ESTCP

FINAL REPORT

Underground Thermal Energy Storage (UTES) as a DoD Facilities UESC Energy Conservation Measure

Eric Myers
Brandon Caves
Chuck Hammock
Gulf Power Company

November 2022

ESTCP Project EW18-5311

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
30/11/2022

2. REPORT TYPE
ESTCP Final Report

3. DATES COVERED *(From - To)*
9/17/2018 - 9/17/2022

4. TITLE AND SUBTITLE
Underground Thermal Energy Storage (UTES) as a DoD facilities UESC Energy Conservation Measure

5a. CONTRACT NUMBER
18-C-0090

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Eric Myers, Brandon Caves and Chuck Hammock
Gulf Power Company

5d. PROJECT NUMBER
EW18-5311

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Gulf Power Company
One Energy Place
Pensacola, FL 32520

8. PERFORMING ORGANIZATION REPORT NUMBER
EW18-5311

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Environmental Security Technology Certification Program
4800 Mark Center Drive, Suite 16F16
Alexandria, VA 22350-3605

10. SPONSOR/MONITOR'S ACRONYM(S)
ESTCP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
EW18-5311

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This project was proposed to build confidence in the underlying Underground Thermal Energy Storage (UTES) technology in its proposed Aquifer Thermal Energy Storage (ATES) configuration through the extensive documentation, and before/after energy metering requirements of an ESTCP Project. The purpose of this demonstration is to engineer, construct, and extensively document a DoD UTES system installation, whose construction is funded primarily via a Utility Energy Service Contract (UESC) contracting vehicle.

15. SUBJECT TERMS
Underground Thermal Energy Storage, UTES, DoD Facilities, UESC Energy Conservation Measure, UESC, District heating and cooling, geothermal, energy efficiency, installation resilience, HVAC, thermal energy storage, TES, heat pump

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
UNCLASS	UNCLASS	UNCLASS	UNCLASS	107	Eric Myers / (850) 444-6830

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

FINAL REPORT
Project: EW18-5311

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

ACRONYMS AND ABBREVIATIONS

ADC	Adiabatic Dry Cooler
AHU	Air Handling Unit
ATES	Aquifer Thermal Energy Storage
BTES	Borehole Thermal Energy Storage
BTU(H)	British Thermal Unit (per Hour)
CGD	Certified Geothermal Designer
COP	Coefficient of Performance
CxA	Commissioning Agent
DDC	Direct Digital Control
DoD	Department of Defense
DoE	U.S. Department of Energy
EER	Energy Efficiency Ratio
ESTCP	Environmental Security Technology Certification Program
etc.	Etcetera
GHP	Geothermal Heat Pump (also known as GSHP or GSHC System)
GHG	Green House Gas
GHX	Ground Heat Exchanger
GPM	Gallons Per Minute
GSHP(C)	Ground Source Heat Pump (or sometime Cooling (system) is substituted for the word Pump. Alternately called a GHP
HVAC	Heating, Ventilating and Air-Conditioning
kWh	Kilo-Watt Hour
LCC	Life Cycle Cost
NASP	Naval Air Station Pensacola
NAVFAC SE	Naval Facilities Engineering Command Southeast
NEBB	National Environmental Balancing Bureau
NIST	National Institute of Standards and Technology
PE	Professional Engineer
PO	Performance Objective
POC	Points of Contact
PV	Photo-Voltaic
TAB	Test, Adjust and Balance
TRNSYS	Transient

UESC	Utility Energy Service Contract
US	United States
UTES	Underground Thermal Energy Storage
VAV	Variable Air Volume

ABSTRACT

INTRODUCTION

This project was proposed to build confidence in the underlying Underground Thermal Energy Storage (UTES) technology in its proposed Aquifer Thermal Energy Storage (ATES) configuration through the extensive documentation, and before/after energy metering requirements of an ESTCP Project. The purpose of this demonstration is to engineer, construct, and extensively document a DoD UTES system installation, whose construction is funded primarily via a Utility Energy Service Contract (UESC) contracting vehicle.

TECHNOLOGY DESCRIPTION

Though there are other architectures of UTES in use throughout the world, this project will be focused on ATES. The candidate's Bases, buildings, and geologies/aquifers were investigated, and it was determined that the most effective version of UTES to implement under ESTCP/UESC would be ATES because:

1. UESC projects must be as cost effective as possible since their entire cost is normally funded from energy savings.
2. Gulf Power's operating territory, located in the "panhandle" of Florida, is blessed with both prolific aquifers that minimize the cost of water wells, many drillers, and a regulatory authority, the FL Department of Environmental Protection (DEP) and its associated Water Management Districts (WMDs), that have permitted thousands of geothermal injection wells.

PERFORMANCE AND COST ASSESSMENT

Table A.1. Performance and Cost Assessment

Perfromance Assessment

Baseline System		
	Total	KBTU/Yr
KWh/Yr	**6,204,180**	21,168,662
Therms/Yr	**112,613**	11,261,292

ATES System (ECM)		
	Total	KBTU/Yr
KWh/Month	**5,484,932**	18,714,589
Therms/Yr	**849**	84,942

Cost Assessment

Cost Element	Estimated Cost
ATES Cold & Warm Wells	$ 1,965,706
Adiabatic Dry Coolers/Outside and Underground ATES Piping	$ 3,212,774
Mechanical Room Local HVAC Plants X 4 Buildings	$ 5,194,232
Electrical Utility Upgrades X 4 Buildings	$ 1,165,907
O&M Cost for 2 Years	$ 205,477
Commissioning & TAB	$ 176,106

IMPLEMENTATION ISSUES

Despite the various architectures of Underground Seasonal Thermal Energy Storage (USTES) being rare in the United States, its implementation as part of this project, if the project had continued into construction phase, would have been relatively straight-forward. The main implementation issue related to the ATES system was lack of funding outside of the UESC. Essentially the UESC would pay for the ATES Wells, but NASP could not find funding for the remaining architecture of the system.

EXECUTIVE SUMMARY

INTRODUCTION

This project was proposed to build confidence in the underlying Underground Thermal Energy Storage (UTES) technology in its proposed Aquifer Thermal Energy Storage (ATES) configuration through the extensive documentation, and before/after energy metering requirements of an ESTCP Project. The purpose of this demonstration is to engineer, construct, and extensively document a DoD UTES system installation, whose construction is funded primarily via a Utility Energy Service Contract (UESC) contracting vehicle. The demonstration should occur because from a DoD energy prospective, ATES will reduce the building's HVAC energy consumption, conservatively speaking, by at least 30% vs. the existing HVAC system. The ATES, system will also contribute to the needs of DoD by building enhanced resiliency into the buildings' HVAC system by utilizing inside-the-fence underground resources to heat and cool the buildings, and to store cooling and/or heating energy.

OBJECTIVES

The objective of this demonstration is to engineer, construct, and extensively document a DoD UTES system installation, funded via a UESC contracting vehicle. Furthermore, through the extensive documentation, and before/after energy metering requirements of an ESTCP Demonstration Project, this project will build confidence in the underlying UTES technology, both in its proposed ATES configuration, and its closed-loop/borehole BTES counterpart configuration.

Validate:

The project will validate the performance, costs, and benefits of the technology by monitoring and comparing the existing energy consumption of the buildings before and after the GHP/UTES technology is deployed and by carefully tracking the cost associated with its installation and presenting this data in report form.

Findings and Guidelines:

It is expected that the insights gained, data obtained, and reports published from the successful deployment of GHPs with UTES at NASP will provide DoD policy makers with publications of a "new" technology that can demonstrate it is possible to successfully utilize UTES under a UESC to reduce energy and water consumption cost effectively.

Technology Transfer:

The demonstration will create conditions to facilitate the transfer of UTES technology by training DoD personnel in UTES systems. Hard data indicating the real construction cost and energy cost associated with this project will be documented and provided to DOD personnel. Several newsletters will be created using data from this project. The newsletters will be mailed out to individuals who have signed up on a mailing list.

Acceptance:

Acceptance of the technology within the DoD can best be accomplished by providing documented energy and water savings associated with the project, having strong references from the DoD partners involved with the project, and the PI/Co-PI being readily available to future DoD personnel that are considering the technology.

TECHNOLOGY DESCRIPTION

Though there are other architectures of UTES in use throughout the world, this project will be focused on ATES. The candidate's Bases, buildings, and geologies/aquifers were investigated, and it was determined that the most effective version of UTES to implement under ESTCP/UESC would be ATES because:

1. UESC projects must be as cost effective as possible since their entire cost is normally funded from energy savings. ATES systems, with their direct use of groundwater, via just a few water wells, at UESC-scaled projects, are generally both lower in capital cost and operating cost than their closed loop BTES counterpart's due to the later requiring 100's of boreholes (wells) on mid-size projects and only transferring heat via conduction vs. convection. They also benefit from the actual "mass transport" of a highly efficient heat transfer medium (water) in and out of the geology.
2. Gulf Power's operating territory, located in the "panhandle" of Florida, is blessed with both prolific aquifers that minimize the cost of water wells, many drillers, and a regulatory authority, the FL Department of Environmental Protection (DEP) and its associated Water Management Districts (WMDs), that have permitted thousands of geothermal injection wells.

PERFORMANCE ASSESSMENT

The following information provides a summary of the data analysis used for each performance objective.

Facility Energy Usage Reduction:

Table ES.1. Facility Energy Usage Analysis

Total Area (Sq Ft)	456000														
Energy Analysis Summary Sheet - ATES for Bldgs 3901, 3902, 3903, & 3904															
Baseline System															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	KBTU/Yr	KBTU/Sqft/Yr
KWh/Yr	405,404	360,712	469,236	503,732	574,896	612,752	639,568	644,300	593,888	551,724	448,252	399,716	**6,204,180**	21,168,662	
Therms/Month	10,116	8,975	9,510	8,988	9,590	8,987	9,240	9,590	8,987	9,415	9,318	9,896	**112,613**	11,261,292	
														32,429,954	**71.12**
ATES System (ECM)															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	**KBTU/Yr**	**KBTU/Sqft/Yr**
KWh/Month	336,329	303,809	376,605	408,470	504,551	591,287	622,003	624,338	555,620	463,546	363,608	334,766	**5,484,932**	18,714,589	
Therms/Month	-	502	-	-	-	-	-	-	-	-	-	347	**849**	84,942	
														18,799,531	**41.23**
KWh Savings/Yr	**719,248**														
Therms Savings/Yr	**111,764**														
														Percent Reduction in EUI	42%
Electric Savings/Yr ($)	**$ 60,625.39**		Gas Rate	$ 0.583											
Gas Savings/Yr ($)	**$ 65,158.12**		Electric Rate	$ 0.084											
Total	**$ 125,783.51**														
Capital Cost	**$ 1,965,706**														
Payback (Yrs)	**15.6**														
Notes:	The Baseline System data is modeled and calibrated to metered data. The ATES System is modeled data since the project did not progress to the construction phase.														

Maintainability of the System:

Not enough data since NASP was unable to provide maintenance costs or logs for the baseline system. However, it is obvious that the maintenance would be the same or less since the ATES system replaced the use of a cooling tower, and boiler and other items are similar in maintenance cost.

Successful execution of a Utility Energy Service Contract (UESC) utilizing Underground Thermal Energy Storage (UTES):

The estimated simple payback for this project was calculated to be greater than 15 years. This was based on the cost of the new geothermal wells and rehabbing of the existing irrigation wells. See Table Above.

COST ASSESSMENT

Table ES.2. Cost Model for a ATES System

Cost Element	Data Tracked During the Demonstration	Estimated Costs
ATES Cold & Warm Wells	• Equipment (Pumps/Inj. Valves) • Branch electrical circuits; 6 ea.	$1,965,706
Adiabatic Dry Coolers / Outside and Underground ATES Piping	• Interconnecting utility ATES piping • System Adiabatic Dry Coolers • Elec. Branch Circuits	$3,212,774
Mechanical Room Local HVAC Plants x 4 Buildings	• Three 85-ton Heat Recovery GHP Chillers/Heaters Modules • Pumps • Heat Exchangers • Expansion and Buffer Tanks • 2- AHU Hot Water Coils	$5,194,232
Electrical Utility Upgrades x 4 Buildings	• 12kV Power Lines • XFMRs • New 480V services • Service Panels	$1,165,907
O&M Cost for 2 Years	• Operation and Maintenance Cost:	$205,477
Commissioning & TAB	• Cost of Commissioning • Cost of TAB	$176,106

Cost Element: ATES Cold & Warm Wells

- An ATES system utilizes cold and warm wells as the storage device for seasonal energy and then extracted when the stored energy can be used more efficiently by the HVAC system. The ATES system consists of a total of six water wells. Three wells were to be rehabbed existing water wells, and three wells were to be newly constructed wells.

The wells are 10” in diameter, and 255’ deep. The newly constructed wells have a 60-foot screened interval.

- Each well contains a 40 HP submersible pump and a 4” injection valves sized for 493 GPM.

Cost Element: Dry Coolers or Cooling Towers

- The ATES system is designed to use adiabatic dry coolers as the active device for capturing the seasonal energy for storage into the GHX or wells. Large dry coolers/cooling towers operating at low fan and pump speeds to minimize energy consumption with minimal loss in heat rejection capacity. The ATES system consists of two adiabatic dry coolers capable of 1,490 tons of cooling in the wet mode and 1,079 tons in the dry mode.

Cost Element: Mechanical Room Local HVAC Plants

- The modular chillers are the engine behind the ATES system. They are the device that uses the source water produced by the ATES system to generate chilled and hot water for use by the AHUs. Their high efficiency at ideal conditions as well as their ability to operate with heat recovery capabilities will have an impact on energy savings. The modular chiller for this project consists of three 85-ton modules with heat recovery capabilities.
- Inline pumps were used for this project for the Dry Cooler loop, the chilled water loop, the hot water loop, and the source water loop
- The hot water heating coils in the Air Handlers were designed to be replaced with deeper coils to utilize lower temperature water.
- Buffer tanks were used for the hot, chilled, and source water loops to gain system volume.

Cost Element: Electrical Utility Upgrades

- The electrical upgrades consist of new 12kV power lines, upgraded transformers, a new 480 V to each building, and new service panels

Cost Element: Operation and Maintenance Cost

- The O&M Cost consists of Operation and Maintenance Costs of the new system for a period of two years.

Cost Element: Commissioning and TAB

- Commissioning and TAB was determined for this project. Commissioning and TAB costs can reasonably be interpolated or extrapolated on a square foot basis. The approximate total floor area for the combined four buildings is approximately 392,036 square feet.

IMPLEMENTATION ISSUES

Despite the various architectures of Underground Seasonal Thermal Energy Storage (USTES) being rare in the United States, its implementation as part of this project, if the project had continued into construction phase, would have been relatively straight-forward.

The main implementation issue related to the ATES system was lack of funding outside of the UESC. Essentially the UESC would pay for the ATES Wells, but NASP could not find funding for the remaining architecture of the system. If the project would have been able to simply convert an already water cooled system to ATES the total cost would have been much less and the payback period would have been much lower. The buildings chosen at NASP needed an electrical upgrade to support water cooled heat recovery chillers to be utilized in place of the currently installed water cooled centrifugal chillers installed in the central plant.

- Regulatory/Permitting Challenges: Though the challenges described herein are specifically related to the implementation of ATES (in Florida), the issues encountered will be generally applicable for most ATES projects throughout the US. With the project involving water wells/injection wells, they fall under the jurisdiction of the FL Department of Environmental Protection (FL DEP), hereinafter referred to as FLDEP. In the arena of so-called Underground Injection Control (UIC), the FLDEP acts on behalf of the Federal Government's Environmental Protection Agency (EPA). They have been given the authority to rule on groundwater injection though a legal mechanism called "Primacy". For more details on Primacy, see https://19january2021snapshot.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program_.html Although ATES projects simply withdraw local groundwater, change it a few degrees and transfer it back to the aquifer from whence it came, legally this is considered a "Class V Injection Well" and therefore it falls under EPA's jurisdiction and in this case, a UIC permit is required from FLEPD. In some states, this is a complex affair. In FL it proved to be a rather easy permit to obtain. However, the injection permit did not have to be obtained sine the project did not move forward to the construction phase.

- ATES regulations/permitting: As described previously, the fact that ATES systems inject water into the ground invoke the need for a Class V, UIC permit to inject the water. "Class V" is basically a group of widely diversified type wells that EPA groups together when they don't fall into any other category. It includes everything from "Cesspools" (no longer used), drainage wells for storm water, recharge wells for aquifers, saltwater intrusion barrier wells and more. To determine if the EPA itself or a State Authority issue the Class V UIC permit, see the hyperlink in paragraph 8.2 which is also included with the following figure.

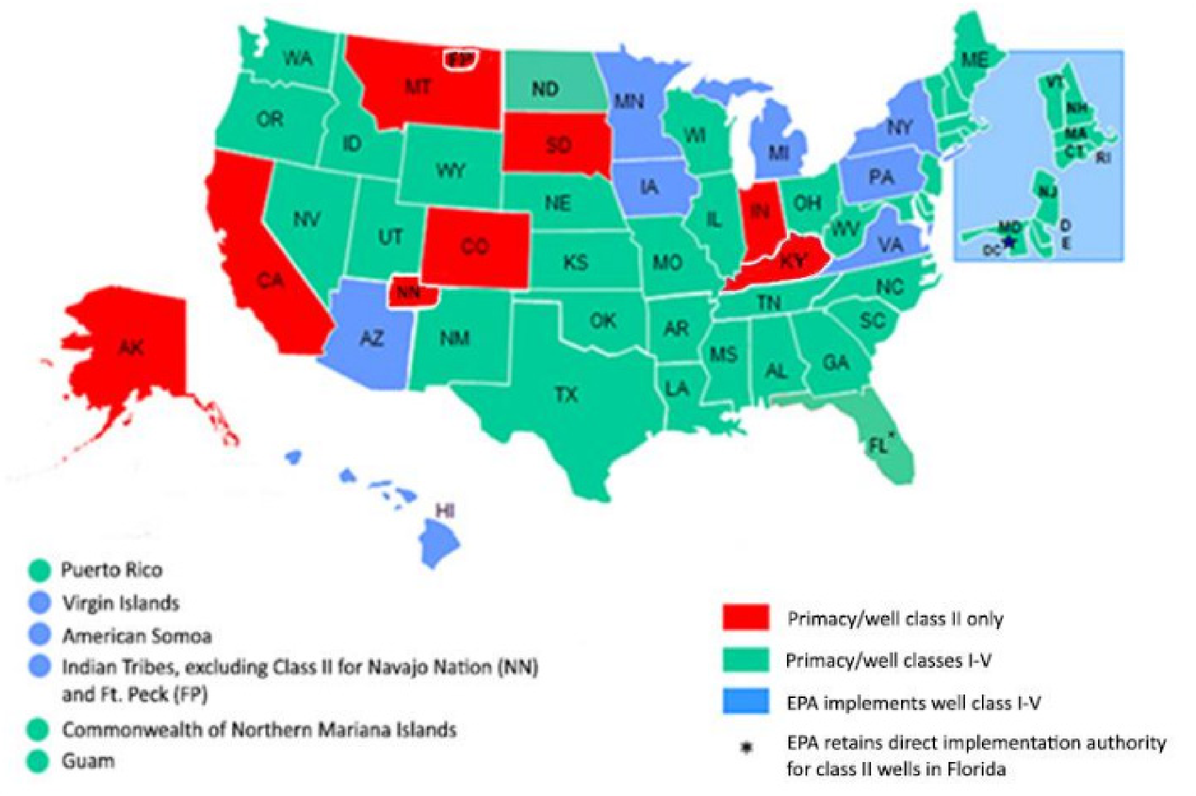


Figure ES.1. Map of States with/without Primacy to Issue Class V UIC Permits

This report is intended to guide potential users of this technology in all 50 states. As an illustration of the regulatory situation in other states, Florida (FL) serves as a good example. There are in excess of 5000 "air conditioning (injection) wells" (a cousin to an ATES wells) active in Florida. The statewide UIC program manager in FL, Joe Haberfield, PG, advises that permitting these wells typically only takes a few weeks and is in fact handled under the same "General Permit #0001" for all projects. When considering an ATES system for a specific Base, the UIC permit, while critical, is not necessarily a complicated or protracted exercise. The key take-away is to talk to the applicable state's UIC Coordinator, discuss the project in depth, understand their position for what is required to obtain a UIC permit and determine where the decision authority resides. If it is not the UIC Coordinator, attempt to meet with the ultimate decision makers and understand their position. Sometimes, decision authority is as high-up as the head of the entire State's EPA (equivalent) program, and sometimes, a "local" water management district's manager can sign off. In certain states, UIC permits can be done under "permit by rule" protocols or via a "general permit", and the process is relatively painless.

1.0 INTRODUCTION

This project was proposed to build confidence in the underlying Underground Thermal Energy Storage (UTES) technology in its proposed Aquifer Thermal Energy Storage (ATES) configuration through the extensive documentation, and before/after energy metering requirements of an ESTCP Project. The purpose of this demonstration is to engineer, construct, and extensively document a DoD UTES system installation, whose construction is funded primarily via a Utility Energy Service Contract (UESC) contracting vehicle. The demonstration should occur because from a DoD energy prospective, ATES will reduce the building's HVAC energy consumption, conservatively speaking, by at least 30% vs. the existing HVAC system. The ATES, system will also contribute to the needs of DoD by building enhanced resiliency into the buildings' HVAC system by utilizing inside-the-fence underground resources to heat and cool the buildings, and to store cooling and/or heating energy.

1.1 BACKGROUND

This project will address an opportunity within the DoD of reducing the billions of dollars spent on energy and millions of dollars spent on water each year. This project will neatly intersect the energy-water nexus by significantly reducing both energy and water consumption at DoD facilities. The technology involved in the demonstration will be an ATES system. The ATES system will be coupled with Geothermal Heat Pumps (GHP) and/or heat-recovery (GHP) chillers to heat and cool the buildings, and possibly provide domestic hot water. The ATES system will store waste heat and "cold" in the underground aquifer for use in the opposite season. The ATES system will consist of two "sets" water wells (one set of Warm Wells, and one set of Cold Wells). Water will be pumped from the warm wells during the heating season and used for building heat. A heat rejection device such as a cooling tower, or Adiabatic Dry Cooler (ADC) will remove additional heat before injecting the cold water into the cold well(s). In the cooling season, the flow direction is reversed, and the stored cold water is used to cool the building. The buildings will be heated and cooled via the ATES water coupled to geothermal heat pumps via a plate and frame heat exchanger. Should the domestic water heating load be sufficient, domestic water-to-water heat-pumps can also be utilized in the system to provide domestic hot water.

<u>Current Technology State of the Art</u>:

To heat their buildings, DoD currently primarily burns fossil fuels, utilizes electric resistant heat or extracts heat from the cold winter air via air-cooled heat pumps and then the "waste cooling" of the heat pump is discarded into the ambient air where it is carried off-base by convection and wind. Cooling is typically accomplished by either air-cooled condensing units or water-cooled chillers that are assisted by cooling towers that evaporate millions of gallons of water for heat rejection.

DoD rarely takes advantage of the local geology by utilizing Geothermal Heat Pumps which allow access to the superior heat sink/heat source/energy storage capability of the underground and virtually never do they utilize advanced UTES architectures like ATES. However, UTES has been implemented recently by DoD at the Marine Corps Logistics Base (MCLB) in Albany, GA, and at Ft. Benning in Columbus, GA. The UTES system at Ft. Benning is an ATES system like the demonstration project at Naval Air Station Pensacola (NASP). The system at MCLB utilized the BTES architecture.

Current State of Technology in DoD

UTES has been implemented recently by DoD at the Marine Corps Logistics Base (MCLB) in Albany, GA, and at Ft. Benning in Columbus, GA. The UTES system at Ft. Benning is an ATES system similar to the demonstration project at NASP. The UTES systems at MCLB includes a total of 4 Borehole Thermal Energy Storage (BTES) systems. To our knowledge coupling GHPs with BTES and seasonally store waste heating/cooling has not been accomplished in the US beyond the four systems at MCLB and there are only a handful of ATES systems in the US though there are thousands of ATES systems in Europe (primarily in the Netherlands).

Technology Opportunity:

If adopted, coupling GHPs with UTES will create Energy Security and resiliency by storing much of its building's thermal energy needs (space heating and cooling and domestic/process hot water) on-base via a system with limited or no moving parts. It also has the capability to significantly reduce energy and water consumption as described herein.

