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Fort Riley Net Zero Water Program Water Balance Report

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August 2012

Pacific Northwest NATIONAL LABORATORY

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Richland, Washington 99352

Summary

In 2011, the Department of the Army launched the Net Zero Initiative to advance the sustainability of the Army by managing natural resources with the goal of "net zero." The net zero concept is founded on the idea of consuming natural resources in balance with what is available to the installation, creating an environment of long term sustainability. The Army is pursuing net zero in energy, water, and waste. As part of the Net Zero Initiative, the Army nominated eight pilot sites to demonstrate "net zero water." Fort Riley was selected to be one of the eight pilot installations because of garrison support, climatic demands, water availability, and existing strong water conservation program. The combination of these qualities is intended to be a showcase of possible solutions for Army installations with similar characteristics.

In support of the net zero water program at Fort Riley, the Army contracted Pacific Northwest National Laboratory (PNNL) to develop a water balance. PNNL subcontracted Water Savers, LLC to develop the water balance for Fort Riley. A water balance collects information from multiple sources to examine how water is used at an installation. The objective of the water balance is to assess water use at the end-use level to gain a thorough understanding of how water is consumed at Fort Riley. This report presents the results of the water balance for Fort Riley. The water balance is an important benchmark for the Army net zero project because it shows where water is being used at Fort Riley, how much water is being used to perform the mission of Fort Riley, and what technologies and practices have worked well at reducing potable water at the installation.

The results of the water balance will be used to prioritize efficiency improvements to help reduce water use at Fort Riley. Water efficiency measures will be included in the next phase, the net zero water roadmap. The roadmap will provide each net zero water installation a list of prioritized projects that will be used to help form a framework for an implementation strategy to meet net zero water goals.

The water balance assessment was developed following a three-phased approach, which is detailed in this report:

1. Pre-audit data analysis: compilation of data from Fort Riley to understand the general use patterns and trends in water use, population, and building inventory
2. Water audits: facility walk-through audits to collect key information on equipment and processes that consume water at Fort Riley
3. Water balance analysis: analysis of background data and information gathered during the water audits to quantify water use at the end-use and comparison of these end-uses to the total water supplied to the site to reveal the largest water uses at Fort Riley

Water use was assessed in barracks, administration buildings, operational/training facilities, dining facilities, laundry facilities, motor pools, the Installation Vehicle Wash Facility, irrigation, and various other facilities. The estimated water end-uses at Fort Riley total approximately 609 million gallons (Mgal) annually (Table S.1). The average water supplied to Fort Riley between fiscal year (FY) 2007 and FY 2011 was 789 Mgal. The difference between the water supply and end-use estimate is 23%. This percentage represents a variety of miscellaneous uses that were not assessed during the water balance due to the large and complex nature of Fort Riley operations. Little information was available on cooling towers and boilers that could represent up to 10% of this unaccounted for consumption. The unknown

uses also may be due to meter discrepancies, unknown system losses, and inherent variability in the water balance analysis. Overall, the major end-uses for Fort Riley were assessed and are detailed in the report.

The top five water-using categories at Fort Riley are plumbing fixtures in family housing, plumbing fixtures in barracks, hospital uses, distribution system losses, and irrigation in family housing. These five uses comprise 48% of the total water consumption at Fort Riley (Figure S.1).

Table S.1. Water Use by Major Water Use Categories

Water Use Category	Average Annual Water Use (1000 gallons)	% 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%

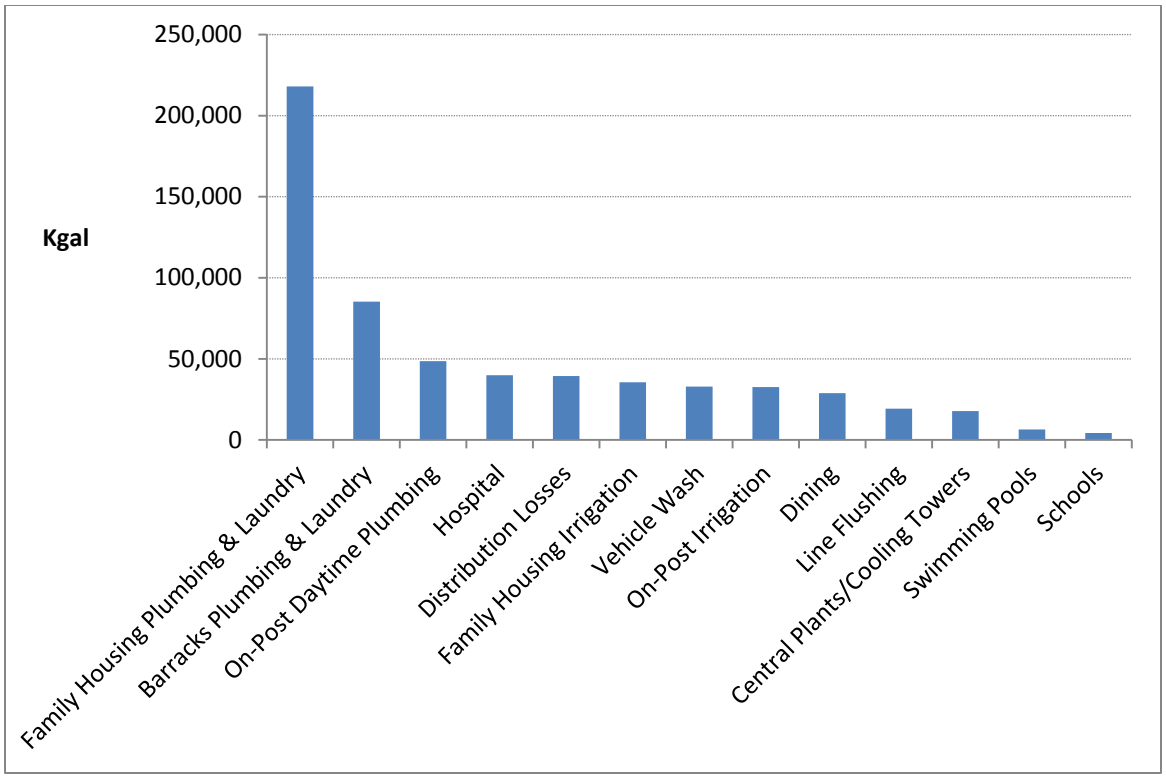

Figure S.1. Fort Riley Annual Water Use Breakout by Major End-Use Including Family Housing

Fort Riley is supplied with water from multiple ground source wells. The water is treated in an on-site water treatment plant located at the Custer Hill cantonment area. Water is distributed throughout the installation for various end-uses and is discharged to one of two on-site wastewater treatment plants. Treated wastewater is discharged to local watersheds that eventually feed the Kansas River, which travels along the south and eastern sides of the installation, where water infiltrates ground water sources (Figure S.2). This system is the net zero water framework for Fort Riley.

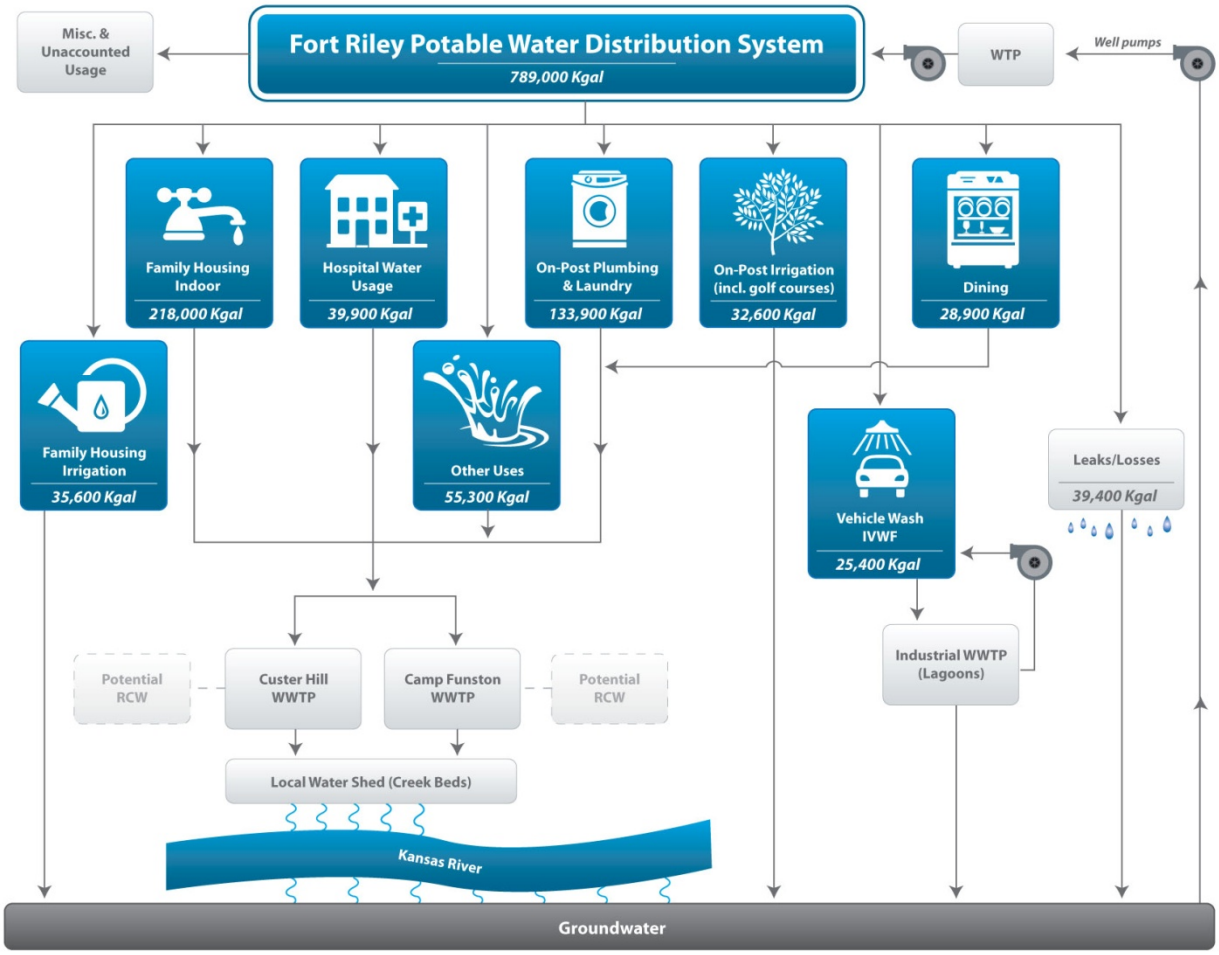

Figure S.2. Fort Riley Potable Water Distribution System Flow Chart

Acknowledgments

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SFC Clay-Brown

SFC Kelly

Acronyms and Abbreviations

AEWRS	Army Energy and Water Reporting System
EO	Executive Order
FY	fiscal year
gal/sqft	gallons per square foot
gpf	gallons per flush
gpm	gallons per minute
GSA	General Services Administration
IACH	Irwin Army Community Hospital
ILA	industrial, landscaping, and agricultural
IVWF	Installation Vehicle Wash Facility
Kgal	thousand gallons
LEED	Leadership in Energy and Environmental Design
MBH	thousand British thermal units per hour
Mgal	million gallons
MWR	Morale, Welfare, and Recreation
PFC	physical fitness center
PNNL	Pacific Northwest National Laboratory
RSMS	Readiness Sustainment Maintenance Site
TMP	transportation motor pool
WTP	water treatment plant
WUI	water use intensity
WWTP	wastewater treatment plant

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1.0 Phase 1: Understanding the Basics – Water Supply and Use

1.1 General Site Overview

Fort Riley covers 100,671 acres in northeast Kansas and is home to the 1st Infantry Division. The post is divided into six major cantonment areas: the Main Post, Custer Hill, Camp Funston, Camp Forsyth, Camp Whiteside, and the Marshall Army Airfield (Figure 1.1). Fort Riley was established in 1853 and was named in honor of the Major General Bennett C. Riley, who led the first military escort along the Santa Fe Trail. Fort Riley serves as an Active Component/Reserve Component installation.

