FINAL REPORT
FEASIBILITY STUDY FOR HVAC RETROFIT WITH A GEOTHERMAL SYSTEM
MOUNT GRANT GENERAL HOSPITAL
HAWTHORNE, NV

August 2006

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FEASIBILITY STUDY FOR HVAC RETROFIT WITH A GEOTHERMAL SYSTEM
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DISCLAIMER STATEMENT

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EXECUTIVE SUMMARY

The Geo-Heat Center conducted a feasibility study for the Mount Grant General Hospital to retrofit their aged heating, ventilating, and air-conditioning (HVAC) system to a geothermal system. This work has been funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-04, Task 3: *Heating System Replacement for Mt. Grant General Hospital, Hawthorne, NV.*

Two basic geothermal resource utilization scenarios were identified: (1) use the existing El Capitan well, which is located approximately 1.5 miles southwest of the hospital or (2) drill a new well on the hospital property. Within these scenarios, many possibilities emerged to develop the geothermal resource, and six were examined in detail:

1. Use El Capitan well
   a. Construct pipeline to Mount Grant General Hospital only
      i. Boiler retrofit.
      ii. Boiler + chiller retrofit.
   b. District heating system for county buildings (excluding schools)
      i. Hospital, Library, Courthouse, and Public Safety Buildings.
      ii. Above buildings + hospital expansions and outbuildings + fire station.
   c. District heating system for county buildings (including schools).
2. Drill new well on hospital property
   a. Geothermal heat pump system for the original hospital using lower temperature groundwater (80-100^{o}F).

An economic analysis was conducted, and three economic indicators were used to compare alternatives: simple payback period, net present value (NPV), and return on investment (ROI). For each of the above cases, we considered ownership by Mount Grant General Hospital (or Mineral County) or by an energy services company (ESCO) offering a 25% and a 50% energy savings to potential customers.

A summary of the economic analysis is presented in the table on Page iii, and some of the conclusions of this study are as follows:

- Including absorption cooling in the geothermal retrofit projects does not improve economics significantly.
- From the perspective of an ESCO, Scenario 1(c) and Scenario 2(a) are marginally attractive at 25% (and less) energy savings to customers. Under these scenarios, simple payback periods are about 15 years, NPVs are positive, and returns on investment are about 10%. However, the retrofit costs of the Mineral County Schools would need to be examined in more detail to support Scenario 1(c).

- The economic viability of a district heating system without grants or incentives, which are in limited supply at this time, proved to be challenging. Each successive scenario of using the El Capitan well in a district heating application that was considered in this study resulted in additional mechanical retrofit and geothermal pipeline construction cost that compete with energy savings. Should more customers be considered beyond Scenario 1(c), a larger capacity pump and pipeline would be needed, which would further compete with savings.
- It would appear from this study that in order for the hospital to connect to an economically viable district geothermal heating system, a new application(s) equivalent to a heating load of about 150,000 ft^2 floor space (or nearly 10 times the floor space of the original hospital), would need to exist near the hospital or closer to the El Capitan well. This is due to the fact that the further the load is from the geothermal source, the more the pipeline construction costs (as well as mechanical retrofit costs) compete with energy savings realized by the project owner.
- From the perspective of Mount Grant General Hospital or Mineral County as a project owner, none of the El Capitan well uses appear to be viable, simply due to the large capital cost (i.e. at least $1.1 million, most of which is pipeline cost) and relatively long payback periods. On the other hand, Scenario 2(a) (geothermal heat pumps for boiler replacement at the original hospital) is quite economically attractive. The case of the hospital owning this project outright has the greatest return on investment (35.7%) of all the cases examined, as well as the lowest payback period (8.8 years). The estimated capital cost for this case of about $225,000 is approximately half of a quote for boiler upgrade already received by the hospital.
- The Geo-Heat Center recommends the following course of action for the Mount Grant General Hospital:
    - Refurbish or upgrade existing controls, especially on fan dampers
    - It is G. Culver's opinion that the boilers can be successfully de-scaled for future use. This would be required anyway, even with a geothermal retrofit, so that the boilers could be used as a back-up heating system.
    - Consider use of heat recovery units on fan systems S-1 and S-2 to reduce energy consumption in both heating and cooling.
    - Consider pursuing Scenario 2(a) by first drilling a 500-ft deep test well on the hospital property, south of the building, for use in an open-loop geothermal heat pump system. This will give more insight into the geothermal retrofit design, and will help in refining the economics. It is possible that future grants from the U.S. Department of Energy may be available for this type of activity.

Summary of Economic Analysis of Geothermal Retrofit Alternatives for the Mount Grant Genreral Hospital, Hawthorne, NV

	Scenario	Capital Cost (with 5% Contingency)	Annual Energy Savings	Simple Payback Period (years)			Net Present Value			Return on Investment		
				100% of Energy Savings Realized by Project owner	**75%** of Energy Savings Realized by Project owner	**50%** of Energy Savings Realized by Project owner	**100%** of Energy Savings Realized by Project owner	**75%** of Energy Savings Realized by Project owner	**50%** of Energy Savings Realized by Project owner	**100%** of Energy Savings Realized by Project owner	**75%** of Energy Savings Realized by Project owner	**50%** of Energy Savings Realized by Project owner
1(a)-i	Construct pipeline to Mt. Grant Hospital only - boiler retrofit	$1,098,195	$41,026	26.8	>30	>30	($296,906)	($473,277)	($649,648)	4.8%	2.9%	0.6%
1(a)-ii	Construct pipeline to Mt. Grant Hospital only - boiler + chiller retrofit	$1,164,345	$44,470	26.2	>30	>30	($299,254)	($497,436)	($695,619)	5.0%	3.0%	0.8%
1(b)-i	District heating system for county buildings - Original Hospital, Library, Courthouse, and Public Safety Building	$1,283,746	$60,878	21.1	28.6	>30	($140,030)	($395,930)	($651,831)	6.7%	4.3%	1.8%
1(b)-ii	District heating system for county buildings - Hospital, Library, Courthouse, Public Safety Building, Hospital SNF and CT expansions, Business Office outbuilding, Medical Center, Medical Annex, and Fire Station	$1,438,096	$91,593	15.7	21.2	>30	$218,038	($164,917)	($547,872)	10.0%	6.6%	3.5%
1(c)	District heating system for county buildings - All buildings included in Scenario 1b-ii + Mineral County Schools	$2,068,096	$187,462	11.0	14.8	22.7	$1,206,822	$435,799	($335,223)	17.7%	10.8%	6.1%
2(a)	Geothermal heat pump system for boiler replacement in original hospital only	$224,228	$25,606	8.8	15.4	>30	$215,486	$39,115	($137,256)	35.7%	10.3%	0.3%

INTRODUCTION AND BACKGROUND

This work has been funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-04, Task 3: *Heating System Replacement for Mt. Grant General Hospital, Hawthorne, NV.*

The motivation for conducting this project originated from interest by Dr. Daniel Dees, Chief of Staff of the Mount Grant General Hospital in reducing fuel consumption and costs associated with heating the hospital by replacing the heating plant with geothermal energy. The main hospital heating plant currently consists of two No. 2 diesel-fired boilers that were installed in 1963 when the hospital was originally constructed.

The Hawthorne, NV area possesses a known geothermal resource. Warm wells occur throughout town, but the best evidence of the resource potential came from drilling of the so-called “El Capitan Well” in 1980 by the El Capitan Lodge and Club, for irrigation of a proposed golf course at that time. The groundwater temperature at the bottom of the hole was recorded at 210^{o}F. The well is capable of producing approximately 500 gpm of water at about 200^{o}F. The well, in addition to about 20 acres of land surrounding the well, is now owned by Mineral County.

Historically the El Capitan well has never been used. In the early 1980s, the Geo-Heat Center, operating under federal grants from the U.S. Department of Energy, conducted a number of “proof of concept” studies and feasibility studies for utilizing the hot water from the El Capitan well. Some scenarios examined in these studies were: a geothermal district heating system for the town of Hawthorne, a heating system for the Mineral County Schools, and heating of the El Capitan Lodge and Club. The success of these projects, however, was contingent upon federal financial assistance that never materialized.

More recently, there has been considerable interest in the potential of the geothermal resource at Hawthorne, NV for electrical power generation. The Geothermal Program Office of the Naval Air Weapons Station (NAWS), China Lake, CA reported on a number of geophysical and geochemical studies of the Hawthorne area (NAWS, 2002). Those studies suggested that resource temperatures up to 325^{o}F are possible, and a seismic survey was subsequently recommended to aid in siting a test hole that could be drilled as deep as 8,000 ft. The seismic survey was completed in 2005 in an area south of Hawthorne on military property, and formal results are not yet available. The geothermal resource at Hawthorne, NV has also been identified by GeothermEx, Inc. (2004) under contract by the California Energy Commission, as one possible geothermal resource that could supply electrical power to the California market.

OBJECTIVE AND SCOPE

The objective of this project is to determine the feasibility of replacing the aged heating plant at Mount Grant General Hospital with a geothermal system.

Two basic geothermal resource utilization scenarios were identified: (1) use the existing El Capitan well or (2) drill a new well on the hospital property. Within these scenarios, several possibilities emerged to develop the geothermal resource. In Scenario 1, if the El Capitan well were to be used, the economics of a pipeline construction would be more attractive if more customers could share costs and benefits. In Scenario 2, drilling a new well on the hospital property would most likely result in encountering lower temperature groundwater at 80 to 100°F, and thus geothermal heat pumps are considered. Therefore, we define 6 possible geothermal utilization scenarios as follows:

1. Use El Capitan well
   a. Construct pipeline to Mount Grant General Hospital only
      i. Boiler retrofit
      ii. Boiler + chiller retrofit.
   b. District heating system for county buildings (excluding schools)
      i. Hospital, Library, Courthouse, and Public Safety Buildings.
      ii. Above buildings + hospital expansions and outbuildings + fire station.
   c. District heating system for county buildings (including schools).
2. Drill new well on hospital property
   a. Geothermal heat pump system for the original hospital using lower temperature groundwater (80-100°F).

