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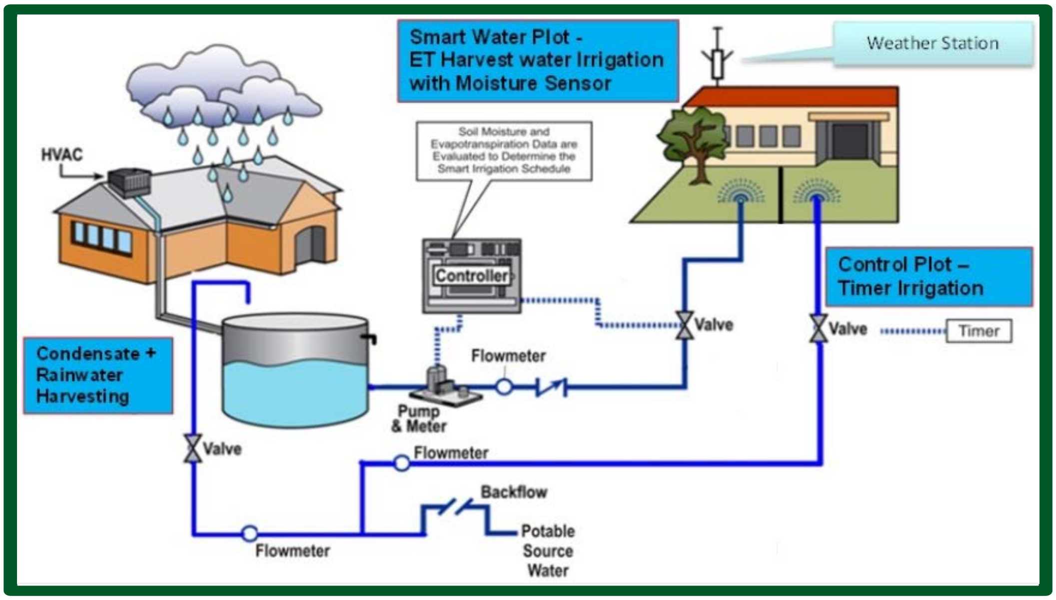

Smart Water Conservation System for Irrigated Landscape

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14. ABSTRACT
The primary project objective was to validate the retrofit of an existing landscape irrigation system with a smart water conservation system to reduce potable water use by as much as 70% in support of meeting EO 13693. Additional performance objectives were to validate energy reduction, cost effectiveness, and system reliability while maintaining satisfactory plant health. This report provides potential users with cost and performance data for using the smart system components on an existing landscape and on new developments.

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ACRONYMS AND ABBREVIATIONS

AFCEC	Air Force Civil Engineer Center
CERL	Construction Engineering Research Laboratory
DoD	Department of Defense
DOE	Department of Energy
DPW	Department of Public Works
EISA	Energy Independence and Security Act
EO	Executive Order
ESTCP	Environmental Security Technology Certification Program
ET	Evapotranspiration
FEMP	Federal Energy Management Program
FY	Fiscal Year
gal	Gallon
gph	Gallons per hour
HVAC	Heating, Ventilation and Air Conditioning
ILA	Industrial, Landscaping, and Agricultural
mph	Miles Per Hour
MTBF	Mean Time Between Failures
MTTF	Mean Time to Failure
MWDSC	Metropolitan Water District of Southern California
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NBVC	Naval Base Ventura County
PLC	Programmable Logic Controller
psi	Pounds Per Square Inch
ROI	Return on Investment
SIR	Savings to Investment Ratio
SMS	Soil Moisture Sensor
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	Underground Storage Tank

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EXECUTIVE SUMMARY

From January 2013 through January 2015, the U.S. Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) sponsored the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) and the Construction Engineering Research Laboratory (CERL) in a joint effort to demonstrate a smart water conservation system that reduces the volume of potable water required for landscape irrigation. A suite of specific water saving technologies was demonstrated including: Evapotranspiration (ET) irrigation controller; centralized and site-specific sensor inputs (ET gauge, rain, soil moisture, leak detection); efficient sprinkler distribution systems; and water harvesting (rain and air conditioning condensate).

DoD has numerous facilities that use inefficient irrigation practices (timer based and manual watering systems) that are no longer sustainable given the limited water supplies in many U.S. locations and future water demand. Executive Order (EO) 13693 requires the federal government to reduce potable water usage 36% by 2025. The smart water conservation system may provide DoD a pathway to preserve green landscape assets while simultaneously reducing potable water demand for landscape irrigation, hence complying with the EO. In addition, to move forward with greater energy independence, DoD seeks ways to reduce energy use as required by the Energy Independence and Security Act (EISA). Reducing potable water demand for landscape irrigation correlates to lower energy costs necessary to treat and convey water to DoD facilities.

OBJECTIVES OF THE DEMONSTRATION

The primary project objective was to validate the retrofit of an existing landscape irrigation system with a smart water conservation system to reduce potable water use by as much as 70% in support of meeting EO 13693. Additional performance objectives were to validate energy reduction, cost effectiveness, and system reliability while maintaining satisfactory plant health. This report provides potential users with cost and performance data for using the smart system components on an existing landscape and on new developments.

The demonstration was conducted for two different climatic regions in the southwestern part of the United States (U.S.), where a typical DoD building landscape irrigation system was retrofitted with an integrated suite of commercially-available water conservation technologies designed to decrease potable water usage. The demonstration sites were Naval Base Ventura County (NBVC), Port Hueneme, California, and Fort Hood, Killeen, Texas.

TECHNOLOGY DESCRIPTION

The smart water conservation system demonstrated during this project was composed of an integrated suite of commercially available technologies for irrigating landscape (i.e., turf and low-water demand ground cover). The primary system components include the following elements

- Advanced ET controllers to reduce potable water usage by minimizing operating times (calculates run time based on real-time weather conditions).
- Rainwater and Heating, Ventilation, Air Conditioning (HVAC) condensate water harvesting system to displace potable water usage, including a collection system, first flush diverter, and associated piping and storage tanks.

- Irrigation hardware to sustain installation vegetation at increased efficiency, including efficient sprinkler heads and pressure regulating valves to ensure optimum nozzle pressure and prevent misting/overspray.

DEMONSTRATION RESULTS

The smart water conservation system at NBVC met primary water reduction goals and all of the additional performance objectives with the exception of economic payback. The system did not meet the economic payback period due to the high cost of the water harvesting tank, relatively low cost of potable water, and relatively small size of the smart turf plot. However, as the amount of irrigated landscape increases, and/or the cost of water increases, the payback period will trend to a more favorable figure due to the substantial water reduction provided by the ET controller.

IMPLEMENTATION ISSUES

Several specific troubleshooting issues were encountered during the demonstration, including reliability of controller equipment (at Fort Hood) and the diversion of first flush runoff to prevent system fouling with particulates. Where water storage is required for system effectiveness, capital requirements for tank storage limits the cost-effectiveness of the systems. Offsetting potable water with rainwater to irrigate turf landscape at the NBVC site, where there is minimal to no summer rain, would require a larger tank (over 20,000 gallons) to store winter rain. In southern California, the goal is to install the largest tank possible to meet summer irrigation requirements. However, the economics do not indicate that there is a reasonable return on investment.

The ideal geographic areas to implement a smart water conservation system are locations such as Tucson, Arizona, and Fort Hood, Texas, which receive summer monsoonal rains that replenish the water harvesting tank during the summer months when demand is greatest. In addition, facilities in these locations are also known to generate large amounts of air conditioning condensate. Areas that have high local water costs or limited water supply options may also benefit from water harvesting.

The implementation of smart ET irrigation controllers, even without water harvesting storage at new construction and retrofitted facilities, would still provide an immediate reduction in potable water use. Smart ET controllers with centralized and site-specific sensor inputs, such as ET gauge, rain, soil moisture, and leak detection, combined with a high-efficiency irrigation distribution system provides a Return on Investment (ROI) ≤ 6, and should be considered for implementation throughout DoD.

NAVFAC EXWC technology transfer plans include reaching out to the DoD Public Works offices responsible for designing new (or retrofit) construction projects requiring retention of storm water on site. Technology transfer actions planned for this project include:

1) Distribution of a smart water acquisition package consisting of sample drawings, cost data, example statement of work, and an excel spreadsheet to support potential users in determining economic viability of the technology,
2) Presentation of project results in magazine articles, conferences, and webinars, and
3) Widespread dissemination of fact sheets, pocket cards, PowerPoint presentations, posters, and videos. Targeted groups for this technology include irrigation and storm water managers, utilities-energy managers, Water Media Field Teams, U.S. Army's Net Zero Installation Forum, Public Works field divisions and the U.S. Air Force Civil Engineer Center (AFCEC).

1.0 INTRODUCTION

From January 2013 through January 2015 the U.S. Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) sponsored the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) in collaboration with the Construction Engineering Research Laboratory (CERL) to demonstrate a smart water conservation system for landscape irrigation. The demonstration was conducted at two different climatic regions in the southwestern part of the U.S., where the typical DoD building landscape irrigation system was retrofitted with an integrated suite of commercially-available water conservation technologies designed to reduce potable water usage. The demonstration sites were Naval Base Ventura County (NBVC) Port Hueneme, California, and Fort Hood, Killeen, Texas.

Unfortunately, significant equipment failures and instrumentation issues at the Fort Hood demonstration site resulted in data gaps that prevented adequate assessment of the Fort Hood smart water conservation technology. This report focuses on findings from the NBVC Port Hueneme demonstration. The more comprehensive final report for this effort includes key site information and lessons learned from the Fort Hood demonstration which are provided in the appendices. The primary project objectives were to:

1) demonstrate the feasibility of retrofitting an existing, traditional landscape irrigation system with a smart water conservation system that uses water harvesting and real-time weather data to optimize irrigation scheduling, and

2) validate the smart water conservation system's ability to reduce both potable and overall water consumption for irrigation at DoD installations located in semi-arid regions where alternative water conservation measures are being pursued.

1.1 BACKGROUND

DoD operates numerous facilities in the southwestern U.S. that utilize irrigation systems and practices which are highly inefficient and no longer sustainable given current water supplies and projected future water demand. DoD facilities located within this region, and their respective missions, are particularly impacted by this decreasing water supply and quality (e.g., salinity issues), increasing cost of water production, and degradation of ecological habitat, with these issues anticipated to intensify into the future.

In addition, the Federal Energy Management Program (FEMP) of the U.S. Department of Energy (DOE) estimates that the federal government used approximately 164 billion gallons of potable water in fiscal year (FY) 2007 (Annual Report to Congress on Federal Government Energy Management and Conservation Programs: FY 2007 FEMP, January 2010). DoD consumed 117 billion gallons of water, representing 71.1% of the federal government water consumption at an annual cost of $359M.

The smart water conservation system demonstrated during this project comprised an integrated suite of commercially-available technologies for irrigating landscape (i.e., turf and low-water demand ground cover). The technologies can be deployed as a retrofit or on new construction projects as a complete system or individually, based on site conditions and requirements.

One of the main components of the suite is the Evapotranspiration (ET) controller which adjusts daily irrigation run times based on real-time weather conditions rather than the inefficient traditional timer based design. A rainwater harvesting system augmented with air conditioning condensate capture conserves water by displacing potable water normally used for irrigation purposes. Figure 1, Schematic Diagram of the Smart Water Conservation System and Traditional Irrigation System (§ 2.3), illustrates the conceptual schematic diagram of the demonstration study, detailing both the smart water conservation system and traditional irrigation system (i.e., control) as well as the location of flowmeters that were used to quantitatively evaluate and compare performance of each system. Section 2.0 provides details of the individual components.

1.2 OBJECTIVE OF THE DEMONSTRATION

The primary objectives of this project were to:

1. Demonstrate the feasibility of retrofitting an existing traditional landscape irrigation system with smart water conservation technologies; and
2. Demonstrate the effectiveness of the smart water conservation technologies in reducing water consumption, decreasing operating costs, and maintaining landscape compared to the traditional landscape irrigation system (timer based irrigation).