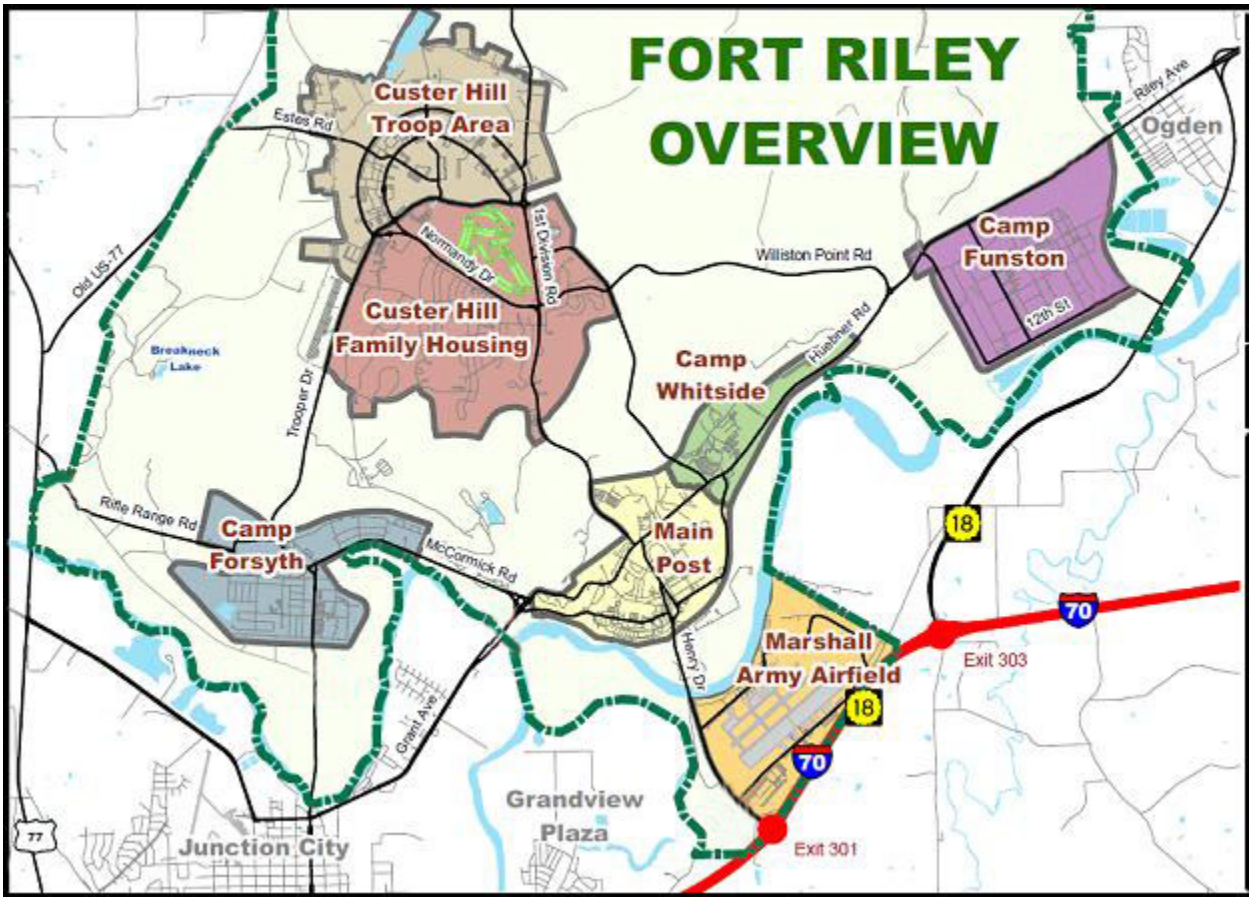

Figure 1.1. Fort Riley Map

1.2 Water Supply and Wastewater Treatment

The water supply system that serves Fort Riley is supplied by a system of subterranean wells that supply water via one 24-inch diameter concrete main to the central water treatment facility in the Custer Hill cantonment area. The water treatment plant (WTP) is designed to provide 10 million gallons (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 cast iron supply main distributes water to various storage towers and throughout the installation. Line flushing is a regular process for Fort Riley's water distribution system to maintain residual chlorine levels at terminal ends of the piping network.

The raw water supply to the WTP, 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 staff has 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. Data loggers for these sub-meters will be collected and further analyzed as part of the roadmap.

Fort Riley has two on-site wastewater treatment plants (WWTPs), which discharge into local creek watersheds that eventually feed the Kansas River and replenish the local aquifer. Storm and sanitary sewer systems are separate at Fort Riley, but minor infiltration and intrusion is expected. 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 storm events. Currently, the Camp Funston WWTP discharges an average of 0.7 Mgal daily.

1.3 Water Use Analysis

1.3.1 Potable Water Use

Fort Riley consumes an average of 789 Mgal of water annually based on average total use between fiscal year (FY) 2007 and FY 2011. This potable water is supplied to the entire post, including family housing and various other reimbursable customers. Fort Riley experiences higher summer peak loads, mainly due to landscape irrigation and cooling tower consumption (Figure 1.2).

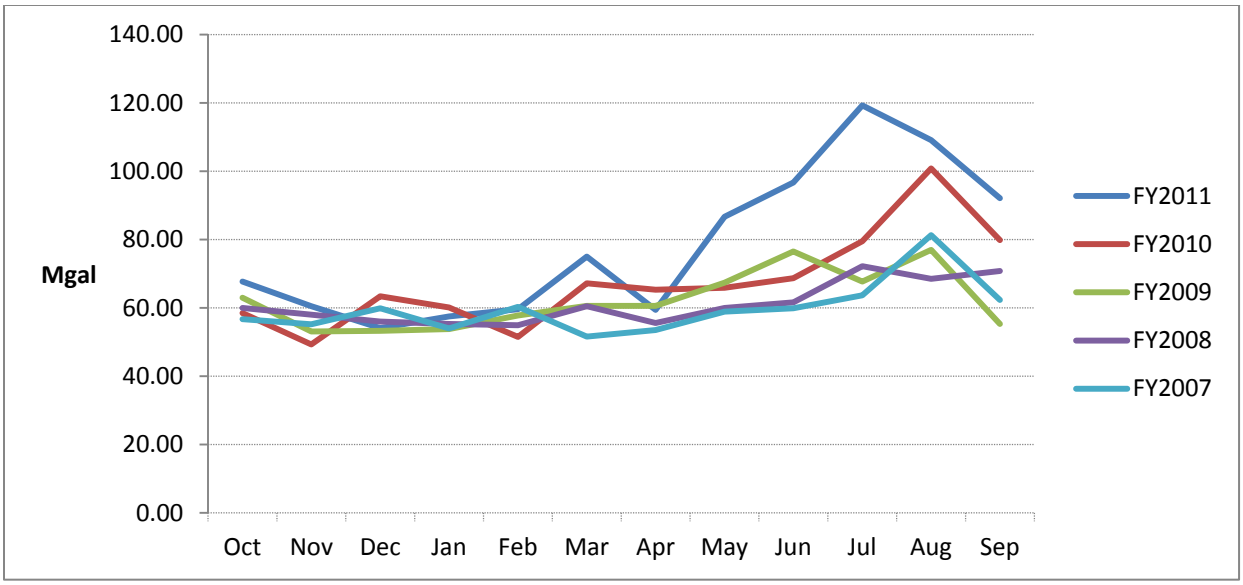

Figure 1.2. Fort Riley Annual Potable Water Use

Fort Riley reports potable water use, excluding privatized family housing and various other reimbursable customers, quarterly into the Army Energy and Water Reporting System (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 581 Mgal in FY 2011 to a low of approximately 445 Mgal in FY 2008. The baseline consumption reported in FY 2007 was 448 Mgal (Figure 1.3).

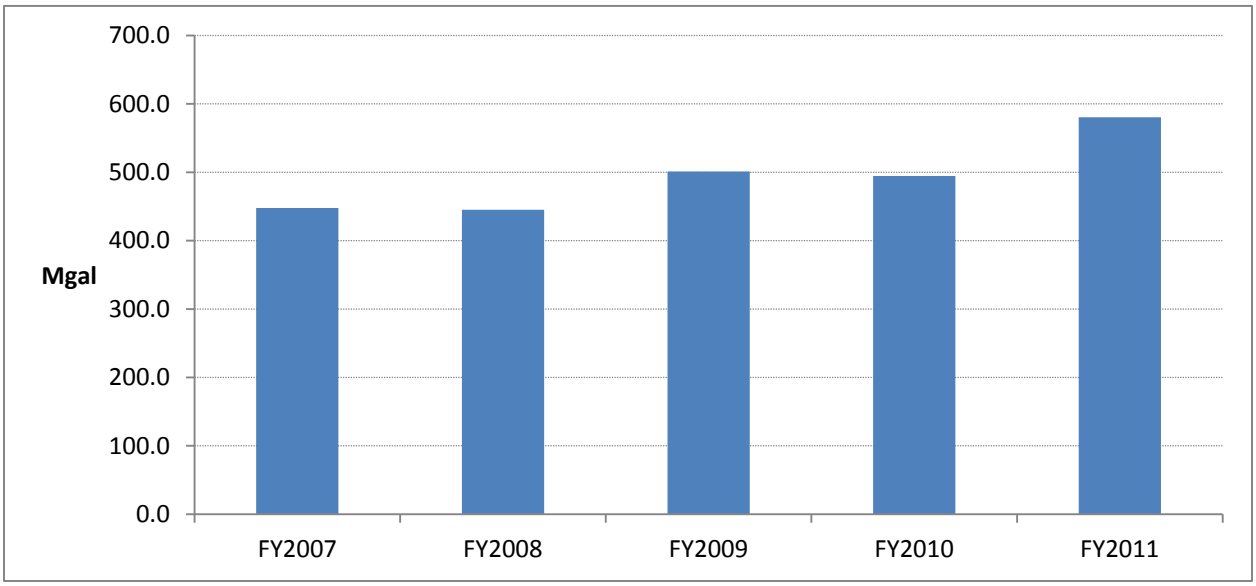

Figure 1.3. FY 2007 – FY 2011 Total Potable Water Use Reported in AEWRS

Executive Order (EO) 13514 requires Federal agencies to set a baseline for potable water use at FY 2007 and reduce potable water use intensity (WUI) by 2% per year based on FY 2007 baseline through

FY 2020, which is a total reduction of 26%. However, the Army net zero water program has accelerated the WUI reduction goal for net zero water installations to 26% by FY 2015 and 50% reduction by FY 2020. Fort Riley's potable WUI was 48 gallons per square foot (gal/sqft) in FY 2007 and has decreased to 40 gal/sqft through FY 2011, putting Fort Riley on track to meet the Army's net zero water goal (Figure 1.4).

