# Fort Riley Net Zero Water Roadmap

**July 2013**

# Fort Riley

# Net Zero Water Roadmap

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# Executive Summary

The Department of the Army created the Net Zero initiative to advance the sustainability of the Army by managing natural resources with the goal of establishing net zero installations. Net zero espouses the concept of consuming natural resources responsibly based upon knowledge of long-term resource availability, thereby creating a sustainable environment to support each installation's continuing mission. The Army is pursuing net zero programs in energy, water, and solid waste. The net zero initiative was launched with installation-level pilot programs designed to establish an implementation framework and to learn key lessons about alternative approaches to net zero success. Fort Riley volunteered as a pilot installation for net zero water. This roadmap lays out a comprehensive strategy for Fort Riley to meet net zero water.

To focus its efforts, Fort Riley has developed a net zero water definition that is tailored to their location, site-specific characteristics, and anticipated garrison utilization in the future:

> *By FY 2020, Fort Riley will limit the consumption of freshwater resources and return water back to the regional watershed so as not to deplete the groundwater and surface water resources of that region in quantity and quality over the course of a year.*

Along with striving to meet this goal, a major tenet of the net zero water program is significant reduction in the demand for potable water. To this end, Fort Riley will reduce its water use intensity (WUI, measured in gallons per square foot of gross building area) by 50 percent from fiscal year (FY) 2007 to FY 2020.

## Net Zero Water Strategy

To meet the goals of the net zero water program, Fort Riley must aggressively implement efficiency improvements across the major water end-uses and it must investigate ways to access alternative water sources. The Fort Riley pathway toward net zero water is outlined in this document, which lays out a roadmap for how the installation can meet the WUI goal. This roadmap identifies specific water conservation measures (WCMs) and helps to prioritize potential alternative water source projects.

### Net Zero Water Projects Overview

As part of background data collection for the roadmap, current potable water sources and uses were evaluated and described in a water balance assessment.[1] The results of the water balance delineate significant consumption categories and estimate losses as well (Figure ES.1).

[1] Elam, E.C., F.W. Wheeler, P.E. Bassett, J.W. Dupre, K.L. McMordie Stoughton. 2012. *Fort Riley Net Zero Water Balance Report. Pacific Northwest National Laboratory,* Richland, WA. PNNL-21675.

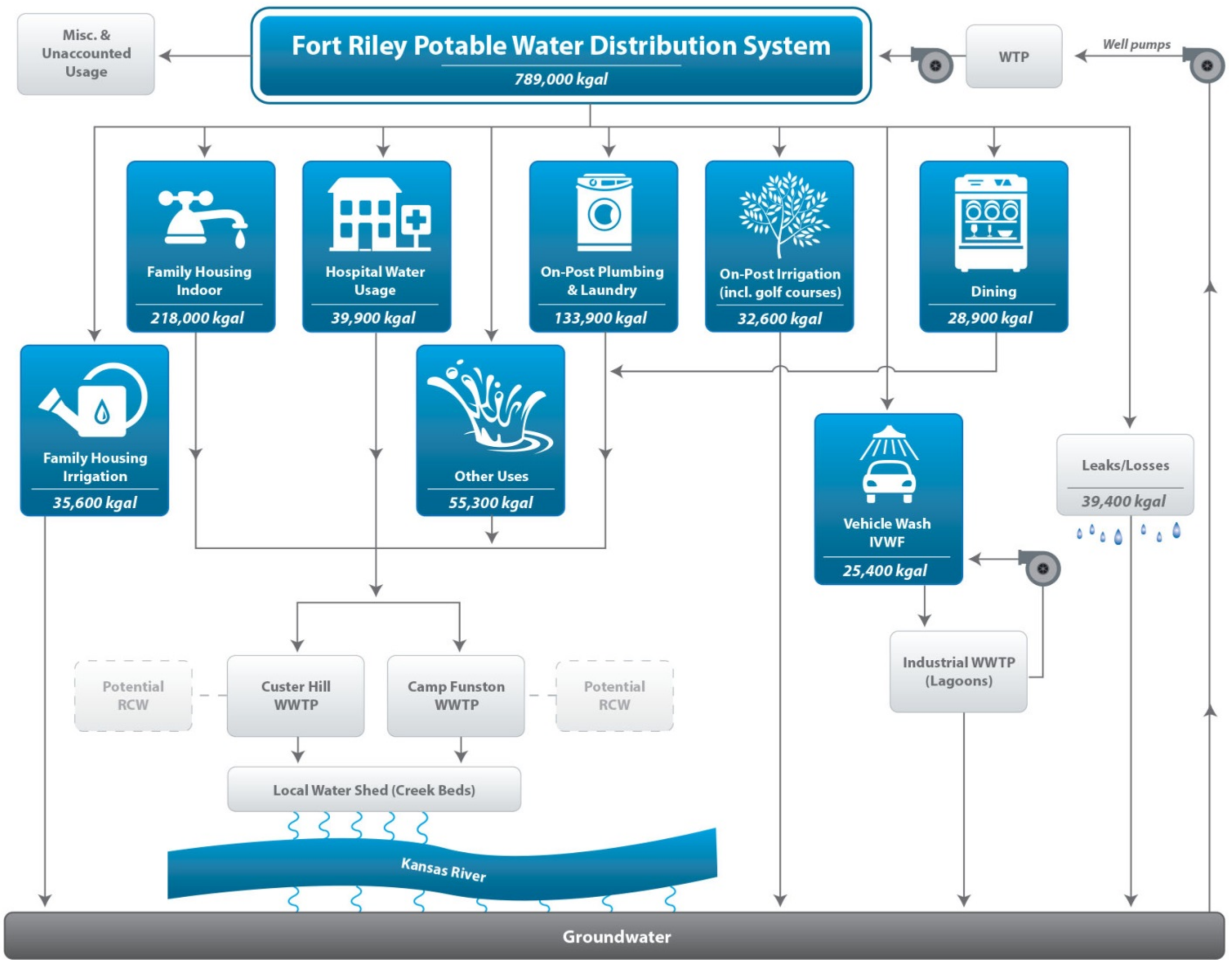


**Figure ES.1**. Fort Riley Potable Water Distribution and End-Use Flow Chart

The assessment identified the following end-use categories that comprise the largest percentages of potable water consumption, and therefore likely affect the net zero goals: on-post domestic use and laundry (22 percent); leak and loss estimates; hospital (7 percent), irrigation (6 percent), vehicle wash (5 percent); and several others with commensurate water consumption patterns including the dining facilities, and miscellaneous uses.

Family housing, including domestic use and irrigation, represents the single largest water use at Fort Riley. Over the past several years Fort Riley has experienced substantial year-over-year increases in summer potable water consumption coinciding with the expansion of irrigated family housing units, particularly in the Forsyth and Custer Hill areas (Figure ES.2).

However, family housing is privatized and though this water consumption category may be targeted through indirect means such as the Environmental Protection Agency's (EPA's) on-site education and outreach programs, they are excluded from Army water use reporting. Thus, family housing is excluded from implementation of WCMs, which could reduce potable water consumption

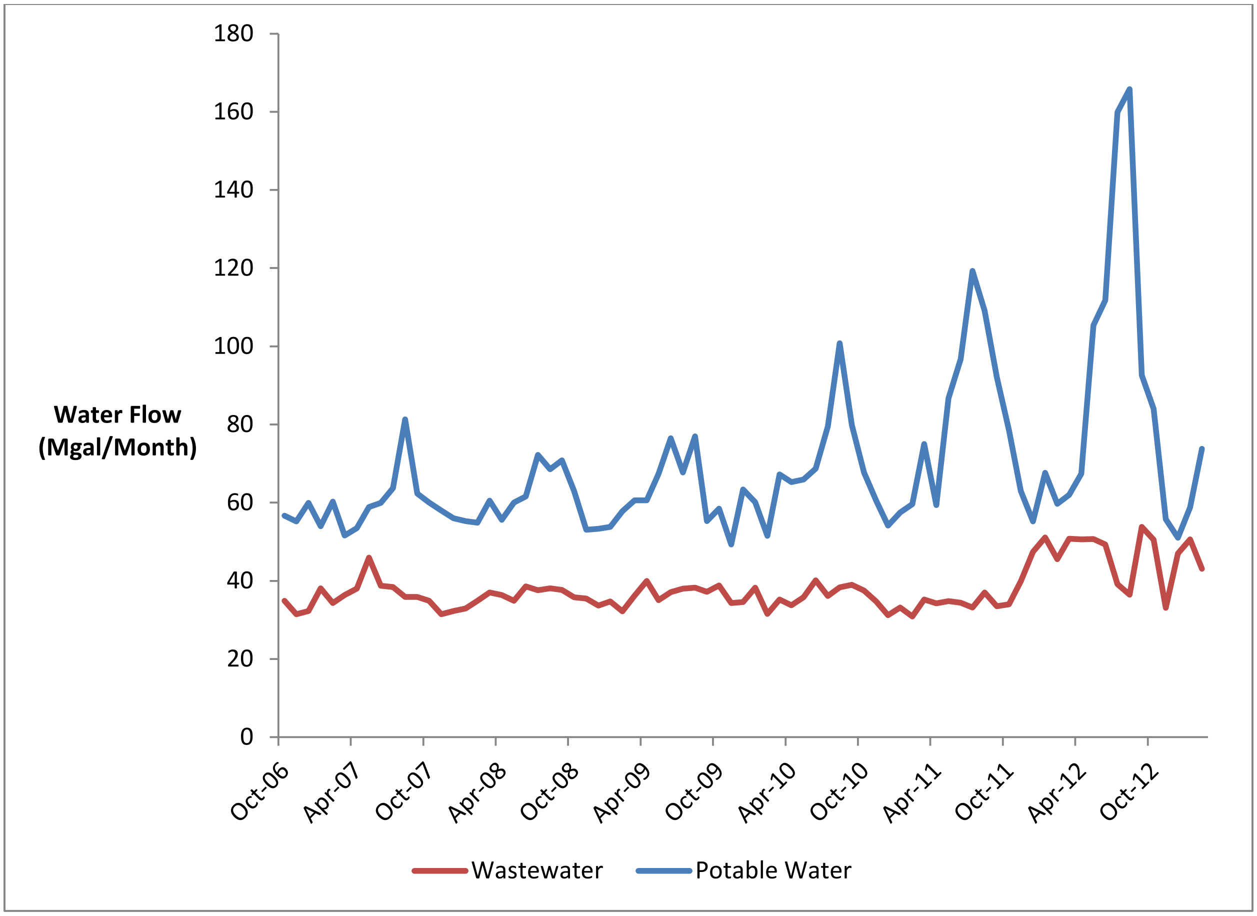


**Figure ES.2**. Summer Potable Water Peak and Wastewater Flows

Significant opportunities exist at Fort Riley to reduce potable water consumption, including replacement or retrofit of domestic fixtures in barracks, administrative, and operations/training facilities; commercial kitchen retrofits; irrigation retrofits; and potable water distribution line replacement. Potable distribution system replacement is currently occurring on the Main Post.

A life-cycle cost (LCC) analysis was performed on each WCM to identify the projects that are cost effective and should be considered for implementation (Table ES.1). The simple payback, savings-to-investment ratio (SIR), and net present value (NPV) indicators are reported to show cost effectiveness relative to each WCM category, which includes water and energy savings where applicable.

**Table ES.1.** Water Conservation Measures Life Cycle Cost Results

| Project Category | Net Zero Water Project | Water Savings (kgal/yr) | Natural Gas Savings (MMBtu/yr) | Installed Cost ($) | Cost Savings ($/yr) | Simple Payback (yr) | SIR | NPV |
|---|---|---|---|---|---|---|---|---|
| **Plumbing** | Administrative | 7,000 | 7,700 | $280,300 | $31,500 | 8.9 | 1.2 | $39,300 |
| | Barracks | 38,000 | 145,600 | $2,065,700 | $219,500 | 9.4 | 1.4 | $56,500 |
| | Motorpools | 3,800 | 4,200 | $361,900 | $19,200 | 18.9 | 0.8 | ($33,600) |
| | Operations and Training | 16,500 | 18,200 | $872,200 | $76,500 | 11.4 | 1.3 | $38,100 |
| | Warehousing | 2,500 | 2,800 | $447,800 | $14,100 | 31.9 | 0.5 | ($79,400) |
| | ***Bundled Domestic Plumbing*** | 67,900 | 178,500 | $4,027,800 | $360,800 | 11.2 | 1.2 | $20,900 |
| **Irrigation** | Controllers-Distribution | 8,600 | - | $177,300 | $12,700 | 14 | 1.1 | $4,400 |
| **Commercial Kitchen** | Commercial Kitchen Equipment | 5,001 | 11,133 | $510,478 | $69,625 | 7.3 | 2.0 | $127,573 |
| **Pool** | Pool Covers | 562 | 24,569 | $22,260 | $3,307 | 6.7 | 2.6 | $1,261 |
| **Reclaimed Wastewater** | Reclaim Custer Hill Effluent | 61,137 | - | $2,141,362[a] | $54,335 | 39 | 0.4 | ($86,673) |

kgal is thousand gallons; MMBtu is million British thermal units.
(a) Includes pumping, storage, and interconnection to golf course and Installation Vehicle Wash Facility supply piping.

The LCC evaluation indicates that implementation of all WCMs with a SIR greater than 1.0 can reduce potable water consumption by approximately 70-80 million gallons (Mgal) per year dependent on how projects are bundled together leaving Fort Riley approximately 170 Mgal/yr short of the net zero WUI reduction goal in FY 2020.

A WCM that has significant potential to reduce potable water consumption at Fort Riley is use of reclaimed wastewater from the Custer Hill wastewater treatment plant (WWTP) for non-potable uses including irrigation, vehicle wash make-up, and other non-potable water uses. This WCM is not cost-effective.

## Time-Phased Implementation Strategy

As part of the roadmap process, a workshop was held in April 2013 with personnel from Fort Riley's Department of Public Works (DPW) and regional EPA participants to review the results of the water balance, evaluate proposed WCMs, and establish a strategy for meeting the net zero water goals. Attendees also investigated funding options for WCM implementation and brainstormed approaches for using alternative water sources such as the effluent from the WWTP. As part of the workshop, two scenarios were discussed as described below (Figure ES.3).

**Scenario 1 –Implementation of LCC-effective WCMs.** Implementing LCC-effective WCMs can reduce Fort Riley's demand for potable water up to 80 Mgal/yr. Scenario 1 also includes modest annual improvements from loss prevention activities such as Fort Riley's current potable water piping and infrastructure replacement project in the main cantonment. To meet the FY 2020 WUI goal equivalent to a 50% reduction from FY 2007 baseline, Fort Riley will have to pursue the replacement or conservation of an additional 170 Mgal/yr of potable water under this scenario.

**Scenario 2 –Implementation of LCC-effective WCMs, EPA Outreach Programs, and Alternative Water.** This scenario includes implementation of all LCC-effective WCMs (Scenario 1), in addition to reductions in potable water consumption through the following:

1. The EPA sewer mining project, which, though largely a testing and validation platform, can help replace up to 2.2 Mgal/yr.
2. Use of alternative water[1] by reclaiming wastewater from the Custer Hill WWTP, which is not a cost-effective measure, could help Fort Riley reduce potable water consumption by an additional 61 Mgal/yr in potable water consumption.
3. On-site outreach and education programs conducted by the EPA and DPW, which could contribute to additional potable water conservation of 8% to 18% through indirect means (~20 to 45 Mgal/yr from family housing water use[2]).

Total potable water reduction from Scenario 2 is potentially up to 180 Mgal/yr. Under this scenario, Fort Riley will have to pursue the replacement or conservation of an additional 80 Mgal/yr of potable water to meet the FY 2020 WUI goal.

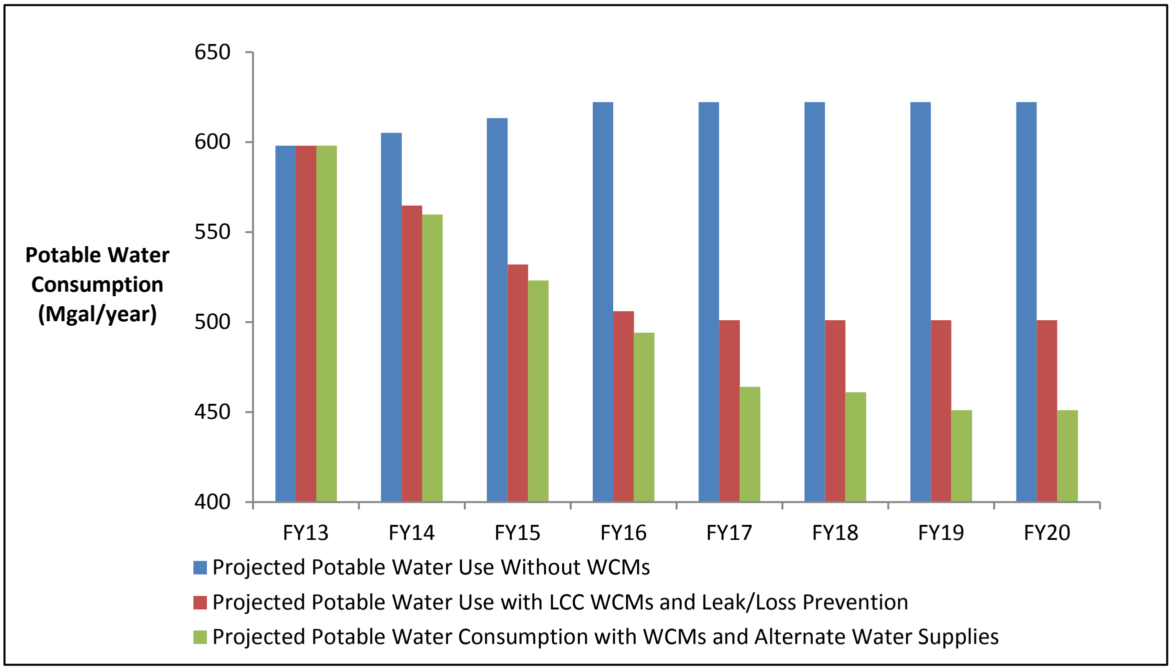


**Figure ES.3**. Reduction in Potable Water Consumption under Scenario 1 and Scenario 2.

[1]Alternative water is defined as non-potable water collected on-site, not obtained from freshwater sources (surface or groundwater) or purchased from an outside source.

[2] Environmental Protection Agency. 2002. *Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs*. Washington, DC.

To meet the potable WUI reduction goal of 50% compared to the FY 2007 baseline, Fort Riley must achieve a building WUI of 24 gal/sqft, reduced from the FY 2007 baseline of 48 gal/sqft. If Fort Riley reduces water use by implementing the cost effective WCMs outlined in the roadmap, in addition to leak and loss prevention, which current infrastructure projects should accommodate, the potable WUI will be 35 gal/sqft. This would be short of the net zero water goal by approximately 13 gal/sqft. If Fort Riley implements cost effective WCMs and is able to capitalize on a funding mechanism that enables sourcing and utilization of alternate water supplies, total demand for potable in FY 2020 would be approximately 451 Mgal/yr with a corresponding WUI of 32 gal/sqft. This is also short of the net zero water goal approximately by 8 gal/sqft (Figure ES.4).

With the implementation of WCMs, loss prevention strategies, infrastructure improvements, and potential expansion of reclaimed water, Fort Riley can deploy technically viable solutions in the pursuit of water conservation objectives. Though ultimately they may not meet the defined 50% reduction relative to the baseline, implementation of WCMs can result in a 27% reduction in WUI by FY 2020. Implementation of WCMs in conjunction with use of alternate water sources can result in a 33% reduction from the baseline WUI demonstrating both significant and impactful progress towards the NZW goal.

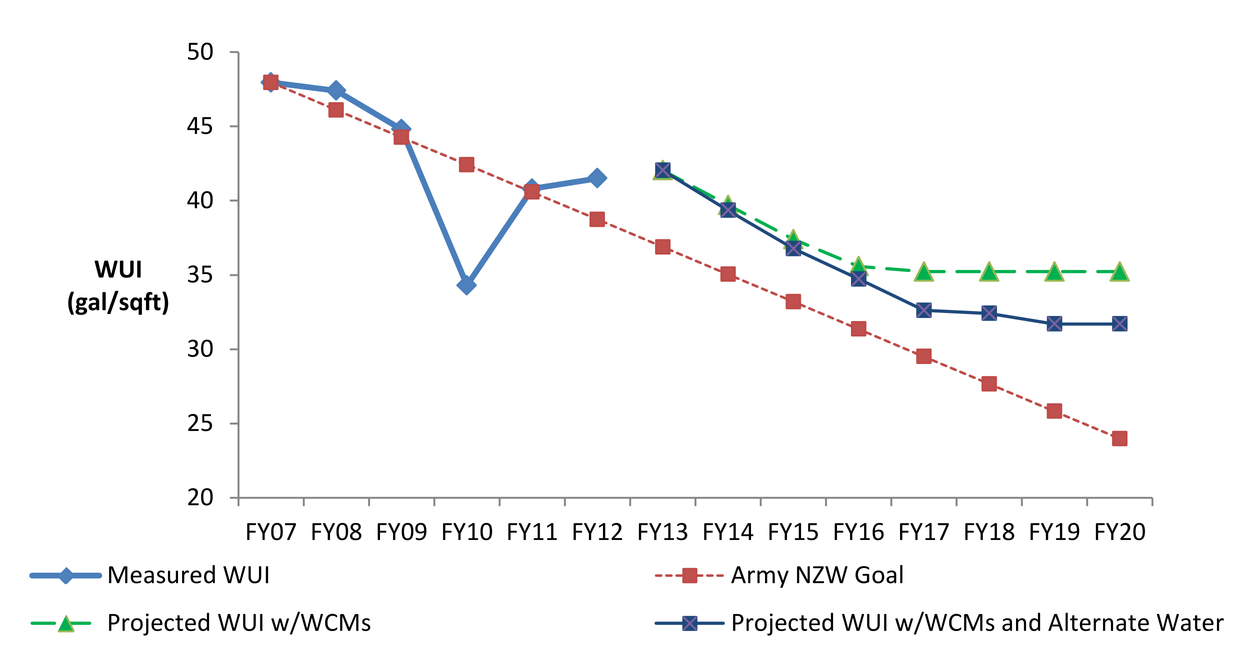


**Figure ES.4**. Fort Riley Projected Progress Toward the Net Zero Water WUI Reduction Goal

Fort Riley can meet the intent of their net zero water definition at the regional watershed level. In the Kansas-Lower Republican basin, well over half of all irrigation and public supply water use is derived from surface water sources (Kenny, 2004). To the extent that Fort Riley captures precipitation from impervious surfaces and contributes that stormwater to receiving surface water sources through outfalls, the site is supplying the watershed with a usable freshwater source that would otherwise be obtained through alternate means such as drawing on groundwater resources.

Quantifying this contribution is relatively straightforward. With an average annual precipitation rate of 33 inches and an impervious surface area of approximately 2,000 acres,[1] almost 2 billion gallons of water hit these surfaces annually. While a significant percentage of the precipitation can be lost to evapotranspiration, depending on ambient conditions and event duration, runoff from impervious surfaces over the course of year could still be expected to displace in excess the amount of potable water pumped and consumed on site. The net benefit to the site is not realized because the stormwater is not contained and reused. However, the net benefit to the regional watershed from that non-potable freshwater contribution is applicable given the known end-uses.

[1] Includes Custer Hill Troop Area, Main Post, Camp Funston, Marshall Army Air Field, and Camp Whitside. Does not include roadway surfaces.

# Acronyms and Abbreviations

| | |
|---|---|
| AEWRS | Army Energy and Water Reporting System |
| AFO | acoustic fiber optics |
| AWWA | American Water Works Association |
| CERL | Construction Engineering Research Laboratory |
| CY | calendar year |
| DOD | Department of Defense |
| DPW | Department of Public Works |
| DU | distribution uniformity |
| ECIP | Energy Conservation Investment Program |
| EO | Executive Order |
| EPA | Environmental Protection Agency |
| EPAct | Energy Policy Act |
| ESCO | energy service company |
| ESPC | energy savings performance contract |
| ET | evapotranspiration |
| ETo | reference evapotranspiration |
| EU | emission uniformity |
| FEMP | Federal Energy Management Program |
| fps | feet per second |
| FY | fiscal year |
| gal/sqft | gallons per square foot |
| gpf | gallons per flush |
| gpm | gallons per minute |
| IACH | Irwin Army Community Hospital |
| IDIQ | indefinite-delivery, indefinite-quantity |
| ILA | industrial, landscaping, and agricultural |
| IVWF | Installation Vehicle Wash Facility |
| kgal | thousand gallons |
| LCC | life cycle cost |
| LEED | Leadership in Energy and Environmental Design |
| M&V | measurement and verification |

| | |
|---|---|
| MBR | membrane bioreactor |
| Mgal | million gallons |
| MILCON | Military Construction |
| MWR | Morale, Welfare, and Recreation |
| NIST | National Institute of Standards and Technology |
| NOAA | National Oceanic and Atmospheric Association |
| NPV | net present value |
| NZW | net zero water |
| O&M | operations and maintenance |
| OMA | Operations and Maintenance, Army |
| PDSI | Palmer Drought Severity Index |
| PNNL | Pacific Northwest National Laboratory |
| psi | pounds per square inch |
| PV | present value |
| PVC | polyvinyl chloride |
| RSMS | Readiness Sustainment Maintenance Site |
| SIR | savings-to-investment ratio |
| SRM | sustainment, restoration, and modernization |
| UESC | utility energy service contract |
| WCM | water conservation measure |
| WTP | water treatment plant |
| WUI | water use intensity |
| WWTP | wastewater treatment plant |

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# 1.0 Introduction

In 2011, the Department of the Army created the Net Zero initiative to advance the sustainability of the Army by managing natural resources with the goal of establishing net zero installations. The net zero concept is founded upon the idea of consuming natural resources responsibly based upon knowledge of long-term resource availability, creating a sustainable environment to support the installation's long-term mission. The Army is pursuing net zero programs in energy, water, and solid waste. To kick off the net zero initiative, the Army requested installations to volunteer to become a pilot installation in one or more of the net zero areas.

Eight installations volunteered to be pilots for water and solid waste, with nine for energy. Two of these installations were designated as pilots in all three areas (Figure 1.1). Fort Riley is one of the eight water pilot sites.

To support Fort Riley, the Army contracted with Pacific Northwest National Laboratory (PNNL) to develop a roadmap to assist Fort Riley in implementing its net zero water program. The roadmap provides a strategy for Fort Riley and lays out a time-phased approach for project implementation to reach the net zero water reduction requirements and site-specific net zero water goal.


**Figure 1.1**. Net Zero Pilot Installations

## Net Zero Water Definition and Goals

The Army has broadly defined a net zero water installation as an installation that limits the consumption of freshwater resources and returns water back to the same watershed so as not to deplete the groundwater and surface water resources of that region in both quantity and quality over the course of a year. The net zero water strategy attempts to balance water availability and use to ensure a sustainable water supply for years to come. This concept is of increasing importance because water scarcity is a serious issue in many parts of the United States. The continued drawdown of major aquifers is a significant problem for our nation's future. Strategies such as replacement of domestic fixtures, recycling and reusing discharged wastewater, and outreach and education programs have all been shown to reduce the demand and consumption of potable water.

It can be very difficult for the pilot installations to achieve the Army's definition of net zero water because the definition is tied to a singular watershed system. Some of the pilot installations may not meet this definition because they use or effect water resources from multiple watersheds. Therefore, each pilot installation has developed a tailored net zero water definition that suits the environment at the site. For example, Fort Riley receives water from the Lower Republican watersheds, but discharges to a surface water source that influences both the lower Republican and Kansas River watersheds. Therefore, Fort Riley has developed a tailored net zero water definition:

> *By FY 2020, Fort Riley will limit the consumption of freshwater resources and return water back to the regional watershed so as not to deplete the groundwater and surface water resources of that region in quantity and quality over the course of a year.*

Along with meeting the tailored definition, net zero pilot installations must also empirically reduce water demand. Executive Order (EO) 13514 requires Federal agencies to set a baseline for potable water use at fiscal year (FY) 2007 and reduce potable water use intensity (WUI measured in gallons per square foot of building area) by 2% per year based on an FY 2007 baseline through FY 2020, for a total reduction of 26%. EO 13514 also requires the reduction of industrial, landscaping, and agricultural (ILA) water use[1] by 2% per year through FY 2020 based on an FY 2010 baseline. However, for the net zero water pilot installations, the Army has accelerated the WUI reduction goal. As part of the net zero water pilot, Fort Riley is also required to meet the following goal as follows:

- Reduce potable water use intensity (WUI) (gallons per square foot) by 26% in fiscal year (FY) 2015 and 50% by FY 2020 based on an FY 2007 baseline
- Reduce industrial, landscaping, and agricultural (ILA) water use by 20% by FY 2015 and by 40% by FY 2020 based on an FY 2010 baseline

Fort Riley does not currently use any ILA water because all water on-post is supplied from freshwater sources and treated to potable standards. Therefore, Fort Riley is required to meet the potable WUI goal only until or unless ILA water is pursued as a strategy to conserve potable water. This roadmap targets this potable WUI reduction goal and helps Fort Riley form a strategy to meet its net zero water commitment.

### Current Net Zero Water Goal Progress

Fort Riley is currently meeting the EO 13514 potable WUI reduction goal for FY 2012 at 42 gallons per square foot (gal/sqft); this is slightly higher than the net zero WUI glide path of 39 gal/sqft. Note that the net zero glide path is a straight line average decrease over the 13 years from FY 2007 to FY 2020 (Figure 1.2).

[1] This category represents non-potable uses of freshwater in ILA applications that are not included in the potable water category.