The primary success criteria for the smart water conservation system was to reduce potable water usage for landscape irrigation by 70%, while maintaining or increasing landscape condition. Table 2 (§ 3.2) summarizes all the established quantitative and qualitative performance objectives, their respective success criteria for determining progress towards meeting the goals, and the final results.

The performance objectives defined for the demonstration and whether they were met are summarized below:

- Reduction of potable water usage (Achieved 81%)
- Reduction of potable water costs (Achieved 81%)
- Economic payback period (Not Achieved 53 years)
- Savings to Investment Ratio (SIR) (Not Achieved 0.53)
- Overall energy use reduction (Achieved 57.4%)
- System Availability (Achieved 98%)
- Landscape aesthetics (Slightly diminished but satisfactory)
- Plant/turf health (Slightly diminished but satisfactory)
- Ease of use (Achieved)

1.3 REGULATORY DRIVERS

An appreciable amount of water use in the U.S. is for irrigation purposes (i.e., at 33%; U.S. Geological Survey [USGS], 2014); therefore, the results of this demonstration project may provide a mechanism for DoD facilities to more easily meet regulatory requirements for water conservation and sustainability enforced at the federal, state, and installation level.

Executive Order (EO) 13693, *Planning for Federal Sustainability in the Next Decade,* was released on March 25, 2015 and expands upon, but also revokes, previous EOs 13514 and 13423, which outline sustainability goals for federal agencies (e.g., DoD). As such, EO 13693 serves as the current federal regulatory driver for this demonstration project and requires agencies to improve water use efficiency and management, as follows:

i. Reducing agency potable water consumption intensity measured in gallons per gross square foot by 36% by FY 2025 through reductions of 2% annually through FY 2025 relative to a baseline of the agency's water consumption in FY 2007;

ii. Installing water meters and collecting and utilizing building and facility water balance data to improve water conservation and management;

iii. Reducing agency industrial, landscaping, and agricultural (ILA) water consumption measured in gallons by 2% annually through FY 2025 relative to a baseline of the agency's ILA water consumption in FY 2010; and

iv. Installing appropriate green infrastructure features on federally-owned property to help with storm water and wastewater management.

Additionally, drought conditions have persisted within the southwestern U.S. requiring states – particularly California – to establish mandates for reductions in water usage. On April 1, 2015, Governor Brown of California signed EO B-29-15 into law, proclaiming a Continued State of Emergency throughout the state due to the ongoing drought.

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2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

The smart water conservation system demonstrated during this project comprised an integrated suite of commercially-available technologies for irrigating landscape (i.e., turf and low-water demand ground cover). The primary system components are described in further detail in Section 5.

1. Advanced ET controller to reduce potable water usage by minimizing operating times (calculates run time based on real-time weather conditions). System includes the following components:
   - Soil Moisture Sensor (SMS) – shuts down irrigation once optimum soil moisture is reached
   - Rain gauge – shuts down irrigation on rainy days
   - ET gauge – estimates daily water loss from plant and land surfaces
   - Leak flow sensors – shuts down irrigation if a pipe/sprinkler ruptures
2. Rainwater and Heating, Ventilation, and Air Conditioning (HVAC) condensate water harvesting system to displace potable water usage, including a:
   - Pipeline collection system
   - First flush diverter
   - Underground Storage Tank (UST) for harvested water
   - Pumping and float switch system
3. Irrigation Hardware:
   - Efficient sprinkler heads – to provide uniform coverage and prevent misting/ overspray
   - Pressure regulating valves – to ensure optimum nozzle pressure and prevent misting/ overspray

The rainwater harvesting system comprises off-the-shelf plumbing and tank components, including a "first flush" diverter that redirects the first part of a rain event, which normally contains the greatest concentration of pollutants, away from the harvesting tank. The "first flush" contains contaminants such as bird droppings and suspended solids that can clog sprinkler components, thereby reducing irrigation efficiency and increasing maintenance requirements. It is better to remove the debris prior to entering the tank, and conventional design guidance suggests diverting 1 liter per square meter roofing for lightly loaded roofs and 2 liters per square meter for heavier loads.

The resultant harvested rainwater and HVAC system condensate water is used to irrigate a portion of the landscape via an advanced ET controller system, integrated with a pump and a water efficient sprinkler system. The advanced ET controller used at the Port Hueneme demonstration site was the Calsense 2000E smart irrigation modular controller, developed by the Calsense Corporation.

The Calsense controller uses real-time weather data via radio signals broadcasted or hardwired from local weather stations and site-specific soil and rain sensor inputs to adjust watering schedules. The system allows remote control via personal computer and includes remote features such as manual operation and program adjustment, along with dial and switch settings. These features can potentially provide substantial travel savings by allowing routine irrigation programming modification and, in some cases, more complicated troubleshooting, to be conducted remotely.

The advanced controller used at the Fort Hood demonstration used an SMS and the Baseline 3200 irrigation controller, developed by Baseline Incorporated. The controller can be configured to keep the soil moisture at user-defined levels for maintaining optimum plant health, and kept below field soil moisture capacity.

Figure 1 presents a schematic diagram of the smart water conservation system (including all components) as well as the traditional irrigation system (i.e., control plot) that was evaluated during the project at Port Hueneme.

2.2 TECHNOLOGY DEVELOPMENT

The smart water conservation system was devised from existing sensor and water harvesting technologies developed in agriculture and turf industries. Rainwater has been harvested for centuries from the roofs of buildings, and condensate water is currently being harvested and used for irrigation at several large institutions on the east coast. The rainwater and HVAC condensate are advantageous water sources because they require no pre-treatment (other than a first flush diverter) and can be inexpensively harvested and applied to landscape irrigation. The sensor technologies have been used and extensively tested in the last 20 years by reputable universities across the U. S.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The primary advantages of implementing the smart water conservation system over a traditional irrigation system are:

1) The conservation of potable water resources; and
2) The cost savings associated with reducing potable water use.

Specific technical advantages of the smart water conservation system compared to a traditional irrigation system are provided in Table 1. Advantages and Limitations of Selected Irrigation Systems.

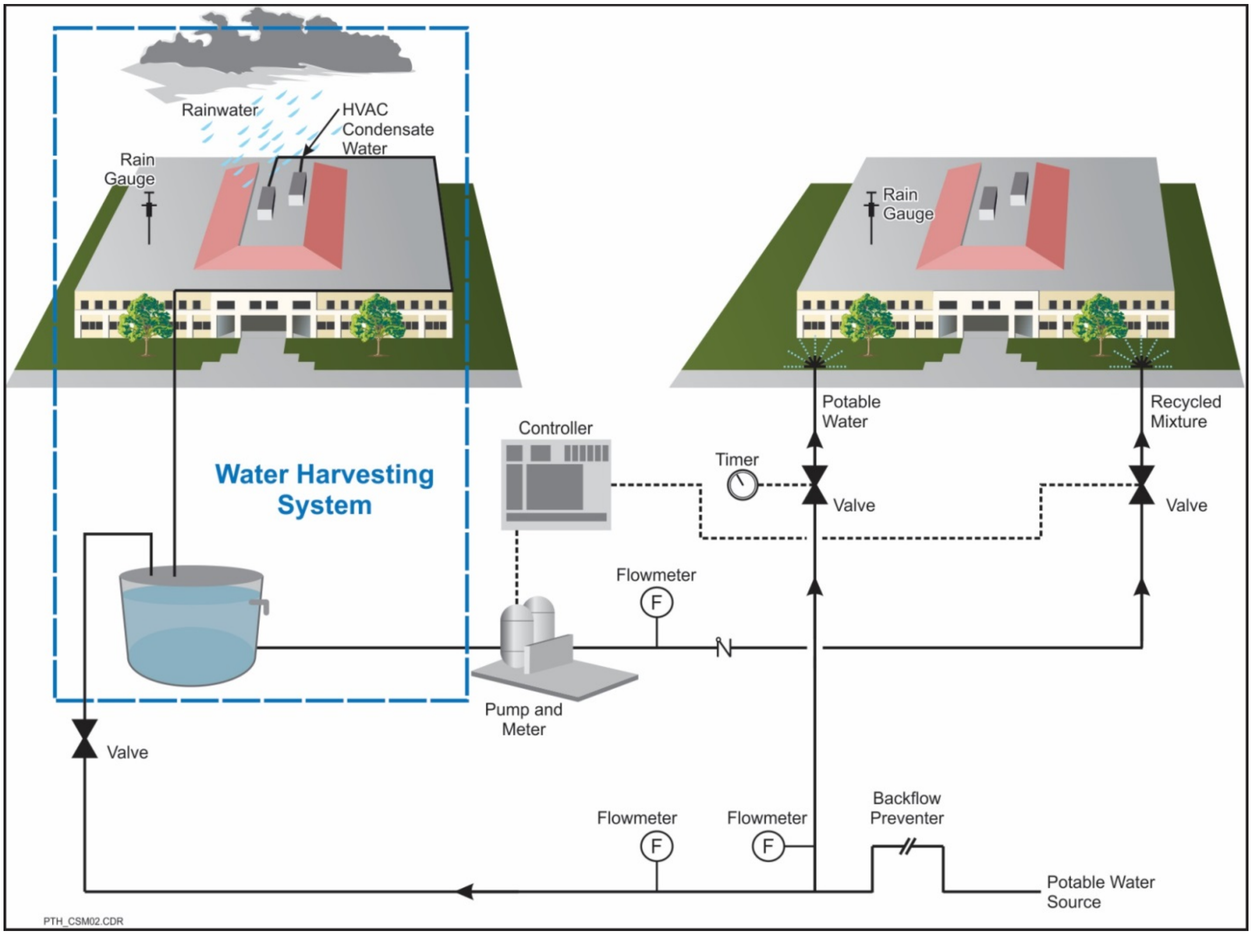

Figure 1. Schematic Diagram of the Smart Water Conservation System and Traditional Irrigation System

Table 1. Advantages and Limitations of Selected Irrigation Systems

Irrigation System	Advantages	Limitations
Smart Water Conservation System	• Uses harvested water to offset the use of potable water; potable water is only used if necessary to supplement the volume of water required for irrigation. Less water used results in reduced energy usage. • Controller collects and evaluates real-time sensor data to determine when it is necessary to irrigate and how much water to apply based on site conditions. • Provides remote access to the controller which allows operators to modify certain operational settings of the system without being present at the site. • Equipped with high-efficiency volume sprinkler nozzles and pressure regulating devices to achieve a more uniform distribution of water throughout the landscape. • Supports compliance with EO 13693	• HVAC condensate from rooftops can be easily routed to above or below-grade tanks using gravity, whereas floor-level HVAC systems may require pumping systems. The added cost to install and maintain a pumping system can negatively impact feasibility. • Condensate collection systems for large buildings with decentralized/multiple HVAC units can be expensive to plumb, which can negatively impact feasibility. For buildings with multiple HVAC units, it is best to draw condensate water from those that chill outside air and are nearest to the water harvesting tank. Units that chill outside air will provide more condensate water than those units that intake re-circulated indoor air. • Application in an extremely arid climate is limited to non-turf landscape and small areas of turf. The volume of water needed to support a substantive turf area in an arid climate is exorbitantly high and not considered sustainable. • HVAC condensate may not be practical in a semi-arid climate, where indoor air is mostly re-circulated, and HVAC unit temperature set points are intentionally high to conserve energy.
Traditional Irrigation System	• May be applicable in any climate (i.e., arid and/or semi-arid). • Are economical in many regions of the country where potable water is inexpensive.	• Rely entirely on potable water. • Timer-based and will operate whenever programmed to, regardless of whether irrigation is necessary. Typically, timer-based systems are adjusted higher than needed to account for consecutive hot days that stress turf beyond the wilting point. • Require personnel to be onsite to make adjustments to the watering schedule. • Do not provide high-efficiency irrigation hardware.

3.0 PERFORMANCE OBJECTIVES

The primary success criteria for the smart water conservation system was to reduce potable water usage for landscape irrigation by 70%, while maintaining or increasing landscape condition. Table 2, Summary of Quantitative and Qualitative Performance Objectives (§3.2), summarizes all the established quantitative and qualitative performance objectives, their respective success criteria for determining progress towards meeting the goals, and the final results for the Port Hueneme demonstration site.