METHODOLOGY AND REPORT ORGANIZATION

The method and approach conducted by the Geo-Heat Center to accomplish the project objectives are summarized as follows:

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- Visited the hospital site and met with hospital maintenance staff,
- Compiled and reviewed data and information on the existing hospital heating system,
- Visited Mineral County buildings and gathered preliminary data for a potential geothermal district heating system for these buildings,
- Conducted an economic analysis of alternatives.

Design aspects for a geothermal retrofit of this type consist of a number of geological, mechanical, and economic considerations. Thus, these topics are addressed in this report in the following subsections (which follow this section):

- *Hawthorne Geothermal Resources:* describes the known geothermal resource from regional and local (i.e. at the hospital property) perspectives in the context of direct-use applications (i.e. excluding geothermal power plants),
- *Existing Heating, Ventilating, and Air Conditioning (HVAC) Systems:* summarizes the systems currently used by the hospital for heating and cooling, laying the groundwork for describing how these systems could be retrofitted to a geothermal system. This section also briefly describes HVAC systems at other neighboring county buildings that might be included in a geothermal district system,
- *Existing HVAC Systems Energy Consumption* summarizes annual energy consumption and cost related to heating and cooling of the hospital and other buildings,
- *Geothermal Retrofit Description and Economic Comparison of Alternatives:* describes

work required to retrofit the hospital and other buildings under the scenarios described above, presents cost estimates, and compares alternatives based on simple payback period net present value, and return on investment,

- *Concluding Summary and Recommendations:* summarizes the findings of this study and presents recommendations for further action.

HAWTHORNE GEOTHERMAL RESOURCES

Regional Geothermal Resource

The geothermal resource at Hawthorne, NV is believed to be similar to other Basin and Range resources. Conceptual models of geothermal reservoirs attempt to describe their mode of recharge, fluid circulation path, heat source, and discharge or outflow path. The generalized conceptual model of Basin and Range geothermal reservoirs is that recharge to the geothermal reservoir is by meteoric waters (rain and snowmelt) that sink to considerable depths, usually along fault lines and fracture zones at higher elevations. Groundwater then becomes heated at depth, circulates and rises due to buoyancy effects along lower faults.

Figure 1 shows the conceptual model of the geothermal reservoir at Hawthorne, NV. Hot water rises into layered and inter-fingered permeable lake bed deposits and migrates down hydraulic gradient (to the north) toward Walker Lake. The resource is referred to as a "blind" resource, since groundwater never reaches the surface as warm or hot springs. Wells drilled into the permeable material intersect the hot water, with the hottest wells intersecting faults.

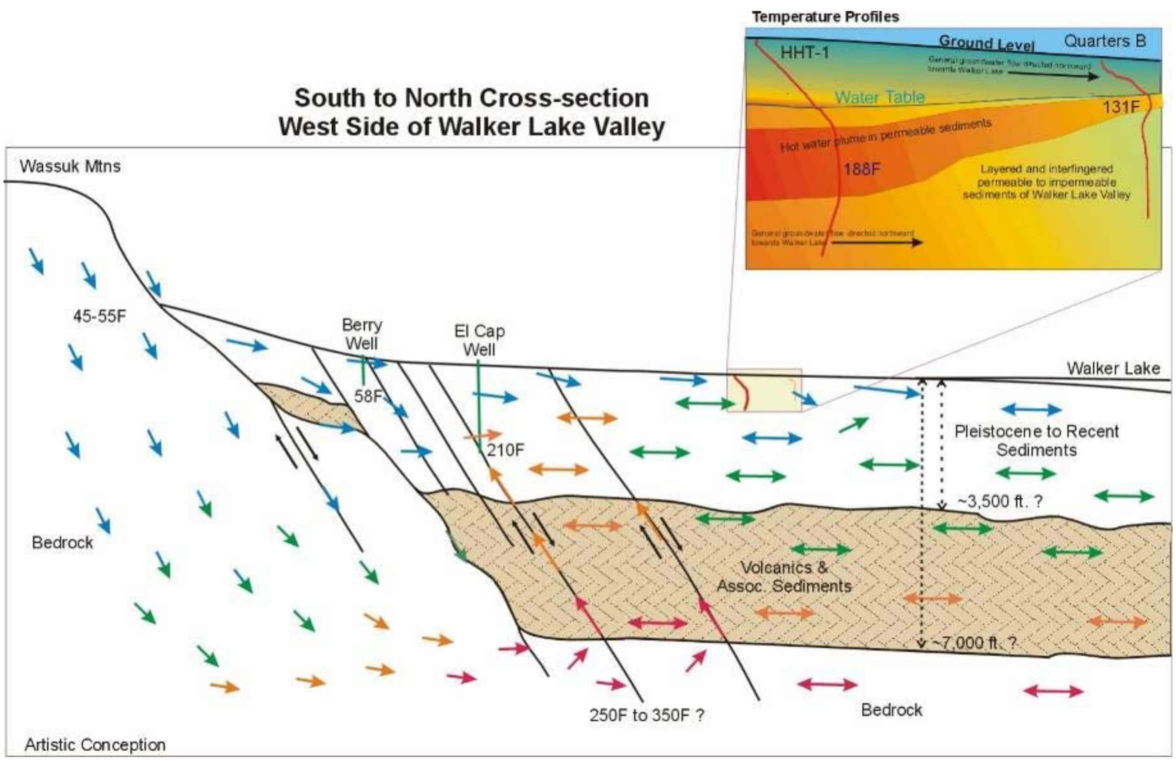

Figure 1. *Conceptual model of the geothermal resource at Hawthorne, NV (Source: NAWS, 2002).*

Figure 2 shows some of the well locations, depths, and temperatures along with mapped surface faults in the Hawthorne area. The important things to note from Figure 2 are that there are no known faults or even reasonable projections of known faults close to the hospital property where hot water could be intersected. An examination of the well water temperatures shows that groundwater temperature varies in both lateral and vertical directions. Temperatures decrease northward from the El Capitan well toward Walker Lake. Wells labeled "HHT-1" and "Quarters B" have maximum well water temperatures of 188°F at a depth of 550 ft and 131°F at a depth of 190 ft, respectively. With increasing depth, groundwater temperature decreases to the bottom of these wells at depths of 800 ft and 600 ft, respectively.

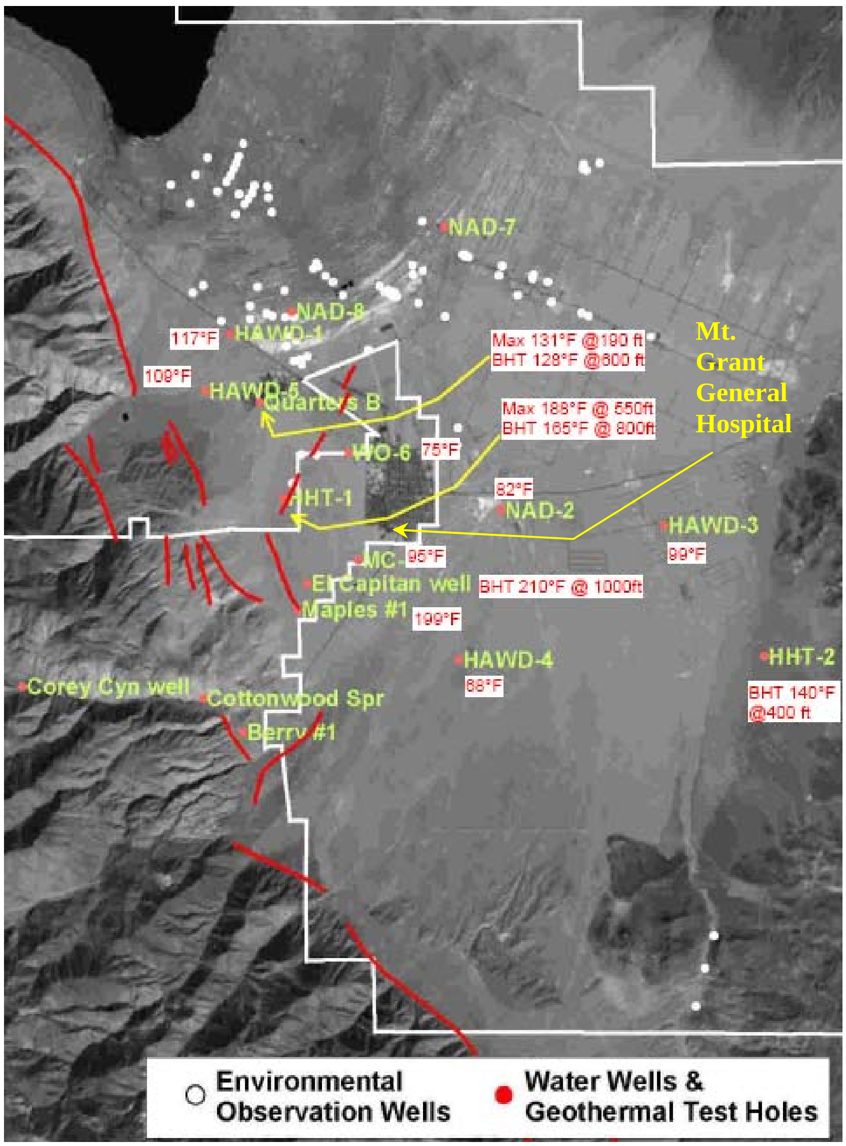

Figure 2. *Well and fault locations in the Hawthorne, NV area. (Source: GeothermEx, 2004).*

To the best of our knowledge, a temperature profile of the El Capitan well does not exist. The bottom hole temperature at a depth of 1,000 ft was recorded at 210^{o}F when the well was drilled in 1980. Upon pumping, the well produces 202^{o}F water, suggesting that some cooler is entering through casing perforations at a depth somewhere between 600 and 1000 ft.