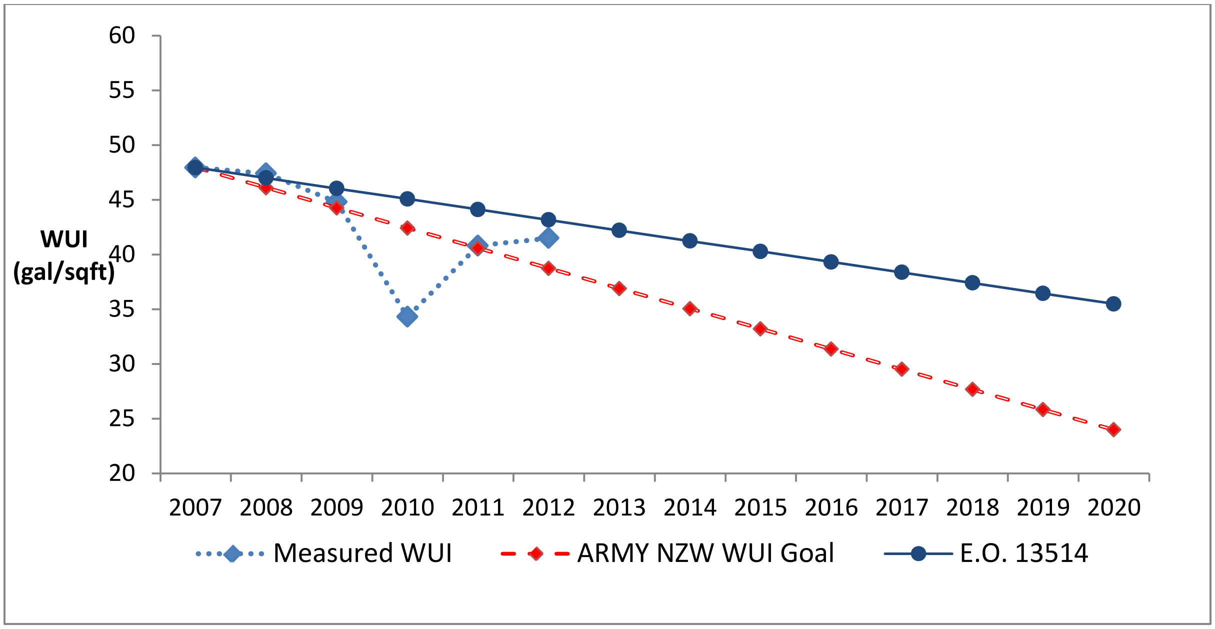


**Figure 1.2**. Annual Potable WUI and Projected WUI Reduction Glidepath

To maintain the net zero glide path objective, Fort Riley will have to reduce its FY 2012 potable water use as reported in Army Energy and Water Reporting System (AEWRS) by approximately 251 million gallons (Mgal) annually in order to meet the FY 2020 WUI goal of 24 gal/sqft. With WUI plotted along with historical and future potable water consumption (Mgal/yr), the challenge becomes more evident (Figure 1.3).

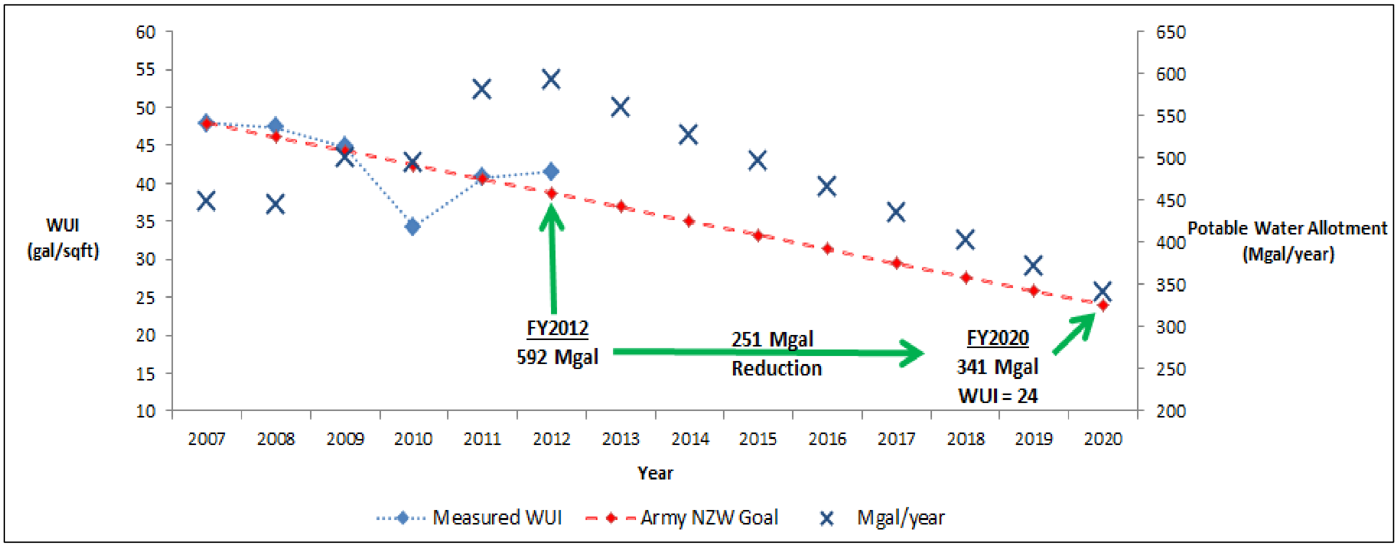


**Figure 1.3**. Net Zero Glidepath to Meet FY 2020 Goal

Although Fort Riley has maintained their target WUI goal for several years, potable water use increased significantly in FY 2012, which caused the installation's WUI to increase by 3 gal/sqft and exceed the net zero glide path goal by approximately 40 Mgal/yr.

There are multiple contributors to the 32% increase in potable water consumption over the previous five years. The most significant effect on potable water use is likely due to the expansion of irrigated turf in on-post common spaces and among irrigated family housing areas. Additionally, because all water on-site is potable, the continuous expansion of family housing areas has placed an uncharacteristically large burden on construction water uses for soil preparation and dust control. Though family housing is removed from AEWRS reporting, potable irrigation and construction water is apportioned based on the difference between winter (baseline) and summer peaks such that as more housing is established, more potable water will be apportioned to the post whether it is actually consumed there or not. Recent comparative seasonal data indicates spikes of more than 100 Mgal/month, whereas historical peaks (FY2007) prior to significant expansion activities indicated a summer spike of 25 Mgal/month.

Drought-related effects from the past year have also increased demand for water from the vehicle wash facility due to high evaporative loss and limited recharge from precipitation. Finally, additional end-uses such as line flushing likely have increased the demand for potable water while having no corresponding increase in wastewater production.

Collectively, when coupled to fairly static site-wide square footage estimates and despite continued expansion of irrigated turf space through FY 2016, Fort Riley needs to reduce its potable water consumption by over 250 Mgal/yr to meet the net zero WUI reduction goal.

# 2.0 Summary of Regional Water Demand and Availability

It is important to understand the regional water supply, demand, and availability when creating a net zero water strategy. The issues that face the Republican River Basin and Kansas River regions will directly affect Fort Riley's ability to meet mission critical water needs. This section provides an overview of regional and Fort Riley water demands, and potential long-term availability and sustainability issues.

## Fort Riley Water Supply

Fort Riley falls within two sub-basins of the Kansas-Lower Republican Basin: the Lower Republican and Upper Kansas. The Kansas-Lower Republican Basin covers 10,500 square miles. Population in the basin was estimated to be 1,025,644 in 2000 and is projected to reach 1,583,584 by 2040 (Kansas Water Office 2009).

For the production of potable water, Fort Riley withdraws freshwater from shallow alluvial aquifers that border the Republican River downstream of Milford Lake but prior to the confluence with the Smoky Hill River. These two rivers combine to form the Kansas River. Located in the Camp Forsyth area, eight groundwater wells with maximum pumping capacities varying from 700 to 1,200 gallons per minute (gpm) withdraw freshwater that supplies the central water treatment facility located to the immediate north of the well field. The water treatment plant (WTP) produces an average of 2 to 3 Mgal per day, but is designed to provide up to 10 Mgal per day at maximum capacity, allowing potable water demand to grow. Though the WTP may be capable of higher treatment volumes, pumping data indicates that Fort Riley has come very close to maximum production capacity of the well field at approximately 5,000 gpm (7 Mgal per day), which is well below the capacity of the WTP. Though high withdraw rates were commonly associated with shorter duration events, such as mid-August 2012 when seven of eight wells were operating (Otto 2013), well logs suggest that the frequency of higher pumping rates is increasing with the expansion of irrigated turf areas on-post and in family housing.

An additional concern at Fort Riley is the condition and integrity of the potable water supply infrastructure. For example, two wells have been completely removed from service due to failure (Wells #2 and #8), whereas additional wells have had to reduce their operating capacity due to the loss of pumping capacity from failed screens in the well bore (Wells #1, #5, and #6). It is unknown if this is due to excessive pumping, age and condition of the screened interval, or some combination of mechanical and operational variability. With an average pipeline age of approximately 50 years, Fort Riley has recently been engaged in a significant potable water line replacement project around the Main Post. Along with the pipeline replacements, strategic new sub-metering installations are intended to enable more effective estimates of consumption, conservation, and loss.

Fort Riley's water system currently services approximately 55,000 people via 283 miles of water line (Otto 2012). Population in the surrounding area including Riley, Geary, and Pottawatomie counties, was 108,583 in 2010, but projections estimate a decline to 106,403 by 2025 (Jenicek et al.

2011). However, the population within the broader Kansas-Lower Republican Basin is estimated to grow 54% from 2000 to 2040 (Kansas Water Ofice 2009).

## Long-Term Regional Water Sustainability

Three studies examined the water supply sustainability throughout the nation, and can be used to forecast Fort Riley's future water supply. Taken together, these studies provide evidence that Fort Riley will continue to face water supply challenges in the future.

The Army Corps of Engineers' Construction Engineering Research Laboratory (CERL) developed a water sustainability assessment for Fort Riley (Jenicek et al. 2011). The main objective of the analysis was to assess Fort Riley's vulnerability to regional water shortage. CERL found that Fort Riley's watershed is vulnerable due to the growing regional water demand, population growth, and climate change (Figure 2.1). The study found that water use in the local area declined almost 30% from 1985 to 2005. However, within the regional area along the Republican River, there is a water recharge shortage that is projected to continue into the future. (Jenicek et al. 2011)

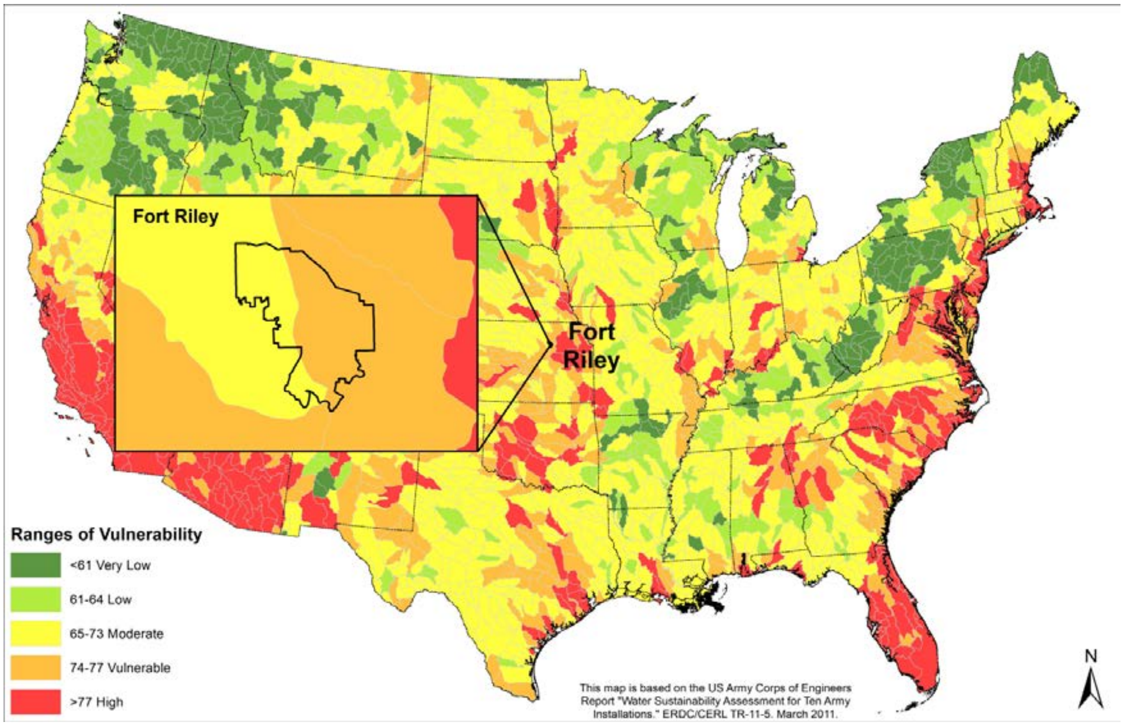


**Figure 2.1**. Water Sustainability Vulnerability for Fort Riley

Tetra Tech produced a similar study in 2010 that estimated the long-term climate change effects on water availability across the United States (Roy et al. 2010). As part of the research, a water supply sustainability index was produced that assessed the nation's water supply under two scenarios: (1) water availability under the influence of future climate change and (2) water availability with no projected climate change. This index was created to predict where water shortages will most likely occur. The water supply sustainability index without climate change for the Fort Riley area shows that Fort Riley falls within a moderate water supply sustainability index. With potential climate change, Fort Riley falls within a high risk area (Figure 2.2) (Roy et al. 2010).

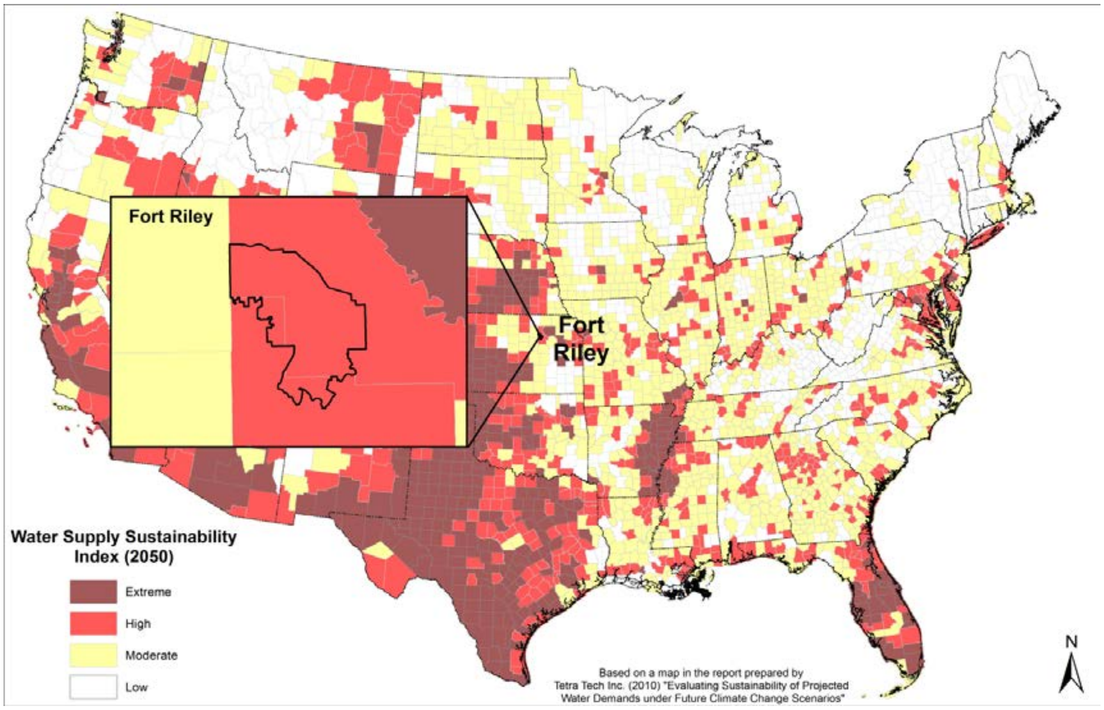


**Figure 2.2**. Water Supply Sustainability Index (2050) and Climate Change for Fort Riley

Short-term and long-term droughts are common in the region. Though 2013 precipitation has been capable of reducing the drought conditions in Kansas, the 2012 drought registered as one of the most severe since modern record keeping began in 1895. The Palmer Drought Severity Index (PDSI) was developed as a way to determine historical long-term soil moisture conditions. The PDSI for 1895 to 1995 shows that the Fort Riley region had a 10% to 15% occurrence of severe and extreme drought for that period. Historical NOAA drought data from 1996 to 2010 shows that Fort Riley's occurrence of severe and extreme drought was less than 5% over this period (Giever and Loper 2011). The region currently overdraws water from the aquifer and is projected to continue to overdraw. Since the amount of water in the aquifer is unknown, the severity of the water recharge shortage is also unknown. Water scarcity will occur if current conditions continue, but when that scarcity will occur is unknown (Jenicek et al. 2011).

Equally important to historical and modern drought conditions is that the withdraw of water from the Lower Republican is based on water allocations in the Republican River Compact signed between Colorado, Nebraska, and Kansas. The compact is complex and the water allocations are now highly disputed between the states. For example, Kansas claims in legal proceedings that upstream partners in the compact are exceeding withdraw rates depriving Kansas of its full water claim. Though Fort Riley technically is not subject to state water regulations, the Lower Republican River and associated alluvial aquifer certainly may be affected by the withdraw rates of upstream consumers of groundwater and surface water systems in the Republican River watershed and variations to aquifer recharge rates.

Fort Riley lies in a highly vulnerable region for water scarcity considering historic water availability concerns, natural drought conditions, forecasted climate change effects, growing regional population, and regional water shortages. The net zero water program will help Fort Riley in meeting its mission critical water needs if future water supplies are constrained.

# 3.0 Summary of Fort Riley Water Balance

The Fort Riley water balance provides information on water supplied to the installation and estimated water use by facility type and end-use. It then compares these uses to the total water supplied. The water balance is an important benchmark for the net zero water initiative because it provides information on where water is being used, how much water is being used to perform the installation's mission, and the key areas that Fort Riley should target for water reduction and efficiency improvements (Elam et al. 2012).

## Water Supply and Wastewater Treatment

Fort Riley's water supply system is supplied by a system of wells via one 24-inch diameter concrete main to the central water treatment facility in the Custer Hill cantonment area. The WTP is designed to provide 10 Mgal per day at maximum capacity. Currently, the plant produces an average of 2 to 3 Mgal per day to meet water demands on-post, allowing for significant future growth.

The WTP consists of multi-stage treatment, including de-aeration, softening, flocculation, filtration, and chlorination. Once treated, one 20-inch diameter supply main distributes water to various storage towers and throughout the installation. Regular line flushing of the water distribution system is performed to maintain residual chlorine levels at terminal ends of the piping network.

The WTP's raw water supply, as well as the treated potable water supply to the post, is metered via pressure differential sensors installed on the respective supply lines. Fort Riley personnel have encountered discrepancies between the raw supply and the treated supply. As part of the water balance analysis, minimally invasive sub-meters were installed at each supply location to provide a calibration of the existing meter systems and weir based production data. As part of the roadmap process, Fort Riley took ownership of the meters and is currently evaluating infrastructure needs for the communication network at the water production plant.

Fort Riley has two on-site wastewater treatment plants (WWTPs) which discharge into local surface water sources that eventually supply the Kansas River. Storm and sanitary sewer systems are separate at Fort Riley, but there is some minor infiltration and intrusion of these systems. One of the WWTPs is located in the Custer Hill cantonment area and can treat 2.3 Mgal per day under normal conditions with a maximum treatment capacity of 7.5 Mgal during storm events. Currently, the Custer Hill WWTP discharges an average of 0.767 Mgal daily.

The other WWTP is newly built, located in the Camp Funston cantonment area, and can treat 2.5 Mgal per day under normal conditions, with a maximum treatment capacity of 6.8 Mgal per day during significant precipitation events, and high storm water runoff. Currently, the Camp Funston WWTP discharges an average of 0.7 Mgal daily.

## Reported Potable Water Use

Fort Riley reports potable water use, excluding privatized family housing and various other reimbursable customers, quarterly into AEWRS. A variety of different methods are used to separate family housing and other reimbursable customer consumption, including billing based on square footage, sub-metering, and estimated consumption billing. Five years of this reported water use was provided for the water balance analysis. During this period, Fort Riley reported an annual water use varying from a high of 592 Mgal in FY 2012 to a low of approximately 445 Mgal in FY 2008. The baseline consumption reported in FY 2007 was 448 Mgal (Figure 3.1).

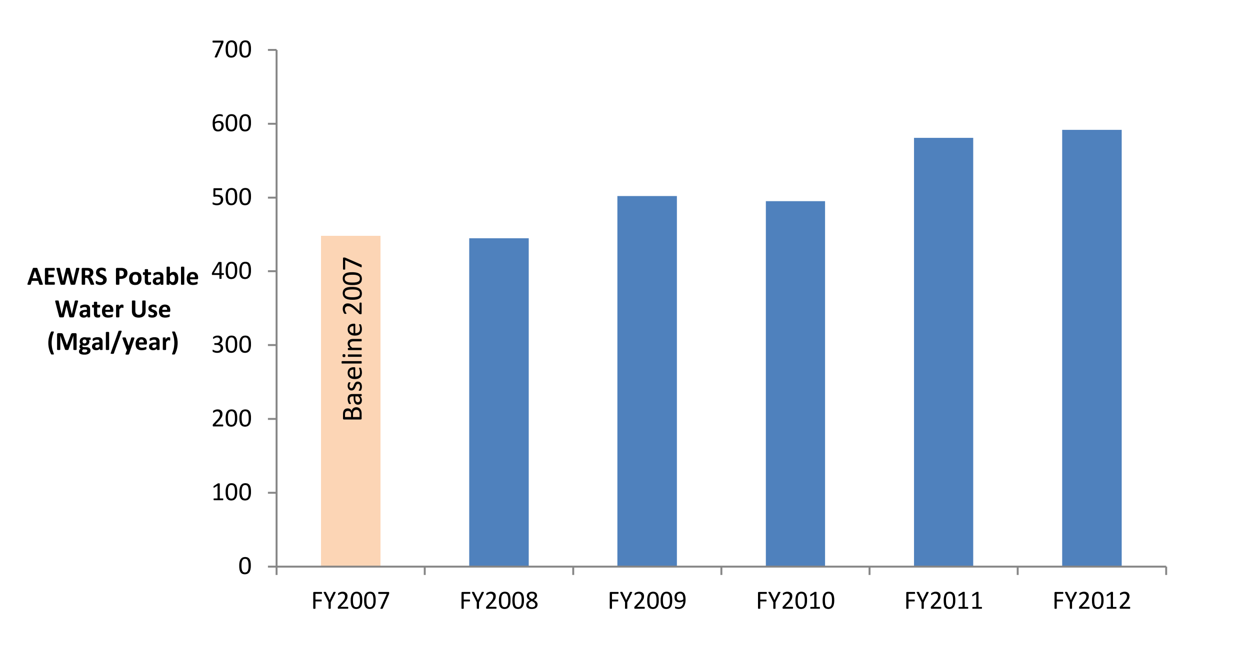


**Figure 3.1**. Total Annual Water Consumption at Fort Riley, FY 2007 to FY 2011 (AEWRS)

## Current End-Use Water Consumption

In the water balance assessment, water consumption was assessed in barracks, family housing, physical fitness centers, dining facilities, administration buildings, motor pools, the vehicle wash facility, irrigation (site wide including golf course), and the hospital. Fort Riley's top five water-use categories are family housing domestic plumbing fixtures, plumbing fixtures in barracks, on-post irrigation (including the golf course, common areas, and irrigation at privatized family housing), the hospital, and military daytime domestic plumbing (Table 3.1).

**Table 3.1**. Estimated Water Use by Major End-Use Category

| Water Use Category | Average Water Use (kgal) | % of Total Use |
|---|---|---|
| **Family Housing Domestic Plumbing** | 186,500 | 24% |
| **Barracks Domestic Plumbing** | 73,000 | 9% |
| **Hospital** | 39,900 | 5% |
| **Distribution System Losses** | 39,400 | 5% |
| **Family Housing Irrigation** | 35,600 | 5% |
| **Military Daytime Domestic Plumbing** | 35,100 | 4% |
| **On-Post Irrigation (includes Golf Course)** | 32,600 | 4% |
| **Family Housing Laundry** | 31,500 | 4% |
| **Dining / Various Kitchen Equipment** | 28,900 | 4% |
| **Installation Vehicle Wash Facility** | 25,400 | 3% |
| **Line Flushing** | 19,300 | 2% |
| **Chiller Plants / Cooling Towers** | 15,500 | 2% |
| **Civilian/Contractors Domestic Plumbing** | 13,500 | 2% |
| **On-Post Laundry** | 12,300 | 2% |
| **Motor Pools / Vehicle Washing** | 7,500 | <1% |
| **Schools** | 4,300 | <1% |
| **Family Housing Swimming Pools** | 3,500 | <1% |
| **Morale, Welfare, and Recreation Swimming Pools** | 2,900 | <1% |
| **Boiler Plants** | 2,300 | <1% |

kgal is thousand gallons.

The water balance was based on estimated end-uses of approximately 609 Mgal annually. The average potable water supplied to Fort Riley between FY 2007 and FY 2011 was 789 Mgal, noting that in FY 2012 the peak was slightly more than 1,000 Mgal. While family housing collectively accounts for more than 40% of the end-use estimate, the top five uses not including distribution system loss comprise 67% of the total water consumption at Fort Riley based on the rolling annual average, therefore providing an indication of where to focus resources (Figure 3.2).

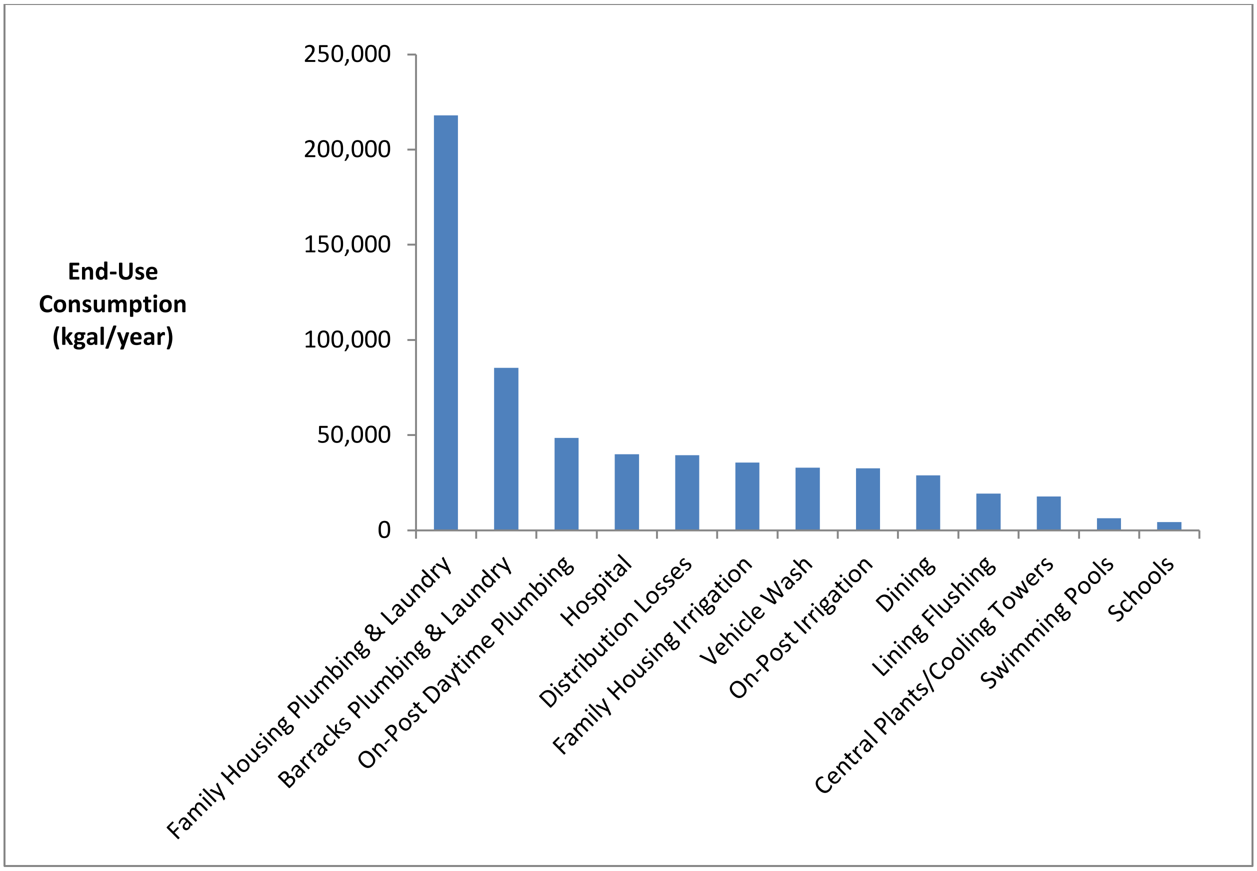


**Figure 3.2**. Fort Riley Annual Water Use Breakout

The difference between the water supply and the end-use estimate was 23%, and represented a variety of miscellaneous uses that were not assessed during the water balance due to Fort Riley's large and complex operations and infrastructure. This is not an uncharacteristically high "unknown" water amount, particularly given the lack of supporting metering and sub-metering, but it is a volume of water that is expected to be allocated and/or reduced as part of a strategic metering program being addressed as infrastructure improvements are made or installed.

### Privatized Family Housing

The single largest consumer of potable water at Fort Riley is privatized family housing, which consists of 4,042 privatized family housing units, most of which are 3 or 4 bedroom houses (77% of available houses). Approximately 14,400 military personnel and family members reside in Fort Riley family housing. Between FY 2007 and FY 2011, privatized family housing averaged 186,000 kgal of water per year plus nearly 36,000 kgal per year for irrigation (information from billing data), and 31,500 kgal per year for laundry, comprising over 40% of total Fort Riley end-use consumption.

The actual growth in family housing units has been modest, varying from 2% to 7% growth in available homes per calendar year.[1] Additionally, according to family housing representatives at

[1] DPW email correspondence with Corvias Family Housing Contractor. 5/28/2013.

Fort Riley, new family housing domestic fixtures reflect current equivalencies for water and energy conservation objectives.  However, there are several important caveats:

1. Growth in family housing units is increasingly dominated by 3 and 4 bedroom houses; in calendar year (CY) 2006, approximately 60% of housing was 3 to 4 bedroom, and by CY 2016 it is expected to be 86%.

2. Most of these new family housing units include individually irrigated and controlled turf and landscaping areas.

3. The new family housing “communities” include large irrigated public use areas that are independently controlled.

This net zero water roadmap does not include privatized family housing for implementation of conservation measures because family housing is not owned by the Army.  Family housing efficiency improvements and reduction efforts are the responsibility of the private, non-Federal owner and are outside Fort Riley’s net zero water program.  Though direct WCMs may not be applicable to family housing, given the effect on potable water consumption, there is value in collaborating with Corvias, the military housing contractor, to understand and manage use patterns, help to establish and monitor metering and sub-metering goals, and assist with the implementation and measurement of the EPA education and outreach projects at Fort Riley.

