American Recovery and Reinvestment Act (ARRA)

FEMP Technical Assistance

U.S. Naval Bases
Sasebo, Misawa, Japan & Whidbey Island, Lemoore, U.S.
Project 253 U.S. Navy Design Study of GSHP Systems at Japan

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September 2010

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Executive Summary

Two Navy bases (i.e., Sasebo and Misawa) in Japan are seeking to retrofit one or two of their existing buildings with ground source heat pump systems (GSHP) to reduce the current energy bills as well as implementing a renewable technology in the base. Since the ARRA funds have been awarded for these bases, the DOE FEMP team provided technical assistance for the bases, including a site visit and the final report for a feasibility study of implementing GSHP systems at the bases. In addition, a soil conductivity test at Whidbey Island base, and GSHP Design and installation cost estimate for Lemoore base were performed as parts of this project.

U.S. Naval Base Sasebo

A feasibility study for a Navy lodging building at Sasebo base was performed to evaluate energy and cost savings potential by applying GSHP systems. The current HVAC system for the building is a conventional Air Handling Unit (AHU) system with chiller. The heating and the DHW are provided by district steam. The building is close to a surface water source, which could be used for the heat source/sink for the chosen GSHP system. The annual water temperature measured close to the site is available for this feasibility study. The study result shows that the open loop GSHP system can save 338.5 MMBtu of total energy annually, which corresponds 21.7% energy saving. The expected annual energy cost saving based on the current utility rate is about $7,724. The capital cost for the project was estimated based on the cost information obtained from a Japanese GSHP installer and other literature. The capital cost for the proposed system would be about $250,000, and the 32 years of simple payback can be achieved with the given capital cost and energy cost savings. The corresponding green house gas reduction would be 5 tons annually.

U.S. Naval Base Misawa

A feasibility study for a HQ administrative building at Misawa base was performed to evaluate energy and cost savings potential by applying GSHP systems. The current HVAC system for the building is a conventional AHU system with chiller. The heating is provided by district steam. There is enough land area available close to the building to install the vertical boreholes for GHX. The study result shows that the vertical borehole GSHP system can save 817.0 MMBtu of total energy annually, which corresponds 36.5% total energy saving. The expected annual energy cost saving based on the current utility rate is about $8,211. The capital cost for the project was estimated based on the cost information obtained from a Japanese GSHP installer and other literature. The capital cost for the proposed system would be about $306,958, and the 37 years of simple payback can be achieved with the given capital cost and energy cost savings. The corresponding green house gas reduction would be 116.5 tons annually.

Borehole Test Report – Whidbey Island Naval Base

The report presents the borehole test results conducted by a subcontractor at Whidbey Island Naval base. The results from the test will be used for further investigation for the GSHP system application at the base. The test borehole was drilled through 271 feet with nominal 6-inch diameter, and a thermally enhanced grout (K=0.88 Btu/ft-F) was used for the grouting. Field testing was performed on the test borehole to estimate the thermal properties of the ground formation. The test results show that the thermal conductivity, the thermal diffusivity, and the undisturbed deep ground temperature were 1.21 Btu/hr-ft-F, 0.90 ft^2/day, and 56.0 F, respectively.

Geothermal Heat Pump System Ground Heat Exchanger Design and Installation Cost Estimate for Lemoore Base

The work was performed to provide a ground source heat exchanger design, associated costing, and other recommendations as may be appropriate for converting Building 803C at Lemoore base to a renewable/sustainable geothermal heat pump system with geothermal heat pump domestic hot water heating. The final GHX design shows that about 49 to 50 boreholes (7 x 7 or 5 x10 layout) would be suitable to provide proper heat sink/source for the building. The distance between the boreholes would be 20 to 30 ft. The installation cost estimate which does not include any inside work or heat pump unit installation would be around $250,000 - $325,000. In conclusion, this project will require no more than 50 boreholes approximately 260' deep on 30 foot centers. This bore field will address both space conditioning and water heat loads for Building 803C. The study shows that this is a viable project that should move forward if funding for the loop field and inside work is available. Further simulation modeling analysis with the borehole design provided in this study can estimates the energy and cost savings by implementing the proposed GSHP system for the building.

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Description of ARRA Program

On Feb. 13, 2009, Congress passed the American Recovery and Reinvestment Act (ARRA) of 2009 at the urging of President Obama, who signed it into law four days later. A direct response to the economic crisis, the Recovery Act has three immediate goals:

- Create new jobs and save existing ones
- Spur economic activity and invest in long-term growth
- Foster unprecedented levels of accountability and transparency in government spending.[1]

In a competitive grant approach across the services and commands, the national labs were awarded over $7,600,000 from the Department of Energy Federal Energy Management Program (DOE FEMP) to support Department of Defense (DOD) needs. The ARRA funds are dedicated to technical assistance projects aimed at bringing the most advanced energy efficiency, renewable power generation assessments and analyses to DOD installations.

Two Navy bases (i.e., Sasebo and Misawa) in Japan are seeking to retrofit one or two of their existing buildings with ground source heat pump systems to reduce the current energy bills as well as implementing a renewable technology in the base. Since the ARRA funds have been awarded for these bases, the DOE FEMP team provided technical assistance for the bases, including site visits and the final report for feasibility study of implementing GSHP systems at the base. In addition, a soil conductivity test at Whidbey Island base, and GSHP design and installation cost estimate for Lemoore base are performed as parts of this project.

[1] http://www.recovery.gov/

SECTION 1:

GSHP Feasibility Study for a Navy Lodge Building at U.S. Fleet Activities Sasebo

Background: U.S. Fleet Activities Sasebo

Site Description

Sasebo (Sasebo-shi) is located in Nagasaki Prefecture, at the northwestern tip of Kyushu, in southern Japan. As of 2006, the city has an estimated population of 258,324. The total area of the city is 363.88 km². The city was founded in April 1, 1902. It is the second largest city in Nagasaki Prefecture.

Sasebo is quite mountainous, with two main mountains, Mt. Eboshi (568 meters) and Mt. Shokan (443 meters). Some 208 islands of various sizes span across approximately 25 kilometers from Sasebo Port to Hirado make up Kujukushima -- "The 99 Islands". [2]

U.S. Fleet Activities Sasebo is a United States Navy naval base, in Sasebo, Japan, on the island of Kyūshū. It provides facilities for the logistic support of forward-deployed units and visiting operating forces of the United States Pacific Fleet and designated tenant activities.[3] Figure 1 shows the site map of Sasebo base.

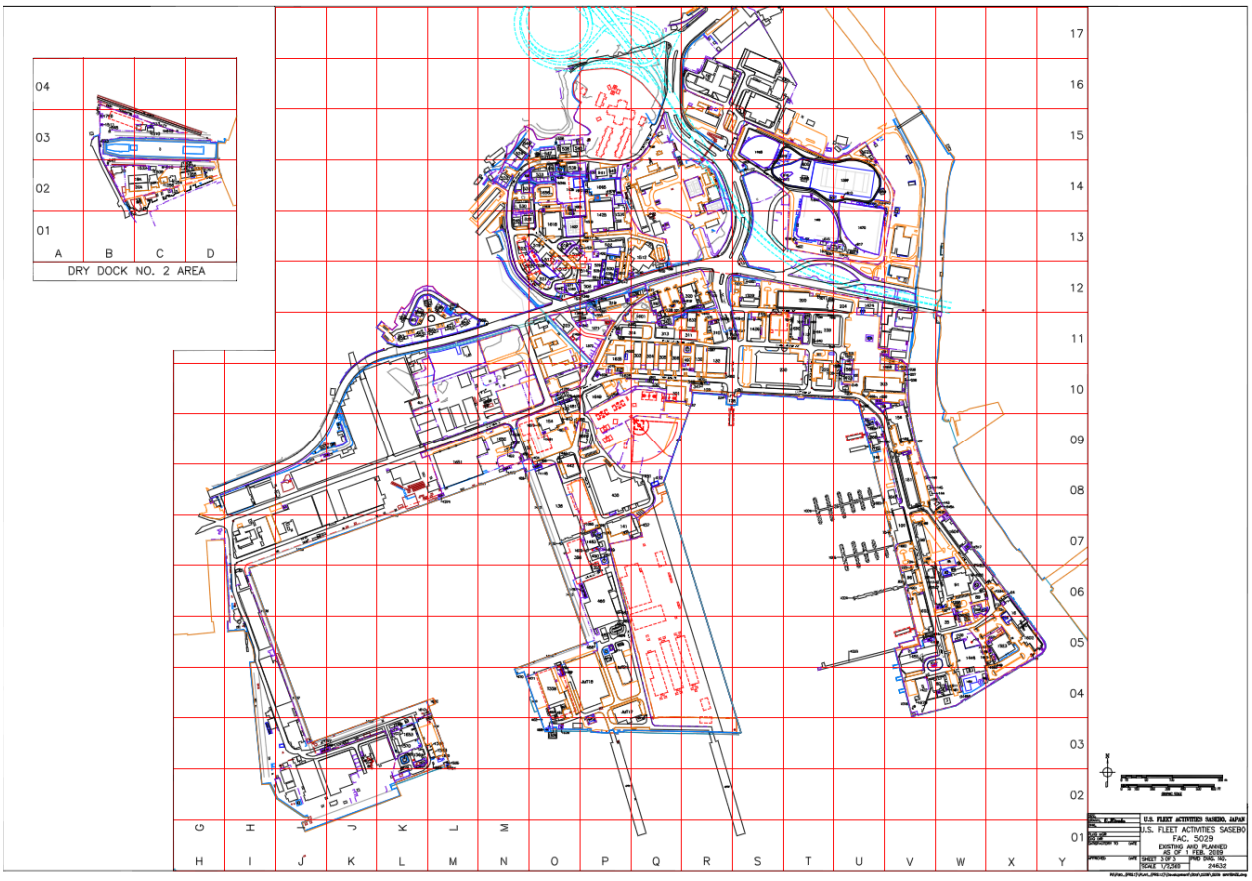


Figure 1: Site Map of Sasebo Base

[2] https://www.cnic.navy.mil/Sasebo
[3] http://en.wikipedia.org/wiki/United_States_Fleet_Activities_Sasebo

Site Visit

As an effort to provide quality technical assistance for the American Recovery and Reinvestment Act (ARRA) project, the assessment team from ORNL visited the site from February 15 to 16, 2010. Several buildings in the base were visited based on the discussions and recommendations from site personnel. The summary of the site visit is shown below.

Areas Visited Site	Mission/Use Type
Building 1602	Navy Lodge
Building 16	Navy Lodge - extension
Building 1455	Navy Gateway inn and suites
Building 1603	Navy Gateway inn and suites
Building 151	Large BEQ

Based on site visits, discussions with the site personnel, and other case studies conducted close to the site, the assessment team decided to perform a feasibility study for the application of GSHP system for Building 1602: Navy Lodge. Appendix A presents the pictures taken during the site visit.

Energy Use Accounting

Historical monthly utility bills were obtained from the base. The space heating and the DHW heating is provided by the district steam. Table 1 and Figure 2 show the monthly utility bills for Building 1602 (FY09). The first and second row of the table show the monthly steam and electricity uses, respectively.

Facility/Ship Name	JON	Commdity Type	Units Type	Rate	Oct Units/ Charges	Nov Units/ Charges	Dec Units/ Charges	Jan Units/ Charges	Feb Units/ Charges	Mar Units/ Charges	Apr Units/ Charges	May Units/ Charges	Jun Units/ Charges	Jul Units/ Charges	Aug Units/ Charges	Sep Units/ Charges	FY Total Charges
SAS-1602	'1H84U0012009	ST	MBTU	$22.79	19.9	20.7	59.8	116.7	115.9	51.3	32.3	24.8	29.6	16.3	14.8	15.2	517.3
					$453.52	$471.75	$1,362.84	$2,659.59	$2,641.36	$1,169.13	$736.12	$565.19	$674.58	$371.48	$337.29	$346.41	$11,789.26
Total For JON 1H84U0012009																	$11,789.26
SAS-1602	'1H84U0022009	EL	MWH	$77.56	33	24.4	17.7	21.7	21.9	17.7	18.8	20.8	33.6	32.5	38.5	37	317.6
					$2,559.48	$1,892.46	$1,372.81	$1,683.05	$1,698.56	$1,372.81	$1,458.13	$1,613.25	$2,606.02	$2,520.70	$2,986.06	$2,869.72	$24,633.05
Total For JON 1H84U0022009																	$24,633.05
SAS-1602	'1H84U0032009	FW	KGAL	$3.55	127	102.4	133.1	154.2	114	102.4	107.4	122.2	166.6	74.4	84.2	155.5	1443.4
					$450.85	$363.52	$472.51	$547.41	$404.70	$363.52	$381.27	$433.81	$591.43	$264.12	$298.91	$552.03	$5,124.06
Total For JON 1H84U0032009																	$5,124.06
SAS-1602	'1H84U0042009	SE	KGAL	$4.17	114.3	92.2	119.8	138.8	102.6	92.2	96.7	110	149.9	67	75.8	139.9	1299.2
					$476.63	$384.47	$499.57	$578.80	$427.84	$384.47	$403.24	$458.70	$625.08	$279.39	$316.09	$583.38	$5,417.66
Total For JON 1H84U0042009																	$5,417.66
Total For This Report																	$46,964.03

Table 1: Monthly Utility Bills - FY09

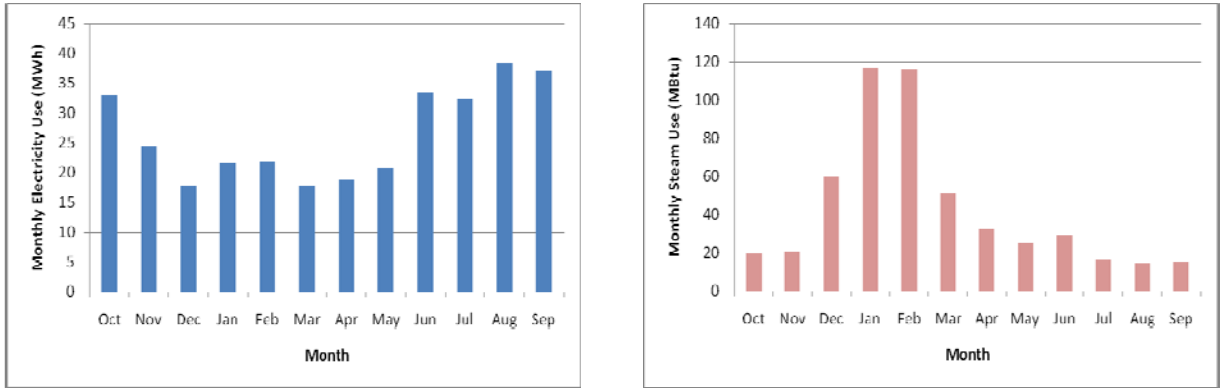


Figure 2: Monthly Elec. and Steam Uses

Energy Conservation Measures Identified/Estimated

A building target for the GSHP system application has been identified from the site visit performed on February 15 to 16, 2010. The selected building for the feasibility study is Building 1602 which is a lodge building. Preliminary analysis shows that the building has both cooling and heating load. Initially, the ORNL team considered the vertical borehole type of GHX (ground heat exchanger) for the building, but it was challenging to use this type of GHX since there is not enough land area available for installing vertical boreholes close to the building, and it is highly expectable to reach the ground water table soon after the drilling. Hence, the surface water (i.e., sea water) next to the building was considered to be utilized as heat source/sink to be connected with the GSHP systems, which is also known as sea water source heat pump (SWHP) system (See Figure 3 and Figure 4).