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of this demonstration is to engineer, construct, and extensively document a DoD UTES system installation, funded via a UESC contracting vehicle. Furthermore, through the extensive documentation, and before/after energy metering requirements of an ESTCP Demonstration Project, this project will build confidence in the underlying UTES technology, both in its proposed ATES configuration, and its closed-loop/borehole BTES counterpart configuration.

- Validate:
  - The project will validate the performance, costs, and benefits of the technology by monitoring and comparing the existing energy consumption of the buildings before and after the GHP/UTES technology is deployed and by carefully tracking the cost associated with its installation and presenting this data in report form.
- Findings and Guidelines:
  - It is expected that the insights gained, data obtained, and reports published from the successful deployment of GHPs with UTES at NASP will provide DoD policy makers with publications of a "new" technology that can demonstrate it is possible to successfully utilize UTES under a UESC to reduce energy and water consumption cost effectively.
- Technology Transfer:
  - The demonstration will create conditions to facilitate the transfer of UTES technology by training DoD personnel in UTES systems. Hard data indicating the real construction cost and energy cost associated with this project will be documented and provided to DOD personnel. Several newsletters will be created using data from this project. The newsletters will be mailed out to individuals who have signed up on a mailing list.
- Acceptance:
  - Acceptance of the technology within the DoD can best be accomplished by providing documented energy and water savings associated with the project, having strong references from the DoD partners involved with the project, and the PI/Co-PI being readily available to future DoD personnel that are considering the technology.

1.3 REGULATORY DRIVERS

Many Executive Orders, Policies, Industry Standards, Mandates, and Regulations are pushing all DoD entities to lower energy and/or water consumption. Some examples of these drivers and their relationship to this project are as follows:

Executive Orders:

EO 13514, "Federal Leadership in Environmental, Energy and Economic Performance" stresses Sustainable Buildings, greenhouse gas reduction, water efficiency, and most of the aspects of EO 13423. EO 13423, "Strengthening Federal Environmental, Energy and Transportation Management" mandates reducing energy intensity and water intensity and increasing renewable energy consumption. UTES in the form of ATES proposed for this project provide a means for accessing not only the renewable energy of the earth itself, but also allows the renewable (annually recurring) waste heat and waste cooling of the building to be captured and seasonally stored for use in the offseason. Due to their inherently efficient nature (due to lower/higher heat sink/source temperatures) energy intensity reduction is always achieved with these systems. Evaporative cooling needs are greatly reduced by the UTES system's capability of releasing its heat in winter when the heat can easily flow from the loop into the ambient air, by a "sensible" (vs. latent) heat transfer process.

Legislative Mandates:

EPAct 2005 mandates an increase in the use of renewables and the procurement of energy efficient products and the project provides both of these objectives. The decision to utilize a modular chiller with heat recovery capabilities means that when operating in the heat recovery mode, the effective COP of the unit increases dramatically as a single compressor does the work of two, creating chilled and hot water simultaneously. The Energy Independence and Security Act of 2007 proposes energy reduction goals for all Federal buildings and the UTES system will make a substantial difference in the buildings where it is installed.

Federal Policy:

The Federal Leadership in High Performance and Sustainable Buildings MOU 2006 brought together 16 Federal Agencies to commit to design, construct and operate their facilities efficiently and sustainably which is exactly what the replacement of the existing HVAC systems at NASP will achieve.

DoD Policy:

Strategic Sustainability Performance Plan, Energy Security MOU with DOE, the Army Energy Security Implementation Strategy, the Navy's Task Force Energy and the Air Force Energy Plan all seek the energy efficiency and renewable energy benefits that can be provided by a system such as those provided by coupling GHPs with UTES, the technology behind this ESTCP project.

Guides:

The Whole Building Design Guide (http://www.wbdg.org/) describes the use of geothermal and groundwater cooling specifically as one of the ways to employ renewable energy resources in buildings. More information is at www.WBDG.org.

2.0 TECHNOLOGY DESCRIPTION

Though there are other architectures of UTES in use throughout the world, this project will be focused on ATES. The candidate's Bases, buildings, and geologies/aquifers were investigated, and it was determined that the most effective version of UTES to implement under ESTCP/UESC would be ATES because:

1. UESC projects must be as cost effective as possible since their entire cost is normally funded from energy savings. ATES systems, with their direct use of groundwater, via just a few water wells, at UESC-scaled projects, are generally both lower in capital cost and operating cost than their closed loop BTES counterpart's due to the later requiring 100's of boreholes (wells) on mid-size projects and only transferring heat via conduction vs. convection. They also benefit from the actual "mass transport" of a highly efficient heat transfer medium (water) in and out of the geology.
2. Gulf Power's operating territory, located in the "panhandle" of Florida, is blessed with both prolific aquifers that minimize the cost of water wells, many drillers, and a regulatory authority, the FL Department of Environmental Protection (DEP) and its associated Water Management Districts (WMDs), that have permitted thousands of geothermal injection wells.

2.1 TECHNOLOGY OVERVIEW

This project proposes taking the existing technology of GHPs, which is somewhat known/implemented within the DoD community and coupling it with another technology, UTES. This project would demonstrate that this marriage of GHPs and UTES can truly define "Sustainable Infrastructure" and is innovative in the realm of HVAC systems.

Description:

This project envisions the installation of an ATES system, one of the system types of GHP-UTES HVAC systems. The buildings to receive the ATES HVAC system are existing DoD facilities that are connected to a central chilled water-cooling plant. Each of the buildings contains hot water heating boilers and domestic hot water boilers. The project will include installing heat recovery chillers in each of the four buildings chosen to receive the ATES system. The heat recovery chillers will be connected to the ATES system and will be used to cool the buildings while utilizing the waste heat from the cooling process to provide heat for the building. Domestic hot water will be provided by utilizing water to water heat pumps connected to the ATES system.

The ATES system will be made up of two sets of open loop water wells, cold wells and warm wells. During the heating season water will be extracted from the warm wells and pumped through a plate and frame heat exchanger where it will reject its heat to the building for space and domestic water heating. The ATES water will then be routed through a peak shaving device such as an adiabatic dry cooler or cooling tower to reject more heat from the ATES water into the outside air. The peak shaving device will be utilized only when conditions are favorable for rejecting heat efficiently. The water will then leave the peak shaving device and will be injected into the cold wells where it will be stored in the aquifer for use in the cooling season. In the cooling season, the flow direction will be reversed, and water will be extracted from the cold wells and delivered to the plate and frame heat exchanger where heat is injected into the ATES water from the cooling process of the heat recovery chiller.

The heat recovery chiller in each building will create chilled water for the cooling AHUs in each building, and simultaneously make hot water from the waste heat of the cooling process. The hot water will be used for space heating. The domestic hot water heating will be provided from water-to-water heat pumps. The water-to-water heat pumps will extract heat from the ATES water and deliver it to the domestic hot water for the buildings' domestic hot water needs.

Visual Depiction:

The following diagrams are intended to illustrate the basic arrangement or architecture of an ATES system. Figure 2.1 below is intended to show the basic arrangement of the ATES concept where groundwater is physically extracted from the aquifer, heated or cooled, and re-injected back into the aquifer for later (opposite season) use.

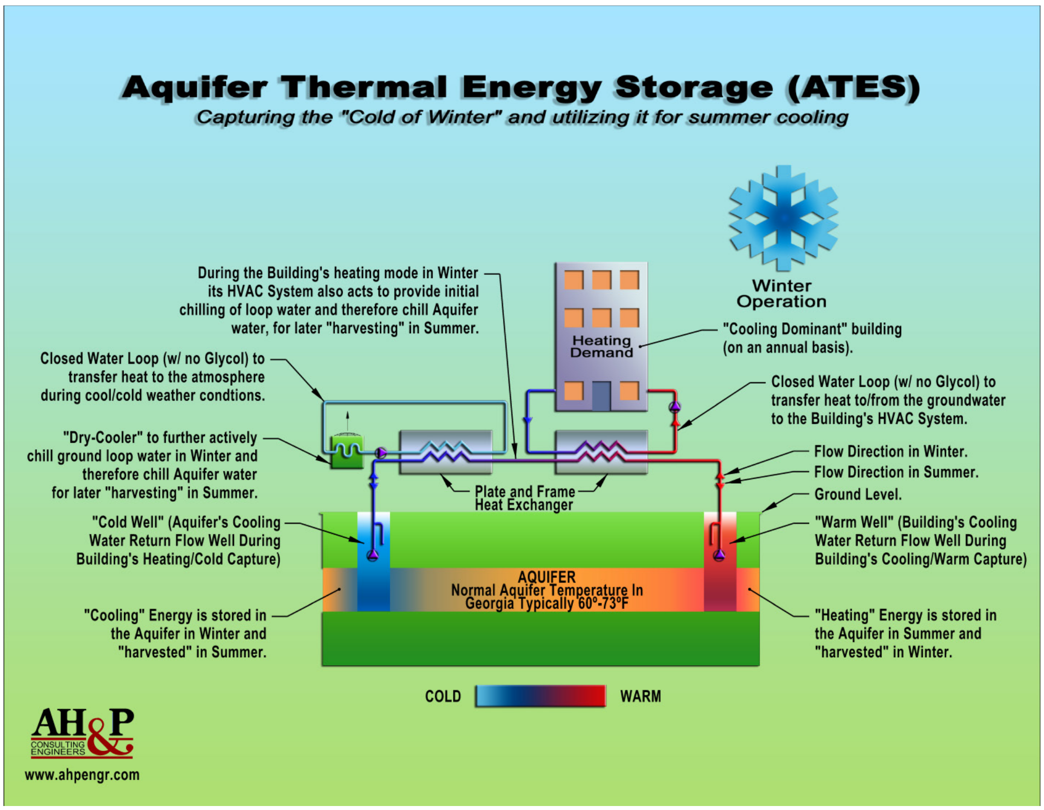


Figure 2.1. Aquifer Thermal Energy Storage (ATES) Overview

ATES wells can act as either injection or extraction wells, so depending on the season water can be extracted from one well then inject into the other well. When the season changes this process can be reversed. The well that was once injecting is now extracting and the well that was extracting is now injecting. This is accomplished by installing an ATES injection valve atop a check valve along with a submersible pump near the bottom of each well. An overall view of the ATES well is in Figure 2.2 and a sample ATES injection valve is in Figure 2.3

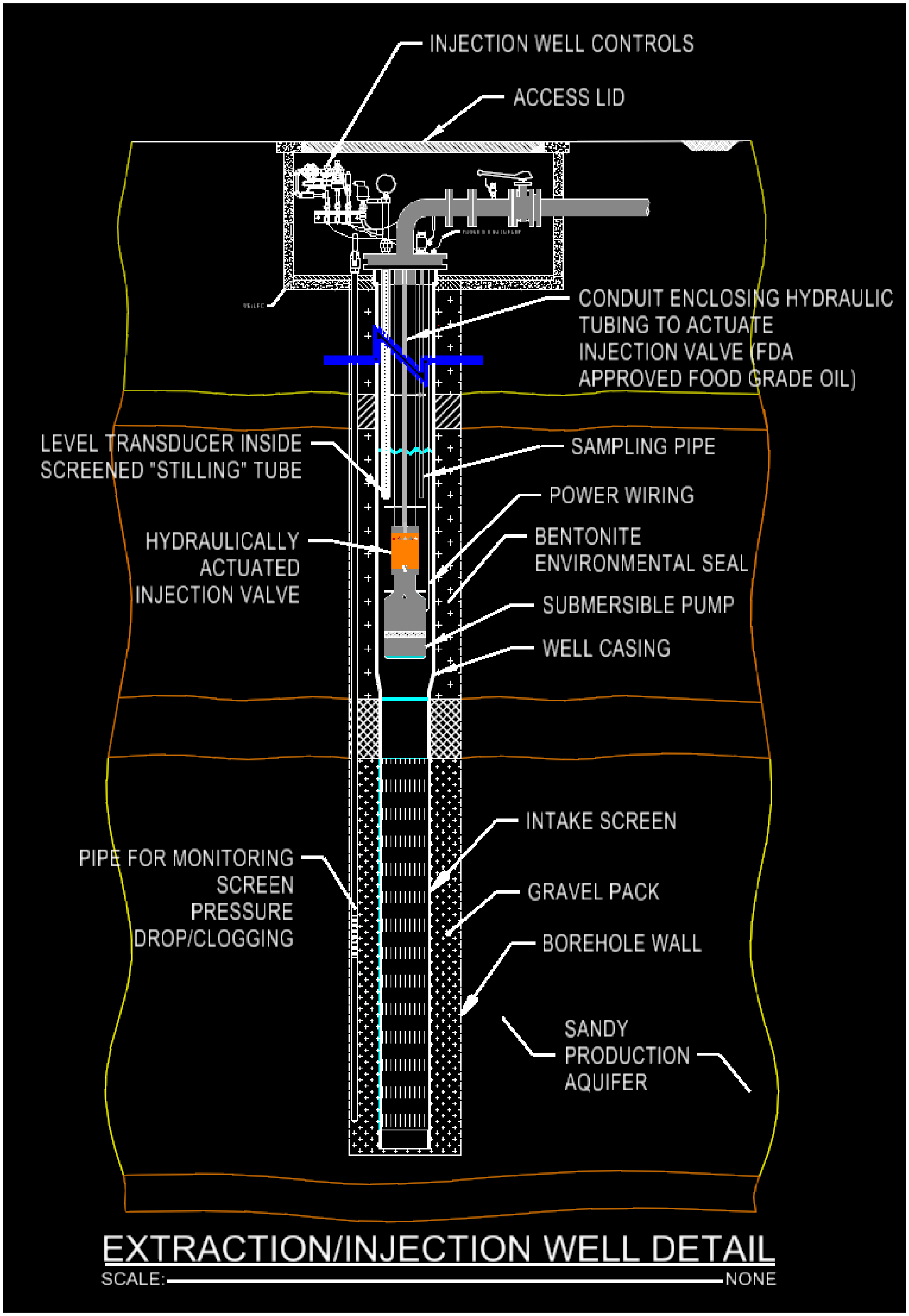


Figure 2.2. ATES Well

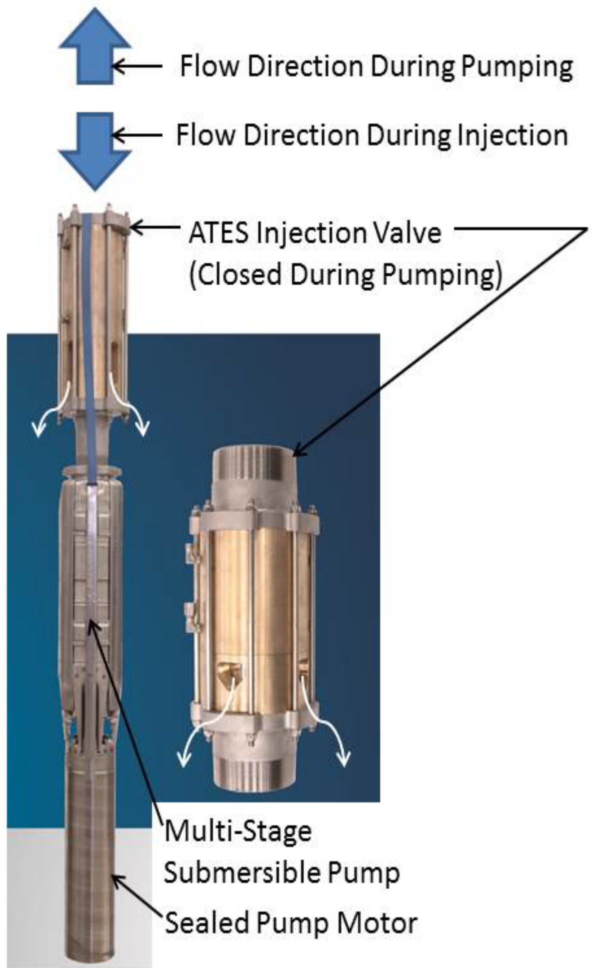


Figure 2.3. ATES Injection Valve

Chronological Summary:

The basic heat pump (reverse Carnot cycle) at the heart of each GHP is approximately 100 years old. GHP's themselves have been in use in this country for over 50 years. Yet, due to obscurity and other issues, GHPs have only achieved 1.5-2.5% market penetration in the U.S., while in portions of other countries have achieved a 10-fold or more market penetration of this remarkable technology. UTES has been wildly successful in the Netherlands, having been implemented in over 1000 projects. Astonishingly, even though we consider America to be the most advanced country in the World, UTES is virtually nonexistent with perhaps two or three partial systems in place in the entire U.S. While GHPs coupled with UTES is new to DoD, globally speaking, it is not new from an equipment or engineering perspective. We have found virtually all the components needed to deploy this technology on both of these projects are already manufactured in North America. With the exception of the proper control algorithms which we are developing, all aspects of the system are available. The major hardware needed to implement an ATES systems are pre-existing in the marketplace and are readily available for commercial deployment.

Expected Applications of the Technology:

GHPs with UTES are a broad description of an HVAC system that comes in many arrangements making it very flexible for wide deployment within DoD. Specifically, and as illustrated by these projects use of "small" (30 ton), "large" (325+ tons), open loop ATES, water-to-air, water-to-water, DX, constant air volume, VAV, and chilled/hot water system sub-types, it is obvious that GHPs with UTES can be deployed in a wide variety of configurations. There are few buildings and/or sites within the DoD domain that cannot utilize GHPs with UTES as one of its various HVAC architectures. From conventional deployments of heating/cooling buildings or domestic water/process loads to unique deployments like runway snow-melt or even heat-pump-less systems that only embrace the UTES portion of this project to store other waste heat sources, solar-thermal, etc., the application of these core technologies is huge within DoD.

2.2 TECHNOLOGY DEVELOPMENT

USTES systems are intended to maximize the energy savings of GHP systems Not only does a USTES system allow the waste heat of cooling systems and waste "cool" of heating systems to be captured, but it also allows for the out-of-season energy capture of the winter's "cold" or summer's "heat" in a cooling dominated or heating dominated buildings, respectively.

While there are numerous operational ATES systems around the world, the ATES system demonstrated for this project, is one of two of this configuration type and operation in the U.S. Open loop geothermal systems are not uncommon for a geothermal heat pump application. However, open loop systems generally allow for one-way water flow. Water is extracted from a dedicated extraction well for both cooling and heating purposes, while injecting water into a dedicated injection well. An ATES system design allows for flow reversibility such that a cold well(s) and hot well(s) is/are intentionally created. Operating the building's HVAC system to utilize the appropriate ATES well increases the HVAC system's COP by supplying the equipment with closet to ideal water temperatures, which decrease the equipment's energy consumption.

The initial step in the design of the ATES system design was to complete an energy model of B3901. B3902, B3903, and B3904 at Naval Air Station Pensacola, FL to determine peak cooling/heating coil loads and annual cumulative cooling/heating coil loads. The energy model was also utilized to simulate the buildings existing energy consumption. Carrier's Hourly Analysis Program (HAP) was utilized for calculating the heating/cooling loads, and for performing the simulations.

Table 2.1. Building Loads

	Cooling		Heating	
Annual Cumulative	24,137,087		231,734	***Btus***
Cooling-to-Heating	104.2	to	1.0	***Ratio***
Peak	6,658.8		752.2	***Btu/hr***
Peak	555		60	***Tons***

With an open loop GHX the maximum water flow of the system is determined and the yield from the wells determined the number of wells that are needed to achieve the desired maximum flow. In particular, with open loop ATES systems not only is there a concern with the water yield from the extraction well, but there is also a concern with the rate at which water can be injected into the injection well without the water mounding to the surface.

To determine if the hydrogeology at NASP could be utilized for an ATES system a pumping test was performed. Existing irrigation wells were located at NASP. These wells facilitated the pumping test while requiring only one additional monitoring well be installed. A local well driller WH Environmental (WHE) was contracted to remove the existing equipment from two of the irrigation wells. Each irrigation well consisted of a large irrigation well and a smaller adjacent well. One of the irrigations wells (Old Irrigation Well #2 264 ft deep - Near the baseball field) was developed (by pumping water at a high rate until the well ran clean) to allow this well to be re-purposed as a pumping test well, and later as a permanent production well. WHE removed existing equipment from the second existing irrigation well (Old Irrigation Well #1 near the cooling tower for the central plant) to allow monitoring of the water level during the pumping test. WHE then sonic drilled an additional 2" monitoring well approximately 35 feet from the Old Irrigation Well #2 location.

After all drilling and well development work was concluded the wells were equipped with water level loggers, and Old Irrigation Well #2 was equipped with a submersible pump. Old Irrigation Well #2 was pumped at a rate of 435 gpm for a duration of 48 hrs. After the test, the drawdown data was collected from each of the water level data loggers as well as the GPM data from the pumping well. This data was analyzed by Underground Energy in AQTESOLV software using the Theis method. The transmissivity was 4,700 ft^2/Day, the Storage Coefficient was 0.004, the aquifer was analyzed as a confined aquifer, and tidal influences were observed in the hydrograph.

As known very well in the geothermal community, the quantity and the depth of water wells for geothermal systems heavily influences the installation cost. The ability to utilize existing wells for test wells, monitoring wells, and for some of the production wells would have reduced capital cost had the project moved into construction phase. High flow rates and therefore the ability to store more energy seasonally using the dry cooler if needed can increase energy efficiency since it gives the ability to make the ground water cooler and cooler each year for this cooling dominated system.

To seasonally store energy in the cold well and to remove additional heat from the warm well, it was decided to utilize a dry cooler for the ATES project. Since the native ground water temperature at NASP is approximately 72° it was decided that there was no need for the dry coolers to include the adiabatic option.

To heat and cool the building, modular heat recovery chillers were utilized in place of the existing central chilled water plant and local hot water plant. The original system was chilled water from a central chilled water plant, and hot water made locally at each building.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

GHPs with UTES offer a variety of cost and performance advantages and feature very few performance limitations due to their inherently efficient nature. Cost and lack-of-knowledge factors are related to their current market penetration limitations and are discussed below.

Performance Advantages:

The benefits of this technology are numerous and include: The ability to enhance already highly efficient GHP technology to achieve a lower first cost, even higher efficiencies and accomplish a renewable HVAC system, minimize the carbon footprint and energy consumption, and eliminate on-site fossil fuel consumption. All this is done while still achieving the ever-important goals of maintainability, system longevity, and minimized Life Cycle Cost (LCC). Unlike other green technologies of wind or PV, we fully expect some type of GHP-UTES to be deployable at over 80% of DoD facilities in the U.S. and abroad.

Cost Advantages:

We expect GHP-UTES to be LCC effective at most DoD facilities with a payback of less than 20 years at most installations. In terms of expected aggregate benefit to DoD, it is expected that GHPs with UTES will provide a benefit of an average of at least 30% less energy consumption than conventional HVAC systems. This value multiplied by at least 60% of the heated and cooled DoD facility inventory could result in significant national energy and cost savings if fully deployed.

Performance Limitations:

GHPs, even without the enhancement of UTES are generally viewed as one of the most, if not the most, efficient architecture to use for an HVAC system. Therefore, their limitations are not really performance related but rather first cost related, and lack-of-knowledge related. Facilities and personnel that are pre-existing users of conventional GHP systems, and those who are motivated to meet renewable and other green goals/mandates, will obviously be more likely to transition into the enhanced form of a GHP system. ATES systems, with their open loop design (physically extract and return groundwater to/from a local aquifer) are more complicated (at least from an evaluation and engineering perspective) but have the benefit of potentially lower first cost and lower operating cost. Figure 2.4, a color coded "ATES Feasibility Map" that our Dutch consultant, IF Tech, has generated for the entire U.S., is shown to provide just a rough initial guideline as to where ATES might successfully be deployed. However, a local hydrological investigation is needed before any ATES site is ruled "in" or "out" as a potential ATES candidate. Please note that with the current demonstration site located south of the Fall Line (generally the dark green/light green NE-SW border/line through the middle of Georgia), it has a high probability of ATES feasibility based on this high-level overview. While upstream of the completion of this project and all the detailed information that will be forth coming, it is an excellent tool to give a broad overview of the U.S.'s geographical potential for ATES.