### Barracks

Fort Riley houses about 5,700 soldiers in 71 barracks totaling 2.8 million square feet.  Plumbing fixtures in barracks accounts for approximately 73 Mgal annually.  Historic limestone constructed barracks remain from the late 1800s continue to be used, while newly constructed barracks are LEED-certified[1] buildings.  Ten unique barracks buildings representing the major groupings of barracks were audited (Buildings 27, 214, 672, 685, 7001A, 7492, 7614, 7844, 8018, and 7886). Using these 10 barracks, general types of water-using equipment for all major groups of barracks were estimated.  Of the 10 buildings audited, 3 had unique footprints, whereas the other 7 were representative samples of the remainder of the barrack type on-post.  The 10 buildings audited represent approximately 15% of all barracks.

Information from each of the selected barracks type was collected, including hot and cold water temperatures; number of toilets, faucets, and showers, and flow rating and measured flow rate of fixtures in each of the rooms.  None of the barracks audited had urinals in individual rooms. Though the older barracks had been retrofitted with higher efficiency plumbing fixtures, the cross-section of barracks audited enabled bundling by type and age and extrapolating potential savings based on those similar features.

Toilets in the barracks rooms were typically floor mount, floor discharge tank-type toilets.  Design flush rates for tank-type toilets in the barracks were based on information stamped on the fixture. Tank-type toilets identified on-site had design flush rates between 1.6 and 3.5 gallons per flush

[1] LEED is the U.S. Green Building Council Leadership in Energy and Environmental Design rating system.

(gpf). The majority of common area restrooms had diaphragm flushometer-style toilets. The flush rates of diaphragm flushometer toilets encountered were between 1.6 and 3.5 gpf, with many of the fixtures exhibiting higher than designed flow measurements. For diaphragm flushometer toilets, the auditors measured flush time in seconds to verify the specified flush rate on the fixture. The time it takes to flush a diaphragm toilet is directly related to the flush rate of the fixture. For example, a 5 second flush indicates a 1.6 gpf toilet. Some of the toilets identified in the audit exhibited flush times in excess of 8 seconds, indicating that the valve was malfunctioning or a higher rated flush valve was installed.

Flow rates of faucets and showerheads were measured using calibrated flow bags.[1] Lavatory faucet flow rates measured between 0.5 and 2.5 gpm, whereas kitchen faucet flow rates typically varied from 2.2 to 2.5 gpm. The majority of faucet aerators had typical 2.2 gpm flow rates. Some of the lavatory and kitchen faucets inspected had flow rates higher than their design, indicating that the aerator in the faucet was damaged, and several had been removed. Showerhead flow rates in the audited buildings varied from 1.5 to 2.5 gpm. Although some higher than expected flow rates were observed, the majority of the fixtures that were identified were functioning as designed.

Information was also recorded regarding laundry facilities in each building. The majority of the washing machines were ENERGY STAR front-loading models.

### Dining Facilities

There are four dining facilities at Fort Riley, offering breakfast, lunch, and dinner to both military and civilian personnel. Approximately 8,100 meals are served daily at the dining facilities consuming 29 Mgal/yr of potable water. Three of these facilities, Cantigny Dining Center, Devil's Den Dining Center, and the Demon's Den Dining Center, were audited to assess key water-using equipment such as steam kettles, garbage disposals, food steamers, ice machines, and dishwashers.

The Cantigny Dining Center serves an average of 3,000 meals daily and has eight ice machines, one large food steamer, a dishwashing machine, and a food pulper with two (2 gpm) pre-rinse spray nozzles. The Devil's Den Dining Center serves an average of 1,100 meals daily and has food steamers, pot and dish washer, food pulpers, disposal, and three pre-rinse spray nozzles. The Demon's Den Dining Center serves an average of 1,800 meals daily and has two ice machines, kettle steamers, pot and dish washers, food pulpers, disposal, and pre-rinse spray nozzles. The Airfield Dining Facility, though not audited, serves an average of 2,200 meals per day and contains equipment similar to that in the Demon's Den Dining Center.

### Administration Buildings and Operational/Training Buildings

Fort Riley has approximately 65 administration buildings covering 863,000 square feet, and approximately 412 operational/training facilities covering more than 3.2 million square feet. Together these buildings account for 20% of the total building area consuming approximately 25 Mgal/yr of potable water. These buildings have offices for military, civilian, and contractor

[1] Water is captured in the flow bag for a 5 second interval and the flow rate is provided in marked intervals on the bag.

personnel. Much like the barracks, the administration buildings vary from historic stone buildings built in the late 1800s to newly constructed LEED-certified facilities. The primary water-using equipment in administration buildings are domestic plumbing fixtures such as those commonly found in lavatories.

### Hospital

Irwin Army Community Hospital (IACH) has 44 patient rooms, and additionally provides outpatient services to approximately 6,500 visitors every month. Key water-consuming systems include restroom fixtures, central steam plant, chiller plant, sterilization units, cafeteria, and other water-cooled mechanical equipment. The IACH is master metered. It uses approximately 40 Mgal of water annually, representing 5% of the total water use at Fort Riley when family housing is excluded. A new hospital that is intended to meet LEED certification is currently under construction. The new hospital is scheduled for completion by FY 2016 (see Section 4.0).

### Irrigation

Fort Riley has more than 120 acres of irrigated landscape consuming almost 69 Mgal/yr. Irrigated turf acreage is expected to increase to more than 150 acres once family housing is completed in FY 2016. The irrigated landscape includes the golf course, family housing, family housing common areas such as parks and ball fields, and common areas and landscaping on-post. The golf course staff has strategically replaced some of the higher water consuming grasses with drought resistant turf. This is directly reflected in their aggressive conservation of potable water used for irrigation requirements. Some of the landscape areas around buildings are xeriscaped with plants that are native or adaptive to the Fort Riley area. Recently, many formal irrigation systems that served non-critical areas have been shut down to reduce water consumption, with controllers disabled and powered off.

As previously discussed, summer peak potable water consumption has been increasing year-over-year, and is consistent with the build-out of irrigated turf in family housing and on-post common areas, noting that the significant peak in summer FY 2012 was likely attributed to the compounding influence of the regional drought, in addition to the expansion of housing and irrigated areas (Figure 3.3).

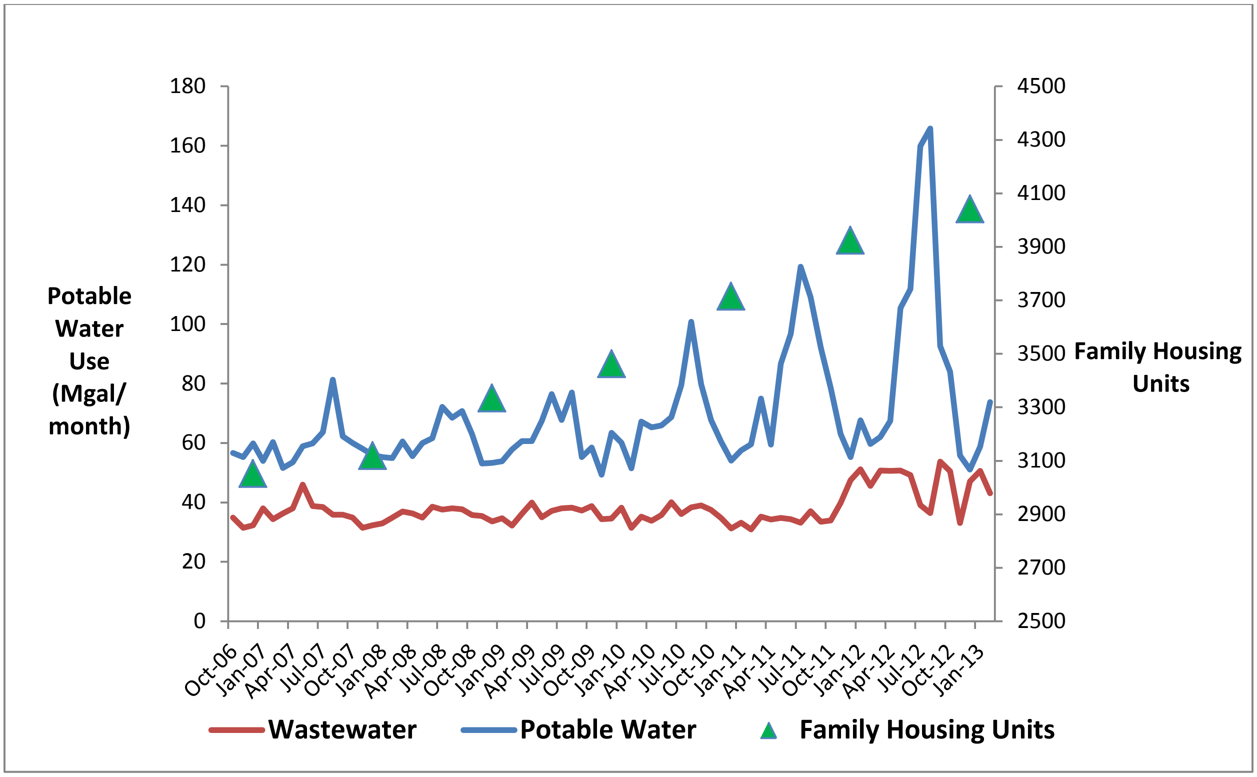


**Figure 3.3**. Peak Summer Consumption and Family Housing Units

### Heating and Cooling Facilities Plants

Fort Riley uses decentralized heating and cooling plants with hundreds of hot water boilers currently operating at the building level. These are closed loop systems, which typically do not experience water loss or consumption. Additionally, there are 27 steam boilers located throughout the post, most of which do have some form of condensate return. Steam boilers can consume significant amounts of water if condensate systems are in disrepair. The bulk of the steaming units at Fort Riley are small to modest sized units and do not represent a significant water consumption category consuming approximately 2 Mgal/yr.

Central chiller plants using evaporative cooling towers are found in several locations throughout the post and consume 16 Mgal/yr. Predominantly used for comfort cooling, the bulk of water consumption therefore occurs during the summer. With DPW tracking seven of these systems, including the large three-cell hospital unit, minimizing water loss from these units is typically subject to operational awareness such as controlling for and eliminating leaking or faulty make-up valves; or minimizing blowdown through appropriate control.

### Vehicle Wash – Installation Vehicle Wash Facility and Motor Pools

The Installation Vehicle Wash Facility (IVWF) is a partial closed-loop system that serves as both vehicle wash and as a recipient of several motor pool outfalls. The facility routinely washes up to approximately 240 vehicles per day. The IVWF consists of five tiered settling basin lagoons that help filter industrial waste. The lowest basin serves as the final collection point for recycled water where it is then pumped up to a transfer station. The transfer station boosts the pressure of water and supplies two flush fill areas for washing tracked vehicles, two water cannons for spraying dirt and debris off vehicles, and one post-wash station that contains 13 high-pressure hoses for detail cleaning of vehicles. Each of these wash stations drains back into the first settling basin, which eventually cascades into the final settling basin, where the process begins again.

Motor pools are also used to wash vehicles. These motor pools have a series of wash bays equipped with a hose that supplies the bays with potable water. Additionally, motor pools have a substantial amount of impervious surface area, several of which collect stormwater runoff and return it to the headworks area of the IVWF through the industrial wastewater lines.

Potable water is used to maintain basin levels and is typically required during the summer as surface evaporation lowers the water level in the settling basins. Rainfall and runoff from impervious surfaces also contribute the make-up to the settling basins; the water balance estimated approximately 35 Mgal/yr was provided by precipitation supplemented with 25 Mgal/yr of potable water.

### Morale, Welfare, and Recreation– Swimming Pools

Morale, Welfare, and Recreation (MWR) is responsible for several activities, including, recreation centers (such as the bowling alley), three pools (two indoor and one outdoor), the Warrior Zone, and personal fitness centers. Water used for domestic plumbing fixtures and laundry in MWR facilities is accounted for in the respective water use estimates for those categories.

There are also three outdoor swimming pools in the family housing neighborhood centers. Each is a recreational pool approximately 50 by 25 meters with a volume of 250,000 gallons. The pools are open from Memorial Day to Labor Day and are neither heated nor covered. The pools are plaster lined, which requires residual water during winter to maintain liner integrity. Because these pools must maintain some water, they are drained approximately 25% for winter storage; the difference of which is made up in the late Spring when the pools become operational again. Total consumption is estimated to be approximately 7 Mgal/yr.

### Leak and Loss Estimates

Another significant water use category is the proposed leak and loss rate. While conservatively estimated at 5% of the total potable water supply, there is potential for this number to be much higher. Applying the American Water Works Association (AWWA) standard (American Water Works Association, 1996) of loss rates for a system of 40 to 50 years old of 10%, the volumetric loss could be in excess of 100 Mgal/yr (based on FY 2012 total produced potable water).

The State of Kansas (Kansas Water Office) has proposed that 15% of potable water production may be attributable to the unknown water use category. Levels below this are acceptable, whereas levels in excess are not acceptable and require further investigation (Environmental Protection Agency 2010). It is worth noting that even modestly sized municipal systems (1,000 Mgal/yr or lower) often have loss rates ranging from 15% to 30% (EPA 2010). With this information taken into consideration, a conservative range of water leaks and losses at Fort Riley is 5% to 10%, which translates to a realistic unknown water use between 18% and 23%.

Fort Riley has instituted a potable water pipe replacement project on the Main Post that includes installation of area or district level zone meters and development of monitoring protocols. This program should be able to assist with validation of end-use estimates as well as loss estimates and enable the site to reduce the amount of unknown water use. With each percent reduction in loss equivalent to almost 1 Mgal/yr, achieving positive results from the comprehensive program is not only impactful, but highly likely as well.

### Other Water Consumption Activities

There are numerous miscellaneous categories that consume potable water. These are typically low use categories such as the veterinary clinic and the blast containment system at the Readiness Sustainment Maintenance Site (RSMS), or those that are not well monitored, metered, or controlled. Perhaps the most significant water consumer in this category is line flushing activities, which are conservatively estimated to be in excess of 20 Mgal/yr. DPW is aware of the most common locations that require line flushing for hygienic purposes (sterilization). Addressed as part of a strategic loss prevention program sub-metering and accounting for water loss at locations that frequently require line flushing is highly recommended (EPA 2010).

### Annual Water Use Pattern

For Riley's annual water consumption varies seasonally, largely due to the significant increase in family housing and on-post irrigation demands, replacement of evaporative loss in the IVWF, and cooling tower consumption, which increases during the summer (Figure 3.4).

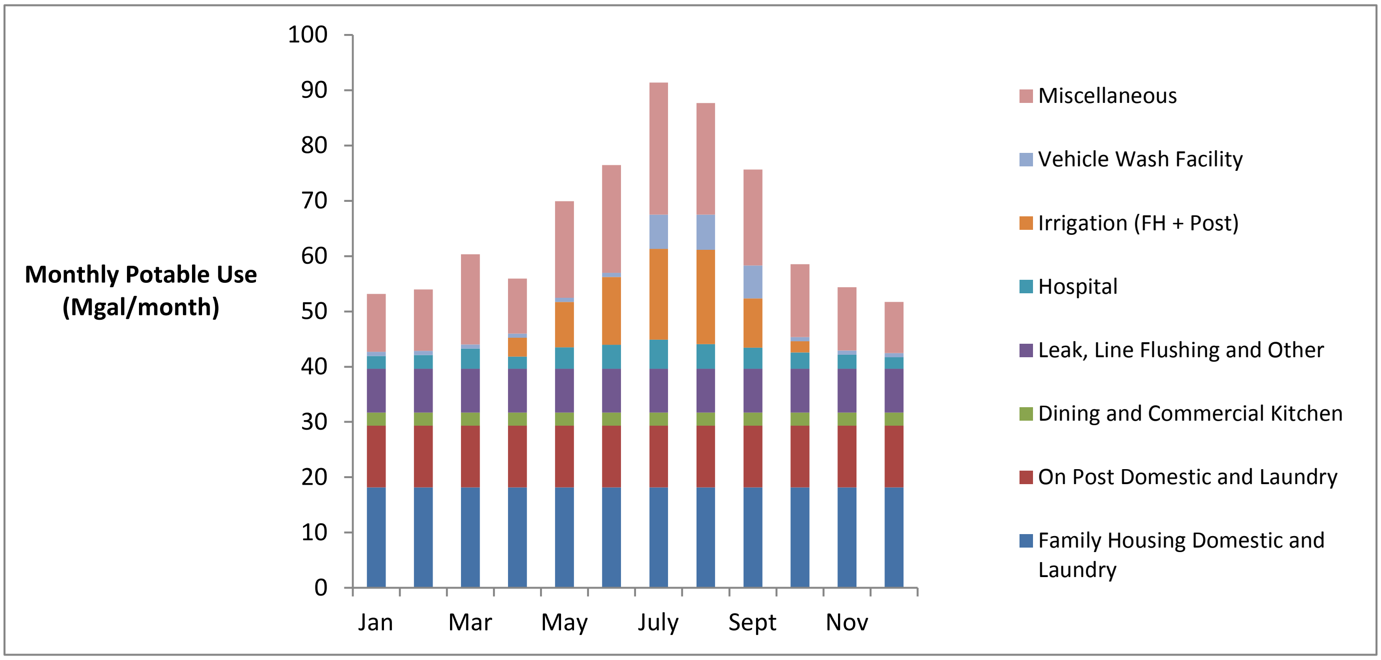


**Figure 3.4**. Fort Riley Potable Water Seasonal Distribution

## Water Cost

Potable water and wastewater treatment at Fort Riley is performed at the Army-owned and operated WTP and the two WWTPs. Fort Riley's water rate is based on a calculation of total operating costs divided by total water produced, commonly referred to as a "net effective" rate. While some operating expenses of the WTP and WWTPs are fixed costs recovering capital outlay and financing, the total operating cost of the systems tends to scale with consumption, e.g., lower consumption equals lower costs, higher consumption equals higher costs. There are multiple tiers of rates charged to reimbursable customers at Fort Riley based on classification: federal, non-federal, etc. The following water and wastewater rates were used for the LCC analysis and are therefore restricted to:

- Potable water: $1.16/kgal for government customers.
- Wastewater: $2.37/kgal for government customers.

# 4.0 Water Conservation Measures

Water conservation measures (WCMs) were developed as part of the roadmap. WCMs are efficiency improvements for existing equipment and systems at Fort Riley, or development of alternate water supplies such as treated WWTP effluent. WCMs were developed for domestic plumbing, irrigation, and commercial kitchen equipment. Additional discussion and potential effects are also included for the new hospital cooling equipment, potable water distribution system, and EPA's projects including sewer mining and education-outreach programs. Though no complementary cost analysis was done for the EPA projects, a net cumulative effect on potable water reduction is expected and is therefore included in the overall water reduction potential (Section 7.0).

As part of the WCM development, a life cycle cost (LCC) assessment was performed on WCMs to understand the cost effectiveness of each project. The main economic indicator used to determine LCC effectiveness is savings-to-investment ratio (SIR). An SIR greater than 1.0 indicates that the project's monetary savings over the life of the project is greater than the initial capital cost, resulting in a cost effective project. This section describes LCC effective WCMs that are recommended for Fort Riley, and also several projects that are ongoing or are under active consideration by the garrison.

## Domestic Plumbing

Plumbing fixture WCMs were assessed by major building groups including barracks, administrative and office buildings, operations and training facilities, and warehouse type buildings. Water reduction for each fixture is based on reduction in flush or flow rate of each device using the baseline established in the water balance for each building group (Appendix A).

**Figure 4.1**. Piston Valve

### Flush Valve Toilets

Fort Riley facilities contain many diaphragm flush valve toilets. The replacement of diaphragm flush valve toilets with high efficiency toilets rated at 1.28 gpf with piston style flush valves (Figure 4.1) was assessed as part of the roadmap. Piston valves have distinct advantages compared to diaphragm valve toilets, including the following:

- Piston valves last longer and have lower operations and maintenance (O&M) costs than diaphragm valves because piston valves contain a screen that prevents debris from entering the inner portion of the valve and they are made of more resilient, longer-lasting material.

- Piston valves corrode less easily, and therefore they will flush at the rated flush rate for the life of the product, whereas diaphragm valves tend to "creep" in water use over time.
- Piston valve retrofit kits will only fit in the specific rated valve; diaphragm valve retrofit kits are interchangeable, meaning a 1.28 gpf valve could be replaced with a 3.5 gpf valve, turning a high efficiency toilet into a high water consuming fixture.
- Piston valves are more tolerant of low pressure, rated at a minimum pressure of 15 pounds per square inch (psi); diaphragm valves require at least 35 psi to operate.
- Piston valves default in the closed position when the valve breaks, whereas diaphragm valves remain open, leaking water continually until repaired.

### Tank Toilets

Fort Riley facilities have numerous gravity style tank toilets. Replacement of these tank toilets with 1.0 gpf WaterSense® labeled[1] high efficiency toilets was assessed.

**Figure 4.2**. Pressure Assisted Toilet

**Pressure assisted toilets:** These toilets contain a vessel inside the tank that is pressurized via the supply line pressure. When the toilet is actuated, water is pushed through the toilet bowl at a high velocity, creating a powerful flush (Figure 4.2). Pressure assisted toilets require less routine maintenance than gravity type equivalents because gravity tank toilets require regular flapper valve replacement. In addition, pressure assisted toilets are precise and deliver the desired flow, even as they age. Pressure assisted units perform at ±5% accuracy of the designed flow, whereas gravity type fixtures are substantially less accurate at nearly ±20% of the designed flow.

Pressure assisted toilets generally are preferred to flapperless toilets because pressure assisted toilets have a stronger flush performance, accelerating the movement of wastewater through the drain line. As such, only high efficiency pressure assisted toilets were provided for the LCC analysis.

### Urinals

Replacement of existing urinals with high efficiency pint (0.125 gpf) piston valve-style urinals was assessed. The same benefits listed above for piston flush valve toilets apply to urinal fixtures, along with lower maintenance, longer life, and more precise water use over the life of the valve.

### Faucets

Replacement of public and private faucets to tamper proof aerator or flow control types was assessed as part of the roadmap.

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[1] WaterSense is a partnership program between the U.S. Environmental Protection Agency and manufacturers whereby EPA certifies water-efficient products through with a WaterSense labeling program see http://www.epa.gov/watersense.

**Public faucets:** In public area restrooms such as administrative and office buildings, restroom faucets should not exceed 0.5 gpm to meet plumbing code. Through the water balance audit, faucets were identified to have flow rates varying from 0.5 (existing aerator) up to 2.5 gpm, which should be retrofitted with high efficiency aerators. Aerators, with flow control inserts, are installed onto the faucet, restricting the flow of water to the rated level. Also, faucet aerators should be tamper proof so that they cannot be easily removed.

**Private faucets**: Standard kitchen faucets (2.2 gpm) in private settings such as lunchrooms, lodging, and barracks should be retrofitted with WaterSense labeled aerators rated at 1.0 gpm. Also, faucet aerators should be tamper proof to prevent easy removal. Private restroom faucets were assessed for replacement with 0.5 gpm high efficiency aerators.

### Showerheads

The replacement of all standard-rated showerheads (2.5 gpm) with 1.5 gpm WaterSense labeled showerheads was investigated. WaterSense labeled showerheads must meet efficiency standards and performance criteria for showerhead coverage and spray intensity. Using WaterSense labeled showerheads ensures that the showerheads provide water savings without sacrificing performance. Also, showerheads should be tamper proof so that users cannot remove the flow control insert.

### Plumbing Fixture Specifications

Appendix B contains recommended plumbing fixture specifications that provide performance-based requirements for high efficiency plumbing fixtures and appliances.

### Domestic Plumbing LCC Results

The LCC analysis for plumbing fixtures produced mixed results. The most cost effective measures were faucets and showerheads because of reasonably low installation costs, but more important are the energy savings gained by reducing the demand for hot water. However, on their own, toilets and urinals generally are not cost effective as they consume cold water only and have no corresponding hot water component. Additionally, removing the existing fixture and replacing the valve and the fixture bowl carries an expensive “first cost” or capital outlay in comparison to the water savings. In particular, the barracks toilet and urinals projects have poor economics because of the high number of fixtures in each building. However, leveraging the savings from showerheads and faucet retrofits by bundling plumbing projects together allows for some of the toilet and urinal projects to be LCC effective. Namely, bundling the barracks, administrative buildings, and operations facilities together provides an SIR of 1.42, approximately 62 Mgal/yr of water conservation, and a net present payback of $134,000.

## Irrigation

Irrigation at Fort Riley has historically not been a significant contributor to the overall consumption of potable water until more recently (Section 3). With the expansion of family housing, family housing common areas, and new irrigation infrastructure around the Main Post, irrigation now accounts for approximately 70 Mgal/yr and is second only to domestic plumbing use. Further, as family housing continues to expand; net irrigated landscape is expected to increase an additional 20%.[1] Based on percent growth in demand, this could lead to peak water consumption approaching 100 Mgal/yr.

### Advanced Irrigation Controls

The replacement of timer-based controllers with an advanced weather-based system that applies water based on the predicted evapotranspiration requirements of the landscape was assessed as part of the roadmap. Each controller is programmed with zone-specific requirements for irrigation needs such as turf type, soil conditions, and irrigation equipment configuration. The centralized system sends local weather-related data wirelessly to each controller. Supplemental irrigation is applied to each zone based on the data supplied to the controller, which provides an accurate amount of water based on the needs of the plants.

An additional strategy that can be deployed based on ambient conditions is deficit irrigation, which assigns a reduced level of irrigation that can be used during droughts or other water-constrained times, rather than the providing 100% of the water required by the plant as calculated by the weather-based system. Most turf types can tolerate between 60% and 80% of the total irrigation requirement over an extended period of the growing season, while surviving and having acceptable appearance (Harivandi et al. 2009). Deficit irrigation is a way to limit large increases in water use during low precipitation. In addition to the advanced centralized controller, other efficiency measures can be implemented at Fort Riley to conserve water, as discussed in the following.

### Distribution System Enhancements

Fort Riley irrigation systems have a variety of misaligned and mismatched heads that decrease overall system efficiency. It is recommended that field performance audits be conducted to identify opportunities to repair and replace irrigation equipment to improve the irrigation distribution performance. Irrigation audits should be developed under an accepted procedure such as the Irrigation Association's Certified Landscape Irrigation Audit Program or its equivalent. The audit should check the system's precipitation rate and distribution uniformity. Distribution uniformity provides information on how effectively irrigation water is applied to the landscape. Additionally, it can supply information on sprinkler systems such as misaligned and mismatched heads, required repairs, and distribution system improvements.

The audit should verify the installation of specified water management sensors as part of the new weather-based system to ensure they are functioning properly. The audit should also verify the irrigation schedule and ensure that the system inputs closely match the actual needs of the landscape.

[1] Assumes 122 irrigated acres on site currently; 152 irrigation acres at full build out. Metrics do not include golf course irrigation, which has static acreage or variation due to drought conditions such as FY 2012.

The comprehensive irrigation system audits should provide information on distribution system opportunities to improve system efficiency. Potential enhancements for irrigated systems include two main areas:

- Replacement of misaligned, broken, and mismatched heads
- Improvements to the distribution system that adjust sprinkler head placement

Both of these enhancements will improve the system distribution uniformity and increase system efficiency, requiring less water to achieve the same results. Distribution system enhancements typically increase system efficiency by 10%.[1]

### Landscape Conversions

Low visibility landscaped areas use approximately 25% less water than high visibility areas, based on differences of average annual irrigation factor (annual water use per square foot) between two types of turf-based landscapes. Where "high visibility" areas have an annual irrigation factor of 26 gal/sqft; "low visibility" areas use 19 gal/sqft. An even more conservative approach is to replace existing turf with drought-resistant turf, which can reduce irrigation demands by an additional 25% to 30% (14 gal/sqft) (Pacific Northwest National Laboratory 2012).

A very good example of this practice can be found at the Fort Riley golf course. The conversion of turf on the fairways and roughs has eliminated seasonal irrigation demands in these areas, requiring only the tee boxes and greens to be watered. As a result, the golf course has reduced the demand for potable water by approximately 50%. It is also for this reason that no WCMs were proposed for implementation at the golf course considering the current irrigation practices are keeping potable water consumption at a minimum. If alternate water sources were identified and used at the golf course, the site should consider an appropriate weather based controller to manage the application of water as needed.

### Irrigation LCC Results

The implementation of WCMs is estimated to conserve a minimum of 9 Mgal/yr and includes installation of weather based controllers and high efficiency distribution nozzles. Areas evaluated include building(s) 500 and 580; ball fields; Main Post, St. Mary's Chapel, and Cemetery. LCC results indicate a modest NPV and SIR of 1.1.

### Irrigation System and Management Guidelines

Appendix D contains recommended guidelines for the water-efficient design, installation, and management of irrigation systems.

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[1] System efficiency increases from distribution system enhancements are derived from direct experience from similar projects that have implemented similar measures.

## Hospital and Medical Equipment

No WCMs are considered in this report for the IACH due to the construction of the new hospital. As a LEED facility and in consultation with personnel, the new hospital has specified high efficiency plumbing fixtures. However, the new hospital is planned to have double the installed capacity of the cooling equipment in comparison to old IACH. To understand how this may affect future water consumption, total tonnage of the chillers and evaporative cooling towers was obtained from the Army Corp of Engineers to model multiple water consumption scenarios based on variable load and ambient conditions at Fort Riley. As modeled, the new hospital with the proposed chiller capacity of 2,250 tons, can be expected to require approximately 15 Mgal/yr (range of 12.6 to 18.3) based on a range of operational variability under historically normal ambient conditions, but could be well over 20 Mgal/yr under warmer and dryer conditions.[1] Total cooling load in the new hospital is anticipated to be approximately two times the original IACH according to site personnel.

The modeling effort however raised an issue regarding the old hospital and an indeterminate gap between the metered consumption and what the hospital should be consuming based on the size (in number of patient rooms and monthly visits), and the capacity of the cooling/heating systems. For comparison, several hospitals across other net zero installations were analyzed to understand potential gaps in the metered data. As an example, a hospital at another net zero site has 145 beds and 65,000 visitors per month, and consumes a total of 27 to 30 Mgal/yr; this is 35% less than the old IACH. The cooling tower system there is 2,600 tons total, consumes 75% of the hospitals total demand for water in the summer time, 40% in the winter, and has an annual total cooling tower make-up of 17 Mgal/yr. The hospital is master metered and the cooling tower systems are sub-metered.

Knowing that the new hospital has approximately two times the chiller capacity of the IACH and the make-up number was modeled to be approximately 15 Mgal/yr., the difference between what the hospital was consuming based on metered data and the model that indicated what it should be consuming is approximately 10-15 Mgal/yr. Though this means little moving forward with the new hospital, there are certainly modest considerations that should be incorporated into the mechanical design and operations of the new facility. The new hospital at a minimum should incorporate the following considerations into the design and operations of the new facility:

- Sub-meter the logical large water consumers, including cooling tower make-up, cooling tower blowdown, chilled water loops, steam boilers, irrigation, and high purity water production.
- Initiate a monitoring program that can capture deviations from the “norm” once established consumption patterns are developed.
- Develop and implement a best practices approach to addressing hygiene concerns associated with the installation of high efficiency fixtures.