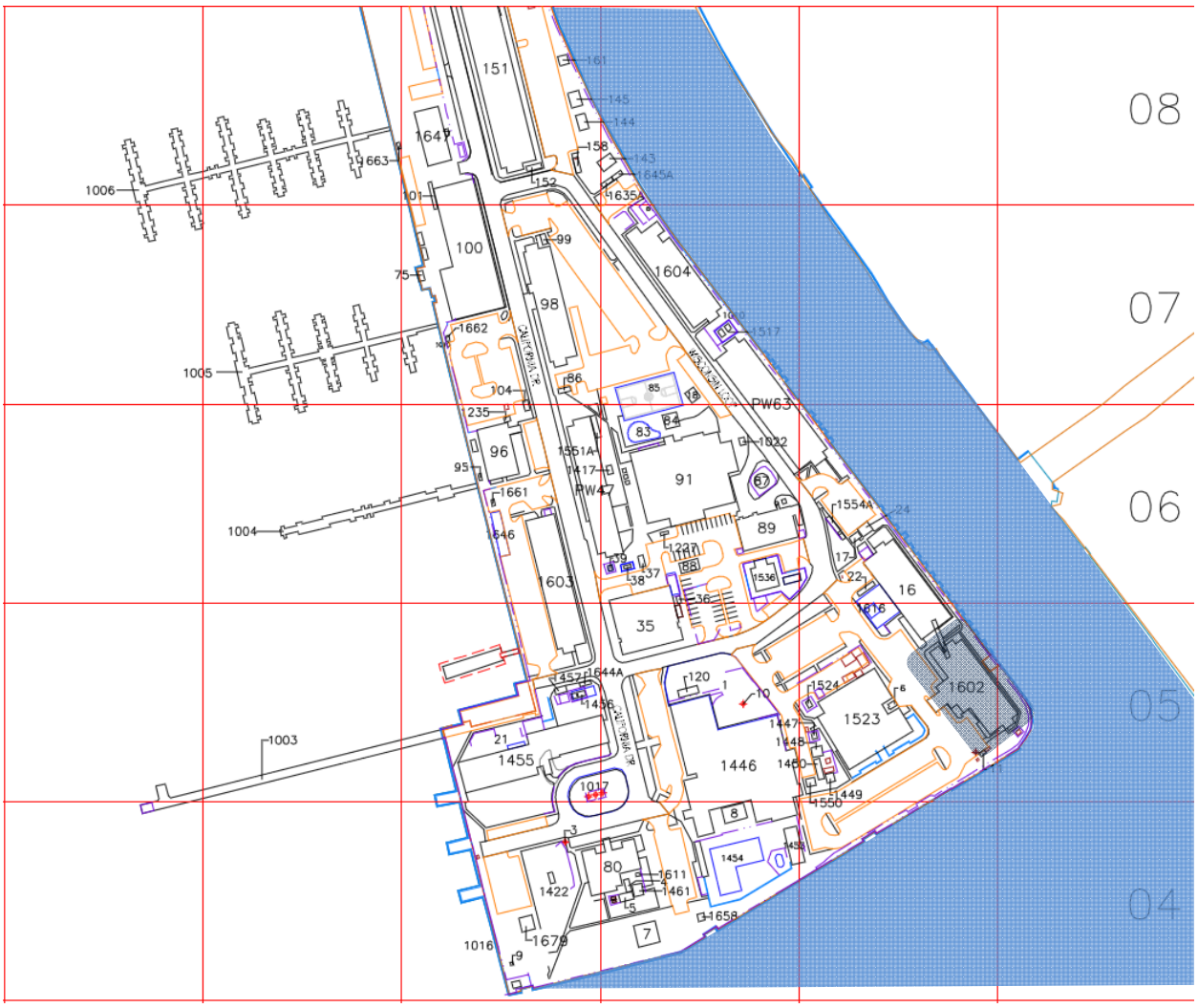


Figure 3: Building 1602 (grey shaded) Next to the Surface Water

Figure 4: Surface Water Available Next to the Building

Building Description

The selected building is the Navy Lodge building. Figure 5 shows the entrance of the building. The facility operates as a hotel providing temporary berthing and as the lodging facility for visiting Sasebo base. The building is two story building and contains 26 guest rooms. The total floor area is about 1,642 m^2 (17,674 ft^2). The building is connected to Building 16 which is also part of the lodge building.[4] The building has reinforced concrete structure for its foundation, wall, and roof.

The cooling is provided by a chiller/cooling tower (See Figure 6) installed at the building, and the heating and the domestic water heating are provided by the district steam with the heat exchanger (See Figure 7) in the building. The type of the AHU unit is a Fan Coil Unit (FCU) which is installed each room. The capacity of the chiller and cooling tower has been identified from the site visit and the as-built drawing for the building simulation modeling.

The building is operated year around, and the typical hotel occupancy has been assumed for the building simulation modeling.

[4] For this study, only building 1602 will be analyzed.

Figure 5: Building 1602 - Navy Lodge

Figure 6: Chilling Unit and Cooling Tower

Figure 7: Heat Exchanger

Building Simulation Modeling

As a next step of the feasibility study, the as-built building simulation model was developed based on the site visit, the as-built drawings, and the series of communications with the site personnel. The chosen simulation program is the eQuest program which uses the DOE-2 as simulation engine. Figure 8 shows the 3-D rendering of the simulated building model. The building operating schedules such as occupancy schedule, lighting & equipment schedule, and HVAC schedule were defined by the default values provided in the simulation program, which is the typical operating schedule for hotel buildings.

After initial simulation, the results were compared with the provided monthly utility bills, and the simulation was calibrated to be matched with the utility bills.

Figure 9 shows the calibrated as-built simulation results. The monthly simulated energy use versus monthly utility bills from FY08 and FY09 are also shown in Figure 10. There are some variations between the simulated and bills, but the simulated results are close enough for the analysis. The % difference between the simulated and measured electricity and steam use for FY09 is 4.2% and 0.9%, respectively.

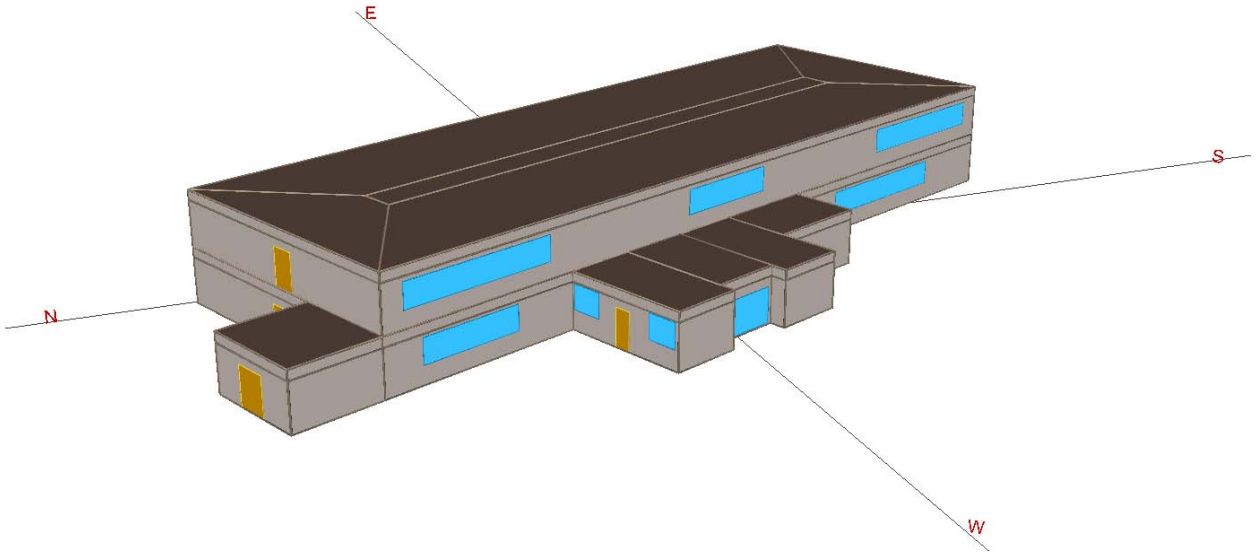


Figure 8: eQuest 3-D Rendering of the Building 1602 Simulation Model

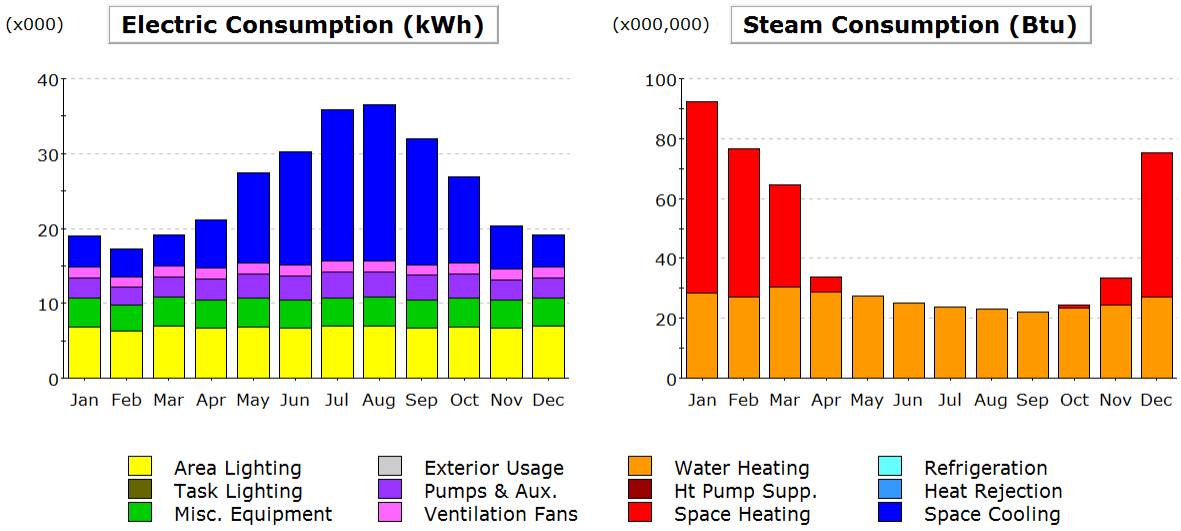


Figure 9: As-Built Simulation Result

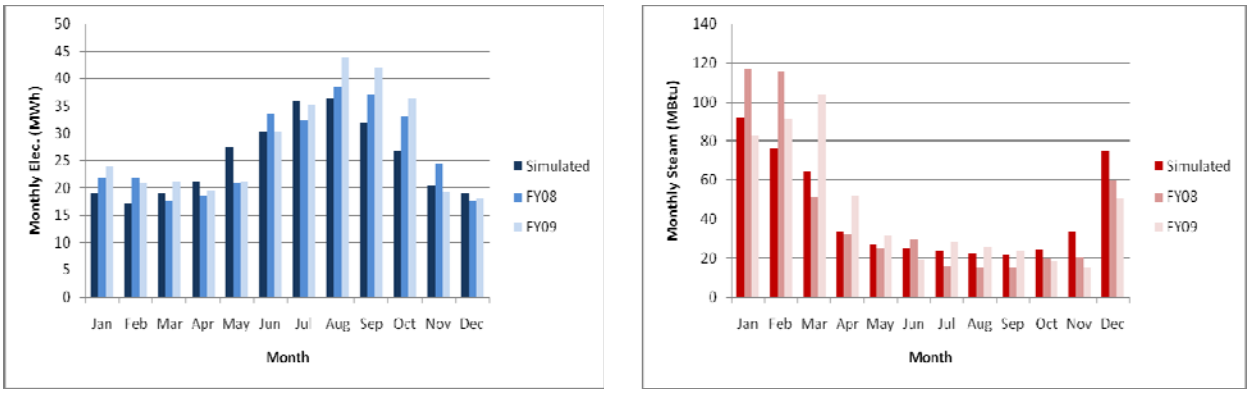


Figure 10: Simulated Monthly Elec. and Steam Use vs. Monthly Utility Bills for FY 08 and FY09

Application of GSHP System

As discussed earlier, the sea water available next to the building is used for the heat sink/source for this study. The selected type of the heat exchanger is the open loop system. Therefore, the sea water will be directly pumped to the heat exchanger in the building. Since the system may handle the sea water as a medium, additional design such as filtering, titanium heat exchangers, etc. should be considered. The increased capital cost for these additional designs could be offset by no needs for borehole drilling, and GHX pipe installation.

Several studies about the sea water source heat pump systems show the capital cost and the operation experience of the installed system. One study by Zhen et al. (2007)[5] shows that the capital cost for a sea water source heat pump system that was installed at Dalian, China is about $43.4 million dollar for 22,000 ton system. The unit cost is about $2,000/ton. The expected payback for this system was about 5.8 to 12.5 years. Although the system capacity in this study is much bigger than the proposed system for the Building 1602 (i.e., about 50 ton), the study shows that the SWHP system can be economically feasible. In addition, the same study describes that the maintenance cost for the SWHP system is typically lower than the conventional system based on the experiences with several existing SWHP systems in China. Another study by Zhang (2006)[6] shows that the phenomenon of fouling or corrosion in seawater circulating system have not appeared in four months of continuous operation, which indicated that sea water can be an ideal heat source or sink as long as the problem on seawater treatment be solved commendably. Additionally, the study by Zhen et al. (2007) also estimates that the environmental impact on the marine ecosystem can be negligible by discharging warmer/colder water into the sea. Given the system described in Zhen's study is far bigger system than the proposed system in this study, the environmental impact from the proposed system is expected to be negligible.