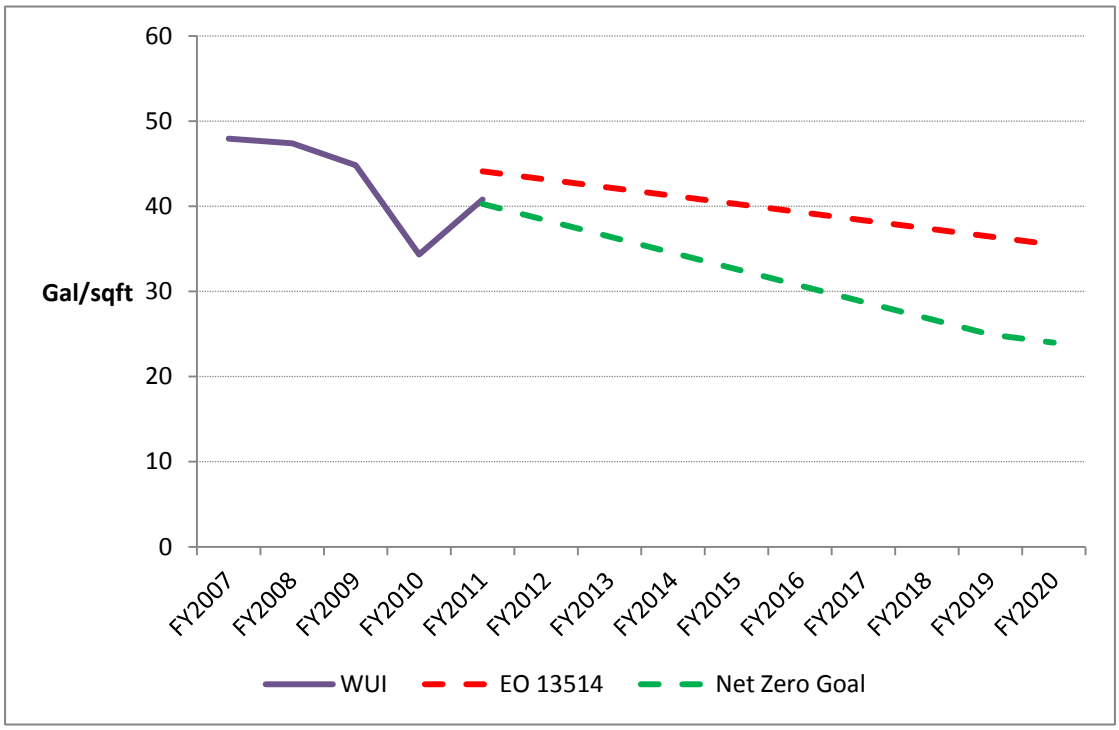

Figure 1.4. Annual Potable WUI and Projected Net Zero WUI Reduction Goal

1.3.2 Industrial, Landscaping, and Agricultural Water Use

Fort Riley does not use non-potable freshwater[1] for industrial, landscaping, and agricultural (ILA) use per EO 13514. EO 13514 requires Federal agencies to reduce ILA water use by 2% per year based on an FY 2010 baseline. All water supplied to Fort Riley from the on-site WTP is potable. Therefore, all water uses at Fort Riley are included in the potable water category. Fort Riley has the potential to use non-potable water that is reclaimed from the WWTPs, but this water is not considered ILA water use because it is not from a freshwater source (see Section 1.3.3 for information on Fort Riley's reclaimed water).

1.3.3 Alternate Water Sources

Fort Riley has potential alternate water sources from both on-site WWTPs. Wastewater could be reclaimed from the WWTPs and used beneficially for non-potable applications such as irrigation. Currently, all wastewater is discharged to creeks feeding the Kansas River. Intermediate collection points could be implemented adjacent to the WWTPs, prior to discharge to the creek beds, but no systems are currently planned. The Custer Hill WWTP is near the golf course and Installation Vehicle Wash Facility

[1] Freshwater is naturally occurring water supplied from surface or groundwater sources, including, but not limited to, lakes, streams, and aquifers which have low concentrations of total dissolved solids.

(IVWF), and would substantially reduce potable water use on-site by reclaiming treated wastewater for golf course irrigation. The Camp Funston WWTP is located farther away from potential end-uses and may require significant infrastructure changes to implement a reclaimed water system. Alternate water projects will be evaluated as part of the roadmap activities.

1.3.4 Sub-Metered Uses at Fort Riley

Fort Riley has a variety of sub-meters in use, primarily for billing reimbursable customers. However, not all reimbursable customers are billed via meter readings.

1.4 Water Costs

All water treatment and wastewater treatment at Fort Riley is performed at Army-owned and operated WTP and the two WWTPs. Fort Riley water rate are 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, the total operating cost of each of the systems tends to scale with consumption, e.g., lower consumption equals lower costs, higher consumption equals higher costs.

The following list provides the water and wastewater rates that are charged to reimbursable customers at Fort Riley:

- Potable water: $1.47/Kgal for government customers; $2.19/Kgal for non-government customers

- Wastewater treatment: $2.16/Kgal for government customers; $3.69/Kgal for non-government customers

1.5 Personnel

Fort Riley provided personnel data, divided into military personnel, civilian/contractors, and dependent family members on-post. The categories were based on occupancy patterns, generally the number of people who live on-post and the number of people who only are on-post during the day. Military personnel who live in barracks were assumed to be on-post 345 days per year based on the annual number of leave days allowed for enlisted soldiers. Military personnel and their families who live in family housing were assumed to be on-post 350 days annually. Civilian/contractors and off-post military personnel were assumed to be on-post 260 days annually. These data were used to estimate water use in domestic plumbing fixtures.

Fort Riley's military personnel total 19,120 as of September 30, 2011 (most recent data available). From the Barracks Utilization Report issued January 2012 (Fort Riley 2012), the number of military personnel living in barracks was approximately 5,645. A total of 3,888 military personnel, along with 10,518 dependents, live on-post in family housing. The remaining 9,587 military personnel are assumed to live off-post. The number of civilian and contractor personnel is estimated at 8,307.

1.6 Building Inventory

Fort Riley has a variety of building types. The building inventory was analyzed prior to the water balance site visit to identify the key buildings to survey during the audit. Buildings were targeted that represent Fort Riley's major water users, including barracks, dining facilities, motor pools, family housing, operational/training facilities, and administration buildings (Figure 1.5). In total, over 1.95 million square feet of building space was audited during the water balance site visit, approximately a 10% sample of building space.

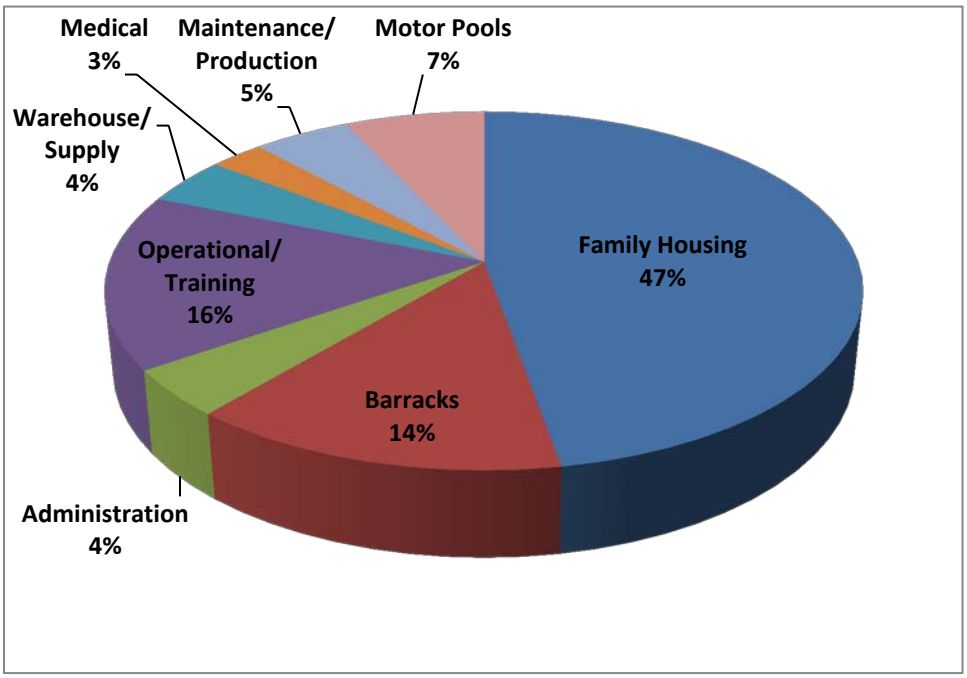

Figure 1.5. Building Type Breakout at Fort Riley

2.0 Phase 2: Gathering Information on Water End-Uses

Buildings were audited during the week of January 24, 2012. Working closely with Fort Riley personnel, the water assessment team audited all of the major water-using equipment and their applications in a variety of building types, and interviewed key personnel.

2.1 Domestic Plumbing

Domestic plumbing fixtures were audited in all of the major building types at Fort Riley, including barracks, administration buildings, physical fitness centers (PFCs), family housing, and shops. Toilets, urinals, faucets, and showerheads were assessed (Figure 2.1).

Figure 2.1. Fort Riley's Typical Domestic Plumbing Fixtures

2.1.1 Barracks

Fort Riley has 71 barracks buildings containing approximately 2.8 million square feet, accounting for 14% of the total building space. Scattered throughout Fort Riley, barracks building types range from

historic stone buildings built in the late 1800's to newly constructed, LEED[1] certified barracks. Ten unique barracks buildings were audited to gather information on water-consuming equipment. These were Buildings 27, 214, 672, 685, 7001A, 7492, 7614, 7844, 8018, and 7886. These barracks buildings were chosen as representative samples of all barracks facilities at Fort Riley.

Toilets in the barracks rooms were typically floor mount, floor discharge tank-type toilets. 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 (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 team 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 that were 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.[2] Lavatory faucet flow rates measured between 0.5 and 2.5 gallons per minute (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 or 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 functioned as designed.

2.1.2 Administration/Office Buildings, Operational/Training Buildings

Fort Riley has approximately 65 administration/office buildings containing over 863,000 square feet, accounting for 4% of the total building space. Fort Riley also has approximately 412 operational/training facilities containing over 3.2 million square feet, accounting for 16% of the total building space. Administration and operational buildings were audited using the same techniques as those used in the barracks (Section 2.1.1). Administration and operational buildings at Fort Riley vary from historic stone buildings built in the late1800's to modern, LEED certified facilities.

Most of the toilets in the administration and operations buildings audited were flushometer-style toilets rated at 1.6 gpf, although some older 3.5 gpf toilets were identified. However, most toilets flushed with higher volumes based on the long flush times that were observed by the auditors. Tank type toilets rated at 1.6 gpf were identified in some of the historic administration buildings. The auditors noted that in buildings that had been built or undergone major renovations after 2005, the toilets tended to have flush times that better matched the 1.6 gpf rating. Older, non-renovated, buildings tended to have high flush volumes, possibly due to sedimentation buildup in the diaphragm flush valves or improper flush valve retrofits in toilets.

[1] U.S. Green Building Council Leadership in Energy and Environmental Design rating system.
[2] Water is captured in the flow bag for a 5 second interval and the flow rate is provided in marked intervals on the bag.

Non-water urinals are present in one of the administration buildings, which has been recently remodeled. The audit team observed typical flush valve urinals in the remaining facilities with designed flush rates that varied from 0.5 to 1.6 gpf. The audit team observed that most faucet aerators at Fort Riley were rated between 0.5 and 2.5 gpm. Aerators in the audited LEED certified buildings were rated and flowed at 0.5 gpm. Very few showerheads were identified in the sample buildings of this category, but were generally rated at a flow rate of 2.5 gpm.

2.1.3 Morale, Welfare, and Recreation Facilities

Fort Riley Morale, Welfare, and Recreation (MWR) is responsible for several activities including PFCs, a child development center, pools, golf course, and the Warrior Zone.

The King Field House, the main PFC, was surveyed for the audit. Built in 1889 in the Main Post cantonment area, the King Field House averages 25,000 visitors monthly and has 15 employees. Data collection techniques for this PFC were the same as those used in the barracks (Section 2.1.1). King Field House has a lobby bathroom and locker room for each gender. Toilets at the King Field House used a mix of manual and sensor-operated flush valves and were rated at 1.6 gpf; however, the average flush volume was more than 2.0 gpf, indicating that the valves could be malfunctioning. Urinals in the men's restrooms and locker rooms also used a mix of manual and sensor-operated valves and were generally rated at 1.0 gpf. Lavatory faucets were rated 0.5 gpm. Shower areas were generally community shower areas with showerheads rated at 1.5 gpm.

The Warrior Zone, built in 1978 and remodeled in 2011, is an MWR facility used both to train troops in computer-aided simulations and to provide a place where soldiers can go for recreation. Approximately 570 soldiers use the facility daily. Toilets in the Warrior Zone were rated at 1.6 gpf, with manual piston valves operating as designed. Urinals located in the men's restrooms were also manually operated piston valves flowing at an average of 0.5 gpf. Lavatory faucets at the Warrior Zone were rated 0.5 gpm. The Warrior Zone has a small kitchen area that serves limited meals and drinks. It contains multiple deepwell sinks.

