sources and do not employ the services of municipal water utility companies. To determine their cost of water service they must aggregate costs for production, filtering and purification, and delivery of the water. Each installation is required to determine its water production cost to establish its Rate A. Rate A is the resale rate charged to government entities operating onsite. Most FORSCOM installations also provide their own sewer services and sewer Rate A is determined in the same fashion as water.

There are two components to Rate A for water or sewer use at FORSCOM installations: purchase/production costs and maintenance costs. The purchase cost is simply the amount charged by the municipal water utility providing service to the installation. The production cost covers expenditures for the operation of the water or wastewater plant and all related facilities to include electrical costs for pumping. The cost of maintenance includes two categories: normal maintenance and abnormal maintenance. (Note: cost of capital, which includes acquisition cost, annual charge and administrative overhead, is not factored into Rate A). In our study we have used the purchase/production cost component of Rate A as the avoided cost. The potential impact of water use reduction on maintenance is a complex issue that would probably require an in-depth analysis to resolve and is beyond the scope or purpose of this study, which is preliminary screening. A determination of impact on maintenance should be considered in comprehensive facility audits. The Rate A charged by each of the installations evaluated in this study is shown in Table H.1.

There is a large variation or spread in water costs, much larger than those typically found in electricity or fossil fuel costs. For example, Fort Carson's Rate A for water is 660% of Fort Stewart's. Installations that purchase water or sewer services from a municipality and also produce a fraction of their water onsite (e.g., Drum, Carson, and Polk) have the highest purchase/production costs. Similarly, Fort Drum and Fort Sam Houston have high sewer purchase/production costs. But there are some apparent production and maintenance cost anomalies that lead to questions. For example, why is Fort Carson's water maintenance cost higher than all the other installations when it only produces a small fraction of its total water onsite? Why are Fort Polk's and Fort Dix's production costs for water and sewer twice as high on the average as the other forts that produce their own water and treat their own sewage? These anomalies can only be explained with additional

Table H.1. Components of Rate A for the Study Installations

<u>Installation</u>	<u>Water \$/Kgal Prod/Maint/Total</u>	<u>Sewer \$/Kgal Purch/Maint/Total</u>
Fort Bragg	0.34/0.36/0.70	0.21/0.21/0.42
Fort Campbell	0.43/0.08/0.51	0.54/0.04/0.58
Fort Carson	1.81/0.57/2.38	1.42/1.09/2.51
Fort Dix	1.81/0.62/2.43	2.53/0.18/2.72
Fort Drum	0.84/0.32/1.16	1.13/0.09/1.22
Fort Hood	0.27/0.38/0.65	0.32/0.31/0.63
Fort Polk	0.92/0.17/1.09	0.91/0.14/1.06
Fort Lewis	0.23/0.42/0.65	0.45/0.94/1.39
Fort Sam Houston	0.34/0.29/0.63	1.42/0.11/1.53
Fort Stewart	0.14/0.22/0.36	0.46/0./0.

research into how production and maintenance costs are established. To accurately ascertain the cost savings potential at FORSCOM installations, a complete understanding of the production and maintenance cost calculation process is required.

H.2 Occupancy, Characterization of End Uses, and Penetration Rates

Domestic water usage in an office building or similar facility depends on many factors including building population, occupant density, gender mix, and the type of plumbing fixtures in the building (Behling et al. 1992). Many assumptions were made in this study relative to these factors. For example, the approach used to characterize the water efficiency of existing end-use equipment was to treat pre-1980 and post-1980 facilities differently. Pre-1980 plumbing end uses were typically characterized by higher unit water usage than fixtures installed post-1980. For instance, older gravity flow toilets typically use 5 to 7 gallons per flush, whereas many post-1980 units use 3.5 gallons per flush. New gravity flow toilets use 1.6 gallons per flush. It is apparent that the replacement of post-1980 vintage toilets will result in some water use reduction, while replacing the older toilets with new more efficient toilets will lead to even greater water savings.

Due to the broad scope of this study, very little site-specific information was made available on the vintage or efficiency of existing end-use equipment. For example, how many old toilets, urinals, and showerheads have been replaced through renovation or conservation projects? And were high-efficiency fixtures and appliances or conventional fixtures installed? The term used to describe the number of efficient fixtures in operation is the "penetration rate." For new buildings constructed

after 1995, the penetration rate may be one-hundred percent; the Energy Policy Act of 1992 mandates that as of January 1995 manufacturers must produce toilets that have a flush rate of 1.6 gallons or less. Similar regulations are also in effect for domestic showerheads and lavatories. To improve the confidence level of the savings estimates generated in this study, site surveys and audits are required to accurately characterize equipment and determine penetration rates.

These onsite studies should include an evaluation of occupancy levels and water practices in addition to a characterization of existing water end-use equipment. Water use is directly linked to building occupancy. Toilet, urinal, lavatory, and shower use is predictable. Therefore, if reliable information on occupancy levels is made available, accurate estimations of water use can be made. It is also important to determine site-specific water use practices, especially in the areas of landscape irrigation, vehicle washing, and process uses. Techniques such as the use of timers, recycling water, and xeriscaping can lead to great savings in these areas.