Since the annual/monthly water temperature for the surface water should be entered as an input parameter for the simulation modeling, the water temperature measurements from several points near the base were obtained from the site personnel. Figure 11 shows the three sampling points for the measurements of water temperature. Table 2 shows that the monthly water temperature measurements from 3 different sampling sites. For the simulation, the temperature measured from the point #1 was used since the measurement point is the closest to Building 1602. Because the temperature was measured from 2ft depth, the actual water temperature from deeper water could be slightly warmer during the winter and slightly cooler during the summer, which would reduce the cooling/heating energy further.

[5] Zhen, Li, D.M. Lin, H.W. Shu, Shuang Jiang, Y.X. Zhu (2007) District Cooling and Heating with Seawater as Heat Source and Sink in Dalian, China, Renewable Energy 32, 2603-2616.
[6] Lo, Zhang and Hu Songtao (2006), Research on the Heat Pump System Using Seawater as Heat Source or Sink, Building Energy & Environment

In a real system, the DHW system also could be replaced with the water-to-water heat pump systems that use the surface water as medium, but in this simulation study, an air source heat pump water heater for the DHW was simulated due to the simulation incapability. Figure 12 shows the energy use after modifying the baseline simulation model by replacing the system with GSHP system connecting to the surface water. As shown, there are no changes in the lighting and equipment electricity use, but large increase in pump energy as the system will need to circulate the surface water to the building.

The total annual energy savings (MMBtu/yr) was calculated. The total annual energy savings would be 338.5 MMBtu/yr, which corresponds to a 21.7% savings. When the electricity and steam rates[7] obtained from the base were used for the cost saving calculation, the total annual cost savings would be $7,724, which corresponds a 21.7% savings.

Figure 11: Three Sampling Points for the Water Temperature Measurements

[7] Electricity rate: $77.56/MWh, Steam rate: $22.79/MBtu

SAMPLING POINT # 1 : Near the Sasebo Bridge

SAMPLING INFORMATION : Surface water, 2 ft depth
SAMPLING PERIOD : April 2008 thru March 2009

MONTH	APL	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Water temp (C)	12	18.5	20.5	21	29	24.5	22.5	18	13.5	7	8.5	10.5
Water temp (F)	53.6	65.3	68.9	69.8	84.2	76.1	72.5	64.4	56.3	44.6	47.3	50.9

SAMPLING POINT # 2 : Hizukushi area (near JMSDF Kurashima pier)

SAMPLING INFORMATION : Middle water, 7 ft depth

SAMPLING PERIOD : April 2008 thru March 2009

MONTH	APL	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Water temp (C)	14.5	18.5	20	25	29	27.5	25	20.5	16.5	12	10.5	12
Water temp (F)	58.1	65.3	68	77	84.2	81.5	77	68.9	61.7	53.6	50.9	53.6

SAMPLING POINT # 3 : Near the SSK dry dook area

SAMPLING INFORMATION : Surface water, 2 ft depth
SAMPLING PERIOD : April 2008 thru March 2009

MONTH	APL	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Water temp (C)	15.5		19.5		28		25		16.5		11	12.5

Table 2: Measured Water Temperatures from 3 Sampling Points

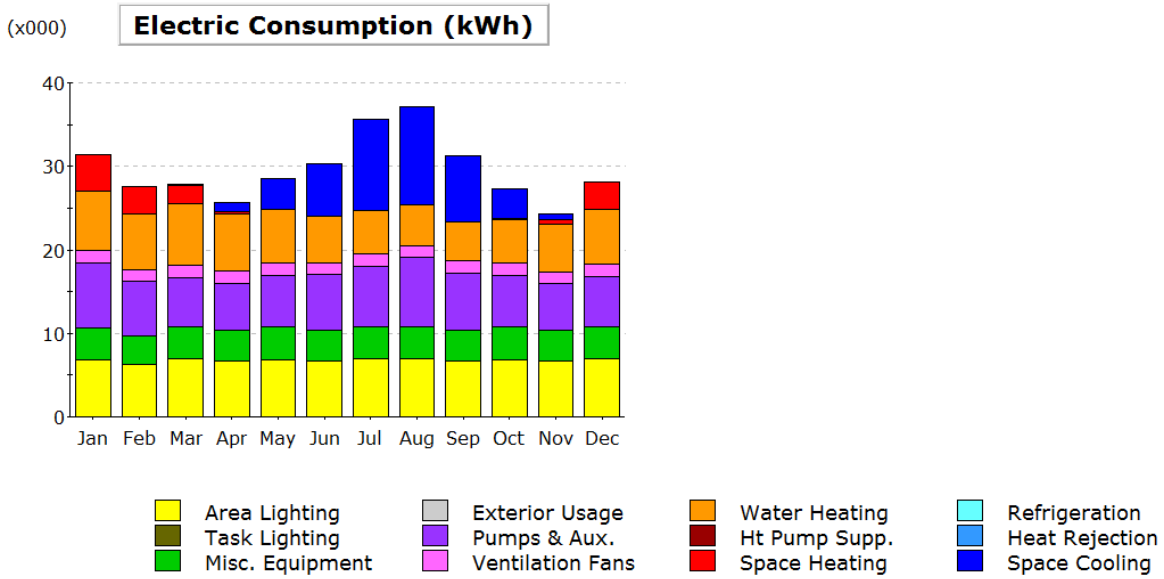


Figure 12: Simulation Results - GSHP System

Cost Analysis

The capital cost for this project has been estimated using available resources. Since there is no published information available for the average GSHP installation cost in Japan currently, the U.S. average GSHP system installation cost information used in previous studies is used as one of references in this study. Although the average cost information in Japan is not available, the ORNL team did obtain some cost information from personal communications with Japanese GSHP installers, researchers, etc. Hence, both of the resources (i.e., U.S. average, and Japanese installation case study) were used for the cost analysis. According to various GSHP installers, the typical cost for the open loop type of GSHP system would be 40-70% cheaper than the vertical borehole type system since there is no need for drilling and pipe installation. However, since the selected system will use the sea water as medium, the additional cost for titanium heat exchanger and filters would make the total installation cost for the proposed system close to the typical borehole system. However, it is recommended to contact the available installer for more accurate cost information. In this study, the cost for the vertical borehole is assumed to be close to the proposed open loop system.

According to the technical report from Department of Defense, the average capital cost for the GSHP system installed at commercial buildings was $6,951.5/ton. The Japanese cost information obtained from an installer shows that the heat exchanger installation cost for typical vertical boreholes is about $60 to $80/meter of borehole not including heat pump itself. Since the heat pump unit cost is about 20% above the heat exchanger installation according to the installers, and the about 90 meter of borehole would be appropriate for one ton as rule-of-thumb, the cost per ton for the proposed system

Cost per ton = (90 (meter/ton of borehole) x ($60 to $80/meter)) x 120 (%)
= $6,480 to $8,640/ton

In addition, the cost for heat pump DHW system was investigated to be included. According to a source[8], the unit cost for HPWH is about $18,000/200 gallon. Since the size of the DHW for this building is about 600 gallon, the capital cost would be $54,000

Cost for 600 gallon heat pump DHW = $18,000/200 gallon x 3 = $54,000

Therefore, the capital cost for the building was calculated based on the unit capital cost information above. The simulation results show that the capacity of the heat pump for the building is about 26 tons. Therefore, the total capital cost would be

Total Capital Cost = ($6,480 to $8,640/ton) x 26 tons + $54,000/600 gallon heat pump DHW
= $222,480 to $278,640 ($168,480 to $224,640 for without DHW)

Since the total annual energy cost saving was calculated as $7,724,

Simple payback = ($222,480 to $278,640)/$7,724 = 28.8 to 36 years.

Figure 13 shows the monthly energy cost differences between the as-built and the GSHP system applied building.

[8] http://www1.eere.energy.gov/femp/pdfs/FTA_HPWH.pdf

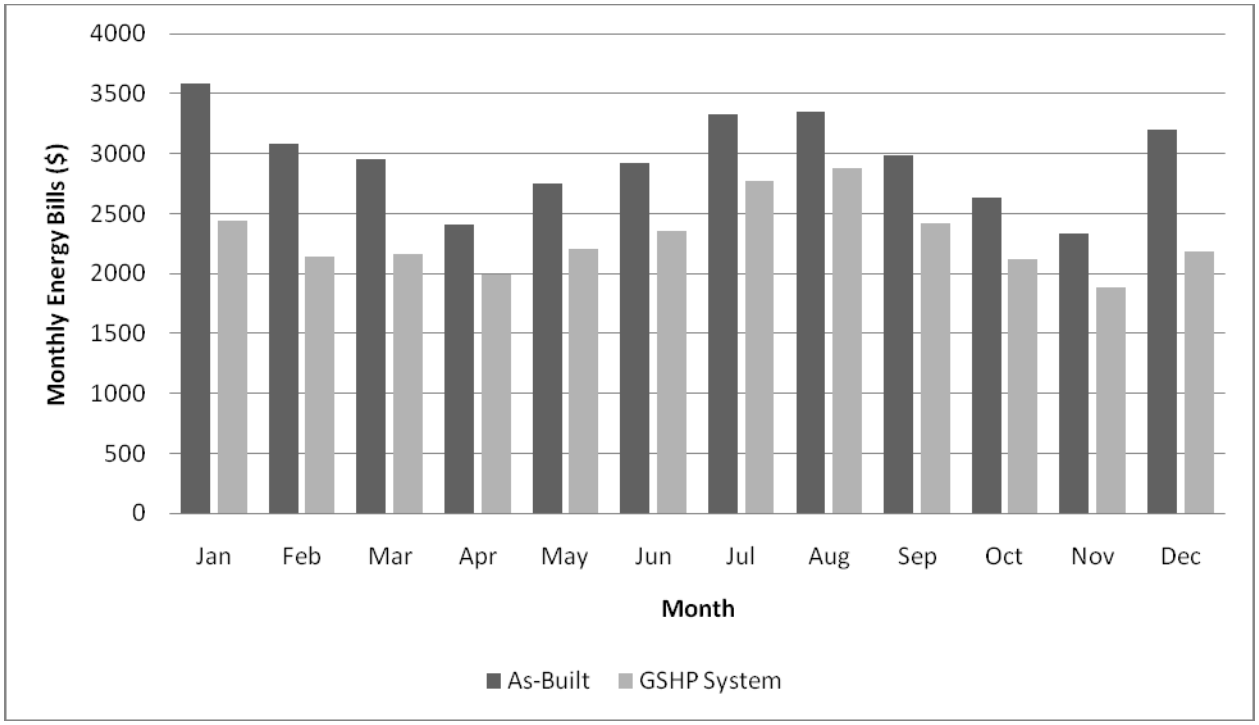


Figure 13: Monthly Energy Cost - As built vs. GSHP System

Potential Green House Gas Reductions

Carbon emission reductions due to the energy savings are also calculated. Since the heating was provided by the district steam, it was assumed that natural gas was the main fuel to produce the district steam. In addition, 40% of distribution loss was assumed. Although the building is located at Japan, the average generation electricity emission factor (lbs/MWh) for U.S. was used for the calculation. According to the eGrid 2007, the emission rate for carbon dioxide in U.S. was 1,408 lbs/MWh. A separate source, EPA's AP42, *Compilation of Air Pollutant Emission Factors,* was used for the emission rate from the on-site natural gas boiler. According to this source, the CO_2 emission rate from natural gas boiler is 120,000 lb/10^6scf, which is 117.65 lbs/MMBtu. Therefore, the total greenhouse emission reduction would be 5.1 tons annually by applying the GSHP system.

Job Created

The estimation of job creation potential through DOE Recovery Act Funding was calculated based on the guideline provided by DOE, which is capital cost divided by 92,000. Since the capital cost of the project was estimated as $222,480 to $278,640, there will be 2.4 to 3.1 job-years created if the recommended GSHP system will be implemented on the base.

Conclusion

A feasibility study for a Navy lodging building at Sasebo base was performed to evaluate energy and cost savings potential by applying GSHP systems. The current HVAC system for the building is a conventional AHU system with chiller. The heating and the DHW is provided by district steam. The building is close to surface water source, which could be used for the heat source/sink for a GSHP system. The annual water temperature measured close to the site is available for this feasibility study. The study result shows that the open loop GSHP system can save 338.5 MMBtu of total energy annually, which corresponds to a 21.7% energy savings. The expected annual energy cost saving based on the current

utility rate is about $7,724. The capital cost for the project was estimated based on the cost information obtained from a Japanese GSHP installer and other literature. The capital cost for the proposed system would be about $250,000, and the 28.8 to 36 years of simple payback can be achieved with the given capital cost and the energy cost savings. The corresponding green house gas reduction would be 5 tons annually. The longer simple payback (i.e., 30+ years) in GSHP retrofit projects is not unusual to be found due to the relatively high initial cost. However, the benefit of the proposed GSHP system is not only energy and cost savings. There are other benefits, including:

- Use of a renewable energy technology – use virtually unlimited resource (i.e., sea water)
- Carbon emission reduction
- Elimination of treatment of cooling tower water
- Elimination of blow-down and water makeup for cooling tower
- The success of the sea water heat pump project in a U.S. Naval base could be a valuable reference case with other bases, where the sea water source would be easily accessible.

However, there could be also potential hurdles for this project, including

- It could be hard to find a proper installer for the proposed system. The sea water heat pump system is a relatively new technology and not popular in Japan.
- The cost estimate in this study is based on the traditional GSHP cost. The actual installation cost would be differ, so the simple pay back would be longer (or shorter with the same reason)
- O&M cost for the sea water treatment could be higher than typical GSHP system. But, the O&M cost for cooling tower, make-up water cost for cooling tower will not be required for the proposed system.

Table 3 summarizes the energy and cost savings, and emission reductions.