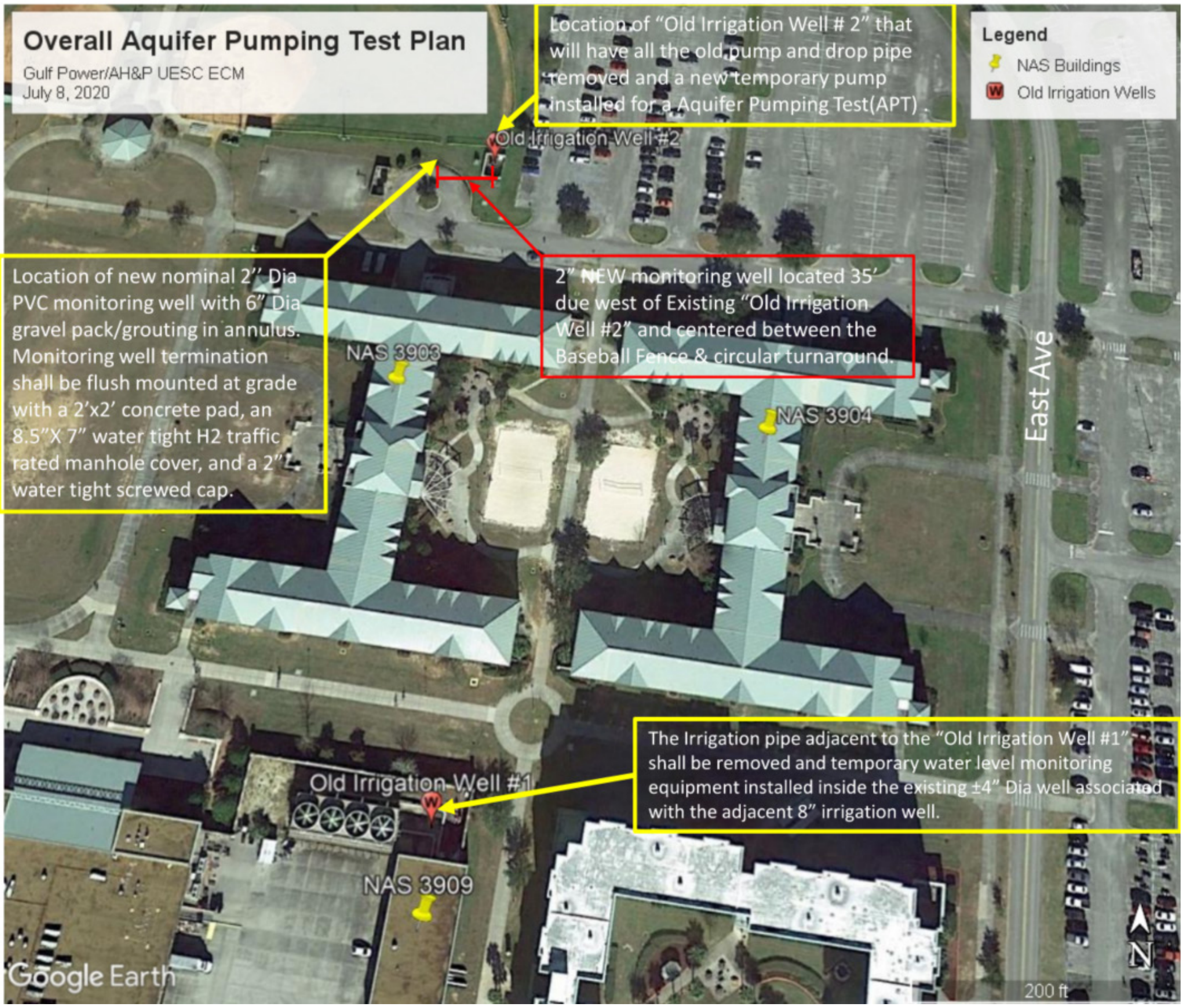


Figure 2.4. Aquifer Pumping Test Plan

Aquifers can generally be classified as either containing oxygen (oxic or aerobic) or without oxygen (anoxic or anaerobic). Oxygenated aquifers tend to be near the surface of the earth (so-called surficial aquifer) and due to issues like fertilizer run-off, may also contain nitrogen and other undesirable contaminants. While either type of aquifer can potentially be utilized, anoxic aquifers may be preferred, as the water remains anoxic, and potential biological or mineral precipitate issues are minimized. Intra-aquifer transfers of water are also not preferred due to environmental considerations and other issues. The ATES demonstration project intends to stay in the same aquifer with our extraction and injection wells. Overall, an aquifer that has an upper and lower confining layer (typically made of clay on top and sometimes rock on the bottom), is generally considered the optimum aquifer for an ATES project. This project intends to utilize an aquifer free of surface contaminants with an upper confining layer, if possible, to generally ensure it will be anoxic.

To ensure a high level of performance in deploying UTES at any facility, beyond some of the geologic and aquifer considerations previously mentioned, we believe the key to successful deployments will have in common:

- on-site test boreholes drilled with detailed drilling logs of the geology analyzed/recorded
- water flow pumping test ATES being accomplished
- adequate GHP-UTES design guidelines being developed
- accurate hour-by-hour energy analysis of the building's thermal loads being completed
- proper computer modeling of the GHX/BTES or the ATES being accomplished
- thorough, high-quality designs, plans, and specifications being provided to the installing contractor and their drillers.

In terms of economic considerations, ATES systems will not be economical unless there is an adequate aquifer on site. Figure 2.4 is a good starting point to understand where adequate aquifers exist, but previous or new test wells will generally be necessary to determine the actual adequacy of each specific site when ATES systems are being contemplated.

Cost Limitations:

Overall, DoD clients that are seeking the absolute lowest first cost will not deploy GHP systems with UTES, but those seeking to comply with all the energy mandates and those seeking true Energy Security for their installation will carefully consider these system types.

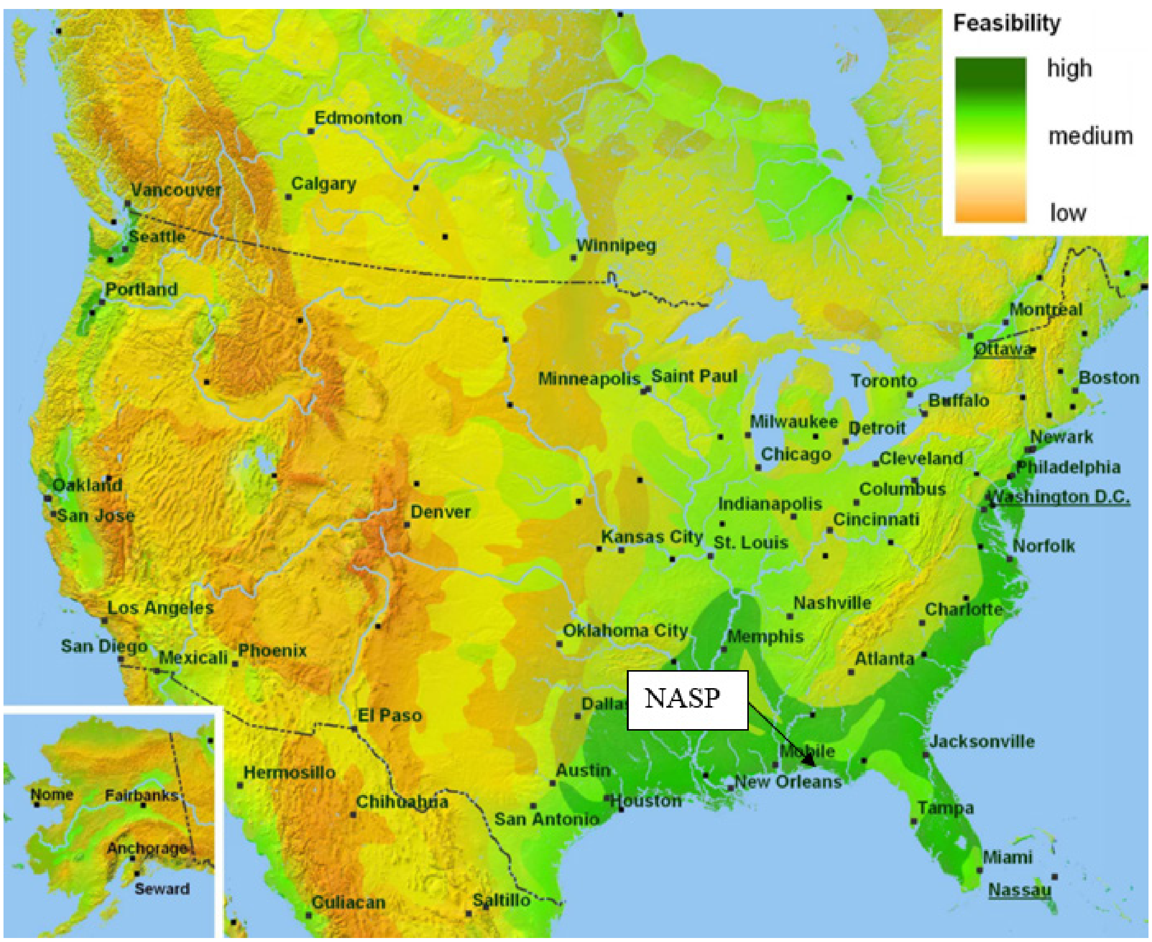


Figure 2.5. North America ATES Feasibility Map (Courtesy of IF Technology)

Potential Barriers to Acceptance:

The primary barrier to acceptance will be fear of the unknown as these systems are not yet broadly utilized across DoD. An ATES system with its submersible pumps sometime creates questions, but if there are already domestic water wells on the installation, this tends to be less of a concern. Maintenance personnel should already be familiar with maintaining systems that utilize submersible pumps.

3.0 PERFORMANCE OBJECTIVES

The technology and economic Performance Objectives (PO) are summarized in the following "Table 4.1". Descriptions of how PO Energy and Water goals are measured and how they are determined to be successful is also included.

Energy and Water Security

The PO is aligned with NASP's need to reduce energy and water intensity. ATES is an on-Base resource and technology that both reduce the overall energy intensity of the buildings HVAC and/or process energy, but also literally capture the seasonally renewable energy of the building's waste heat and "waste cool" and also capture the "cold of the winter" air and store these resources until they are needed.

Cost Avoidance

Cost and water resource reductions associated with the deployment of this technology are determined by modeled or metered before and after measurements to determine the savings associated with this project. By storing a large amount of the thermal heating or cooling energy needed to heat and cool DoD buildings in the naturally underground geology and groundwater "inside the fence", importation of electrical power "across the fence" is reduced while on-site consumption of fossil fuels is eliminated.

Greenhouse Gas Reduction

Reduction of Greenhouse Gas (GHG) emissions is achieved by a reduction in KWH consumption. The burning of fossil fuels for the demonstration buildings is also eliminated.

Since the project did not proceed to the construction phase the performance objective results were estimated by comparing the modeled baseline data with the ECM data.

3.1 TSUMMARY OF PERFORMANCE OBJECTIVES

Table 3.1. Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Facility Energy Usage Reduction	Energy Usage Intensity (EUI) KBtu/SqFt/Yr.	Energy Modelling Data	30% reduction compared to baseline	42% Reduction in EUI Compared to Baseline. See Appendix.
Maintainability of the System	Maintenance Schedule	Record of Maintenance of the ATES System	ATES system requires little or no more maintenance that the baseline system.	Not enough data since NASP was unable to provide maintenance costs or logs for the baseline system. However, it is obvious that the maintenance would be the same or less since the ATES system replaced the use of a cooling tower, and boiler and other items are similar in maintenance cost.
Qualitative Objectives				
Successful execution of a Utility Energy Service Contract (UESC) utilizing Underground Thermal Energy Storage (UTES)	Capital Cost / Energy Savings	Energy Modelling Data	Cost of project paid for by energy savings (15 yr. payback)	The estimated simple payback for this project was calculated to be greater than 15 years. This was based on the cost of the new geothermal wells and rehabbing of the existing irrigation wells.

3.2 PERFORMANCE OBJECTIVES DESCRIPTIONS

Below are descriptions:

3.2.1 Reduce Facility HVAC Energy Usage Compared to the Energy Usage Measured before Implementation of ATES:

Definition:

The project's new HVAC system will have lower energy consumption than the building's existing baseline HVAC system.

Purpose:

Reduce the energy consumption of DoD facilities to help accomplish their stated goals of building energy reduction, improved energy security, increased sustainable infrastructure, and more.

Metric:

The energy usage intensity (kBtu/ft^2/Yr.) of each building's existing and new HVAC systems was determined by modelling efforts since the project did not move forward to the construction phase.

Office buildings in the U.S. have been measured by DOE to have HVAC energy intensities around 92.88 kBtu/ft^2/Yr. in one survey performed as part of their Commercial Building Energy Consumption Survey or CBECS (DOE, 2003). The modeling of the baseline systems was calibrated to metered energy data.

Data:

The area (square footage) of the conditioned space used in the denominator of the above metric is taken from area take-offs of the vector-based computer-aided design (CAD) drawings provided by the military installations to the investigators. The numerator in terms of BTU or kWh for the new and existing systems were taken from a computer model which was calibrated using a combination of electric meter data; gas consumption in BTUs (converted from cu. ft.) from existing gas meters; temperature sensors and mass/volumetric flow meters to determine energy delivery.

Analytical Methodology:

With instrumentation and data-loggers placed on the various existing HVAC system components, and with electric and gas meter readings during the months leading up to the construction of the ATES system, the data was used to inform the baseline estimated HVAC energy consumption of the building receiving the ATES systems. However, with the ATES facility being served by a multi-thousand-ton central chilled water plant, changing weather/occupancy levels, etc., required computer modeling and extrapolation techniques to be utilized to help inform the baseline energy consumption calculations when appropriate.

Success Criteria:

The performance objective was successful. The modeled EUI of the baseline system is 71.12 KBTU/SqFt/Yr., while the modeled EUI of the ATES system is approximately 41.23 KBTU/SqFt/Yr. which is a **42% reduction.**

3.2.2 Ensure the Maintenance of the ATES system is equal or less than with the Maintenance of the Baseline System:

Definition:

The project's new HVAC system will require no more maintenance than the baseline system.

Purpose:

Equal or reduced HVAC maintenance while still achieving reduced energy usage.

Metric:

The maintenance required of the ATES system was be determined by analyzing the maintenance schedule for each piece of new equipment vs the maintenance schedule for the baseline equipment.

Data:

The maintenance schedule for the baseline system will be compared with the maintenance schedule for the ATES system.

Analytical Methodology:

The method for analyzing the data should be a simple comparison of maintenance schedules to determine if the ATES system requires less than or equal maintenance of the baseline system. However, since the project did not move to the construction phase, bidding of the maintenance costs for the ATES system was performed. However, NASP was not able to provide maintenance costs for the baseline equipment.

Success Criteria:

This PO is considered met since the new heat recovery chillers maintenance schedule is comparable with the existing water-cooled chillers located in the central plant. The heat recovery chillers also take the place of the boilers, which in turn reduces the overall maintenance required. The adiabatic dry coolers for the ATES system has similar or less maintenance that that of the cooling towers installed for the baseline system. The submersible pumps for the ATES system also has less maintenance than the installed condenser water pumps for the baseline system. This is due to the fact that the submersible pumps cannot be easily accessed and are designed for lower maintenance.

3.2.3 Execute a successful UESC utilizing UTES:

Definition:

Construct and extensively document a DoD UTES system installation, funded via a UESC contracting vehicle. Furthermore, through the extensive documentation, and before/after energy metering requirements of an ESTCP Demonstration Project.

Purpose:

To build confidence in the underlying UTES technology.

Metric:

Extensive documentation, and before/after energy metering requirements of the ESTCP Demonstration Project.

Data:

The Construction Cost of the project divided by the energy savings will result in the payback of the system.

Analytical Methodology:

The construction cost of the system was recorded from bids of the system. The energy savings was determined by comparing the modeled energy usage of the baseline system with the modeled energy usage of the newly installed ATES system.

Success Criteria:

This PO is considered unsuccessful since the cost of the project is calculated to be paid for by energy savings in greater than 15 years. This is based on the cost of the installation of the new ATES, and rehabilitation of the existing irrigation wells to be repurposed as ATES wells plus the electrical costs associated with these items.

4.0 FACILITY/SITE DESCRIPTION

The selected facility for this demonstration is the Naval Air Station in Pensacola, FL (NASP). The specific area on NASP chosen for the demonstration is Chavalier Field. Chavalier Field contains 12 buildings (3900 – 3912) all connected to a central chilled water plant (Building 3909). Each of the 12 buildings has their own dedicated hot water heating boilers and domestic hot water systems. The four buildings chosen for this demonstration are buildings 3901, 3902, 3903, & 3904.

4.1 FACILITY/SITE LOCATION AND OPERATIONS

Demonstration Site Description:

The demonstration site is located on NASP at Chavalier Field. Chavalier Field is directly adjacent to Pensacola Bay. Chavalier Field is very flat, low elevation (nearly sea level), with sandy soil. NASP is located south of the Fall Line in the southeastern United States. The facilities chosen for this demonstration are four-story barrack buildings with an exterior of brick and stucco. The buildings were constructed in approximately 1999.

Key Operations:

The military operations in the area appear to be limited to recreation and residency. The four buildings chosen for the demonstration are all Barracks. The demonstration will consist of converting these buildings over from the central chilled water plant and local hot water boilers to heating and cooling provided by the ATES system. During the changeover, the barracks will be minimally affected. The existing heating and cooling will be valved off while simultaneously starting up the new ATES system.

Location/Site Map:

The buildings located in the rectangle are the buildings chosen for this demonstration.

Figure 4.1. Site Map Naval Air Station Pensacola

<u>Other Concerns</u>:

A positive concern related to the demonstration site is related to injection well permitting in the State of Florida. Underground Injection Control (UIC) permits are commonly issued in Florida for HVAC systems.

4.2 FACILITY/SITE CONDITIONS

<u>Geographic Criteria</u>:

The climate zone for the site selected is in zone #2 which is classified as hot and humid. NASP is located on the Gulf of Mexico where ground water is very abundant. There are abandoned irrigation wells on NASP that were pump tested at 800 GPM when installed per information found on the old drilling permits.

Facility Criteria:

Buildings 3901, 3902, 3903, and 3904 are all four-story barrack buildings. Each building is approximately 110,000 square feet. The buildings are currently connected to the central chilled water plant. Each building has its own heating hot water boiler(s), and its own domestic hot water boiler(s). There are three abandoned irrigation wells nearby the chosen buildings. The abandoned irrigation wells will be repurposed if possible as ATES wells to serve the proposed ATES system.

Facility Representativeness:

NASP represents characteristics common to other military installations such as the abundance of ground water. Most military installations below the fall line in the southeastern United States will have access to abundant groundwater. NASP like other installations maintain their own potable water supply from groundwater. Installations that utilize groundwater for drinking will be very familiar with maintaining wells, and submersible pumps. Most military installations below the fall line in the Southeast are very cooling dominated and therefore will greatly benefit from a system that takes advantage of stored energy in the aquifer to save energy in the cooling mode.

Other Selection Criteria:

Since the goal of this project is to successfully engineer, construct and extensively document a DoD UTES system installation, funded via a UESC contracting vehicle, it is important to implement this project in Gulf Power's (Nextera's) location in the panhandle of Florida because the UESC contract for this demonstration is partnered with them.

5.0 TEST DESIGN

A detailed description of the system is illustrated in Section 5.3 of this Final Report. The UTES system will demonstrate a different method of creating a more efficient way of applying GHX systems with seasonal energy storage. The existing systems at the site are considered conventional HVAC systems, whose performance will be compared against the performance of the demonstration project installed at the same site. For NASP, the dual duct AHU's and VAV boxes will be coupled with an ATES system consisting of heat recovery modular chillers, warm and cold wells, and adiabatic dry coolers/cooling towers in lieu of the centrifugal chillers, cooling tower and hot water boiler currently installed. Existing HVAC system performance data at each of the 4 buildings are being monitored and recorded, which will be compared against performance data of the new UTES system to determine the energy consumption comparison-based performance objective's success or failure.

Fundamental Problem:

The fundamental problem for UTES systems is to find a way to effectively and efficiently store a renewable energy resource (outside air thermal energy) for later use when HVAC equipment can utilize that energy more efficiently. If so, this will increase equipment operating efficiency (Higher COPs and EERs) and lower energy consumption. However, methods and strategies have to be implemented to actively store this seasonal energy as there are energy consumption and capital costs involved to perform this process. Ultimately, the goal is to minimize capital costs and energy consumption of the UTES system, while minimizing the energy consumption of the HVAC equipment. If the energy savings of the HVAC equipment is greater than the energy consumption of the UTES system, then this will be considered successful. This achievement will lead to higher system operating COPs over conventional HVAC, conventional GHP systems, and even conventional hybrid GHP systems (GHP systems coupled with open loop cooling tower(s)).

Demonstration Question:

Therefore, each demonstration project will attempt to answer the question of: "Can a UTES system be effectively, efficiently, and economically implemented and be capable of storing a renewable seasonal energy resource (outside air thermal energy), and be funded via a UESC contracting vehicle?" This question will be applied to this demonstration project, which will help determine the feasibility of UTES via a UESC at other locations.

5.1 CONCEPTUAL TEST DESIGN

To provide an overview of the test design, the following items will be used to evaluate the performance objective of the UTES system (ATES).

Hypothesis:

A UTES system can be effectively, efficiently, and economically implemented and be capable of storing a renewable seasonal energy resource (outside air thermal energy) and be funded via a UESC contracting vehicle.

Independent variable:

The amount of seasonal energy that can be captured and stored and whether it can be accomplished effectively, efficiently, and economically. This value is directly manipulated by how many adiabatic dry coolers/cooling towers are utilized and how many groundwater ATES wells are utilized. The adiabatic dry coolers or cooling towers are the active means for capturing the seasonal energy while the ATES wells are the passive means for storing it.

Dependent variable(s):

The amount of seasonal energy that is able to be used. This can be observed in several ways. This can be directly observed by monitoring the temperature of the underground formation via installed temperature sensors. Alternately, air temperatures, water temperatures, air flows, and water flows can be monitored to determine the amount of seasonal energy captured. Equipment COPs and EERs can also be monitored to determine if the seasonal energy captured is translating to energy consumption reduction of the installed HVAC system.

Controlled variable(s):

Changes in set-points, such as lowering or raising heating/cooling set-points, and changes in occupancy schedules would influence both the dependent and independent variables. This would also have an impact on the energy consumption comparison between the baseline and the demonstration project. Since a portion of the objective for the demonstration is to capture each building's waste cooling and/or water heating, changes to either of these variables will affect each system's ability to store seasonal energy by either increasing or decreasing the amount of waste cooling or heating available for seasonal storage purposes.

Test Design:

Several things will need to be accomplished to test the stated hypothesis. The baseline performance will have to be compared to the demonstration project performance to determine the energy consumption savings of the UTES system over a conventional HVAC system (measured). Installation costs will also have to be tracked carefully to complete an accurate life-cycle cost analysis of implementing the UTES system.

Test Phases:

Along with the baseline and demonstration data collection process, a Commissioning (Cx) process as well as a Test, Adjust, and Balance (TAB) will be accomplished for each UTES system. All of these procedures will be used to verify and validate the data (cost and performance) acquired to ensure the comparison of the demonstration project to the baseline is accurate so that the performance objectives can be evaluated accurately.

5.2 BASELINE CHARACTERIZATION

The following information is used to describe the baseline characterization used to support the demonstration.

Reference Conditions:

In order to accurately compare the baseline existing performance against the demonstration project's performance, a year's worth of data is being collected for the existing system. Once the demonstration project installation is completed at NASP, as much performance data as possible will be collected and compared against the baseline's performance data. The list of baseline conditions being collected at NASP can be seen in Table 5.1.

Table 5.1. NASP: List of Baseline Reference Conditions

Naval Air Station Pensacola – Buildings 3901, 3902, 3903, & 3904		
#	Reference Condition	Units
1	Energy Usage	KWh
2	Natural Gas Usage	Therms
3	Outside Air Temperature	°F
4	Outside Air Relative Humidity	%RH
5	Chilled Water Supply Temperature (Bldg. 3902 only)	°F
6	Chilled Water Return Temperature (Bldg. 3902 only)	°F
7	Chilled Flow Rate (Bldg. 3902 only)	°F
8	Heating Water Supply Temperature (Bldg. 3902 only)	°F
9	Heating Water Return Temperature (Bldg. 3902 only)	°F
10	Heating Water Flow Rate (Bldg. 3902 only)	°F
11	Occupancy Schedule if Available (3901, 3902, 3903, 3904)	People

Baseline Collection Period:

Baseline data collection started on January 10, 2020, and will continue until the demolition process for the demonstration project installation begins. Not all data was available starting on January 10^{th}. Some instruments and telemetry had to be installed to collect some of the data.