The Child Development Center, the golf course pro shop, and various other MWR facilities contained similar commercial plumbing fixtures, including newer toilets and urinals rated at 1.6 and 0.5 gpf, respectively, and older toilets and urinals rated at 3.5 and 1.0 gpf or greater, respectively. The majority of faucets identified included original aerators with flow rates from 2.2 to 2.5 gpm, though modern buildings included 0.5 gpm flow restrictors on many of the lavatory faucets. Showerheads were occasionally present, primarily sports recreation sites such as pools, the golf course, and ball field areas, and had flow rates from 1.5 to 3.0 gpm.

2.1.4 Family Housing

Approximately 14,400 military personnel and family members currently live in Fort Riley family housing areas. Family housing is privatized and is operated by Picerne Military Housing. Currently, Fort Riley has 2,201 family housing units. By FY 2016, Fort Riley will have 3,827 privatized family housing units that will measure roughly 9.5 million square feet, with new homes being completed weekly.

Data collection techniques for family housing were the same as those used in the barracks (Section 2.1.1). The majority of older homes had 1.6 gpf tank-style toilets. New homes had 1.28 gpf tank-style toilets, along with approximately 400 toilets rated at 1.6 gpf that were being phased out. Due to the conformity of each unit, all lavatory faucets had a flow rate of 1.5 gpm. All kitchen faucets were rated at 2.2 gpm. In the newer homes, the measured flow ranged from 2.0 to 2.5 gpm. All of the showers were rated at 2.5 gpm, with flow rates from 2.0 to 2.5 gpm. At the time of the walk-through audits, the homes were being standardized with the equipment described above.

2.1.5 Maintenance Shops, Motor Pools, Warehouse and Supply

Fort Riley has more than 315 buildings related to maintenance, utilities, motor pools, storage, and supply. Data collection techniques for this category of facilities were the same as those used in the barracks. All facilities analyzed during the water balance site visit contained typical commercial plumbing fixtures, including newer toilets and urinals rated at 1.6 and 0.5 gpf, respectively, and older style toilets and urinals rated at 3.5 gpf and 1.0 gpf or greater, respectively. The majority of faucets identified included original aerators, with flow rates from 2.2 gpm to 2.5 gpm, though modern buildings included 0.5 gpm flow restrictors on many of the lavatory faucets. Two of the four vehicle maintenance motor pools contained lavatory wash fountains. This type of lavatory basin is generally actuated by a foot pedal that allows multiple streams of water to flow from a common spigot and is efficient only if multiple people use it at the same time.

2.2 Kitchen Equipment

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, which was provided by dining personnel. Three of the dining facilities were audited, including Cantigny Dining Center, Devil's Den Dining Center, and Demon's Den Dining Center.

During the walk-through audits, team members recorded nameplate information for water-using appliances, such as ice machines, food steamers, dish machines, garbage disposals, food waste pulpers, pre-rinse sprayers, and tray conveyor systems (Figure 2.2). Nameplate information was used to determine the manufacturer-specified water use for each piece of equipment. The team made counts and flow measurements of faucets and pre-rinse spray valves using calibrated flow meter bags. Kitchen personnel were interviewed to determine approximate run times or fill/empty cycles for equipment.

Cantigny Dining Center serves an average of 3,000 meals daily and has the following water-using equipment.

- Six Scotsman dispensing ice machines located on top of the soft drink dispensers located in the dining area
- Two larger Scotsman ice machines used for all other ice purposes, with a combined ice production amount of 1,500 lb per day
- One Blodgett C206/AB food steamer
- One Hobart CRS110A dishwashing machine
- One food waste pulper, and two pre-rinse sprayer nozzles with an average flow rate of 1.9 gpm

The Devil's Den Dining Center serves an average of 1,100 meals daily and has the following water-using kitchen equipment.

- One Manitowoc ice machine with 550 lb of ice production daily
- One Alto-Sham food steamer
- One large Vulcan kettle steamer
- One Hobart CRS110A dish machine
- One Insinger CA-3 rack pot washer
- Two food waste pulpers
- One Waste King 5000-3 garbage disposal
- Three pre-rinse sprayer nozzles with average flow rates of 1.4 gpm

The Demon's Den Dining Center serves an average of 1,800 meals daily and has the following water-using kitchen equipment.

- Two Manitowoc ice machines with a combined ice production of 2,200 lb per day
- One Alto-Sham 20-20ESG/OLX food steamer
- Two Stellar Sirius 6 food steamers that were not used
- One large kettle steamer
- Two small Cleveland kettle steamers
- One Champion 56PW dish machine
- One Champion PP-28 pot washer
- One ISE SS-300 garbage disposal
- One Somat SPC 605 food waste pulper
- Three pre-rinse sprayer nozzles with average flow rates of 2.1 gpm

The Airfield Dining Facility was not inspected during the site visit, but was reported by Fort Riley personnel to serve an average of 2,200 meals per day and to contain the similar equipment as Demon's Den Dining Center.

Figure 2.2. Dining Facilities Commercial Kitchen Equipment

2.3 Laundry Equipment

During the site visit, information was recorded on laundry facilities in each building that was outfitted with a washing machine or dryer. The majority of the washing machines were ENERGY STAR rated front loading models located in the barracks and family housing facilities (Figure 2.3). For this water balance, it was assumed that each occupant in the barracks and family housing facilities washes and dries two loads of laundry per week. While the actual number of laundry loads per person per week may vary, two loads is a reasonable average for water balance calculation. Laundry equipment is also used in the Fort Riley PFCs to wash towels and clothing. It was estimated that 16 loads are washed per day at the King Field House facility, based on interviews with facility personnel.

Figure 2.3. Typical Laundry Washing Machine

2.4 Heating and Cooling

Heating and cooling equipment was audited, including hot water and steam boilers, chillers, and cooling towers.

2.4.1 Heating Boilers

Fort Riley has approximately 290 heating boiler plants currently operating. Nearly all are closed loop hot water boilers. Water consumption typically is low for hot water boilers because the only losses are due to leaks in the hot water distribution lines. Steam boilers can use a large amount of makeup water if they are not properly fitted with condensate return systems. There are 27 steam boilers located in buildings throughout the post. Most had at least some level of condensate return. Meter logs for the boilers were not available; water consumption from this end-use category was estimated based on a sample of the boilers identified during walk-through inspections. Steam boiler water consumption will be investigated further during the roadmap phase.

2.4.2 Chillers/Cooling Towers

Fort Riley has numerous cooling towers located throughout the base, though only seven of these units are tracked by the Directorate of Public Works. Information on cooling tower tonnage and operating hours was not available at the time of the audit. Cooling tower capacity and consumption will be investigated further during the roadmap phase of this project.

2.5 Medical Facilities

A LEED certified hospital is under construction and is scheduled to be completed by FY 2016. In the meantime, patients on base use the Irwin Army Community Hospital (IACH), which is scheduled to be demolished when the new hospital is finished.

The IACH facility has 44 patient rooms and provides outpatient services to an estimated 6,500 people every month. The audit team toured the hospital and assessed the main water-using equipment, including the restroom fixtures, central steam plant, chiller plant, sterilization units, cafeteria, and other water-cooled mechanical equipment. The hospital is billed by Fort Riley as a reimbursable customer at an average annual consumption of 47,370 Kgal. Water consumption inside the facility (i.e., water consumption excluding irrigation) is metered by hospital personnel to track water volume through the water softening system and scheduling of brine tank refresh. Meter log information was not obtained for this facility to balance against the estimated billing structure for the hospital.

2.6 Installation Vehicle Wash Facility and Motor Pools

The motor pools near the IVWF use water primarily for parts washing, individual vehicle washing, and other vehicle maintenance purposes. Each motor pool visited during the walk-through inspections contained at least one wash bay, or wash station, where pressure washers are used for individual vehicle washing. Personnel estimated that on average 4.5 vehicles per day are washed at each motor pool wash station, 5 days per week. Each wash averages 30-45 minutes for smaller vehicles and up to 2 hours for

larger tanks or other tracked vehicles. Most of the motor pool facilities have drains that are routed to a lift station that passes wastewater through an oil separator and pumps it into the settling basin lagoons of the IVWF.

The IVWF (Figure 2.4) serves as the final step of the industrial WWTP for the Fort Riley motor pools. As many as 240 vehicles per day may pass through the wash facility. The facility 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 water to 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.

This system is considered a "partial closed loop" because water is lost through evaporation and infiltration. For this reason, potable makeup water is provided at the facility to maintain basin water levels. Rainfall over the settling basins will contribute an average of 35 Mgal annually, based on historical average rainfall. However, based on information obtained during walk-through inspections, the system uses an average of 25 Mgal of potable water per year as makeup, with the majority of this consumption occurring during the dry season of July, August, and September. This presents a significant opportunity for use of alternate water sources, which will be analyzed during the roadmap phase of the net zero project.

Figure 2.4. Post-Wash Station at the Installation Vehicle Wash Facility

Additional vehicle washing occurs at the General Services Administration (GSA) car wash, transportation motor pool (TMP), and Buildings 1460 and 1470. Aircraft are washed at the airfield wash racks. Information regarding frequency of washes was obtained by facility personnel (Appendix A, Section A.8).

2.7 Irrigation

Fort Riley has more than 112 acres of irrigated landscape area, including the golf course, family housing, and landscaping around various on-post buildings. The irrigation season is from early March through late October or early November, depending on the weather. The turf areas are primarily native grasses, but recently some of the higher water consuming grasses in the golf course area were replaced with drought-resistant turf. Many 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.

Because the water balance site visit occurred in the winter, the audit team did not observe the irrigation systems at the main buildings of Fort Riley in operation. Instead, the team interviewed the ground maintenance manager, who provided a thorough explanation of the current irrigation system and practices along with information on planned improvements. Irrigation systems at the golf course were partially inspected, with thorough explanation from the grounds maintenance personnel of how the system is operated, and components of the system were examined.

Irrigation in family housing covers approximately 70 acres. Landscape irrigation will increase to 116 acres after FY 2016 housing is finalized. The irrigation systems are timer-based controlled with above-surface distribution sprayers.

Fort Riley has an 18-hole golf course that is irrigated using nine separate controllers, which are configured in a block system in which one valve operates up to 10 rotors (Figure 2.5). The systems are operated manually to control costs. In addition, only the tee boxes and greens are irrigated The fairways/rough areas have been updated to natural grasses, which are resistant to drought and cold temperatures. The recent changes in the operation of the golf course's operation have decreased annual water consumption between 5 and 6 Mgal. This is the minimum amount of water needed to maintain turf health on tee boxes and greens based on turf areas.

Building 500 was identified during site audits as the only facility on-post that utilized a formal irrigation system. The system consists of timer-based controllers and distribution system composed of 11 turf rotor zones and 1 pop-up sprayer zone for planter beds. The system operates every other day for an average of 42 minutes per zone, supplying an estimated 34 gpm through each zone valve. This equates to approximately 1.5 Mgal annually.

Additional on-post irrigation was identified by Fort Riley staff after water balance audit site visits took place. Locations that were identified as having irrigation systems include St. Mary's Chapel, Sturgis Field, Calvary, Cemetery, Building 580, the Sacco Ball Fields, and the Welcome Sign at Henry Guard Shack. Information provided about these systems indicated an additional 48.6 acres of irrigated landscape on-post.

Figure 2.5. Irrigation Components at Fort Riley Golf Course

2.8 Swimming Pools

Fort Riley MWR manages two indoor swimming pools and one outdoor pool. The outdoor pool is a 50 by 25 meter lane pool. This pool is open Memorial Day through Labor Day. It is filled once at the beginning of the season and partially emptied at the end of the season. The Eyster indoor pool, which is the primary pool used on site, is 50 by 25 meter lane pool that is open year round. The Eyster pool is heated to approximately 84 °F and the ambient air temperature in the building is kept at a steady 86 °F. The Long indoor pool is used only for training soldiers in underwater or surface water survival situations. This pool is a 25 by 12.5 meters, with an average water temperature of 80 °F. Potable water is supplied as makeup to each of the pools to replace water loss from evaporation and leaks in the shell.