The smart and control plots were selected at comparable areas, having similar initial landscape, plant health, plot size, microclimate, sun/wind exposure (i.e., based on the presence of Building 1100 directly adjacent to the study area), and usage/traffic within the landscape.

3.1 REDUCTION OF POTABLE WATER CONSUMPTION

Purpose: DoD has substantial landscape areas that are irrigated with inefficient, traditional systems that can benefit from technologies that reduce potable water usage in landscape. The primary objective is to determine if these smart water conservation technologies, along with a water harvesting system, can be retrofitted into existing facilities to reduce potable water use by up to 70% in support of meeting EO 13693.

Metric: During the demonstration project, the volume of water used for irrigation at both the smart and control plots was measured and recorded/downloaded monthly to determine the reduction in potable water usage between the smart water conservation system and traditional irrigation system, respectively.

Data: A total of 24 months of water usage data were collected during the demonstration project. The cumulative volume of water data was collected for each irrigation event by the controller on the smart water conservation system. These data were downloaded monthly.

Success criteria: Achieve a reduction in potable water consumption greater than 70%.

Achievement: Success criteria were achieved with a reduction in potable water consumption of 81%.

3.2 REDUCTION OF POTABLE WATER COSTS

Purpose: The primary purpose of the cost reduction performance objective is to determine the annual cost savings resulting from the displacement of potable water use and any resulting decrease in electrical use due to the smart water conservation system. The percent reduction in potable water cost is expected to be approximately equal to the reduction in potable water consumption, since there is only a minimal cost associated with pumping the harvested water and supplemental potable water. In addition, because the pumping occurs on-site, pump size and pressure is optimized, and pressure loss is held to a minimum. The reduction in potable water cost can be used to determine the payback on investment for follow-on system implementation.

Table 2. Summary of Quantitative and Qualitative Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Reduction of potable water usage	Amount of potable water used for irrigation (gal)	• Metered water usage • Historic metered water usage	> 70% reduction in potable water use	Achieved 81%
Reduction of potable water costs	Water and electrical costs	• Metered water usage • Historic metered water usage • Current/hist. water rates • Calculated electrical usage • Current and historic electrical costs • Hours of pump operation	> 50% reduction in potable water cost	Achieved 81%
Economic payback period	Cost savings from smart water conservation system	• Capital equipment costs • Electrical costs • Water costs	≤ 20 years	Not Achieved 53 years
Savings to Investment Ratio (SIR)			SIR >1.0	Not Achieved 0.53
Overall energy use reduction	Pumping costs per amount of water used for irrigation	• Metered water usage • Historic metered water usage • Calculated electrical usage • Historic metered electrical usage • Hours of pump operation	> 40 % reduction in energy	Achieved 57.4%
System Availability	Time system is operational	• Downtime, Uptime • Number of failures • Time to repair • Mean Time Between Failure • Mean Time To Failure • Maintenance and repair logs	> 95% Availability	Achieved 98%
Qualitative Performance Objectives				
Landscape aesthetics	Appearance: professional opinion of recognized experts in turf science	• Photographic records	Equal or improved appearance of landscape	Slightly diminished appearance but satisfactory
Plant/turf health	Appearance: professional opinion of recognized experts in turf science	• Photographic records	No degradation or improvement of plant/turf health	Slightly diminished but satisfactory
Ease of use	Ability of landscape technician/manager to use/maintain the technology	• Feedback from the landscape technician on maintainability	Equal or reduced workload on landscape technician	Achieved*

(*Some additional workload was caused by pump failure after the demonstration period.)

Metric: Total volume of water used to irrigate the control plot and smart plot, an average water rate/cost, an average electrical cost, and hours of pump operations were used to calculate reduction in potable water cost.

Data: During the demonstration project, potable water use, harvested water use, and flow data were collected (over a 24-month period) and used to determine hours of pump operation. The cumulative volume of water data was collected during each irrigation event by the controller on the smart water conservation system. These data were downloaded monthly. Water rates and electrical costs were captured from average local utility bills.

Success Criteria: Achieve a reduction in potable water cost greater than 50% to support an economic payback/return on investment.

Achievement: Success criteria were achieved with a reduction in potable water cost of 81%.

3.3 ECONOMIC PAYBACK PERIOD AND SAVINGS TO INVESTMENT RATIO

Purpose: The primary purpose of the economic payback period and SIR performance objectives are to demonstrate the economic feasibility of implementing a smart water conservation system at an existing DoD facility. Specifically, these performance objectives will determine if the system or components are financially feasible for potential widespread implementation at sports field, parade grounds, and/or landscape near buildings.

Metric: System capital equipment costs were compared to annual cost saving to calculate an economic payback period and SIR. Costs for the smart water conservation system design, capital equipment, installation, potable water, pumping, and annual maintenance were included in the evaluation.

Data: The data required to complete the analysis include costs for electrical and water; design, capital equipment, and installation of the smart water conservation system; and operation and maintenance.

Success Criteria: Achieve an economic payback period of less than or equal to 20 years and a SIR greater than 1.0.

Achievement: Not achieved. The payback for the smart water conservation system deployed at Naval Base Ventura was 53 years. SIR = 0.53.

3.4 OVERALL ENERGY USE REDUCTION

Purpose: The purpose of the energy use reduction performance objective is to demonstrate the overall energy saving resulting from using smart water conservation technologies compared to traditional irrigation systems. Potable water used for irrigation purposes at NBVC is provided by the Port Hueneme Water Agency, whose source water includes local groundwater and water purchased from Calleguas Municipal Water District. The Calleguas Municipal Water District imports water from the Metropolitan Water District of Southern California (MWDSC), which acquires raw water from Northern California (Sacramento Delta) and the Colorado River.

The MWDSC-published energy cost for water supplied to users in southern California is $161 per acre foot.

On-site harvested water is free of treatment chemicals and has a significantly smaller electrical footprint than potable water. Specifically, a smaller pump, operating at lower pressure due to reduced friction losses, results in increased energy saving using harvested water. Quality of rainwater should also enhance overall turf health which may reduce the requirement for fertilizers and maintenance. Energy reductions for these benefits are not included in the calculations, but are important factors to note.

Metric: The metrics used to measure energy use reduction were: (1) the published energy cost to supply water to customers in southern California, and (2) the energy cost to irrigate with an on-site pump. Regional energy cost for potable water is $161 per acre foot (or $0.49/1,000 gal) and the average cost of electricity is $0.14 KWh.

Data: The data required is the volume of water used to irrigate the control plot and smart plot, cost of electrical power, and hours of pump operation.

Success Criteria: Achieve an energy use reduction of greater than 40%.

Achievement: The smart water conservation system achieved an energy use reduction of 57.4% compared to the traditional irrigation system.

3.5 RELIABILITY AND AVAILABILITY

Metric: System reliability is defined as the probability that equipment provided will perform its designed function over a specified period, or simply the amount of time the system performs as designed. Reliability is quantified as Mean Time Between Tailures (MTBF) for repairable products such as pumps, and Mean Time To Failure (MTTF) for non-repairable products such as sensors.

The same data used to monitor reliability were used to compute availability for each of the individual components and the system as a whole. System availability is projected to be over 95%. Data sheets were used to capture the date and duration of each repair and the associated system downtime. The collected information provides a repair record that identifies problematic system components and design practices.

Success Criteria: The reliability and availability success criteria established for the smart water conservation system is greater than 95%

Achievement: Target 95% was achieved.

3.6 EASE OF USE

Purpose: The purpose of the "Ease of Use" qualitative performance objective is to provide an evaluation with respect to the feasibility of implementing a smart water conservation system for irrigation.

Metric: The performance metric is the ability of landscape technicians or managers to use and/or maintain the smart water conservation system technology.

Data: The project engineers interviewed landscape technicians to obtain their feedback or input on the "ease of use" of the smart water conservation system. The landscape technicians provided feedback on their ability to operate the Calsense 2000E smart irrigation modular controller, and system maintenance based on "workload" and "ease of use". In addition, data was compiled on reliability, maintainability, and time required for operation and maintenance.

Success Criteria: The success criteria are equal or reduced workload on landscape technicians or managers due to implementation of the smart water conservation system.

Achievement: Overall, workload was only marginally increased; therefore, the "Ease of Use" qualitative performance objective was achieved.

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4.0 FACILITY/ SITE DESCRIPTION

4.1 FACILITY/ SITE LOCATION AND OPERATIONS

The demonstration of the smart water conservation technology for landscape irrigation was conducted at NBVC, located northwest of Los Angeles, California. NAVFAC EXWC specializes in environmental and energy projects, including water conservation. NAVFAC EXWC Building 1100 served as the demonstration site for the smart water conservation system. Building 1100 is a relatively new building (constructed in 1994) and houses over 500 engineers, scientists, and support staff. Figure 2, Demonstration Area Immediately North of Building 1100 Depicting the Smart Plot, provides a general layout of the demonstration area immediately north and west of Building 1100, including the location of the smart plot, control plot, approximate rainwater harvesting area, 17,000 gallon UST and Calsense 2000E controller, and two 20-ton rooftop HVAC systems.

The smart plot and control plot were carefully selected based on the comparability of each area. Figure 2 provides a general plan view of the smart plot and control plot at Building 1100. Both the smart and control plot have a turf area (1,000 square feet) located at the main entrance of Building 1100 with an accompanying Myoporum ground cover area (6,500 square feet) situated further away from the main entrance. Specifically, each area is the same size, contains similar landscaping, and is located on the north side of Building 1100; therefore, sun and wind exposure are similar. Additionally, the control plot was equipped with an existing traditional irrigation system, which served as the baseline against which the smart water conservation system was measured during the project.

4.2 FACILITY/SITE CONDITIONS

Due to its proximity to the Pacific Ocean, Port Hueneme is described as having a Mediterranean climate and often experiences periods of fog in the early mornings. The average temperature is approximately 60 ºF with an average high and low of 70 ºF and 51 ºF, respectively. On occasion, Port Hueneme experiences hot, high winds blowing from the desert region known as “Santa Anas,” which can blow at gusts greater than 40 miles per hour (mph) on the coast. Monthly rainfall, ET rates for grass (tall fescue), and humidity in Port Hueneme were used to properly size the water harvesting system.