Existing Baseline Data:

Initially gas meter data was provided by NASP, however the gas meter data was incomplete and did not appear to be accurate. Manual gas meter readings have been performed routinely since January to acquire more accurate data. Electric meter readings have been provided by NASP. Readings will continue to be provided for the baseline system until the system is switched over to the demonstration system. Existing chilled water flow rate readings have been provided by NASP for building 3902. This data is being used in conjunction with temperature sensors to be installed during this demonstration to assist with verification of actual cooling load, and calibration of the energy model.

To estimate the building's energy consumption and energy savings associated with energy conservation measures (ECMs), a combination of spreadsheet analysis tools and energy modeling using Carrier's Hourly Analysis Program (HAP) modeling program were used.

The HAP program typically requires the building features, equipment, and operation to be input in order to create a dynamic model, which in turn approximates the annual energy consumption of the building.

As with any computer program that attempts to model the complexities of a building's operation, certain program limitations and assumptions are inherent both in the program and in the data that is input. As an example, the program assumes that all equipment is operating correctly, even though in reality control sensors may not be precisely calibrated, thus increasing or decreasing the actual energy consumption of the equipment. In other cases, intermittent operation of system equipment cannot be readily determined, estimated or modeled. The final results will differ somewhat from the actual energy consumption and demand.

Typically, the process of creating the model involves making observations of the facility in order to estimate cooling and heating load elements such as occupancy, miscellaneous equipment loads, building envelope characteristics and similar load related data. These observations also permit confirmation of the types of HVAC systems that are installed in the different facilities, and input of their characteristics. Finally, an estimate of the building occupancy profiles, as well as the operating time frames for both equipment and lights is made based upon interviews with the building manager, field observations and Owner provided information. Once the building parameters, internal load and equipment data are input into the software, the results are calibrated to match the electric meter billing history consumption and demand.

The lighting power density modeled will be based on typical buildings with retrofit LED lights. A design verification model will be created in HAP to verify that that the U-values used for the building envelope were approximately correct. Then the design verification model will be modified by altering the internal loads (people, lights, miscellaneous and operational schedules) to reflect the current conditions. The model will then be calibrated to be within 10% overall for the kWh for the year, with none of the months exceeding 30%.

The central plant load and energy usage was modeled by inputting the existing chiller and pump data into carrier HAP.

The main data points collected used in the energy model is the electric meter readings collected by NASP and the gas meter readings collected by manual readings.

<u>Baseline Estimation</u>:

To determine the energy savings of the demonstrated system versus the baseline system some estimation will be made. Particularly in regard to the energy usage reduction of the central plant. Operations of the central plant can change from year to year based on weather, equipment failures, building occupancy schedule, etc. Some estimation will have to be made in regard to the operation of the central plant before and after the demonstration project.

<u>Data Collection Equipment</u>:

New and existing data-logging equipment was used at the site for obtaining baseline reference data. Various types of equipment and methodologies are being used to obtain the information critical for comparison purposes. A private cellular network connection is being used to remotely download the recorded data.

A detailed list of the data collection equipment used for the demonstration project is as follows in Table 5.2.

Table 5.2 NASP: List of Baseline Data Logging Equipment

Naval Air Station Pensacola - Buildings 3901, 3902, 3903, 3904, & 3909			
#	Description	Method/Device	Building/Location
1	Electic Consumption	Spreadsheets provided by NASP	3901, 3902, 3903, 3904
2	Total Gas Consumption	Manual Gas Meter Readings	3901, 3902, 3903, 3904
3	Domestic Hot Water Usage	Ultrasonic Flow Meter & Temperature Sensors	3902
4	Heating Hot Water Usage	Ultrasonic Flow Meter & Temperature Sensors	3902
5	Chilled Water Usage	Temperature Sensors (Used in Conjunction with NASP flow meter data)	3902

5.3 DESIGN AND LAYOUT OF SYSTEM COMPONENTS

System Design:

The building's existing HVAC system consists of VAV chilled water AHU's for cooling and VAV hot water AHU's for heating. The chilled water AHU's are equipped with a chilled water coil designed for 44°F entering water temperature and a modulating two-way valve designed to maintain 54°F air to each zone. The hot water AHU is equipped with a hot water coil designed for 180°F entering water temperature. The chilled water is produced at a nearby central plant facility, which supplied chilled water to multiple facilities. The hot water is produced by a natural gas boiler installed in the mechanical room.

For this demonstration project, the existing boiler, and pumps, will be removed and be replaced with a new heat recovery chiller. The chilled water piping will be disconnected from the central plant and chilled and hot water will be provided by the heat recovery chiller. The heat recovery chiller will utilize source water supplied by the ATES system. The ATES system will have warm and cold wells that will operate as injection or extraction wells depending upon building heating/cooling loads and outside air conditions. The water extracted from the aquifer will be hydraulically separated from the WSHP source water by a stainless-steel plate-and-frame heat exchanger (HX). This will ensure that the water injected back into the underground formation will be free any refrigerant that could possibly leak from the heat recovery chiller.

An adiabatic dry cooler or cooling tower will also be utilized for this project to provide an active means of storing seasonal energy into the underground aquifer. Depending on the time of year and outside air conditions, the dry cooler/cooling tower will operate to capture the cold of winter and store its energy for use during the cooling dominant months of the year. Due to the location of the facility in the Southeast and results from preliminary modeling, building loads are cooling dominated and the operation of the dry cooler/cooling tower is needed to achieve a balanced load condition on the underground aquifer.

Components of the System:

There are several key components to the ATES system. Each component is critical to achieving a successful system capable of providing enough heating and cooling source energy for the demonstration buildings. Each well will have a submersible pump and control valve capable of allowing each well to operate as either an injection or extraction well. During cooling dominant times of the year, water will be extracted from the cold well, passed thru the plate HX, and injected into the warm well. During heating dominant times of the year, water will be extracted from the warm well, passed thru the plate HX, and injected into the cold well. This motive behind this design is to raise the COP of the HVAC equipment during applicable times of the year to increase energy efficiency and reduce energy usage.

The adiabatic hybrid dry-cooler or cooling tower functions as the cold-capture (i.e., heat rejection) device during milder (lower) outside ambient conditions. The adiabatic dry-cooler or cooling tower can operate in the wet mode if needed, to increase energy storage. The installation and operation of the dry cooler or cooling tower allows the design to actively store seasonal energy in the underground aquifer at optimal times of the year until the stored energy is needed. Given the load imbalance of this facility, the dry cooler/cooling tower is critical to achieving a balanced thermal load on the aquifer.

The use of heat recovery chillers for the project is also important. Heat recovery chillers can operate against a wide range of source water temperatures to provide heating or cooling, depending on the load of the particular zone. Heat recovery chillers allow for maximum operating flexibility for this demonstration project. Down to certain entering source water temperatures, heat recovery chillers EERs increase when operating in the cooling mode. Alternately, up to certain entering source water temperatures, heat recovery chillers can provide free heating when in the heat recovery mode.

System Depiction:

The following Diagrams and schematics will help depict the ATES system and how it is applied to this demonstration project.

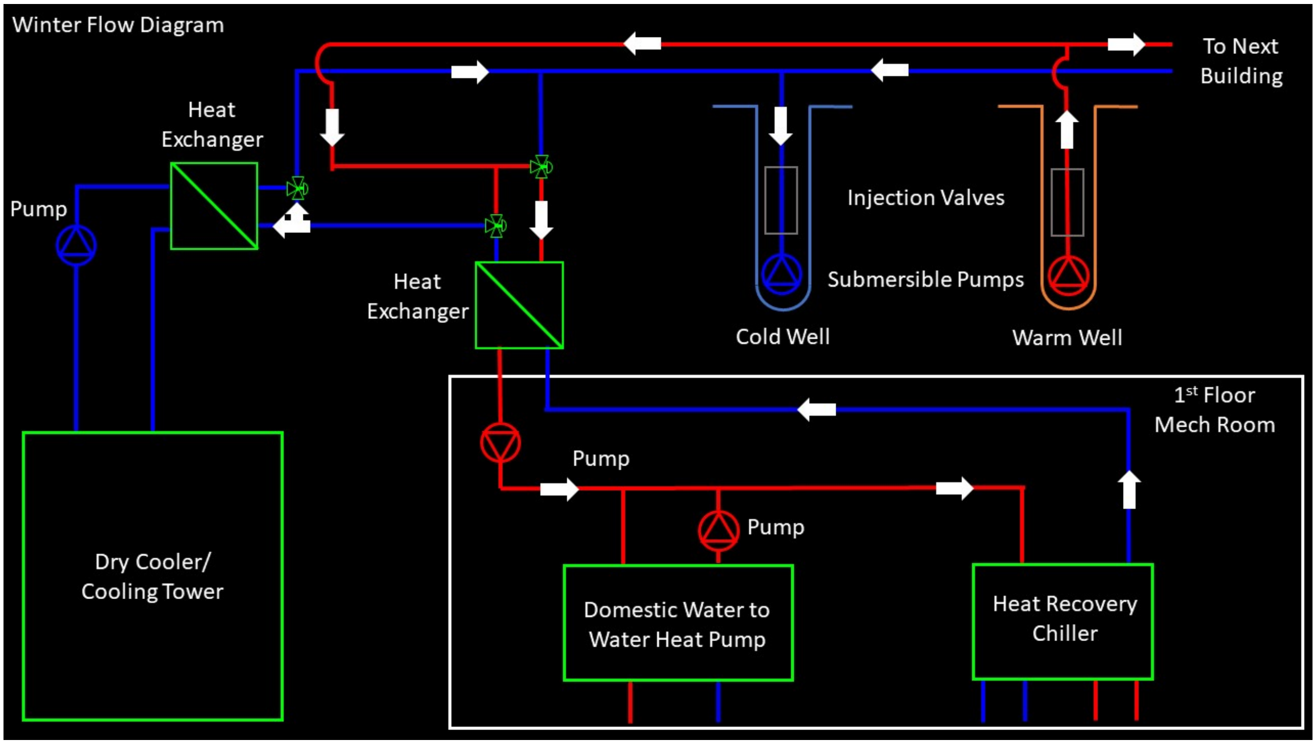


Figure 5.1 ATES Cold Charging Mode Flow Schematic Diagram

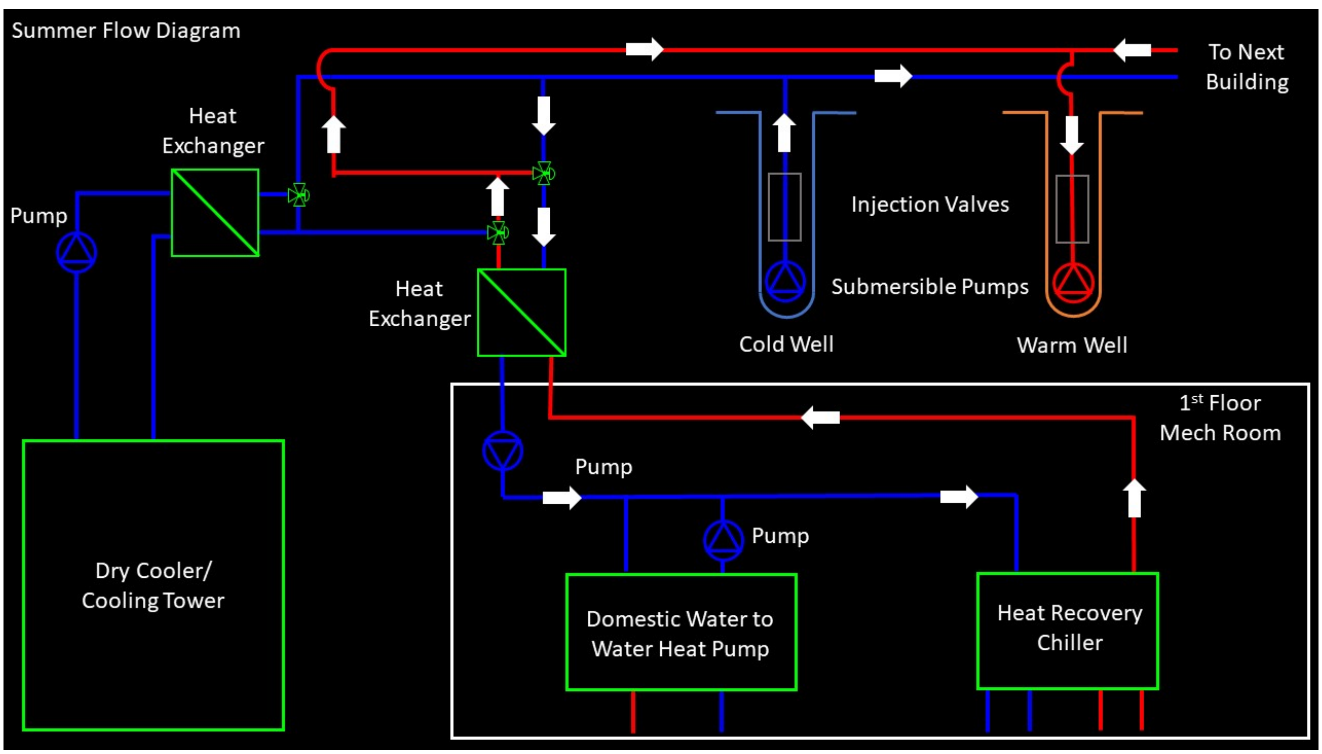


Figure 5.2. ATES Cold Discharging Mode Flow Schematic Diagram

System Integration:

The demonstrated system will coexist with the original chilled water central plant and the original hot water system at each building. The chilled water central plant capacity will be able to be reduced by the amount of chilled water load of the four connected buildings to the ATES system. The building's interior chilled and hot water piping will remain but will be served by the new heat recovery chiller.

System Controls:

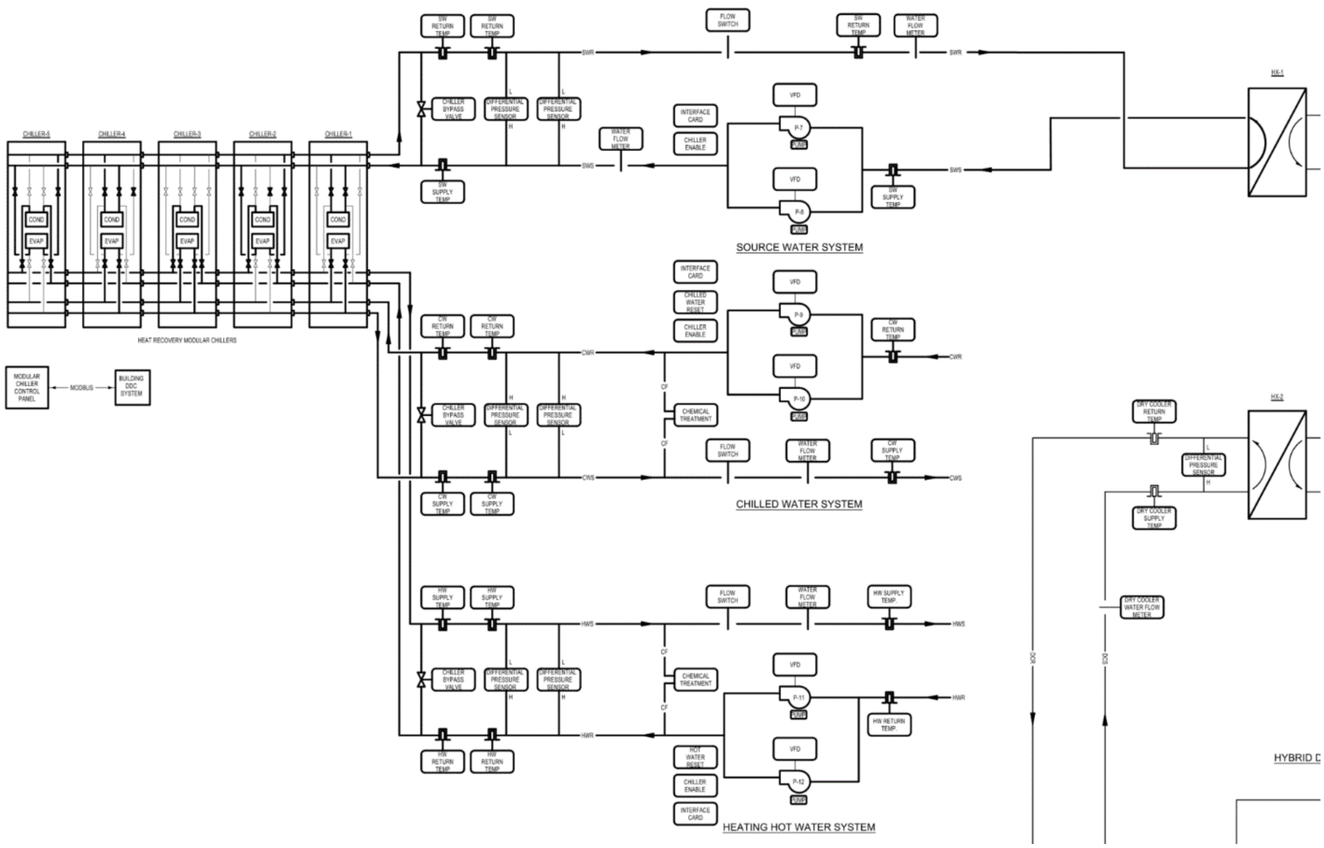


Figure 5.3. System Controls

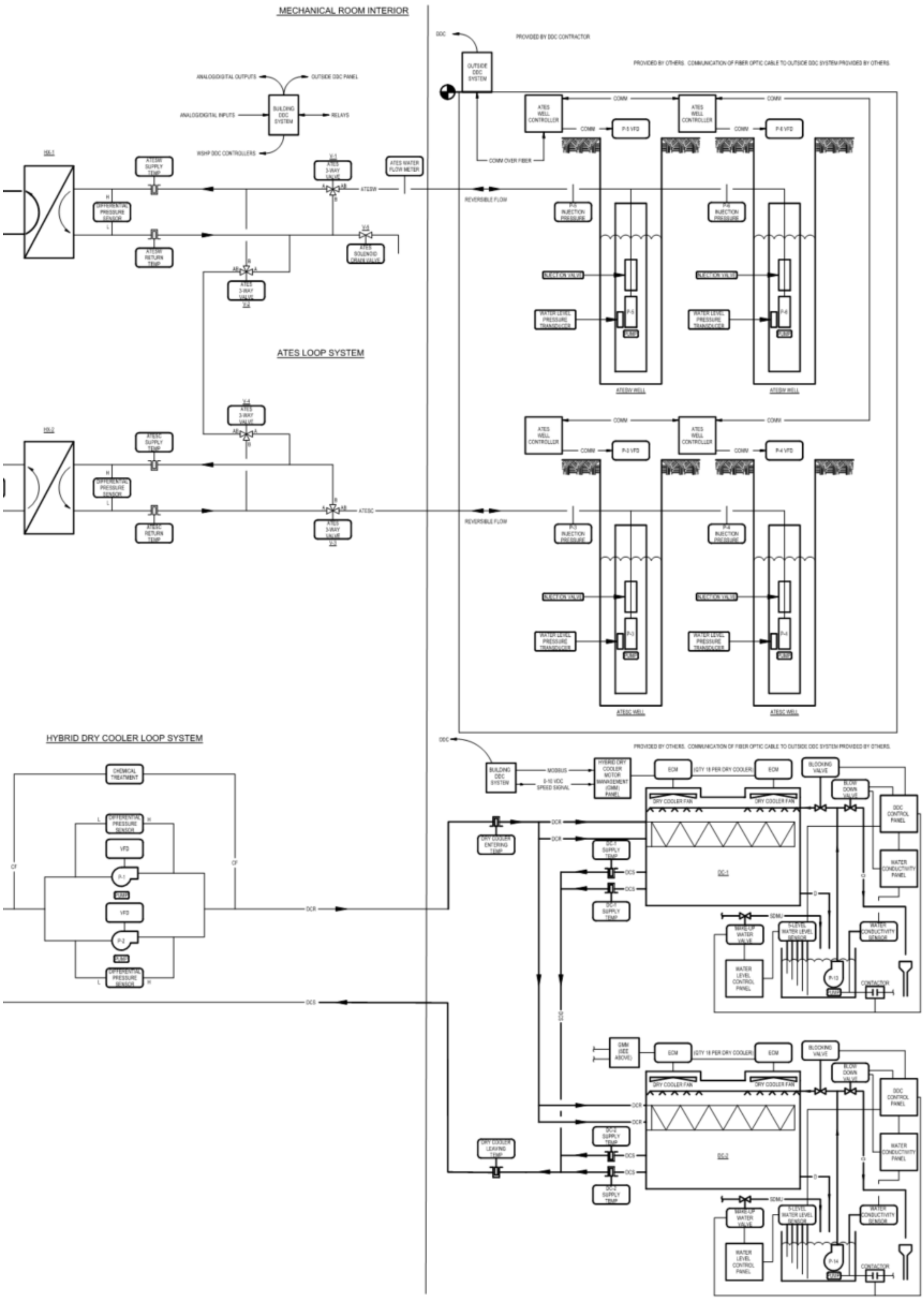


Figure 5.4. System Controls Cont.

5.4 OPERATIONAL TESTING

The following information is used to provide a description of significant operational phases of the technology.

Operational Testing of Cost and Performance:

Baseline reference information was collected up to the point where the design phase ended. After the design phase ended and the construction phase did not move forward data collection was halted.

Modeling and Simulation:

The data collected during the design process was used to calibrate the energy model for the baseline system. This calibrated energy model allowed a more accurate model of the ATES system to be simulated. The data collection related to building heating and cooling loads was compared against the Carrier HAP model completed to determine the hour-by-hour loads of the building. The ATES system's operation was compared against the Carrier HAP model. This was used to simulate and optimize the system controls and set points. When particular performance results were different than expected or if certain parameters were changed, adjustments to the system operation were made.

Timeline:

The data was collected for a full calendar year. This allowed for a better calibration of the HAP energy model.

5.5 SAMPLING PROTOCOL

The following information illustrates the sampling protocol used in the collection data to validate the technology cost and performance under real-world conditions.

Data Collector(s):

Due to the secure network infrastructure at NASP, the data had to be collected manually and via a private cellular network. Gas meter data was obtained by manual periodic readings. Electric meter readings were provided by NASP personnel. Some data was recorded by the DDC system and collected by the controls contractor. The data collected through the private cellular network was collected in real time.

Data Collection Diagram:

The location of the electric meters is not known, and the electric meter data was sent to us in a spreadsheet form by NASP. The location of gas meters and BTU meters are shown below.

See the appendix for more detail concerning data collectors.