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 not heated. These pools are lined with plaster, which requires residual water during winter to keep the lining wet to prevent cracking. Pool personnel indicated that there is a 25% drain off of pool water when out of season. Potable water is supplied as makeup to each of the pools to replace water loss from evaporation and leaks in the shell during the swim season.

2.9 Distribution System Losses

Fort Riley personnel indicated that the majority of the water distribution system is free of major leaks, but water supply leaks are fairly frequent in the older infrastructure, primarily in the Main Post cantonment area. A 5% leak/loss rate was used in calculations of this water balance. This percent loss is based on typical distribution loss rate of between 2 and 10% (AWWA 2009). Actual losses may vary from month-to-month.

2.10 Miscellaneous Consumption

The miscellaneous consumption category includes other water uses identified on-site that have very low water consumption. These include the following:

- Veterinary clinic cage washing practices – This practice is performed for approximately 90 minutes per day with a 3.5 gpm sprayer nozzle on a typical garden hose. Total annual consumption is approximately 115 Kgal.
- Hydrant flushing – This practice is performed regularly, but no scheduled hydrant flushing is recorded. Hydrants are flushed for an estimated average of two hours, once per month. Lines are flushed to maintain residual chlorine levels in terminal ends of the water distribution piping network. It is estimated that the line flushing requires 216 Kgal per hydrant annually.
- Line Flushing – Additional line flushing was encountered at the Outdoor Recreation Building and measured at approximately 3 gpm. According to Fort Riley staff, similar flushing occurs at a minimum of 11 additional locations. Each of these flushing practices occurs constantly to maintain residual chlorine levels in water distribution supply lines. In addition, the Combined Arms Collective Training Facility flushes lines twice a week and discharges water to the mock soccer field at the site. In total, line flushing accounts for an average of 20,000 Kgal annually.
- Schools – There are a number of schools located on-post at Fort Riley. Annual consumption data for the schools was provided by Fort Riley staff based on a compilation of sub-metered and estimated data. Average consumption for the Fort Riley schools is 4,300 Kgal annually.
- Blast containment system at the Readiness Sustainment Maintenance Site (RSMS) – The AquaMiser system installed at this facility is an extremely efficient, high pressure blast system used to clean machine parts. Based on system operation details and equipment specifications, this system uses an estimated 137 Kgal of water per year.

The remaining water use for this category is derived from the balance of water consumption remaining after all previous categories have been assigned. This categorical use may account for human consumption or janitorial use, or be distributed through the end-use categories previously discussed in Section 2.

3.0 Phase 3: Constructing the Water Balance

3.1 Summary of Water Balance Process

After completing the building audits, the assessment team analyzed water use by major end-use categories. The objective of the analysis was to identify Fort Riley's largest water users to help prioritize efficiency opportunities. The following sections illustrate the results of the water balance analysis. Information on seasonal fluctuations along with a breakout of major end-use categories is provided.

3.2 Overall Water Balance Results

A water balance compares the total supply coming into the site to the sum of the estimated end-uses. The water balance analysis provides a breakout by the major water end-uses at Fort Riley with a low and high range of water use for each category (Table 3.1). A high and low range of water use was determined because water use varies with occupancy levels, weather patterns, and equipment differences among buildings.[1] For Fort Riley, the estimated end-use average totals approximately 559 Mgal annually based on consumption reporting from FY 2007 to FY 2011. The average volume of water supplied to Fort Riley during the same period was 789 Mgal. The difference between the water supply and end-use estimate is approximately 29%. This percentage represents a variety of miscellaneous uses that were not assessed during the water balance due to the large and complex nature of Fort Riley mission and operations. Additionally, little information was available regarding boiler and cooling tower consumption and operation. It is suspected that these two categories could account for an additional 5 to 10% of total water consumption. The unknown uses also may be due to meter discrepancies, unknown system losses, and inherent variability in the water balance analysis. Overall, the major end-uses for Fort Riley were assessed and are detailed in this report.

Plumbing fixtures[2] are the largest water end-user, at 308 Mgal annually, representing 39% of the total water use at Fort Riley. Plumbing fixture consumption is further divided into various facility uses, with family housing accounting for 60% of all plumbing fixture consumption, barracks plumbing fixtures at 23%, military daytime plumbing fixture use at 11%, and civilian/contractor use at 6%. Irrigation is the second largest end-user of water, accounting for approximately 6% of the total, or 50 Mgal annually. The hospital, laundry equipment, and distribution systems losses account for the third, fourth, and fifth largest end-users of water, each accounting for approximately 5% of total water consumption (Figure 3.1).

[1] Appendix A provides the methods used to determine the low and high ranges of water use.
[2] Plumbing fixture end-uses include toilets, urinals, restroom faucets, showerheads, and domestic kitchen faucets.

Table 3.1. Water Use by Major End-Use Categories[3]

Water Use Category	Low Water Use (Kgal)	High Water Use (Kgal)	Average Annual Water Use (1000 gallons)
Family Housing Domestic Plumbing	139,900	233,100	186,500
Barracks Domestic Plumbing	54,800	91,300	73,000
Hospital	33,900	45,900	39,900
Distribution System Losses	35,500	43,300	39,400
Family Housing Irrigation	24,900	46,300	35,600
Military Daytime Domestic Plumbing	26,300	43,900	35,100
On Post Irrigation (includes Golf Course)	24,500	40,800	32,600
Family Housing Laundry	25,200	37,800	31,500
Dining / Various Kitchen Equipment	24,600	33,200	28,900
Installation Vehicle Wash Facility	21,600	29,200	25,400
Line Flushing	15,400	23,200	19,300
Chiller Plants / Cooling Towers	9,500	21,500	15,500
Civilian/Contractors Domestic Plumbing	10,100	16,900	13,500
On-Post Laundry	9,800	14,800	12,300
Motor Pools / Vehicle Washing	4,900	10,100	7,500
Schools	3,900	4,600	4,300
Family Housing Swimming Pools	3,200	3,900	3,500
MWR Swimming Pools	2,600	3,200	2,900
Boiler Plants	1,800	2,800	2,300
Misc. and Unaccounted	244,900	191,900	179,900

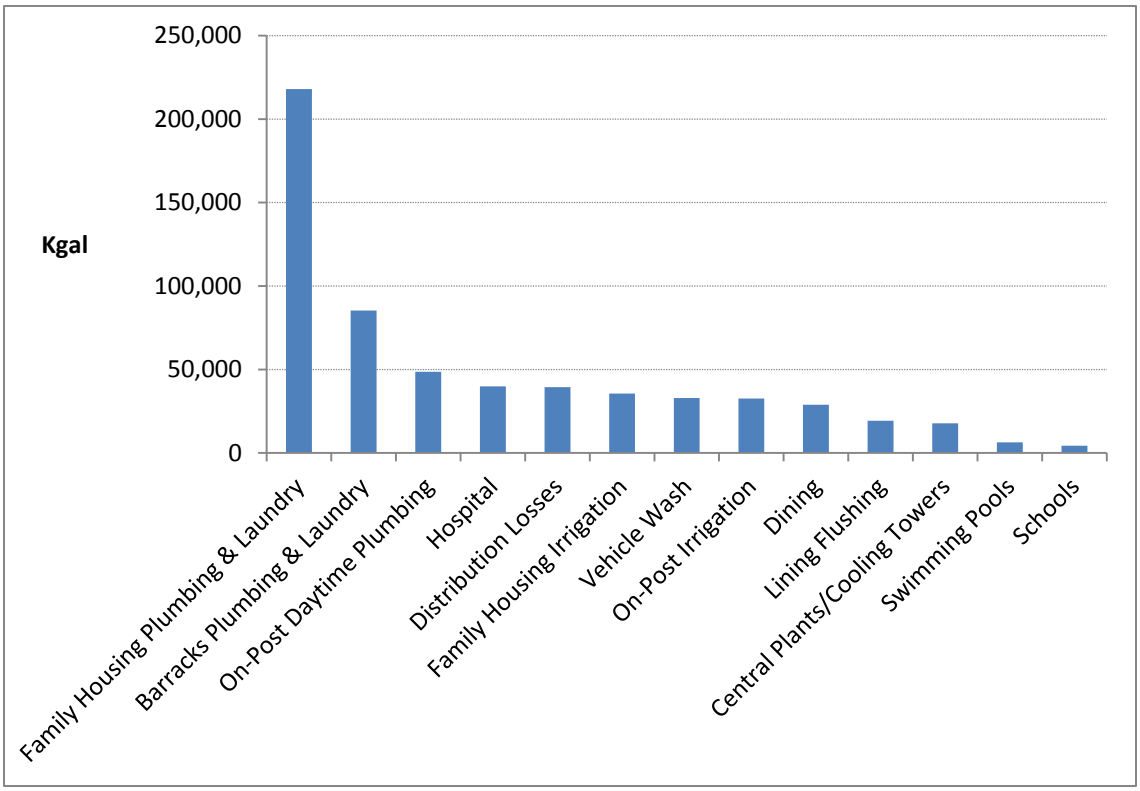

Figure 3.1. Fort Riley Water Use Breakout Including Family Housing

[3] Appendix A provides the data sources for each end-use category.

Fort Riley's family housing is privatized Thus, water use associated with family housing is excluded from the water use reported by Fort Riley to the Army. Excluding privatized family housing, plumbing fixture water use in the barracks and by personnel who occupy Fort Riley during daytime hours accounts for 26% of the total. The hospital and distribution system losses each account for 9% of the total. The IVWF and dining hall consumption each account for 6% of the total (Figure 3.2).

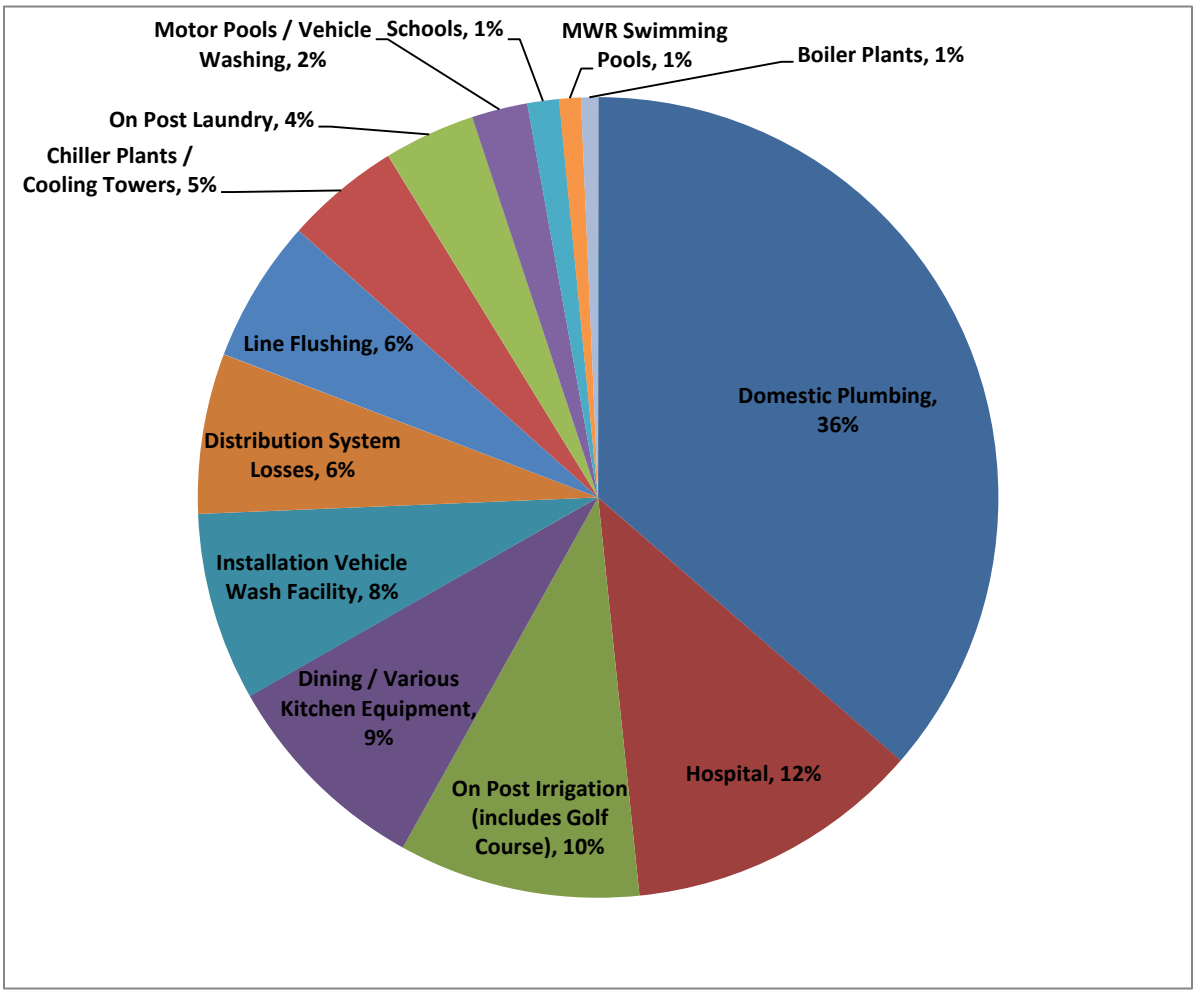

Figure 3.2. Fort Riley Water Use Breakout Excluding Family Housing

The remainder of this section describes the water use estimates of each major category. Appendix A provides the methods used in calculating the water use.