[1] See Appendix C for hospital cooling tower water consumption analysis completed for historical monthly mean and above mean ambient conditions.

From the site-supplied water quality obtained from water treatment operators, it is unlikely that controlling for higher cycles of concentration will lead to any meaningful reductions in water consumption. Increasing the cycles of concentration by one could reduce potable water consumption from 0.5 to 0.7 Mgal/yr, or less than 5% of total make-up.

Additionally, due to the expansion of cooling tower tonnage in the new hospital, the total amount of potable water required for cooling tower make-up and thereby evaporative loss, could be significantly higher than the current supply. Appropriately, this large consumer should be managed to maximize the cycles of concentration, which will minimize water consumption. A discussion was conducted at the roadmap meeting addressing potential alternative uses of cooling tower blowdown, including irrigation for the green roof or area irrigation needs of the hospital grounds. If fully used, cooling tower blowdown could offset potable water by 3 to 4 Mgal/yr. The mechanism to do so however was not clearly identified at the hospital. Two constraints discussed included hygiene concerns when reusing cooling tower water and the potential for positive testing for Legionella. Additionally, it is unknown what type of landscaping will be used on the green roof. The water chemistry from the cooling tower blowdown would have to be consistent for use as irrigation water including acceptable dissolved solid content, and water conditioning chemicals such as anti-scale and biocides. Though technically viable, it is not a priority.

## Commercial Kitchen Equipment

Kitchen fixture WCMs were assessed in the main dining facilities. Water reduction for each fixture or piece of equipment is based on a reduction in flow rate of each device using the baseline established in the water balance (Appendix A).

### Food Steamers

There are nine food steamers in the dining facilities that can be considered for replacement. Traditional steamers can use as much as 40 gallons of water per hour. Replacement of existing steamers with an ENERGY STAR qualified electric connectionless steamer was assessed. Newer connectionless steamers use only 10% to 20% of the water of older models and incorporate a vacuum system to allow steam to be formed at a lower temperature, thereby using considerably less energy than those systems with vacuum assist. Secondarily, food steamed in this manner is heated quicker and is more likely to maintain nutritional value.

### Pre-rinse Spray Valves

The dining facilities collectively contain nine pre-rinse sprayers in the kitchens varying in measured flow from 1.4 to 2.1 gpm. Pre-rinse sprayers are often used at dishwashing stations to remove food waste. Typically, hot water is used through these sprayers, so reducing total water flow provides thermal energy savings due to the commensurate reduction in hot water. Replacing the existing sprayers with 1.24 gpm straight pre-rinse spray heads will save both water and natural gas.

### Garbage Disposals and Pulper Retrofits

The dining facilities contain a combination of garbage disposals and waste food pulpers. Both disposals and pulpers require water during grinding and waste removal. The water supply to these units commonly runs without flow restriction and can readily exceed the required flow rate per the manufacturer-recommended specifications. Demand-based flow control of the water, which limits the supply water only when the disposal is operating, can be accomplished through inline solenoid valve retrofit.

### Ice Machines

The dining facilities contain multiple types of ice machines producing several tons of ice per day that that can be retrofitted for energy savings. The dining ice machine can be retrofitted with a counter flow heat exchanger. These units direct cold wastewater from the existing ice machine through counter flow heat exchange and into a cold wastewater reservoir. The fresh potable water enters the reservoir through a winding stainless steel tube, and is chilled via non-contact heat exchange. Since the potable water is pre-chilled when it reaches the ice machine, the unit enables increased ice production with reduced energy savings by requiring shorter compressor cycles (up to 35% less energy). The retrofit LCC analysis includes electrical savings only.

### Dish Machine Replacements

Replacing existing commercial dishwashers at the dining facilities (four total: two Hobart and two Champions) with ENERGY STAR rated commercial dishwashers can reduce water demand by approximately 50%, and reduce energy consumption up to 11,000 therm/yr. There are distinct advantages to ENERGY STAR rated dishwashers. ENERGY STAR machines reduce the final rinse water use by spraying larger water droplets to sanitize the dishware more efficiently. Commercial dishwashing machines use detergents and sanitary chemicals in a concentration ratio to the amount of water used. ENERGY STAR machines also use waste heat exchangers to preheat the water supply before it reaches the internal dishwashing machine heating system, thereby reducing the demand for hot water.

### Commercial Kitchen Equipment LCC Results

The LCC analysis showed that the kitchen equipment retrofits are cost effective, with an SIR of 1.95. Energy savings and water savings were included in the LCC calculations. Kitchen fixture and equipment retrofits could save an estimated 5,000 kgal of water annually and provide an energy savings of 11,000 therms/year due to hot water conservation. As a bundled project, kitchen equipment replacement and retrofits have the highest NPV of all projects.

## Distribution System Upgrades

The potable water system is discussed here primarily for informative purposes since piping and infrastructure replacement work is currently being conducted on the potable water distribution and storage systems. Fort Riley owns more than 280 miles of potable water distribution piping and more than 140 miles of wastewater line (Otto 2013).

The distribution infrastructure consists of a variety of piping materials; potable water is predominantly cast iron (36%) and polyvinyl chloride (PVC) (30%), with the remainder consisting of asbestos cement and unknown material. The wastewater lines are predominantly vitrified clay

(34%) and PVC (17%), but the largest percentage of piping is unlisted and unknown. In many areas of Fort Riley, the distribution system is more than 50 years old and water loss attributable to leaks and line loss is expected.

The water and wastewater distribution systems at Fort Riley have been analyzed previously, including a potable water system study (Bucher, Willis, and Ratliff Corporation 1996) and a water leak detection survey (Systems Engineering 1997). More recent activities, such as construction and demolition of family housing communities, would update the findings of these documents.

It is worth noting that as a result of these previous studies, Fort Riley invested in water metering capabilities on the Main Post to quantify water use and reduce the amount of unaccounted for water use. Unfortunately, the meters were not enabled or approved to wirelessly transmit information.

Fort Riley is undertaking a significant effort to replace sections of potable water infrastructure located on the Main Post. Additionally, strategic area meters are being installed to capitalize on upgraded systems and to enable a strategic monitoring and verification program.

### Other Strategies for Leak Detection and Loss Mitigation

As described previously, Fort Riley DPW is replacing key aging infrastructure while concurrently installing area meters and developing a formal monitoring program. In addition to these measures, Fort Riley may also consider other innovative technologies to detect and mitigate leaks in remaining portions of the distribution system not covered by recent infrastructure improvements and activities.

**Leak noise loggers**: Leak noise loggers are acoustic listening devices that can detect and record leaks in the water distribution systems. Leak noise loggers can be attached to the system to monitor the frequency of sounds in a distribution system and can determine if a sound is a water leak. Loggers can be attached temporarily to record a sample of sounds in a given zone of the distribution system or left in place to operate for an extended period. More sophisticated loggers can monitor sound in discrete low flow times and remotely transmit real-time data to a centralized system for analysis. This type of logger can be monitored through an automatic meter reading system.

**Inline detection**: It can be difficult to detect leaks in large distribution lines greater than 12 inches, because large pipes do not transmit sound as well as smaller diameter pipes. Also, non-metallic pipe material, such as asbestos cement or PVC, does not transmit sound well. Inline detection technology, including streaming cable inline detectors, free-floating inline detectors, and acoustic fiber optics, can be an effective option for these situations.

- *Streaming cable inline detectors*: With this technology, a cable attached with an acoustic sensor is inserted into the pressurized distribution line. A parachute is attached to the sensor, which moves the sensor through the pressurized line, and an acoustic signal is transmitted from the sensor that can be analyzed for leaks.

- *Free-floating inline detectors*: A fairly recent innovation, free-floating inline technology consists of an acoustic sensor that is installed in a small, ball-like housing, which is inserted into a pressurized line. The ball records and stores digital signatures as it moves through the line and monitors its exact location to pinpoint leak locations.

- *Acoustic fiber optics*: A fiber optic cable is inserted into a water main that can detect sounds. This information is recorded and uploaded for leak analysis.

## EPA Outreach and Education Program

EPA and the Fort Riley Department of Public Works (DPW) are also collaborating on water conservation projects through the development of a targeted social and behavioral water reuse and conservation campaign that would be executed via a variety of mechanisms including conservation 'competitions', social marketing, educational outreach, and comparative analysis. In context with Fort Riley's net zero water goals and objectives, the projects are intended to foster and encourage behavioral changes needed to reduce water consumption on the installation and promote long-term community water conservation.

In addition to reducing water loss, a behavioral/social study would help the installation to target specific areas of water reuse and conservation that affect and resonate with the community, helping to create and foster long-term change in sustainable decision-making (Vallano 2012). Secondarily, the project will demonstrate innovative water monitoring technologies, explore social and behavioral aspects of technology demonstration and implementation, and, monitor and record the results

## Summary Results of Net Zero Water Projects

Each WCM was evaluated to determine its overall water and energy use, installation costs, and O&M costs for existing and retrofit equipment. This information was used to perform an LCC analysis. The LCC analysis evaluates the projects savings and investment streams over the life of the projects to determine SIR and NPV.

SIR is the ratio of the net present savings to the total installed costs. An SIR greater than 1 deems the project LCC effective. The SIR results presented meet the requirements for the Energy Conservation Investment Program (ECIP) projects (Appendix A). NPV is the savings stream over the life of the project minus the project's investment stream. An NPV greater than zero shows that the project saves more money than the project costs over the life of the project, and is therefore LCC effective.

Another factor that was considered in the analysis is called the "cumulative water savings-to-investment ratio." This factor is the ratio of total water (in gallons) saved over the life of project to the total cost of the project. This value is not an indicator of LCC effectiveness, but rather indicates the relative level of water saved per dollar invested or the "bang for the buck." This value can be used to help prioritize projects that will produce relatively high water savings.

The following provides the SIR, NPV, and cumulative water SIR for each WCM (Table 4.1). Also included are annual water savings, energy savings, and installation cost. Energy savings include equipment-level savings from reduced hot water from water efficient showers and faucets, as well as pumping energy reductions.

**Table 4.1**. Fort Riley Water Conservation Measure Economic Analysis Results

| Technology Group | Annual Water Savings (kgal) | Annual Natural Gas Savings (therms) | Total Installed Cost | Annual Cost Savings (first year) | Net Present Value | Simple Payback (years) | SIR |
|---|---|---|---|---|---|---|---|
| **All Plumbing** | 67,900 | 178,500 | $4,027,800 | $360,800 | $20,900 | 11.2 | 1.2 |
| **Plumbing-Admin** | 7,000 | 7,700 | $280,300 | $31,500 | $39,300 | 8.9 | 1.6 |
| **Plumbing-Barracks** | 38,000 | 145,600 | $2,065,700 | $219,500 | $56,500 | 9.4 | 1.4 |
| **Plumbing-Motorpools** | 3800 | 4,200 | $361,900 | $19,200 | ($33,600) | 18.9 | 0.8 |
| **Plumbing-Ops & Training** | 16,500 | 18,200 | $872,200 | $76,500 | $38,100 | 11.4 | 1.3 |
| **Plumbing-Warehouse** | 2,500 | 2,800 | $447,800 | $14,100 | ($79,400) | 31.9 | 0.5 |
| **Irrigation** | 8,600 | - | $177,300 | $12,700 | $4,400 | 14 | 1.1 |
| **Commercial Kitchen** | 5,000 | 11,100 | $510,500 | $69,600 | $127,600 | 7.3 | 1.9 |
| **Pool** | 600 | 24,600 | $22,300 | $3,300 | $1,300 | 6.7 | 2.6 |
| **TOTALS** | 82,037 | 214,173 | $4.74M | $446,340 | $154,101 | - | - |

1.1.1.1Appendix A– Technical Analysis Methods includes each line item WCM, the empirics used to assess cost effectiveness, and the findings.

# 5.0 Alternative Water Projects

To meet Fort Riley's net zero water goal, the installation will have to look outside conventional conservation projects and increase the use of alternative water such as stormwater detention, sewer mining, and reclaimed wastewater. Increasing the percent contribution from stormwater runoff and capture is one of the objectives to reducing the demand for potable water in the IVWF facility. Site personnel are actively pursuing opportunities to identify and tie in motor pools that are currently isolated or do not contribute to the IVWF via the industrial wastewater system. Additionally, the EPA sewer mining project is an opportunity, though quite modest at 2 Mgal/yr, to further reduce potable water requirements of the IVWF. The project, which is intended to evaluate the effectiveness of membrane bio-reactor technologies, pulls water from the sanitary sewer, treats the water, and then discharges it into the industrial wastewater line terminating at the first vehicle wash settling pond.

## Stormwater Detention

Accessing alternative non-potable water supplies is not a novel concept at Fort Riley. As a result of an infrastructure assessment completed in 2006, Fort Riley further examined effects from rainfall runoff in the Custer Hill area and mitigation practices that could reduce peak flows (HNTB 2007). The stormwater detention study, in addition to identifying drainage patterns and hydrologic routing, analyzed best management practices, low impact development improvements, and water retention strategies for flow equalization and use of stormwater systems in the Custer Hill area.

Among the options considered, raising the Cameron Springs Pond level to accommodate a 25-year rain event was evaluated. The total proposed storage volume for this project was not clearly identified; however, a volume of 30 acre-feet was included as representing a jurisdictional limit, currently 5 acre-feet. If accessible, the increased capacity alone could offset potable water consumption in excess of 8 Mgal/yr which could be used for non-potable uses such as IVWF make up or irrigation. Though current site-wide priorities do not include used water storage on Custer Hill, due to location, if this project were considered to have merit, it would be reasonable to supplement the reservoir with wastewater from the Custer Hill WWTP.

## Custer Hill Wastewater Treatment Plant Reuse

Reuse of wastewater at the Custer Hill location could potentially offset all the potable water currently used in the vehicle wash, golf course, and additional irrigation demands on-post, such as family housing units on Custer Hill. As conceptually proposed by WaterSavers, LLC (2012), effluent from the current WWTP plant would be stored at the golf course and supplied to the stormwater system serving the vehicle wash (Figure 5.1).

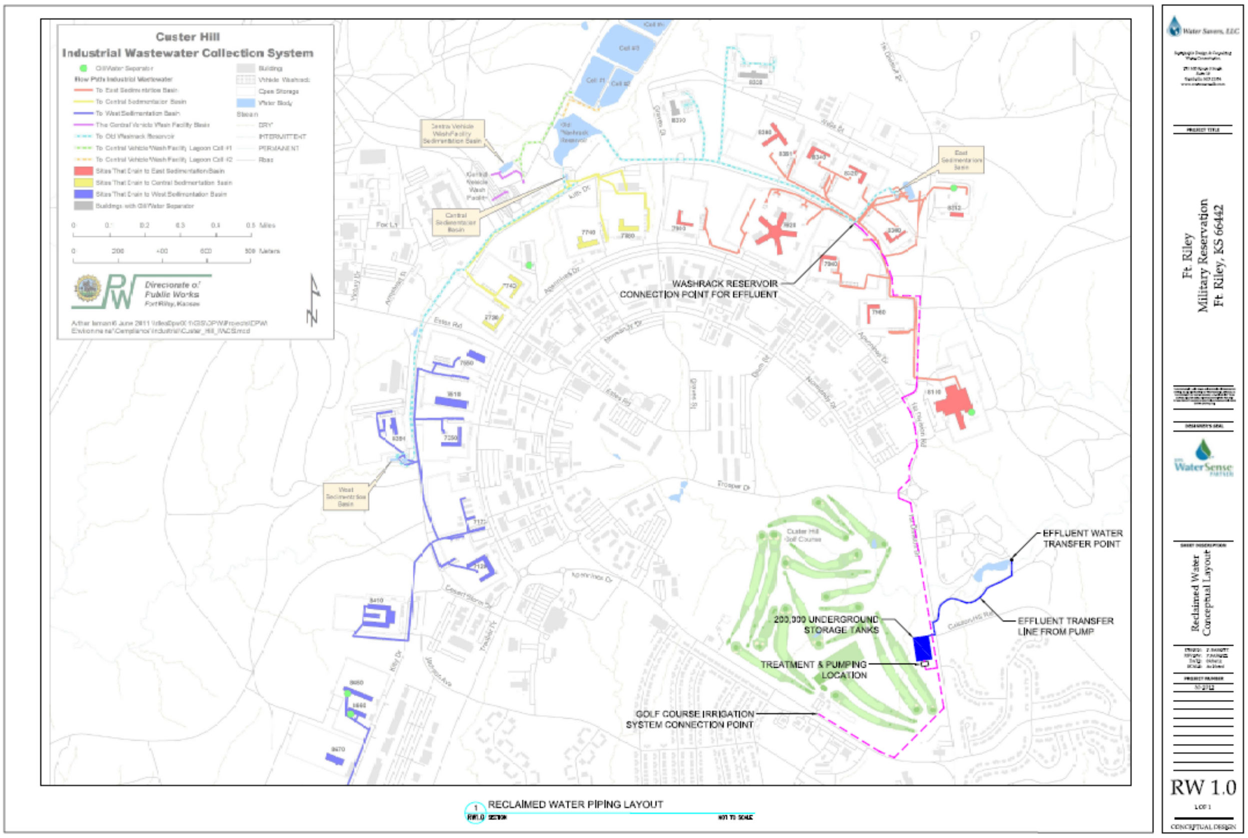


**Figure 5.1.** Custer Hill WWTP Reuse Project

As configured, this project is not cost effective (Table 5.1). If additional potable water offsets were identified such as large evaporative cooling processes and/or additional irrigation demands, project economics may improve. As is, to achieve a positive NPV or SIR of 1.0, the price for potable water would have to be at least $5.00/kgal in order to break even. As a self-producer of potable water, Fort Riley's low total cost of production and distribution make this project difficult to consider.

**Table 5.1.** Fort Riley Reclaimed Water Economic Analysis Result

| Technology Group | Annual Water Savings (kgal) | Annual Natural Gas Savings (therms) | Total Installed Cost | Annual Cost Savings (first year) | Net Present Value | Simple Payback (years) | SIR |
|---|---|---|---|---|---|---|---|
| Reclaimed System | 61,137 | - | $2,141,400 | $54,335 | ($86,673) | 39 | 0.4 |

## Custer Hill Membrane Bioreactor Project

The Army is partnering with EPA and the Army Corps of Engineers to demonstrate innovative technologies such as the membrane bioreactor (MBR) technology at Fort Riley, which is intended to reclaim and process wastewater through the decentralized treatment of sewage, and distribute that flow for non-potable water end-uses (Figure 5.2). This approach, sewer mining, eliminates the need for re-plumbing inside buildings to separate effluents and can allow for placement of the treatment process near potential sites of reuse so long as sewer lines are available. Despite the potential advantages of decentralized approaches, potential increases in operating and monitoring costs are a concern when moving away from centralized wastewater treatment plants. Effective demonstration of this approach will evaluate and emphasize development of low maintenance systems with simple monitoring and control requirements, while reducing the potable water burden. The project schedule has proposed to install and operate commercial-off-the-shelf equipment in FY2013, with follow on projects in FY2015 and FY2016 for using more novel anaerobic systems. Additionally, installation and testing of sewer mining approaches at Fort Riley will:

- Demonstrate this approach to build familiarity in an operational context;
- Generate data on performance, including microbial risk assessment, and;
- Provide a test-bed to compare performance of current designs) with more advanced concepts which minimize energy and maintenance costs (Garland 2012).

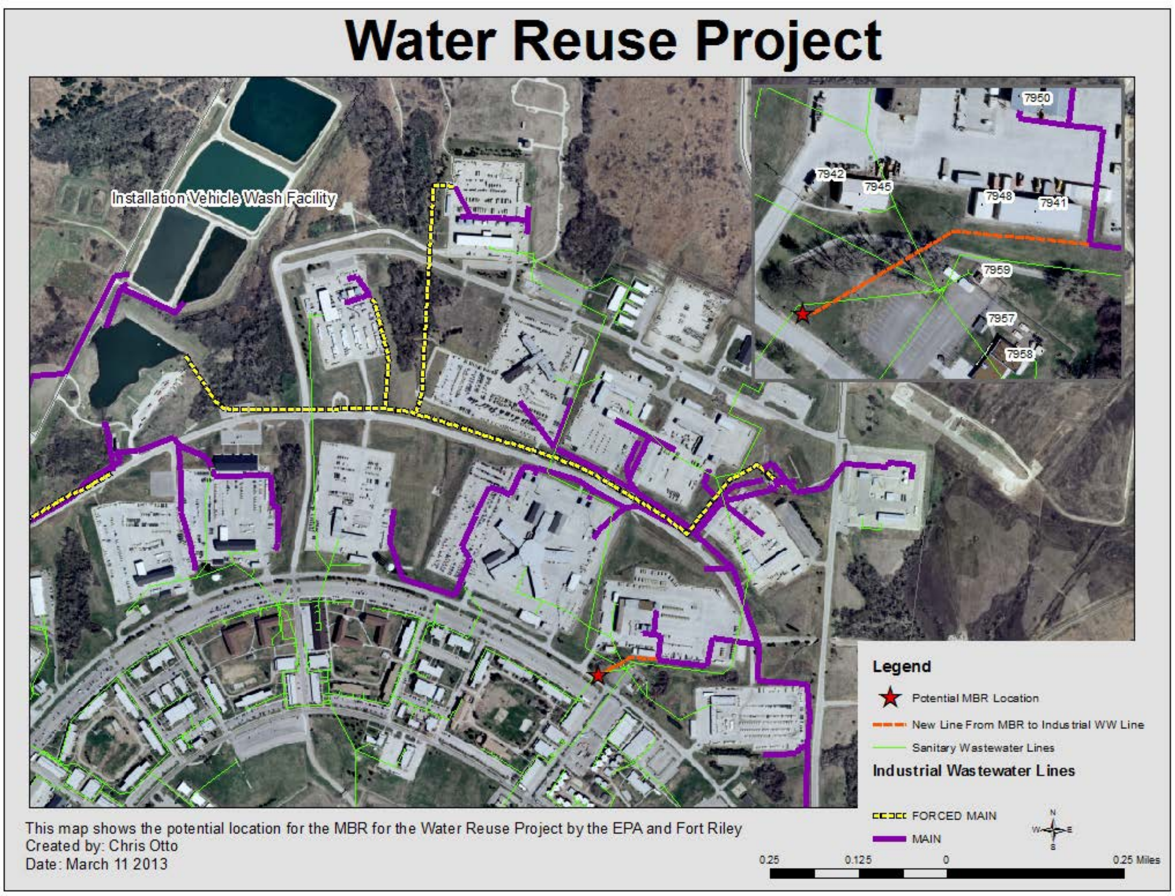


**Figure 5.2.** EPA Decentralized Wastewater Treatment Project

MBR technology captures wastewater from the sanitary sewer line, treat the water with both aerobic and anaerobic processes and then return it to an industrial wastewater main. One of primary objectives of the project is to thoroughly investigate the performance, capital, and operating costs of the treatment technologies; additionally, Fort Riley will be able to offset potable water demand at the IVWF by 2 to 3 Mgal/yr.

Should the technology prove to be technically viable and produce reuse water at a reasonable cost, the project may continue to operate at the current size and site.  An additional objective is to evaluate strategic locations for permanent installation and operation that will enable a direct comparison of the decentralized wastewater treatment costs to those represented by the more traditional installation and operation of distribution lines from a central WWTP.

# 6.0 Projected Water Demand and Use

Once the individual WCMs were analyzed, only those found to be cost effective were assigned tentative implementation windows based on (1) implementation time requirements, including analysis, design, and contracting; (2) expected availability of funding, which differs by funding type; and (3) logical sequencing of projects. The annual Fort Riley water demand was then projected through FY 2020 taking into account the effect of the projects and the expected population growth. Tentative project scheduling is laid out in a later section of this report.

The baseline analysis (Figure 6.1) illustrates potable water consumption and Fort Riley's WUI at the end of FY 2012. It also indicates the reduction in potable water consumption required to meet the FY 2020 WUI goal of 24 gal/sqft which is equivalent to approximately 340 Mgal/yr AEWRS reported potable water.

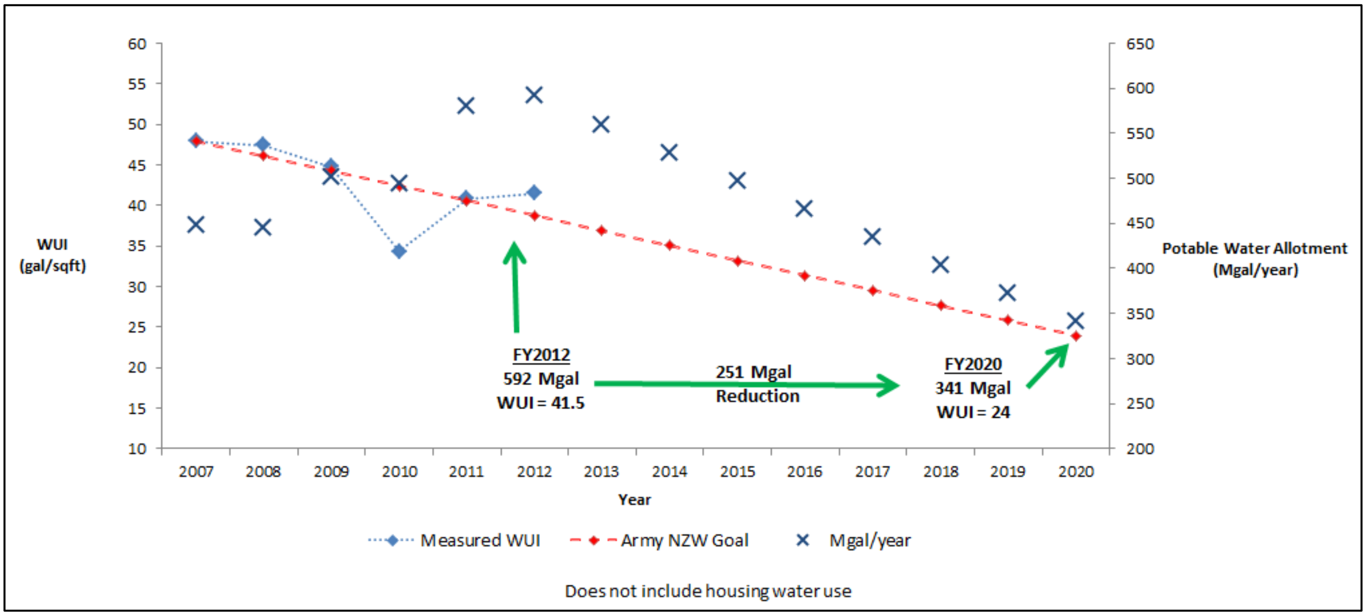


**Figure 6.1.** Fort Riley WUI and Glide Path to FY2020

## Future Water Demand and Projected FY 2020 Water Balance

Fort Riley's population is expected to hold relatively stable through FY 2015 (Otto, 2012). This should enable the site to implement WCMs and practices that can provide measurable reductions in potable water consumption without a change in population. Beyond FY 2015, however, the population of Fort Riley is contingent on base realignment strategies. While the last realignment in 2006 increased the number of Soldiers at Fort Riley, the total number of Soldiers in future years is currently being determined by the Army. Fort Riley's population could move up or down by FY 2020.

With a stable population, the primary component driving Fort Riley's water consumption is likely the effect of expansion of irrigated family housing, and irrigated common areas in family housing and on-post. Historically, Fort Riley's water balance has been dominated by domestic fixture potable water use accounting for 38% (including family housing) of potable water consumption as reported in the water balance. Over the same time span, on-post irrigation accounted for 10% of the total potable water use. More recently, however, the peak irrigation load has varied from 60 to 100 Mgal per month. When compared to the baseline average monthly consumption, the irrigation season in FY 2012, May through September, has been consuming 30% of all the potable water produced for Fort Riley, a peak that is expected to increase as family housing is completed. It is therefore reasonable to conclude that the single largest effect Fort Riley can have on potable water consumption is to find viable solutions to reduce or replace potable water use for irrigation purposes, in addition to domestic plumbing projects and loss prevention.

The roadmap assessment assessed three options for Fort Riley to show the overall impact on water demand through the study period:

1. **No Water Conservation Option:** If Fort Riley does not implement WCMs, the demand for potable water will likely increase through FY 2015 because of the full build-out of family housing to approximately 622 Mgal/yr. From FY 2016 through FY 2020, future water consumption should largely reflect irrigation demands and variations in post population.[1]

2. **Implementation of WCM's, Loss Prevention, and EPA Outreach Program:** If Fort Riley reduces water use by implementing the cost effective WCMs outlined in the roadmap in addition to leak and loss prevention, which current infrastructure projects should accommodate, Fort Riley can reduce potable water by approximately 100 Mgal/yr resulting in a total demand of 500 Mgal/yr by FY 2020.

3. **Implementation of WCM's, Loss Prevention, EPA Outreach Program, and Reclaimed Wastewater:** This scenario includes implementation of all of the water conservation projects and programs, as well as using of reclaimed wastewater for irrigation and other non-potable uses on the Custer Hill area. Execution of these projects would result in a reduction of approximately 150 Mgal/yr (Figure 6.2).

[1] This assumes static gross square footage.