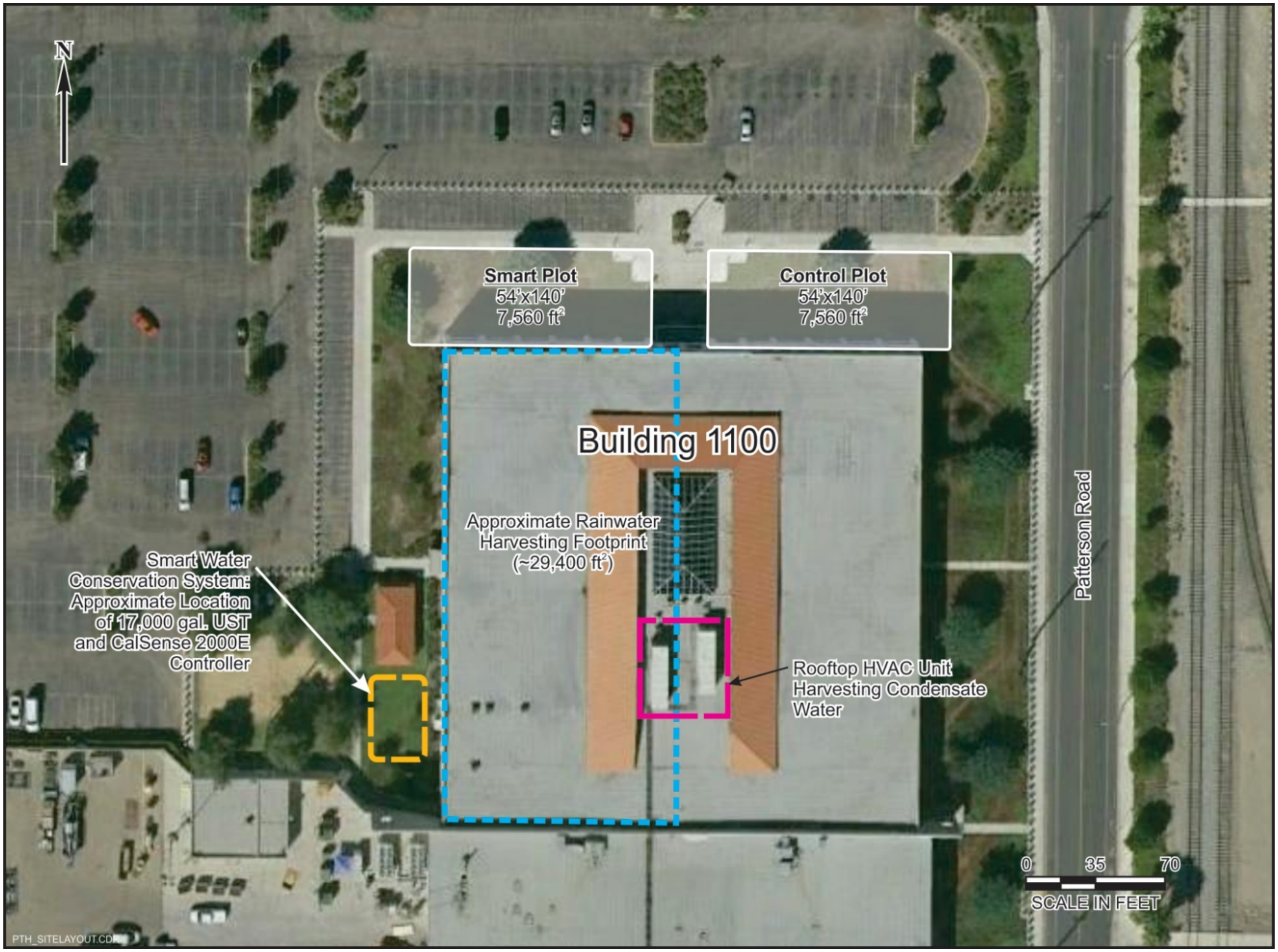

Figure 2. **Demonstration Area Immediately North of Building 1100 Depicting the Smart Plot, Control Plot, the Approximate Rainwater Harvesting Area, and the Underground Water Storage Tank**

5.0 TEST DESIGN

5.1 CONCEPTUAL TEST DESIGN

Figure 1 (§ 2.3) illustrates the conceptual schematic diagram of the demonstration study, detailing both the smart water conservation system and traditional irrigation system (i.e., control) as well as the location of flowmeters used to quantitatively evaluate and compare the performance of each system.

Figure 3, Process Flow Diagram for Operation of the Smart Water Conservation System, presents a general process flow diagram for operation or irrigation using the smart water conservation system. The Calsense 2000E controller received soil moisture and ET data to determine the pump operation schedule (i.e., time and duration of operation). The controller communicates daily with a pre-existing nearby Calsense ET gauge located on NBVC. The ET gauge is designed to evaporate water at the same rate as tall fescue (representative of existing turf) via a ceramic evaporation plate. ET data is then automatically sent to the controller, which calculates run time for the next irrigation cycle. The ET gauge is inspected and filled with distilled water every two months to ensure proper operation.

Irrigation set points or soil moisture content levels were established within the controller to control irrigation to maintain target soil moisture levels. Harvested water (along with potable water, if necessary) within the UST served as the water source and a pump was used to transport this water from the UST to the smart plot during periods of irrigation (i.e., as determined by the controller).

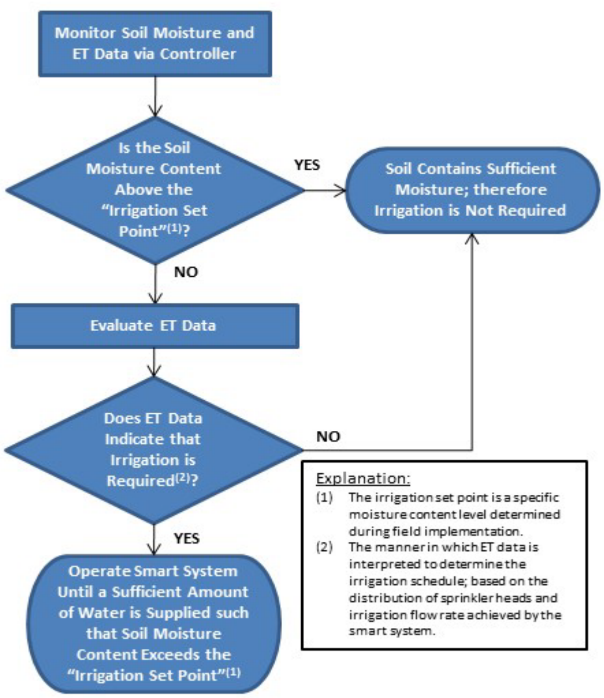

Figure 3. Process Flow Diagram for Operation of the Smart Water Conservation System

5.2 BASELINE CHARACTERIZATION

A separate area at the demonstration site served as the control plot and was irrigated using the existing traditional irrigation system. The control plot was directly adjacent to the smart plot; therefore, it was expected to be highly comparable with micro-climates, soil conditions, and exposure to sun, shade, and wind as the smart plot. Also, there were similarities in the landscape features, such as types of turf, plants, and vegetation density, between the smart plot and control plot.

The control plot was approximately 7,560 ft^2 and covered by two irrigations stations: one for the turf area and the other for ground cover. The turf area was approximately 1,034 ft^2. The station for the ground cover could not be outfitted with a flow meter without major demolition and construction; therefore, only the turf area was monitored with a flow meter during the demonstration project. Irrigation at the control plot was regulated by a timer. To capture flow data for the demonstration, a second Calsense controller was added and configured to operate as a simple timer.

Irrigation using a timer-based system is solely dependent on (1) the time of the year (i.e., summer month versus. non-summer month), (2) the day of the week, and 3) the time of day.

- During the summer months, the timer was set to irrigate the turf and landscape on Monday, Wednesday, Friday, and Saturday between the hours of 10:00 p.m. and 6:00 a.m., which was consistent with current irrigation schedules.
- During the fall/winter/spring months, the timer was set to irrigate the turf and landscape on Mondays and Thursdays between the hours of 10:00 p.m. and 6:00 a.m. This schedule was based on discussions with the irrigation manager from the NBVC Public Works Office.

The 2-year demonstration study began following installation and an initial evaluation of both the smart water conservation system and traditional irrigation system. The overall performance of the traditional irrigation system was assessed using a flow meter capable of monitoring flowrate and total water volume. These performance metrics were monitored monthly using this flow meter. Some adjustments were made by the landscape technician to the timer on the traditional irrigation system throughout the demonstration period to adjust for drought conditions and maintenance crew activities. Groundskeepers turned off irrigation during the winter months and a few days prior to mowing.

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

This section provides a description of the primary components of the smart water conservation system, including the advanced ET controller, rainwater and HVAC condensate water harvesting system, and irrigation hardware. The conceptual design and layout of the smart water conservation system (including components) is illustrated in Figure 1 (§ 2.3) and the spatial layout of the demonstration site is illustrated in Figure 2 (§4.2).

5.3.1 Advanced ET Controller

The Calsense 2000E smart irrigation modular controller is a Programmable Logic Controller (PLC) and the main interface for the smart water conservation system. Using this controller, operators can program the system to operate/irrigate based on site- and area-specific conditions. Overall, the basic functionality of the Calsense 2000E smart irrigation modular controller includes:

- Ability to control eight irrigation systems (with the option to upgrade up to 32 irrigation systems);
- Flexible programming options and self-diagnostic feedback to identify field wiring, sensor input, and solenoid/valve issues during operation;
- Four separate programmable settings to input different start times, system timing duration, and watering days;
- Ability to draw from non-potable (e.g., harvested) water sources and control pumps and actuated valves, as necessary, to control operation;
- The controller utilizes the following sensors to irrigate the smart plot: (1) a pre-existing nearby Calsense ET gauge to calculate the irrigation run time correlating to existing weather conditions, (2) a soil moisture sensor to terminate irrigation if actual soil moisture meets the programmed set-point, and (3) a rain gauge that terminates irrigation upon a rain event.

5.3.2 Rainwater and HVAC Condensate Water Harvesting System

The smart water conservation system includes a water harvesting system, capturing both rainwater and HVAC condensate water to displace potable water usage for irrigation. The water harvesting system captures roof rainwater from the western half of Building 1100, which gravity feeds through three downspouts to a 17,000 gallon UST located approximately 25 feet west of the building foundation. At the base of the building, rooftop runoff flows through first flush diverters to redirect the first portion of a storm event to the storm sewer. The first flush of rooftop runoff typically contains debris such as bird droppings and sand-sized particles that can accumulate in the UST, or clog the sprinkler irrigation hardware.

A nominal 17,000 gallon UST (16,755 gallons) was constructed onsite to store the harvested water. For a large facility, such as NAVFAC EXWC, an HVAC system can potentially generate 0.4 to 5.3 Gallons Per Hour (gph) of condensate water, depending on the cooling load placed on the chillers (approximately 25,000 gallons annually). In addition, the annual precipitation at Port Hueneme is 14.3 inches.

5.3.3 Water Efficient Sprinkler Heads, Flow Meters and Pressure Regulating Device

Efficient irrigation hardware, including pipeline design, multiple high-efficiency volume sprinkler nozzles, pressure regulating valves, and flow meter, were also part of the smart water conservation system. For the demonstration project, Rain Bird® MPR 10 Series sprinkler nozzles were used and integrated with a pressure regulating valve set at 30 pounds per square inch (psi). These sprinkler nozzles are designed to provide even water distribution within a 10-ft. radius, when properly installed and pressurized. The regulating valve device minimizes water loss caused by excessive/over pressure to the sprinkler nozzle, which causes misting resulting in overspray. Appendix A provides the specification sheet for the Rain Bird® MPR 10 Series sprinkler nozzles.

A flow meter was installed in the irrigation pipeline as a subsystem of the Calsense 2000E controller. The controller can detect these changes in flowrate and shut down the irrigation system or provide an e-mail alert to operators.

5.4 OPERATIONAL TESTING

The primary metric used to measure the performance of the smart water conservation system was the reduction in potable water consumption used for irrigation compared to the timer-based, traditional irrigation system. Flow rates and cumulative water volumes were the primary data collected to evaluate the performance of the system. These performance data were collected from the demonstration site monthly for two years, which was scheduled in three phases (i.e., startup, performance monitoring, and demonstration completion).

Once the smart water conservation system was completely installed on November 1, 2013, a 1 to 2-day system startup and shakedown period was conducted to fully validate and determine the optimal program settings for the controller, based on soil moisture and ET data. In addition, the performance of the irrigation hardware (i.e., sprinkler nozzles and pressure regulating valve) and metering system (i.e., flow meters that measured performance of the system) were monitored and evaluated during startup/shakedown.

Performance data (i.e., flowrates and volumes of water from flow meters #1 through #4) was collected from January 01, 2013 through December 30, 2014 during the demonstration project. The data was logged manually and digitally through on-demand output obtained from the PLC/controller. Field test data sheets were utilized to assist in collecting data and to capture qualitative observations made by irrigation system operators, such as the occurrence of standing water, odor, algae formation in the UST, clogging of sprinkler heads, and overall aesthetic condition of the landscape.

Photographs of each plot (i.e., smart plot and control plot) were taken at the first, sixth, twelfth, and 24th month of the performance monitoring to qualitatively assess the health of the vegetation within each plot. The evaluation included documentation of any degradation in aesthetics or stress, and/or disease resulting from each respective irrigation practice. This qualitative objective was measured by turf scientists on a scale from 1 to 9 (i.e., where 9 is the highest level) using their professional judgment. The photographs and respective expert evaluation were used to determine and document the aesthetics or condition of each plot.

The final evaluation of the smart water conservation system was performed at the conclusion of the demonstration project and involved interpretation of both the quantitative and qualitative performance objectives (see Table 2, §3.2). Critical data collected during the demonstration project included the facility’s metered water consumption, the water rates for the facility, and flowrates stemming from the water harvesting system and cumulative volume of potable water applied to the control plot.