	Annual Elec. Use (MWh/yr)	*Annual Steam (MMBtu/yr)*	*Annual Total Energy Use (MMBtu/yr)*		*Annual Elec. Cost ($/yr)*	*Annual N.G. Cost ($/yr)*	*Total Cost ($/yr)*		*Conceptual Implementation Costs ($)*	*Simple Payback*
Baseline	304.8	521.8	1,561.8		23,641.8	11,891.6	35,533.4			
GSHP System	358.6	0.0	1,223.4		27,809.1	0.0	27,809.1		250,560.0	
Savings	**-53.7**	**521.8**	**338.5**	**(21.7%)**	**-4,167.3**	**11,891.6**	**7,724.3**	**(21.7%)**		**32.4**

	Annual Elec. Use (MWh/yr)	*Annual N.G. Use (MMBtu/yr)*	*Annual CO2 Emission from Power Plant (lbs/yr)*	*Annual CO2 Emission from Site (lbs/yr)*	*Total Annual CO2 Emission (lbs/yr)*	*Total Annual CO2 Emission (tons/yr)*
Baseline	304.8	521.8	429,186.6	85,941.9	515,128.4	257.6
GSHP System	358.6	0.0	504,838.4	0.0	504,838.4	252.4
Savings	-53.7	521.8	-75,651.8	85,941.9	10,290.0	5.1

Table 3: Summary – Sasebo Navy Lodge Building

Action Plan for Implementation of ECM's

An opportunity has been identified for this site, which is GSHP system application for the Navy Lodge building.

The project is feasible at this site. For the actual installation, the assessment team recommends contacting the GSHP designers and installers to perform engineering design, and the cost estimate.

SECTION 2:

GSHP Feasibility Study for a Misawa HQ Building
U.S. Naval Air Facility Misawa

Background: Naval Air Facility Misawa

Site Description[9]

Misawa Air Base (IATA: MSJ, ICAO: RJSM) is a United States military facility located 3 NM (5.6 km; 3.5 mi) northeast of the railway station in Misawa, 3 mi (4.8 km) west of the Pacific Ocean, 10 mi (16 km) northeast of Towada, 18 mi (29 km) northwest of Hachinohe, and 425 mi (684 km) north of Tokyo, in Aomori Prefecture, in the Tōhoku region in the northern part of the island of Honshū of Japan. It is a Pacific Air Forces (PACAF) facility with the 35th Fighter Wing (35 FW) as its host wing.

Misawa is the only combined, joint service installation in the western Pacific. It houses three U.S. military services (Army, Navy, and Air Force), as well as the Japan Self-Defense Forces. The base is home to 5,200 US military personnel, as well as 350 US civilian employees and 900 Japanese national employees.

Site Visit

As an effort to provide quality technical assistance for the American Recovery and Reinvestment Act (ARRA) project, the assessment team from ORNL visited the site from February 11 to 12, 2010. Several buildings in the base were visited based on the discussions and recommendations from site personnel. The summary of the site visit is shown below.

Areas Visited Site	Mission/Use Type
Building 1440	MoMAU (Mobile Mine Assembly Unit)
Building 980	Misawa HQ Building
Building 520	BQ/Hotel

Bldg 1440 – MoMAU, a building that is getting ready to undergo some renovations including an HVAC upgrade. The building has ~ 30-40 people that occupy it M-F 730-1600, also for one week every quarter there is 24-7 occupancy. There are two rooms that require specialized cooling requirements due to battery storage. These rooms will not be included in our assessment.

Bldg 980 – NAF-Misawa HQ, a rectangular building with mainly office and classroom space. We received the drawings for this building, however, they are older and there have been some upgrades since then. We worked with the Japanese Mechanical Engineer to get updated information.

Bldg 520 – BQ / Hotel – This building has radiator heating and no cooling. Space for a well-field is limited, so this will be a challenging building as well.

Based on the site visit, discussions with the site personnel, and other case studies conducted close to the site, the assessment team decided to perform a feasibility study for the application of GSHP system for Building 980: Misawa HQ Building. The building is an office type building, and has both cooling and heating loads, which will be ideal for the GSHP system application. Appendix B presents the pictures taken during the site visit.

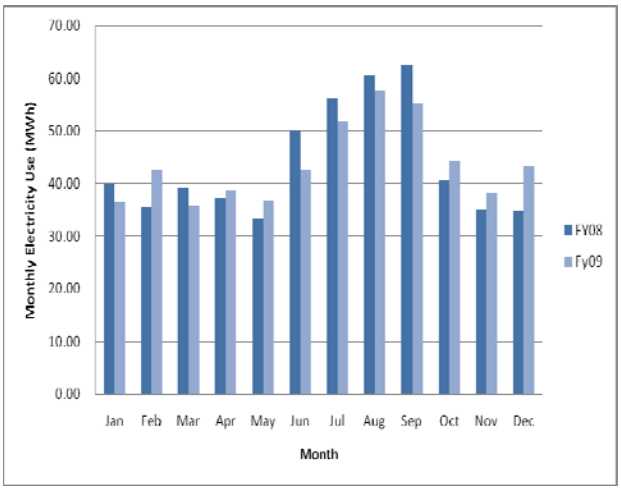
[9] Site description was referred to Wikipedia.org (http://en.wikipedia.org/wiki/Misawa_Air_Base)

Energy Use Accounting

Historical monthly utility bills were obtained from the base. Table 4 and Figure 14shows the monthly utility bills for the building 980 (FY08 & 09).

Month	Monthly Elec. Use		Monthly Steam Use	
	FY08	FY09	FY08	FY09
	kWh	kWh	BTU	BTU
Jan	39,853	36,551	110,510,400	129,729,600
Feb	35,514	42,601	103,303,200	110,510,400
Mar	39,173	35,941	72,072,000	67,267,200
Apr	37,226	38,620	55,255,200	57,657,600
May	33,297	36,837	-	24,024,000
Jun	50,110	42,497	-	-
Jul	56,236	51,796	-	-
Aug	60,389	57,713	-	-
Sep	62,625	55,299	-	-
Oct	40,671	44,244	-	-
Nov	35,101	38,144	19,219,200	31,231,200
Dec	34,790	43,291	192,192,000	76,876,800
Total	524,985	523,534	552,552,000	497,296,800

Table 4: Monthly Utility Bills – FY08-09



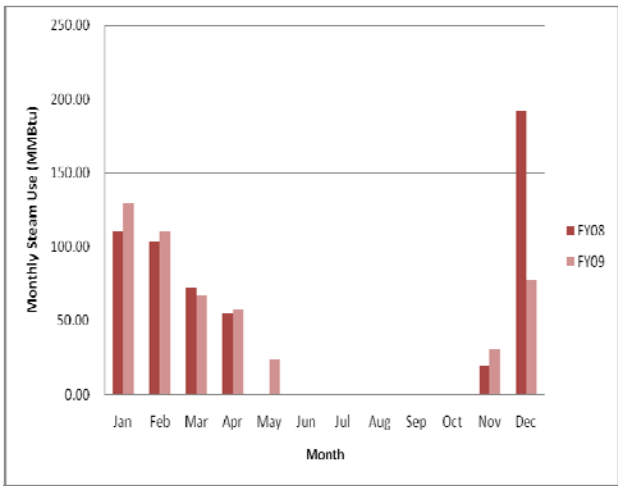


Figure 14: Monthly Elec. and Steam Uses for FY08 and FY09

Energy Conservation Measures Identified/Estimated

A building target for the GSHP system application has been identified from a site visit performed on February 11 to 12, 2010. The selected building for the feasibility study is Building 980 which is NAF-Misawa HQ, a rectangular building with mainly office and classroom spaces. Figure 15 shows the area map for Building 980. Preliminary analysis shows that the building has both cooling and heating load. There is plenty of land available next to the building for vertical borehole type GHX installation. Figure 16 presents the aerial view of the building with the possible two locations for GHX installation, and Figure 17 shows the view of the parking lot next to the building for possible GHX installation.

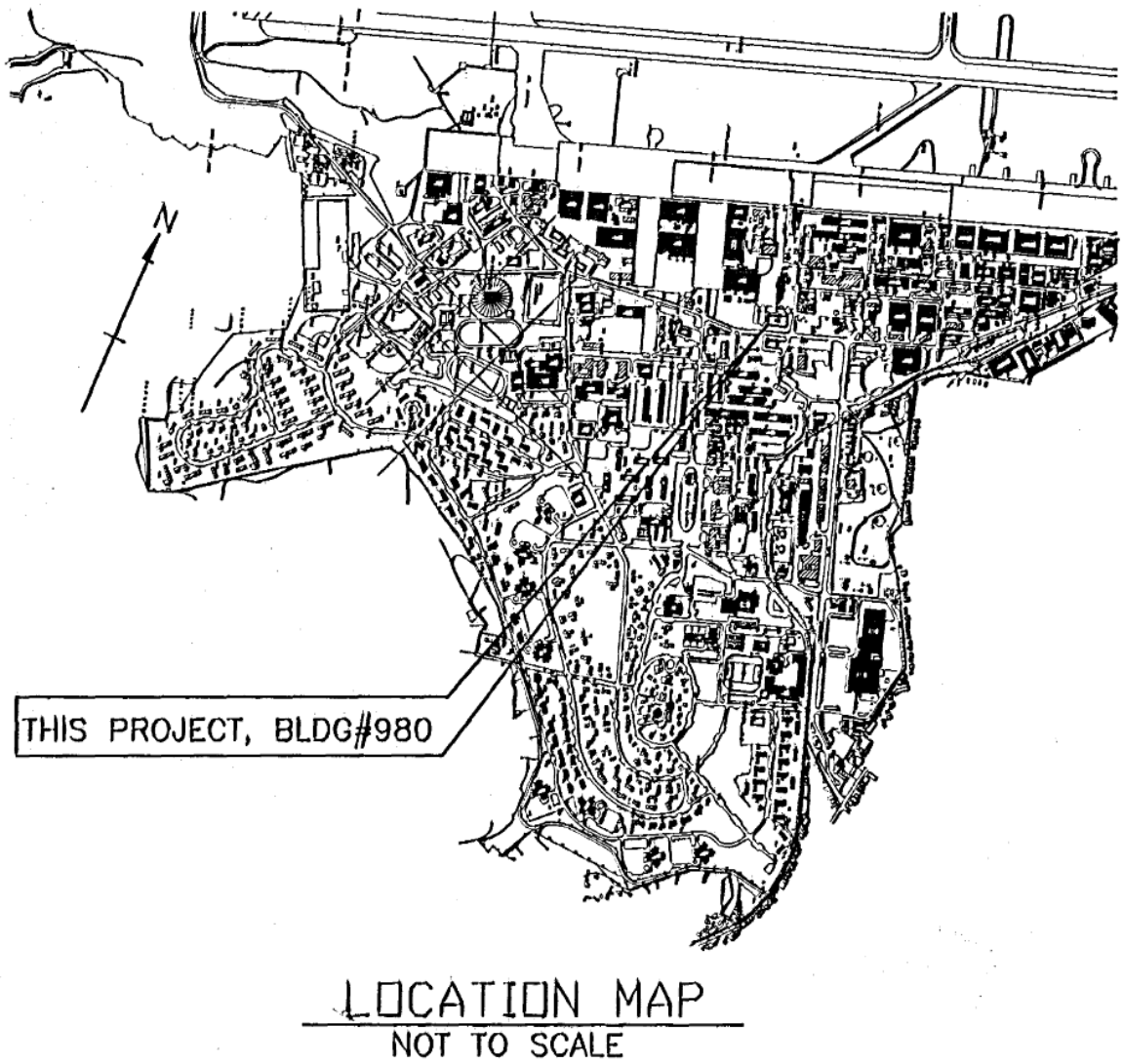


Figure 15: Location Map of the Building 980

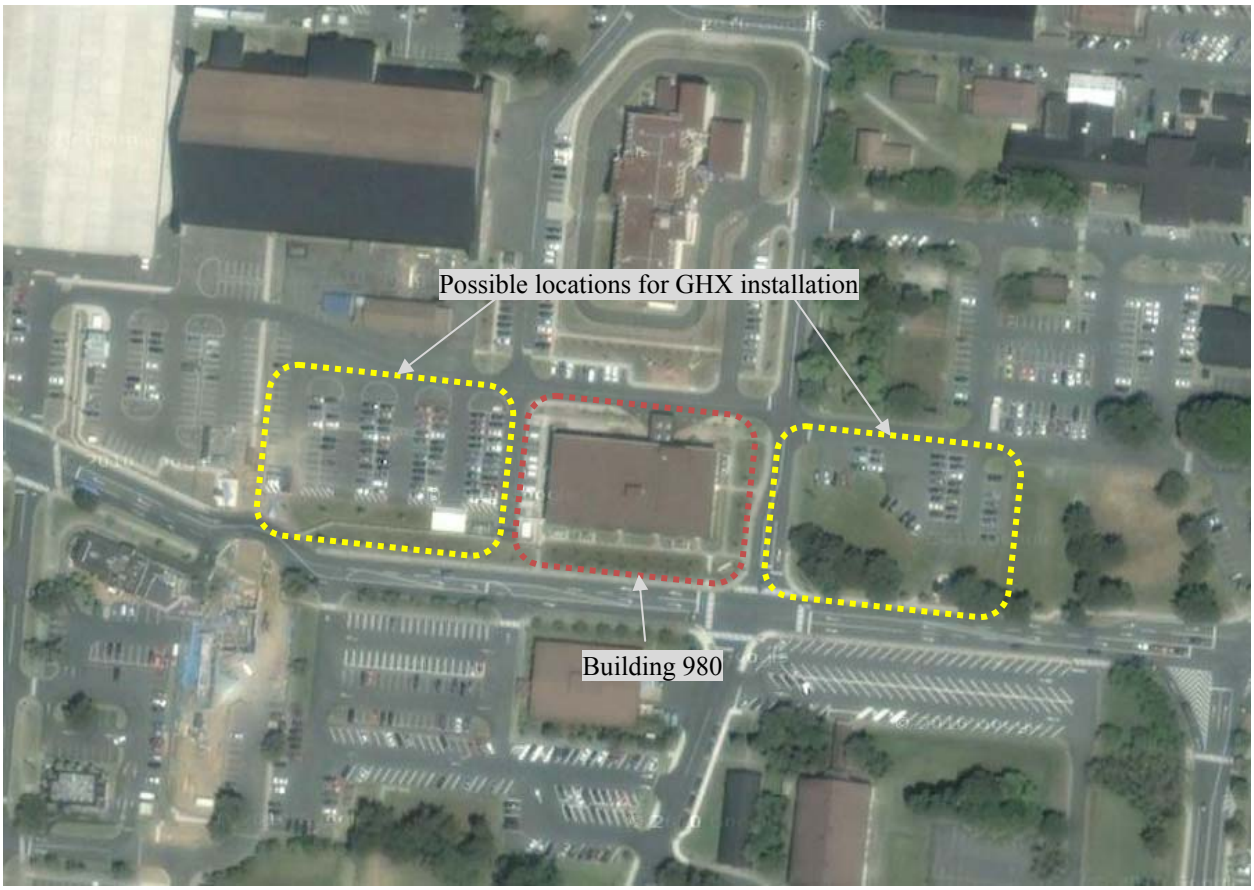


Figure 16: Building 980 with Possible Locations for GHX Installation

Figure 17: Parking Lot Next to the Building (Possible GHX Installation)

Building Description

The selected building is the NAF-Misawa HQ building.
Figure 18 shows the entrance of the building. The facility operates as an administrative building and has offices and classrooms. Figure 19 shows an office space in the building. The building is a two-story building. The total floor area is about 2,806 m^2 (30,203 ft^2). The building has reinforced concrete structure for its foundation, wall, and roof.