3.2.1 Annual Water Use Distribution

Fort Riley's annual water consumption varies seasonally, largely due to a significant increase in water use during the summer (Figure 3.3). Increased activity on-post during summer, primarily in the IVWF and cooling tower consumption, accounts for the majority of the water use increase. Irrigation also accounts for a portion of the summer peak water demand.

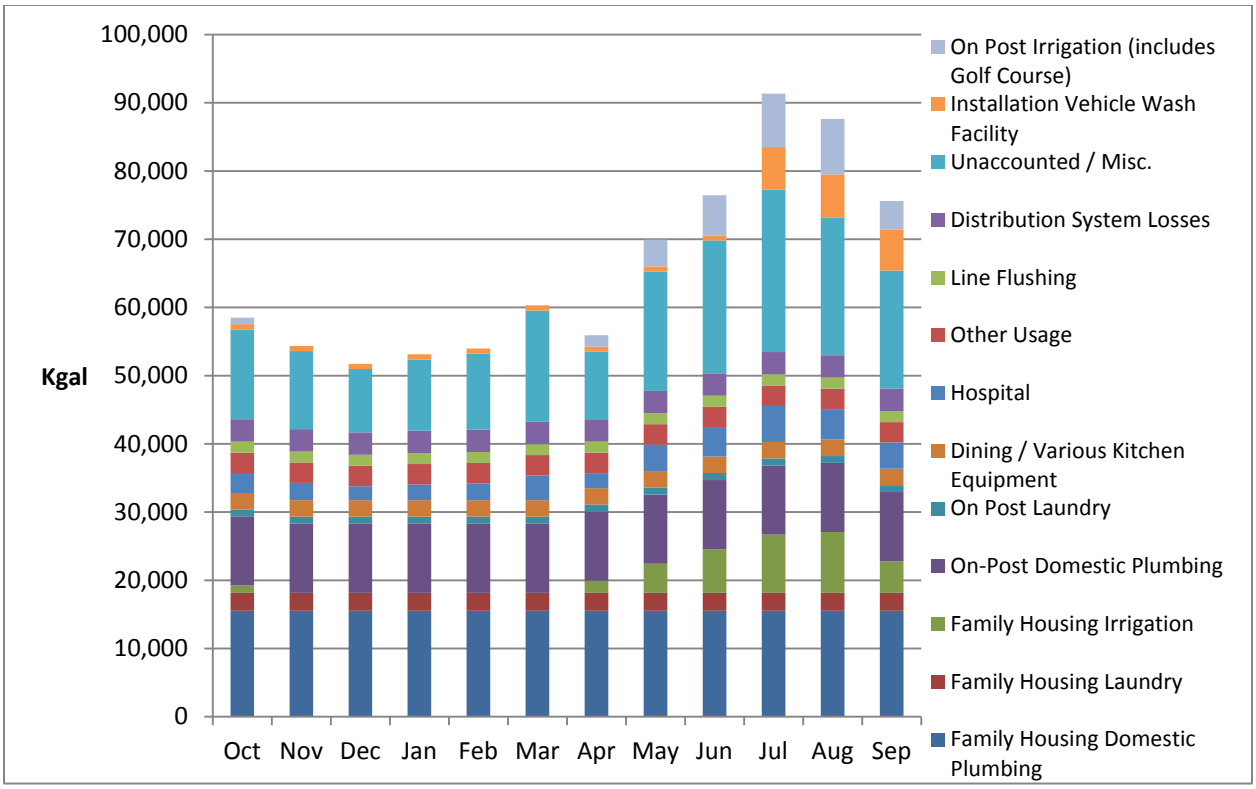

Figure 3.3. Fort Riley Fiscal Year Water Use Distribution

3.2.2 Water Flow Diagram

The water balance can also be depicted as a water flow diagram for Fort Riley's potable water distribution system, which illustrates water use by major water use category and the discharge for each use (Figure 3.4).

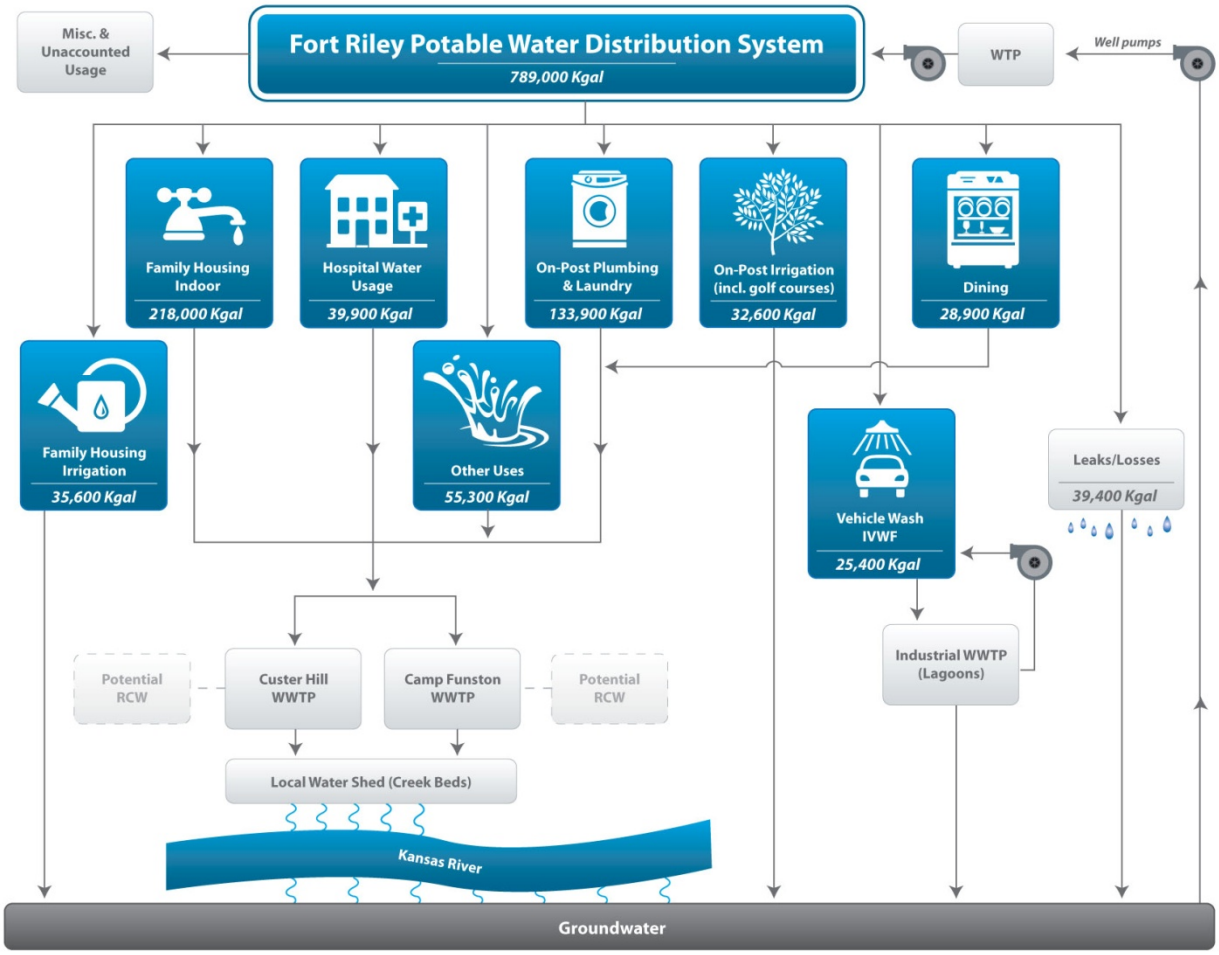

Figure 3.4. Fort Riley Potable Water Distribution System

3.3 Breakout of Major End-Uses

This section describes the results of the water balance for specific end-use categories, including domestic plumbing fixtures and irrigation.

3.3.1 Domestic Plumbing Fixtures

Domestic plumbing fixture water use was estimated by compiling the data collected during the walk-through audits and extrapolating the data across the population at Fort Riley. The end-use equipment included in this category is toilets, urinals, faucets, and showers. Water use for these fixtures was categorized by major users (Table 3.2).

Table 3.2. Water Use by Domestic Plumbing Fixtures by User Type

User Type	Toilets (Kgal/yr)	Urinals (Kgal/yr)	Bath Faucets (Kgal/yr)	Showers (Kgal/yr)	Kitchenette Faucets (Kgal/yr)	Total Domestic Plumbing Consumption (Kgal/yr)
Military and Families in Family Housing	21,600 - 29,200	-	46,300 - 62,700	92,700 - 125,400	27,800 - 37,600	188,400 - 254,900
Enlisted Soldiers in Barracks	9,400 - 10,400	37 - 40	20,300 - 22,400	40,600 - 44,900	12,200 - 13,500	82,500 - 91,200
Military During Daytime Hours	14,300 - 19,300	8,100 - 11,000	2,800 - 3,700	6,900 - 9,300	3,400 - 4,700	35,500 - 48,000
Civilians and Contractors	8,500 - 11,400	2,200 - 3,000	1,100 - 1,500	300 - 400	1,500 - 2,000	13,600 - 18,400
Total for Category	54,200 - 69,800	10,700 - 13,700	70,300 - 90,600	140,000 - 180,400	44,900 - 57,800	319,900 - 412,400

The results of this analysis reveal shower water use provides ample opportunity for savings. When including family housing, shower use at Fort Riley represents 44% of the total. Lavatory faucets are the second biggest user, representing 22% of the total (Figure 3.5). When family housing is excluded, showers are the largest user, representing 35% of the total with toilets as the second largest user at 25% (Figure 3.6).