5.5 DATA COLLECTION PROTOCOL

Flow and electrical use data were measured/calculated from the control plot and smart plot to validate the quantitative performance objectives (see Table 2, §3.2). Table 3, Demonstration Project Monitoring Parameters (§5.6), provides the monitoring parameters for the demonstration project. At the onset of the demonstration, the flow meters were evaluated daily for a one-week period to ensure accuracy of flow measurements. Table 4, Monthly Water Use for Smart and Control Plot (§5.6), shows flow data that was obtained by a facility technician or project engineer at the end of each month for the duration of the 2-year demonstration project.

The controller collected all water-related data daily, and stored the data on an internal flash memory for a 31-day period. A laptop computer with Calsense Command Center Software was used to manually collect the data via cable connection on a weekly basis.

Flow meters were operated by manually operating the irrigation system once a month for a set time to visually validate accuracy of flowrate and ensure proper operation. Expected flowrates were compared with baseline flows to ensure reasonableness of the data and identify any discrepancies. Flow data accuracy within 5% is considered reasonable.

The qualitative data was provided by a turf expert highly familiar with plant and turf biology to evaluate any degradation in aesthetics or stress and/or disease to the vegetation. Photographic records were taken for both the smart plot and control plot and used for making visual assessments of the quality/condition of the landscape.

5.5.1 Equipment Calibration and Data Quality

All instrumentation and sensors were calibrated as specified by the manufacturer. Instruments underwent initial calibration and were reevaluated periodically to ensure proper calibration. If there were discrepancies in the data, instruments were inspected and recalibrated, as necessary.

5.5.2 Quality Assurance

Quality assurance of the test protocol was accomplished with monthly inspections of flow meter readings to ensure that the flow meters were functioning properly and within the quantitation limits specified in the demonstration plan.

5.6 SAMPLING RESULTS

Flow meter and ET data were compiled and used to evaluate water collection, irrigation use on control and test plots, energy usage, and ET as a driver for water demand to maintain vegetation. Visual inspections were made to assess the effectiveness of the systems in maintaining turf on the control and test plots. All flow data were captured using industrial-grade flowmeters with an accuracy of ±2%. To ensure the validity of the data, all flow metering devices were calibrated at the onset and data reviewed during the demonstration phase.

Table 3. Demonstration Project Monitoring Parameters

Parameter	Method	Medium Sampling Frequency	Accuracy
Water Volume *	Calibrated flow meters (Flow meter #2 – Flow meter #1)	Volume of rainwater, monthly	± 5%
Water Volume	Calibrated flow meter (Flow meter #1)	Volume of HVAC condensate water, monthly	± 5%
Water Volume	Calibrated flow meter (Flow meter #3)	Volume of potable water entering UST, monthly	± 2%
Water Volume	Calibrated flow meter (Flow meter #4)	Volume of harvested and potable water used to irrigate smart plot, monthly	± 2%
Water Volume	Calibrated flow meter (Flow meter #5)	Volume of potable water used to irrigate control plot, monthly	± 2%

*Tank water level measures were also taken to validate accuracy of flow meters and to validate mass balance of the water harvest tank.

Table 4. Monthly Water Use for Smart and Control Plot

Month/Year	Total Water Smart Plot (gal) *	Potable Water Smart Plot (gal)	Potable Water Control Plot (gal)
2013			
January	0	0	296
February	0	0	1,461
March	0	0	2,153
April	855	0	1,846
May	883	0	2,302
June	1,020	0	2,902
July	1,013	0	3,118
August	1,716	1,264	3,549
September	2,192	1,811	3,329
October	1,884	2,072	3,496
November	455	763	3,160
December	0	0	3,321
2014			
January	0	0	3,137
February	140	0	650
March	534	0	77
April	1,459	0	1,377
May	2,873	0	4,477
June	2,843	2,087	4,742
July	3,846	1,546	4,970
August	3,296	1,683	4,975
September	2,730	328	4,767
October	1,836	1,293	3,237
November	533	0	2,345
December	0	0	942
2015			
January **	0	0	24
February **	0	0	0
Total	**30,108**	**12,848**	**66,653**

Figure 4, Water Savings by ET and Moisture Sensor, shows the monthly volume of water applied on the smart and control plots over the 2-year demonstration period. The water applied on the smart plot includes comingled rainwater, HVAC condensate, and potable make-up water while the water applied to the control plot is potable water only (shown in blue). The difference in volume illustrates water saved by using the ET and soil moisture sensor over a traditional simple timer-based design. Approximately 36,521 gallons of water was saved over the 2-year period with the ET and soil moisture sensor system, equating to 54.8 % water reduction efficiency.

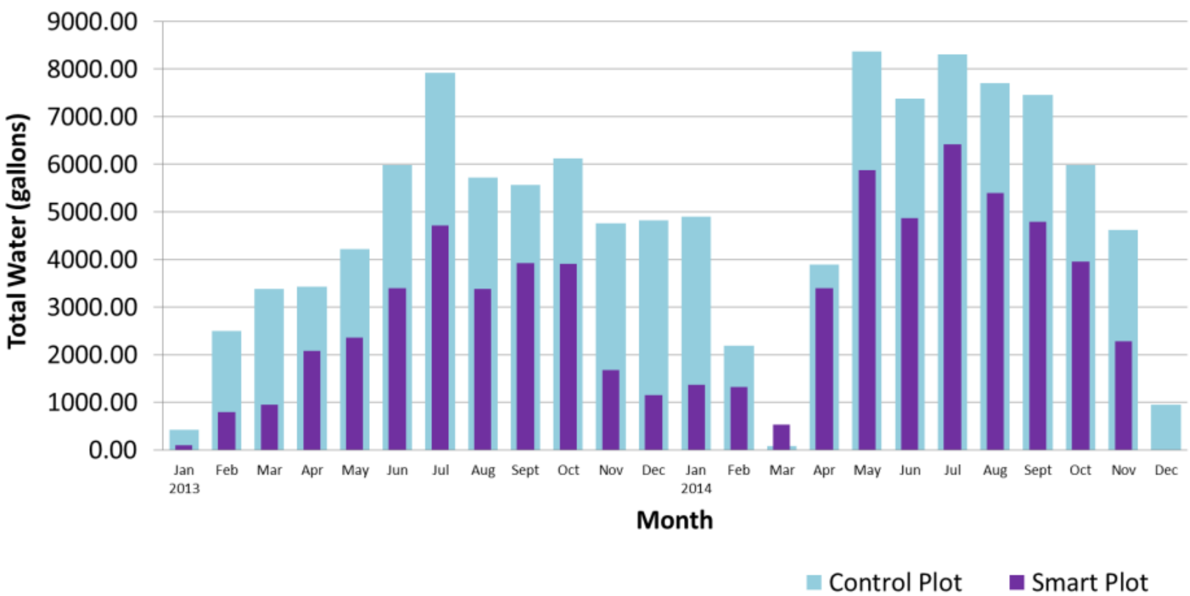

Figure 4. Water Savings by ET and Moisture Sensor

Figure 5, ET Controller and Soil Moisture Sensor Contribution, illustrates the contribution of the ET controller and soil moisture sensor for the total? water reduction during the 2-year demonstration. Data were derived by accounting for the days that the soil sensor overrode the computed ET irrigation runtime (i.e., if the soil in the smart plot had adequate moisture to sustain satisfactory turf health, then no additional water was applied).

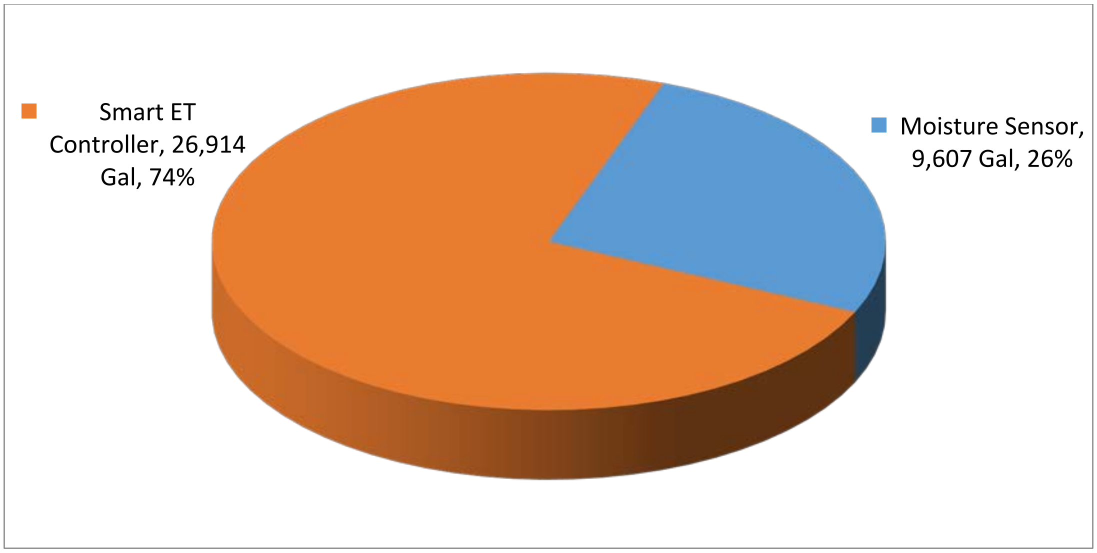

Figure 5. **ET Controller and Soil Moisture Sensor Contribution**

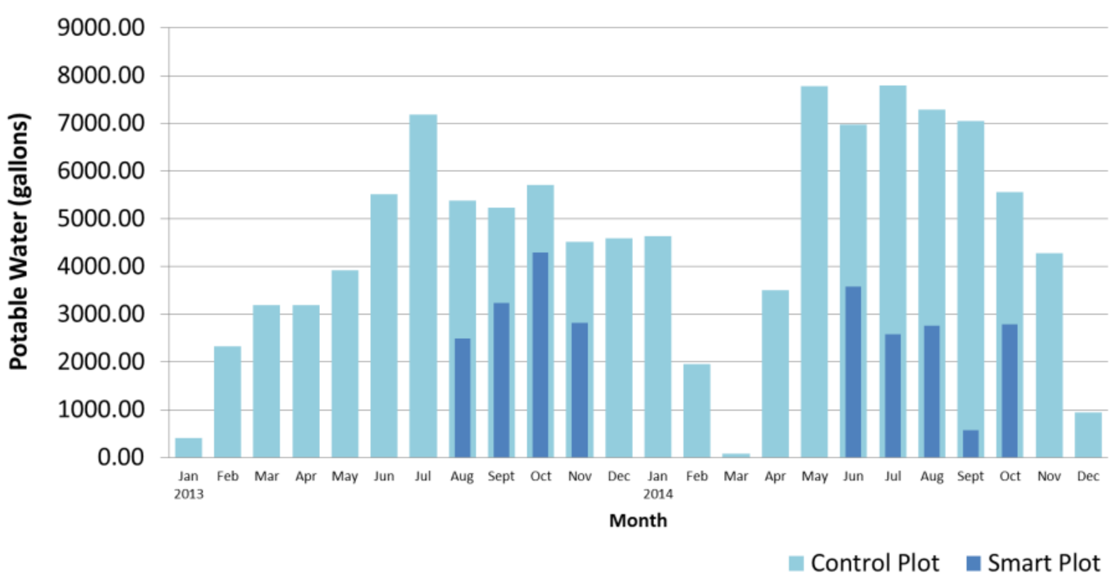

Figure 6. **Potable Water Savings by ET and Moisture Sensor**

Figure 6, Potable Water Savings by ET and Moisture Sensor, shows the monthly volume of potable water applied to both the control and smart plots during the demonstration period. It illustrates the potable water displaced by the smart water conservation system. Approximately 53,805 gallons of potable water were saved at the smart plot over the 24-month demonstration period when compared to the control plot, equating to an 81% reduction in potable water usage.