The lateral and vertical distribution of groundwater temperature is shown in the artistic conception in the inset of Figure 1. The inset shows the hot water plume rising because of buoyancy as it moves north toward Walker Lake. Figure 1 also shows the El Capitan well intersecting the fault at total depth, indicating that a temperature reversal cannot be ruled out if the well were to be deepened. However, a caveat here is the assumption that the dip of this fault parallels the faults in more competent formations to the west for its entire depth, but this may not be true in the lake bed sediments.

Figure 3 shows horizontal temperature contours based on bottom hole and/or production temperature of wells. The data presented in this figure has implications for re-injection of used geothermal fluids, in addition to the geothermal potential at the hospital property.

The Geo-Heat Center contacted the Nevada Division of Environmental Protection regarding injection of geothermal fluids. Nevada injection regulations essentially prohibit injection of fluids into an aquifer where its water quality could be potentially degraded. For injection purposes, all groundwater is considered to be in an aquifer that is potentially usable for drinking water, regardless of the water quality or occurrence of groundwater. This is because groundwater could be "cleaned up" for drinking if absolutely necessary, or it could eventually migrate to a usable aquifer. The State of Nevada has exempted some aquifers as being drinkable based on certain criteria. For example, one of these exempted aquifers is at Steamboat Springs, south of Reno, which is currently being used for geothermal fluids for electricity generation.

There are no currently exempted aquifers in the Hawthorne area from underground injection regulations. Therefore, injection of geothermal fluids in the Hawthorne area must be into an accepting aquifer that is of similar or lesser quality. In addition, the cone of impression (or recharge) must not artificially cause a hydraulic gradient toward a drinking well or another aquifer; the lesser quality water must be carried down regional hydraulic gradient before it can reach drinking water aquifers. To be able to quantify the fate of injected water requires knowledge of injection and production rates, and a number of aquifer hydraulic and chemical properties, which are not well know at this time.

Production of geothermal water from the El Capitan well will most likely result in injection into a higher water quality zone. Therefore, we have assumed injection at a location of ¾ mile due west of the hospital at a depth of 600 ft.

Geothermal Potential on the Mt. Grant Hospital Property

Based on the previous discussion, there is no evidence to support the presence of hot enough water under the hospital property at feasible drilling depths to sustain direct-use heating (i.e. 140+^{o}F groundwater). Therefore, the geothermal resource potential on the hospital property itself has implications most likely for geothermal heat pump application. Groundwater temperatures are likely in the range of 80°F to 100°F. To access groundwater at temperatures above 140°F, a well on the order of 2,000 to 5,000 ft deep would be required, and there would be no guarantee that this type of resource could be found; groundwater under the town of Hawthorne may continue to increase up to a point, but then may begin to decrease. Likewise, to access groundwater at temperatures above 190°F, a well on the order of 5,000 to 7,000 ft would most likely be required.

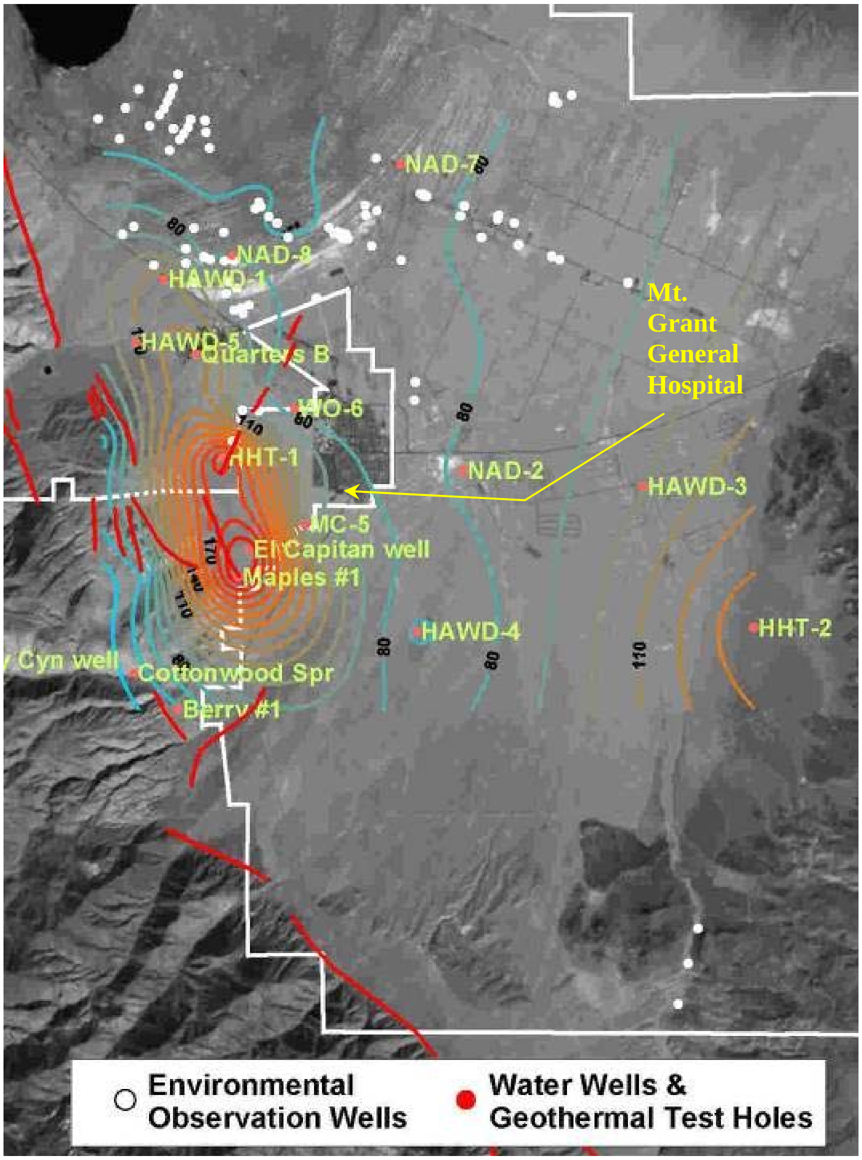

Figure 3. *Groundwater temperature contour map around Hawthorne, NV. (Source: NAWS, 2002).*

EXISTING HVAC SYSTEMS DESCRIPTION

This section describes the existing heating, ventilating, and air conditioning (HVAC) systems currently used by the hospital and neighboring county buildings for heating and cooling. The neighboring County buildings are those that might be included in a geothermal district system as shown in Figure 4.

Mount Grant General Hospital

The system at the Mount Grant General Hospital is a mixture of central and unitary systems and equipment. The original hospital building was constructed in 1963 and is approximately 16,000 ft^2 in plan area. Two additions have been constructed since then: a skilled nursing facility in 1994 at the west end of the original hospital (approximately 4,000 ft^2), and a CT wing in 1997 at the northeast corner (approximately 1,500 ft^2).

Original Hospital Building: The original part of the hospital is the only portion heated by hot water. The central (or primary) heating plant consists of two low pressure steam boilers rated at 80 hp input (2.75 million Btu/hr), with one boiler serving as a backup to the other. Adjusting for elevation and age of the boilers, their efficiency is likely on the order of 50%, giving a rated output of about 1.38 million Btu/hr.

Steam from the boilers is currently routed to two end uses: domestic hot water and space heating. Hot water for patient rooms, sinks, etc. is supplied through one 462 gallon storage tank with steam-to-water immersion heaters. A second 462 gallon storage tank for kitchen and laundry use has been abandoned and replaced by LPG-fired storage tanks near their end uses.

The space heating system consists of a steam-to-water tube and shell heat exchanger supplying hot water at a temperature of 210^{o}F (at design conditions) to two air handlers (S-1 and S-2) located in the penthouse area, an outdoor air preheat coil on S-1, and baseboard convectors in patient rooms (23 total patient rooms).

Air handling unit S-1 is part of a multi-zone system serving the laboratory, surgery room, operating room, central supply room, trauma room, emergency room, and nursery, and S-2 serves a single zone (hallways, etc.). System S-1 is configured in a hot deck/cold deck arrangement, where the hot and cold air streams are proportioned to satisfy the individual zone thermostats. Chilled water for the S-1 cold deck is provided by a 20-ton Trane chiller, installed in 1963 with the original construction. System S-2 is configured with a hot water-to-air coil with cooling provided by an evaporative cooler installed outside the penthouse on the hospital rooftop. The S-1 fan is rated at 5,650 cfm, and is a 100% outdoor air system (i.e. all return air is exhausted). The S-2 fan is rated at 5,625 cfm with about 70% of the air being exhausted. These quantities of exhaust air result in a significant energy demand on the heating system.

Rooftop evaporative coolers also provide additional cooling to various rooms in the original part of the hospital. These are the kitchen, storeroom, laundry, X-ray, insurance office, and the beauty shop.

Figure 4. *Aerial photograph showing the location of the Mount Grant General Hospital and other Mineral County-owned buildings (Source: Google Earth).*

During the Geo-Heat Center's site visit in May 2006, hospital staff indicated that the baseboard convectors in patient rooms provide inadequate heat when outdoor air temperatures begin to drop below the mid 30s^{o}F. Consequently, supplemental electric resistance heating elements have been installed in packaged unitary air conditioners in the patient rooms. These air conditioners also provide cooling for the patient rooms. The electric resistance elements are rated at 1.25 kW, and the air conditioning units are rated at 8,000 Btu/hr.

Also discovered during the Geo-Heat Center's site visit in May 2006 was that the heating system is not performing efficiently. The boilers are scaled and some pneumatic controls are not functional. The hospital staff is well aware of this and has obtained preliminary bids for boiler replacement. One proposal was received in March 2005 for $379,900, which included retrofitting the mechanical room, but did not include any structural or concrete work. Therefore, it is conceivable that an all-inclusive retrofit would today approach $500,000.

Finally, the heating system for the original portion of the hospital was oversized. This conclusion was also noted during the course of a previous study by Chilton Engineering (1981) directed by the Geo-Heat Center, under contract with the U.S. Department of Energy. Appendix A contains excerpts from the Chilton (1981) report of an analysis of the hospital heating requirements. Their conclusion was that the boilers were oversized by a factor of 2, even after including a safety factor of 25%.