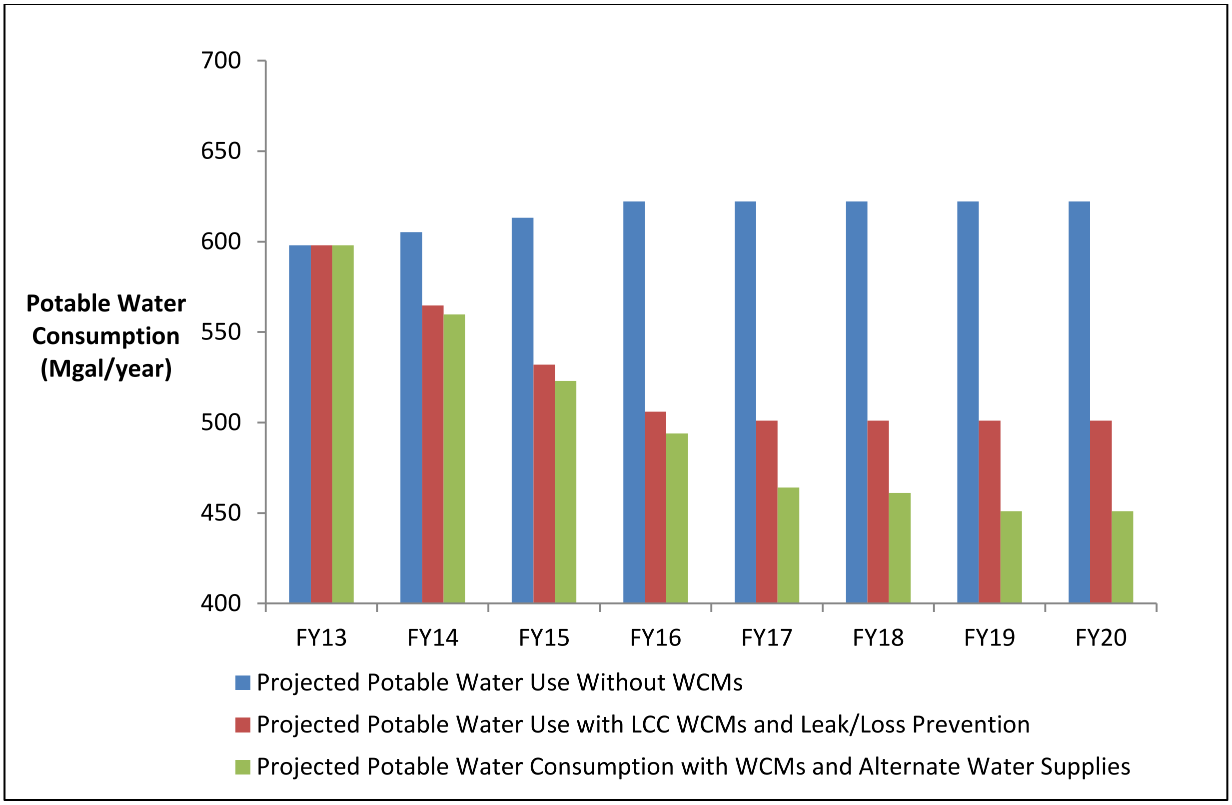


**Figure 6.2.** Potable Water Consumption from FY 2012 through FY 2020.

### Population-Based Water Use Intensity

The Army tracks WUI for all installations as water use per square foot of facility space. An alternative metric to consider when assessing water use is a population-based WUI. Since population drives many water end-uses such as plumbing fixtures, a population-based WUI may be a more useful metric than a building-based WUI.

The population-based potable WUI of Fort Riley in FY 2012 was 28 gallon per person per day, based on the potable water use supplied to the site and the daily average population. More recently, Fort Riley has been notified that portions of the 4th Brigade will be reduced approximately 1,700 active duty personnel by September 2017. Civilian personnel are also expected to be reduced proportionally as well though the number has not been finalized. For conservative purposes, the minimum loss of 1,700 personnel, or approximately 3 percent of the Fort Riley's total base population,[1] was accounted for in the population based WUI metric.

If Fort Riley does not implement recommended projects, the population WUI will increase to 30 gallon per person per day by FY 2020. However, if WCMs are implemented per the conservative scenario, Fort Riley's population WUI will be 25 gallons per person per day. If all recommended WCMs are implemented in the aggressive scenario, the daily total demand of potable water will be 22 gallons per person per day.

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[1] Population data provided by Chris Otto, Fort Riley DPW. Total population includes military active, military retirees, family members on and off-post, and civilian employees including contractors.

# 7.0 Implementation Strategy

## Project Prioritization

As part of the roadmap process, a workshop was held in April 2013 with personnel from Fort Riley's DPW, regional EPA participants, the Army Corps of Engineers, and Corvias (military housing contractor) to review the results of the water balance, evaluate proposed WCMs, and establish a strategy for meeting the net zero water goals and objectives. Attendees also investigated funding options for WCM implementation and brainstormed approaches for using alternative water sources such as the effluent from the current Custer Hill WTP. Workshop attendees developed a prioritization of the WCMs. The prioritization process scores each project based on a list of four criteria:

- Water supply and consumption effects
- Mission risk reduction
- Cost implications
- Implementation risk

Multiple questions were asked under each criteria and participants scored each question on a scale from 0 to 10 based on the relative importance of the issue (Appendix E). Weighted scores were tallied from each participant and an average was taken of the scores to develop an overall list of prioritized projects (Table 7.1).

**Table 7.1.** Fort Riley Weighted Average Score of Project Prioritization Exercise

| Criteria | Domestic Plumbing Fixtures | Commercial Kitchen Equipment | Irrigation Efficiency Improvements | Reclaimed Waste Water | Education Outreach |
|---|---|---|---|---|---|
| Water Supply and Consumption Effects | 1.2 | 0.8 | 1.0 | 1.5 | 1.1 |
| Mission Risk Reduction | 0.8 | 0.8 | 0.9 | 1.3 | 0.3 |
| Cost Implications | 1.2 | 1.3 | 0.8 | 0.4 | 1.0 |
| Implementation Risk | 0.8 | 1.0 | 0.7 | 0.5 | 0.4 |
| **Total Score** | 4.0 | 3.8 | 3.4 | 3.7 | 2.87 |
| **Rank** | **1** | **2** | **4** | **3** | **5** |

## Project Implementation Schedule

During the workshop, Fort Riley personnel provided a general timeline for WCM implementation, reclaim system development, and education/outreach, which can be used to plan projects to meet the net zero water goals (Table 7.2).

**Table 7.2.** Project Timeline for Implementation

| Net Zero Project | FY13 | FY14 | FY15 | FY16 | FY17 | FY18-FY20 |
|---|---|---|---|---|---|---|
| Irrigation controllers and efficiency improvements | Develop as part of utility energy service contract (UESC) project | Install weather-based controllers | Distribution system improvements | Distribution system improvements | Convert to reclaim water | Convert to reclaim water |
| Domestic plumbing fixtures | Develop as part of UESC project | Replace fixtures | Replace fixtures | Replace fixtures | | |
| Reclaim waste water for golf course, vehicle wash, or other irrigation | MILCON project request | Project design | Project design | | Project install | Project install |
| Leak detection | Leak detection surveys | Leak repairs | Leak repairs | Leak repairs | Leak repairs | |
| Education Outreach with EPA | Develop with EPA | Initiate program | Continue program | Continue program | Continue program | Continue program |
| Commercial kitchen equipment | Develop as part of UESC project | Replace equipment | Replace equipment | | | |

## Project Funding Options

The traditional approach for funding water projects at Army installations has been through direct appropriations for specific projects.  The general types of appropriated funds include

- Military Construction (MILCON)
- Energy Conservation Investment Program (ECIP)
- Operations and Maintenance, Army (OMA):
    - QUTM-Energy and Government-Owned Utility Systems
    - Sustainment, Restoration, and Modernization (SRM)

However, the likelihood of reduced appropriated funds, projects not directly tied to an installation's mission may be deferred or not funded. Fortunately, there are now a number of alternative funding approaches available to Army installations for water efficiency improvements, including

- Energy Savings Performance Contracts (ESPCs)
- Utility Energy Service Contracts (UESCs)

Energy savings performance contracts have been available to federal facilities since authorized in 1986. This law allows the Federal government to contract with private sector energy service companies (ESCOs) to acquire energy-efficiency projects financed by private capital. The ESCO finances the capital cost of the energy project and recovers its costs through a share of the energy savings resulting from the installed project for the duration of the contract (up to 25 years).

The most common approach for working with a utility to implement energy-efficiency projects is via a UESC. With a UESC, the utility typically arranges financing to cover the capital costs of the project. Then the utility is repaid over the contract term from the cost savings generated by the energy-efficiency measures. Unlike ESPCs, UESCs do not have special requirements for measurement and verification (M&V) of energy savings.

The primary advantage of using direct appropriation funding for a water project is that there is no "loan," thus no repayment is required. A secondary advantage is that the government retains all of the cost savings from the water projects. However, the Army installation is responsible for proper project management, execution, operation, and maintenance. The source of capital funding will depend on the size and scope of the project. Funding can come from the installation's budget for O&M or minor construction, if the water project is small.

Projects over $750,000 can be funded through ECIP funding. ECIP is the only direct investment in water conservation for the Department of Defense (DOD). The program requires congressional notification prior to project startup and periodic status updates thereafter. ECIP is a subset of the DOD MILCON program, established to improve energy efficiency and reduce water consumption at existing military facilities.

To receive ECIP funding, a water project must, at a minimum, meet specific economic criteria of an SIR of at least 1.25 and a payback of less than 10 years. The FY 2012 ECIP guidance for the Army includes a 5% goal for water conservations projects. Federal installations will be challenged by the need to identify a single project or the bundling of smaller projects, to reach that threshold, while still meeting the SIR and payback criteria. Another drawback to ECIP-funded projects is time between the call for ECIP projects and receipt of actual funding, which can be two to three years. Design of these projects is normally funded the year before implementation. Both design and construction are paid with MILCON appropriation and, therefore, do not compete for resources with other requirements in the installation budget.

Smaller projects can be implemented through other appropriated mechanisms including general OMA, OMA funded QUTM and SRM funds. These funding sources do not have a minimum size, but must be less than $750,000. OMA funds are provided annually to installations, so there is typically a shorter turnaround time than receiving ECIP funds for implementing water projects. QUTM is a mechanism for sites to receive OMA funds, focused on low and no cost energy and WCMs at all garrisons. In general, there is no minimum SIR requirement for SRM and OMA funds. However, QUTM requires a simple payback of less than 10 years and projects are prioritized based on the SIR (Table 7.3).

**Table 7.3.** Fort Riley Water Project Funding Options

| | Project Size ($) | Time to Execute | Financial Requirements | Water Set Aside | Focus | Comments |
|---|---|---|---|---|---|---|
| **SRM** | New work/minor construction limited to $750K | 1 year | None | No | O&M projects | |
| **ECIP** | Greater than $750K | 2 years | SIR = 1.25 renewable energy projects<br>SIR = 1.0 overall program average<br>SIR = 2.0 | Yes | Renewable energy (35%), energy conservation (55%), water conservation (5%) and energy security (5%) | $50M in FY 2012 for Army |
| **QUTM** | New work/minor construction limited to $750K | 1 year | Payback less than 10 years | No | Low cost/no cost energy WCMs | Funds available FY 13-15. $55M in FY13 |
| **MILCON** | Greater than $750K | 5 years | None | No | Infrastructure projects | |
| **UESC** | Usually more than $1M, $3-5M preferred | 2-3 years | Total project payback less than 10 years | No | Energy/water efficiency projects, renewable energy | Utility must support UESC |
| **ESPC** | Usually more than $1M, $3-5M preferred | 2-3 years | Maximum contract term 25 years to pay back capital costs and financing | No | Energy/water efficiency projects, renewable energy | |

Fort Riley plans to use multiple funding/financing sources to implement the WCMs and achieve the water reduction goals. They are in the early stages of developing a UESC contract with either the electric or natural gas utility. This will be the first choice for financing water projects. However, with the low cost of water, many of the water projects will have to be bundled with energy reduction projects to achieve the required rate of return. At the same time, Fort Riley will pursue ECIP and QUTM funding for other water projects (Appendix F).

During the roadmap workshop held at Fort Riley, a specific funding source for each WCM and alternative water project was identified (Table 7.4).

**Table 7.4.** Fort Riley Funding Options for Roadmap Projects

| Roadmap Project | Funding Type | Considerations/Notes |
|---|---|---|
| **Irrigation controllers and efficiency improvements** | UESC, SRM | Use UESC for cost effective replacement projects. Use SRM to supplement UESC, and make efficiency improvements through sprinkler head replacements. |
| **Domestic plumbing** | UESC, OMA-QUTM; SRM | Use UESC for plumbing fixture replacement when cost-effective. Supplement UESC with QUTM and/or SRM to complete all plumbing fixture replacements. |
| **Reclaim water for golf course, vehicle wash, and other irrigation** | SRM<br>MILCON | SRM funding will be used for system design. MILCON funding will be requested for the system to distribute the reclaim water to the golf course, vehicle wash, and other irrigation systems. |
| **Leak detection** | OMA-SRM | Conduct leak detection surveys and make repairs, as needed, using SRM. |
| **Commercial kitchen equipment** | UESC, QUTM | Include cost effective projects in the UESC project, and supplement with QUTM/SRM as needed. |

# 8.0 Cumulative Time-Phased Project Impacts

With the implementation of WCMs, loss prevention strategies, infrastructure improvements, and potential expansion of reclaimed water, Fort Riley can repair, replace, or deploy technically viable solutions in the pursuit of water conservation objectives. Annual potable water consumption at Fort Riley could be reduced by up to 25% from FY 2012 if the recommended WCMs are implemented and the site is capable of reclaiming wastewater for use in non-potable applications. Despite the aggressive pursuit of these strategies, it will be difficult for Fort Riley to achieve their net zero goal of a 50% reduction in WUI. However, as previously discussed, technically viable solutions exist, and the pursuit of their implementation will have a significant effect on the reduction of potable freshwater consumption at Fort Riley.

## Net Zero Water WUI Reduction Goal

In addition to meeting the site-specific net zero water definition, Fort Riley is pursuing the building-based potable WUI reduction goal of 50% compared to the FY 2007 baseline. To meet the goal, Fort Riley must achieve a building WUI of 24 gal/sqft, reduced from the FY 2007 baseline of 48 gal/sqft. If Fort Riley reduces water use by implementing the cost effective WCMs outlined in the roadmap in addition to leak and loss prevention, which current infrastructure projects should accommodate, the potable WUI will be 35 gal/sqft. This would be short of the net zero water goal by approximately 13 gal/sqft. However, this would meet the goal of EO 13514, and would result in a 27% reduction in WUI by FY 2020 (Figure 8.1).

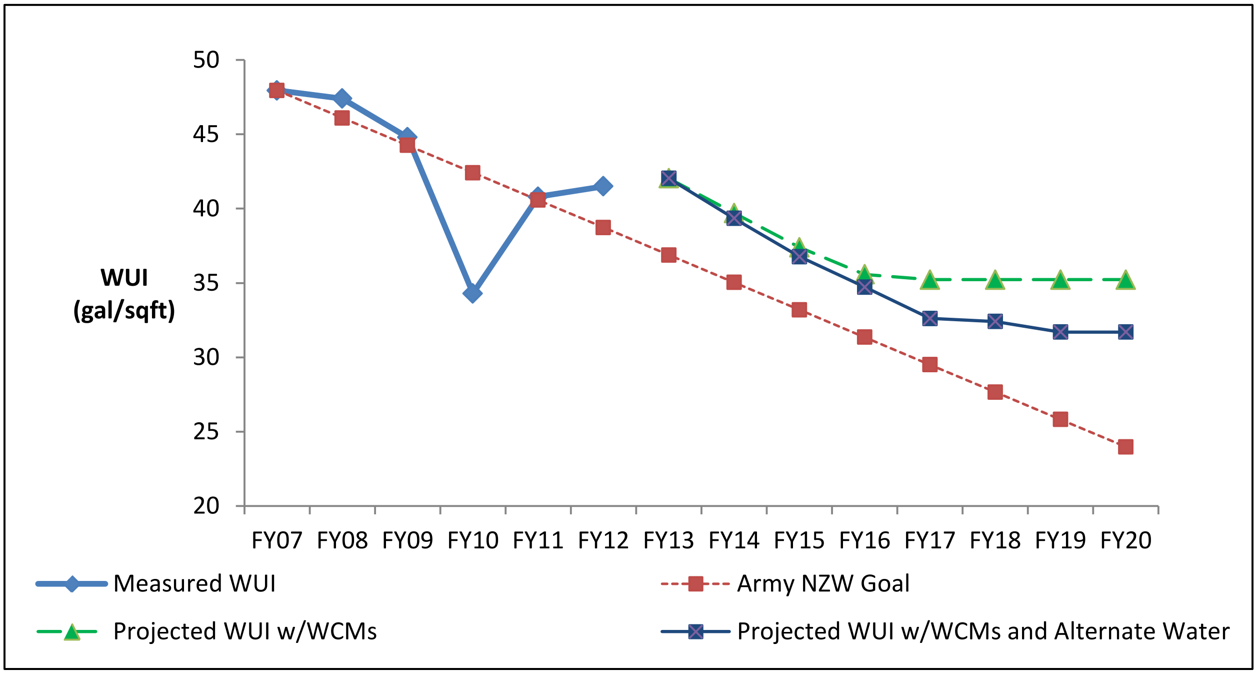


**Figure 8.1**. Fort Riley Projected Progress Toward the Net Zero Water WUI Reduction Goal

If Fort Riley implements cost effective WCMs and is able to capitalize on a funding mechanism that enables use of alternate water supplies starting in FY 2017, total demand for potable in FY 2020 would be approximately 451 Mgal/yr with a corresponding WUI of 32 gal/sqft (Figure 8.2). This is also short of the net zero water goal approximately by 8 gal/sqft. Again, this exceeds the goal established by EO 13514 and results in a 33% reduction from the FY2007 baseline.

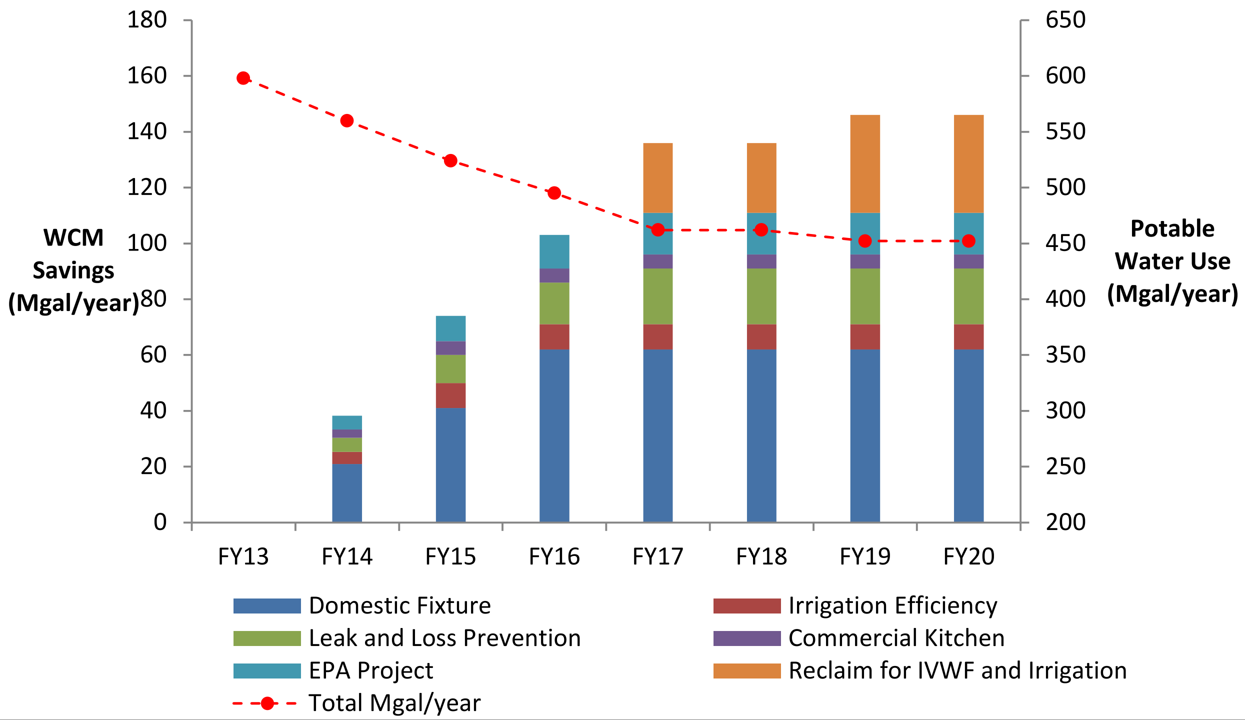


**Figure 8.2.** Time Phased WCMs and Cumulative Reduction in Potable Water

## Fort Riley Net Zero Water Objective

Though the empiric WUI goal will be difficult to achieve, that doesn't preclude Fort Riley from having the ability to meet their overall net zero water objective defined as:

> *To limit the consumption of freshwater resources and return water back to the regional watershed so as not to deplete the groundwater and surface water resources of that region in quantity and quality over the course of a year.*

In meeting the regional watershed level net zero objective, Fort Riley should consider the effect that WCM conservation projects can have on potable water consumption, but also that the site captures and contributes multiple sources of water that are ultimately returned to the regional freshwater resources.

For example, implementation of WCM projects has been demonstrated to be capable of reducing the potable water burden by approximately 80 Mgal/yr. When coupled with EPA based projects as well as reclaimed wastewater, the total potential reduction is over 150 Mgal/yr. Looking beyond the site boundaries however, the combined outfall of the Custer Hill and Funston WWTP was 410 Mgal in FY2011, and nearly 550 Mgal in FY2012. These outfalls supplement the Lower Republican and Kansas River Watersheds, which invariably provide surface water for downstream uses dominated by agricultural and public supply water demands.

Additionally, as addressed in the Stormwater Detention Study (HNTB, 2007), though Fort Riley does not retain stormwater, a substantial amount of precipitation is collected through impervious surfaces, and routed to outfalls throughout the site. With 33 inches of annual precipitation and calculated stormwater runoff rates ranging from several hundred to several thousand cubic feet per second (cfs) among the drainage basins, Fort Riley is likely contributing more freshwater back to the regional watershed than is withdrawn from its wells over the course of any given year.

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# Appendix A – Technical Analysis Methods

This appendix documents the methods and assumptions used to estimate water savings potential, implementation cost, economic performance, and overall project feasibility.

## Plumbing Fixture Retrofit Analysis Approach

Domestic plumbing fixture water conservation projects were developed by taking the water consumption of the existing equipment and comparing it to the reduced water consumption of the retrofit or replacement fixtures for toilets, urinals, faucets, showerheads, and clothes washers (Elam et al. 2012). Projects were developed for distinct building groups at Fort Riley: office buildings, lodging, motor pools, barracks, and day care centers.

The basic formulas used in estimating water use in domestic fixtures for the existing conditions and retrofit case are as follows.

**Toilets and Urinals Annual Water Use (gallons per year) =**

*Flush rate (gallons per flush) × number of flushes per day × number of occupants × number of operating days per year*

**Showers and Faucets Annual Water Use (gallons per year) =**

*Flow rate (gallons per minute) × minutes of operation per use × number of uses per day × number of occupants × operating days per year*

**Showers, Faucets, and Laundry Annual Energy Use (watts per year) =**

*Hot water use (gallons per year) × specific heat of water (watt-hr/gram-C) × mass of water (gram/gal) × increase in temperature (°C) ÷ boiler efficiency*

**Laundry Annual Water Use (gallons per year) =**

*Gallons per load (gpl) × loads of laundry washed per week × number of occupants × operating days per year*

Assumptions made in the analysis are documented below (Table A.1).

**Table A.1**. Domestic Plumbing Fixture Retrofit Analysis Assumptions

| Category | Fixture Type | Assumption | Data Source/Notes |
|---|---|---|---|
| **Daytime male toilet/urinal use** | Toilet/urinal | 1 use per 2 hours | AWWARF 1999 and 2000 |
| **Daytime male urinal use** | Urinal | 75% of total number of restroom uses (if available) | AWWARF 2000 |
| **Daytime female toilet use** | Toilet | 1 use per 2 hours | AWWARF 1999 and 2000 |
| **Lavatory faucet use (non-residential)** | Faucet | 6 seconds per use | WaterSavers historical project data |
| **Lavatory faucet use (residential)** | Faucets | 5 minutes per day | AWWARF 1999 |
| **Kitchenette faucet use** | Faucet | 2 minutes per day (if available) | AWWARF 1999 and 2000 |
| **Shower use** | Shower | 8 minutes per day (if used) | AWWARF 1999 |
| **Current toilet flush rate** | Toilet | 1.8 – 4.5 gallons per flush (gpf) | Observed flush rates during site visit in January 2012 |
| **Current urinal flush rate** | Urinal | 1.0 – 2.3 gpf | Observed flush rates during site visit in January 2012 |
| **Current lavatory faucet flow rate** | Faucet | 0.5 – 2.2 gallons per minute (gpm) | Measured flow rates during site visit in January 2012 |
| **Current kitchenette faucet flow rate** | Faucet | 2.0 – 2.2 gpm | Measured flow rates during site visit in January 2012 |
| **Current showerhead flow rate** | Showerhead | 2.2 – 3.0 gpm | Measured flow rates during site visit in January 2012 |
| **Replacement toilet flush rate** | Toilet | 1.28 gpf for flush valve toilets; 1.0 gpf for tank toilets | Rating for high efficiency toilet |
| **Replacement urinal flush rate** | Urinal | 0.125 gpf | Rating for pint urinal |
| **Replacement lavatory and kitchenette flow rate** | Faucet | 0.5 and 1.0 gpm | Rating for high efficiency fixtures |
| **Replacement showerhead flow rate** | Showerhead | 1.5 gpm | Rating for high efficiency fixture |

During the water balance, walk-through audits of representative building groups and building types (Table A.2) were completed to assess the potential for fixture retrofits.

**Table A.2**. Fort Riley Plumbing Fixture counts by building group

| Facility Numbers | Fixture Category | Qty | Existing | Proposed | Total Est. Qty for Building Type |
|---|---|---|---|---|---|
| **Bldg 214** (208, 223, 227, 402, 410, 470, 471, 540, 541, and 542 have similar equipment; qty is different) | Toilets | 26 | Tank type 1.6 gpf | Replace with 1.0 gpf pressure assisted equivalent | 204 |
| | Toilets | 4 | Commercial flush valve 1.6 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 40 |
| | Urinals | 2 | 1.0 gpf washdown urinal | Replace with pint-flush HEU system | 22 |

| Facility Numbers | Fixture Category | Qty | Existing | Proposed | Total Est. Qty for Building Type |
|---|---|---|---|---|---|
| | Lav Faucets | 26 | 2.2 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 204 |
| | Kitchenette Faucets | 26 | 2.2 gpm threaded kitchenette faucets | Retrofit with 1.0 gpm laminar flow controls | 204 |
| | Showers | 32 | 2.2 to 2.5 gpm showerheads | Replace with 1.5 gpm low-flow pressure compensating showerheads | 252 |
| **Bldg 7001A** (7001B-F, 7002A-B, 7003A-D, 7081A-B, 7081E-F, and 7498 have similar equipment; qty is different) | Toilets | 36 | Tank type 1.6 gpf | Replace with 1.0 gpf pressure assisted equivalent | 666 |
| | Toilets | 2 | Commercial flush valve 1.6 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 32 |
| | Lav Faucets | 36 | 2.2 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 666 |
| | Kitchenette Faucets | 36 | 2.2 gpm threaded kitchenette faucets | Retrofit with 1.0 gpm laminar flow controls | 666 |
| | Showers | 36 | 2.5 gpm showerheads | Replace with 1.5 gpm low-flow pressure compensating showerheads | 666 |
| **Bldg 7492** (411, 7494, 7496, 7647, 7649, 7872, 7874, 7876, 7882, 7884, and 7886 have similar equipment; qty is different) | Toilets | 78 | Tank type 1.6 gpf | Replace with 1.0 gpf pressure assisted equivalent | 881 |
| | Toilets | 2 | Commercial flush valve 1.6 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 24 |
| | Urinals | 1 | 1.0 gpf washdown urinal | Replace with pint-flush HEU system | 12 |
| | Lav Faucets | 80 | 2.2 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 953 |
| | Kitchenette Faucets | 78 | 2.2 gpm threaded kitchenette faucets | Retrofit with 1.0 gpm laminar flow controls | 953 |
| | Showers | 78 | 2.2 to 2.5 gpm showerheads | Replace with 1.5 gpm low-flow pressure compensating showerheads | 881 |

| Facility Numbers | Fixture Category | Qty | Existing | Proposed | Total Est. Qty for Building Type |
|---|---|---|---|---|---|
| **Bldg 685** (686, 687, 688, 695, 696, 7648, and 7404 have similar equipment; qty is different) | Toilets | 78 | Tank type 1.6 gpf | Replace with 1.0 gpf pressure assisted equivalent | 539 |
| | Toilets | 4 | Commercial flush valve 1.6 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 32 |
| | Lav Faucets | 78 | 2.2 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 539 |
| | Kitchenette Faucets | 78 | 2.5 gpm threaded kitchenette faucets | Retrofit with 1.0 gpm laminar flow controls | 539 |
| | Showers | 78 | 2.2 to 2.5 gpm showerheads | Replace with 1.5 gpm low-flow pressure compensating showerheads | 539 |
| **Bldg 7844** (7815A-B, 7842, 7846, 7848, 7850, 7886, 8002, 8006, 8008, 8012, 8014, 8018, 8038, 8040, 8042, 8048, and 8054 have similar equipment; qty is different) | Toilets | 56 | Tank type 1.6 gpf | Replace with 1.0 gpf pressure assisted equivalent | 836 |
| | Toilets | 2 | Commercial flush valve 1.6 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 38 |
| | Urinals | 1 | 1.0 gpf washdown urinal | Replace with pint-flush HEU system | 19 |
| | Lav Faucets | 56 | 2.5 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 836 |
| | Kitchenette Faucets | 2 | 2.5 gpm threaded kitchenette faucets | Retrofit with 1.0 gpm laminar flow controls | 386 |
| | Showers | 56 | 2.2 to 2.5 gpm showerheads | Replace with 1.5 gpm low-flow pressure compensating showerheads | 836 |
| **Bldg 7614** (7404, 7610, 7648, 7812, and 7818) have similar equipment; qty is different) | Toilets | 30 | Commercial flush valve 3.5 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 233 |
| | Urinals | 3 | 1.6 gpf blowout urinal | Replace with pint-flush HEU system | 24 |
| | Lav Faucets | 18 | 2.2 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 140 |
| | Showers | 20 | 2.0 to 2.5 gpm showerheads | Replace with 1.5 gpm low-flow pressure compensating showerheads | 155 |

| Facility Numbers | Fixture Category | Qty | Existing | Proposed | Total Est. Qty for Building Type |
|---|---|---|---|---|---|
| **Admin, Operations, Maintenance, Motor Pool, Training** variety of fixture types and quantities; estimate based on walkthrough inspections. | Toilets | 9 | Tank type 1.6 gpf | Replace with 1.0 gpf pressure assisted equivalent | 666 |
| | Toilets | 2 | Commercial flush valve 3.5 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 832 |
| | Urinals | 3 | 1.0 gpf washdown urinal | Replace with pint-flush HEU system | 679 |
| | Lav Faucets | 8 | 2.5 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 5434 |
| | Kitchenette Faucets | 2 | 2.5 gpm threaded kitchenette faucets | Retrofit with 1.0 gpm laminar flow controls | 1067 |
| **(Bldg 407 used as example)** | | | | | |
| **Admin, Operations, Maintenance, Motor Pool, Training** variety of fixture types and quantities; estimate based on walkthrough inspections. | Toilets | 9 | Commercial flush valve 1.6 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 1497 |
| | Lav Faucets | 8 | 2.2 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 5434 |
| | Showers | 2 | 2.5 gpm showerheads | Replace with 1.5 gpm low-flow pressure compensating showerheads | 135 |
| **(Bldg 408 used as example)** | | | | | |
| **Admin, Operations, Maintenance, Motor Pool, Training** variety of fixture types and quantities; estimate based on walkthrough inspections. | Toilets | 1 | Commercial flush valve 1.6 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 1497 |
| | Toilets | 3 | Commercial flush valve 3.5 gpf (china and diaphragm valve) | Replace china and valve with 1.28 gpf HET with piston valve | 832 |
| | Urinals | 2 | 2.4 gpf blowout urinal | Replace with pint-flush HEU system | 679 |
| | Lav Faucets | 4 | 2.2 gpm threaded lavatory faucets | Retrofit with 0.5 gpm laminar flow controls | 5434 |
| **(Bldg 7305 used as example)** | | | | | |

## Irrigation Retrofit Analysis Approach

The *Army Landscaping Water Use Estimating Tool* (PNNL 2012) was used to estimate landscape irrigation water use in areas not supported by metering. The tool takes into account basic information about the landscape areas. Using historical precipitation and evapotranspiration data and, basic information on the irrigated areas such as soil type, turf type, landscape appearance, and system efficiency, the tool estimates typical irrigation water requirements for Manhattan, KS. The tool was used to estimate the supplemental water requirements for Fort Riley in addition to evaluating golf course irrigation requirements were there no self-imposed limitations e.g., irrigation based on ambient conditions.