Figure 5.5. NASP: Location of Manual Reading Gas Meters

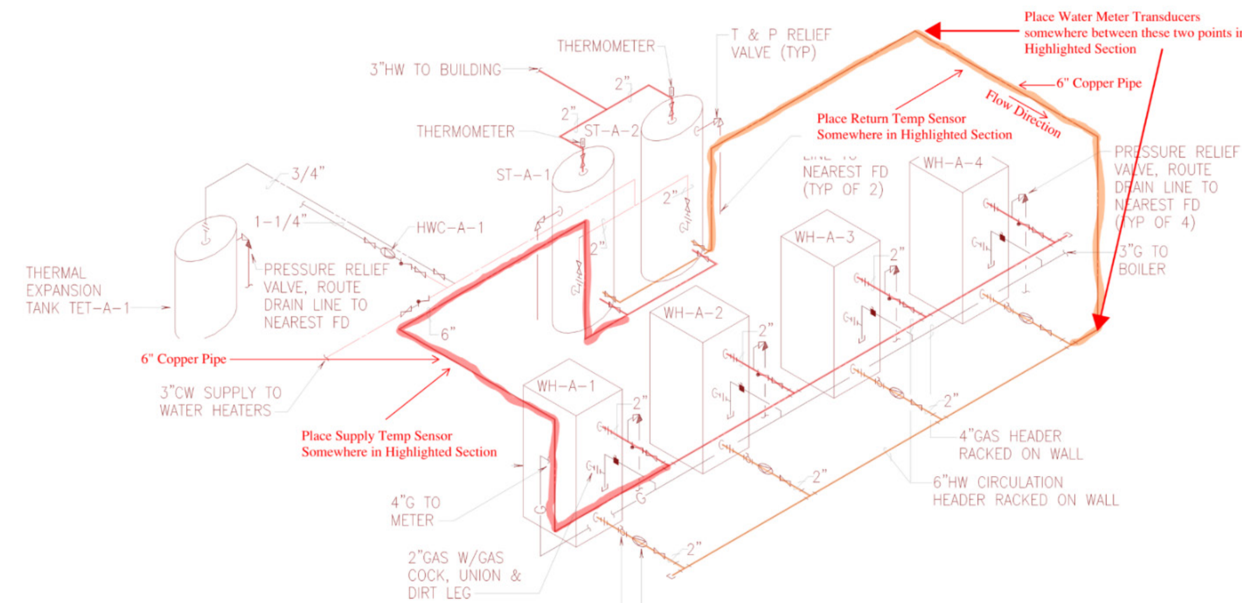


Figure 5.6. NASP Bldg 3902: Location of Domestic Hot Water BTU Meter

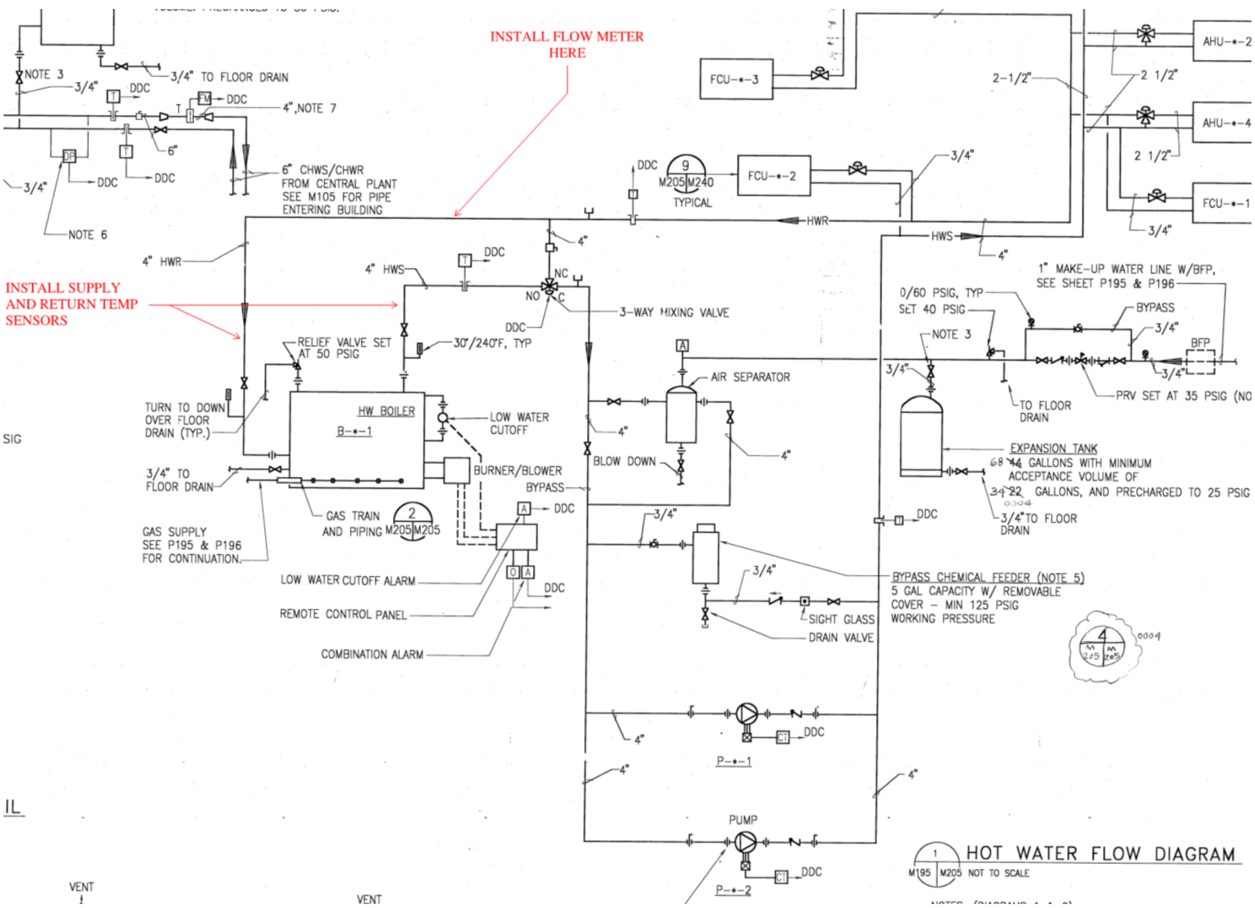


Figure 5.7. Location of Heating Hot Water BTU Meter

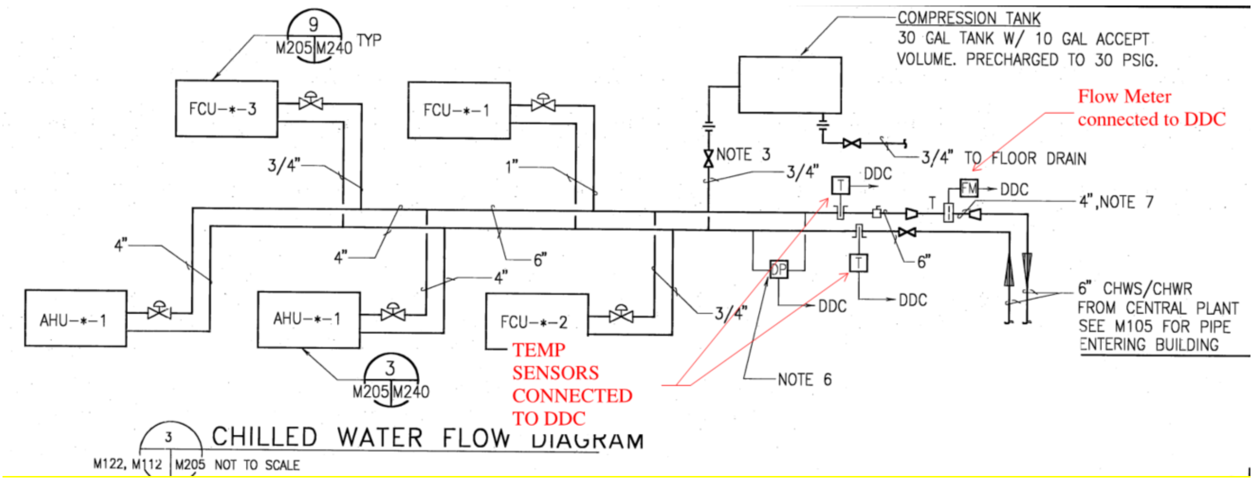


Figure 5.8. NASP: Location of Chilled Water BTU Meter

5.6 SAMPLING RESULTS

The results of the sampling served to verify the gas meter usage data which was provided by NASP was correct, and to further calibrate the HAP model using chilled water load data. The results of the sampling related to natural gas usage revealed the gas meter data provided by NASP was incorrect. Therefore, manual gas meter readings were utilized to calibrate the HAP model. To further calibrate the model, electric meter readings were utilized.

Calibration verification of AH&P provided metering equipment was performed by using calibrated meters which AH&P keeps on the shelf for verification of sensors. AH&P keeps a full set of calibrated instruments to meet the National Environmental Balancing Bureau (NEBB) standards.

Table 5.3. Energy Usage Summary (FY – 2018)

Bldg	Description	Elec. (MWH)	N.G. (MBTU)	N. G Therms
3900	Galley	2,314.90	7,226.60	72.27
3901	H - Barracks	823.60	-	-
3902	H - Barracks	604.60	-	-
3903	H - Barracks	898.10	12.70	0.13
3904	H - Barracks	785.00	-	-
3905	H - Barracks	658.70	-	-
3906	H - Barracks	773.60	0.30	0.00
3907	H - Barracks	959.10	-	-
3908	H - Barracks	883.70	0.20	0.00
3910	O - Barracks	181.90	-	-
3911	Med and Dental Clinic	431.00	99.00	0.99
3912	Enlisted Club	257.40	45.30	0.45
3909	Central Plant	5,042.90	-	-

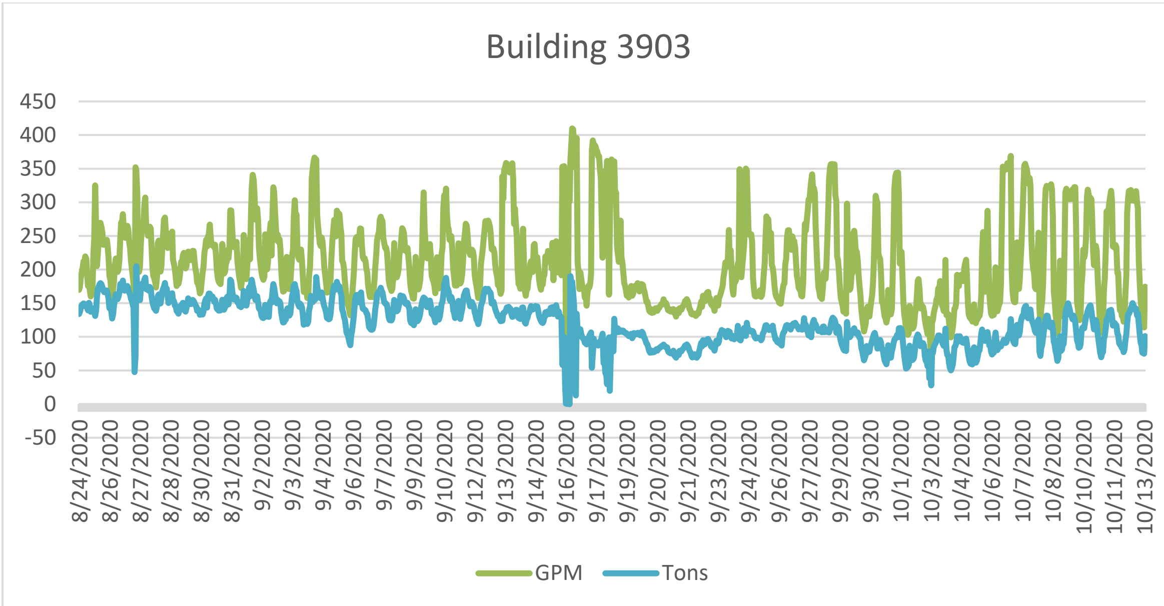


Figure 5.9. Chilled Water Load

6.0 PERFORMANCE ASSESSMENT

The following information provides a summary of the data analysis used for each performance objective.

Facility Energy Usage Reduction:

Table 6.1. Energy Analysis Summary Sheet

Total Area (Sq Ft)	456000														
Energy Analysis Summary Sheet - ATES for Bldgs 3901, 3902, 3903, & 3904															
Baseline System															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	KBTU/Yr	KBTU/Sqft/Yr
KWh/Yr	405,404	360,712	469,236	503,732	574,896	612,752	639,568	644,300	593,888	551,724	448,252	399,716	**6,204,180**	21,168,662	
Therms/Month	10,116	8,975	9,510	8,988	9,590	8,987	9,240	9,590	8,987	9,415	9,318	9,896	**112,613**	11,261,292	
														32,429,954	**71.12**
ATES System (ECM)															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	**KBTU/Yr**	**KBTU/Sqft/Yr**
KWh/Month	336,329	303,809	376,605	408,470	504,551	591,287	622,003	624,338	555,620	463,546	363,608	334,766	**5,484,932**	18,714,589	
Therms/Month	-	502	-	-	-	-	-	-	-	-	-	347	**849**	84,942	
														18,799,531	**41.23**
KWh Savings/Yr	**719,248**														
Therms Savings/Yr	**111,764**														
														Percent Reduction in EUI	42%
Electric Savings/Yr ($)	**$ 60,625.39**		Gas Rate	$ 0.583											
Gas Savings/Yr ($)	**$ 65,158.12**		Electric Rate	$ 0.084											
Total	**$ 125,783.51**														
Capital Cost	**$ 1,965,706**														
Payback (Yrs)	**15.6**														
Notes:	The Baseline System data is modeled and calibrated to metered data. The ATES System is modeled data since the project did not progress to the construction phase.														

<u>Maintainability of the System:</u>

Not enough data since NASP was unable to provide maintenance costs or logs for the baseline system. However, it is obvious that the maintenance would be the same or less since the ATES system replaced the use of a cooling tower, and boiler and other items are similar in maintenance cost.

<u>Successful execution of a Utility Energy Service Contract (UESC) utilizing Underground Thermal Energy Storage (UTES):</u>

The estimated simple payback for this project was calculated to be greater than 15 years. This was based on the cost of the new geothermal wells and rehabbing of the existing irrigation wells. See Table Above.

7.0 COST ASSESSMENT

7.1 COST MODEL

Table 7.1. Cost Model for an ATES System

Cost Element	Data Tracked During the Demonstration	Estimated Costs
ATES Cold & Warm Wells	• Equipment (Pumps/Inj. Valves) • Branch electrical circuits; 6 ea.	$1,965,706
Adiabatic Dry Coolers / Outside and Underground ATES Piping	• Interconnecting utility ATES piping • System Adiabatic Dry Coolers • Elec. Branch Circuits	$3,212,774
Mechanical Room Local HVAC Plants x 4 Buildings	• Three 85-ton Heat Recovery GHP Chillers/Heaters Modules • Pumps • Heat Exchangers • Expansion and Buffer Tanks • 2- AHU Hot Water Coils	$5,194,232
Electrical Utility Upgrades x 4 Buildings	• 12kV Power Lines • XFMRs • New 480V services • Service Panels	$1,165,907
O&M Cost for 2 Years	• Operation and Maintenance Cost:	$205,477
Commissioning & TAB	• Cost of Commissioning • Cost of TAB	$176,106

1. **Cost Element: ATES Cold & Warm Wells**
   - An ATES system utilizes cold and warm wells as the storage device for seasonal energy and then extracted when the stored energy can be used more efficiently by the HVAC system. The ATES system consists of a total of six water wells. Three wells were to be rehabbed existing water wells, and three wells were to be newly constructed wells. The wells are 10” in diameter, and 255’ deep. The newly constructed wells have a 60-foot screened interval.
   - Each well contains a 40 HP submersible pump and a 4” injection valves sized for 493 GPM.

2. **Cost Element: Dry Coolers or Cooling Towers**
   - The ATES system is designed to use adiabatic dry coolers as the active device for capturing the seasonal energy for storage into the GHX or wells. Large dry coolers/cooling towers operating at low fan and pump speeds to minimize energy consumption with minimal loss in heat rejection capacity. The ATES system consists of two adiabatic dry coolers capable of 1,490 tons of cooling in the wet mode and 1,079 tons in the dry mode.

3. **Cost Element: Mechanical Room Local HVAC Plants**
   - The modular chillers are the engine behind the ATES system. They are the device that uses the source water produced by the ATES system to generate chilled and hot water for use by the AHUs. Their high efficiency at ideal conditions as well as their ability to operate with heat recovery capabilities will have an impact on energy savings. The modular chiller for this project consists of three 85-ton modules with heat recovery capabilities.
   - Inline pumps were used for this project for the Dry Cooler loop, the chilled water loop, the hot water loop, and the source water loop
   - The hot water heating coils in the Air Handlers were designed to be replaced with deeper coils to utilize lower temperature water.
   - Buffer tanks were used for the hot, chilled, and source water loops to gain system volume.

4. **Cost Element: Electrical Utility Upgrades**
   - The electrical upgrades consist of new 12kV power lines, upgraded transformers, a new 480 V to each building, and new service panels

5. **Cost Element: Operation and Maintenance Cost**
   - The O&M Cost consists of Operation and Maintenance Costs of the new system for a period of two years.

6. **Cost Element: Commissioning and TAB**
   - Commissioning and TAB was determined for this project. Commissioning and TAB costs can reasonably be interpolated or extrapolated on a square foot basis. The approximate total floor area for the combined four buildings is approximately 392,036 square feet.

7.2 COST DRIVERS

As in any project where a reduction in energy consumption is a key point, energy rates must be considered when selecting any technology for future implementation. The locations for the demonstration site have some of the lowest electrical energy cost in the United States. Other regions, where electrical energy costs are higher, will experience a greater annual electrical cost savings. This also applies to natural gas consumption and its associated energy cost. Water consumption is also a key factor that often gets overlooked in a cost analysis. Water consumption costs can help in most regions, especially those with high water usage costs, when water consumption can be substantially decreased, or even eliminated.

Another cost driver is installation costs associated with drilling wells or boreholes. Some regions of the United States have lower drilling costs than others. This is generally attributed to the law of supply and demand. Areas, such as Texas, have more drillers than Georgia due to the oil and gas industry. As the oil and gas industry ebbs and flows, there are an abundance of drillers available, which has an impact and helps decrease the cost of drilling.

The underground geology and hydrogeology are also important cost drivers. For ATES, hydrogeology is important as its operation is directly dependent upon the ability of the system to extract and inject groundwater. Geology is almost just as important as it is highly unlikely, for example, for a crystalline aquifer (i.e., rock) to achieve the ability for sufficient groundwater extraction or injection. Some site will have ideal conditions, which will lead to a decrease in capital investments cost. Sites who can achieve lower installation costs with ideal site conditions, along with lower energy/water costs, will benefit the most from the USTES technology.

7.3 COST ANALYSIS AND COMPARISON

The cost analysis and comparison for the ATES demonstration was performed against a conventional HVAC system. In this particular case, the costs associated with the ATES system was compared to a replacement system for the mechanical room HVAC system similar to the current HVAC system in place. The current system was a central chilled water plant with local heating boilers. The chilled and hot water is delivered to hot and chilled water air handlers located in the penthouse.

The ATES demonstration project was coupled with a maintenance project for the interior mechanical construction aspect. Contractor construction prices were obtained for the interior mechanical room work and utilized for the cost analysis and comparison. The cost analysis for the ATES demonstration assumes a construction project to replace the existing HVAC system would be due to occur in the near future. This is a reasonable assumption as the existing system is over 20 years old. The cost analysis also assumes the boiler would be replaced and the existing interior piping would be replaced in support of the replacement system.

Since the existing HVAC system was dependent upon the operation of a chilled water central plant, it is assumed a local air-cooled chiller would be installed for supplying the building's chilled water system. This is also reasonable as other buildings of this demonstration project's size utilized local air-cooled chillers when a renovation project took place to eliminate the need for the chilled water central plant. To complete the life-cycle cost analysis, the energy model created for the existing HVAC system was utilized to calculate HVAC electrical and natural gas consumption. The original energy model was modified to reflect the use of a local air-cooled chiller in lieu of a chilled water central plant. The HVAC monthly energy consumption is illustrated in Table 7.3.

Table 7.2. Modeled Conventional HVAC Monthly Energy Consumption

NASP – B3901, 3902, 3903, & 3904			
Baseline HVAC Energy Consumption			
Month-Year	Electrical (KWh)	Gas (Therms)	Total (kBTU)
Aug	644,300	9,590	3,157,400
Sep	593,888	8,987	2,925,058
Oct	551,724	9,415	2,824,006
Nov	448,252	9,318	2,461,208
Dec	399,716	9,896	2,353,399
Jan	405,404	10,116	2,394,798
Feb	360,712	8,975	2,128,261
Mar	469,236	9,510	2,552,049
Apr	503,732	8,988	2,617,558
May	574,896	9,590	2,920,593
Jun	612,752	8,987	2,989,422
Jul	639,568	9,240	3,106,202
Total:	6,204,180	112,613	32,429,954

Construction costs associated with the ATES wells, corresponding piping outside the mechanical room, and interior mechanical room work coupled to the ATES wells were obtained from the Contractor's bid price. Construction cost was estimated if the new system would have been a comparable hot water/chilled water AHU replacement system. The costs associated with both the ATES system and conventional HVAC system were utilized for the cost analysis.

The investment costs associated with the ATES project and the alternate conventional HVAC system were input into the BLCC5 program (https://energy.gov/eere/femp/building-life-cycle-cost-programs) accordingly with the energy consumption data illustrated in Section 6.0 for Performance Objective No. 1 used in the life-cycle cost analysis (LCCA) comparison. Energy rates for electricity ($0.084/kWh) and natural gas ($0.583/therm) were also obtained from NASP personnel. The LCCA utilized a 20-year length of study period (October 1, 2023, through September 30, 2046) with a Constant Dollar Analysis and a Real Discount Rate of 3.0%. Performing a cost comparison analysis computes the following results:

- Savings-to-Investment Ratio (SIR): 0.97
- Adjusted Internal Rate of Return: 2.83%
- Simple Payback occurs in year: 15

The full comparative analysis report is included in the Appendix with the Table 7.4 below summarizing the inputs used:

Table 7.3. Conventional vs. ATES Cost Comparison Summary

NASP – B3901, 3902, 3903, & 3904 – Cost Comparison Input Summary		
Input	**Conventional HVAC Project**	**Demonstration HVAC Project**
Initial Investment ($)	$9,954,495	$11,920,201
Annual HVAC Electrical Consumption (kWh)	$6,204,180	$5,484,932
Annual HVAC Natural Gas Consumption (therms)	112,613	849
Annual Evap Water Consumption (1,000 gal)	2,759	0
Initial Annual HVAC Electrical Cost ($)	$521,151	$460,734
Initial Annual HVAC Natural Gas Cost ($)	$65,653	$495
Initial Annual HVAC Evaporative Water Cost ($)	$11,036	$0
General Maintenance ***Savings*** ($)	$0	$0
Chemical Treatment ***Savings*** ($)	$0	$0

8.0 IMPLEMENTATION ISSUES

8.1 OVERVIEW

Despite the various architectures of Underground Seasonal Thermal Energy Storage (USTES) being rare in the United States, its implementation as part of this project, if the project had continued into construction phase, would have been relatively straight-forward.

The main implementation issue related to the ATES system was lack of funding outside of the UESC. Essentially the UESC would pay for the ATES Wells, but NASP could not find funding for the remaining architecture of the system.

8.2 REGULATORY/PERMITTING CHALLENGES

Though the challenges described herein are specifically related to the implementation of ATES (in Florida), the issues encountered will be generally applicable for most ATES projects throughout the US. With the project involving water wells/injection wells, they fall under the jurisdiction of the FL Department of Environmental Protection (FL DEP), hereinafter referred to as FLDEP. In the arena of so-called Underground Injection Control (UIC), the FLDEP acts on behalf of the Federal Government's Environmental Protection Agency (EPA). They have been given the authority to rule on groundwater injection though a legal mechanism called "Primacy". For more details on Primacy, see https://19january2021snapshot.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program_.html. Although ATES projects simply withdraw local groundwater, change it a few degrees and transfer it back to the aquifer from whence it came, legally this is considered a "Class V Injection Well" and therefore it falls under EPA's jurisdiction and in this case, a UIC permit is required from FLEPD. In some states, this is a complex affair. In FL it proved to be a rather easy permit to obtain. However, the injection permit did not have to be obtained sine the project did not move forward to the construction phase.

8.2.1 ATES regulations/permitting

As described previously, the fact that ATES systems inject water into the ground invoke the need for a Class V, UIC permit to inject the water. "Class V" is basically a group of widely diversified type wells that EPA groups together when they don't fall into any other category. It includes everything from "Cesspools" (no longer used), drainage wells for storm water, recharge wells for aquifers, saltwater intrusion barrier wells and more. To determine if the EPA itself or a State Authority issue the Class V UIC permit, see the hyperlink in paragraph 8.2 which is also included with the following figure.