The cooling is provided by an air-cooled type chiller (Figure 20) next to the building, and the space heating is provided by the district steam (See Figure 21) in the building. In addition, there is a packaged AC unit dedicated to the communication room. There are several central AHU units serving the most of the building area. The capacity of the chiller has been identified from the site visit and the as-built drawing for the building simulation modeling.

The building is operated year around, and the typical office occupancy has been assumed for the building simulation modeling.

Figure 18: Front Entrance of the Building 980

Figure 19: Office Space in the Building

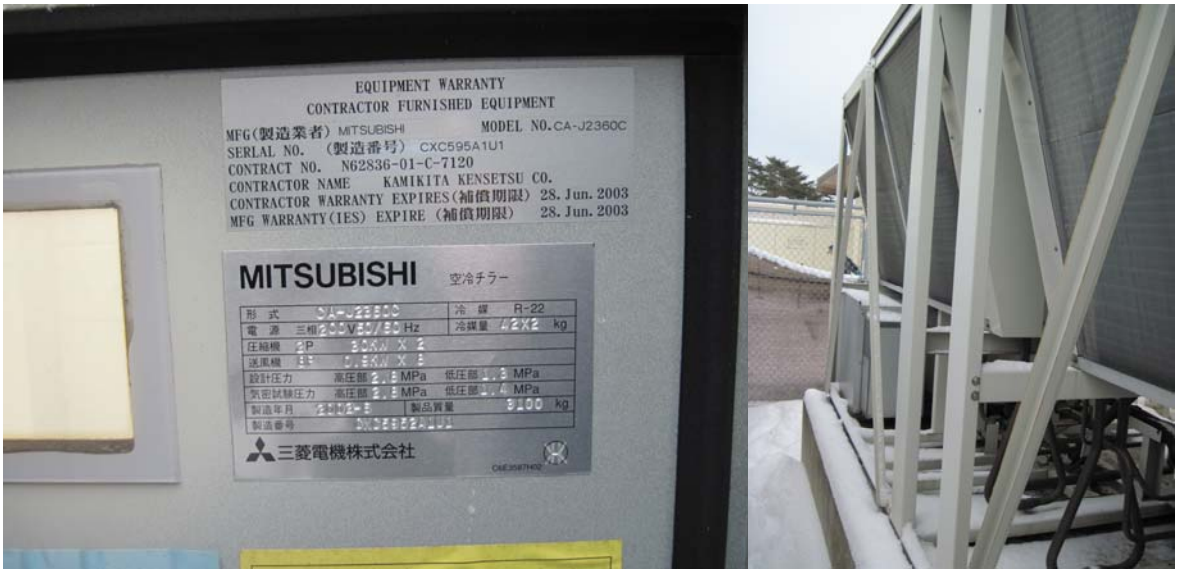


Figure 20: Air Cooled Chiller

Figure 21: Steam Header

Building Simulation Modeling

As a next step of the feasibility study, the as-built building simulation model was developed based on the site visit, as-built drawing, and the communication with the site personnel. The chosen simulation program is the eQuest program which uses the DOE-2 as simulation engine. The building operating schedules such as occupancy schedule, lighting & equipment schedule, HVAC schedule were referred to the default values in the simulation program, which is the typical operating schedule for the office buildings.

After initial simulation, the results were compared with the provided monthly utility bills, and the simulation was calibrated to be matched with the utility bills.

Figure 22shows the calibrated as-built simulation results. The monthly simulated energy use versus monthly utility bills from FY08 and FY09 are also shown in Figure 23. There are some variations between the simulated and bills, but the simulated results are close enough for the analysis. The % difference between the simulated and measured electricity and steam use for FY09 is 1.7% and 7.2%, respectively.

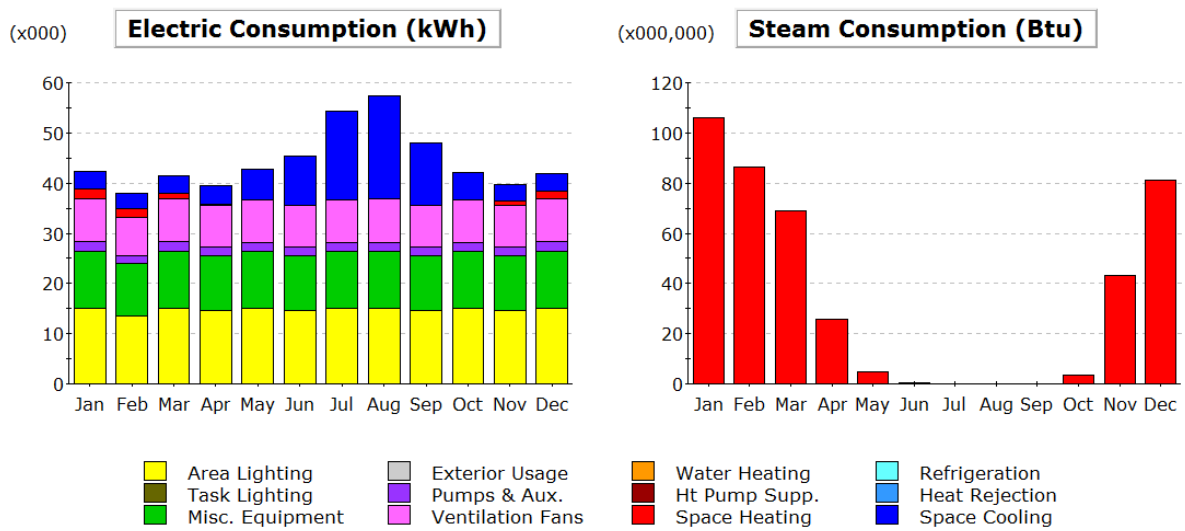


Figure 22: As-Built Simulation Result

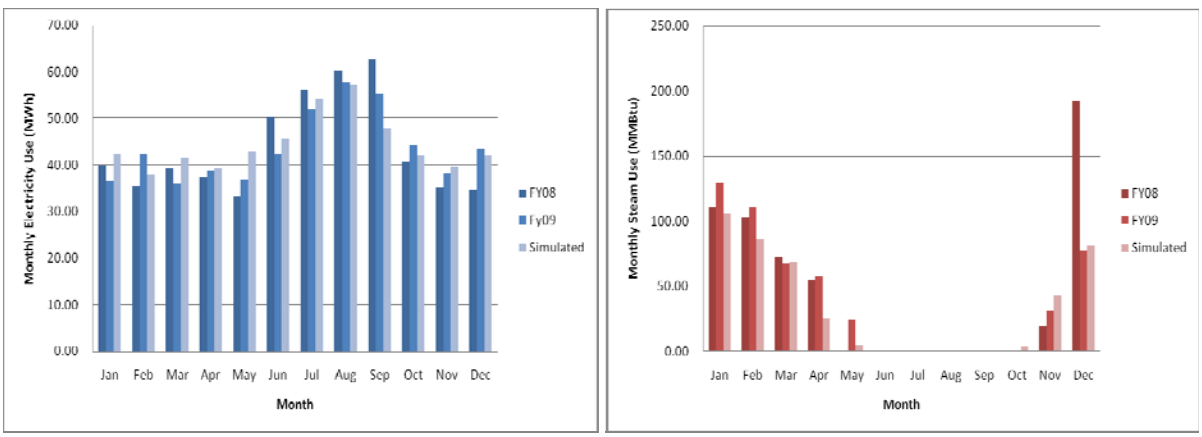


Figure 23: Simulated Monthly Elec. and Steam Use vs. Monthly Utility Bills for FY 08 and FY09

Application of GSHP System

Based on the site visit and the building drawings, the vertical borehole type of heat exchanger was selected for the building. The required size of borehole was determined based on the simulated monthly building cooling and heating load, the peak cooling and heating load, and the borehole test results. The commercially available borehole design software, Ground Loop Design (GLD) geothermal design studio was used for the sizing. Appendix C shows the detailed inputs and outputs of the software.

The result shows that 72 boreholes with about 210ft depth of each borehole will be required to meet the building load. The 210ft of the depth was recommended based on the drilling test performed at the base previously.

Next step is to modify the original simulation model to replace the current HVAC system with the proposed GSHP system. In this study, the water-to-air heat pump system type with vertical boreholes was

chosen. All the input assumptions made from the GLD sizing procedure have been entered into the eQuest simulation program, and the results are shown at Figure 24.

The total annual energy savings (MMBtu/yr) was calculated. The total annual energy savings would be 817.0 MMBtu/yr, which corresponds to a 36.5% savings. When the electricity and steam rate[10] obtained from the base was used for the cost saving calculation, the total annual cost saving would be $8,211, which corresponds to a 33.6% savings.

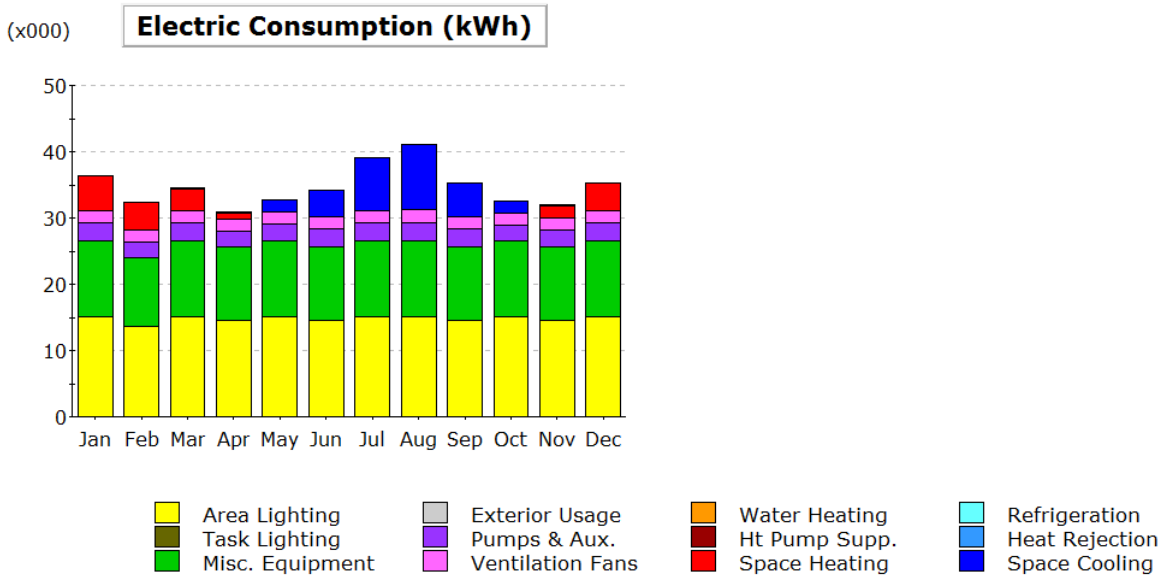


Figure 24: Simulation Results - GSHP System

Cost Analysis

The capital cost in this project was estimated using available resources. Since there is no information available for the average GSHP installation cost in Japan currently, the U.S. average GSHP system installation cost information used in previous studies are used as one of references in this study. Although the average cost information in Japan is not available, the ORNL team did obtain some cost information from personal communications with Japanese GSHP installers, researchers, etc. Hence, both of the resources will be used for the cost analysis. However, the base is recommended to contact local installer to obtain more realistic capital cost in this region.

According to the technical report from Department of Defense, the average capital cost for the GSHP system installed at commercial buildings was $6,951.5/ton. The Japanese cost information obtained from an installer shows that the heat exchanger installation cost for typical vertical boreholes is about $60 to $80/meter of borehole not including heat pump itself. Since the heat pump unit cost is about 20% above the heat exchanger installation according to the installers, and the about 90 meter of borehole would be appropriate for one ton as rule-of-thumb, the cost per ton for the proposed system

Cost per ton = (90 (meter/ton of borehole) x ($60 to $80/meter)) x 120 (%)
= $6,480 to $8,640/ton

[10] Electricity rate: $30.9/MWh, Steam rate: $8.75/MBtu

Hence, based on the capital cost information above, the capital cost for the building was calculated. The total length of the GHX pipe was calculated as 11,890 ft (3,624 meters). Therefore, the average installation cost with heat pump system would be:

Capital Cost = 3,624 (meter) x 70 ($/meter) x 120%
= $304,416

Since the total annual energy cost saving was calculated as $8,211, the simple payback would be 37 years[11]. Figure 25 shows the monthly energy cost difference between the as-built and the GSHP system applied building.