<u>Hospital Expansions – SNF and CT Areas:</u> As mentioned above, two newer wings have been constructed at the hospital: a 4,000 ft^2 skilled nursing facility (SNF) and a 1,500 ft^2 computed (or computerized) tomography (CT) facility. Both of these areas are conditioned with packaged rooftop units with gas (LPG) heat and direct expansion (DX) cooling.

The SNF wing is conditioned with 4 packaged rooftop units. Each unit is a Carrier brand rated at 4 tons cooling capacity. The rated heating capacity is 57,000 Btu/hr with 74,000 Btu/hr gas input (i.e. an efficiency of 80%). Hot water in the SNF is generated with a 100 gallon LPG-fired storage tank.

The CT wing is conditioned with 2 packaged rooftop units, each manufactured by Bryant. The larger unit is rated at 3 tons cooling capacity with a heating capacity of 69,000 Btu/hr at 85,000 Btu/hr gas input (80% efficiency). The smaller unit is rated at 1.5 tons cooling with a heating capacity of 29,000 Btu/hr at 36,000 Btu/hr gas input (80% efficiency). Hot water is generated using a 30 gallon tank with a 4.5 kW electric heating element.

<u>**Hospital Outbuildings**</u>

The Geo-Heat Center surveyed the heating and cooling systems of a number of outbuildings affiliated with the Mount Grant General Hospital. These are referred to as the Medical Center, the Business Office outbuilding, and the Medical Clinic Annex (used by visiting doctors).

The Medical Center is a 7,500 ft^2 building used for clinical purposes. The building has 5 zones, each conditioned by a packaged rooftop unit with gas (LPG) heat and DX cooling. Four of these are manufactured by Rheem and the fifth is manufactured by Bryant. The Rheem units are rated at 3.5 tons of cooling capacity with a heating capacity of 97,000 Btu/hr at 120,000 Btu/hr gas input (80% efficiency). The Bryant unit is rated at 4 tons cooling capacity with a heating capacity of 77,000 Btu/hr at 95,000 Btu/hr gas input (80% efficiency).

The Business Office outbuilding is a 2,000 ft^2, two-zone office building. The building is cooled with two rooftop evaporative cooling units. Heat is provided by two Coleman-brand, forced-air LPG gas furnaces with a heating capacity of 47,000 Btu/hr at 56,000 Btu/hr gas input (approx. 80% efficiency). At the time of the Geo-Heat Center's site visit, a computer server room was being constructed with two 2-ton Friedrich-brand split cooling units with an electrical disconnect for a possible third cooling unit.

The Medical Annex is a 1,500 ft^2 building that provides office space for visiting medical doctors. The building is conditioned with a Rheem-brand forced-air, split system. The system is rated at 5 tons of cooling capacity with a heating capacity of 120,000 Btu/hr at 150,000 Btu/hr gas input.

Mineral County Fire Station

The Mineral County Fire Station is an approximately 5,600 ft^2 building, consisting of a 2,000 ft^2 office area and a 3,600 ft^2 garage that houses emergency vehicles. The office area is conditioned with a Carrier-brand forced-air, split system with 5 tons of rated cooling capacity. The rated heating capacity is 107,000 Btu/hr at 132,000 Btu/hr gas input (80% efficiency). The garage is heated with two ceiling-mounted, LPG-fired, forced-air unit heaters. These are rated at 80,000 Btu/hr at 100,000 Btu/hr gas input (80% efficiency). According to the Fire Chief, the unit heaters in the garage are rarely operated, except on very cold days.

Mineral County Courthouse

The HVAC system at the Mineral County Courthouse was described by Chilton Engineering (1981). It is a single large dual duct forced-air system with 12,775 cfm supply air and 10,000 cfm return air capacity. Heating and cooling are accomplished via two water-air coils. The hot water coil has a capacity of 400,000 Btu/hr at 20 gpm of 180^{o}F entering water. The hot water is supplied from an oil-fired hot water boiler, rated at 1 million Btu/hr input. Domestic hot water is supplied by two small electric water heaters.

Mineral County Public Safety Building

The HVAC system at the Mineral County Public Safety Building was also described by Chilton Engineering (1981). It is a large multi-zone forced-air system with 15,050 cfm supply air and 12,050 cfm return air capacity. Heating and cooling are accomplished via two water-air coils. The hot water coil has a capacity of 745,500 Btu/hr at 50 gpm of 180^{o}F entering water. The hot water is supplied from an oil-fired hot water boiler, rated at 1.48 million Btu/hr input, which also supplies hot water to a 1,000 gallon storage tank and to a 50,000 Btu/hr unit heater in the mechanical room.

Mineral County Library

The HVAC system at the Mineral County Library was also described by Chilton Engineering (1981). It is a direct-fired oil multi-zone forced-air system with 6,100 cfm supply air. A new wing has been constructed since that time, significantly increasing the floor space of the library. This new addition is heated with a LPG-fired furnace system.

Mineral County Schools

The HVAC systems at the Mineral County Schools were examined for the feasibility of a geothermal retrofit by the Spink Corporation (1981) directed by the Geo-Heat Center, under contract with the U.S. Department of Energy.

Although examination of the details of the HVAC systems at the Mineral County Schools is beyond the scope of this present report, the Geo-Heat Center spoke to maintenance personnel at the school during the May 2006 site visit. During the mid 1990s, the school renovated all HVAC systems to LPG, upgraded control systems, improved building envelopes, and undertook some new construction. Therefore, the analysis given by the Spink Corporation (1981) is no longer applicable. The Geo-Heat Center also learned that the annual school budget for heating is on the order of $100,000.

EXISTING HVAC SYSTEMS ENERGY CONSUMPTION

An estimate of annual energy consumption and cost for HVAC systems that are potentially retrofittable to geothermal is necessary for an economic analysis. Several methods are available for estimating HVAC energy usage in buildings. These methods range from utility bill analyses to detailed computer modeling of hourly loads in buildings. The most accurate method is from utility bills, but sometimes difficult since HVAC systems are generally not metered separately. In the case of the Mount Grant General Hospital, the boiler is the only piece of equipment using #2 diesel, so annual energy costs are known fairly accurately. Likewise, Chilton Engineering (1981) reported gallons of heating fuel used for the Mount Grant General Hospital, Library, Mineral County Courthouse, and Public Safety Building. However Chilton Engineering (1981) did not examine cooling systems, and the existing packaged HVAC units at other potentially retrofittable buildings did not exist at that time.

In order to estimate annual HVAC energy consumption for the above-described buildings, we used RETScreen, a software tool developed by Natural Resources Canada (NRC, 2005) for economic evaluation of renewable energy projects. RETScreen employs a combination of the degree-day procedure and bin method (methods based on local weather conditions) to calculate annual energy consumption in buildings. The nearest weather data was taken from Tonopah, NV. The result of the calculation is annual quantity of fuel used, from which an annual cost can be determined. In cases such as the Mount Grant General Hospital (original building) and other buildings examined by Chilton Engineering where the annual fuel use is known, we simply adjusted the peak hour load in the RETScreen software to match the annual fuel use. The same approach was taken for the Mineral County Schools, where it is known that the annual cost for heating is approximately $100,000. Peak cooling loads were estimated at 400 ft^2/ton. Results of the energy consumption analysis are shown in Table 1 for potentially retrofittable buildings.

Note that “Building Clusters” are used in RETScreen. For this analysis, we define the building clusters as: **(1)** Mt. Grant General Hospital original building, **(2)** Courthouse and Public Safety, **(3)** Library, **(4)** SNF and CT hospital additions, **(5)** Medical Center, Business Office, Fire Station, and Medical Annex, and **(6)** Mineral County Schools.

Table 1.

RETScreen Load & Network Design - Combined heating & cooling project

Heating project	Unit	Estimate		Notes/Range
Site conditions				
Nearest location for weather data		Tonopah		*See Weather Database*
Heating design temperature	°C	-10.1	13.8 °F	-40 to 15 °C
Annual heating degree-days below 18°C	°C-d	2,933	5,279 °F-d	*Complete Monthly inputs*
Domestic hot water heating base demand	%	0%		0% to 25%
Equivalent degree-days for DHW heating	°C-d/d	0.0		0 to 10 °C-d/d
Equivalent full load hours	h	1,987		

Monthly inputs

Month	°C-d <18°C	°F-d <65°F	Month	°C-d <18°C	°F-d <65°F	Month	°C-d <18°C	°F-d <65°F
January	579	1,043	May	88	159	September	3	5
February	435	783	June	0	0	October	199	358
March	394	709	July	0	0	November	413	743
April	251	451	August	0	0	December	571	1,028

Base case heating system	Multiple buildings - space heating		**Building clusters**					
See technical note on heating network design			**1**	**2**	**3**	**4**	**5**	**6**
Heated floor area per building cluster	ft²	212,080	16,000	21,580	6,000	5,500	13,000	150,000
Number of buildings in building cluster	building	12	1	1	1	2	4	3
Fuel type			Diesel (#2 oil) - gal	Diesel (#2 oil) - gal	Diesel (#2 oil) - gal	Propane - gal	Propane - gal	Propane - gal
Seasonal efficiency	%	-	60%	60%	60%	75%	75%	75%
Heating load calculation								
Heating load for building cluster	Btu/ft²	-	52	15	8	40	40	15
Total heating demand	million Btu	**8,334**	1,653	643	95	437	1,033	4,471
Total peak heating load	million Btu/h	**4.2**	0.8	0.3	0.0	0.2	0.5	2.3
Fuel consumption - unit		-	gal	gal	gal	gal	gal	gal
Fuel consumption - annual		-	20,012	7,786	1,155	6,114	14,452	62,534
Fuel rate - unit		-	USD/gal	USD/gal	USD/gal	USD/gal	USD/gal	USD/gal
Fuel rate		-	2.200	2.200	2.200	1.550	1.550	1.550
Fuel cost	**USD**	**192,500**	USD 44,026	USD 17,129	USD 2,540	USD 9,477	USD 22,401	USD 96,928
Proposed case energy efficiency measures								
End-use energy efficiency measures	%	0%	0%	0%	0%	0%	0%	0%
Net peak heating load	million Btu/h	4.2	0.8	0.3	0.0	0.2	0.5	2.3
Net heating demand	million Btu	8,334	1,653	643	95	437	1,033	4,471

Table 1 (*continued*).