In addition, modeled water consumption for irrigation was compared to historical potable water use over time to examine the large spike in water use during the summer (Figure A.1).

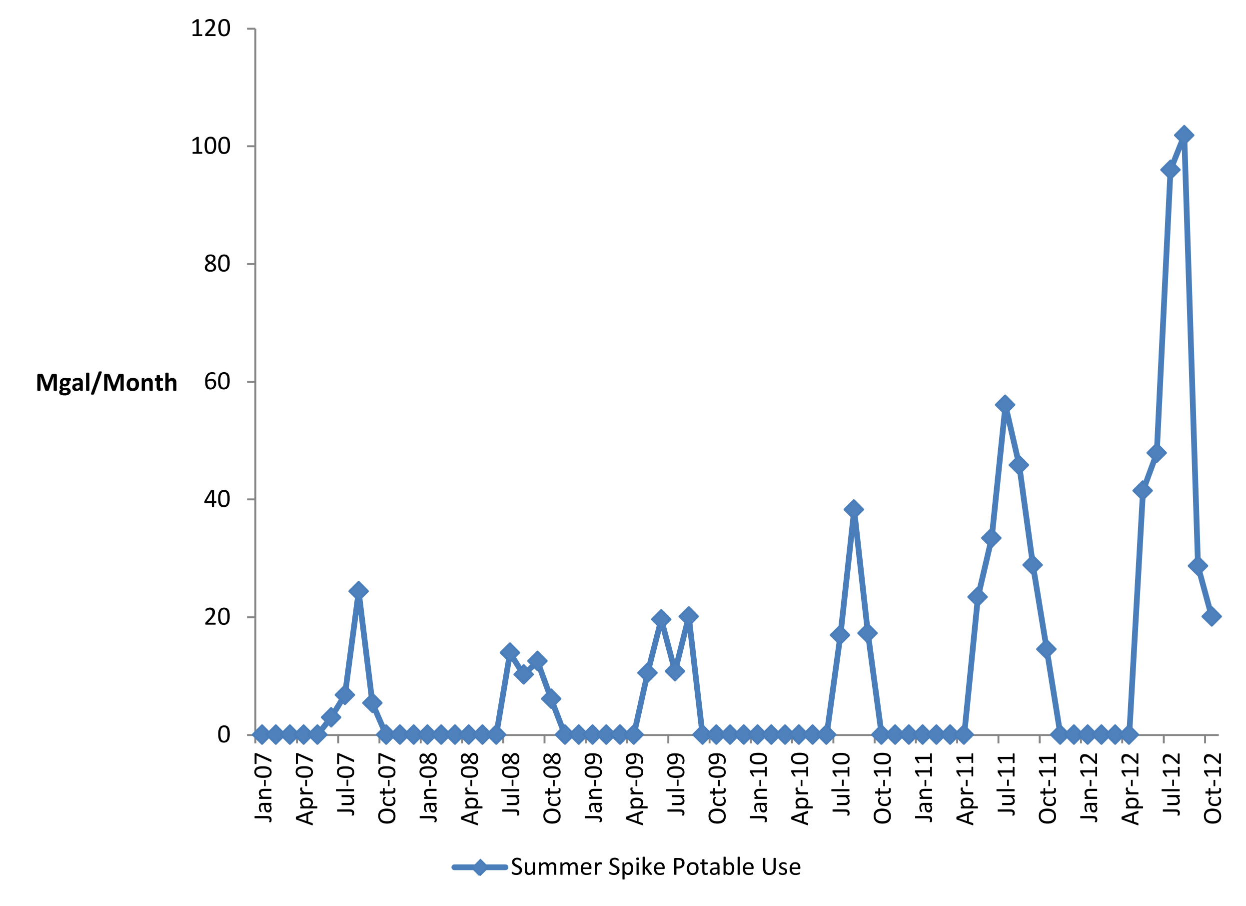


**Figure A.1**. Fort Riley Summer Potable Water Peak vs. Baseline

The model predicts that Fort Riley's annual water use factor should be approximately 12-15 gallons per square foot of turf space (PNNL, 2012). However, based on of historical water use during the summer months, the current amount of irrigation applied to Fort Riley turf areas not including the golf course is over 30 gallons per square foot if the peak is attributed to irrigation demands. Under normal ambient conditions, average efficiency, and average turf appearance, the summer peak might account for 20 to 30 Mgal per month when analyzed using the irrigation tool. This indicates the need for irrigation control and improved efficiencies, or there is an alternate seasonal demand for water that is not disposed of through the sewer system.

Distribution system enhancements were estimated to save 10% and advanced controls were estimated to save 30% compared with the existing landscape irrigation. This is consistent with other irrigation audits on systems of similar age using limited control. These potential savings were provided by WaterSavers, LCC that delivered technical support to PNNL in the water balance and roadmap assessments. The savings are based on the actual potential at Fort Riley as well as typical savings achieved for similar installations.

## Commercial Kitchen Retrofit Analysis Approach

Kitchen equipment use was estimated based on equipment runtime and typical use patterns of similar commercial kitchens. All kitchen equipment water use follows the same general calculation methods:

- Avg. flow rate (gpm) × 60 min/hr × avg. equipment runtime (hr per day) × days per year

Fluctuations in use such as number of meals, tons of production (ice), and occupancy were considered when developing calculations for kitchen equipment. Average use was normalized to produce consumption as presented in Section 3 of this report (Table A.4).

**Table A.4**. Kitchen Equipment Consumption

| Kitchen Equipment Type | Replacement or Retrofit Technology | Total Current Water Consumption (kgal/yr) |
|---|---|---|
| **Ice Machines** | (24) counterflow heat exchangers on existing ice machines | - |
| **Pre-Rinse Sprayers** | (8) 1.24 gpm pre-rinse sprayers | 699 |
| **Garbage Disposals Retrofit** | In line flow restrictor | 5,256 |
| **Convection Steamers** | (9) | 526 |
| **Dish Machines** | (4) | 1,708 |
| **Tray Conveyor Retrofit** | (8) In line flow restrictors | 876 |
| **Food Waste Pulper** | In line flow restrictor | 3,504 |

## Life Cycle Cost Analysis Approach

A detailed life cycle cost (LCC) analysis was performed for the water conservation measures (WCMs) that were investigated as part of the roadmap process. The LCC analysis evaluated the discounted streams or present values, of costs associated with potential retrofit equipment in comparison to the existing, or base case, equipment, over the period of remaining life of the existing equipment.

Components of the LCC analysis for each WCM include:

- Capital costs
    - Retrofit installed cost
    - Retrofit rebate if applicable
    - Present value of replacement cost of WCM[1]
- Present values of electricity and natural gas costs, for both base and retrofit cases

[1] This item also quantifies any value of remaining life of the retrofit equipment. A negative value for this present value is indicative of a credit for remaining life.

- Present value of wastewater discharge costs that are charged to reimbursable customers at Fort Riley, for both base and retrofit cases
- Present value of annual operations and maintenance costs, for both base and retrofit cases
- Lifetimes for both the current product years to fail and the lifespan of the retrofit. Lifetimes for retrofit types are as follows:
  - Irrigation controls and distribution upgrades – 15 years
  - Rainwater harvesting systems – 20 years
  - Toilets and urinals– 20 years
  - Lavatory faucets, kitchen faucets, and showerheads – 12 years
  - Pre-rinse sprayer replacements – 12 years
  - Front load washing machines – 10 years
  - Ozone laundry support systems – 12 years
- Ice machines – 15 years
- Growth indices over the life of the WCM that takes into account potential population variance of Fort Riley (held stable throughout)

Outputs of the analysis that determine the economics of the WCMs include:

- Net savings or net present value (NPV) – the difference between the base case and retrofit case life-cycle costs.
- Simple payback – the installed cost, net of any rebates, divided by the total first-year cost savings.
- Savings-to-investment ratio (SIR) – the present value of total cost savings divided by the sum of the installed cost (net of any rebates) and the present value of net replacement costs. Note that the SIR calculation assumes that savings continue unabated for the life of the retrofit equipment, meeting Energy Conservation Investment Program (ECIP) requirements.

Other outputs of the analysis include:

- Annual water, wastewater, and energy savings – the amounts avoided each year by a WCM.
- First year cost savings – the initial dollar value of annual water, wastewater, and energy savings, which may change over time due to price escalation rates.
- Cumulative water savings-to-investment ratio – the cumulative water savings (over the analysis period) divided by the present value of incremental investment (both base case and replacement). This metric is somewhat similar to the SIR, with the primary difference being that physical units are used in the numerator.[1]

**Analysis Assumptions:**

The following is a list of assumptions used.

[1] Physical units are not discounted.

- Rates calculated using information provided by Fort Riley personnel were used in the analysis:
  - Potable water rate: $1.16 per thousand gallons (kgal)
  - Wastewater treatment rate: $2.37/kgal
  - Natural gas rate: $0.50/therm
  - Electricity rate: $0.08/kWh
- Future cash flows were discounted using a 3.0% real discount rate, which is the current DOE rate specified by the National Institute of Standards and Technology's (NIST) Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – 2011, the latest annual supplement to NIST Handbook 135 (National Institute of Standards and Technology 2012).
- Regionally appropriate (Census Region 4) NIST industrial energy price escalation rates and discount factors were used.
- Wastewater discharge prices will escalate in line with electricity price escalation rates.
- The duration of the savings of each proposed measure is equal to the time to failure of the existing equipment; credit for value of remaining retrofit life at the end of the analysis period effectively applies annual retrofit capital costs.
- For any ECIP-specific calculations, the duration of the savings of each proposed measure is equal to the expected life of the retrofit equipment.
- Inflation data, from a gross domestic product chain-type price index, were used to calculate real water price indices from nominal water price forecasts. These inflation data were obtained from the *Annual Energy Outlook 2013* (Energy Information Agency 2013).

### WCMs Evaluated and Metrics

| Project ID | Building Group/Area | Technology Type | Project Description | 1st-year Water Savings (kgal) | 1st-year Natural Gas Savings (therms) | Total Installation Cost | First-year Cost Savings | Simple Payback | ECIP SIR | NPV | Cum Ratio (gal/$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 CAB | Toilets & Urinals | HET & pint HEU | 587 | - | $291,561 | $3,378 | 86.3 | 0.2 | ($74,103.11) | 33 |
| 2 | 1 SB & 2nd BDE | Toilets & Urinals | HET & pint HEU | 1,383 | - | $471,004 | $6,980 | 67.5 | 0.2 | ($112,609.04) | 48 |
| 3 | 1st BDE | Toilets & Urinals | HET & pint HEU | 776 | - | $355,962 | $4,323 | 82.4 | 0.2 | ($89,546.06) | 35 |
| 4 | 4 BCT | Toilets & Urinals | HET & pint HEU | 939 | - | $462,329 | $5,382 | 85.9 | 0.2 | ($117,388.76) | 33 |
| 5 | Garrison & Non-Divisional | Toilets & Urinals | HET & pint HEU | 319 | - | $145,625 | $1,882 | 77.4 | 0.2 | ($36,113.51) | 36 |
| 6 | Misc | Toilets & Urinals | HET & pint HEU | 2,009 | - | $153,910 | $8,580 | 17.9 | 0.9 | ($7,481.04) | 212 |
| 7 | 1 CAB | Faucets & Showers | high efficiency/ tamper proof | 5,523 | 27,206 | $31,424 | $33,650 | 0.9 | 13.6 | $88,269.94 | 2,225 |
| 8 | 1 SB & 2nd BDE | Faucets & Showers | high efficiency/ tamper proof | 8,833 | 35,651 | $53,580 | $49,889 | 1.1 | 11.8 | $129,263.15 | 2,087 |
| 9 | 1st BDE | Faucets & Showers | high efficiency/ tamper proof | 7,183 | 35,881 | $38,828 | $44,014 | 0.9 | 14.4 | $115,992.79 | 2,342 |
| 10 | 4 BCT | Faucets & Showers | high efficiency/ tamper proof | 5,996 | 24,202 | $41,809 | $33,868 | 1.2 | 10.3 | $86,464.29 | 1,816 |
| 11 | Garrison & Non-Divisional | Faucets & Showers | high efficiency/ tamper proof | 2,040 | 10,114 | $13,213 | $12,461 | 1.1 | 12.0 | $32,313.92 | 1,954 |
| 12 | Misc | Faucets & | high efficiency/ | 2,432 | 12,544 | $6,419 | $15,099 | 0.4 | 30.0 | $41,424.82 | 4,797 |

| Project ID | Building Group/Area | Technology Type | Project Description | 1st-year Water Savings (kgal) | 1st-year Natural Gas Savings (therms) | Total Installation Cost | First-year Cost Savings | Simple Payback | ECIP SIR | NPV | Cum Ratio (gal/$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Showers | tamper proof | | | | | | | | |
| 13 | Custer Hill | Toilets & Urinals | HET & pint HEU | 205 | - | $20,435 | $922 | 22.2 | 0.7 | ($2,008.29) | 163 |
| 14 | Forsyth | Toilets & Urinals | HET & pint HEU | 38 | - | $5,313 | $185 | 28.8 | 0.5 | ($778.93) | 117 |
| 15 | Funston | Toilets & Urinals | HET & pint HEU | 238 | - | $18,704 | $1,028 | 18.2 | 0.8 | ($979.29) | 207 |
| 16 | MAAF | Toilets & Urinals | HET & pint HEU | 33 | - | $2,375 | $142 | 16.8 | 0.9 | ($71.68) | 228 |
| 17 | Main Post | Toilets & Urinals | HET & pint HEU | 4,197 | - | $221,280 | $17,154 | 12.9 | 1.2 | $11,700.50 | 308 |
| 18 | Whitside | Toilets & Urinals | HET & pint HEU | 57 | - | $6,443 | $264 | 24.4 | 0.6 | ($758.90) | 144 |
| 19 | Custer Hill | Faucets & Showers | high efficiency/ tamper proof | 94 | 330 | $426 | $507 | 0.8 | 15.0 | $1,343.24 | 2,801 |
| 20 | Forsyth | Faucets & Showers | high efficiency/ tamper proof | 18 | 61 | $111 | $94 | 1.2 | 10.8 | $242.43 | 2,004 |
| 21 | Funston | Faucets & Showers | high efficiency/ tamper proof | 110 | 384 | $390 | $590 | 0.7 | 19.1 | $1,586.91 | 3,559 |
| 22 | MAAF | Faucets & Showers | high efficiency/ tamper proof | 15 | 54 | $50 | $83 | 0.6 | 21.1 | $223.37 | 3,925 |
| 23 | Main Post | Faucets & Showers | high efficiency/ tamper proof | 1,931 | 6,750 | $4,618 | $10,385 | 0.4 | 28.4 | $28,463.33 | 5,294 |
| 24 | Whitside | Faucets & Showers | high efficiency/ tamper proof | 26 | 92 | $134 | $142 | 1.0 | 13.3 | $371.20 | 2,480 |
| 25 | Custer Hill | Toilets & Urinals | HET & pint HEU | 2,267 | - | $300,714 | $10,833 | 27.8 | 0.6 | ($42,277.76) | 122 |
| 26 | Funston | Toilets & Urinals | HET & pint HEU | 26 | - | $2,486 | $117 | 21.2 | 0.7 | ($220.34) | 172 |
| 27 | MAAF | Toilets & Urinals | HET & pint HEU | 158 | - | $35,168 | $879 | 40.0 | 0.4 | ($6,753.99) | 73 |
| 28 | Main Post | Toilets & Urinals | HET & pint HEU | 184 | - | $16,083 | $809 | 19.9 | 0.8 | ($1,190.37) | 186 |
| 29 | Custer Hill | Faucets & Showers | high efficiency/ tamper proof | 1,043 | 3,645 | $6,279 | $5,608 | 1.1 | 11.3 | $14,473.41 | 2,103 |
| 30 | Funston | Faucets & Showers | high efficiency/ tamper proof | 12 | 42 | $52 | $65 | 0.8 | 15.9 | $173.30 | 2,958 |
| 31 | MAAF | Faucets & Showers | high efficiency/ tamper proof | 73 | 254 | $734 | $391 | 1.9 | 6.7 | $939.58 | 1,255 |
| 32 | Main Post | Faucets & Showers | high efficiency/ tamper proof | 85 | 297 | $336 | $456 | 0.7 | 17.2 | $1,219.59 | 3,200 |
| 33 | Custer Hill | Toilets & Urinals | HET & pint HEU | 5,323 | - | $402,490 | $22,810 | 17.7 | 0.9 | ($17,842.92) | 215 |
| 34 | Forsyth | Toilets & Urinals | HET & pint HEU | 510 | - | $49,346 | $2,278 | 21.7 | 0.7 | ($4,606.76) | 168 |
| 35 | Funston | Toilets & Urinals | HET & pint HEU | 1,246 | - | $102,492 | $5,410 | 18.9 | 0.8 | ($6,399.44) | 197 |
| 36 | MAAF | Toilets & Urinals | HET & pint HEU | 2,039 | - | $149,847 | $8,698 | 17.2 | 0.9 | ($5,680.87) | 221 |
| 37 | Main Post | Toilets & Urinals | HET & pint HEU | 2,039 | - | $132,301 | $8,546 | 15.5 | 1.0 | ($976.05) | 250 |
| 38 | Whitside | Toilets & Urinals | HET & pint HEU | 170 | - | $17,945 | $772 | 23.2 | 0.7 | ($1,936.80) | 154 |
| 39 | Custer Hill | Faucets & Showers | high efficiency/ tamper proof | 2,449 | 8,560 | $8,385 | $13,170 | 0.6 | 19.9 | $35,496.75 | 3,698 |
| 40 | Forsyth | Faucets & Showers | high efficiency/ tamper proof | 234 | 820 | $1,028 | $1,261 | 0.8 | 15.5 | $3,345.27 | 2,888 |
| 41 | Funston | Faucets & Showers | high efficiency/ tamper proof | 573 | 2,003 | $2,135 | $3,082 | 0.7 | 18.3 | $8,266.82 | 3,399 |
| 42 | MAAF | Faucets & Showers | high efficiency/ tamper proof | 938 | 3,278 | $3,122 | $5,044 | 0.6 | 20.4 | $13,615.72 | 3,804 |
| 43 | Main Post | Faucets & | high efficiency/ | 938 | 3,278 | $2,756 | $5,044 | 0.6 | 23.1 | $13,702.32 | 4,309 |

| Project ID | Building Group/Area | Technology Type | Project Description | 1st-year Water Savings (kgal) | 1st-year Natural Gas Savings (therms) | Total Installation Cost | First-year Cost Savings | Simple Payback | ECIP SIR | NPV | Cum Ratio (gal/$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Showers | tamper proof | | | | | | | | |
| 44 | Whitside | Faucets & Showers | high efficiency/ tamper proof | 78 | 273 | $374 | $420 | 0.9 | 14.2 | $1,107.70 | 2,647 |
| 45 | Custer Hill | Toilets & Urinals | HET & pint HEU | 821 | - | $210,552 | $4,727 | 44.5 | 0.3 | ($42,918.87) | 63 |
| 46 | Forsyth | Toilets & Urinals | HET & pint HEU | 26 | - | $9,496 | $172 | 55.2 | 0.3 | ($2,128.30) | 44 |
| 47 | Funston | Toilets & Urinals | HET & pint HEU | 240 | - | $67,007 | $1,425 | 47.0 | 0.3 | ($14,028.00) | 58 |
| 48 | MAAF | Toilets & Urinals | HET & pint HEU | 47 | - | $15,763 | $302 | 52.3 | 0.3 | ($3,457.53) | 48 |
| 49 | Main Post | Toilets & Urinals | HET & pint HEU | 556 | - | $125,619 | $3,060 | 41.1 | 0.4 | ($24,487.61) | 72 |
| 50 | Whitside | Toilets & Urinals | HET & pint HEU | 21 | - | $7,272 | $138 | 52.7 | 0.3 | ($1,600.36) | 48 |
| 51 | Custer Hill | Faucets & Showers | high efficiency/ tamper proof | 378 | 1,321 | $5,831 | $2,032 | 2.9 | 4.4 | $4,402.80 | 821 |
| 52 | Forsyth | Faucets & Showers | high efficiency/ tamper proof | 12 | 41 | $263 | $64 | 4.1 | 3.1 | $118.45 | 569 |
| 53 | Funston | Faucets & Showers | high efficiency/ tamper proof | 110 | 385 | $1,856 | $593 | 3.1 | 4.0 | $1,247.43 | 752 |
| 54 | MAAF | Faucets & Showers | high efficiency/ tamper proof | 22 | 76 | $437 | $116 | 3.8 | 3.4 | $227.96 | 628 |
| 55 | Main Post | Faucets & Showers | high efficiency/ tamper proof | 256 | 894 | $3,479 | $1,376 | 2.5 | 5.0 | $3,092.23 | 931 |
| 56 | Whitside | Faucets & Showers | high efficiency/ tamper proof | 10 | 34 | $201 | $53 | 3.8 | 3.3 | $102.92 | 619 |
| 57 | Post-wide | Ice Machine Retrofits | Install counterflow heat exchangers on (24) existing ice machines | - | - | $22,678 | $2,696 | 8.4 | 1.5 | $785.33 | - |
| 58 | Post-wide | Pre-Rinse Sprayer Replacements | 1.24 gpm (8) pre-rinse sprayers | 82 | 466 | $2,112 | $530 | 4.0 | 2.6 | $1,204.50 | 415 |
| 59 | Post-wide | Garbage Disposal Retrofits | Install in-line flow-restrictors to match manufacturer's specifications | 1,752 | - | $8,008 | $6,360 | 1.3 | 9.8 | $5,552.65 | 2,690 |
| 60 | Post-wide | Pulper Retrofits | Install in-line flow-restrictors to match manufacturer's specifications | 1,752 | - | $12,012 | $6,360 | 1.9 | 6.5 | $5,227.01 | 1,793 |
| 61 | Post-wide | Convection Steamer Replacements | Install (9) High efficiency connectionless convection steamers | 486 | - | $91,625 | $6,600 | 13.9 | 0.9 | ($3,640.43) | 68 |
| 62 | Post-wide | Dish Machine Replacements | Install (4) High efficiency dish machines (1 in each dining hall) | 666 | 10,667 | $366,124 | $46,125 | 7.9 | 1.9 | $118,157.45 | 30 |
| 63 | Post-wide | Tray Conveyor Retrofits | Install (8) in-line flow-restrictors to limit water flow to conveyor | 263 | - | $7,920 | $954 | 8.3 | 1.5 | $286.48 | 408 |

| Project ID | Building Group/Area | Technology Type | Project Description | 1st-year Water Savings (kgal) | 1st-year Natural Gas Savings (therms) | Total Installation Cost | First-year Cost Savings | Simple Payback | ECIP SIR | NPV | Cum Ratio (gal/$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | troughs (2 restrictors for each conveyor) | | | | | | | | |
| 64 | Eyster Pool | Liquid Pool Cover | Install direct injection liquid pool cover system to minimize evaporation and heat loss | 296 | 12,967 | $9,562 | $1,745 | 5.5 | 3.2 | $843.33 | 381 |
| 65 | Long Pool | Liquid Pool Cover | Install direct injection liquid pool cover system to minimize evaporation and heat loss | 62 | 2,730 | $4,972 | $367 | 13.5 | 1.3 | ($63.08) | 154 |
| 66 | Custer Hill Pool | Liquid Pool Cover | Install direct injection liquid pool cover system to minimize evaporation and heat loss | 203 | 8,872 | $7,726 | $1,194 | 6.5 | 2.7 | $480.76 | 323 |
| 67 | Post-wide | RCW Infrastructure and Supply System | Install Reclaimed water system to supply golf course irrigation and IVWF | 61,137 | - | $2,141,362 | $54,335 | 39.4 | 0.4 | ($86,673.42) | 438 |
| 68 | Golf Course | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | - | - | $- | $- | NA | | | |
| 69 | Building 500 | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | 555 | - | $11,425 | $815 | 14.0 | 1.1 | $284.77 | 789 |
| 70 | Building 580 | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | 2,233 | - | $45,990 | $3,282 | 14.0 | 1.1 | $1,146.36 | 789 |
| 71 | Sacco Ball Fields | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | 1,418 | - | $29,200 | $2,084 | 14.0 | 1.1 | $727.85 | 789 |
| 72 | Main Post & St Mary's Chapels | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | 133 | - | $2,738 | $195 | 14.0 | 1.1 | $68.24 | 789 |
| 73 | Sturgis Field | Irrigation | Install weather | 390 | - | $8,030 | $573 | 14.0 | 1.1 | $200.16 | 789 |

| Project ID | Building Group/Area | Technology Type | Project Description | 1st-year Water Savings (kgal) | 1st-year Natural Gas Savings (therms) | Total Installation Cost | First-year Cost Savings | Simple Payback | ECIP SIR | NPV | Cum Ratio (gal/$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | System Upgrades | based controllers and high efficiency distribution nozzles | | | | | | | | |
| 74 | Calvary | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | 2,180 | - | $44,895 | $3,204 | 14.0 | 1.1 | $1,119.06 | 789 |
| 75 | Cemetery | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | 1,666 | - | $34,310 | $2,449 | 14.0 | 1.1 | $855.22 | 789 |
| 76 | Welcome Sign By Henry Guard Shack | Irrigation System Upgrades | Install weather based controllers and high efficiency distribution nozzles | 35 | - | $730 | $52 | 14.0 | 1.1 | $18.20 | 789 |
| | | | **Bundled Project Listings** | | | | | | | | |
| B51 | All Plumbing | | | 67,865 | 178,472 | $4,027,787 | $360,752 | 11.2 | 1.2 | $20,847.56 | 210 |
| B52 | Plumbing - Barracks | | | 38,018 | 145,598 | $2,065,661 | $219,505 | 9.4 | 1.4 | $56,487.39 | 202 |
| B53 | Plumbing - Admin | | | 6,964 | 7,670 | $280,280 | $31,495 | 8.9 | 1.6 | $39,333.91 | 354 |
| B54 | Plumbing - Motorpools | | | 3,848 | 4,238 | $361,851 | $19,159 | 18.9 | 0.8 | ($33,636.58) | 152 |
| B55 | Plumbing - Ops & Training | | | 16,536 | 18,212 | $872,219 | $76,535 | 11.4 | 1.3 | $38,091.73 | 270 |
| B56 | Plumbing - Warehouse | | | 2,499 | 2,752 | $447,776 | $14,058 | 31.9 | 0.5 | ($79,428.89) | 80 |
| B57 | Plumbing - Barracks - 1 CAB | | | 6,109 | 27,206 | $322,984 | $37,028 | 8.7 | 1.5 | $14,166.83 | 201 |
| B58 | Plumbing - Barracks - 1 SB & 2nd BDE | | | 10,216 | 35,651 | $524,583 | $56,869 | 9.2 | 1.4 | $16,654.11 | 212 |
| B59 | Plumbing - Barracks - 1st BDE | | | 7,959 | 35,881 | $394,790 | $48,336 | 8.2 | 1.6 | $26,446.73 | 214 |
| B60 | Plumbing - Barracks - 4 BCT | | | 6,935 | 24,202 | $504,138 | $39,250 | 12.8 | 1.0 | ($30,924.47) | 149 |
| B61 | Plumbing - Barracks - Garrison & Non-Divisional | | | 2,359 | 10,114 | $158,838 | $14,343 | 11.1 | 1.2 | ($3,799.59) | 161 |
| B62 | Plumbing - Barracks - Misc | | | 4,441 | 12,544 | $160,328 | $23,680 | 6.8 | 2.0 | $33,943.78 | 355 |
| B63 | Plumbing - Admin - Custer Hill | | | 299 | 330 | $20,861 | $1,429 | 14.6 | 1.0 | ($665.05) | 205 |
| B64 | Plumbing - Admin - | | | 56 | 61 | $5,424 | $279 | 19.4 | 0.7 | ($536.50) | 146 |

| Project ID | Building Group/Area | Technology Type | Project Description | 1st-year Water Savings (kgal) | 1st-year Natural Gas Savings (therms) | Total Installation Cost | First-year Cost Savings | Simple Payback | ECIP SIR | NPV | Cum Ratio (gal/$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forsyth | | | | | | | | | | |
| B65 | Plumbing - Admin - Funston | | | 348 | 384 | $19,095 | $1,618 | 11.8 | 1.2 | $607.63 | 260 |
| B66 | Plumbing - Admin - MAAF | | | 49 | 54 | $2,424 | $224 | 10.8 | 1.3 | $151.70 | 287 |
| B67 | Plumbing - Admin - Main Post | | | 6,128 | 6,750 | $225,898 | $27,539 | 8.2 | 1.8 | $40,163.84 | 387 |
| B68 | Plumbing - Admin - Whitside | | | 84 | 92 | $6,577 | $405 | 16.2 | 0.9 | ($387.70) | 181 |
| B69 | Plumbing - Motorpools - Custer Hill | | | 3,309 | 3,645 | $306,992 | $16,441 | 18.7 | 0.8 | ($27,804.35) | 154 |
| B70 | Plumbing - Motorpools - Funston | | | 38 | 42 | $2,537 | $182 | 13.9 | 1.0 | ($47.04) | 216 |
| B71 | Plumbing - Motorpools - MAAF | | | 231 | 254 | $35,902 | $1,270 | 28.3 | 0.5 | ($5,814.41) | 92 |
| B72 | Plumbing - Motorpools - Main Post | | | 269 | 297 | $16,419 | $1,266 | 13.0 | 1.1 | $29.22 | 234 |
| B73 | Plumbing - Ops & Training - Custer Hill | | | 7,772 | 8,560 | $410,875 | $35,980 | 11.4 | 1.3 | $17,653.82 | 270 |
| B74 | Plumbing - Ops & Training - Forsyth | | | 744 | 820 | $50,374 | $3,539 | 14.2 | 1.0 | ($1,261.49) | 211 |
| B75 | Plumbing - Ops & Training - Funston | | | 1,819 | 2,003 | $104,627 | $8,493 | 12.3 | 1.2 | $1,867.38 | 248 |
| B76 | Plumbing - Ops & Training - MAAF | | | 2,976 | 3,278 | $152,968 | $13,742 | 11.1 | 1.3 | $7,934.84 | 278 |
| B77 | Plumbing - Ops & Training - Main Post | | | 2,976 | 3,278 | $135,057 | $13,590 | 9.9 | 1.4 | $12,726.27 | 314 |
| B78 | Plumbing - Ops & Training - Whitside | | | 248 | 273 | $18,319 | $1,192 | 15.4 | 0.9 | ($829.10) | 193 |
| B79 | Plumbing - Warehouse - Custer Hill | | | 1,199 | 1,321 | $216,383 | $6,760 | 32.0 | 0.5 | ($38,516.08) | 79 |
| B80 | Plumbing - Warehouse - Forsyth | | | 37 | 41 | $9,759 | $235 | 41.5 | 0.4 | ($2,009.85) | 55 |
| B81 | Plumbing - Warehouse - Funston | | | 350 | 385 | $68,862 | $2,018 | 34.1 | 0.4 | ($12,780.57) | 73 |
| B82 | Plumbing - Warehouse - MAAF | | | 69 | 76 | $16,200 | $418 | 38.8 | 0.4 | ($3,229.57) | 61 |
| B83 | Plumbing - | | | 812 | 894 | $129,098 | $4,436 | 29.1 | 0.5 | ($21,395.38) | 90 |

| Project ID | Building Group/Area | Technology Type | Project Description | 1st-year Water Savings (kgal) | 1st-year Natural Gas Savings (therms) | Total Installation Cost | First-year Cost Savings | Simple Payback | ECIP SIR | NPV | Cum Ratio (gal/$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Warehouse - Main Post | | | | | | | | | | |
| B84 | Plumbing - Warehouse - Whitside | | | 31 | 34 | $7,473 | $191 | 39.2 | 0.4 | ($1,497.44) | 60 |
| B85 | Commercial Kitchen | | | 5,001 | 11,133 | $510,478 | $69,625 | 7.3 | 2.0 | $127,572.98 | 60 |
| B86 | Pool | | | 562 | 24,569 | $22,260 | $3,307 | 6.7 | 2.6 | $1,261.01 | 310 |
| B87 | Reclaimed Water System | | | 61,137 | - | $2,141,362 | $54,335 | 39.4 | 0.4 | ($86,673.42) | 438 |
| B88 | Irrigation | | | 8,609 | - | $177,317 | $12,656 | 14.0 | 1.1 | $4,419.85 | 789 |
| | | | **TOTAL without reclaim project** | **82,036** | **214,174** | **$4,737,842** | **$446,340** | **108.5** | **11.1** | **$154,101.40** | |
| | | | **TOTAL with reclaim project** | **143,173** | **214,174** | **$6,879,204** | **$500,676** | **147.9** | **11.5** | **$67,427.98** | |

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# Appendix B – Plumbing and Water Appliances Specifications

The following information provides specifications that Fort Riley can use for all future purchases related to plumbing fixtures and water appliances.