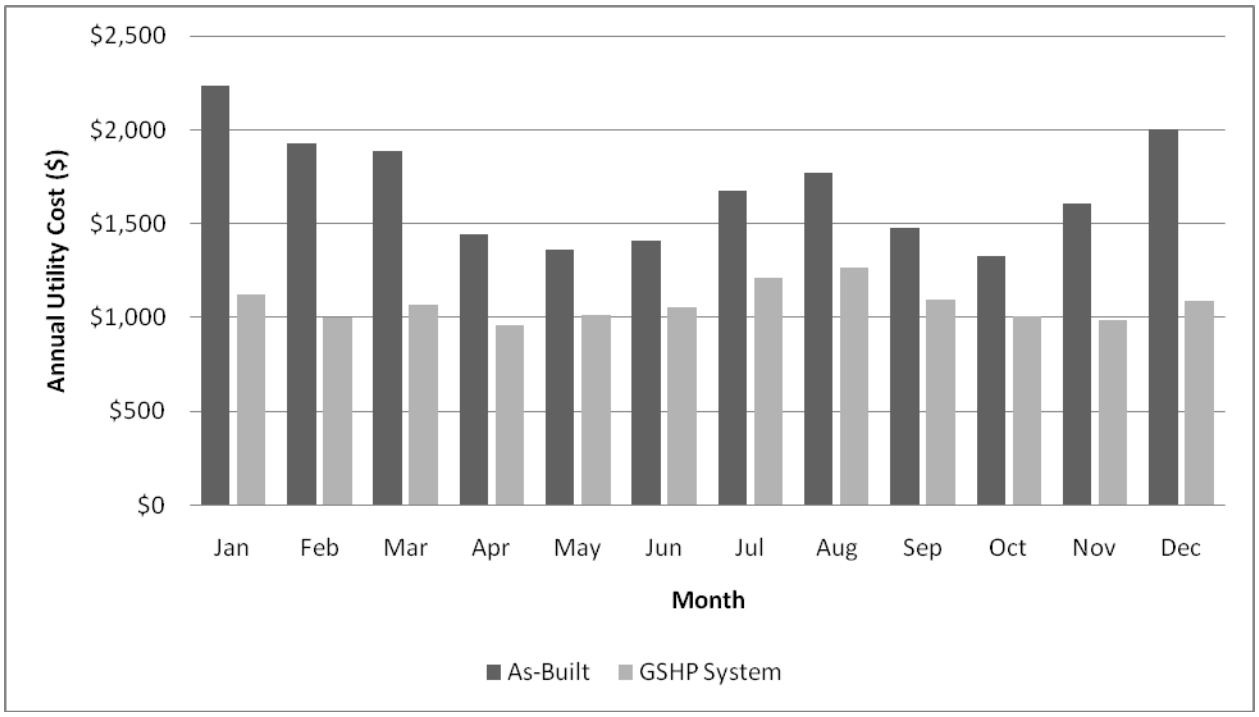


Figure 25: Monthly Energy Cost - As-built vs. GSHP System

Potential Green House Gas Reductions

Carbon emission reductions due to the energy savings are also calculated. Since the heating was provided by the district steam, it was assumed that natural gas was a main fuel to produce the district steam. In addition, 40% distribution loss was assumed. Although the building is located at Japan, the average generation electricity emission factor (lbs/MWh) for U.S. was used for the calculation. According to the eGrid 2007, the emission rate for carbon dioxide in U.S. was 1,408 lbs/MWh. A separate source, EPA's AP42, Compilation of Air Pollutant Emission Factors was used for the emission rate from the on-site natural gas boiler. According to this source, the CO2 emission rate from natural gas boiler is 120,000 lb/10^6scf, which is 117.65 lbs/MMBtu. Therefore, the total greenhouse emission reduction would be 116.5 tons annually by applying the GSHP system.

[11] Base personnel recommended using 2.5% inflation factor. Although this feasibility study only uses simple payback as cost effectiveness metric, if we use the 2.5% inflation factor, the payback time will be close to 25 years.

Job Created

The estimation of job creation potential through DOE Recovery Act Funding was calculated based on the guideline provided by DOE, which is capital cost divided by 92,000. If the recommended GSHP system will be implemented on the base, there will be 3.3[12] job-years created.

Conclusion

A feasibility study for a HQ administrative building at Misawa base was performed to evaluate energy and cost savings potential by applying GSHP systems. The current HVAC system for the building is a conventional AHU system with chiller. The heating is provided by district steam. There is enough land area available close to the building to install the vertical boreholes for GHX. The study results show that the vertical borehole GSHP system can save 817.0 MMBtu of total energy annually, which corresponds to a 36.5% total energy savings. The expected annual energy cost savings based on the current utility rate is about $8,211. The capital cost for the project was estimated based on the cost information obtained from a Japanese GSHP installer and other literature. The capital cost for the proposed system would be about $306,958, and the 37 years of simple payback can be achieved with the given capital cost and energy cost savings. The corresponding green house gas reduction would be 116.5 tons annually. Similar with the previous feasibility study for Sasebo base, the Misawa base study also shows longer simple payback (i.e., 37 years). In case of Misawa study, the cheaper energy rate is specifically one of the reasons for the longer payback. For example, if the same elec. and steam rate of the Sasebo base were used for the payback calculation, the simple payback for Misawa HQ building would be about 22 years. However, the benefit of the proposed GSHP system is not only energy and cost savings. There are other benefits, including:

- Use of a renewable energy technology – use virtually unlimited resource (i.e., surface water)
- Carbon emission reduction
- Elimination of treatment of cooling tower water
- Elimination of blow-down and water makeup for cooling tower
- Typically, the maintenance cost for the vertical borehole GSHP system is minimal. Hence, there will be additional O&M cost savings.

However, there could be also potential hurdles for this project, including

- The cost estimate in this study is based on the average GSHP cost. Typically, the capital cost for the GSHP system varies largely depending on the location, installer, etc. The actual installation cost can differ, so the simple pay back would be longer (or shorter with the same reason).
- The cost of borehole drilling could vary depending on the status of the underground soil components.

Table 5 summarizes the energy and cost savings, and emission reductions.

[12] Number of job created = Total capital cost ($)/$92,000

	Annual Elec. Use (MWh/yr)	*Annual Steam (MMBtu/yr)*	*Annual Total Energy Use (MMBtu/yr)*		*Annual Elec. Cost ($/yr)*	*Annual N.G. Cost ($/yr)*	*Total Cost ($/yr)*		*Conceptual Implementation Costs ($)*	*Simple Payback*
Baseline	532.7	420.1	2,237.5		20,773.7	3,674.9	24,448.7			
GSHP System	416.3	0.0	1,420.6		16,237.3	0.0	16,237.3		304,416	
Savings	**116.3**	**420.1**	**817.0**	**(36.5%)**	**4,536.5**	**3,674.9**	**8,211.4**	**(33.6%)**		**37.0**

	Annual Elec. Use (MWh/yr)	*Annual N.G. Use (MMBtu/yr)*	*Annual CO2 Emission from Power Plant (lbs/yr)*	*Annual CO2 Emission from Site (lbs/yr)*	*Total Annual CO2 Emission (lbs/yr)*	*Total Annual CO2 Emission (tons/yr)*
Baseline	532.7	420.1	749,985.3	69,188.0	819,173.3	409.6
GSHP System	416.3	0.0	586,206.7	0.0	586,206.7	293.1
Savings	116.3	420.1	163,778.6	69,188.0	232,966.6	116.5

Table 5: Summary Table – Misawa HQ Office Building

SECTION 3:

Borehole Test Report
– Whidbey Island Naval Base

This section presents the borehole test results conducted by a subcontractor at Whidbey Island Naval base. The results from the test will be used for further investigation for the GSHP system application at the base.

August 3rd, 2010

Gregory Drilling
17609 NE 70th Street
Redmond, WA
98052

Attention: **Mr. Chris Gregory**

Re: **Geothermal Investigation**
Whidbey Island Naval Base
Whidbey Island, Wa

GeoTility Corporation (GeoTility) is pleased to submit the following report describing a geothermal investigation conducted at the Whidbey Island Naval Base in Whidbey Island, WA. The report describes a program that involved drilling a test borehole and conducting thermal property testing at the site.

1.0 Scope of Work

The scope of the investigation included:

- Drilling of one deep test borehole.
- Installation of heat exchange piping within the deep borehole.
- Testing of thermal properties by conducting a Formation Thermal Conductivity (FTC) test in conformance with ASHRAE recommended procedures.
- Preparation of a project report.

2.0 Drilling Summary

The drilling was conducted with equipment operated by Gregory Drilling beginning June 1st, 2010. The borehole was drilled vertically to a depth of 217 feet using a mud rotary drilling method.

GeoTility Geothermal Installations Corporation
200 – 1649 Cary Road, Kelowna, B.C. V1X 2C1
Tel: (250) 762-5776 Fax: (250) 762-0206 www.geotility.ca

DRILLING INVESTIGATION

Details of the deep borehole (BH-1):	
Borehole Diameter	Nominal 6-inch
Drilled Angle	Vertical
Drilled Depth	217 feet
Drill Method	Mud rotary from 0 to 217 feet
HX Loop Depth	217 ft – confirmed by depth measurement
HX Loop Pipe	1-inch SDR 11 HDPE
Grout	Tremie grouted with thermally enhanced grout (K = 0.88 btuh/ft – F) Based on tremie inserted to 217 feet.

3.0 BORE LOGS

Soil/rock cuttings and sediments returned to the surface while drilling were classified and logged. A borehole log is provided as Attachment 1 to this document. Note that logging from drill cuttings has limitations (as compared to logging from core samples), but it is useful for these purposes.

4.0 FORMATION THERMAL CONDUCTIVITY (FTC) TEST

Field testing was performed on the test borehole to estimate the thermal properties of the ground formation. Testing and analysis were carried out in compliance with the practices and standards presented by Kavanaugh[1]. The methods described allow values of the ground thermal conductivity and diffusivity to be interpreted from the test data.

Resulting Ground Thermal Properties	
Thermal Conductivity	1.21 Btu/hr-ft-°F
Thermal Diffusivity	0.90 ft^2 / day
Undisturbed deep ground temperature	56.0 °F

[1] Kavanaugh, S.P., 2000, "Field Tests for Ground Thermal Properties - Methods and Impact on Ground Source Heat Pump Design," ASHRAE Transactions, 106 (1), pp. 851-855

Remarks regarding the test results:

- In reference to tables published by Kavanaugh and Rafferty[2], based on the materials and moisture content observed, the thermal conductivity is expected to be in the range of 0.8 - 1.6 Btu/h-ft-°F. The measured ground thermal conductivity is within this range.
- The resulting thermal diffusivity is also in agreement with the values prescribed for the observed ground composition.
- Measurements of the local deep ground temperature are above average when compared with those recorded at other locations in the region.

Detailed results of the thermal properties testing are presented in Attachment 2.

5.0 Conclusions

The following conclusions are drawn:

- The ground thermal conductivity is considered in the average range, given the geological formation. As a result, this site's conductivity is well suited for the implementation of a geothermal system.
- The mean earth temperature for this site is above average when compared with the expected value for other locations in the region. This will result in smaller heat exchangers where the heating loads dominate.

6.0 Limitations

All information contained herein, presented for the exclusive use of Gregory Drilling, is intended solely for application to the subject site and subject project. Any use of this report by a third party, pertaining specifically to the results of the installation and thermal properties testing of the test borehole, is the responsibility of such third parties. GeoTility Corporation accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

Characterizing the ground properties is inherently difficult due to the variable nature of the earth's structure. However, material samples collected from this investigation are believed to provide a fairly representative geological cross-section of the area intended for ground heat exchanger installation. Despite this knowledge, no geological investigation can completely eliminate the uncertainties associated with the implementation of the GHX. Ultimately, the presence of anomalous subsurface features or processes may influence the performance of the GHX throughout its operational life.

[2] Kavanaugh, S.P., and Rafferty, K., 1997, *Ground-Source Heat Pumps – Design of Geothermal Systems for Commercial and Institutional Buildings*, ASHRAE, pp. 26-27, Chap. 3

7.0 CLOSURE

We trust that the foregoing information has been provided in an appropriate manner. Please do not hesitate to call us at (425) 788-4900 if you have questions.

Sincerely,

GEOTILITY CORPORATION

Stuart Yanow, P.Eng.
Senior Engineer

ATTACHMENTS

1) Driller's Logs
2) Formation Thermal Conductivity Test Analysis

Attachment 1

Driller's Logs

Driller's Logs

BH-1

Depth	Material or Formation
0 to 6"	**Grass & Topsoil**
6" to 53 ft	**Silty Sand and Gravels**
53 to 96 ft	**Sand / Silt with Gravels (Brown)**
96 to 100 ft	**Gravels & Cobbels**
100 to 190 ft	**Blue Grey Clay**
190 to 215 ft	**Dense Grey Clay**
215 to 217 ft	**Basalt**

Attachment 2

Formation Thermal Conductivity Test Analysis

Formation Thermal Conductivity

Whidbey Island

Prepared for Gregory Drilling

3-Aug-10

I. OVERVIEW

This report summarizes the results of detailed field testing completed to determine the thermal characteristics of subsurface materials at the proposed ground heat exchanger (GHX) location. Analyses were completed using the Line Source Method and following the guidelines set out by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE).

II. BOREHOLE DATA - ID NO. BBT-609

Drilling Date:	1-Jun-10	U-Bend:	1- inch nominal (19 mm) SDR-11 HDPE
Diameter:	5 7/8" in	Grout Type:	Wyo-Ben Groutwell (20% solids)
Depth:	217.0 ft	Grouted Portion:	Entire loop

III. UNDISTURBED GROUND TEMPERATURE

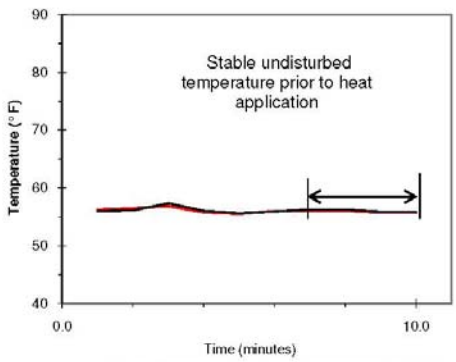


Figure 1. Mean return fluid temperature during unheated circulation.

Undisturbed Temp. Test Data

Start Date:	07/06/10
Start Time:	12:17
Time:	10 min

Results

The estimated undisturbed ground temperature is:

56.0 °F

IV. THERMAL CONDUCTIVITY

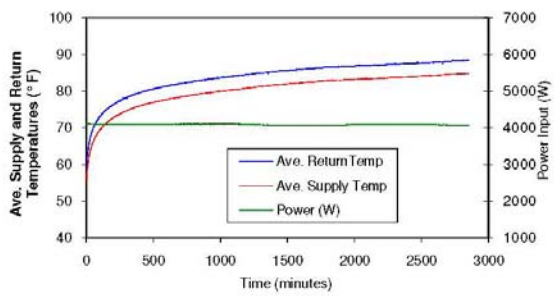


Figure 2. Power supplied and fluid temperature during the FTC Test.