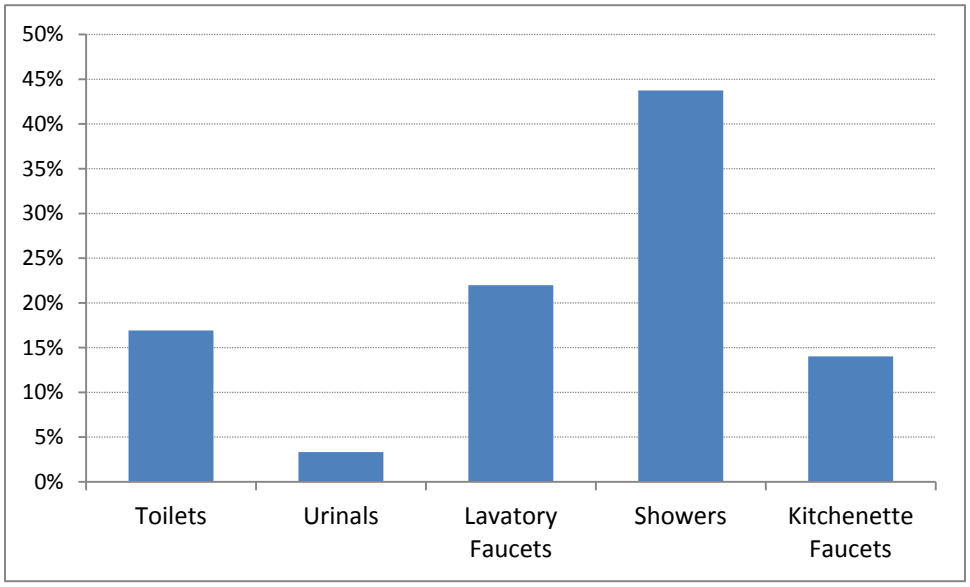

Figure 3.5. Domestic Plumbing Fixture Water Use Breakout Including Family Housing

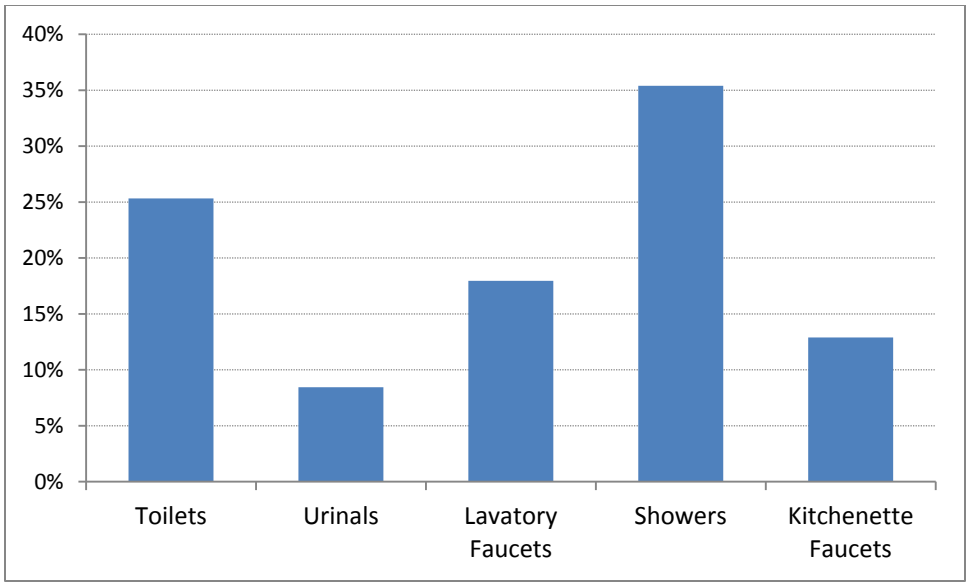

Figure 3.6. Domestic Plumbing Fixture Water Use Breakout Excluding Family Housing

3.3.2 Irrigation

A modeling tool was used to estimate irrigation requirements for Fort Riley's irrigated areas. It is estimated that Fort Riley consumes between 42 and 52 Mgal of water annually in irrigated areas. On-post irrigation is primarily on the golf course and represents approximately 15% of the total irrigation water use. Family housing irrigation represents 85% of the total irrigation water use. Combined, irrigation water consumption accounts for approximately 6% of the total water consumption.

Two primary areas of turf are irrigated, including the golf course and the landscaped area around Building 500. The golf course is the largest irrigation water use, estimated at 5,000 to 6,000 Kgal annually based on meter data. Typical water use for a golf course of this size is much higher, at approximately 50,000 Kgal per year based on evapotranspiration data. The low irrigation water use at the Fort Riley golf course is a result of the following factors:

- Only tee boxes and greens are irrigated. In the past, the entire course was irrigated via timer-based controls and water consumption was in line with what would be expected for a course of this size.
- To reduce consumption and remove fairways from the formal irrigation system, drought tolerant grasses have been planted that require little supplemental irrigation.
- Controller systems are no longer regulated by a simple timer. Rather, groundskeepers manually turn on irrigation zones when needed. According to golf course personnel, the course is in fair health, but is receiving the bare minimum to keep tee boxes and greens functional. If additional, or alternative, water sources were available, the golf course would utilize these sources to improve course health and appearance.

The other area of on-post irrigation identified during the site visit is at Building 500. This facility has a traditional timer-based control system with 12 active zones. It consumes an estimated 1,500 Kgal of water per year, based on watering schedules and information about distribution equipment recorded during site visits.

The additional on-post irrigated areas were analyzed using the landscape irrigation estimator tool, indicating an annual consumption of 27,100 to 35,400 Kgal annually, providing an annual irrigation factor range of 12.0 to 15.8 gal/sqft/yr.

Family housing irrigation is spread across multiple systems with more than 70 acres of irrigated landscape. The majority of the irrigation systems are timer-based controllers and standard rotor and sprayer distribution systems. In recent years, weather-based systems have been installed in new construction areas to maximize water efficiency. The landscape irrigation estimator tool provides a consumption range of 36,000 to 48,000 Kgal annually, providing an annual irrigation factor range of 12.0 to 15.8 gal/sqft/yr.

3.3.3 Other Uses

All other uses make up 27% of the water consumption at Fort Riley, totaling approximately 249 Mgal per year. Smaller water uses were derived from metered data or determined using engineering estimates. The following list provides annual water use and the general source of water use for each category (Appendix A).

- Laundry: Annual laundry water use is estimated at 52.1 Mgal, representing 5.6% of total water consumption. This is further divided into family housing laundry consumption, estimated at 37.4 Mgal annually, and on-post laundry consumption, estimated at 14.7 Mgal annually.
- Irwin Army Community Hospital: Annual water use is 47.4 Mgal based on billed data provided by Fort Riley, representing 5.1% of the total water consumption in FY 2011.
- Distribution system losses: Annual losses are estimated at 46.8 Mgal based on a 5% loss rate, based on information provided by Fort Riley personnel.
- Dining/kitchen equipment: Annual water use is 34.3 Mgal based on calculations of three dining facilities and extrapolated across all four facilities, representing 3.7% of total water consumption. This does not include the hospital cafeteria, which is included in the hospital calculations presented above.
- IVWF: Annual water use is estimated at 25 Mgal based on operational data obtained on-site, representing 3.2% of total water consumption.
- Line flushing: In total, line flushing accounts for an average of 20 Mgal annually.
- Schools: Average consumption for the Fort Riley schools is 4.3 Mgal annually.
- Central plants: Limited information was available on boiler and cooling tower water consumption. The following figures are estimated, but there are likely significant variances in consumption:
  - Heating boilers annual water use is estimated at 2.7 Mgal annually.
  - Cooling tower annual water use estimated at 18.5 Mgal annually.
- Vehicle washing in motor pools: Annual water use is estimated at 8.9 Mgal, representing less than 1% of total consumption, based on use patterns and vehicle counts gathered from Fort Riley personnel.

- Swimming pools: Annual water use is estimated at 7.7 Mgal, representing less than 1% of total consumption, based on operation patterns and specifications of pools obtained during site visits. Swimming pool consumption is further divided into family housing pools, estimated at 4.2 Mgal annually, and For Riley MWR pools, estimated at 3.5 Mgal annually.

3.3.4 Miscellaneous and Unknown Water Consumption

The miscellaneous and unknown water consumption is based on a remainder of water consumption after all other end-uses have been calculated. Minor uses include hydrant flushing, water used in new construction for dust suppression and soil conditioning, veterinary clinic cage washing, RSMS site blast containment system, and various other uses under 0.2 Mgal are also included in this consumption category.

After balancing all other uses at Fort Riley, miscellaneous and unknown water consumption was determined to be nearly 23%. For a site of this size, a 15 to 20% variance could be considered a reasonable and conservative unknown water use. The additional unknown consumption at Fort Riley is most likely attributable to central plant consumption and additional line flushing activities not captured during site visits or from Fort Riley personnel.

3.4 Recommendations

Based on the assessment done during the water balance, there are two general recommendations regarding water metering and billing:

- It is recommended that sub-meters be installed for all reimbursable customers and family housing supplies for accurate billing and reporting.

- It is recommended that Fort Riley personnel evaluate WTP, WWTP, and infrastructure repairs and upgrades annually to provide accurate marginal rates. Often, the cost of repairing infrastructure is excluded from a marginal rate, resulting in a lack of funding for such repairs. Accurate determination of water and wastewater costs is also extremely important for establishing reimbursable rates to various customers.

4.0 Next Steps: Net Zero Water Roadmap

The results of the water balance will be used in the net zero water roadmap. The goal of the roadmap is to help the installation reach the net zero water goals. As part of the roadmap, water efficiency projects will be investigated. Based on the largest consumers of water identified in the water balance, projects will be prioritized to maximize water use reduction. For Fort Riley, the largest water uses are irrigation and domestic plumbing fixtures. Therefore, the roadmap will target these end-uses for efficiency opportunities. The roadmap will also investigate alternative water sources to help reduce the use of potable water at Fort Riley, among other strategies.

The roadmap process consists of investigating water efficiency projects and performing a life-cycle cost analysis on each measure (Figure 4.1). Then the Pacific Northwest National Laboratory (PNNL) team will conduct a roadmap workshop, where the efficiency projects will be discussed with Fort Riley personnel to help prioritize water conservation projects.

The evaluation by Fort Riley personnel will be used to prioritize the projects to meet net zero water goals for Fort Riley. Lessons learned from the water balance and roadmap workshop will be compiled into a roadmap document to help form a strategy for net zero water at Fort Riley.

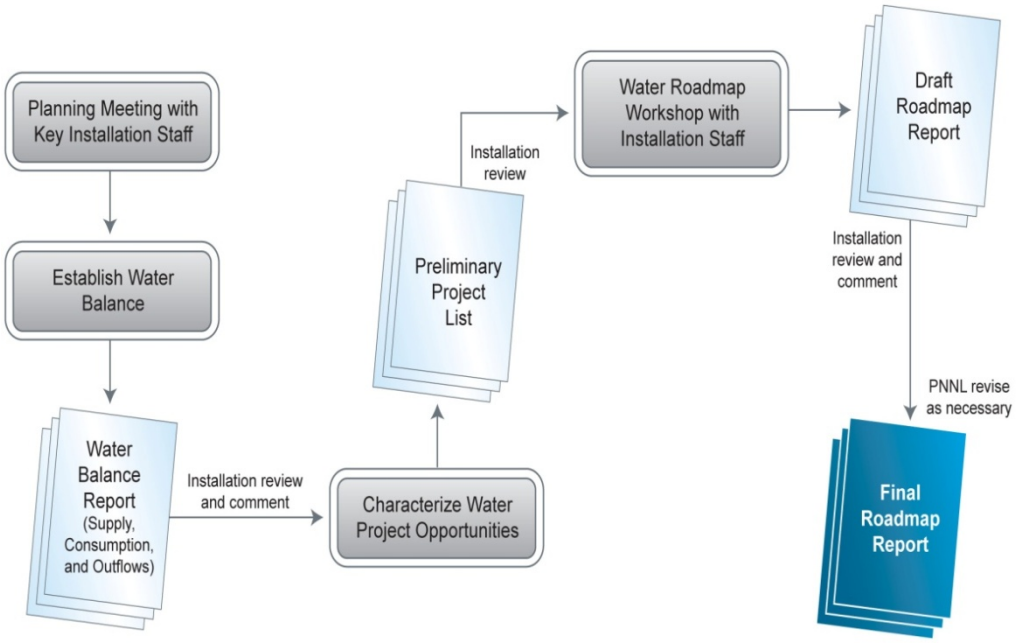

Figure 4.1. Roadmap Process

5.0 References

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Appendix A

Methods Used In Water Balance Estimates

This appendix provides an overview of the methods and assumptions used in the Fort Riley water balance assessment. The overall structure for the water assessment is based on methods presented in the American Water Works Association *Water Audits and Loss Control Manual 36* (AWWA 2009). However, the comprehensive water assessment methods were developed specifically by PNNL and Water Savers LLC and tailored for a multi-building installation. It builds on and incorporates best practices gained from past assessments at Federal facilities.