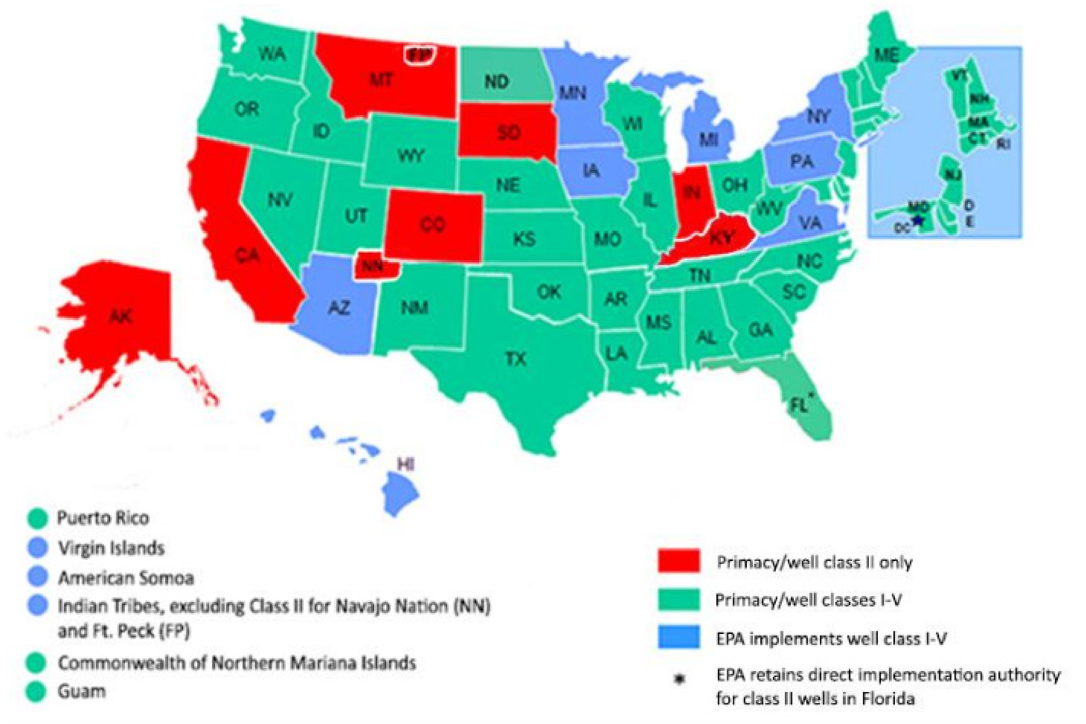


Figure 8.1 Map of States with/without Primacy to Issue Class V UIC Permits

https://19january2021snapshot.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program_.html

This report is intended to guide potential users of this technology in all 50 states. As an illustration of the regulatory situation in other states, Florida (FL) serves as a good example. There are in excess of 5000 "air conditioning (injection) wells" (a cousin to an ATES wells) active in Florida. The statewide UIC program manager in FL, Joe Haberfield, PG, advises that permitting these wells typically only takes a few weeks and is in fact handled under the same "General Permit #0001" for all projects. When considering an ATES system for a specific Base, the UIC permit, while critical, is not necessarily a complicated or protracted exercise. The key take-away is to talk to the applicable state's UIC Coordinator, discuss the project in depth, understand their position for what is required to obtain a UIC permit and determine where the decision authority resides. If it is not the UIC Coordinator, attempt to meet with the ultimate decision makers and understand their position. Sometimes, decision authority is as high-up as the head of the entire State's EPA (equivalent) program, and sometimes, a "local" water management district's manager can sign off. In certain states, UIC permits can be done under "permit by rule" protocols or via a "general permit", and the process is relatively painless.

8.3 END-USER CONCERNS/RESERVATIONS/DECISION MAKING FACTORS

In general, GHPs of any form (conventional, ATES or BTES) are fairly rare in the US market. Many experts put the market penetration of GHPs at around 1% of the US HVAC market, so there may be some hesitation to try something "new". Generally, though, in the DoD realm, due to the emphasis for energy efficiency, energy security and renewables, there has been some exposure to some form of GHPs on most installations. Terminology is also an issue as GHPs go by many other names such as Ground Source Heating and Cooling, Geo-Exchange, etc., but, in the end, they all are about using the geology/groundwater to heat and cool buildings. Properly engineered and installed GHP systems will always outperform their air-cooled counterparts and, in all but the coldest climates/load profiles, GHPs eliminate the need for on-site fossil fuel consumption, so they are generally preferred by most end users. The only time concerns arise is when the end-user has experienced and improperly engineered and/or installed system and therefore they have inappropriately "written off" the technology itself. This can normally be addressed by a proper educational presentations/discussions and references to other DoD personnel that have had good success with GHPs. Other concerns are GHPs higher first cost due to the HVAC project having to bear the cost of what is truly a nearly indefinite lasting, "inside the fence", underground utility. Users that understand that aspect of the project, and are focused on LCC, are typically willing to embrace the technology. ATES systems are simply higher performing conventional open-loop and closed-loop GEO and typically have lower capital cost and use less energy than conventional GHPs. Emphasis on the basics is key: the geology/groundwater is a superior heat source as it's warmer than the air in winter, it is a superior heat sink as its colder than the air in summer and it offers you the ability to store a building's waste heat and "waste cool".

8.3.1 ATES Concerns

Overall, if the military base has management, engineering, geologist, managerial or administrative personnel which are involved with traditional HVAC systems, they can fairly quickly gain an understanding of the fundamentals of an inject well type system. If they have water wells on base for irrigation or domestic water usage, they will generally have a basic understanding of a water supply well. Their past history (at work or even in their personal home) of maintaining submersible pumps will generally eliminate concerns about maintenance. Generally, with a properly designed well, these water-cooled devices are reasonably low maintenance, and the remainder of the HVAC system is similar to the HVAC architecture they are already utilizing, and the elimination of a combustion boiler is a big plus.

8.4 PROCUREMENT ISSUES

The clear majority of the entire ATES system is considered standard Commercial Off The Shelf (COTS) products. The major equipment and all the basic components have been available for decades. The heat recovery chillers are readily available from multiple US manufacturers. All pumps are standard products, and the AHUs and all the ductwork and piping outside the mechanical room were to be reused. The horizontal HDPE piping is a robust well established piping system utilized throughout the US for much more demanding applications like natural gas and to protect the nation's fiber optic cables. Two equipment exceptions, while COTS internationally, are rare in the US and are highlighted below.

8.4.1 Adiabatic Dry Cooler Issues:

Generally speaking, the most economical form of heat rejection is the ubiquitous cooling tower with its attendant high consumption of water due to its design as an evaporative cooling device. On the other end of the water consumption spectrum is a less prevalent, but COTS dry-cooler consisting of outdoor coils and fans for sensible heat transfer only with no water consumption.

However, a rare (in the US) adiabatic dry-cooler (sometimes referred to as a hybrid dry-cooler) was chosen for the design to allow adiabatic cooling in the summertime should there ever be a failure of the ATES system. While common in Europe and elsewhere, these are rare in the US. Nevertheless, there are multiple manufactures of this product, and the selected units were made in North America. The adiabatic dry coolers fit the design very well, due to their unique ability to provide a "water-energy" nexus slider bar of sorts where the Base can choose to trade KWH reduction or water reductions based on how often they operate the adiabatic mode. On future ATES projects, if water reduction is not a high priority, less expensive cooling towers should be considered.

8.4.2 Injection Control Valves-imported from Europe

In the US, open loop GHP system do not typically have high level injection valve designs or controls. One reason for this is that they do not ever reverse the flow of the groundwater in order to store and reuse a building's waste heat or "waste cold". Another reason is typical HVAC engineers are not schooled or experienced in the nuances of groundwater chemistry. Regrettably, many US engineers, not understanding that groundwater may harbor water chemistry issues that can be prevented if maintained in a pressurized state or sometimes an anoxic state, simply release the injected water in the well near the surface. To avoid those issues on the ATES project, it was decided to provide world-class injection valves that from a manufacturer that had extensive experience in ATES systems. After US manufacturers were investigated, the search turned to Europe and elsewhere. After extensive investigation, ultimately a firm in Switzerland was selected. Ironically, this company was the European branch of a US firm, but with no demand yet for ATES valves in the US, this product is only manufactured in Europe and in metric dimensions and European electrical characteristics (230 VAC/50 Hz). These seemingly minor inconvenience can create some delays, but though the use of US and Swiss piping adapters/fittings, and the ability of the hydraulic unit to be furnished at 120 VAC/60 Hz, the issues can be resolved easily.

8.5 ENGINEERING/SPATIAL ISSUES

8.5.1 Hydraulic Conductivity

Underground Energy LLC was obtained as a consultant to assist with ATES well pumping test analysis and the ATES well system hydraulic simulation to properly engineer the system. The objectives of the analysis and simulation was to analyze the pumping test data collected by AH&P, then use calculated aquifer transmissivity to develop a simple numerical groundwater model. The final objective was to simulate aquifer hydraulic effects of a 6-well ATES system operating at design flow rate under steady state conditions.

While the hydraulic conductivity allowed for high flow rates in and out of the aquifer, the native water level below grade does not allow for a great amount of water mounding in the aquifer before positive pressure is needed to inject the water back into the aquifer. The design of 3 extraction and three injection wells (which would not be operating at steady state) should be sufficient for the system.

8.5.2 Water Quality Issues

An aquifer is generally considered to be optimal for ATES use if the groundwater movement is low (typically in the magnitude of a few feet per year, it has good "yield" (GPM per foot of drawdown), and it has proper water quality. Typically, desired water quality characteristics include water low in iron (especially the species FE^{2+}, FE^{3+}), free of surface contaminates like nitrates (NO_3^-) or other pollutants. Especially important is to determine where the so-called Re-Dox interface is located and ensure the oxygenated water and the nearly oxygen free water (anoxic water) do not mix during the operation of the system. Rainwater and near surface water will always contain some oxygen due to the presence of atmospheric oxygen. Deep (100+ ft. deep) groundwater will generally not contain much oxygen. Water at NASP was sampled and was determined to have a significant amount of iron in the water. Iron was measured at 4,510 ug/L while Ferric Iron was measured as 16.6 mg/L. Highly detailed water chemistry analysis information is beyond the scope of this Final Report, but more information can be found in the Appendix. As an illustration of water chemistry and ATES design that would be highly risky would be to take deep anoxic water that was laden with iron and expose it to air by cascading (aerating it) down the injection well (or injecting it into an oxygenated aquifer) so that the iron would oxidize and precipitate out. Next opportunistic iron-eating bacteria could now utilize the iron-oxide as a food source causing biological fouling. Couple this approach with improper well and gravel pack design that extracts sand or clay from the formation and then an injection well that might have operated for decades might clog in a matter of months. It is important that water quality be analyzed, and good well design executed to experience the trouble-free ATES injection wells that can be found throughout the world when the aquifer is fully investigated, and the ATES wells properly engineered.

8.5.3 Mechanical Room and Real Estate Limitations

Retrofitting ATES systems into existing mechanical spaces and available land can range from simple to problematic. Military base's land usage ranges from low density development to very high density (e.g., around naval docks, urban areas) situations. According, installing the outside ATES systems often require careful planning, and if the aquifer beneath the base is prolific, sometimes 100s or even 1000's of tons (as in the case of NASP) of capacity can be installed with just several pairs of ATES wells. In the case of the ATES project, land was not an issue, and the base was suitable for the architecture with the selection of system type being driven more by circumstances and funding availability. Certain building types also lend themselves to their adaptability to ATES. The tight footprint of the modular chillers and the removal of the existing boilers provided sufficient room for the heat recovery chiller installation. The project consisted of a central chilled water plant and an aged local boiler we appropriately replaced with a modular heat recovery chiller. Elimination of the boiler provided the needed real estate for the new Heat Recovery Chiller ATES system. In other situations, (e.g., packaged DX equipment), the mechanical system may not lend themselves to be easily retrofitted to indoor mechanical system that are compatible with ATES, though those instances are probably rare.

8.5.4 Accessibility for ESTCP monitoring and tuning of the ATES and BTES (Cyber Security)

Due to security concerns, direct connection to the base -wide energy monitoring system was not allowed at either site. All energy monitoring was done by on-site data-logging equipment that was downloaded by independent cell modem-based monitoring equipment to keep it separate from all DoD systems so that at least some monitoring could be done more frequently and without a site visit.

9.0 REFERENCES

DOE, 1995. The Commercial Buildings Energy Consumption Survey (CBECS), Energy Information Administration (EIA) of the Department of Energy (DOE), Total Energy Consumption Per Square Ft. table, Office Building, Retrieved March 15, 2013 from http://www.eia.gov/emeu/consumptionbriefs/cbecs/pbawebsite/summarytable.htm

VDI-4640, 2006. Thermische Nutzung des Untergrundes-Unteriridische Thermiscche Energiespeicher-Blatt 3 (Utilization of the Subsurface for Thermal Purposes-Underground Thermal Energy Storage-Part 3), A Guideline for Underground Thermal Energy Storage (UTES) produced by the Verin Deutscher Ingenieure (VDI), or in English, the "Association of German Engineers".

(EPA 2012). eGRID2012 Version 1.0, U.S. annual non-baseload CO_2 output emission rate, year 2009 data, U.S. Environmental Protection Agency, Washington, DC.

Dougherty, D. June 2012. The Status of the Geothermal Industry. Power Point Presentation at the American Ground Water Trust, Ground Source Heating and Cooling for Residential and Commercial Properties – Latest Technologies, Economic Advantages, Environmental Impacts and Regulations Forum. Crystal City, Virginia. June 12, 2012.

Industry Insights. 2010. 2009/2010 Geothermal Heating and Cooling Systems State Regulatory Oversight Survey: jointly published by the Geothermal Heat Pump Consortium (GeoExchange), Ground Water Protection Council, International Ground Source Heat Pump Association and the National Ground Water Association (NGWA), 637p. Retrieved from http://info.ngwa.org

InterEnergy Software Gas Technology Institute. BinMaker Pro (Version 4.0), Des Plaines, IL.

Available from http://interenergysoftware.com

Florida Department of Environmental Protection, Classes of Injection Wells

Available from https://floridadep.gov/water/aquifer-protection/content/uic-wells-classification

10.0 POINTS OF CONTACT

All important Points of Contact (POC) involved in the demonstration, including Co-Investigators, sponsors, industry partners, regulators, etc. The list herein includes the POC Name, Organization, Phone Number, Email Address, and Role in Project.

Table 10.1. Points of Contact

Point of Contact	Organization	Phone & E-mail	Role in Project
Eric L. Myers, PE	Gulf Power 1 Energy Pl, Pensacola, FL 32520	Office: (850) 444-6830 eric.myers@nexteraenergy.com	Principal Investigator
Charles (Chuck) W. Hammock, Jr.	Andrews, Hammock & Powell, Inc., 250 Charter Lane, Macon, GA 31210	Office: (478) 405-8301, Ext 6362 chammock@ahpengr.com	Co-Principal Investigator
Brandon Caves	Andrews, Hammock & Powell, Inc., 250 Charter Lane, Macon, GA 31210	Office: (478) 405-8301, Ext 6384 bcaves@ahpengr.com	Co-Investigator
Kim Hopkins	Andrews, Hammock & Powell, Inc., 250 Charter Lane, Macon, GA 31210	Office: (478) 405-8301, Ext 6367 khopkins@ahpengr.com	AH&P Administrative Contact
Sabrina Williams-Hopkins, CEM	NAVFAC SE Public Works Department Pensacola	Office: (850) 452-2332, DSN 459 sabrina.williams1@navy.mil	Naval Air Station Pensacola Point of Contact
Elizabeth Goll, PE	Florida Power & Light 700 Universe Blvd, Juno Beach, FL 33408	Phone: (305) 588-3945 Elizabeth.goll@fpl.com	Lead Project Manager

APPENDIX A NAS PENSACOLA PUMPING TEST ANALYSIS AND ATES WELL SYSTEM HYDRAULIC SIMULATION

NAS Pensacola Pumping Test Analysis and ATES Well System Hydraulic Simulation

22 March 2021

for

AH&P CONSULTING ENGINEERS

by

Underground Energy, LLC

Underground ENERGY

Project Objectives

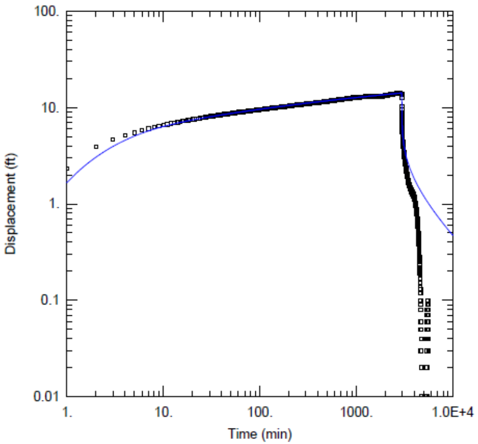
- Analyze pumping test data collected by AH&P
- Use calculated aquifer transmissivity to develop a simple numerical groundwater model
- Simulate aquifer hydraulic effects of 6-well ATES system operating at design flow rate under steady state conditions

Aquifer Testing and Analysis

- Pumping test performed by AH&P on 10 Dec 2020
  - Existing irrigation well (264 ft deep) used for pumping test
  - Pumped at 435 gpm for 48 hr
  - Drawdown data collected from pumped well and obs well
- UE analyzed data in AQTESOLV using Theis method
  - Transmissivity: 4,700 ft^2/d
  - Storage coefficient: 0.004
  - Analyzed as confined aquifer
  - Tidal influence observed in hydrograph

Underground ENERGY

Pumping Test Analysis Results



NAS PENSACOLA ATES AQUIFER TEST ANALYSIS

Data Set: C:\Program Files (x86)\HydroSOLVE\AQTESOLV Pro 4.0\Pensacola.aqt
Date: 03/22/21 Time: 21:29:47

PROJECT INFORMATION

Company: Underground Energy, LLC
Client: AH&P
Project: AHP.2021.01
Location: Pensacola, FL
Test Well: Pumping Well #1
Test Date: 12-10-2020

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW (#1)	0	0

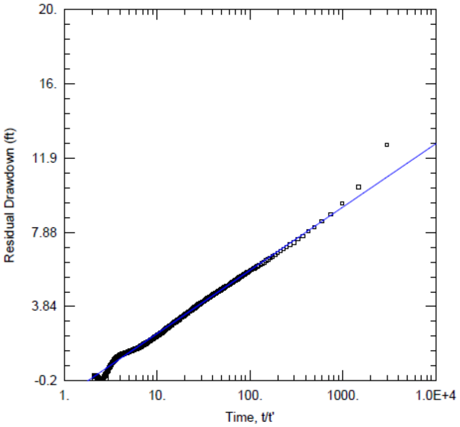
Observation Wells

Well Name	X (ft)	Y (ft)
▫ New MW	49	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 4951.5 ft^2/day
S = 0.003863
Kz/Kr = 1.
b = 250. ft



NAS PENSACOLA ATES AQUIFER TEST ANALYSIS

Data Set: C:\Program Files (x86)\HydroSOLVE\AQTESOLV Pro 4.0\Pensacola.aqt
Date: 03/22/21 Time: 21:35:12

PROJECT INFORMATION

Company: Underground Energy, LLC
Client: AH&P
Project: AHP.2021.01
Location: Pensacola, FL
Test Well: Pumping Well #1
Test Date: 12-10-2020

AQUIFER DATA

Saturated Thickness: 250. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW (#1)	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ New MW	49	0

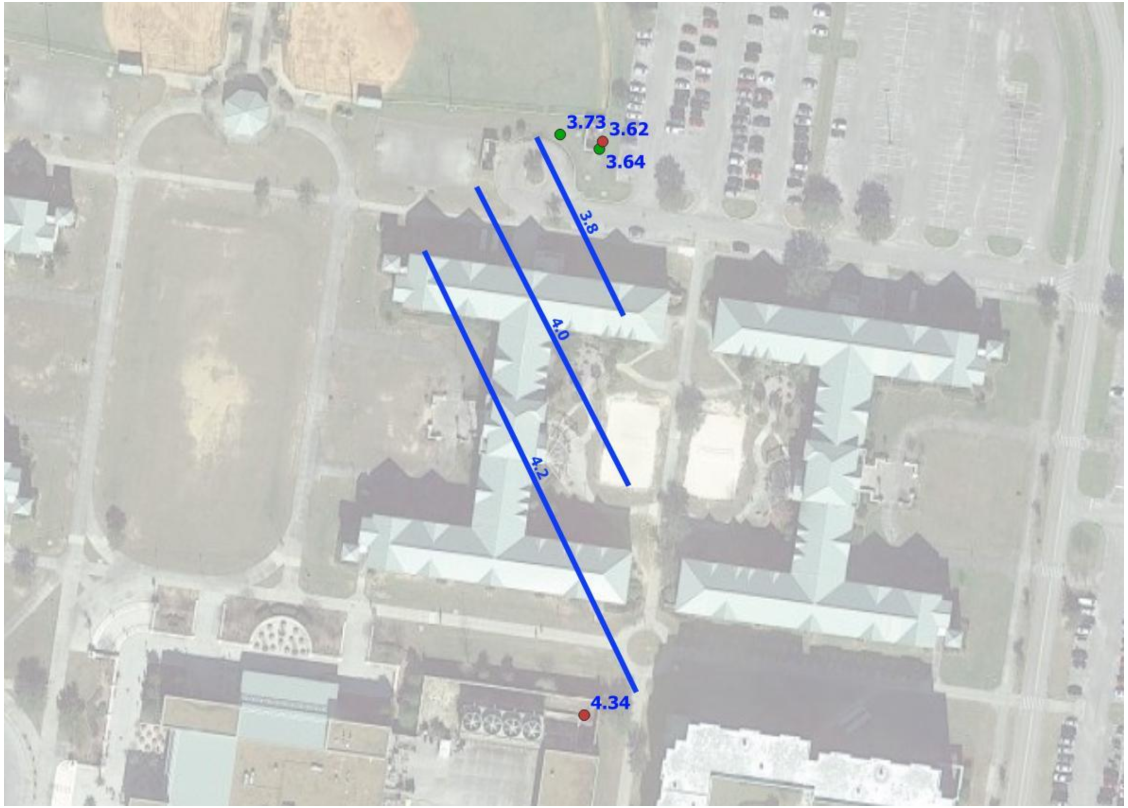
SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 4457.6 ft^2/day
S/S' = 2.055

Underground ENERGY

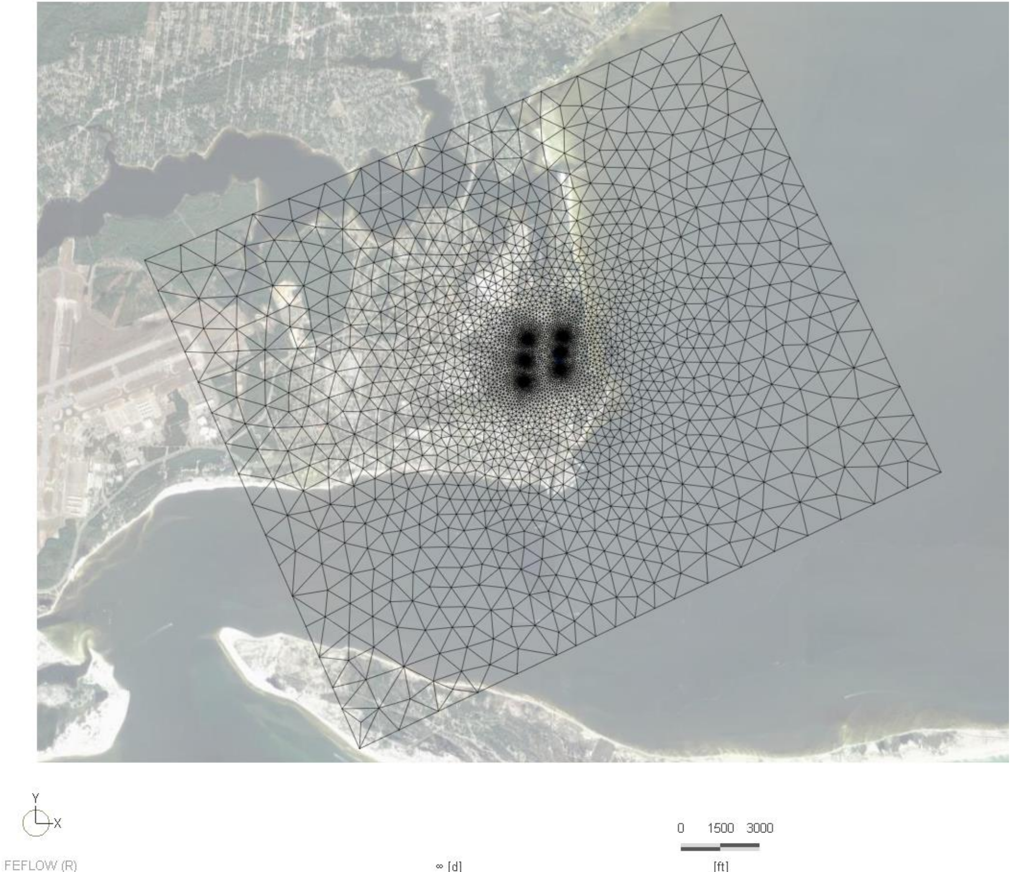
Hydraulic Head Measurement



- Four wells manually gauged and surveyed by AH&P
- Mean hydraulic head value ~ 4 ft
- Groundwater flow to E-NE
- Measured hydraulic gradient 0.002