Heat Application Test Data

Start Date:	07/06/10
Start Time:	12:26
Duration:	47.5 hours

Power (Q)

Source:	10 kW Generator
Mean Q:	4086 W

Flow Rate

Ave. ΔT:	6.53 °F
Flow:	2.37 gpm

GEOTILITY SYSTEMS CORP.
200 – 1649 CARY ROAD, KELOWNA, B.C. V1X 2C1
TEL: (250) 762-5776 FAX: (250) 762-0206 www.geotility.ca

Formation Thermal Conductivity

Whidbey Island

Prepared for Gregory Drilling

3-Aug-10

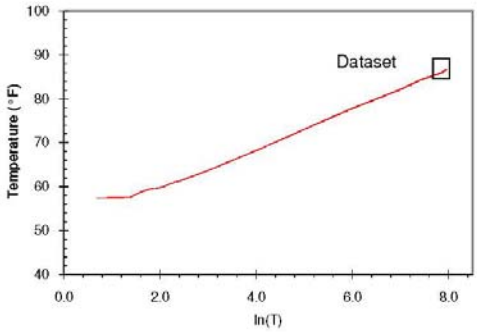


Figure 3. Dataset selected for the Line Source analysis.

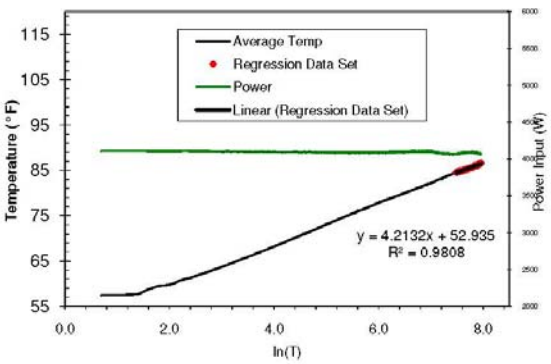


Figure 4. Linear regression of fluid temperature and the natural logarithm of time for the selected dataset.

Results

Linear Regression

Start:	11:36	6-Jul-10
End:	17:58	8-Jul-10
Slope:	4.21 °F	
R^2:	0.9808	

Regression Dataset - Power

Mean:	4086 W/ft
Q/L:	18.8 W/ft

Thermal Conductivity

Borehole BBT-609 has a thermal conductivity of:

1.21 Btu/h•ft•°F

Thermal Diffusivity

With reference to Tables 3.3 and 3.4 in ASHRAE 1997, testing of BBT-609 indicates a thermal diffusivity of:

0.90 ft^2/day

IV. SUMMARY

Field testing completed at borehole BBT-609 indicates an undisturbed ground temperature of 56°F and a thermal conductivity of 1.21 Btu/h•ft•°F).

GEOTILITY SYSTEMS CORP.
200 – 1649 CARY ROAD, KELOWNA, B.C. V1X 2C1
TEL: (250) 762-5776 FAX: (250) 762-0206 www.geotility.ca

SECTION 4:

Geothermal Heat Pump System Ground Heat Exchanger Design and Installation Cost Estimate

GEOTHERMAL HEAT PUMP SYSTEM GROUND HEAT EXCHANGER DESIGN AND INSTALLATION COST ESTIMATE

For

Building 803C, U. S. Naval Air Station

700 Avenger Avenue, Lemoore, California 93246

A LETTER REPORT

Prepared by:

Phil Rawlings, CGD

The Rawlings Company

Greenville, Texas

June 13, 2010

GEOTHERMAL HEAT PUMP SYSTEM GROUND SOURCE HEAT EXCHANGER DESIGN AND INSTALLATION COST ESTIMATE
For
Building 803C, U. S. Naval Air Station
700 Avenger Avenue, Lemoore, California 93246

This letter report is prepared in response to UT-Battelle, LLC (for the Department of Energy), and Oak Ridge National Laboratory Purchase Order 4000092623. The objective of this work is to provide a revised ground source heat exchanger design, associated costing, and other recommendations as may be appropriate for converting Building 803C to a renewable/sustainable geothermal heat pump system with geothermal heat pump domestic hot water heating. This work is done based on the materials (by others) provided by Oak Ridge National Laboratory (included herein as attachments). No site visit was required. The previously mentioned materials have issues that have resulted in an initial, but erroneous decision to not use geothermal heat pump systems for space conditioning and water heating in Building 803C[13].

This report includes a new ground heat exchanger design to serve Building 803C's space conditioning and water heating requirements, estimated costing for same, and new means for dedicated geothermal heat pump system domestic water heating. Also included is a review of the materials provided with corrections and/or recommendations based on the overall data set that was provided.

Analysis Methodology:

The initial work was to review each of the documents and assess the validity of the information provided. The following are said reviews of each document's relevant content. Each of these documents is provided as an Attachment to this report for reference.

Attachment A: Feasibility Study on Ground Source Heat Pumps at Two NAVFAC Facilities in California (Technology & Management Services, Inc. – January 2008)

This report is now somewhat dated, but does have relevant content. Comments are as follows:

- Existing fan coil unit capacities are listed on page 9, as is domestic hot water system capacities.

[13] The previous feasibility study (Attachment A) provided the energy savings potential and cost analysis. However, the study did not provide the detailed borehole design required for the building, which will be critical factor for the capital cost estimate. Part of the reason for this was that there was no borehole test result (i.e., soil thermal conductivity test) available when the study was performed. After the borehole test at the site (attachment C), this study by Phil Rawlings was performed to design the borehole field to meet the peak building cooling/heating load.

- Original proposed system recommendations are on pages 16-18
- Static water level and soil data on page 17 is superseded by the thermal conductivity test drilling report (Attachment B). The well log included in the Formation Thermal Conductivity Test and Data Analysis report (Attachment C) includes the drilling well log data from Attachment B.
- System A recommendations on page 17 indicate replacing all existing fan coils with ¾ ton geothermal heat pumps. Considering the potential for load variations driven by orientation (southwestern), floor (1st or 3rd versus 2nd), exposure (corner versus center quarters), and use (day room), if individual heat loss/heat gain calculations have not been performed, this must be done. This will insure proper geothermal heat pump equipment sizing. Furthermore, the total capacity of 41 – ¾ ton heat pump units does not satisfy the most recent peak cooling load capacity requirement provided in Attachment E.
- System B on page 17 has the same sizing issues. Also, in this scenario, water-to-water geothermal heat pump capacity availability has changed since the report was issued. If this approach is pursued, leave equipment capacity size selection to the contractor so long as there is sufficient capacity to address peak load.
- Individual heat pumps versus the two-pipe central plant approach have their positives and negatives – primarily superior comfort control for the individual geothermal heat pumps with associated higher system cost versus fan coils and water-to water geothermal heat pumps operating as dictated for heating or cooling only operation with lower cost. A decision by others is required.
- The attachments listed as a part of this report were not provided.

Attachment B: <u>GSHP TEST HOLE DRILLING, LOOPING AND GROUTING INFORMATION, NAS LEMOORE (Guardino Well Drilling, Inc. – April 2009)</u>

- The 4th page lists well log data included in the Formation Thermal Conductivity Test and Data Analysis report (Attachment C)
- The 4th page lists the static water level (18 feet below existing grade)

Attachment C: <u>Formation Thermal Conductivity Test and Data Analysis (GRTI – April 2009)</u>

- Page 2 lists formation thermal conductivity and thermal diffusivity as well as the measured undisturbed deep earth formation temperature throughout the borehole's U-bend assembly
- The average temperature (71.8º F) from range listed on page 2 (71-72.5º F) will be used for ground heat exchanger calculations.
- The well log from Attachment B is listed on page 5
- The actual U-bend insertion depth (256') is listed on page 5

Attachment D: NAS LEMOORE GEOTHERMAL HEAT PUMP BOREHOLE LOAD ANALYSIS, Building 803C (DEC Engineers – April, 2009)

- This load analysis is not usable as a point of reference. It is based on peak design heating and cooling loads that differ greatly from the load data provided in Attachment E.
- This calculation used 71º F for the design ground temperature, not the average of water temperatures present when the test was begun. The average of the lowest (71º F) and warmest deep earth temperature (72.5º F) – 71.8º F should have been used.
- This calculation used 85º F for the geothermal heat pump maximum entering water temperature, which is not feasible with 71.8º F deep earth temperature.
- This calculation used 34º F for the geothermal heat pump minimum entering water temperature, which is not appropriate for the documented very warm deep earth ground temperatures and the building's heavily dominant cooling load.

Attachment E: Requested Information for the Building 803C at Lemoore (Piljae Im E-mail – April, 2010)

- Page 2 has peak heating and cooling data used for this report's calculations.
- Page 2 has total cooling and heating energy used for this report's calculations.

Loop Field Calculation:

The data available from Attachments A-E provided the information necessary to perform loop field design calculations using GCHPCalc 5.0.3 ground heat exchanger design software. Existing natural conditions and heating versus cooling load imbalance necessitated multiple design evaluations for each of the two system

options (Attachment A, Systems A and B) being considered. Furthermore, two loop field configurations were considered to illustrate the possibility of using a square (7 X 7 – 49 boreholes) or rectangular (5 X 10 – 50 boreholes) well field as site usable surface area may dictate. As a point of reference, the inputs for each of the two systems are provided.

As will be discussed below, both system options should utilize a dedicated water-to-water geothermal heat pump to heat domestic hot water. This water heating unit will not require additional loop field. Instead, it will unload the existing heavily cooling dominant loop field when operating. However, since it will not typically be operating under full load during the peak cooling load time of day, its heat absorption is not used to reduce ground heat exchanger requirements.

<u>GCHPCalc 5.0.3 Calculation Inputs – Individual ClimateMaster 1 Ton Tranquility 20 water-to-air geothermal heat pumps with ECM fan motors in all 41 rooms</u>:

- Building peak loads provided are block loads: Peak heat loss is 204.028 KBTU/HR; peak heat gain is 395.325 KBTU/HR. Annual cooling energy is 748.097 MBTU; Annual Heating Energy is 165.832 MBTU. Operation is 7 days a week, Annual Equivalent Full Load Cooling Hours are 1,729, and Annual Equivalent Full Load Heating Hours are 275.
- Peak block loads were averaged (KBTU/HR) for the 41spaces as follows:
    - Cooling: 8:00 AM-Noon = 6.8, Noon-4:00 PM = 9.7, 4:00 PM-8:00 PM = 7.8, and 8:00 PM-8:00 AM = 5.8
    - Heating: 8:00 AM-Noon = 4.0, Noon-4:00 PM = 3.2, 4:00 PM-8:00 PM = 4.0, and 8:00 PM-8:00 AM = 5.0
- Heat Pump Entering Water Temperature maximum in cooling is 95º F, minimum in heating is 65º F. Design loop field flow rate is 3 GPM per nominal ton of geothermal heat pump capacity.
- The average temperature for the undisturbed earth is 71.8º F
- Formation thermal conductivity is 0.86 Btu/hr-ft-º F; formation thermal diffusivity is approximately 0.55 ft^2/day.
- Borehole diameter is 6”, U-bend assembly is 1” DR-11 HDPE, grout thermal conductivity is 1.00 Btu/hr-ft-º F; flow within the system piping is turbulent, and U-bend piping is typically side-by-side and against the borehole wall (orientation B/C).
- Two vertical grid arrangements were considered – 7 X 7 (49 boreholes) and 5 X 10 (50 boreholes)

- There is one borehole per parallel circuit
- Three separation arrangements were considered – 20', 25', and 30'

GCHPCalc 5.0.3 Calculation Inputs – Individual fan coils in all 41 rooms with ClimateMaster Tranquility water-to-water geothermal heat pumps providing hot/chilled water.

All inputs are the same except for specific geothermal heat pump data differences between water-to-air and water-to-water equipment selection's capacities and performance and the resulting changes to Annual Equivalent Full Load Cooling/Heating Hours. Annual Equivalent Full Load Cooling Hours are 1,715, and Annual Equivalent Full Load Heating Hours are 258.

GCHPCalc 5.0.3 Loop Field Calculation Results – Individual ClimateMaster Tranquility 20 water-to-air geothermal heat pumps with ECM fan motor in all 41 rooms:

Layout	Separation (feet)	Total Borehole Required (feet)	Depth Per Borehole (feet)	Long Term Ground Temperature Rise (º F)
7 X 7	20	14,910	304	7.0
7 X 7	25	12,910	264	3.7
7 X 7	30	12,170	249	2.2
5 X 10	20	14,770	296	6.8
5 X 10	25	12,860	257	3.6
5 X 10	30	12,150	243	2.1

See Attachment F for output printout of each calculation.

GCHPCalc 5.0.3 Calculation Results – Individual fan coils in all 41 rooms with ClimateMaster Tranquility water-to-water geothermal heat pumps providing hot/chilled water.

Layout	Separation (feet)	Total Borehole Required (feet)	Depth Per Borehole (feet)	Long Term Ground Temperature Rise (º F)
7 X 7	20	16,190	331	7.1
7 X 7	25	14,020	286	3.8
7 X 7	30	13,220	270	2.2

5 X 10	20	16,050	321	6.9
5 X 10	25	13,960	279	3.6
5 X 10	30	13,190	264	2.2

See Attachment G for output printout of each calculation.

Ground Heat Exchanger Application Recommendations:

The previous questionable design information (Attachment D) has necessitated providing the detailed review and calculation information contained herein. Actual design recommendations are as follows:

- If sufficient loop field area is available, 30' spacing is strongly recommended as a sustainable design. Note the "Long term Ground Temperature Rise" columns – 2.1-2.2 º F long term change in the core of the loop field is a sustainable design. If space is limited, 25' spacing could be used, but 20' spacing can not – 6.8-7.1 º F rise is not a sustainable design.
- There is little difference between rectangular and square loop field layout – but – note that the rectangular layout exposes more of the boreholes to otherwise undisturbed soil, requiring slightly less depth per borehole. This indicates the loop field layout can be tailored as necessary to fit the ground surface area available.
- The decision on individual space geothermal heat pumps versus individual space fan coils and mechanical room water-to-water geothermal heat pumps is by others.
- A water-to-water geothermal heat pump for domestic hot water heating is strongly recommended, and will require no additional loop field. The water heating geothermal heat pump is of significant size, but will typically maintain the temperature of the storage tank rather than operate at full load capacity. Full load requirements for the building typically occur in the noon to 4:00 PM portion of the day, while water heating recovery is typically an early morning or evening requirement. Therefore, I do not recommend considering water heating capacity to reduce the ground heat exchanger capacity.
- U-bends are to be 1" DR-11 high density polyethylene (HDPE)
- Grout is to be a silica sand thermally enhanced Bentonite grout with a thermal conductivity of no less than 1.0.
- Trench depth is to be 4' maximum.
- Graded and/or load bearing trench bottoms are not required.