## Indoor Plumbing Fixtures

Federal law mandates that all plumbing fixtures meet or exceed the minimum Energy Policy Act of 1992 (EPAct) requirements. Fixture specifications should exceed the EPAct requirements. Water-efficiency measures in buildings can easily reduce water use by 30% or more. In a typical 100,000 square foot office building, low-flow fixtures and equipment can save 1,000,000 gallons of water per year or more, based on 650 building occupants each using an average of 20 gallons per day.

The following lists purchasing specifications for all plumbing fixtures at Fort Riley:

**Faucets:**

- Private lavatory and bathroom faucets and aerators will have a maximum flow rate of 1.5 gallons per minute at a flowing water pressure of 60 pounds per square inch (psi).
- Public restroom faucets will have a maximum flow rate of 0.5 gallons per minute at a flowing water pressure of 60 psi.
- All faucet aerator will be vandal-proof so that users cannot remove the aerator.

**Showerheads:**

- Showerheads will have a maximum flow rate of 2.0 gallons per minutes at 80 psi and be WaterSense qualified.
- All showerheads will be vandal-proof so that users cannot remove the flow restrictor.

**Toilets:**

- Tank toilets will not exceed 1.28 gallons per flush and shall be WaterSense qualified.
- Flushometer style toilets will not exceed 1.28 gallons per flush and will be equipped with piston style valves.
- Existing 1.6 gallons per flush flushometer diaphragm valves should be replaced with 1.6 gallons per flush flushometer piston valves upon repair.

**Urinals:**

- Urinals will not exceed 0.125 gallons per flush and will be equipped with piston style valves.

**Water Using Appliances:**

- Laundry washing machines shall be ENERGY STAR qualified.
- Commercial kitchen equipment:

- Dishwashing machines will be ENERGY STAR qualified.
- Commercial pre-rinse spray valves will have a maximum flow rate of 1.25 gallons per minute at 60 psi and be equipped with an integral automatic shutoff.
- Ice machines shall be air-cooled and will be ENERGY STAR qualified.
- Food steamers shall be ENERGY STAR qualified.

Combination ovens shall not use more than 10 gallons per hour in full operation mode.

# Appendix C – Cooling Tower Consumption Analysis

The following includes calculations used to determine evaporation, blowdown, and make-up rates of the new hospital cooling system. The analysis assumes a total installed capacity of 2,250 tons and three gallons per minute per ton of recirculating water flow rate. Seasonal variation is proposed as would be expected by staged chiller operation, as well as variation to the cooling tower range.

## PSYCHROMETRIC CALCULATIONS - COOLING TOWER EVAPORATION AT MEAN ANNUAL AMBIENT CONDITIONS

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **INLET AIR CALCULATIONS** | | | | | | | | | | | | | |
| | Month | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | |
| | Dry Bulb Temp - °F. | 29 | 33 | 44 | 54 | 64 | 74 | 79 | 78 | 69 | 56 | 44 | 30 | |
| | Wet Bulb Temp - °F | 26 | 29 | 39 | 48 | 58 | 66 | 70 | 69 | 61 | 50 | 39 | 27 | |
| | Rel. Humidity - % | 68.958 | 63.091 | 64.774 | 65.620 | 70.836 | 66.749 | 65.116 | 64.711 | 64.501 | 66.817 | 64.774 | 69.802 | |
| | Elevation - ft | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | |
| | P(Total) - in Hg | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | |
| | Enthalpy - BTU/lb dry air | 9.436 | 10.589 | 14.844 | 19.355 | 25.392 | 31.238 | 34.581 | 33.716 | 27.464 | 20.466 | 14.844 | 9.815 | |
| | **TOWER OUTLET AIR AND COOLING TOWER CALCULATIONS** | | | | | | | | | | | | | |
| | Temp out - °F | 62.34 | 62.55 | 65.50 | 69.74 | 73.62 | 79.35 | 82.29 | 81.55 | 75.74 | 68.11 | 65.50 | 60.08 | |
| | h out - BTU/lb dry air | 28.44 | 28.59 | 30.84 | 34.36 | 37.89 | 43.74 | 47.08 | 46.22 | 39.96 | 32.97 | 30.84 | 26.81 | |
| **10 °F Cooling Tower Range and Full Utilization** | CW Flow - gpm | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | |
| | Range - °F | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |
| | **Evaporation - gpm** | **36** | **38** | **42** | **46** | **50** | **55** | **58** | **57** | **54** | **47** | **42** | **36** | |
| | Blowdown-gpm | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 19 | 18 | 16 | 14 | 12 | |
| | **Make-up-gpm** | **48** | **50** | **56** | **62** | **67** | **74** | **77** | **76** | **71** | **63** | **56** | **48** | |
| **10 °F Range (staged chiller operations)** | CW Flow - gpm | 2250 | 2250 | 4500 | 4500 | 4500 | 6750 | 6750 | 6750 | 6750 | 4500 | 4500 | 2250 | |
| | Range - °F | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | **ANNUAL TOTALS (gal)** |
| | **Evaporation - gpm** | **12** | **13** | **28** | **31** | **33** | **55** | **58** | **57** | **54** | **32** | **28** | **12** | |
| | Blowdown-gpm | 4 | 4 | 9 | 10 | 11 | 18 | 19 | 19 | 18 | 11 | 9 | 4 | |
| | **Make-up-gpm** | **16** | **17** | **37** | **41** | **45** | **74** | **77** | **76** | **71** | **42** | **37** | **16** | |
| | Monthly Cooling Tower Make-Up Total | 172,950 | 180,925 | 403,102 | 887,370 | 964,137 | 2,096,771 | 2,187,151 | 2,176,180 | 2,037,395 | 910,541 | 403,102 | 172,038 | **12,591,663** |
| **15 °F Range (staged chiller operations)** | Range - | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | |
| | **Evaporation - gpm** | **19** | **20** | **43** | **46** | **49** | **79** | **82** | **82** | **77** | **47** | **43** | **19** | |
| | Blowdown-gpm | 6 | 7 | 14 | 15 | 16 | 26 | 27 | 27 | 26 | 16 | 14 | 6 | |
| | **Make-up-gpm** | **26** | **26** | **57** | **61** | **65** | **106** | **110** | **109** | **103** | **62** | **57** | **25** | |
| | Monthly Cooling Tower Make-Up Total | 278,102 | 285,992 | 616,988 | 1,327,307 | 1,413,531 | 3,017,315 | 3,122,225 | 3,107,676 | 2,938,977 | 1,343,355 | 616,988 | 274,794 | **18,343,250** |

**PSYCHROMETRIC CALCULATIONS - COOLING TOWER EVAPORATION AT MEAN ANNUAL MAXIMUM AMBIENT CONDITIONS**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **INLET AIR CALCULATIONS** | | | | | | | | | | | | | |
| | Month | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | |
| | Dry Bulb Temp - °F. | 41 | 47 | 57 | 67 | 77 | 86 | 92 | 90 | 82 | 70 | 55 | 43 | |
| | Wet Bulb Temp - °F | 32 | 35 | 44 | 52 | 62 | 70 | 73 | 72 | 65 | 54 | 43 | 31 | |
| | Rel. Humidity - % | 34.237 | 24.989 | 33.599 | 35.937 | 43.934 | 46.435 | 41.778 | 43.229 | 41.194 | 35.135 | 35.922 | 18.091 | |
| | Elevation - ft | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | |
| | P(Total) - in Hg | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | 28.701 | |
| | Enthalpy - BTU/lb dry air | 11.795 | 13.059 | 17.257 | 21.623 | 28.185 | 34.581 | 37.301 | 36.373 | 30.449 | 22.827 | 16.757 | 11.387 | |
| | **TOWER OUTLET AIR AND COOLING TOWER CALCULATIONS** | | | | | | | | | | | | | |
| | Temp out - °F | 65.44 | 65.78 | 68.46 | 71.17 | 76.46 | 82.29 | 84.54 | 83.78 | 78.62 | 70.84 | 66.65 | 62.28 | |
| | h out - BTU/lb dry air | 30.80 | 31.06 | 33.26 | 35.62 | 40.69 | 47.08 | 49.80 | 48.87 | 42.95 | 35.33 | 31.76 | 28.39 | |
| | CW Flow - gpm | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | 6,750 | |
| **10 °F Cooling Tower Range and Full Utilization** | Range - °F | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |
| | **Evaporation - gpm** | **43** | **47** | **51** | **57** | **62** | **66** | **70** | **69** | **66** | **61** | **50** | **45** | |
| | Blowdown-gpm | 14 | 16 | 17 | 19 | 21 | 22 | 23 | 23 | 22 | 20 | 17 | 15 | |
| | **Make-up-gpm** | **58** | **62** | **66** | **72** | **77** | **81** | **85** | **84** | **81** | **76** | **65** | **60** | |
| **10 °F Range (staged chiller operations)** | CW Flow - gpm | 2250 | 2250 | 4500 | 4500 | 4500 | 6750 | 6750 | 6750 | 6750 | 4500 | 4500 | 2250 | **ANNUAL TOTALS (gal)** |
| | Range - °F | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |
| | **Evaporation - gpm** | **14** | **16** | **34** | **38** | **42** | **66** | **70** | **69** | **66** | **41** | **34** | **15** | |
| | Blowdown-gpm | 5 | 5 | 11 | 13 | 14 | 22 | 23 | 23 | 22 | 14 | 11 | 5 | |
| | **Make-up-gpm** | **19** | **21** | **46** | **51** | **55** | **88** | **94** | **92** | **87** | **54** | **45** | **20** | |
| | Monthly Cooling Tower Make-Up Total | 206,010 | 223,233 | 491,885 | 1,100,885 | 1,195,552 | 2,505,835 | 2,674,796 | 2,618,589 | 2,493,790 | 1,166,596 | 483,714 | 217,212 | **15,378,098** |
| **15 °F Range (staged chiller operations)** | Range - | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | |
| | **Evaporation - gpm** | **22** | **23** | **49** | **54** | **57** | **91** | **95** | **94** | **90** | **56** | **49** | **22** | |
| | Blowdown-gpm | 7 | 8 | 16 | 18 | 19 | 30 | 32 | 31 | 30 | 19 | 16 | 7 | |
| | **Make-up-gpm** | **29** | **31** | **66** | **71** | **77** | **121** | **127** | **125** | **120** | **74** | **65** | **30** | |
| | Monthly Cooling Tower Make-Up Total | 313,594 | 330,848 | 710,341 | 1,544,281 | 1,652,847 | 3,440,909 | 3,620,379 | 3,560,708 | 3,410,611 | 1,607,826 | 698,938 | 321,799 | **21,213,081** |

# Appendix D – Irrigation System and Management Best Practices for Fort Riley

This irrigation best practices guide provides requirements that apply to irrigation system design, installation, operation, and maintenance. Given the recent expansion of irrigated turf at Fort Riley and the impact of summer peak consumption on the site's overall water balance, personnel should work to ensure that the systems are optimized for efficient water use with the goal to conserve and protect water resources.

## PG 1 – Practice Guideline for Assuring Quality of an Irrigation System

Practice Guideline 1 (PG 1) is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs to ensure quality of the irrigation system. It is the responsibility of Fort Riley to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical, and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To assure that a high-quality irrigation system is designed, installed, maintained, and managed:

1. A qualified irrigation designer or irrigation consultant shall design the system for the efficient and uniform distribution of water based on the requirements of PG 2. "Qualified" means certified formally trained, licensed, or other similar qualification that meets state and local requirements.

2. A qualified irrigation contractor shall be selected to install the irrigation system based on the requirements of PG 3. The irrigation contractor shall test the completed system to verify that the system operates according to the design criteria.

3. The landscape architect, irrigation designer, irrigation consultant, or local water district representative shall perform one or more site observations during system installation to check for adherence to the design. The observation should inspect the installation of the backflow prevention assembly, main line, laterals, valves, sprinkler heads, drip/micro-irrigation equipment, control wire, controller, and water conserving devices and should ensure that the intent of the irrigation designer or consultant has been preserved.

4. The irrigation system shall be maintained for ongoing efficient performance based on the requirements of PG 4.

5. The controller programming (scheduling) shall be managed to respond to the changing need for water in the landscape (see PG 5).

6. Following installation of a new system, a field performance audit shall be conducted using an accepted procedure such as the Irrigation Association's Certified Landscape Irrigation Audit Program or equivalent. The audit shall be scheduled within a reasonable time period following completion of the installation and as established by the local water purveyor or other governing

authority. The audit shall check the performance of the system for conformance with state and local requirements, including meeting standards for the minimum precipitation rate and lower quarter distribution uniformity (DU) and, where possible, emission uniformity (EU) for drip/micro-irrigation systems. In addition, the audit shall also verify the installation of specified water management devices such as a rain shutoff device and/or soil moisture sensors. Finally, the irrigation schedule shall be evaluated to ensure that the irrigation system meets the supplemental water needs of the plants without wasting water.

For geographical areas where a landscape water allowance applies, financial incentives should be established for property owners. The incentive should be based on the amount of water applied to the landscape in excess of the established landscape water allowance. The water purveyor or other governing authority shall coordinate the water rate incentives.

## PG 2 – Practice Guideline for Irrigation System Design

PG 2 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper design of an irrigation system. It is the responsibility of Fort Riley to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical, and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To ensure that the irrigation system is designed to efficiently and uniformly distribute the water, and to conserve and protect water resources, the irrigation designer shall:

1. Obtain direct knowledge of site conditions and not rely solely on plot plans to generate a design.

2. Meet all applicable state and local codes, including plumbing and electrical codes.

3. Specify manufacturer, model, type, and size of all components to eliminate ambiguity at construction and to facilitate management of the system. The selection of pipe, electrical wire, and other materials shall be based on design parameters, environmental conditions, and code requirements.

4. Design the irrigation system to minimize installation and maintenance difficulties. The selection and placement of sprinkler and drip/micro-irrigation components should be guided by the expected size of larger specimen plants through a minimum three-year establishment period for shrubs and ten years for trees.

5. Provide a complete irrigation design package (Addendum) to the owner of the system. Refer to Addendum A for a list of recommended items to include in the design package.

6. Apply the following rules of maximum safe flow rate for municipal water suppliers, with the lowest safe flow rate prevailing as the design guideline:

   a. The maximum allowable pressure loss through the meter should be less than 10% of the static pressure at the meter.

b. The maximum flow rate through the meter should not exceed 75% of the maximum safe flow rate through the meter.

c. The velocity of water through the service line supplying the meter should not exceed 7.5 feet per second (fps).

d. Select main and lateral pipe sizes so that the velocity of water moving through the irrigation pipe does not exceed state and local requirements, or the industry standard of 5 fps.

7. Where applicable, specify a water source that meets peak demands for landscape water with irrigation duration of no more than 10 hours per day. This guideline helps determine the correct size of the supply meter. Also consider local statutes, anticipated irrigation intervals, or site uses that may dictate different irrigation durations (for example, golf courses). This guideline is intended to match the system requirements to the particular site, not dictate the actual hours of operation on any given day.

8. Specify protection of the water source in accordance with state and local requirements. Where no requirements exist, assess the degree of hazard and specify the appropriate backflow prevention device.

9. For commercial installations, specify a metering device that measures the total landscape water use separate from other uses.

10. For systems on a municipal supply, allow for a reduction in static pressure of up to 10 pounds per square inch (psi) to accommodate possible expansion in the supply network.

11. Specify pressure regulation where variable or excessive static pressure exists.

12. Specify the recommended operating (working) pressure at the maximum design flow rate of the system.

13. Use drip/micro-irrigation where appropriate to reduce evaporation losses and surface runoff, and to avoid applying water on hardscapes. For zones with drip/micro-irrigation:

    a. Specify filtration at the control valve to remove particulate matter.

    b. Separate drip/micro-irrigation zones from overhead irrigated zones since drip/micro-irrigation systems are not as susceptible to water losses due to evaporation, wind, or surface runoff. Separate zoning allows the irrigator to adjust water requirements given these differing conditions.

    c. Consider differing plant water requirements and root zone depths and use separate drip/micro-irrigation zones where practical.

    d. Specify pressure-compensated devices to improve overall uniformity.

    Specify pressure regulation upstream from the drip/micro-irrigation components. Pressure increases can potentially damage a drip/micro irrigation system that has no pressure regulator on the zone controls. Pressure compensated emitters do not serve this function. Pressure regulating devices can be omitted only when the absolute maximum possible pressure is known to be lower than the maximum allowable pressure for all drip/micro-irrigation components.

e. Connect (loop) the ends of individual laterals to improve system uniformity and limit possible contamination if drip tubing is damaged. This helps to equalize system pressure and can increase uniformity and also allows water to flow from both sides of damaged drip tubing, thus flushing out any debris.

f. Use air release valves to minimize ingestion of dirt or other contaminants into the emitters.

g. Use flush valves to flush the laterals after completion of the irrigation cycle.

14. Select components and design zones to achieve a minimum operational lower quarter DU or EU according to the following table:

**Table D.1**. Minimum Operational Uniformity

| Type of Zone | Type of Uniformity | Minimum Uniformity |
|---|---|---|
| **Spray** | Lower Quarter DU | 55% |
| **Rotor** | Lower Quarter DU | 70% |
| **Rotary** | Lower Quarter DU | 75% |
| **Drip/micro-irrigation** | Emission Uniformity | 80% |

15. Design the layout of heads and other emission devices for zero overspray across or onto a street, public driveway or sidewalk, parking area, building, fence, or adjoining property. Overspray may occur during operation of the irrigation system due to actual wind conditions that differ from the design criteria.

16. Specify any required equipment changes in a way that meets or exceeds the minimum lower quarter DU, EU, and overspray criteria.

17. Design sprinkler head spacing with a minimum of "head-to-head" coverage (minimum 50% of diameter) unless the coverage is designed for wind derating. Wind derating should be based on wind criteria for the time period that the system is normally run.

18. Use separate station/zones (hydrozones) for areas with dissimilar water or scheduling requirements.

19. When selecting system components, place a high priority on avoiding surface runoff. Select components to keep the sprinkler precipitation rate below the infiltration rate of the soil and/or use repeat cycles to allow the water to soak into the root zone. Separate station/zones for sprinklers at the top and toe of sloped areas.

20. Locate sprinkler heads based on a thorough evaluation of physical, environmental, and hydraulic site conditions, including typical wind conditions during the normal irrigation period.

21. In regions where a landscape water allowance applies, include an estimate of the future monthly landscape water allowance, based on historical reference evapotranspiration (ETo), landscape area and the landscape water adjustment factor provided by the purveyor or water provider.

22. Provide monthly base irrigation schedules where the frequency of irrigation (when to irrigate) depends on replenishing allowable depletion (how much to irrigate) of the soil moisture between irrigation watering based on monthly reference historical evapotranspiration data. For each station/zone (or hydrozone as applicable), the designer shall specify the plant type, soil type, average root zone depth, precipitation rate, lower quarter distribution uniformity, area square footage, target gallons per minute flow rate, recommended operating pressure range, and maximum recommended cycle run time without runoff. The designer shall recommend a site specific rainfall factor to convert historical rainfall to effective rainfall. This is useful for budgeting purposes and for schedule compensation when a rain shutoff device is not installed. Refer to PG 5 for additional scheduling requirements.

23. Recommend the following water-conserving concepts and equipment where appropriate and economically justified:

    a. Use an alternative non-potable water source (such as reclaimed water) where practical and allowed by law. Special management practices and components may be required when using alternative water sources.

    b. Integrate controls with water-conserving sensors if not connected to advanced weather-based system such as:

        - Rain, freeze, and/or wind sensors to suspend irrigation during weather conditions that are unfavorable for irrigation.
        - Environmental sensors that can actively measure weather conditions to determine daily plant water need.

    c. Soil moisture sensors to monitor soil moisture and suspend irrigation if the moisture reserve in the root zone is significantly above the allowable depletion limit.

    d. To mitigate the effects of wind, use low-trajectory sprinkler nozzles along with the appropriate modified head spacing. Select components that do not mist when manufacturer's pressure specifications are met.

    e. Install water-conserving devices such as:

        - Check valves to minimize low-head drainage.
        - Pressure regulators or pressure compensating screens, stems or nozzles to control high pressure.

    f. Install irrigation meters that meet the following specification:

        - Electronic output signal that supports a remote display mounted at the controller to simplify manual reading of the total landscape irrigation water use.

- Electronic flow rate output signal that is compatible with the controller for automated management of the landscape irrigation water use. This allows the controller to measure and control the amount of water use, as well as to indicate leaks (e.g., broken pipes or sprinklers).

g. A controller that has multi-program capability with at least four start times (for multiple repeat soak cycles) and run time adjustments in one-minute increments.

h. For larger sites where a significant potential water savings may result, a controller that allows for flexible irrigation scheduling and advanced water management features. These features may include incorporating current (real time or daily) evapotranspiration data, water budgeting, and soil moisture monitoring.

i. A separate common wire from the controller to each hydrozone station valve to allow for sensor-based control of each hydrozone.

## PG 3 – Practice Guideline for Installing an Irrigation System

PG 3 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper installation of an irrigation system. It is the responsibility of Fort Riley to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical, and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To ensure that the irrigation system is installed to efficiently and uniformly distribute the water, and to conserve and protect water resources, the irrigation contractor or installer shall:

1. Contact all appropriate utility companies prior to beginning installation, to locate underground utilities including gas, electrical, telephone, and cable lines. Installation shall not be started until all underground utilities are located and marked. The contractor/installer shall coordinate with the property owner to locate, identify, and mark all privately owned underground utilities. Installation shall not be started until all private utilities are located and marked.

2. Prior to beginning installation, verify that the point of connection, flow rate, and static and dynamic pressures meet design criteria.

3. Install the irrigation system according to the design specifications and manufacturer's published performance standards. The design shall reflect the practices defined in PG 2.

4. Review planting plans prior to installation to minimize conflicts between larger plants and irrigation heads. Also review construction plans for conflicts between hardscape and sprinkler head placement.

5. Inform Fort Riley personnel and irrigation designer of unusual or abnormal soil conditions that may affect the design and management of the irrigation system.

6. Where deviations from the design are required, for example, running pipe around a tree or other structure, redline the plan drawing to note the deviation. Always consult with the designer prior to making the change to ensure that the change is within design performance specifications.

7. Furnish an "as-built" record set of drawings to Fort Riley personnel of the system. Within the record set of drawings, describe the system layout and components including all changes from the original design.

8. Test the irrigation system to verify that it meets the design criteria.

9. Perform an irrigation audit using an accepted procedure set forth in the Irrigation Association's Certified Landscape Irrigation Audit Program or equivalent. Provide Fort Riley personnel with system specifications and a performance summary report by station/zone that includes the plant type, soil type, average root zone depth, precipitation rate, lower quarter DU, area square footage, target gallons per minute flow rate, recommended operating pressure range, and maximum recommended cycle run time without runoff. Retain a reference of each station/zone's lower quarter DU, precipitation rate, operating pressure, and flow rate at the controller. (Also see item 5 of PG 2.)

10. If the system is not connected to the advanced weather-based system, review the irrigation schedule that should accompany the design. If no such schedule exists, then create an irrigation schedule (see PG 5). Review the irrigation schedule, specifically the rationale and methods for determining irrigation days, station/zone run times and start times. Operate the system. Add repeat cycles and adjust cycle run time to eliminate runoff.

11. Document the location and operation of the controller, valves, sensors, pressure regulators, backflow device, sprinkler heads, and drip/micro-irrigation devices. Review advanced programming features such as multi-cycle irrigation to prevent runoff and the use of the percentage water increase/decrease function. Educate the owner on features and capabilities of the system, including the maintenance requirements of PG 4.

12. Make recommendations for landscape water conservation. Emphasize the following topics:

    a. Maintaining proper operation of system components.

    b. Landscape irrigation is meant to supply water to supplement rainfall.

    c. Plant water requirements may change from day-to-day.

    d. Importance of hydrozoning according to plant water requirements.

    e. Benefits of using drip/micro-irrigation components.

    f. Benefits of applying water-conserving landscaping practices such as the use of mulch and soil amendments.

    g. Benefits of assigning someone to be held accountable for water use in the landscape.

13. Provide product warranties and operating instructions for all equipment.

When contracting irrigation installation contractors, Fort Riley should strongly consider the following practices. While these practices work to conserve and protect water resources, they also protect the owner's interests:

1. Ensure that the irrigation contractor and maintenance contractor are currently licensed, certified (where applicable), insured, and legally authorized to install irrigation systems in your area.

2. Ask all contractors for references of previous work and contact those references to seek information on the contractor's quality of service and timeliness in performing the job.

3. Ensure the contract, at minimum, includes the scope of work, prices, permits required, warranties, necessary exclusions, and payment terms. The scope of work should clarify the extent of contractor liability should damage to site utilities occur. Similarly, the scope of work should clarify the extent of property owner liability should damage to unmarked private utilities occur. Also ask the contractor for written warranties on materials and labor.

4. Insist in the contract that the irrigation contractor, designer, or consultant provide design documents at the beginning of the project (see the Irrigation Design Package in Addendum A). Also insist that an "as built" record set of drawings be provided at the completion of the project. Drawings may be required to locate system components that wear or break as the system ages, or for additions and/or modifications to the landscape.

5. Consider the possible effect of the irrigation system installation on plants and the landscape. For instance, preferably any trenches should be dug outside the drip line of existing trees. Otherwise tree roots may be cut. Determine whether landscape restoration should be part of the scope of work.

6. Determine the permits that are required prior to installation of the irrigation system. Find out which parts of the system will be subject to third party observations, reviews, or inspections.

7. Ensure that the backflow prevention device and other components meet all applicable state and local code requirements.

8. Ensure that the system meets precipitation rate requirements prescribed by state or local codes. The precipitation rate in every hydrozone must be in compliance.

9. Require design features that promote efficient use and uniform distribution of water as required in PG 2.

10. Understand the expected monthly irrigation water use (budget) and cost.

11. Learn how the system will operate. For example, how long will it run per week, normally and in the peak growing season? What is the expected maximum run time on a day of the warmest month? Will the system run only at night? How much water will the system use in the peak growing season? Should you expect dry spots in your turf during the warmest month of the year?

12. Ensure that system can be managed to promote efficient use of water. The system should be designed and managed to accommodate a cycle-and-soak irrigation principle that allows the water to infiltrate instead of running off. Learn how to schedule irrigation cycles to incorporate this principle.

## PG 4 – Practice Guideline for Maintaining an Efficient Irrigation System

PG 4 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper maintenance of an irrigation system. It is the responsibility of Fort Riley to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical, and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To ensure that the irrigation system continues to efficiently and uniformly distribute the water, and continues to conserve and protect water resources, the maintenance contractor, owner, manager, or irrigation contractor shall:

1. Establish a periodic maintenance schedule for inspection and reporting performance conditions to the end-user (or owner) of the irrigation system. Report any deviations from the original design. Create a station/zone map for ease of system inspection and controller programming.