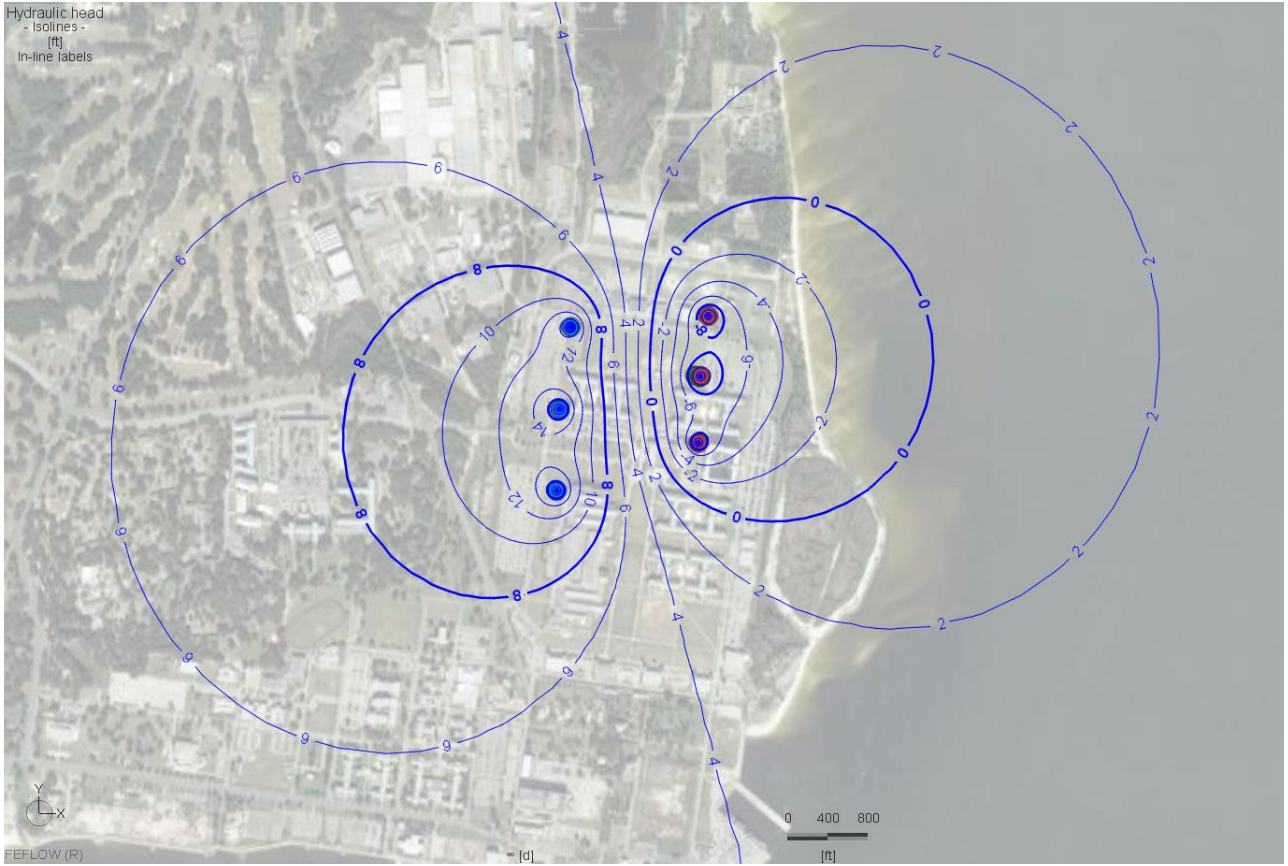
Underground ENERGY

Groundwater Flow Model



- FEFLOW 2D finite element mesh
  - ~8,000 nodes
  - Mesh refinement around 6 ATES wells
- Prescribed head boundary condition (4 ft) at model perimeter
- Uniform aquifer transmissivity distribution of 4,700 ft^2/d
- Steady state simulation

Simulation Results



- 3 Cold Wells
  - 493 gpm ea
  - Injection
  - Maximum head = 40 ft
- 3 Warm Wells
  - 493 gpm ea
  - Injection
  - Minimum head = -33 ft

Underground ENERGY

APPENDIX B ENERGY ANALYSIS SUMMARY SHEET

Total Area (Sq Ft)	456000

Energy Analysis Summary Sheet - ATES for Bldgs 3901, 3902, 3903, & 3904

Baseline System

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	KBTU/Yr	KBTU/Sqft/Yr
KWh/Yr	405,404	360,712	469,236	503,732	574,896	612,752	639,568	644,300	593,888	551,724	448,252	399,716	**6,204,180**	21,168,662	
Therms/Month	10,116	8,975	9,510	8,988	9,590	8,987	9,240	9,590	8,987	9,415	9,318	9,896	**112,613**	11,261,292	
														32,429,954	**71.12**

ATES System (ECM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**	**KBTU/Yr**	**KBTU/Sqft/Yr**
KWh/Month	336,329	303,809	376,605	408,470	504,551	591,287	622,003	624,338	555,620	463,546	363,608	334,766	**5,484,932**	18,714,589	
Therms/Month		502	-	-	-	-	-	-	-	-	-	347	**849**	84,942	
														18,799,531	**41.23**

KWh Savings/Yr	**719,248**
Therms Savings/Yr	**111,764**

Percent Reduction in EUI	42%

Electric Savings/Yr ($)	**$ 60,625.39**
Gas Savings/Yr ($)	**$ 65,158.12**
Total	**$ 125,783.51**

Gas Rate	$ 0.583
Electric Rate	$ 0.084

Capital Cost	**$ 1,965,706**
Payback (Yrs)	**15.6**

Notes:	The Baseline System data is modeled and calibrated to metered data. The ATES System is modeled data since the project did not progress to the construction phase.

APPENDIX C WATER QUALITY REPORT

eurofins | Environment Testing America

ANALYTICAL REPORT

Eurofins TestAmerica, Savannah
5102 LaRoche Avenue
Savannah, GA 31404
Tel: (912)354-7858

Laboratory Job ID: 680-192755-1
Client Project/Site: Naval Air Station Pensacola

For:
Andrews, Hammock & Powell, Inc
250 Charter Lane
Suite 100
Macon, Georgia 31210

Attn: Chuck Hammock

Authorized for release by:
12/28/2020 10:37:17 AM

Jerry Lanier, Project Manager I
(912)250-0281
Jerry.Lanier@Eurofinset.com

LINKS

Review your project results through TotalAccess

Have a Question? Ask The Expert

Visit us at: www.eurofinsus.com/Env

Table of Contents

Job ID: 680-192755-1

Laboratory: Eurofins TestAmerica, Savannah

Narrative

CASE NARRATIVE

Client: Andrews, Hammock & Powell, Inc

Project: Naval Air Station Pensacola

Report Number: 680-192755-1

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In the event of interference or analytes present at high concentrations, samples may be diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

RECEIPT
The samples were received on 12/12/2020; the samples arrived in good condition, properly preserved and on ice. The temperature of the coolers at receipt was 2.7 C.

METALS (ICP)
Sample NASP Pump #1 (680-192755-1) was analyzed for Metals (ICP) in accordance with EPA Method 200.7. The samples were prepared on 12/16/2020 and analyzed on 12/17/2020.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

ALKALINITY
Sample NASP Pump #1 (680-192755-1) was analyzed for alkalinity in accordance with SM 2320B. The samples were analyzed on 12/24/2020.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

AMMONIA
Sample NASP Pump #1 (680-192755-1) was analyzed for ammonia in accordance with EPA Method 350.1. The samples were analyzed on 12/22/2020.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

FERROUS IRON
Sample NASP Pump #1 (680-192755-1) was analyzed for ferrous iron in accordance with SM 3500-Fe-D. The samples were analyzed on 12/23/2020.

This analysis is normally performed in the field and has a method-defined holding time of 15 minutes. This sample(s) was performed in the laboratory outside the 15 minute timeframe.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

FERRIC IRON
Sample NASP Pump #1 (680-192755-1) was analyzed for ferric iron in accordance with SM 3500 FE D. The samples were analyzed on 12/24/2020.

This analysis is normally performed in the field and has a method-defined holding time of 15 minutes. This sample(s) was performed in

Job ID: 680-192755-1 (Continued)

Laboratory: Eurofins TestAmerica, Savannah (Continued)

the laboratory outside the 15 minute timeframe.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

NITRATE-NITRITE AS NITROGEN
Sample NASP Pump #1 (680-192755-1) was analyzed for nitrate-nitrite as nitrogen in accordance with EPA Method 353.2. The samples were analyzed on 12/18/2020.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

TURBIDIMETRIC SULFATE
Sample NASP Pump #1 (680-192755-1) was analyzed for Turbidimetric Sulfate in accordance with EPA SW-846 Method 9038. The samples were analyzed on 12/19/2020.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

TOTAL HARDNESS (AS CACO3) BY CALCULATION
Sample NASP Pump #1 (680-192755-1) was analyzed for total hardness (as CaCO3) by calculation in accordance with SM 2340B. The samples were analyzed on 12/22/2020.

No analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Sample Summary

Client: Andrews, Hammock & Powell, Inc
Project/Site: Naval Air Station Pensacola

Job ID: 680-192755-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received	Asset ID
680-192755-1	NASP Pump #1	Water	12/11/20 10:38	12/12/20 09:20	

Method Summary

Method	Method Description	Protocol	Laboratory
200.7 Rev 4.4	Metals (ICP)	40CFR136A	TAL SAV
SM 2340B	Total Hardness (as CaCO3) by calculation	SM	TAL SAV
2320B-2011	Alkalinity, Total	SM	TAL SAV
350.1-1993 R2.0	Nitrogen, Ammonia	MCAWW	TAL SAV
353.2-1993 R2.0	Nitrogen, Nitrate-Nitrite	MCAWW	TAL SAV
9038	Sulfate, Turbidimetric	SW846	TAL SAV
SM 3500	Iron, Ferric	SM	TAL SAV
SM 3500 FE D	Iron, Ferrous	SM	TAL SAV
200.7-1994 R4.4	Preparation, Total Metals	EPA	TAL SAV

Protocol References:

40CFR136A = "Methods for Organic Chemical Analysis of Municipal Industrial Wastewater", 40CFR, Part 136, Appendix A, October 26, 1984 and subsequent revisions.

EPA = US Environmental Protection Agency

MCAWW = "Methods For Chemical Analysis Of Water And Wastes", EPA-600/4-79-020, March 1983 And Subsequent Revisions.

SM = "Standard Methods For The Examination Of Water And Wastewater"

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

Laboratory References:

TAL SAV = Eurofins TestAmerica, Savannah, 5102 LaRoche Avenue, Savannah, GA 31404, TEL (912)354-7858

Client: Andrews, Hammock & Powell, Inc
Project/Site: Naval Air Station Pensacola

Job ID: 680-192755-1

Qualifiers

General Chemistry

Qualifier	Qualifier Description
H	Sample was prepped or analyzed beyond the specified holding time
HF	Field parameter with a holding time of 15 minutes. Test performed by laboratory at client's request.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CFU	Colony Forming Unit
CNF	Contains No Free Liquid
DER	Duplicate Error Ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL	Detection Limit (DoD/DOE)
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision Level Concentration (Radiochemistry)
EDL	Estimated Detection Limit (Dioxin)
LOD	Limit of Detection (DoD/DOE)
LOQ	Limit of Quantitation (DoD/DOE)
MCL	EPA recommended "Maximum Contaminant Level"
MDA	Minimum Detectable Activity (Radiochemistry)
MDC	Minimum Detectable Concentration (Radiochemistry)
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
MPN	Most Probable Number
MQL	Method Quantitation Limit
NC	Not Calculated
ND	Not Detected at the reporting limit (or MDL or EDL if shown)
NEG	Negative / Absent
POS	Positive / Present
PQL	Practical Quantitation Limit
PRES	Presumptive
QC	Quality Control
RER	Relative Error Ratio (Radiochemistry)
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)
TNTC	Too Numerous To Count

Detection Summary

Client: Andrews, Hammock & Powell, Inc
Job ID: 680-192755-1
Project/Site: Naval Air Station Pensacola

Client Sample ID: NASP Pump #1
Lab Sample ID: 680-192755-1

Analyte	Result	Qualifier	RL	MDL	Unit	Dil Fac	D	Method	Prep Type
Iron	4510		50.0		ug/L	1		200.7 Rev 4.4	Total/NA
Manganese	16.8		10.0		ug/L	1		200.7 Rev 4.4	Total/NA
Hardness as calcium carbonate	12.5		3.30		mg/L	1		SM 2340B	Total/NA
Calcium hardness as calcium carbonate	6.26		1.20		mg/L	1		SM 2340B	Total/NA
Magnesium hardness as calcium carbonate	6.20		2.10		mg/L	1		SM 2340B	Total/NA
Alkalinity	30.8		5.00		mg/L	1		2320B-2011	Total/NA
Bicarbonate Alkalinity as CaCO3	30.7		5.00		mg/L	1		2320B-2011	Total/NA
Sulfate	16.6		5.00		mg/L	1		9038	Total/NA
Ferric Iron	4.13		0.100		mg/L	1		SM 3500	Total/NA
Ferrous Iron	0.381	HF	0.100		mg/L	1		SM 3500 FE D	Total/NA

This Detection Summary does not include radiochemical test results.

Client Sample Results

Client: Andrews, Hammock & Powell, Inc
Project/Site: Naval Air Station Pensacola

Job ID: 680-192755-1

Client Sample ID: NASP Pump #1

Lab Sample ID: 680-192755-1

Date Collected: 12/11/20 10:38
Date Received: 12/12/20 09:20

Matrix: Water

Method: 200.7 Rev 4.4 - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	**4510**		50.0		ug/L		12/16/20 17:37	12/17/20 23:39	1
Manganese	**16.8**		10.0		ug/L		12/16/20 17:37	12/17/20 23:39	1

Method: SM 2340B - Total Hardness (as CaCO3) by calculation

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Hardness as calcium carbonate	**12.5**		3.30		mg/L			12/22/20 10:34	1
Calcium hardness as calcium carbonate	**6.26**		1.20		mg/L			12/22/20 10:34	1
Magnesium hardness as calcium carbonate	**6.20**		2.10		mg/L			12/22/20 10:34	1

General Chemistry

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Alkalinity	**30.8**		5.00		mg/L			12/24/20 09:39	1
Bicarbonate Alkalinity as CaCO3	**30.7**		5.00		mg/L			12/24/20 09:39	1
Carbonate Alkalinity as CaCO3	<5.00		5.00		mg/L			12/24/20 09:39	1
Ammonia	<0.250		0.250		mg/L			12/22/20 13:32	1
Nitrate as N	<0.0500	H	0.0500		mg/L			12/18/20 18:16	1
Nitrate Nitrite as N	<0.0500	H	0.0500		mg/L			12/18/20 18:16	1
Nitrite as N	<0.0500	H	0.0500		mg/L			12/18/20 18:16	1
Ferrous Iron	**0.381**	**HF**	0.100		mg/L			12/23/20 18:55	1

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Sulfate	**16.6**		5.00		mg/L			12/19/20 17:26	1
Ferric Iron	**4.13**		0.100		mg/L			12/24/20 06:20	1

QC Sample Results

Client: Andrews, Hammock & Powell, Inc
Project/Site: Naval Air Station Pensacola

Job ID: 680-192755-1

Method: 200.7 Rev 4.4 - Metals (ICP)

Lab Sample ID: MB 680-648880/1-A
Matrix: Water
Analysis Batch: 649225

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 648880

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Iron	<50.0		50.0		ug/L		12/16/20 17:37	12/17/20 22:27	1
Manganese	<10.0		10.0		ug/L		12/16/20 17:37	12/17/20 22:27	1

Lab Sample ID: LCS 680-648880/2-A
Matrix: Water
Analysis Batch: 649225

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 648880

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Iron	1700	1752		ug/L		103	85 - 115
Manganese	400	422.2		ug/L		105	85 - 115

Method: SM 2340B - Total Hardness (as CaCO3) by calculation

Lab Sample ID: MB 680-649744/1
Matrix: Water
Analysis Batch: 649744

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Hardness as calcium carbonate	<3.30		3.30		mg/L			12/22/20 10:34	1
Calcium hardness as calcium carbonate	<1.20		1.20		mg/L			12/22/20 10:34	1
Magnesium hardness as calcium carbonate	<2.10		2.10		mg/L			12/22/20 10:34	1

Method: 2320B-2011 - Alkalinity, Total

Lab Sample ID: MB 680-650381/8
Matrix: Water
Analysis Batch: 650381

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Alkalinity	<5.00		5.00		mg/L			12/24/20 08:56	1
Bicarbonate Alkalinity as CaCO3	<5.00		5.00		mg/L			12/24/20 08:56	1
Carbonate Alkalinity as CaCO3	<5.00		5.00		mg/L			12/24/20 08:56	1

Lab Sample ID: LCS 680-650381/9
Matrix: Water
Analysis Batch: 650381

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Alkalinity	250	238.6		mg/L		95	90 - 112

Lab Sample ID: LCSD 680-650381/35
Matrix: Water
Analysis Batch: 650381

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Alkalinity	250	240.2		mg/L		96	90 - 112	1	30

Method: 350.1-1993 R2.0 - Nitrogen, Ammonia

Lab Sample ID: MB 680-649861/36
Matrix: Water
Analysis Batch: 649861

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Ammonia	<0.250		0.250		mg/L			12/22/20 13:13	1

Lab Sample ID: LCS 680-649861/37
Matrix: Water
Analysis Batch: 649861

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Ammonia	1.00	1.044		mg/L		104	90 - 110

Method: 353.2-1993 R2.0 - Nitrogen, Nitrate-Nitrite

Lab Sample ID: MB 680-649289/13
Matrix: Water
Analysis Batch: 649289

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Nitrate as N	<0.0500		0.0500		mg/L			12/18/20 17:45	1
Nitrate Nitrite as N	<0.0500		0.0500		mg/L			12/18/20 17:45	1
Nitrite as N	<0.0500		0.0500		mg/L			12/18/20 17:45	1

Lab Sample ID: LCS 680-649289/17
Matrix: Water
Analysis Batch: 649289

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Nitrate Nitrite as N	1.00	0.9933		mg/L		99	90 - 110
Nitrite as N	0.500	0.5070		mg/L		101	90 - 110

Method: 9038 - Sulfate, Turbidimetric

Lab Sample ID: MB 680-649381/11
Matrix: Water
Analysis Batch: 649381

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Sulfate	<5.00		5.00		mg/L			12/19/20 17:21	1

Lab Sample ID: LCS 680-649381/12
Matrix: Water
Analysis Batch: 649381

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Sulfate	20.0	19.51		mg/L		98	75 - 125

Method: SM 3500 FE D - Iron, Ferrous

Lab Sample ID: MB 680-650126/13
Client Sample ID: Method Blank
Matrix: Water
Prep Type: Total/NA
Analysis Batch: 650126

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Ferrous Iron	<0.100		0.100		mg/L			12/23/20 18:55	1

Lab Sample ID: LCS 680-650126/14
Client Sample ID: Lab Control Sample
Matrix: Water
Prep Type: Total/NA
Analysis Batch: 650126

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Ferrous Iron	2.00	1.911		mg/L		96	80 - 120

Lab Sample ID: 680-192755-1 MS
Client Sample ID: NASP Pump #1
Matrix: Water
Prep Type: Total/NA
Analysis Batch: 650126

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Ferrous Iron	0.381	HF	2.00	2.268		mg/L		94	80 - 120

Lab Sample ID: 680-192755-1 MSD
Client Sample ID: NASP Pump #1
Matrix: Water
Prep Type: Total/NA
Analysis Batch: 650126

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Ferrous Iron	0.381	HF	2.00	2.266		mg/L		94	80 - 120	0	20

Metals

Prep Batch: 648880

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	200.7-1994 R4.4	
MB 680-648880/1-A	Method Blank	Total/NA	Water	200.7-1994 R4.4	
LCS 680-648880/2-A	Lab Control Sample	Total/NA	Water	200.7-1994 R4.4	

Analysis Batch: 649225

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	200.7 Rev 4.4	648880
MB 680-648880/1-A	Method Blank	Total/NA	Water	200.7 Rev 4.4	648880
LCS 680-648880/2-A	Lab Control Sample	Total/NA	Water	200.7 Rev 4.4	648880

Analysis Batch: 649744

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	SM 2340B	
MB 680-649744/1	Method Blank	Total/NA	Water	SM 2340B	

General Chemistry

Analysis Batch: 649289

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	353.2-1993 R2.0	
MB 680-649289/13	Method Blank	Total/NA	Water	353.2-1993 R2.0	
LCS 680-649289/17	Lab Control Sample	Total/NA	Water	353.2-1993 R2.0	

Analysis Batch: 649381

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	9038	
MB 680-649381/11	Method Blank	Total/NA	Water	9038	
LCS 680-649381/12	Lab Control Sample	Total/NA	Water	9038	

Analysis Batch: 649861

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	350.1-1993 R2.0	
MB 680-649861/36	Method Blank	Total/NA	Water	350.1-1993 R2.0	
LCS 680-649861/37	Lab Control Sample	Total/NA	Water	350.1-1993 R2.0	

Analysis Batch: 649879

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	SM 3500	

Analysis Batch: 650126

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	SM 3500 FE D	
MB 680-650126/13	Method Blank	Total/NA	Water	SM 3500 FE D	
LCS 680-650126/14	Lab Control Sample	Total/NA	Water	SM 3500 FE D	
680-192755-1 MS	NASP Pump #1	Total/NA	Water	SM 3500 FE D	
680-192755-1 MSD	NASP Pump #1	Total/NA	Water	SM 3500 FE D	

Analysis Batch: 650381

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
680-192755-1	NASP Pump #1	Total/NA	Water	2320B-2011	
MB 680-650381/8	Method Blank	Total/NA	Water	2320B-2011	

General Chemistry (Continued)

Analysis Batch: 650381 (Continued)

Lab Sample ID	Client Sample ID	Prep Type	Matrix	Method	Prep Batch
LCS 680-650381/9	Lab Control Sample	Total/NA	Water	2320B-2011	
LCSD 680-650381/35	Lab Control Sample Dup	Total/NA	Water	2320B-2011	

Lab Chronicle

Client: Andrews, Hammock & Powell, Inc
Project/Site: Naval Air Station Pensacola

Job ID: 680-192755-1

Client Sample ID: NASP Pump #1

Date Collected: 12/11/20 10:38
Date Received: 12/12/20 09:20

Lab Sample ID: 680-192755-1
Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dil Factor	Initial Amount	Final Amount	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	200.7-1994 R4.4			50 mL	50 mL	648880	12/16/20 17:37	BCB	TAL SAV
Total/NA	Analysis	200.7 Rev 4.4		1			649225	12/17/20 23:39	BCB	TAL SAV
	Instrument ID: ICPE									
Total/NA	Analysis	SM 2340B		1			649744	12/22/20 10:34	BCB	TAL SAV
	Instrument ID: NOEQUIP									
Total/NA	Analysis	2320B-2011		1			650381	12/24/20 09:39	DR	TAL SAV
	Instrument ID: MANTECH									
Total/NA	Analysis	350.1-1993 R2.0		1	2 mL	2 mL	649861	12/22/20 13:32	DR	TAL SAV
	Instrument ID: KONELAB1									
Total/NA	Analysis	353.2-1993 R2.0		1	2 mL	2 mL	649289	12/18/20 18:16	MCL	TAL SAV
	Instrument ID: LACHAT2									
Total/NA	Analysis	9038		1	2 mL	2 mL	649381	12/19/20 17:26	NVF	TAL SAV
	Instrument ID: KONELAB3									
Total/NA	Analysis	SM 3500		1			649879	12/24/20 06:20	TJW	TAL SAV
	Instrument ID: NOEQUIP									
Total/NA	Analysis	SM 3500 FE D		1	2 mL	2 mL	650126	12/23/20 18:55	MCL	TAL SAV
	Instrument ID: KONELAB2									

Laboratory References:

TAL SAV = Eurofins TestAmerica, Savannah, 5102 LaRoche Avenue, Savannah, GA 31404, TEL (912)354-7858