- If trench bottoms are soil or sand with no rock present, header piping can lay directly on the trench bottom.
- If trench bottoms are jagged rock, bed the trench bottom 6” with loose soil or sand prior to piping placement.
- Run a #10 locator wire with all horizontal piping runs throughout the loop field.
- After header installation and testing, bed 6” above the header pipes with loose soil or sand, then backfill with trenching spoils.
- Specialty fill or graded sand is not required. If clean (no roots, construction residue, large sharp edged rocks, etc.), loose soil is present in the trenching spoils, that is acceptable bedding material
- Do not drop smooth rocks larger than a soft ball, rocks with jagged edges, or large clumps of clay directly on the ground heat exchanger loop and/or header pipe.
- Headers are to be step-down-step up reverse return design to balance the flow through each portion of the loop field without mechanical means at the borehole.
- Backfill and compact as required by code/specification
- Place warning tape approximately 1’ below grade. Metallic tape is to be used in previously undisturbed areas. In areas with previous construction/demolition activity, metallic warning tape is not to be used because buried construction residue can give a false locate and result in damage.
- On new construction, fill and compact to within 1” (above or below) of rough grade. Leave any excess tailings piled neatly to be “lost” on the site during finish and final grade work.
- On retrofit applications, backfill and compact to grade, fertilize, mulch, and seed. Grass is to be watered until it sprouts, then ongoing support reverts to the client/owner.
- Loop field grid header piping is to enter the mechanical room through chases installed during waste water rough-in on new construction. Headers are to terminate with butterfly valves.
- Loop field grid header piping is to enter the mechanical room through the exterior wall as near the ground as possible on retrofit applications. Exterior

above grade piping is to be insulated and shielded with a protective cover. Headers are to terminate in the mechanical room with butterfly valves.

- Any vaults used are to be installed per the manufacturer's instructions.
- No antifreeze is required – the loop field is filled with water.
- All code requirements are to be met, and if code requirements are more stringent that the information above, they are to be followed. If the information above is more stringent than code requirements, they are to be followed.

Approximate Ground Heat Exchanger Cost:
The estimated turn-key cost range for this retrofit application ground heat exchanger installed per the listing above is $250,000-$325,000. This is the ground heat exchanger only, piped in to the Building 803C mechanical room and terminated at the butterfly valves. It includes no inside work or geothermal heat pump units. The design, and therefore the cost will not include any antifreeze or vaults. The cost does not include any local or state permits or fees. The estimate used 50 – 260' deep boreholes with 5 – 10 borehole connecting header grids, each routed into the mechanical room.

Conclusions:
Provided the heating and cooling loads provided are accurate, this project will require no more than 50 boreholes approximately 260' deep on 30 foot centers. This bore field will address both space conditioning and water heat loads for Building 803C. This is a viable project that should move forward if funding for the loop field and inside work is available.

ATTACHMENT A

Feasibility Study on Ground Source Heat Pumps at Two NAVFAC Facilities in California (Technology & Management Services, Inc. – January 2008)

- Separate file

ATTACHMENT B

GSHP TEST HOLE DRILLING, LOOPING AND GROUTING INFORMATION, NAS LEMOORE (Guardino Well Drilling, Inc. – April 2009)

- Separate file

ATTACHMENT C

Formation Thermal Conductivity Test and Data Analysis (GRTI – April 2009)

- Separate file

ATTACHMENT D

NAS LEMOORE GEOTHERMAL HEAT PUMP BOREHOLE LOAD ANALYSIS, Building 803C (DEC Engineers – April, 2009)

- Separate file

ATTACHMENT E

Requested Information for the Building 803C at Lemoore (From Piljae Im E-mail – April, 2010)

- Separate file

ATTACHMENT F

GCHPCalc 5.0.3 Loop Field Calculation Results – Individual ClimateMaster Tranquility 20 water-to-air geothermal heat pumps with ECM fan motor in all rooms

- Separate file

ATTACHMENT G

GCHPCalc 5.0.3 Calculation Results – Individual fan coils in all 41 rooms with ClimateMaster Tranquility water-to-water geothermal heat pumps providing hot/chilled water

APPENDIX A

Appendix A provides the site visit report and the pictures taken from U.S. Naval Base Sasebo.

FEMP Site Visit Summary Report

American Recovery and Reinvestment Act (ARRA)
FEMP Technical Assistance
US Navy Design Study of GSHP Systems at Guam & Japan

Agency Name: U.S. Navy
Site Name: U.S. Naval Base Sasebo
City (location), State: Sasebo, Japan
Dates of Site Visit: February 15-16, 2010
Date of FEMP Debrief: February 16, 2010

ASSESMENT TEAM

The following ARRA team members participated in the Site visit:

Piljae Im

SITE SUPPORT

The following site personnel attended the ARRA Inbrief Meeting:

Bryan Long, Energy Engineer
Karl Deikhorn, Public Works Officer
John Currie, Energy Manager

The following site personnel facilitated the data collection by providing additional interview time and/or accompanying us on our inspections, or participated in the training activities:

Tsunemasa Fujisawa, Environmental Engineering Technician
Yasuyuki Fujiyoshi, Mechanical Engineer

The following site personnel attended our ARRA Debrief Meeting:

Bryan Long, Energy Engineer
Karl Deikhorn, Public Works Officer
John Currie, Energy Manager

ACTIVITIES

Buildings/Systems Inspected

Visited Site	Mission/Use Type	Area (ft^2)

Building 1602	**Navy Lodge**
Building 16	**Navy Lodge**
Building 1455	**Navy Gateway inn and suites**
Building 1603	**Navy Gateway inn and suites**
Building 151	**Large BEQ**

Energy Conservation Opportunities Identified

The team identified 1 recommendation for reducing energy consumption, operating costs, and for increasing renewable energy opportunities. The initial list is as follows:

1. Perform feasibility study for installing GSHP systems on the building 1602,16,1455,1603, or 151
    i. All the buildings listed here are next to river or ocean. Therefore, there is a strong opportunity that the surface water can be used as heat sink/source. Seasonal differences in sea water temperature will be obtained from a local engineer, and the information will be used to model the building with a GSHP system. For the analysis, all the drawings for the buildings were obtained, too.

Based on the budget and decision from the base, one of the buildings/sites will be evaluated for the energy conservation potentials.

Photos for Bldg 1602 and 16

Building 1602

Building 1602 (2)

Building 16 (Connected with 1602)

Back side of 1602 (River next to the building) – Potential GHX installation

Chiller Unit

Heat Exchanger-1

Steam Pipes (w/ pressure info.)

Steam Header

View from the roof

Photos for Bldg 1455 and 1603

Building 1455

Lobby area

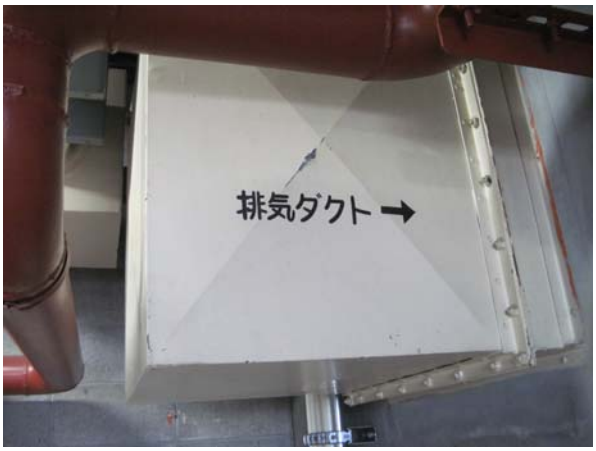
Thermostat in a guest room

Bay

Building 1455 & 1603

Individual AC Unit for suit rooms

Outdoor chilling unit



Ventilation Duct

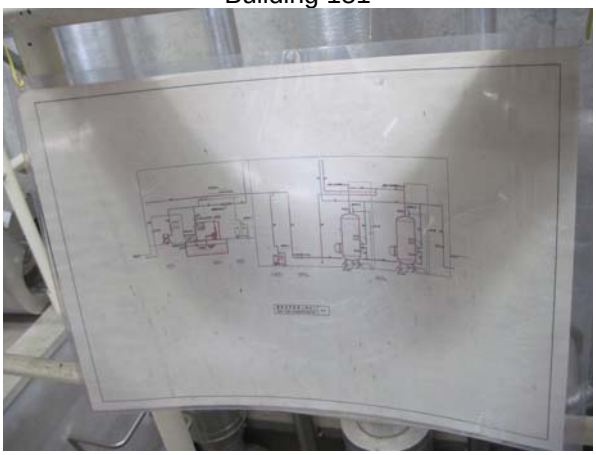
Thermostat in a guest room

Heat exchanger

Photos for Bldg 151

Building 151

Building 151(2)


Mechanical Room Diagram

Outdoor Chilling

DHW storage tank

Bachelor room

APPENDIX B

Appendix A provides the site visit report and the pictures taken from U.S. Naval Base Misawa.

FEMP Site Visit Summary Report

American Recovery and Reinvestment Act (ARRA)
FEMP Technical Assistance
US Navy Design Study of GSHP Systems at Guam & Japan

Agency Name: U.S. Navy
Site Name: U.S. Naval Base Misawa
City (location), State: Misawa, Japan
Dates of Site Visit: February 11-12, 2010
Date of FEMP Debrief: February 12, 2010

ASSESMENT TEAM

The following ARRA team members participated in the Site visit:

Piljae Im

SITE SUPPORT

The following site personnel attended the ARRA Inbrief Meeting:

Bryan Long, Energy Engineer
Shawn Rockwell, Public Works Officer
Sanford Bisese, Deputy Public Works Officer

The following site personnel facilitated the data collection by providing additional interview time and/or accompanying us on our inspections, or participated in the training activities:

Clifford Martin, E-6
Joshua Thonnisen, E-6
Shinji Tenma, Electrical Engineer

The following site personnel attended our ARRA Debrief Meeting:

Bryan Long, Energy Engineer
Shawn Rockwell, Public Works Officer
Sanford Bisese, Deputy Public Works Officer

ACTIVITIES

Buildings/Systems Inspected

Visited Site	Mission/Use Type	Area (ft^2)
Building 1440	**MoMAU (Mobile Mine Assembly Unit)**	
Building 980	**Misawa HQ Building**	
Building 520	**BQ/Hotel**	

Energy Conservation Opportunities Identified

The team identified 1 recommendation for reducing energy consumption, operating costs, and for increasing renewable energy opportunities. The initial list is as follows:

2. Perform feasibility study for installing GSHP systems on the building 1440, 980, or 520

Based on the budget and decision from the base, one of the buildings/sites will be evaluated for the energy conservation potentials.

Additional information for the buildings

- Bldg 1440 – MoMAU, a building that is getting ready to undergo some renovations including an HVAC upgrade. The building has ~ 30-40 people that occupy it M-F 730-1600, also for one week every quarter there is 24-7 occupancy. There are two rooms that require specialized cooling requirements due to battery storage, these rooms will not be included in our assessment.

- Bldg 980 – NAF-Misawa HQ, a nice square building with mainly office and classroom space. We received the drawings for this building, however, they are older and there have been some upgrades since then. We will work with the Japanese Mechanical Engineer to get this information.

- Bldg 520 – BQ / Hotel – This building has radiator heating and no cooling, additionally there is tight spaces to put a well-field, so this will be a challenging building as well.
- There was one building we did not look at that Mike Gabiga, the NAVFAC-FE REM mentioned he thought might be a good building. We will get more information on this building and consider it as well.

Photos for Bldg 1440

Building 1440 (1)

Building 1440 (2)

Steam Heater for Storage Room

Storage Area

HVAC Systems for Storage Area

Mechanical Room

Chilling Unit

Photos for Bldg 980

Building 980

Lobby Area

Kitchen and Dining Area

Office Area

Mechanical Room

Steam Header

AHU Name Plate

HVAC Zoning

Chilling Unit

Name Plate for the Chilling Unit

Photos for Bldg 520

Building 520

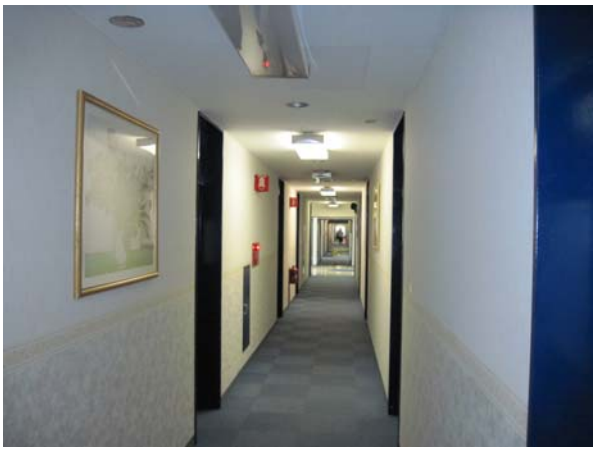
Parking Lot (Potential GHX Location)

Another Parking Lot for GHX Installation

Heat Exchanger for Heating

Domestic Hot Water Storage Tank

Guestroom Heater



Corridor

Steam Header

In Brief Meeting

APPENDIX C

Appendix C provides the GLD results for sizing the boreholes required for the building 980 at Misawa base.

	COOLING	HEATING
Total Length (ft):	**11890.1**	**11075.6**
Borehole Number:	**56**	**56**
Borehole Length (ft):	**212.3**	**197.8**
Ground Temperature Change (°F):	**+1.2**	**+1.3**
Unit Inlet (°F):	**90.0**	**35.0**
Unit Outlet (°F):	**99.7**	**28.6**
Total Unit Capacity (kBtu/Hr):	**964.1**	**733.6**
Peak Load (kBtu/Hr):	**716.9**	**733.6**
Peak Demand (kW):	**7.4**	**42.8**
Heat Pump EER/COP:	**15.7**	**5.0**
System EER/COP:	**15.7**	**5.0**
System Flow Rate (gpm):	**179.2**	**183.4**

Input Parameters

Fluid		Soil	
Flow Rate:	3.0 gpm/ton	Ground Temperature:	55.0 °F
Fluid:	100% Water	Thermal Conductivity:	1.20 Btu/(h*ft*°F)
Specific Heat (Cp):	1.00 Btu/(°F*lbm)	Thermal Diffusivity:	0.80 ft^2/day
Density (rho):	62.4 lb/ft^3		

Piping	
Pipe Type:	1 in. (25 mm) - SDR11
Flow Type:	Turbulent
Pipe Resistance:	0.104 h*ft*°F/Btu
U-Tube Configuration:	Single
Radial Pipe Placement:	Average
Borehole Diameter:	6.00 in
Grout Thermal Conductivity:	0.85 Btu/(h*ft*°F)
Borehole Thermal Resistance:	0.273 h*ft*°F/Btu