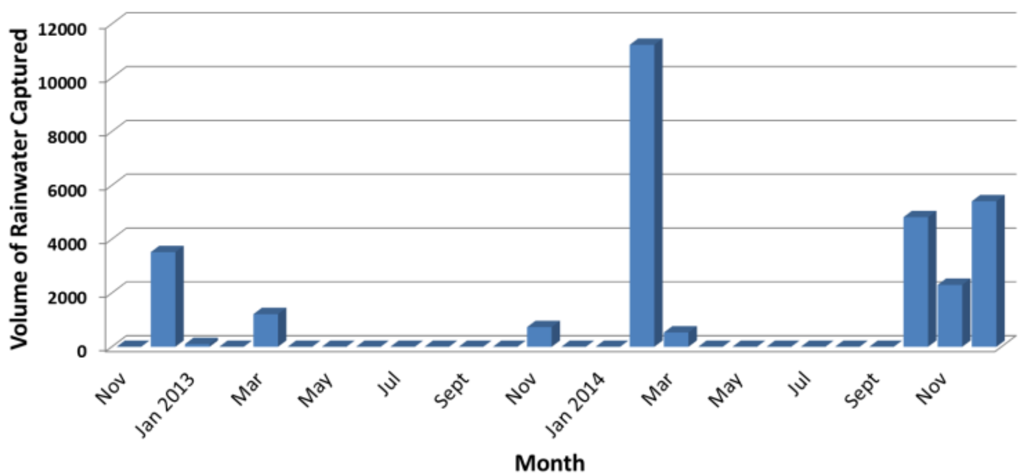

Figure 7. Volume of Rainwater Captured during Demonstration

Figure 7, Volume of Rainwater Captured during Demonstration, illustrates the monthly volume of rainwater captured during the 2-year demonstration period (during the monitoring period Port Hueneme received less than 8 inches of rain per year, well below average rainfall for Southern California). As illustrated, there were only 5 months when the volume of rainwater captured exceeded 2,000 gallons (i.e., December 2012 and February, October, November, and December 2014).

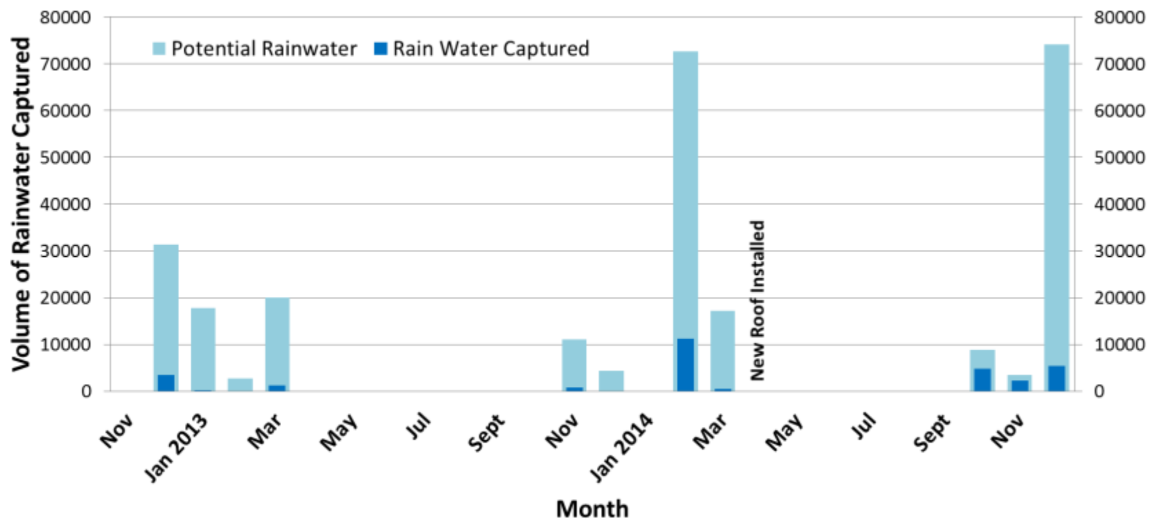

Figure 8. Actual Rainwater Captured Compared to Potential Rainwater from Roof at Port Hueneme

Figure 8, Actual Rainwater Captured Compared to Potential Rainwater from Roof at Port Hueneme, displays the potential amount of rainwater (based on cumulative monthly rainfall and the roof area contributing to the water harvesting tank) and actual amount of rainwater captured during the 2-year demonstration period. The bar graph illustrates that a significant amount of rainwater could have been captured and reused if a larger tank was available. It also illustrates a typical rainy season occurring from November through March in Southern California.

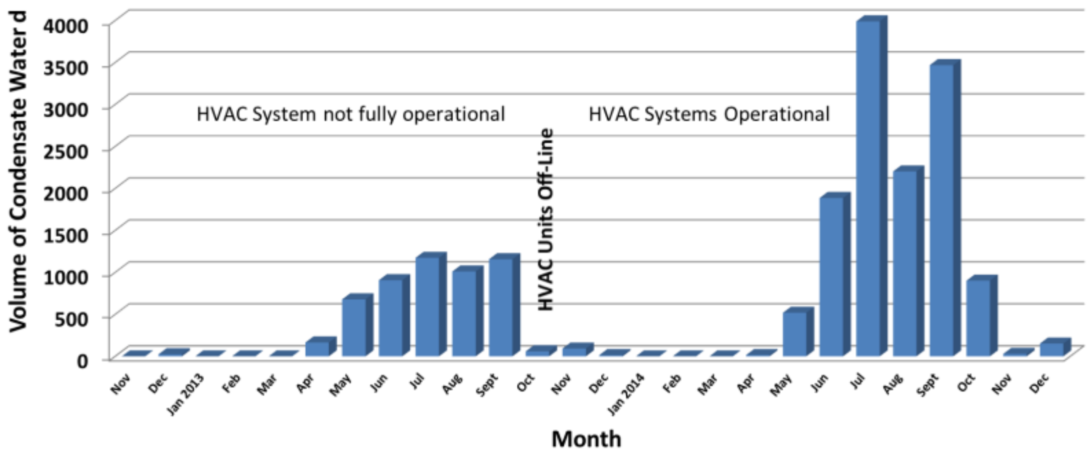

Figure 9. Volume of HVAC Condensate Water Captured during Demonstration

Figure 9, Volume of HVAC Condensate Water Captured during Demonstration, illustrates the monthly volume of HVAC condensate water captured during the 2-year demonstration period. Only one of the two HVAC air handlers was operational in year 1, and one of the air handlers was under repair during the month of August in year 2. The condensate water production from the HVAC unit is at its highest rate during the peak water demand months and generally demonstrates the same peaks as the maximum ET demand of turf (Figure 10, Average Monthly ET Requirement for Turn in Port Hueneme); thus, the condensate water is generally available during the times when the turf is at its maximum demand for irrigation.

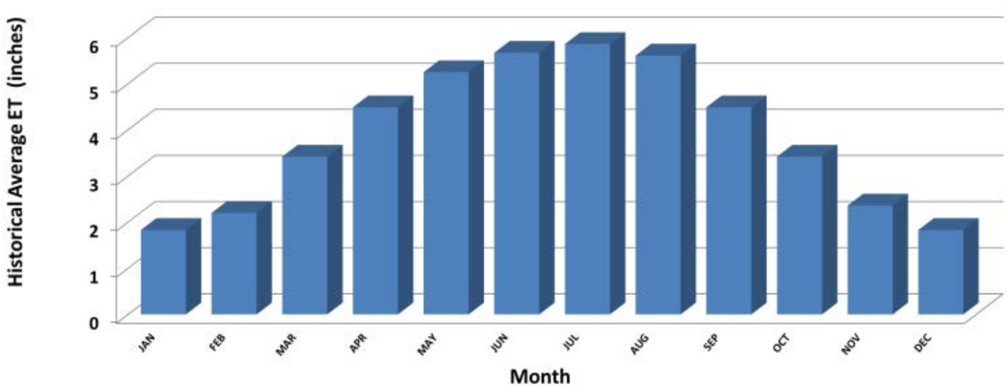

Figure 10. Average Monthly ET Requirement for Turf in Port Hueneme

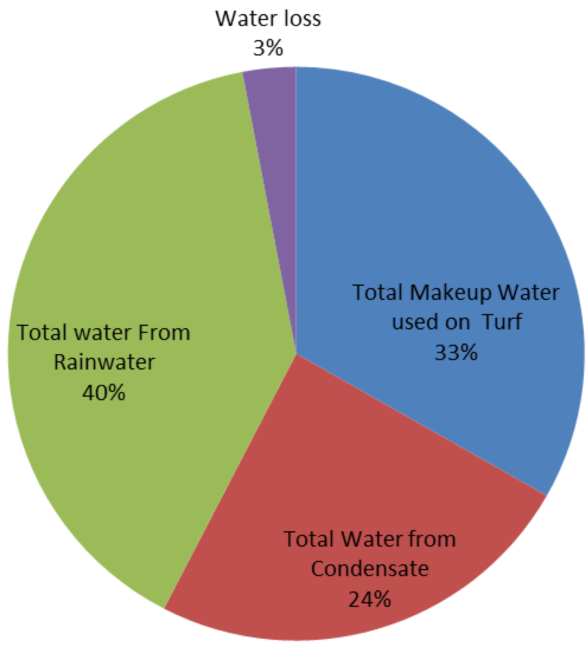

Figure 11. Water Sources Used on Smart and Control Plots

Figure 11, Water Sources Used on Smart and Control Plots illustrates the type or source of water used on the smart and control plots during the demonstration period. The source of water used on the smart plot was relatively equally distributed among rainwater, HVAC condensate water, and potable make-up water at 40%, 24%, and 33%, respectively, with only 3% losses.

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6.0 PERFORMANCE ASSESSMENT

The assessment criteria for the performance objectives are identified in Section 3.0. The specific assessment methodology for each performance objective is discussed in the following subsections.

6.1 REDUCTION OF POTABLE WATER CONSUMPTION

The reduction in potable water consumption is the primary measure of success for the smart water conservation system. The potable water reduction is the percent difference of the metered cumulative flow (volume over time) of the smart plot compared to the control plot. This performance assessment is based on the performance differences between the smart water conservation system and traditional irrigation system; the contribution of rainwater and HVAC condensate water; and the contribution of the individual technologies to the results.

Assessment Criteria:

- 70% reduction in water use for irrigation achieved by the system.

Results: The smart plot reduced potable water usage by 81% when compared to the control plot.

6.1.1 Data Analysis, Interpretation and Evaluation

Monthly irrigation flow data for the control plot and smart plot were collected for a 25-month period from December 2013 to January 2015. The Calsense ET controller was configured to capture irrigation runtime and log cumulative volume of water passing through the paddle wheel flow meter each day. EXWC personnel downloaded the data to a personal computer at the end of each month. Overall, 53,805 gallons of potable water were saved over the 25-month period, equating to an 81% reduction. Overall, 36,521 gallons of total water were saved over the 2-year period, equating to 54.8 % reduction efficiency and demonstrating the value of the ET/soil sensor.

6.2 REDUCTION OF POTABLE WATER COSTS

Potable water consumption data obtained from the controller and flowmeters along with the local water rate were used to calculate the potable water cost for the smart plot and control plot. These two costs were compared to evaluate overall reduction in water cost.

Assessment Criteria:

- Achieve a 50% reduction in potable water costs between the smart plot and the control plot.

Results: The smart water conservation system reduced potable water cost by 81% when compared to the control plot.

6.2.1 Data Analysis, Interpretation and Evaluation

The reduction in potable water cost for the 2-year demonstration study was based on the percent difference of the total cost of the water applied to the smart plot compared to the total cost of water applied to the control plot. The cost of the smart plot includes the cost of electrical power used to pump water from the harvesting tank (i.e., rainwater and condensate water as well as potable make-up water) to irrigate the smart plot and the cost of potable make-up water which maintains irrigation, when rainwater and condensate water are consumed (as well as ensuring the irrigation pump is protected from running dry). The total potable water applied on the control plot during the 2-year demonstration period was 66,653 gallons at a cost of $435.92.

6.3 ECONOMIC PAYBACK

The economic payback was considered the time period within which the discounted future savings of the smart water conservation system repays the initial investment costs. The future savings were determined based on a comparison of the annual reduction of potable water used and the associated cost (as compared to the traditional irrigation system) and any reduction in annual maintenance costs associated with operating the smart water conservation system.