Eurofins TestAmerica Savannah Triage Checklist

- ☐ Date: 12-12-2020
- ☐ Time: 0920
- ☐ Checked By: [signature]
- ☐ Number of Coolers: 1
- ☐ Cooler Type: (Hard) Styrofoam Box
- ☐ Ice Type: (Wet) Dry GelPack None Other
- ☐ Received Via: (Fed-Ex) ( ) UPS (SAT) Bus Client Drop Off US Mail Courier Other
- ☐ Client: Andrews, Hammock + Powell
- ☐ Thermometer ID: CUIR 27/29
- ☐ Uncorrected Cooler Temps (°C): 2.1
- ☐ Correction Factor: +0.3 / -0.3
- ☐ Corrected Cooler Temps (°C): 2.4
- ☐ Other/ Comments: NO COC
- ☐ West Virginia – Yes / No
- ☐ Foreign soil – Yes / No

680-192755

680-192755 Chain of Custody

TestAmerica

FCU066:12.27.18:10

Eurofins TestAmerica, Savannah
5102 LaRoche Avenue
Savannah, GA 31404
Phone (912) 354-7858 Fax (912) 352-0165

Chain of Custody Record

eurofins | Environment Testing America

Client Information	Sampler: Joey Ringer	Lab PM: Lanier, Jerry A	Carrier Tracking No(s):	COC No: 680-120642-45826.1
Client Contact: Chuck Hammock	Phone: 478-832-6384	E-Mail: Jerry.Lanier@Eurofinset.com	State of Origin:	Page: Page 1 of 1
Company: Andrews, Hammock & Powell, Inc	PWSID:	**Analysis Requested**		Job #: 2018182
Address: 250 Charter Lane Suite 100	**Due Date Requested:** NA			
City: Macon	**TAT Requested (days):**			
State, Zip: GA, 31210	**Compliance Project:** Δ Yes Δ No			
Phone: 478-405-8301(Tel)	PO #: Purchase Order Requested			
Email: CHammock@ahpengr.com	WO #:			
Project Name: Naval Air Station Pensacola	Project #: 68024808			
Site:	SSOW#:			

Preservation Codes:
A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA
M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Other:

Sample Identification	Sample Date	Sample Time	Sample Type (C=comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	200.7_CWA - (MOD) Custom Sublist Template	Total Number of containers	Special Instructions/Note
			Preservation Code:		X	X	D	X	
NASP Pump #1	12/11/20	10:38	?	Water					We want to test this sample for all species of iron

680-192755 Chain of Custody

Possible Hazard Identification
[X] *Non-Hazard* [ ] *Flammable* [ ] *Skin Irritant* [ ] *Poison B* [ ] *Unknown* [ ] *Radiological*

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
[ ] *Return To Client* [X] *Disposal By Lab* [ ] *Archive For ______ Months*

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:		
Relinquished by:	Date/Time:	Company	Received by: [signature]	Date/Time: 12-12-20	Company: 0920
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Custody Seals Intact: Δ Yes Δ No	Custody Seal No.:		Cooler Temperature(s) °C and Other Remarks: 2.4 (CF) 2.7°C		

Ver: 01/16/2019

Login Sample Receipt Checklist

Client: Andrews, Hammock & Powell, Inc

Job Number: 680-192755-1

Login Number: 192755

List Source: Eurofins TestAmerica, Savannah

List Number: 1

Creator: Sims, Robert D

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	False	Refer to Job Narrative for details.
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time (excluding tests with immediate HTs)	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Accreditation/Certification Summary

Client: Andrews, Hammock & Powell, Inc Job ID: 680-192755-1
Project/Site: Naval Air Station Pensacola

Laboratory: Eurofins TestAmerica, Savannah

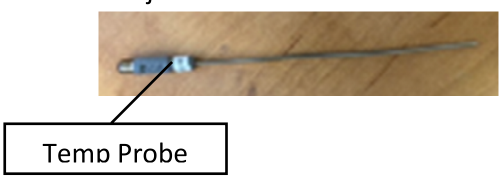
The accreditations/certifications listed below are applicable to this report.

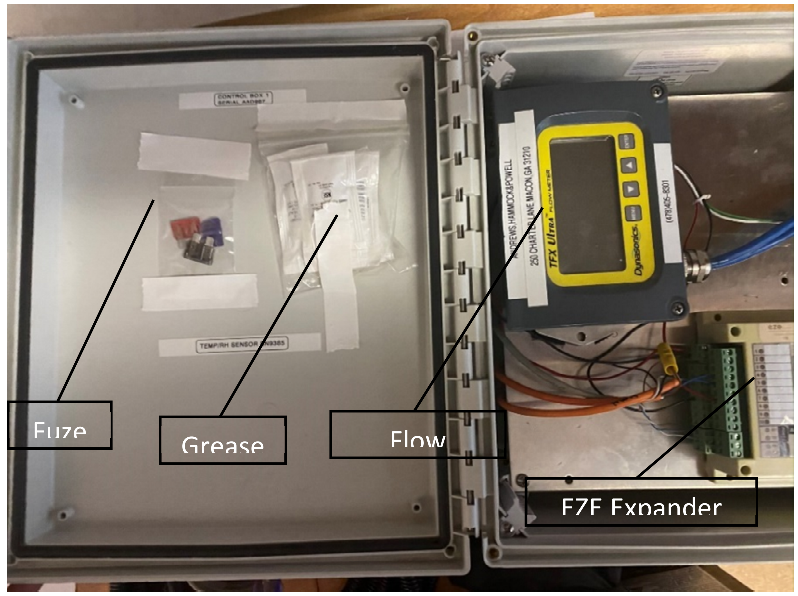
Authority	Program	Identification Number	Expiration Date
Georgia	State	E87052	06-30-21

APPENDIX D INSTALLATION OF DATA LOGGER RECORDING EQUIPMENT

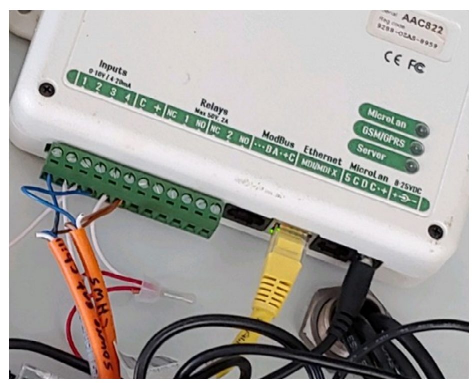
Instructions for Installing New Datalogger Box at NASP

1. In the box there should be
    a. Four 3-amp fuse
    b. 4 packets of grease
    c. Dynasonic flow meter
    d. EZE expander
    e. Two temperature probes
    f. Four pipe clamps
    g. One EZE System Controller
    h. five self-tapping screws
    i. one 5/16 nut driver
    j. one small screwdriver

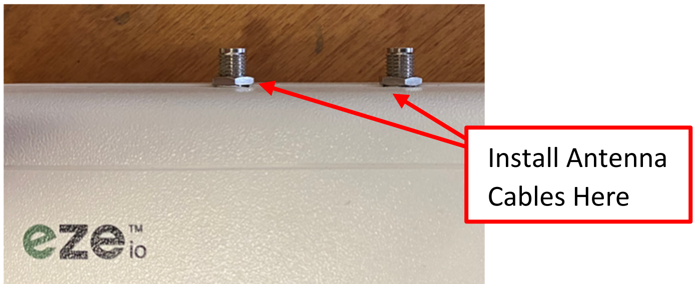


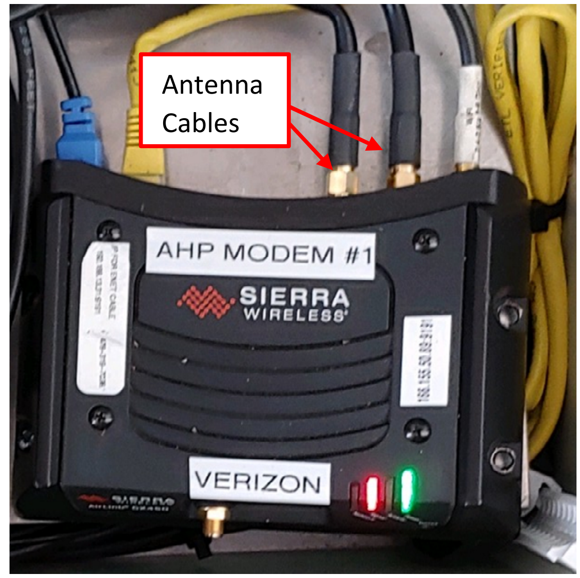


2. The wires inside of the wire loom need to be ran to the other box with the old EZE system inside.
3. Insert the wires into the box (it is easiest to push in the ring connectors first then the ethernet cable)
4. The EZE controller that came in the package needs to replace the EZE system already at NASP to do this make sure that both the battery and the 120V plug are disconnected
5. Unplug everything from the eze controller, use the small screwdriver in the package to disconnect the brown, blue and white wires
6. The EZE Controller is Attached to the box via Velcro. Remove the EZE Controller
7. Connect the new easy controller (if the Velcro is the right side just stick it on, if the Velcro isn't right self-tapping screws where provided to screw the EZE controller in)
8. Reconnect everything except the Ethernet Cord exactly as show in the image to the right



9. The Sierra Wireless Modem is no longer needed, but two of the Antenna Cables need to be connected to the new EZE Controller(if the Antenna Cables are the wrong size a spare Antenna has been provided in the package)

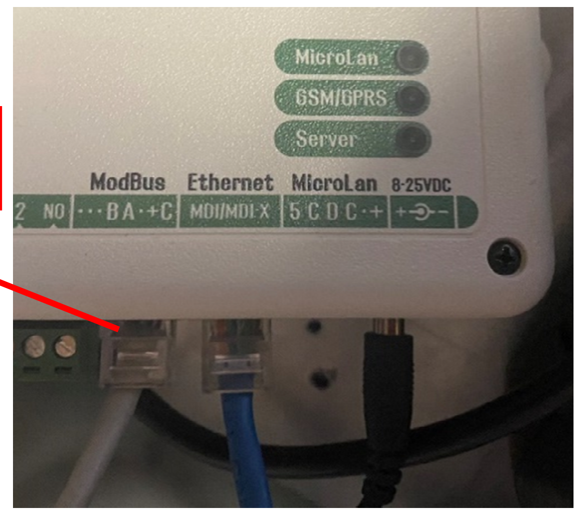




10. The ethernet cable needs to be plugged into the "ModBus" port on the EZE system

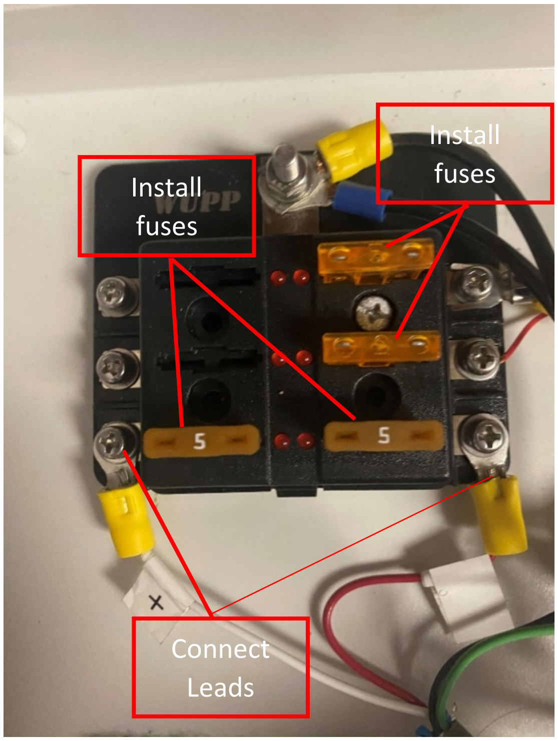
11. The electrical connections need to be connected to the fuse block before touching the fuse block unplug the battery and the AC power to the box.

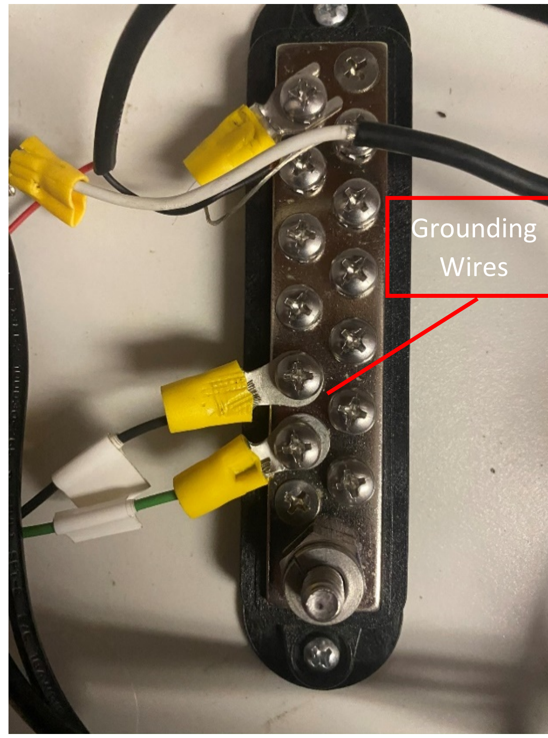
12. Replace the fuses currently inside the fuse block with the three amp fuses



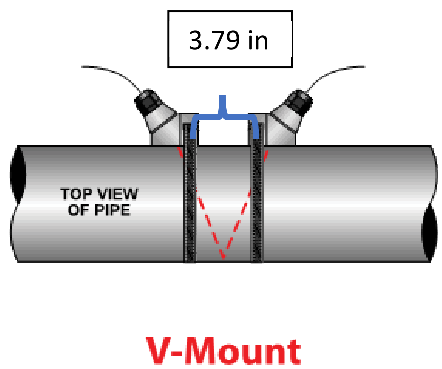
13. Connect the red wire to one terminal of the fuse block and the white wire to another terminal. Insert fuses into the terminals that the red and white wires are connected. (use any of the fuses provided the size doesn't matter).

14. Connect the Black and Green wire to the ground bar(in order to remove the black plastic cap the ground wires must first be disconnected.



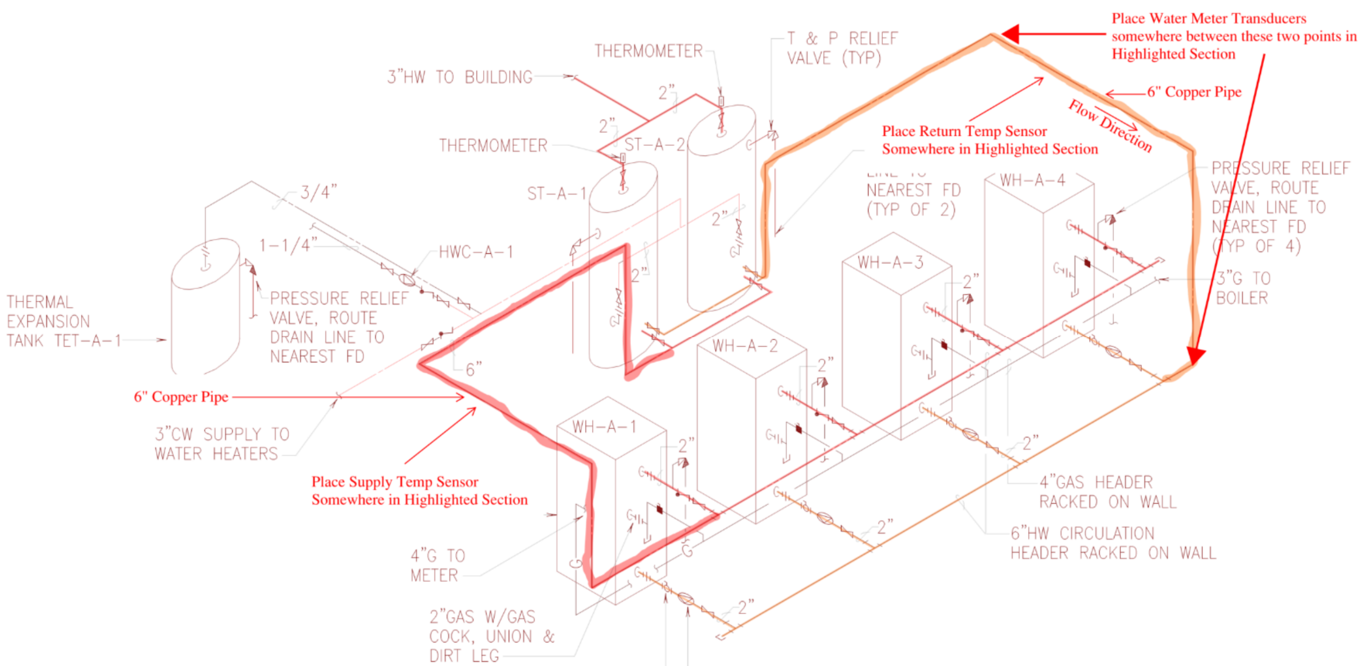


15. Plug the battery and the ac power back in
16. Plug the temperature probe into the orange wire (there is a nub inside the temp probe that lines up with the wire)
17. Insert the probe into the pipe
18. Spread grease on the transducers and attach to pipe using pipe clamps (the transducers need to be 3.79 inches Apart



Install in Building 3901, 3902, 3903, or 3904

- Transducer Spacing for 6" Copper Pipe = 5.82" or approximately 5-13/16"
- Install temperature sensors in thermometer wells filled with mineral oil, or P&T ports if available. If nothing is available, cut insulation, install sensors directly on piping and re-insulate back over the piping.
- Temp Range setting of temp sensors = 61°-201° F. Could not program 60-200



APPENDIX E LIFE CYCLE COST ANALYSIS

NIST BLCC 5.3-22: Detailed LCC Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

General Information

File Name:	P:\2018182 EW-18-5311 UTES as a DOD Facilities UESC Energy Conservation Management\BLCC5\NASP LCCA.xml
Date of Study:	Tue Nov 29 16:06:07 EST 2022
Analysis Type:	FEMP Analysis, Energy Project
Project Name:	ATES - Naval Air Station PEnsacola
Project Location:	Florida
Analyst:	C. Brandon Caves
Base Date:	October 1, 2023
Service Date:	October 1, 2024
Study Period:	20 years 0 months (October 1, 2023 through September 30, 2043)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Discount and Escalation Rates are REAL (exclusive of general inflation)

Alternative: Baseline - Conventional HVAC

Initial Cost Data (not Discounted)

Initial Capital Costs

(adjusted for price escalation)

Initial Capital Costs for All Components:	$9,954,495

Component:

Cost-Phasing

Date	Portion	Yearly Cost
October 1, 2023	100%	$9,954,495
	------------	------------
Total (for Component)		$9,954,495

Energy Costs: Electricity

(base-year dollars)

Average Annual Usage	Price/Unit	Average Annual Cost	Average Annual Demand	Average Annual Rebate
6,204,180.0 kWh	$0.08400	$521,151	$0	$0

Energy Costs: Natural Gas

(base-year dollars)

Average Annual Usage	Price/Unit	Average Annual Cost	Average Annual Demand	Average Annual Rebate
112,613.0 Therm	$0.58300	$65,653	$0	$0

Water Costs: Evaporated Water

(base-year dollars)

	Average Annual Usage		Average Annual Disposal		Average Annual
Water	**Units/Year**	**Price/Unit**	**Units/Year**	**Price/Unit**	**Cost**
@ Summer Rates	2,759.0 ThousGal	$4.00000	0.0 ThousGal	$0.00000	$11,036
@ Winter Rates	0.0 ThousGal	$0.00000	0.0 ThousGal	$0.00000	$0

Life-Cycle Cost Analysis

	Present Value	Annual Value
Initial Capital Costs	$9,954,495	$669,165
Energy Costs		
Energy Consumption Costs	$7,867,063	$528,842
Energy Demand Charges	$0	$0
Energy Utility Rebates	$0	$0
	------------	------------
Subtotal (for Energy):	$7,867,063	$528,842
Water Usage Costs	$153,482	$10,317
Water Disposal Costs	$0	$0
Operating, Maintenance & Repair Costs		
Component:		
Annually Recurring Costs	$0	$0
Non-Annually Recurring Costs	$0	$0
	------------	------------
Subtotal (for OM&R):	$0	$0
Replacements to Capital Components		
Component:	$0	$0
	------------	------------
Subtotal (for Replacements):	$0	$0

Residual Value of Original Capital Components		
Component:	$0	$0
	------------	------------
Subtotal (for Residual Value):	$0	$0
Residual Value of Capital Replacements		
Component:	$0	$0
	------------	------------
Subtotal (for Residual Value):	$0	$0
Total Life-Cycle Cost	$17,975,039	$1,208,324

Emissions Summary

Energy Name	Annual	Life-Cycle
Electricity:		
CO2	2,655,324.06 kg	50,438,434.84 kg
SO2	781.92 kg	14,852.81 kg
NOx	1,027.67 kg	19,520.83 kg
Natural Gas:		
CO2	594,930.30 kg	11,300,825.28 kg
SO2	4,801.28 kg	91,201.23 kg
NOx	499.14 kg	9,481.32 kg
Total:		
CO2	3,250,254.36 kg	61,739,260.12 kg
SO2	5,583.20 kg	106,054.03 kg
NOx	1,526.81 kg	29,002.15 kg

Alternative: ATES

Initial Cost Data (not Discounted)

Initial Capital Costs

(adjusted for price escalation)

Initial Capital Costs for All Components: $11,920,201

Component: HVAC Equipment

Cost-Phasing

Date	Portion	Yearly Cost
October 1, 2023	100%	$9,954,495
	------------	------------
Total (for Component)		$9,954,495

Component: ATES Wells

Cost-Phasing

Date	Portion	Yearly Cost
October 1, 2023	100%	$1,965,706
	------------	------------
Total (for Component)		$1,965,706

Energy Costs: Copy of: Electricity

(base-year dollars)

Average Annual Usage	Price/Unit	Average Annual Cost	Average Annual Demand	Average Annual Rebate
5,484,932.0 kWh	$0.08400	$460,734	$0	$0

Energy Costs: Copy of: Natural Gas

(base-year dollars)

Average Annual Usage	Price/Unit	Average Annual Cost	Average Annual Demand	Average Annual Rebate
849.0 Therm	$0.58300	$495	$0	$0

Water Costs: Copy of: Evaporated Water

(base-year dollars)

	Average Annual Usage		Average Annual Disposal		Average Annual
Water	Units/Year	Price/Unit	Units/Year	Price/Unit	Cost
@ Summer Rates	0.0 ThousGal	$4.00000	0.0 ThousGal	$0.00000	$0
@ Winter Rates	0.0 ThousGal	$0.00000	0.0 ThousGal	$0.00000	$0

Life-Cycle Cost Analysis

	Present Value	Annual Value
Initial Capital Costs	$11,920,201	$801,304
Energy Costs		
Energy Consumption Costs	$6,120,540	$411,437
Energy Demand Charges	$0	$0
Energy Utility Rebates	$0	$0
	------------	------------
Subtotal (for Energy):	$6,120,540	$411,437
Water Usage Costs	$0	$0
Water Disposal Costs	$0	$0
Operating, Maintenance & Repair Costs		
Component: HVAC Equipment		
Annually Recurring Costs	$0	$0
Non-Annually Recurring Costs	$0	$0

Component: ATES Wells		
Annually Recurring Costs	$0	$0
Non-Annually Recurring Costs	$0	$0
	------------	------------
Subtotal (for OM&R):	$0	$0
Replacements to Capital Components		
Component: HVAC Equipment	$0	$0
Component: ATES Wells	$0	$0
	------------	------------
Subtotal (for Replacements):	$0	$0
Residual Value of Original Capital Components		
Component: HVAC Equipment	$0	$0
Component: ATES Wells	$0	$0
	------------	------------
Subtotal (for Residual Value):	$0	$0
Residual Value of Capital Replacements		
Component: HVAC Equipment	$0	$0
Component: ATES Wells	$0	$0
	------------	------------
Subtotal (for Residual Value):	$0	$0
Total Life-Cycle Cost	$18,040,741	$1,212,741

Emissions Summary

Energy Name	Annual	Life-Cycle
Copy of: Electricity:		
CO2	2,347,493.45 kg	44,591,128.12 kg
SO2	691.28 kg	13,130.93 kg
NOx	908.53 kg	17,257.79 kg
Copy of: Natural Gas:		
CO2	4,485.24 kg	85,197.98 kg
SO2	36.20 kg	687.57 kg
NOx	3.76 kg	71.48 kg

Total:

CO_2	2,351,978.68 kg	44,676,326.11 kg
SO_2	727.47 kg	13,818.50 kg
NO_x	912.30 kg	17,329.27 kg