Cooling project	Unit			
Site conditions		**Estimate**		**Notes/Range**
Nearest location for weather data		Tonopah		*See Weather Database*
Cooling design temperature	°C	33.6	92.5 °F	10 to 47 °C
Annual cooling degree-days above 10°C	°C-d	1,616	2,908 °F-d	*Complete Monthly inputs*
Non-weather dependant cooling	%	0%		5% to 30%
Equivalent full load hours	h	1,759		

Monthly inputs

Month	°C-d >10°C	°F-d >50°F	Month	°C-d >10°C	°F-d >50°F	Month	°C-d >10°C	°F-d >50°F
January	0	0	May	160	287	September	237	427
February	0	0	June	323	581	October	49	88
March	0	0	July	447	805	November	0	0
April	0	0	August	400	720	December	0	0

			Building clusters 1	2	3	4	5
Base case cooling system	Multiple buildings - space cooling						
See technical note on cooling network design							
Cooled floor area per building cluster	ft²	62,080	16,000	21,580	6,000	5,500	13,000
Number of buildings in building cluster	building	5	1	1	1	1	1
Fuel type			Electricity	Electricity	Electricity	Electricity	Electricity
Seasonal efficiency	%	-	250%	250%	250%	250%	250%
Cooling load calculation							
Cooling load for building cluster	ft²/RT	-	400	400	400	400	400
Total cooling demand	RTh	**273,035**	70,370	94,911	26,389	24,190	57,176
Total peak cooling load	RT	**155.2**	40.0	54.0	15.0	13.8	32.5
Fuel consumption - unit		-	MWh	MWh	MWh	MWh	MWh
Fuel consumption - annual		-	99	134	37	34	80
Fuel rate - unit		-	USD/kWh	USD/kWh	USD/kWh	USD/kWh	USD/kWh
Fuel rate		-	0.110	0.110	0.110	0.110	0.110
Fuel cost	**USD**	**42,250**	USD 10,889	USD 14,687	USD 4,083	USD 3,743	USD 8,847
Proposed case energy efficiency measures							
End-use energy efficiency measures	%	0%	0%	0%	0%	0%	0%
Net peak cooling load	RT	155.2	40.0	54.0	15.0	13.8	32.5
Net cooling demand	RTh	273,035	70,370	94,911	26,389	24,190	57,176

GEOTHERMAL RETROFIT DESCRIPTION AND ECONOMIC COMPARISON OF ALTERNATIVES

This section describes work required and costs associated with the retrofit scenarios of the hospital and other possible buildings described above. To reiterate, the scenarios examined are:

1. Use El Capitan well
   a. Construct pipeline to Mount Grant General Hospital only
      i. Boiler retrofit.
      ii. Boiler + chiller retrofit
   b. District heating system for county buildings (excluding schools)
      i. Hospital, Library, Courthouse, and Public Safety Buildings.
      ii. Above buildings + hospital expansions and outbuildings + fire station.
   c. District heating system for county buildings (including schools).
2. Drill new well on hospital property
   a. Geothermal heat pump system for the hospital using lower temperature groundwater (80-100^{o}F).

The economic analysis presented here is based on the Geo-Heat Center's understanding that neither the Mount Grant General Hospital itself nor Mineral County are in position to raise capital to undertake and own a large project. Therefore, the most likely sources of capital to undertake any of the above scenarios are through grants and/or third party ownership by entities such as an energy services company (ESCO) (i.e. through a performance contract or similar energy services agreement). Given the scarcity of grants for such a project at this time, ESCO ownership is the more likely scenario.

Life-cycle costs of the various scenarios were conducted using RETScreen software (NRC, 2005). The economic indicators used to evaluate economic viability were: simple payback period, net present value, and return on investment. This type of analysis is similar to that which might be conducted by an ESCO to decide whether or not to pursue a particular project. Grant-funding agencies typically rank projects based on simple payback. For the life-cycle cost analyses, the following assumptions have been made:

- Project Life: 50 years
- Energy cost inflation rate: 2%
- Discount rate: 8%
- Debt term: 10 years
- Debt interest rate: 5%
- Energy Savings Realized by Project Owner: 50 - 100%
- Contingency: 5% of capital costs

The "Energy Savings Realized by Project Owner" is a simple parameter used to analyze alternatives with an ESCO ownership structure. The range we examine in the economic analyses is 50 to 100%, where the value of 100% represents the scenario where the hospital (or county) owns the project, and is included mainly for comparison purposes. The lower this value, the less attractive to the ESCO (i.e. less income for the ESCO), but more attractive to a building owner.

Scenario 1: Use El Capitan Well

El Capitan Well and Pump: The El Capitan well and pump both appear to be serviceable. The pump was run briefly on January 29, 2001 by Dale Bugenig of Eco:Logic Engineering, and the well produced 516 gpm at 202°F (Eco:Logic Engineering, 2001). The pump was sized for golf course irrigation, and has a name plate rating of 700 gpm at 600 ft of head with a 150 hp motor. Therefore, it would be grossly oversized for heating the Mount Grant General Hospital alone, and probably oversized for a small district heating system.

In theory, the addition of a variable frequency drive could allow the pump speed to be turned down to provide the required flow rate, but both the pump and motor would be operating very inefficiently, resulting in relatively high power costs. Thus, a lower horsepower and production rate pump is proposed if geothermal heating from the El Capitan well is pursued.

In addition to pump replacement, it was recommended by Eco:Logic (2001) that two wells that were failed attempts of the drilling of the El Capitan Well be formally plugged and abandoned. Eco:Logic estimated the cost for plugging and abandonment at $36,100.

Injection Well: The rationale for siting an injection well at a location ¾ miles west of the hospital property was described previously. We estimate that the well would need an 8-inch casing with perforated zones determined at the time of drilling, a 4-inch minimum cement grout seal, requiring a 16-inch bore below the conductor. Downhole logs and integrity testing required for injection wells often result in higher cost than for a similar production well. With the expected lithology, the injection well should accept fluid by gravity flow.

Scenario 1a: Construct Pipeline to Mount Grant Hospital Only

In this scenario, we consider retrofitting the original part of the hospital only. Loads and energy costs are those pertaining to “Building Cluster 1” in Table 1. Two options are considered: (i) retrofitting the boiler to geothermal and (ii) retrofitting the boiler and chiller to geothermal.

Supply and Disposal Pipelines: The proposed layout of the geothermal supply and disposal (return) pipeline is shown in Figure 5. The pipelines are made of 4-inch fiberglass reinforced epoxy (FRP). The supply line is pre-insulated and surrounded by an 8-inch nominal diameter PVC jacket. The disposal line is un-insulated.

As shown in Figure 5, the proposed geothermal supply line follows a route from the El Capitan well to the hospital first along a dirt road east to the north side of the “dump road”, and then continues to the power line easement. The pipeline then follows the power line right-of-way to the hospital’s boiler room. The total supply pipeline length is 8,650 ft (1.64 miles). The temperature loss from the geothermal fluid from the El Capitan well to the hospital will be approximately 5°F.

The proposed geothermal disposal (return) line runs from the hospital boiler room along the south side of the hospital, underneath A Street, and directly west to the proposed injection well. The total disposal line length is ¾ miles.

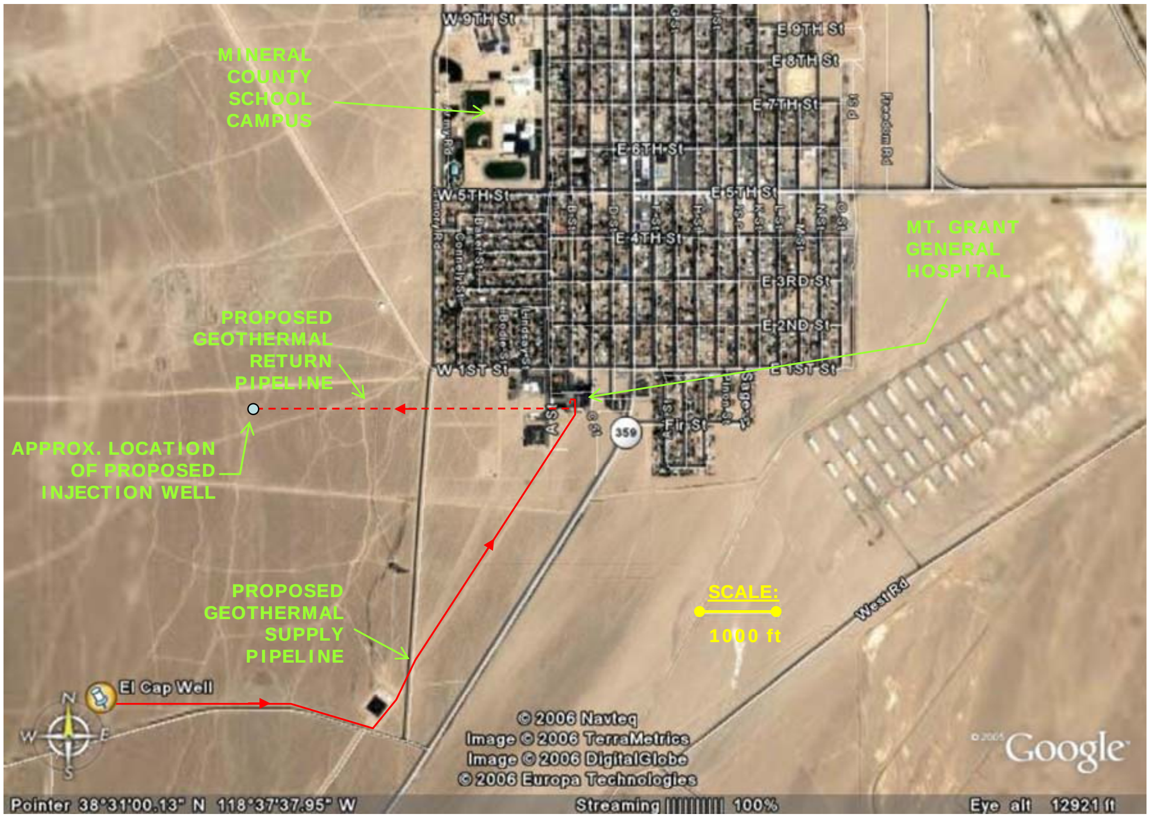

Figure 5. *Proposed layout of geothermal supply and disposal pipelines.*

An underlying assumption should be noted that was made for this preliminary proposed pipeline layout. It was assumed that the right-of-way for the supply pipeline could be obtained at little or no expense. The disposal line, however, would be another matter, as it was assumed that it would cross private property. No attempt was made to estimate acquisition details of property easements.