Assessment Criteria:

- Present worth cost evaluation demonstrates that the economic payback of the smart plot was less than or equal to 20 years.

Results: The payback period for the smart water conservation system was 53 years.

6.3.1 Data Analysis, Interpretation and Evaluation

Two major factors that impacted the overall cost and payback period of the smart water conservation system are (1) the cost of the water harvesting system, and (2) the cost of potable water. The cost of water is set by the regional water agency and varies throughout the DoD. Prices range on average from $1.30 per 1,000 gallons in eastern states to over $6.00 per 1,000 gallons in the southwestern states. The capital cost of the smart water conservation system including material and installation was $75,000.

6.4 OVERALL ENERGY USE REDUCTION

Electrical energy use data were collected and analyzed at project conclusion. The energy consumption data was compared to the calculated value of pumping and treating potable water used to irrigate the control plot.

Assessment Criteria:

- The total energy reduction of the smart water conservation system of 40% compared with the traditional system.

Results: The system achieved a 57.4 % reduction in energy use as compared to the control plot.

6.4.1 Data Analysis, Interpretation and Evaluation

The reduction in energy for the 2-year demonstration was based on the percent difference of the energy used on the control plot compared to the energy used on the smart plot. The energy or electrical cost of the smart plot includes the cost of electrical power used to pump water from the harvesting tank (harvested rain and condensate water as well as potable make-up water) and the electrical cost associated with purchasing the water from MWDSC. The calculations using the collected volume data along with published energy data provide a straightforward comparison.

6.5 LANDSCAPE AESTHETICS AND CONDITIONS

Photographs of the smart plot and control plot were taken during months 1, 6, 12, and 24 of the demonstration period and analyzed by turf scientists to qualitatively assess the health of the vegetation within each plot. This qualitative objective (aesthetics) was measured by turf scientists using their best professional judgment on turf characteristics which is agreed upon by the turf quality standard defined by the National Turfgrass Evaluation Program.

- The aesthetic assessment rating of the smart plot was greater than or equal to the aesthetic assessment rating of the control plot.

Results: The smart plot exhibited a slightly diminished appearance but acceptable aesthetics when compared with control plot. The turf experts from California State University Fresno assigned a turf quality assessment rating of 7 for the smart plot at the start of the test. They assigned a turf quality assessment of 6 on October 2015, several months after the monitoring period.

6.5.1 Data Analysis, Interpretation and Evaluation

Plot photographs were compared and evaluated by turf experts from Cal State Fresno to determine the landscape aesthetics/turf health and provide an aesthetic assessment rating. Prior to the final assessment that was to occur after the monitoring period; the smart water irrigation pump failed which lead to turf die-off for a three-week period. At the conclusion of the monitoring period in January 23, 2015, the turf quality for both plots appeared of comparable quality.

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7.0 COST ASSESSMENT

The cost model developed during this demonstration project serves as a means for evaluating the expected lifecycle operational cost for future deployment of the smart water conservation system. Actual costs were tracked throughout the duration of the demonstration to determine the cost-effectiveness of the system. Upon project completion, the data collected were used to estimate the lifecycle costs of this technology. Startup costs included preparing the site and installing the system. Activities such as grading, excavation, and plant removal were required to support system installation and required necessary labor and materials. System installation required labor, materials, and connection of the system to the existing electrical service. Once the system was installed, operators needed to be trained to ensure that the system is operating properly.

Additionally, maintenance and operational costs contributed to the lifecycle cost of this technology. Maintenance costs included labor, replacement parts, equipment calibration, and solid waste handling and disposal. Costs to keep the system operational (e.g., electricity and potable water costs) were also tracked.

Table 5, Cost Model for Smart Water Conservation System, summarizes the actual site specific smart water conservation system cost for Port Hueneme with and without water harvesting capability. Both scenarios below include the cost of upgrading an existing Calsense controller to include ET functionality with SMS and leak detection via flow meter.

Table 5. Cost Model for Smart Water Conservation System

Cost Element	Data Tracked during Demonstration	Smart Water Conservation System	ET Controller (Stand-alone)
Capital	Vendor pricing (Taken from contract)	$75,000*	$4,995
Water	Utilities pricing	$6.54/1,000 gallons	$6.54/1000 gallons
Electrical	Utilities pricing	$0.14 per KW-hr	Not appreciable
Maintenance	Labor hours	$450 (10 hrs est. at $45/hr)	$90 (2 hrs est. at $45/hr)
Operator training	Training hours	$360 (8 hrs est.at $45/hr)	$180 (4 hrs est. at $45/hr)
Hardware lifetime	Estimate of component service life	50 years (tank) 10 years (Controller) 7 years (pump)	10 years (Controller)

*Include ET controller upgrades

7.1 COST MODEL

7.1.1 Capital Costs

Capital cost is one of the most important factors in determining the feasibility of future system implementation. The equipment and installation cost for the harvest tank, the ET controller, and the pump package are primary cost drivers. The harvesting tank was the most expensive component and significant time was taken to investigate options to reduce cost while maximizing the volume of storage available to collect rainwater. Commercial storage tanks ranging from 5,000 to 20,000 gallons were evaluated with price ranging from $1.50 to $5.00 per gallon depending on tank construction. Significant variations in price exist depending on local site conditions and installation requirements. An aboveground polyethylene tank was the least expensive option, but cost can escalate when implementing conventional seismic and wind restraints required by public works. The primary operational disadvantage of using a polyethylene tank is algae growth within the stored water, which is detrimental to sprinkler systems.

A 17,000-gallon modular polyethylene UST was selected primarily for shallow depth, which was a site constraint, along with multiple potential configurations and decreased potential for algae growth. A cost summary for the UST is presented in Table 6. Underground Tank Cost Summary. The UST size was determined based on landscape area, roof size, annual rainfall, and irrigation demand. Discounts or rebates provided by local organizations to promote water conservation were not included in the cost model.

For this model, an underground system with an estimated cost of $1.75 per gallon was initially chosen; however, the actual cost escalated to $3.23 per gallon. Table 6 provides a summary of the material and labor cost to install the UST.

Table 6. Underground Tank Cost Summary

Nomenclature	Total Cost	Notes
Materials		
6” Sand Base Layer	$503.00	Sand sub-base required below tank and liner
Geotextile Fabric	$1,710.00	Required to strengthen cap for H-20 loading
36 Mil Polypropylene Liner	$5,712.00	Required to contain water (includes installation of liner)
Poly Modules (qty. 280)	$22,764.56	Structural element of underground tank
Manholes	$823.00	Required to install pump and float valves
Materials Total	***$31,512.56***	
Labor		
Excavation	$3,179.00	Required for underground installation
Backfill	$1,808.25	Backfill for cap and sidewalls to support structural elements
Installation of Tank Inlets and Outlets	$1,200.00	Required for rainwater intake and pump outlet
Tank Module Assembly/Installation *	$12,000.00	Labor estimate
Soil Cartage	$1,316.00	Required for retrofit
Labor Total	***$19,503.25***	
Shipping Total	***$1,375.00***	
Total Cost	**$52,390.81**	**$3.13 Cost per gallon**

* 280 modules is approximately 16,755 gallons.

The second largest cost was the ET controller components. A summary of the component cost is provided in Table 7. Capital Cost for ET Controller and Accessories at Building 1100. For clarification, Building 1100 was originally outfitted with a Calsense controller, but not configured for advanced control using an ET gage, nor was the SMS installed in the smart turf plot.

Table 7. Capital Cost for ET Controller and Accessories at Building 1100

Nomenclature	Unit Cost	Existing Equipment on-Site at Building 1100 or on Base	Retrofit Building 1100
Model ET 2000e 6 Station	$3,950.00	Yes	$0.00
Stainless Enclosure w/ Dome Antennae and Transient Protection	$2,360.00	Yes	$0.00
ET Interface	$475.00	Yes	$0.00
Rain Bucket Interface	$475.00	Yes	$0.00
Transient Protect Package	$735.00	Yes	$0.00
ET Gauge	$1,375.00	Yes	$0.00
Stainless Steel Enclosure for ET Gauge	$995.00	Yes	$0.00
Calsense Tipping Rain Bucket	$595.00	Yes	$0.00
Flow Meter	$595.00	No	$595.00
Soil Sensor	$210.00	No	$210.00
Local Radio Stick Antenna	$190.00	No	$190.00
Communication (Phone Line/Ethernet Device)*	$925.00	N/A	$0.00
Communication Hub	$1,850.00	Yes	$0.00
Dash F Option Additional Meter/Valve Interface	$1,000.00	No	$1,000.00
Installation (estimated)			$3,000.00
			$4,995.00

*Currently not available to DoD due to IT restrictions but used extensively in the private sector

7.1.2 Installation Costs

Installation costs consists of the labor hours needed to retrofit the existing irrigation system and install a water harvesting and pump system. The major labor requirement was for the rainwater harvesting components and pump system. Installation included replacement of component parts and rerouting the facilities HVAC and rooftop drainage to flow into the harvesting UST. For this cost element, the total number of labor hours to install the water harvesting and pump system was captured from the contractor cost proposal.

7.1.3 Water Cost

Water purchased from the Port Hueneme Water Agency and United Waters has fluctuated in price over the last several years. The cost of potable water used for irrigating the landscape at Building 1100 was $6.66 per 1,000 gallons in 2011. The average unit cost over the last four years (FY2008 to FY2011) is $6.95 per 1,000 gallons. For purposes of the cost model, the lowest rate occurring at FY 2010 of $6.54 per 1,000 gallons will be used.

7.1.4 Electrical Cost

Electrical power is required to run the controller, sensors, and irrigation pump. The cost model includes the electrical cost to operate the system, which is $0.14 per kilowatt hour based on unit electrical cost information from 2011. The power requirements for the controller and sensors were considered insignificant and were calculated instead from direct metering and then were added to the overall utility cost.

7.1.5 Maintenance Costs

Maintenance costs were the expenditures incurred for any repairs, troubleshooting, and similar maintenance calls necessary for the smart water conservation system to operate properly. Labor costs were assumed at $45 per hour for the cost model.

7.1.6 Operator Training Costs

Operator training costs were the labor costs required for the landscape manager to familiarize oneself with the controller and any unique hardware. Familiarization included making basic program changes and troubleshooting. Training costs were determined by tracking the labor hours used for reviewing product literature multiplied by the hourly rate. Labor costs were assumed at $45 per hour for the cost model.

7.1.7 Lifecycle Costs

The lifecycle costs of the smart water conservation system combined capital costs, installation, maintenance, and yearly operations costs. It was expected that the life of the smart water conservation system ranged from 10 to 15 years, except for the UST which can last up to 50 years. The procurement and installation of the individual system components were a one-time cost. Maintenance and operator costs were based on required annual maintenance, such as filter change-outs and tank cleaning.

7.2 COST DRIVERS

The most significant cost drivers for the implementation of the smart water conservation system at a potential deployment site are the cost of a water harvesting storage tank and the cost of potable water. The cost of the storage tank is directly linked to its size and composition. Determining the proper tank size for a specific site is a challenge, as there is no simple strategy that links tank sizing for irrigation with economic viability. An iterative economic analysis must be performed as highlighted in Section 7.3 that considers tank size based on site average monthly rainfall data, roof area, and irrigation demand (based on turf type and area and average monthly ET) with the cost of potable water. Several tank sizing guidance strategies were employed as a starting point to evaluate economic feasibility. Figure 12, Tank Sizing Options for Building 1100, provides the various tank size options considered for Port Hueneme based on roof area, average monthly rainfall, and turf area if the entire smart plot was 7,560 square feet. Ultimately, the tank at Port Hueneme was sized based on the Energy Independence and Security Act (EISA) Section 438 of 2007, managing on-site the total volume of rainfall from the 95th percentile storm, which was approximated at 20,000 gallons' storage capacity.