2. Periodically review the system components to verify that the components meet the original design criteria for efficient operation and uniform distribution of water:

    a. Verify that the backflow prevention device is working correctly.

    b. Verify that the water supply and pressure are as stated in the design.

    c. Verify that pressure regulators are adjusted for desired operating pressure.

    d. Examine filters and clean filtration elements as required.

    e. Verify proper operation of the controller. Confirm correct date/time input and functional back-up battery.

    f. Verify that sensors used in the irrigation system are working properly and are within their calibration specifications.

    g. Adjust valves for proper flow and operation. Adjust valve flow regulators for desired closing speed.

    h. Verify that heads are properly adjusted – nozzle size, arc, radius, level and attitude with respect to slope.

    i. Repair or replace broken hardware and pipe; restore the system to its design specifications.

    j. Complete repairs in a timely manner to support the integrity of the irrigation design and to minimize the waste of water.

    k. Notify the end-user (or owner) of any deviations from the original design.

    l. Test all repairs.

3. Ensure that the replacement hardware used for system repairs matches the existing hardware and is in accordance with the design. Aftermarket replacement nozzles may not match original parts well enough to preserve distribution uniformity and the precipitation rate. Conduct a performance audit every three to five years to assure that the system is working efficiently and with the desired lower quarter DU and precipitation rate specifications.

4. As plant material matures, trim or remove vegetation as required to preserve system performance. Add additional sprinklers or other hardware as required to compensate for blocked spray patterns or changes in the irrigation needs of the landscape. Ensure that system modifications are in keeping with design specifications and do not cause landscape water demand to exceed the hydraulic capacity of the system.

5. Establish a "winterization" protocol (if required) and a corresponding process for system activation in the spring.

Additional points for an owner to consider are:

6. Ensure that the maintenance contractor is licensed and/or certified (where applicable), is insured, experienced, and reputable, and is legally authorized to maintain irrigation systems in your area. Ask the contractor for references of previous work and contact those references to seek information on the contractor's quality of service and timeliness in performing the job.

## PG 5 – Practice Guideline for Managing the Use of Irrigation Water

PG 5 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper management of the use of irrigation water. It is the responsibility of Fort Riley to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical, and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To conserve and protect water resources and the environment, the irrigation schedule shall be changed as required to provide supplemental water to maintain a functional and healthy turf and landscape with the minimum required amount of water.

To facilitate managing irrigation water use, the irrigation manager, consultant, end-user, owner, maintenance personnel, or contractor shall:

1. Create a site map showing, at a minimum, the location of each point of connection water meter, backflow prevention device, controller, station/zone valves, and landscape area served by each valve.

2. Ensure that a dedicated irrigation water meter has been installed for measuring both the irrigation water flow rate and the volume applied to the landscape. To facilitate managing irrigation water use, the water meter should have an electronic flow rate output signal for interfacing with a remote display or to controllers that can perform leak detection and water management.

3. If necessary, perform an irrigation audit to obtain data for creating a base irrigation schedule:
   a. For each hydrozone, identify plant type and microclimate factors. From soil cores, identify the soil texture and soil infiltration rate for the purpose of estimating the available water holding capacity of the soil. Determine the average effective root zone depth of the hydrozone.
   b. For each station/zone, measure the actual sprinkler performance including operating pressure, precipitation rate, lower-quarter distribution uniformity, and average flow rate.
   c. For each station/zone, recommend a normal operating pressure range. Accurately measure the landscaped area.
   d. For each station/zone, if the soil infiltration rate is less than the precipitation rate, then activate the zone valve and record the run time until runoff is first observed. Recommend the number of cycle starts and soak time between cycles to avoid runoff.
4. Using data collected from the audit, provide a monthly base irrigation schedule where the frequency of irrigation (when to irrigate) is based on replenishing the allowable depletion (how much to irrigate) of the soil moisture between irrigations. Base the monthly schedules on the plant type, root zone depth, soil type, infiltration rate, and monthly historical reference evapotranspiration data. Also account for site topography such as slope. Where there is a potential for surface runoff, use multiple repeat cycle start times to allow the water to infiltrate into the soil. If a rain shutoff device or soil moisture sensors are not installed, then also factor in an estimate of effective rainfall.
5. After the system has been placed into service, evaluate the effectiveness of system water management by monitoring and comparing actual landscape water use to a target design irrigation water budget:
   a. Calculate the design irrigation water budget for normal weather conditions. The design irrigation water budget should be provided by the landscape irrigation designer as one component of the Irrigation Design Package (Addendum A) and based on local historical weather conditions and expected plant water requirements under normal (e.g., non-drought) weather conditions. Base the design irrigation water budget on monthly historical ETo data, monthly effective rainfall estimate from monthly historical rainfall, plant landscape coefficient factors, and site factors.
   b. Calculate the design deficit irrigation water budget for drought weather conditions. For drought conditions, the irrigation goal is to conserve water while still sustaining the integrity of a majority of the landscape. The normal weather method for establishing the design irrigation water budget is generally applicable but is modified. The objective is to assign the water reduction required during the drought, rather than meet normal-weather plant water requirements. Focus on water saving techniques for reducing plant water demand, including reducing or eliminating fertilizers, changing mowing height, adding or improving mulch.

c. Manage the water use of the site. At a minimum, at the beginning and midpoint of each month, monitor water use by reading the system water meter or flow totalizer. Compare actual water use to the budgeted amount of water for the month. At mid-month, if water use exceeds 50% of the current month's irrigation water budget, then modify the schedule to stay within the monthly budget. Frequently adjust the irrigation schedule to meet changing weather conditions.

d. Evaluate system performance. Periodically, and at the end of each irrigation season (or annually), evaluate water management efficiency and overall irrigation system efficiency. The evaluation can highlight strengths and weaknesses in the performance of the irrigation system and how it is being maintained and managed.

6. Periodically, verify that sensors and other components in the irrigation system are working properly. Inspect the irrigation system during operation.

7. Periodically, visually verify that the plant material is healthy and that soil moisture is adequate. Use a soil probe to evaluate root depth, soil structure, and moisture.

8. To further conserve water, the irrigation manager should:

   a. Understand how to use various sensors such as soil moisture and weather sensors to aid in irrigation management.

   b. Install a rain shutoff device to stop irrigation during and directly following a significant rain event.

   c. Install soil moisture sensors to override the controller's schedule when the root zone is adequately moist. Monitoring soil moisture regularly also helps to reduce the guesswork in establishing proper irrigation intervals for each hydrozone.

   d. Install a master valve to stop unscheduled flow of irrigation water.

   e. Use drip/micro-irrigation components for higher distribution uniformity and lower evaporation and runoff.

9. When water supplies are limited, manage the irrigation based on a site-specific Drought Response Plan. The plan should have two primary components, one dealing with landscape maintenance practices and the other with deficit irrigation practices:

   a. Landscape Maintenance Practices: There are many maintenance practices that can help a landscape irrigation system operator cope with a water shortage, including adjusting mowing height, fertilization practices, use of mulch in planter beds, and amending the soil. The owner should determine the overall priorities of the site and evaluate those areas that deserve the greatest attention. Consult a licensed/certified (where applicable) landscape contractor, extension agent, or certified nurseryman for information regarding appropriate maintenance practices.

   b. Deficit Irrigation Practice: Deficit irrigation may be used at the discretion of the irrigation manager. It is most commonly used in response to a drought or other water shortage. The goal of deficit irrigation management is to apply a reduced amount of water while keeping the plant material alive, but potentially placing the plants in a water-stressed condition.

c. It is important to understand that managing plants in a deficit irrigation mode puts them at risk to other environmental and/or biological factors such as pest infestation. Careful and frequent observation of the landscape is essential to such an irrigation strategy.

## Irrigation Design Package

The irrigation designer or consultant should supply an Irrigation Design Package to the owner of the system. The purpose is to provide the system owner with documented site and zone-specific information, and values used in design calculations.

The Irrigation Design Package should include:

1. Site-specific Information

- Site map that includes “north” symbol, topography, and/or key elevations
- Static pressure(s) used in the design; psi
- Monthly historical grass ETo in./month
- Monthly historical rainfall (Rh); in.
- Recommended rainfall factor (RF; %), or supply the method for estimating effective rainfall (Re) from historical rainfall (Rh).
- Monthly historical effective rainfall (Re) (may also be specific to each hydrozone)
- Landscaped area (A); sq. ft, for each hydrozone
- Site's design area-weighted average lower quarter distribution uniformity
- Lower quarter DU for overhead-irrigated hydrozones; %
- Site’s design area-weighted average emission uniformity (EU) for drip/microirrigation hydrozones; %
- Prevailing wind direction during normal period of sprinkler system use (in degrees from north)
- Average wind speed (mph) during normal period of sprinkler system use
- Reference to local information regarding location of subsurface utilities
- Identify heritage trees or special circumstances
- Note if special trenching or installation techniques are required

2. Identification and Location of All Irrigation Components

To aid in initial installation and in future modifications or additions to the system:

- Point of connection water meters and their locations

- Dedicated meters and flow sensors and their locations
- Backflow prevention device(s) and location(s)
- Station/zone valves and their locations
- The site area (location) served by each valve
- Controller(s) and location(s)
- Sensor types and their locations
- Pump(s) and location(s)
- All components (above items plus sprinkler heads, nozzles, drip/microirrigation components, wire, pipe type and size, valve size, etc.) by manufacturer, model, type and size
- Component warranty and product literature (provide to owner)

3. Basic hydraulics (pressure losses and calculations)
   - Point of connection water meter(s)
   - Backflow prevention device(s)
   - Static water pressure; psi
   - Recommended system dynamic (working) water pressure; psi
   - Acceptable system dynamic (working) water pressure range (minimum to maximum); psi
   - Valve and pipe sizing criteria
4. Station/zone and hydrozone information for each station/zone or hydrozone
   - Landscaped area of the zone (A); sq. ft
   - Plant materials
   - Design plant species factor (Ks)
   - Design microclimate factor (Kmc)
   - Design plant density factor (Kd)
   - Design landscape coefficient (KL = Ks × Kmc × Kd)
   - Monthly plant water requirement (PWR) based on historical ETo; in.
   - Soil type (clay, loam, sand, etc.) and soil profile if applicable
   - Design soil infiltration rate (intake rate); in./hour
   - Design available water holding capacity (AW) of the soil; in. of water per in. of soil
   - Design average root zone depth (RZ); in.
   - Design management allowable depletion (MAD)
   - Design allowable depletion (AD); in.

- Design flow rate (Q); gpm
- Design precipitation (application) rate (PR); in./hour
- Design lower quarter DU; %
- Design run time multiplier (RTM)
- Monthly expected station/zone irrigation water budget (VIWR) gallons or ccf
- Recommended sprinkler spacing, noting maximum spacing that maintains the design lower quarter DU; ft
- Recommended operating pressure; psi
- Acceptable operating pressure range (minimum to maximum); psi
- Recommended allowable stress factors (Kas) for deficit irrigation during mild and severe droughts

5. Design Monthly Irrigation Water Budget

    - For each month, compute the design monthly irrigation water budget (VIWR) for the irrigation system by summing the water budget of individual hydrozones. Use the same units as used by the local water purveyor, typically ccf or gallons
      Identify the values used (ETo, KL coefficient, etc.) in the calculation
    - Monthly permitted water withdrawal amount (only applicable for some states with particular requirements)

6. Seasonal (or Annual) Irrigation Water Budget

    - Compute the design irrigation water budget (VIWR,season) for the irrigation season (or for the year) by summing the design station/zone water budgets for all months of the irrigation season; ccf/year or gal/year

7. Monthly and Seasonal Landscape Water Allowance (only if applicable to the region)

    - Water allowance adjustment factor (Kwa) for the particular type of landscape
    - Site's monthly and seasonal landscape water allowance (LWA); ccf/year or gal/year

8. Monthly Irrigation Schedule for each station/zone

    - Document by month the recommended base irrigation schedule. Base the schedule on historical monthly ETo data, plant type (KL coefficient), soil type (for available water holding capacity and soil infiltration rate), root zone depth, allowable depletion, optimum irrigation interval, station/zone precipitation rate, station/zone distribution uniformity, and so forth.
    - Recommended irrigation interval (days between irrigation)
    - Recommended irrigation run time (hours or minutes per irrigation event and time of day)
    - Number of cycle starts (Ncs) required for each irrigation event to avoid runoff

- Maximum cycle start run time (RTcycle) of each hydrozone to avoid runoff (minutes) and recommended soak delay time between cycles (minutes)
- Identify values used (ETo, KL, precipitation rate, etc.) in developing the base irrigation schedule
- Recommended frequency of irrigation system inspection

9. Source of Local Historical or Current Rain Data:
   - Include sources used such as the National Weather Service, local weather channel, local weather station (state location), state cooperative extension service, and so forth.
10. Pumps (if required):
    - Manufacturer, model, type, and size
    - Hydraulic and energy calculations
    - Electrical requirements and projected operating costs
11. Recommendations for Water Conserving Devices:
    - Rain shutoff device
    - Soil moisture sensors
    - Weather station
    - High-wind shutoff device
    - Freeze protection device
    - Flow meter with totalizer
    - Automated control system

## Addendum – Irrigation Design Package

The irrigation designer or consultant should supply an Irrigation Design Package to the owner of the system. The purpose is to provide the system owner with documented site and zone-specific information, and values used in design calculations.

The Irrigation Design Package should include the following.

1. **Site-Specific Information**

- Site map that includes "north" symbol, topography, and/or key elevations
- Static pressure(s) used in the design; psi
- Monthly historical grass ETo in./month
- Monthly historical rainfall (Rh); in.
- Recommended rainfall factor (RF; %), or supply the method for estimating effective rainfall (Re) from historical rainfall (Rh).
- Monthly historical effective rainfall (Re) (may also be specific to each hydrozone)
- Landscaped area (A); sq. ft, for each hydrozone.
- Site's design area-weighted average lower quarter distribution uniformity
- Lower quarter DU for overhead-irrigated hydrozones; %
- Site’s design area-weighted average emission uniformity (EU) for drip/microirrigation hydrozones; %
- Prevailing wind direction during normal period of sprinkler system use (in degrees from north)
- Average wind speed (mph) during normal period of sprinkler system use
- Reference to local information regarding location of subsurface utilities
- Identify heritage trees or special circumstances
- Note if special trenching or installation techniques are required

2. **Identification and Location of All Irrigation Components**

To aid in initial installation and in future modifications or additions to the system

- Point of connection water meters and their locations
- Dedicated meters and flow sensors and their locations
- Backflow prevention device(s) and location(s)
- Station/zone valves and their locations
- The site area (location) served by each valve

- Controller(s) and location(s)
- Sensor types and their locations
- Pump(s) and location(s)
- All components (above items plus sprinkler heads, nozzles, drip/microirrigation components, wire, pipe type and size, valve size, etc.) by manufacturer, model, type and size
- Component Warranty and Product Literature (provide to owner)

3. **Basic Hydraulics (pressure losses and calculations)**
    - Point of connection water meter(s)
    - Backflow prevention device(s)
    - Static water pressure; psi
    - Recommended system dynamic (working) water pressure; psi
    - Acceptable system dynamic (working) water pressure range (minimum to maximum); psi
    - Valve and pipe sizing criteria
4. **Station/zone and Hydrozone Information for Each Station/Zone or Hydrozone**
    - Landscaped area of the zone (A); sq. ft
    - Plant materials
    - Design plant species factor (Ks)
    - Design microclimate factor (Kmc)
    - Design plant density factor (Kd)
    - Design landscape coefficient (KL = Ks × Kmc × Kd)
    - Monthly plant water requirement (PWR) based on historical ETo; in.
    - Soil type (clay, loam, sand, etc.) and soil profile if applicable
    - Design soil infiltration rate (intake rate); in./hour
    - Design available water holding capacity (AW) of the soil; in. of water per in. of soil
    - Design average root zone depth (RZ); in.
    - Design management allowable depletion (MAD)
    - Design allowable depletion (AD); in.
    - Design flow rate (Q); gpm
    - Design precipitation (application) rate (PR); in./hour
    - Design lower quarter DU; %
    - Design run time multiplier (RTM)

- Monthly expected station/zone irrigation water budget (VIWR) gallons or ccf
- Recommended sprinkler spacing, noting maximum spacing that maintains the design lower quarter DU; ft
- Recommended operating pressure; psi
- Acceptable operating pressure range (minimum to maximum); psi
- Recommended allowable stress factors (Kas) for deficit irrigation during mild and severe droughts

5. **Design Monthly Irrigation Water Budget**

   - For each month, compute the design monthly irrigation water budget (VIWR) for the irrigation system by summing the water budget of individual hydrozones. Use the same units as used by the local water purveyor, typically ccf or gallons
     Identify the values used (ETo, KL coefficient, etc.) in the calculation
   - Monthly permitted water withdrawal amount (only applicable for some states with particular requirements)

6. **Seasonal (or Annual) Irrigation Water Budget**

   - Compute the design irrigation water budget (VIWR,season) for the irrigation season (or for the year) by summing the design station/zone water budgets for all months of the irrigation season; ccf/year or gal/year

7. **Monthly and Seasonal Landscape Water Allowance (only if applicable to the region)**

   - Water allowance adjustment factor (Kwa) for the particular type of landscape
   - Site's monthly and seasonal landscape water allowance (LWA); ccf/year or gal/year

8. **Monthly Irrigation Schedule for Each Station/Zone**

   - Document by month the recommended base irrigation schedule. Base the schedule on historical monthly ETo data, plant type (KL coefficient), soil type (for available water holding capacity and soil infiltration rate), root zone depth, allowable depletion, optimum irrigation interval, station/zone precipitation rate, station/zone distribution uniformity, and so forth.
   - Recommended irrigation interval (days between irrigation)
   - Recommended irrigation run time (hours or minutes per irrigation event and time of day)
   - Number of cycle starts (Ncs) required for each irrigation event to avoid runoff
   - Maximum cycle start run time (RTcycle) of each hydrozone to avoid runoff (minutes) and recommended soak delay time between cycles (minutes)
   - Identify values used (ETo, KL, precipitation rate, etc.) in developing the base irrigation schedule

- Recommended frequency of irrigation system inspection

9. **Source of Local Historical or Current Rain Data**:
    - Include sources used such as the National Weather Service, local weather channel, local weather station (state location), state cooperative extension service, and so forth.

10. **Pumps (if required):**
    - Manufacturer, model, type, and size
    - Hydraulic and energy calculations
    - Electrical requirements and projected operating costs

11. **Recommendations for Water Conserving Devices**:
    - Rain shutoff device
    - Soil moisture sensors
    - Weather station
    - High-wind shutoff device
    - Freeze protection device
    - Flow meter with totalizer
    - Automated control system

# Appendix E – Project Prioritization Roadmap Workshop Score Sheet

During the roadmap workshop held at Fort Riley in April 2013, attendees developed a prioritization of the water conservation measures that were developed as part of the Fort Riley water assessment. The prioritization process essentially scored each project based on the following criteria:

- Water supply and consumption effects
- Mission risk reduction
- Cost implications
- Implementation risk

Multiple questions were asked under each criterion.  Each participant scored each question using a scale from 0 to 10 (Table E.1)

**Table E.1.** Fort Riley Roadmap Workshop Participant Questionairre

# Fort Riley NZW Evaluation Score Sheet

**Evaluator:**

| | Weight | Domestic Plumbing | Commercial Kitchen | Irrigation | Reclaim System | Distribution System | Central Plants | O&M Washrack | Education Outreach |
|---|---|---|---|---|---|---|---|---|---|
| **Water Supply and/or Consumption Impacts** | **25%** | | | | | | | | |
| S1. Does the project have a significant reduction on potable water use? | 0.1 | | | | | | | | |
| S2. Does the project encourage improved water use behavior by installation personnel? | 0.05 | | | | | | | | |
| S3. Does the project continue to perform at its initial level without significant degradation over time? | 0.05 | | | | | | | | |
| S4. Does the project substitute alternative sources of non-potable water for potable water? | 0.05 | | | | | | | | |
| **Mission Risk Reduction** | **25%** | | | | | | | | |
| MR1. Does the project diversify water supply sources, thereby increasing water security? | 0.1 | | | | | | | | |
| MR2. Will the project be more reliable than the system/components being replaced? | 0.1 | | | | | | | | |
| MR3. Will the project help ensure successful mission activities in the face of an unforeseen water emergency? | 0.05 | | | | | | | | |
| **Cost Implications** | **25%** | | | | | | | | |
| C1. Does the project save money from a life-cycle cost perspective? | 0.1 | | | | | | | | |
| C2. Does the project reduce the need for maintenance or major overhauls? | 0.1 | | | | | | | | |
| C3. Does the project reduce the need for human (operational) oversight? | 0.05 | | | | | | | | |
| **Implementation Risk** | **25%** | | | | | | | | |
| IR1. Can the project be implemented with alternative funding sources (ESPC/UESC)? | 0.1 | | | | | | | | |
| IR2. Can the project be implemented with SRM funding within the installations budget constraints? | 0.1 | | | | | | | | |
| IR3. Will the project likely be implemented when needed, given funding and other uncertainties? | 0.05 | | | | | | | | |
| * Score based on the following system: | **1.00** | | | | | | | | |

| | | | |
|---|---|---|---|
| Very Strongly/Certainly | 10 | Marginally/Possibly | 2 |
| Significantly/Highly Likely | 7 | No Impact | 0 |
| Moderately/Likely | 5 | Not Applicable | NA |

# Appendix F – Project Funding Options

The traditional approach for funding energy projects at Federal installations has been through direct appropriations. However, with fewer appropriated funds available for maintenance, repair, and replacement, this source of funding is becoming limited and projects not directly tied to the installation's mission may be delayed or not fully funded. Fortunately, there are now a number of alternative approaches available to Federal installations for funding energy and water efficiency improvements. These approaches evolved in the late 1990s in direct response to the decline in appropriated funds. These options cover the full range of choices, from internally financed projects, to funding and financing from the servicing utility, to shared energy savings projects financed entirely by private capital.

The following is a summary of the various funding options available to Federal installations. The summary describes the advantages and disadvantages of each approach, and presents one approach on how to evaluate the alternatives to allow an informed decision on which option or options to pursue (Table F.1, Table F.2, and Table F.3). It may be possible to combine several sources of funding/financing for energy and water projects. For example, utility incentives can be combined with energy savings performance contract (ESPC) financing. The key to success is to fully understand the project objectives and the alternative financing opportunities available. There is not just one "best" approach.

## Appropriated Funds

The primary advantage of using direct appropriation funding for water projects is that there is no "loan," thus no repayment is required. A secondary advantage is that the Federal government retains all of the cost savings from the projects. Because government-appropriated funds come from tax revenues or bonds, the costs to appropriate these funds are competitive with commercial rates, and do not incur interest charges. On the downside, the Federal installation or agency is responsible for proper project management, execution, operation, and maintenance. The source of capital funding will depend on the size and scope of the project. Funding can come from the installation's budget for operations and maintenance (O&M) or minor construction if the energy project is small. These funding sources include sustainment, restoration, and modernization (SRM) funds. Large capital improvements can be funded through the Department of Defense (DOD) Military Construction (MILCON) program. MILCON projects can include energy and water efficiency measures as part of the project. A subset to MILCON projects is the Energy Conservation Investment Program (ECIP).

### Energy Conservation Investment Program

ECIP is the only direct investment in energy conservation for the DOD. The program requires congressional notification prior to project startup and periodic status updates thereafter. ECIP is still an attractive funding mechanism for many installations and energy projects. As a subset to the MILCON program, ECIP establishes funding to improve energy efficiency and reduce water consumption at existing military facilities.

To receive ECIP funding, an energy project must, at a minimum, meet specific economic criteria of a savings-to-investment ratio (SIR) of at least 1.25 and a payback of less than 10 years. The FY 2012 ECIP guidance for the Army includes a 5% goal for water conservations projects. Additionally, ECIP-funded projects must be greater than $750,000. Federal installations will be challenged by the need to identify a single project, or the bundling of smaller projects, to reach that threshold, while still meeting the SIR and payback criteria. Another drawback to ECIP-funded projects is time between the call for ECIP projects and receipt of actual funding, which can be two to three years. Design of these projects is normally funded the year before implementation. Both design and construction are paid with DOD MILCON appropriation and, therefore, do not compete for resources with other requirements in the installation budget.

### Other Appropriated Funding Options

Funds transferred from DOD-wide O&M appropriations to Operations and Maintenance, Army (OMA) accounts can be used to execute projects at the installation level without affecting the installation's operating budget. Utility dollars not spent as a result of reducing energy consumption can be reprogrammed during the budget year to finance unfunded OMA projects, subject to normal OMA statutory limits. SRM funds can also be used for small projects. SRM and OMA funds have no minimum funding requirements and economic requirements such as SIR. New work/minor construction is limited to $750,000 with SRM funds, but repair/retrofit projects are not limited.

Another recent source of Federal appropriated funding for the Army is QUTM funding for Energy and Government-Owned Utility Systems. This funding source provides funding for small, low cost energy and water projects. There is a requirement for a simple payback of 10 years or less.

## Alternative Financing

### Energy Savings Performance Contracts

Energy savings performance contracts allow Federal agencies to conduct energy projects with no upfront capital costs, minimizing the need for congressional appropriations.

An ESPC is a partnership between a Federal agency and an energy service company (ESCO). The ESCO conducts a comprehensive energy audit for the Federal facility and identifies improvements to save energy. In consultation with the Federal agency, the ESCO designs and constructs a project that meets the agency's needs and arranges the necessary funding. The ESCO guarantees the improvements will generate energy cost savings sufficient to pay for the project over the term of the contract. After the contract ends, all additional cost savings accrue to the agency. Contract terms of up to 25 years are allowed.

DOE's Federal Energy Management Program (FEMP) awarded indefinite-delivery, indefinite-quantity (IDIQ) ESPC contracts to 16 ESCOs. Each contract has a $5 billion ceiling, resulting in a potential of up to $80 billion for energy efficiency, water conservation, greenhouse gas emissions reduction, and renewable energy projects at Federally owned buildings and facilities. DOE awarded these umbrella contracts to ESCOs based on their ability to serve Federal agencies under terms and conditions outlined in the IDIQ solicitation. Under these contracts, agencies can use ESPCs in

Federal facilities, both domestic and international. Current information on the availability and use of DOE ESPCs is available on the FEMP web site.[1]

The U.S. Army Engineering and Support Center, Huntsville, Alabama, has also set up an ESPC contracting process that provides engineering, legal, contracting, and program management for Army installations. More information is available from their web site.[2]

### Utility Energy Service Contract

The most common approach for working with a utility to implement energy and water efficiency projects is via a utility energy service contract (UESC). With a UESC, the utility typically arranges financing to cover the capital costs of the project. Then the utility is repaid over the contract term from the cost savings generated by the energy/water efficiency measures. But unlike ESPCs, UESCs do not have special requirements for measurement and verification (M&V) of energy and water savings.

### Assessing Alternative Financing Options

There are probably as many ways to analyze financing alternatives as there are alternatives. One proposed approach provides a simple analysis to determine what funding options are available at an installation and describes a six-step process to determine which alternative is most advantageous. The approach is not prescriptive and is designed to assist an installation in identifying the strengths and weaknesses of the various financing alternatives on a project-by-project basis. The key steps in this process are:

- Define the objectives
- Define the criteria that influence the selection of funding source
- Define potential funding scenarios
- Identify the installation resources required to execute the various options
- Define the risks and benefits of the various scenarios
- Select an energy project financing method

[1] http://www1.eere.energy.gov/femp/financing/espcs.html
[2] http://www.hnd.usace.army.mil/iscx/espcnw.asp

**Table F.1**. Summary of the Appropriate Funds Financing Option

| Source/Mechanism | Advantages | Disadvantages |
|---|---|---|
| ✓ Energy Conservation Investment Program<br><br>✓ Installation/agency budget for O&M projects and minor construction<br><br>✓ Appropriated funding from chain of command<br><br>✓ Line-item funding authorization or appropriations | ✓ Installation does not have to pay back the funding<br><br>✓ Installation/agency retains all of the savings from energy projects<br><br>✓ Minimal contractual obligations<br><br>✓ Longer payback projects can be implemented<br><br>✓ Energy savings measures can be included in major O&M repair and minor construction<br><br>✓ Less cost effective energy projects, such as newer technologies and renewable energy technologies, can be implemented<br><br>✓ Minor construction projects (<$750K) are approved by agency<br><br>✓ No special M&V requirements for energy savings | ✓ Projects not related to the installation's primary mission may be delayed or not funded<br><br>✓ Installation/agency assumes the risk of ensuring proper execution, operation and maintenance<br><br>✓ Installation/agency must wait for budget process to allocate funds (~ 2 years) |

**Table F.2**. Summary of the Utility Energy Service Contracting for Alternative Financing Option

| Source/Mechanism | Advantages | Disadvantages |
|---|---|---|
| ✓ Demand-side management programs, or rebates<br><br>✓ Customized utility/agency energy service agreements<br><br>✓ Energy service agreements under a General Services Administration area-wide contract (this not only includes authority to receive utility incentives, but also is authority for UESC, which is a separate financing resource from incentives/rebates) | ✓ Utility recovers investment through share of energy savings from installed measures<br><br>✓ Projects can be financed by private capital, but is not required<br><br>✓ Utility and installation/ agency can share capital investment<br><br>✓ Installation/agency can execute projects without waiting for Federal budget process to allocate funds<br><br>✓ Can include unique technologies such as thermal energy storage that only reduce energy costs<br><br>✓ Can include free or low-cost energy audits<br><br>✓ Utility provides rebates to reduce the cost to make project economically viable<br><br>✓ No special M&V requirements for energy or water savings | ✓ Less cost effective technology applications may be ignored<br><br>✓ Focus is on projects that benefit the utility (e.g., improve load curve)<br><br>✓ Installation must determine accounting means to accept and retain any incentives<br><br>✓ UESCs may not be available at all installations (utility may not offer UESC services)<br><br>✓ Overall project payback must be less than 10 years for all technologies<br><br>✓ Installation/agency shares energy savings from installed measures with utility |

**Table F.3**. Summary of the ESPC Alternative Financing Option

| Source/Mechanism | Advantages | Disadvantage |
|---|---|---|
| ✓ DOE ESPC<br><br>✓ U.S. Army Corps of Engineers (Huntsville) ESPC | ✓ Projects financed by private capital<br><br>✓ Contractor recovers investment through share of energy savings from installed measures<br><br>✓ Can bundle longer payback technologies (e.g., envelope improvements or renewable energy systems) with short-payback technologies (e.g., lighting or motor retrofits)<br><br>✓ Contractor must guarantee minimum energy and related operation and maintenance cost savings<br><br>✓ Contractor can assume risk for O&M on installed technologies<br><br>✓ Contractor provides specialized expertise and innovative technologies not otherwise available at installation/agency<br><br>✓ Installation/agency able to execute projects without waiting for budget process to allocate funds | ✓ Installation/agency shares energy savings from installed measures with contractor<br><br>✓ Many projects with significant energy savings are not cost effective because of required M&V combined financial structure of ESPC<br><br>✓ DOE ESPC does not allow water-only savings projects |