Geothermal Retrofit Description and Costs: A schematic for retrofit of the boiler only is shown in Figure 6. The geothermal retrofit is quite straightforward, consisting of a plate and frame heat exchanger in parallel with the tube and shell steam-to-water heat exchanger and 3-way valves to permit switching between geothermal water and steam. The plate-type heat exchanger can be located either on the main floor of the boiler room or on the mezzanine over the boiler room. The heat exchanger itself will be relatively small (26 in. long x 13 in. wide x 36 in. high) but will require about 24 in. on each side for infrequent servicing. Two new circulating pumps to circulate hot water rather than steam to the immersion heaters in the hot water tank will be required.

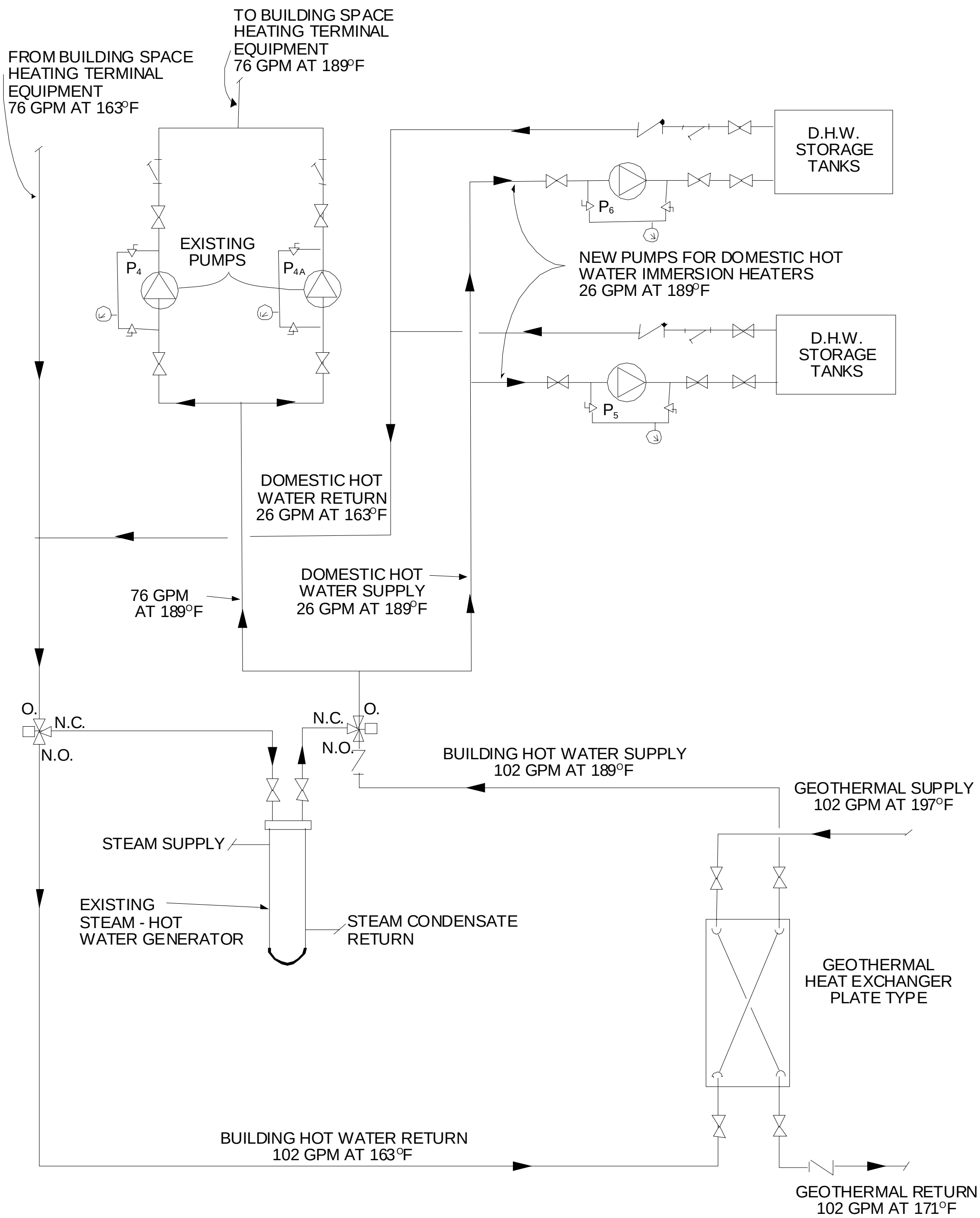

Figure 6. *Schematic of proposed retrofit of the Mount Grant General Hospital boiler system to geothermal.*

The proposed geothermal retrofit design was based on the heating load analysis by Chilton Engineering (1981) (see Appendix A), since the Geo-Heat Center's site visit revealed that not much had changed since the time of that report. Some of the water heating loads have been replaced by individual propane-fired units, and supplemental electric resistance heat has been added in the patient rooms as described above. These loads were included in the retrofit design since it was believed that they could be picked up by geothermal.

A detailed cost breakdown of Scenario 1(a) is shown in Table 2. The total estimated cost of well equipment and pump, pipeline construction, mechanical retrofit work, and associated design fees is about $1.05 million.

As seen in Table 2, the pipeline construction costs represent the most significant portion of the project costs at 69% of the total. Injection well costs are the next most significant portion at about 18% of the total, followed by the submersible pump costs at 7%. Hospital retrofit costs are relatively insignificant in the total project cost at about 2% of the total. Annual well pumping costs with the variable frequency controller are estimated at $3,000.

Retrofit of the chiller in the penthouse area of the hospital would also be straightforward. An absorption heat pump could be swapped directly for the existing chiller. Existing circulating pumps and the cooling tower could be re-used. A Yazaki-brand absorption chiller is rated at 190^{o}F entering heating source water temperature with a design flow rate of about 3.5 gpm/ton of cooling capacity. Therefore for a 20-ton unit, the design flow rate would be 70 gpm. Piping would need to be brought from the heat exchanger shown in Figure 6 to the new absorption chiller, and the building circulating pumps also shown in Figure 6 could be used as is because the peak cooling flow demand would not coincide with peak heating flow demand.

Additional costs incurred above those shown in Table 2 are estimated for the absorption heat pump installation as:

- Absorption heat pump: 20 ton capacity @ $3,000/ton installed = $60,000
- Additional engineering design fees: @ 5% of additional costs = $ 3,000
- Additional annual well pumping costs: = $ 2,000

<u>Economics of Scenario 1(a):</u> The economics of Scenario 1(a) are not attractive, with simple payback periods exceeding 25 years for the boiler retrofit only (Scenario 1a-i). These payback periods correspond to all situations between 100% and 50% of energy savings realized by the project owner. The corresponding net present values are negative, ranging from -$296,906 to -$649,648. Negative present values indicate unattractive investments.

The economics of Scenario 1(a)-ii, where geothermal energy would replace both the boiler and chiller are quite similar to the case where geothermal would replace heating only. Therefore, there is little to no benefit in considering cooling for improvement of the economics due to the cost of the absorption chiller relative to the modest savings in electrical energy consumption.

<u>Scenario 1b: District Heating System for County Buildings (Excluding Schools)</u>

In this scenario, we consider retrofitting the buildings referred to as Clusters 1 through 5 in Table 1. As defined above, these include the building clusters: **(1)** Mt. Grant General Hospital original building, **(2)** Courthouse and Public Safety, **(3)** Library, **(4)** SNF and CT hospital additions, and **(5)** Medical Center, Business Office, Fire Station, and Medical Annex.

Table 2. Detailed Cost Breakdown for Scenario 1(a).
Construct Pipeline from El Capitan Well to Mount Grant Hospital Only