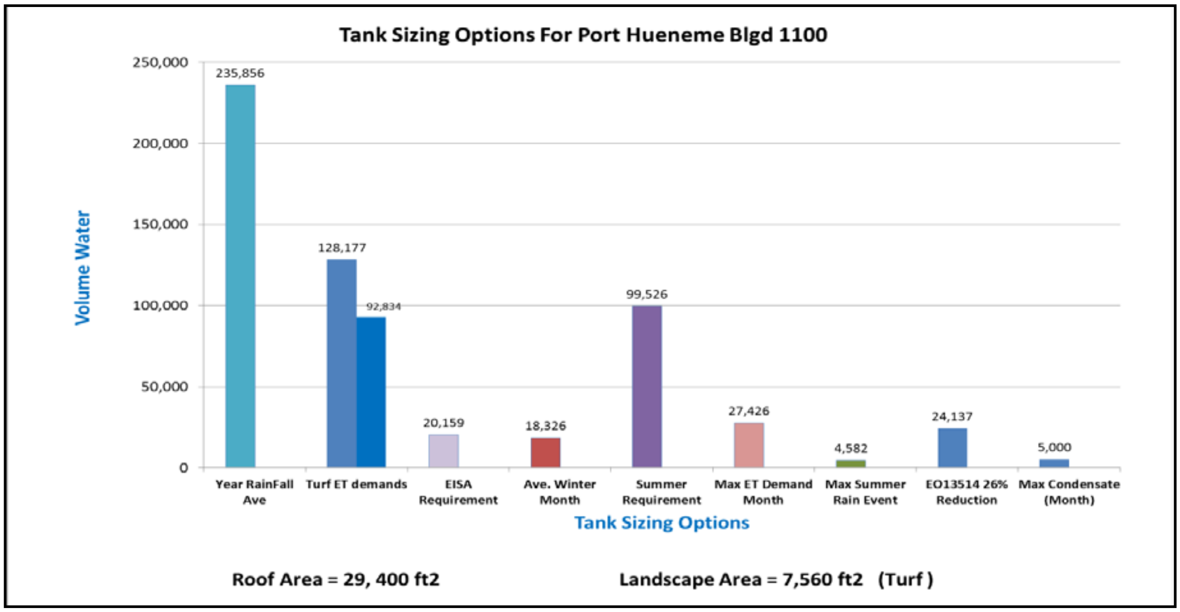

Figure 12. Tank Sizing Options for Building 1100

As mentioned earlier, discussions with the facility manager and the site conditions dictated a below ground tank over the above ground tank. However, each type has been implemented for water harvesting in drought areas in Texas and California. Each type of tank has unique site-specific implementation requirements that increase cost.

Site-specific cost considerations for the underground tank implementation include:

- Determining the existence of underground utilities (retrofit concern)
- Installing sub foundation and cover
- Excavation, and landscape and tree removal (retrofit concern)
- Disposing of excavation spoil (retrofit concern)
- Engineering and design for high groundwater

Site-specific cost considerations for the above ground tank implementation include:

- Engineering and design for seismic and wind loads
- Installing foundation
- Anchoring restraint system for seismic and wind load
- Equipment cost (crane support for larger tanks)

Overall, the cost of potable water compared to the cost savings resulting from water harvested must be considered before installing any tank. Accordingly, a sensitivity analysis was performed illustrating the cost of potable water compared to the amount of water harvested by the system. Given a potable water cost at $6.54 per 1,000 gallons, tank cost would have to be less than $0.50 per gallon to provide a payback at the established 20-year period. If current tank costs were held at $3.13 per gallon, then potable water costs would have to be $34 per 1,000 gallons to meet the 20-year performance objective.

The ideal geographic area to install and implement the entire smart water conservation system are areas such as Tucson, Arizona and Fort Hood, Texas which receive summer monsoonal rains that can replenish the water harvesting tank during the summer months when demand is greatest. In addition, they are also known to generate large amounts of HVAC condensate. In areas such as southern California, the goal is to install the largest tank possible to irrigate as long into the summer as possible. However, the economics do not indicate that there is a reasonable return on investment.

7.3 COST ANALYSIS AND COMPARISON

Table 8, System Payback Summary for Three Smart Water Scenarios, summarizes system payback for three (3) different scenarios at a typical administrative facility surrounded by irrigated turf. Building 1000, found at NBVC, was chosen for the analysis and comparison as it has substantial turf area and could benefit from a smart water conservation system. The turf is currently irrigated with a traditional, timer-based irrigation system.

Scenario 1: DoD Administrative building with turf retrofitted with Smart ET controller.

Scenario 1 assumes the retrofit of Building 1000, replacing a timer based controller with a Calsense controller. This scenario assumes that a new Calsense ET controller will be installed at an estimated cost of $12,000. For this scenario, the water harvesting tank size is 0 gallons and all harvest tank related costs are $0. The facility was built at a time when there was minimal interest in water efficient landscape. The Return On Investment (ROI) is less than six years for retrofitted installations.

Scenario 2: DoD Administrative building with turf retrofitted with Smart System.

Scenario 2 assumes the retrofit of Building 1000, with the entire smart water conservation system excluding the condensate harvesting component since the building does not have air conditioning. The water harvesting tank was sized to satisfy current EISA requirements.

Scenario 3: DoD Administrative building with turf assumed new construction with Smart System.

Scenario 3 assumes new construction of Building 1000, (holding constant the existing size of both the building and turf area) and installing both the smart ET controller and water harvesting component. The building does not have an air conditioning unit, but for this analysis the condensate harvesting is included. The water harvesting tank was sized to concurrently satisfy current EISA requirements for storm water management using a cistern. Only about two of the irrigation zones would be outfitted with purple pipe for coverage by the harvested water, as tank capacity can only match irrigation demand for approximately 2 zones. The ROI is less than 11 years for new construction installations.

In summary, Scenario 1 would be the easiest to implement and has the shortest payback time (i.e., at 5.2 years). With a payback time of 34.1 years, Scenario 2 would be the least favorable option due to its minimal cost effectiveness for reducing potable water use for landscape irrigation in southern California. Leveraging the EISA requirement to manage water with cisterns in future building construction, Scenario 3 may be a practical way to justify the implementation of a smart water conservation system as it has a favorable payback.

Table 8. System Payback Summary for Three Smart Water Scenarios

SITE CONDITIONS/ASSUMPTIONS	Scenario 1	Scenario 2	Scenario 3	UNITS/NOTES
Climate	Mediterranean	Mediterranean	Mediterranean	
Roof Area (plan view)	23,600	23,600	23,600	FT2
Turf Size	35,000	35,000	35,000	FT2
Average Rain Per year	14	14	14	Inches/year
Rainwater Available @ 50% normal	105,301	105,301	105,301	gallons
Average ET Demand for Turf (Blue Grass, Tall fescue)	34	34	34	Inches/year
Average Summer ET requirement for Turf	21	21	21	Inches
Retrofit or New Construction	Retrofit	Retrofit	New Construction	
HARVEST TANK INFORMATION				
Harvest Tank (Estimated Cost per gallon $1.50 -$5.00)	$0.00	$3.11	$3.11	Material and Installation Cost
Above ground or Below ground	Below Ground	Below Ground	Below Ground	
Estimated size of tank	0	20000	20000	gallons
Tank Service life	50	50	50	years
Estimate of total yearly volume of Condensate	15000	0	15000	
UTILITIES UNIT COST				
Water Cost	$6.54	$6.54	$6.54	Cost per 1000 gallons
Electrical cost	$0.14	$0.14	$0.14	Cost per KW-h
SMART WATER SYSTEM COMPONENTS				
Capital Cost of Calsense Controller ($12,000)	$12,000	$12,000	$12,000	
Capital Cost of pump package and makuep water($4141)	$0	$4,141	$4,141	
Capital Cost of Water Harvest Component (Size dependent)	$0	$62,200	$59,090	
Capital Cost of First Flush and Ancillary (5% or Water Harvest)	$0	$3,110	$2,955	
Smart Oper and Maint. cost (1 hours per year)	$0	$50	$50	
Smart Training (One time only)	$60	$60	$60	
If function: No harvest tank = 0, If tank size > 0 = 1	0	1	1	
Capital Cost (Retrofit)	**$0**	**$81,561**	**$0**	
Capital Cost (New Construction)	**$0**	**$0**	**$25,115**	
VOLUME OF WATER NEEDED				
Average Water Demand (ET Demand -Rainwater)	20	20	20	inches
Irrigation Efficiency of Smart Water System	0.55	0.55	0.55	From Demonstration
Total water Needed for Satisfactory Turf (Timer Based)	781,433	781,433	781,433	gallons
Total irrigated water Needed for Satisfactory Turf (Smart)	429,788	429,788	429,788	gallons
Water Harvest Tank efficiency Factor	1.5	1.5	1.5	From Demonstration
Total Potable water for turf Plot	414,788	399,788	384,788	
Economic Analysis Results				
Water Cost annual increase (2% escalation)	0.02	0.02	0.02	Percentage
STATUS QUO: Timer- (Potable Water Cost Year 1)	$5,111	$5,111	$5,111	
SMART PLOT: (Potable Water Cost Year 1)	$2,811	$2,615	$2,517	Assumes potable water needed
SMART PLOT: (Electrical Cost)	$0	$52	$52	
Cost Avoidance (Year 1)	$2,300	$2,393	$2,492	
Water reduction (Percent) reduced by Tank	0.00%	6.98%	6.98%	Percentage
Payback (Retrofit)	**0.0**	**34.1**	**0.0**	**years**
Payback (New Construction)	**5.2**	**0.0**	**10.1**	**years**

In general, it is not cost effective to reduce potable water usage for landscape irrigation due to the relatively short rainy season (and mostly dry summer season) in southern California and the high cost of retrofitting a water harvesting system. Drought prone areas like Tucson, Arizona, and Killeen, Texas, which have consistent rain in the summer due to a monsoonal weather pattern, may have a better payback. In the scenarios above using water harvesting systems, the harvesting system accounts for about 7% of the water used for irrigation. However, as water costs increase and regulations limit the amount of potable water that can be used for irrigation purposes, the viability of using water harvesting systems will increase.

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8.0 IMPLEMENTATION

In some regions of the United States, where water use is more highly regulated due to drought conditions and general water scarcity, implementation of water-saving systems is becoming a necessity. In regions where water is scarce, cost and ease of implementation and operation and maintenance requirements are evaluated to determine whether implementation of water harvesting or smart water conservation systems are feasible options. This section presents the regulations, end use, procurement issues, and lessons-learned which were identified during the demonstration study.

8.1 PERTINENT REGULATIONS, EXECUTIVE ORDERS, CODES AND STANDARDS

There has been little consensus among the regulators with regards to standard plumbing and maintenance of smart water conservation systems, especially in the water harvesting components. However, some states have provided their own guidance manuals on water harvesting and basic minimum standards.

As mentioned in Section 1.3, the primary federal regulatory driver for this demonstration project is EO 13693, which requires federal agencies to improve water use efficiency and management. Since landscape irrigation often represents one of the largest demands of potable water at DoD facilities, smart water conservation systems can make significant progress at achieving the EO 13693 goals.

8.2 END USER CONCERNS

End users should budget for manpower to maintain the smart water conversation system. Most of the maintenance required is on the water harvesting tank and the first flush diverter. The maintenance is not considered exorbitant, but routine actions must be performed at a minimum frequency. Pumps will fail over time and the facility owner should budget for one (1) new pump every 5 years. It would be advisable to procure a backup pump that is available throughout the year in the event of a pump failure.

Tanks losing make-up water would defeat the overall purpose of the smart water conservation system, which is to reduce potable water use and associated energy. All tank systems have the potential to leak, but, with proper installation, the polyethylene material used to encapsulate the tank modules will hold up for years underground.

8.3 PROCUREMENT ISSUES

The equipment used on the smart water conservation system, apart from the NAVFAC-developed first flush diverter, is commercially available off-the-shelf. For future installation, planners should consider procuring soil-based or ET controllers using a credit card, Bills of Material, or small contracts. The basic ET controller can be purchased as-is or customized with options, which could take one or two weeks to build. The first flush diverters originally purchased for the demonstration project were ordered from a company in Australia through a local U.S. distributor requiring a two to three-week lead time. All other components are readily available through local sources.

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