A.1 Data Sources for Water Balance

A variety of data were used when compiling Fort Riley's water balance. Metered data were used when available. For categories of water use in the water balance, which are not metered at Fort Riley, engineering estimates were developed. The general sources of data for each major category are provided below (Table A.1). Specific methods used in the engineering estimates are discussed in the subsequent sections of this appendix.

Table A.1. Water Use by Major Water Use Categories and Data Source

Water Use Category	Low Water Use (Kgal)	High Water Use (Kgal)	Data Sources
Family Housing Domestic Plumbing	139,900	233,100	Water Savers 2012 (based on equipment specifications and population data)
Barracks Domestic Plumbing	54,800	91,300	Water Savers 2012 (based on equipment specifications and population data)
Hospital	33,900	45,900	Billed consumption data provided by Fort Riley
Distribution System Losses	35,500	43,300	Estimated percent loss provided by Fort Riley
Family Housing Irrigation	24,900	46,300	PNNL Army Landscaping Water Use Estimating Tool
Military Daytime Domestic Plumbing	26,300	43,900	Water Savers 2012 (based on equipment specifications and population data)
Family Housing Laundry	25,200	37,800	Water Savers 2012 (based on equipment and process specifications and population data
Dining / Various Kitchen Equipment	24,600	33,200	Water Savers calculation based on equipment and process specifications and population data
Central Vehicle Wash Facility	21,600	31,752	Water Savers calculation based on process information obtained on-site
Chiller Plants / Cooling Towers	9,500	21,500	Estimate based on minimal data provided
Civilian/Contractors Domestic Plumbing	10,100	16,900	Water Savers 2012 (based on equipment specifications and population data)
On-Post Laundry	9,800	14,800	Water Savers calculation based on equipment and process specifications and population data
Motor Pools / Vehicle Washing	4,900	10,100	Water Savers calculation based on equipment and process information obtained on-site
On-Post Irrigation (includes Golf Course)	4,700	7,900	Water Savers calculation based on irrigation schedules and equipment specifications

Water Use Category	Low Water Use (Kgal)	High Water Use (Kgal)	Data Sources
Family Housing Swimming Pools	3,200	3,900	Water Savers calculation based on pool size and operations procedures discussed on-site
MWR Swimming Pools	2,600	3,200	Water Savers calculation based on pool size and operations procedures discussed on-site
Boiler Plants	1,800	2,800	Estimate based on minimal data provided
Misc. and Unaccounted	206,600	252,600	Extrapolated meter data

A.2 Domestic Plumbing Fixtures

Domestic plumbing fixture water use was estimated by calculating the typical water consumption for each end-use fixture including toilets, urinals, faucets, showerheads, dishwashers, and clothes washers. This water consumption was then extrapolated across distinct groups of users at Fort Riley: military living on-post with dependent family members, military living off-post, civilians, and contractors. For information on these personnel groups, see Section A.3.

The basic formulas used in estimating water use in domestic fixtures 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

The assumptions used in calculating domestic plumbing fixtures uses are provided below (Table A.2).

Table A.2. Domestic Plumbing Fixture 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 use (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	Water Savers 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
Toilet flush rate	Toilet	1.28 – 4.5 gpf	Observed flush rates during site visit in January 2012
Urinal flush rate	Urinal	1.0 – 2.3 gpf	Observed flush rates during site visit in January 2012
Lavatory faucet flow rate	Faucet	0.5 – 2.2 gpm	Observed flush rates during site visit in January 2012
Kitchenette faucet flow rate	Faucet	2.0 – 2.2 gpm	Observed flush rates during site visit in January 2012
Showerhead flow rate	Showerhead	1.5 – 3.0 gpm	Observed flush rates during site visit in January 2012

A.3 Personnel Groups

Personnel data were used to estimate water use of domestic plumbing. The number of people for each population type and the data source of the are shown below (Table A.3).

Table A.3. Population and Occupancy Data

Population Group	Number of People	Hours per Day Occupancy	Days per Year Occupancy	Source
Military Personnel - Family Housing	3,888	8	344	Fort Riley 2011
Dependents - Family Housing	10,518	8	344	Fort Riley 2011
Military Personnel - Barracks	5,645	8	344	Fort Riley 2011
Military Personnel - Daytime Usage	19,120	8	241	Fort Riley 2011
Civilians, Contractors, and Visitors	8,307	8	241	Fort Riley 2011

A.4 Irrigation

Metered data are not available for all of the Fort Riley's irrigated areas. Thus, the *Army Landscaping Water Use Estimating Tool* (PNNL 2012) was used to estimate Fort Riley's landscape irrigation water use. Fort Riley's family housing irrigated landscape acreage was provided by Fort Riley personnel for the use in water balance calculations.

The *Landscaping Water Use Estimating 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 provides estimates of typical irrigation water requirements for a given location. Because the tool uses an approximation of irrigation requirements, a low and a high value were calculated to understand a range of possible irrigation levels. For example, irrigation system efficiency, how uniformly the water is applied to a given area and how much of the water released from the system reaches the plants, was not measured during the site audit. Therefore, a low value (65%) and a high value (85%) for irrigation system efficiency were entered into the tool. These efficiencies were based on information gathered by Water Savers during an interview with the ground maintenance manager in January 2012.

The data inputs and assumptions that were used in the tool for the family housing irrigated landscape areas are shown below (Table A.5).

Table A.5. Family Housing Landscape Irrigation Data Inputs and Assumptions

Landscape Appearance	Average	Average
Soil Type	Loam	Loam
Landscape Area	3,049,200	3,049,200
Irrigation System Efficiency	65%	85%
Growing Season Start	April	April
Growing Season Stop	October	October
Annual Irrigation Factor (gal/sqft/yr)	15.75	12.04
Estimated First FY Quarter Irrigation October-December (Kgal/qtr)	3,775.79	2,887.37
Estimated Second FY Quarter Irrigation January-March (Kgal/qtr)	0.00	0.00
Estimated Third FY Quarter Irrigation April-June (Kgal/qtr)	18,761.16	14,346.77
Estimated Fourth FY Quarter Irrigation July-September (Kgal/qtr)	25,484.11	19,487.85
Estimated Annual Irrigation (Kgal/yr)	**48,021.06**	**36,721.99**

Irrigation at the golf course and Building 500 was investigated during walk-through inspections and consumption calculations were performed based on watering schedules and valve specifications (Table A.6). Average flow rates for each zone were multiplied by cycle run time to estimate water use by zone across the irrigation season.

Table A.6. On-Post Irrigation System Consumption

Location	Number of Active Zones	Avg. Flow Rate per Zone (gpm)	Avg. Operation Time per Cycle per Zone (minutes)	Avg. Cycles per Week	Avg. Weeks per Season	Total Current Water Consumption (gal/season)
Golf Course	36.00	40	45	3.5	26	5,896,800
Bldg. 500	12.00	34.2	42	3.5	26	1,568,549

A.5 Laundry

Laundry consumption was estimated using an assumption of two loads per person per week (Table A.7). Laundry equipment specifications were factored in when determining average gallon per load rating for each subcategory.

Table A.7. Laundry Consumption Data

Kitchen Equipment Type	Number of People	Avg. Laundry Loads per Person per Week	Avg. Gallons per Load	Total Current Water Consumption (gal/yr)
Family Housing Laundry	14,406	2.0	25	37,456,000
Barracks Laundry	5,645	2.0	24	14,090,000
Misc. Laundry	-	500.0	22.6	587,000

A.6 Kitchen/Dining

Kitchen equipment use of was estimated based on equipment runtime and typical use patterns for similarly equipped commercial kitchens (Table A.8). All kitchen equipment water use follows the same general calculation methods:

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

Water consumption of dining facilities for food preparation and beverage consumption are estimated based on five gallons per meal served per day (Table A.9).

Table A.8. Kitchen Equipment Consumption

Kitchen Equipment Type	Qty	Average Flow Rate (gpm)	Average Time of Use (hr/day)	Avg. Water Use per Cycle (gallons/cycle)	Avg. Cycles per Day	Avg. Days per Year	Total Current Water Consumption (gal/yr)
Ice Machines	24	-	-	51.3	1	365	449,460
Pre-Rinse Sprayers	8	1.81	2.2	-	-	365	698,610
Garbage Disposals	8	6.00	5	-	-	365	5,256,000
Pulpers	4	8.00	5	-	-	365	3,504,000
Convection Steamers	9	0.33	8	-	-	365	525,600
Dish Machine	4	3.25	6	-	-	365	1,708,200
Tray Conveyors	4	5.00	2	-	-	365	876,000
Misc. Equip.	20	4.95	3	-	-	365	6,508,900

Table A.9. Kitchen Food Prep Consumption

Facility	Number of Meals Served per Day	Average Water Use per Meal (gallons/meal)	Avg. Days per Year	Total Current Water Consumption (gal/yr)
Demon's Den Dining	1,800	5.0	365	3,285,000
Cantigny Dining	3,000	5.0	365	5,475,000
Devil's Den Dining	1,100	5.0	365	2,007,500
Airfield Dining	2,200	5.0	365	4,015,000

A.7 Boiler and Cooling Towers

Cooling tower consumption was estimated based on an assumption of 6,500 tons of cooling at an average load of 60%. Cooling towers generally have makeup rates of 3.0 gpm per 100 tons. This makeup rate is applied to the assumptions of tonnage and load, and applied across a seasonal use factor.

Boiler consumption was estimated based on a sample of steam boiler information. Steam boiler sizes were provided as a total maximum steam production capacity of 8,818 thousand British thermal units per hour (MBH). An assumption of 65% load was applied to boilers. Makeup water was estimated at 2.0 gal/MBH. The actual makeup of steam boilers is affected by many factors, including water quality and percentage of condensate returned. This allows for significant variance in consumption estimates. Hot water boilers require little to no makeup water because heating water is held in a closed loop. As a result, makeup water is required only in the event of leaks. Therefore, water use for hot water boilers at Fort Riley was not estimated.

A.8 IVWF / Motor Pool Vehicle Washing

Fort Riley personnel provided operational data for the IVWF and other vehicle washing stations. Information was collected on vehicle and aircraft washing to estimate annual water use of each application (Table A.10).

Table A.10. IVWF and Vehicle Washing Consumption

Location/ Application	Number of Basin Fills per Year	Fill Runtime (hr)	Number of Uses per day	Length of Use (min)	Number of uses per week	Weeks per year	Flow Rate (gpm)	Total Current Water Consumption (gal/yr)
IVWF	3	480	-	-	-	-	350	30,240,000
Motor Pool Pressure Wash (42 Facilities)	-	-	5	37	5	52	5	8,181,810
GSA Vehicle Wash	-	-	300 gal/day		5	25	-	37,500
1460 Engine wash	-	-	1	120	5	52	2	46,800
1470 Vehicle Wash	-	-	1	33.8	5	52	2.5	30,398
Airfield Aircraft Wash	-	-	9	15.0	5	52	5	180,139
TMP Semi Truck Wash	-	-	1	96.0	5	52	2.5	57,644
TMP Bus Wash	-	-	4	96.0	5	52	2.5	253,635
TMP Fleet Vehicle Wash	-	-	7	24.0	5	52	2.5	108,083

A.9 Swimming Pools

Swimming pool consumption was calculated based on dimensions and operational data obtained on-site. Both evaporation makeup and pool refill were considered (Table A.11).

Table A.11. Pool Consumption

Location/Application	Square Footage Surface Area	Evaporation Rate (in. per week)	Weeks per year	Volume (gallons)	% Fill	Total Current Water Consumption (gal/yr)
Eyster Pool	11,400	4.0	52	341,088	100%	1,821,978
Long Pool	2,400	4.0	52	71,808	100%	383,831
Custer Hill Pool	7,800	4.0	52	233,376	100%	1,247,450
Family Housing Pools (3 total)	10,200	4.0	52	305,184	25%	4,207,179

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