	Unit	Quantity	Unit Cost	Amount	Sub Total	TOTALS	% of Total Project Cost	Comments
Sumbersible Well Pump & Surface Equipment								High temperature, deep setting pump in El Cap Well Set at 516 ft, surface pressure 14 psi @ 104 gpm
Motor (57 hp)	lump	1	$6,953	$6,953				
Pump (10 stage)	lump	1	$5,380	$5,380				
Seal	lump	1	$10,652	$10,652				
Power cable	lump	1	$3,740	$3,740				
Motor lead	lump	1	$1,282	$1,282				
Variable frequency control	lump	1	$22,808	$22,808				
Transformer	lump	1	$13,777	$13,777				
Well head	lump	1	$4,099	$4,099				
Installation	lump	1	$5,000	$5,000				FOB Huntington Beach, CA
TOTAL SUBMERSIBLE PUMP COST						$73,691	7.0%	
Geothermal Supply Pipeline								Routed along power line easement
Pipe	ft	8650	$34.03	$294,360				4-in. FRP insulated, 8-in. PVC jacket, gasketed joints
Trench & backfill	ft	8650	$1.90	$16,435				16 in. wide x 48 in. deep
Manual excavation at joints	ft	8650	$1.41	$12,197				
Pipe installation	ft	8650	$14.95	$129,318				
Pipe joint insulation	ft	8650	$6.00	$51,900				
Pipe bedding	ft	8650	$3.15	$27,248				Sand surround 6 in. minimum
Compaction over pipe	ft	8650	$0.95	$8,218				
Fittings (elbows, etc.)	lump	10	$194	$1,940				
Valves	lump	3	$1,530	$4,590				
Thrust blocks	lump	6	$800	$4,800				
TOTAL SUPPLY PIPELINE COST					$551,004			Total supply pipeline cost: $63.70/ft
Geothermal Return Pipeline								
Pipe	ft	3960	$23.12	$91,555				4-in. FRP uninsulated, gasketed joints
Trench & backfill	ft	3961	$0.95	$3,763				16 in. wide x 24 in. deep
Pipe installation	ft	3962	$13.21	$52,338				
Pipe bedding	ft	3963	$3.15	$12,483				
Compaction over pipe	ft	3964	$0.95	$3,766				
Cut, haul, repave asphalt	ft	50	$20	$1,000				
Fittings (elbows, etc.)	lump	5	$194	$970				
Valves	lump	2	$1,530	$3,060				
Thrust blocks	lump	3	$800	$2,400				
TOTAL RETURN PIPELINE COST					$171,335			Total return pipeline cost: $43.27/ft
TOTAL PIPELINE COST						$722,339	69.0%	
Injection Well								Estimated 600 ft deep
Engineering & hydrogeology	%	15%	$161,240	$24,186				Assume 15% of injection well project cost
Permit fees	lump	1	$2,500	$2,500				
TOTAL DESIGN & PERMITTING					$26,686			
Well Drilling:								
Mobilization/demobilization	lump	1	$39,000	$39,000				
Blowout preventer	lump	1	$10,000	$10,000				May not be required if boiling water not expected
Drilling, 20-in. bore	ft	100	$80	$8,000				
Conductor casing	ft	100	$65	$6,500				
Cement grout seal	ft	100	$20	$2,000				
Integrity test	lump	1	$2,000	$2,000				
Drilling, 16-in. bore	ft	500	$50	$25,000				
Geophysical log	lump	1	$5,000	$5,000				
Blank 8-in. casing	ft	32	$350	$11,200				
Perforated 8-in. casing	ft	44	$250	$11,000				
Filter pack	ft	30	$250	$7,500				
Cement grout seal	ft	350	$12	$4,200				
Integrity test	lump	1	$3,000	$3,000				
Well Development	hr	24	$300	$7,200				
TOTAL WELL INSTALLATION COST					$141,600			
Well Testing:								
Mobilization/demobilization	lump	1	$5,000	$5,000				
Test pump install & removal	ft	400	$15	$6,000				
Development	hr	24	$180	$4,320				
Well testing	hr	24	$180	$4,320				
TOTAL WELL TESTING COSTS					$19,640			
TOTAL INJECTION WELL COST						$187,926	17.9%	
Hospital Mechanical Retrofit								
Circulating pumps	lump	2	$785	$1,570				Pumps rated at 26 gpm design flow
Heat exchanger + installation	lump	1	$6,200	$6,200				
Heat exchanger isolation valves	lump	1	$4,000	$4,000				
Piping (3-in. steel)	ft	100	$38	$3,800				
Piping (1 1/2 in. steel)	ft	6	$30	$180				
Fittings	lump	1	$3,404	$3,404				
3-way pneumatic valve	lump	2	$1,025	$2,050				
Insulation	%	10%	$9,434	$943				10% of piping + valve costs
TOTAL HOSPITAL MECHANICAL						$22,147	2.1%	
Design & Engineering								
Professional engineering fees	%	5%	$818,177	$40,909		$40,909	3.9%	Assume 5% of project cost (excluding inj. well)
TOTAL GEOTHERMAL RETROFIT COST						**$1,047,012**	**100.0%**	

The purpose of considering this scenario is to investigate possible improvement in economics over the scenario of retrofitting the hospital only. Two options are considered: (i) connecting the Mount Grant General Hospital (original building), the Courthouse, Public Safety, and Library buildings to a district heating system and (ii) adding the SNF and CT hospital expansions and the Medical Center, Business Office, Fire Station, and Medical Annex into the district heating system. Based on the economics of Scenario 1, only heating is considered.

<u>Geothermal Retrofit Description and Costs:</u> Retrofit details of the Courthouse, Public Safety, and Library buildings have been examined by Chilton Engineering (1981). In order to reduce the total flow rate required, the hospital could take advantage of outdoor air heat recovery to decrease their heating load. Fan system S-1 is a 100% outdoor air system rated at 5,650 cfm, and fan system S-2 is a 70% outdoor air system rated at 5,625 cfm. At a design outdoor air temperature of 20^{o}F, a heat recovery unit at 70% effectiveness could reduce the load by about 360,000 Btu/hr. Based on the current loads on the boiler, the new geothermal load is estimated at 500,000 Btu/hr. An energy flow schematic of how these buildings might be tied together is shown in Figure 7.

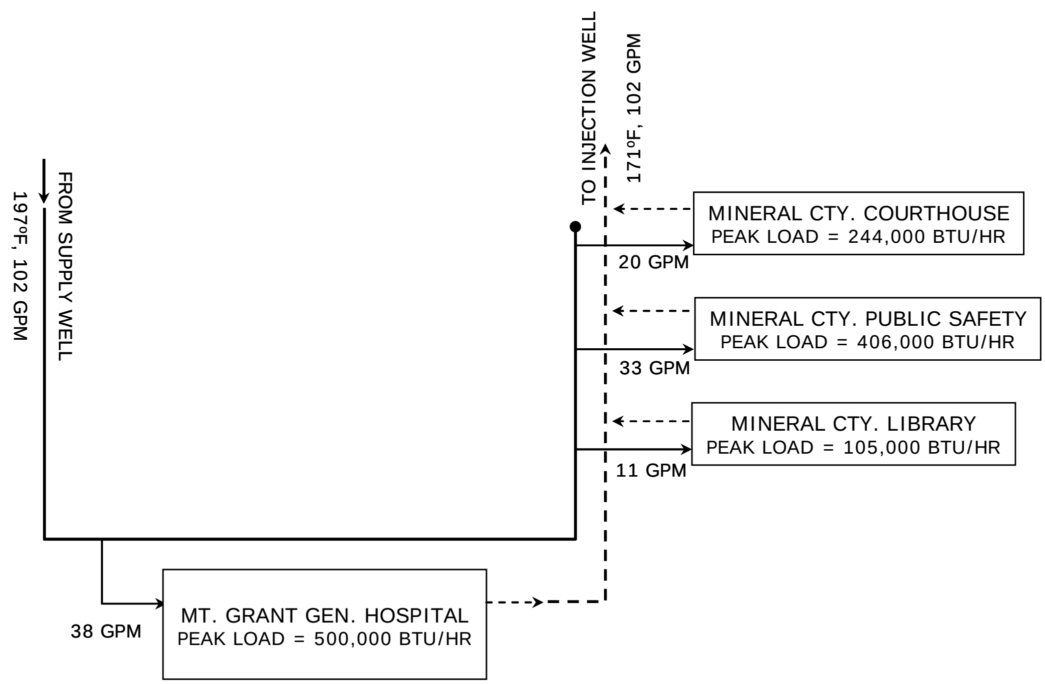

Figure 7. *Energy flow schematic for a district heating system that includes the original hospital, library, public safety building, and courthouse.*

Chilton Engineering (1981) estimated retrofit costs of the Courthouse, Public Safety, and Library buildings. These costs are used here, escalated at 2% annual inflation. Therefore, additional costs to construct the district heating system above those shown in Table 2 are:

- Retrofit costs of Library Building (excluding new expansion): $ 32,300
- Retrofit costs of Public Safety Building: $ 36,900

- Retrofit costs of Courthouse Building: $ 21,600
- Mt. Grant Hospital, heat recovery unit for fan system S-1: $ 10,000
- Mt. Grant Hospital, heat recovery unit for fan system S-2: $ 7,500
- Additional pre-insulated 4-in. geothermal supply line + asphalt repair: 600 ft @ $100/ft $ 60,000
- Additional design fees (5% of project costs): $ 8,415
- TOTAL ADDITIONAL COSTS: $176,715

Case (ii) of Scenario 1(b) involves adding the SNF and CT hospital expansions and the Medical Center, Business Office, Fire Station, and Medical Annex into the district heating system. As shown in Table 1, these buildings account for an estimated $32,000 in annual LPG usage for heat. As the rooftop units in these buildings range in age from 5 to 10 years old, they are not yet at the end of their useful life and would probably not make sense to remove and replace them. Therefore, the most logical geothermal retrofit would be to add hot water coils into ductwork inside the buildings and keep existing units for backup heat. The advantage with this design is that new units could be installed as needed to provide cooling and backup heat.

There are many possible retrofit design options for Case (ii), but to minimize heating coil size and cost, we propose here to tie these buildings into the hospital building loop and make use of 189^{o}F supply water. A schematic of how these buildings might be tied in is shown in Figure 8. With the reduction in peak load at the original hospital building with the added heat recovery units, the additional building loads under this scenario bring the total heating load back up to approximately the original design condition (1.24 million Btu/hr). However, the tradeoff with this design is that 171^{o}F water would be available to the Library, Courthouse, and Public Safety as opposed to 197^{o}F water as in Case (i). To offset this lower water temperature, a higher flow rate would likely be required to these buildings as shown in Figure 8. As concluded by Chilton Engineering (1981), the heating systems in these buildings were also grossly oversized, so it is assumed for now that these buildings could be adequately heated with slightly lower water temperatures.