In addition to the recommendations for more rigorous characterization of water use at FORSCOM installations, further research into federal, state, and local plumbing standards and appliance efficiency codes is also suggested.

H.3 Offsite Facilities

FORSCOM installations often have offsite facilities, including family housing units, which may obtain water and sewer services from a different source or different sources than the installation. Water use and savings at these facilities is certainly significant. However, to reduce the information-gathering burden on FORSCOM utility staff, information on offsite facilities was not pursued in this prioritization study. It is recommended that information on offsite facilities be pursued in the more detailed analyses of the top-ranked facilities.

H.4 Integrated Planning Considerations

Water conservation practices typically have cascading beneficial impacts as is illustrated in Figure H.1 and described below. Replacing an old toilet with an ultra-low flush toilet will trigger a series of resource and cost savings each time the toilet is flushed as follows:

- reduced pumping power to extract water from wells or reservoir
- reduced pumping power required for distributing the water to the end use
- reduced chemical, filtration, and maintenance costs associated with treating and purifying the water
- reduced pumping power and associated costs to transport the wastewater to the sewage treatment plant

Figure H.1. DoD Installation Water Balance

- reduced chemical and maintenance costs, and pumping power associated with sewage treatment
- reduced costs associated with permits allowing the discharge of treated sewer water to a river or stream.

There are other possible considerations and benefits that can accrue from rigorous water conservation programs. For example, in an analogy to energy, stabilized or reduced water use and subsequent reduction of wastewater volume can lead to the postponement or avoidance of water and wastewater facility expansion or the construction of new facilities. Implementation of water conservation programs can also pay big dividends during periods of drought by avoiding the need for water rationing or other water-use restrictions. In addition, not all aquifers or groundwater sources replenish completely during the rainy season. Pulling less water from aquifers can lengthen their useful life and in some cases can contribute to maintaining their water quality.

When developing Master Plans that require new or expanded water and wastewater facilities, FORSCOM installations should evaluate contemporary alternatives such as tertiary treatment and wastewater reuse. If renovation of existing water and wastewater facilities is part of the plan, technologies such as ozonation for water treatment, UV for wastewater treatment, and electro-chemical ion exchange processes for water treatment should be considered both from a cost savings and environmental perspective.

These above issues were not investigated in this study and should be a focus area in any detailed site assessments and studies to follow.

H.5 Calculating WRO Savings

For some of the water resource opportunities, calculating the savings potential was difficult. Many times the technology or technique relied on numerous factors that vary from site to site (e.g., site-specific usage, operating conditions, in-place technologies). To properly identify the savings potential, a site-specific, in-depth study is required. Therefore, the savings potential for some of the technologies discussed in the WRO list (see Appendix D) was not included or was roughly estimated in the analysis because of the ambiguity in calculating the savings, as listed in the following:

• Processes	• Wastewater Treatment
• Irrigation	• Leak Detection

H.5.1 Processes

Processes that are included in the WRO list are cooling towers, single pass cooling, evaporative coolers, boilers, and steam generators. There are opportunities for savings for each of these technologies; however, determining the savings depends on the equipment number, type, size, operating conditions, annual use, etc. Because of these various factors, a site-specific study is essential to determine accurate savings. Also, the water consumption for the plant and process facility type (based on consumption of makeup water fed to the system) was extremely low when compared to other water usage areas (e.g., irrigation, family housing). This deemphasizes the importance of complicated analyses in calculating the savings.

H.5.2 Irrigation

There are many ways to save irrigation and landscaping water (e.g., graywater use for irrigation, xeriscaping, and drip irrigation), but these techniques are very hard to quantify because of the numerous variables involved, such as plant water needs, climate condition, watering restrictions, landscape layout, in-place technologies, etc. Because irrigation was usually a large portion of the total water use at the installations, irrigation savings was estimated by examining case studies that employed various conservation techniques. The savings found in these case studies ranged from 20% to 60% (Rocky Mountain Institute 1991).

H.5.3 Wastewater Recycling and Reuse Systems

Wastewater treatment facilities have potential to save water through a recycling or reuse system. In general, a recycling system is defined as a system that reclaims and filters the water to be used in the same end use, where a reuse system treats the water and uses it for other uses. The savings were difficult to quantify because they depend on the method of treatment, the end use available for reuse, and the end uses in need of recycled water. Therefore, this opportunity was not examined in this initial study.

H.5.4 Leak Detection Program

Leak detection and repair can have a significant opportunity for savings. Most installations have over 10% unaccounted water losses (this can be as high as 30%) which may be due to large system leaks. A CERL study was done at Army installations on the benefits of leak detection. The study reports the benefit-to-cost ratio can be greater than three in leak detection programs (Maloney et al. 1986). However, estimating the savings potential of leak detection requires site-specific data such as distribution system details, leak locations and sizes (requiring rigorous field work), and daily water flow data (for comparison of daytime and nighttime flows).

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