Retrofit costs are difficult to estimate exactly for Case (ii), so we crudely used square-foot cost estimates for medical offices from R.S. Means (2006), which include water coils, piping, circulating pumps, and controls. Therefore, additional costs to construct the district heating system above those shown in Table 2 are:

- SNF & CT hot-water coil retrofit: 5,500 sq.ft @ $6/sq.ft $33,000
- Medical center hot-water coil retrofit: 7,500 sq.ft @ $6/sq.ft $45,000
- Business Office hot-water coil retrofit: 2,000 sq.ft @ $6/sq.ft $12,000
- Medical Annex hot-water coil retrofit: 1,500 sq.ft @ $6/sq.ft $ 9,000
- Fire Station hot-water coil retrofit: 2,000 sq.ft @ $6/sq.ft $12,000
- Pre-insulated supply and return 2-in. FRP pipe in buried trench with asphalt cut and repair: 200 ft @ $75/ft $15,000
- Pre-insulated supply and return 1-in. PEX pipe branch piping in buried trench to Fire Station: 150 ft @ $20/ft $ 3,000
- Pre-insulated supply and return 1-in. PEX pipe branch piping in buried trench to Medical Annex: 550 ft @ $20/ft $ 11,000

- Additional design fees (5% of project costs): $ 7,000
- TOTAL ADDITIONAL COSTS: $147,000

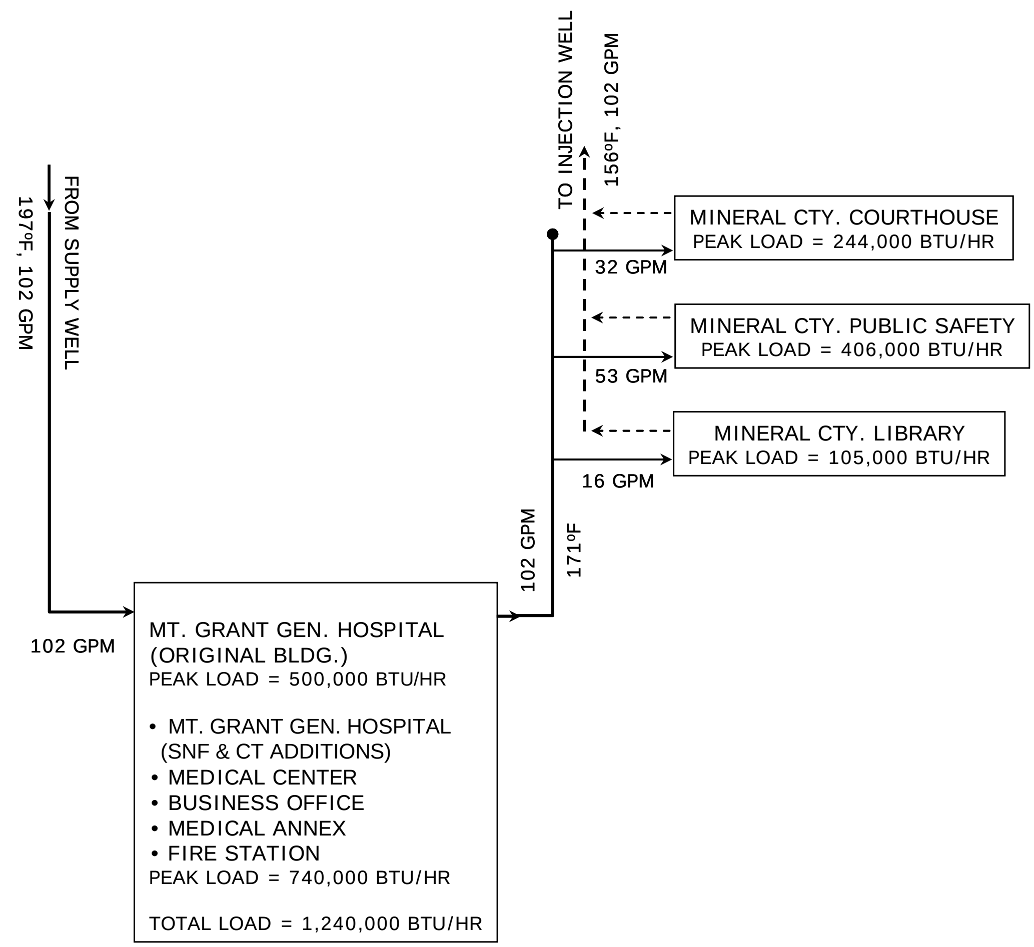

Figure 8. *Energy flow schematic for a district heating system that includes the original hospital, library, public safety building, and courthouse along with SNF and CT hospital additions, hospital business office outbuilding, medical center, medical annex, and fire station.*

Economics of Scenario 1(b): The economics of Scenario 1(b) are more attractive than Scenario 1(a), but likely not attractive enough for an ESCO. For Case (i), the simple payback period is 21 years and about 29 years for 100% and 75% of energy savings realized, respectively. However, both these situations have negative present values.

For Case (ii), the simple payback period is about 16 and 21 years for 100% and 75% of energy savings realized, respectively. The case of 100% of energy savings realized has a positive present value of $218,038, but the case of 75% of energy savings realized (i.e. 25% realized by the building owner) has a negative present value. Therefore, Case (ii) would not be attractive to an ESCO.

Scenario 1c: District Heating System for County Buildings (Including Schools)

In this scenario, we consider retrofitting all buildings referred to as Clusters 1 through 6 in Table 1. The purpose of including the Mineral County Schools is to improve the economics of a district heating system. The Geo-Heat Center did not examine retrofit possibilities in detail at the school buildings, as this was beyond the original scope of work. However, for this study, we consider it in a general sense in order to determine if further examination is warranted.

Geothermal Retrofit Description and Costs: If the Mineral County Schools were to be included in a district heating system, approximately an additional $100,000 annual savings in LPG usage may be possible. One retrofit possibility would be to cascade the used water from Scenario 1(b)-ii down to the schools. As seen in Figure 8, 102 gpm geothermal water at 156°F would be available, which would be sufficient to meet the estimated school heating demand of 2.3 million Btu/hr (Table 1) at 50°F temperature drop. The injection well in this scenario would be re-located due north of the position shown in Figure 5, and west of the Mineral County School Campus.

Retrofitting the school buildings to geothermal would require about another 7,000 ft of 4-in. insulated FRP supply pipeline, 2,000 ft of un-insulated FRP return pipeline, and branch supply and return piping to each building. Assuming that retrofit costs for the buildings to hot water would be similar to the retrofit costs in Scenario 1(b)-ii, the additional costs are estimated as follows:

- Geothermal supply pipeline and branches: $ 500,000
- Geothermal return pipeline and branches: $ 100,000
- Building retrofits to hot water: $ 900,000
- Additional design fees (5% of project costs): $ 75,000
- TOTAL ADDITIONAL COSTS: $1,575,000

Economics of Scenario 1(c): The economics of Scenario 1(c) are more attractive than the previous scenarios, but marginally attractive for an ESCO. The simple payback period ranges from 11 to about 23 years for 100% and 50% of energy savings realized by the project owner, respectively. The case of 100% of energy savings realized has a positive present value of $1.2 million. The case of 75% of energy savings realized (i.e. 25% savings to a building owner) has a positive present value of $435,799, but a payback period of about 15 years. Although 25% savings in cost of energy is probably attractive to the county as a building owner, a 15 year payback is marginal for an ESCO.

Scenario 2: Drill New Wells on Hospital Property

As previously mentioned, groundwater temperatures underlying the hospital are likely on the order of 80 to 100°F. Based on nearby well logs, the water table exists at a depth of about 350 to 400 ft below grade. These conditions would be suitable for a geothermal heat pump system.

Scenario 2a: Geothermal Heat Pump System for Mount Grant Hospital Using Lower Temperature Groundwater

In this Scenario, we consider an open-loop (groundwater) geothermal heat pump system for the original hospital building. More specifically, we consider displacing the heating system only, since the expected groundwater temperature would result in little or no savings over a conventional chiller with cooling tower.

A conceptual diagram of an open-loop heat pump system is shown in Figure 9. As in previous design scenarios, the system consists of two "loops" separated by a stainless steel plate heat exchanger, which isolates groundwater from the heat pump equipment. The use of an isolation heat exchanger also allows for energy-efficient control of the well pump. The building loop temperature is allowed to "float" above a heating setpoint, which when reached, the well pump is activated and moderates the building loop temperature. With this type of control, the required groundwater flow rate is a function of its temperature.

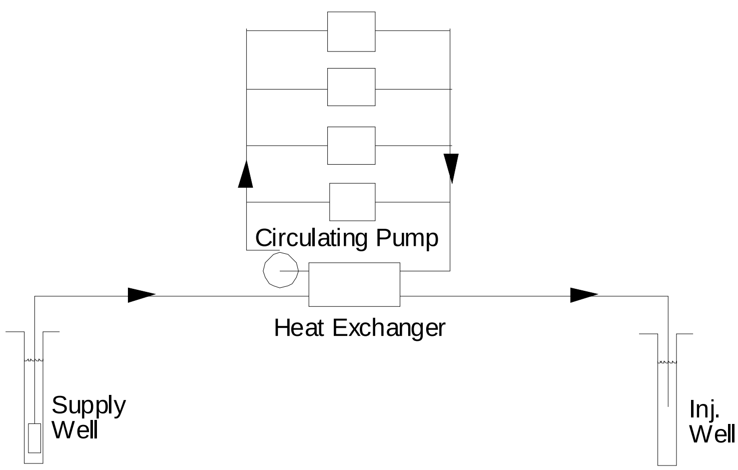

***Figure 9**. Conceptual diagram of an open-loop geothermal heat pump system.*

Supply and Injection Wells: A supply well for an open-loop geothermal heat pump system is no different in construction from a domestic use well. The well can be constructed with a PVC casing and stainless steel screen with slot sizes properly designed to keep fines out of the well. The supply well would be located in an up-gradient groundwater flow direction, which would be south of the hospital building.

Groundwater will be supplied to the hospital via a submersible stainless steel pump with variable speed motor. Based on an installed heat pump capacity of 40 tons and a groundwater temperature of 80^{o}F, approximately 42 gpm flow rate would be required. Estimated well depths are on the order of 500 ft.

Kazemann and Whitehead (1980) used a simple approach to determine the required spacing between supply and injection wells in order to minimize thermal communication between wells.

The approach uses the dominant flow rate (heating in this case) averaged over the heating season. Assuming an aquifer thickness of 100 ft and a 9-month possible heating season, the required well spacing is approximately 115 ft.

Geothermal Retrofit Description and Costs: A schematic of the proposed retrofit for Scenario 2(a) is shown in Figure 10. In summary, existing water coils in the fan systems are proposed to be kept in place, with hot water being provided by water-to-water geothermal heat pumps.

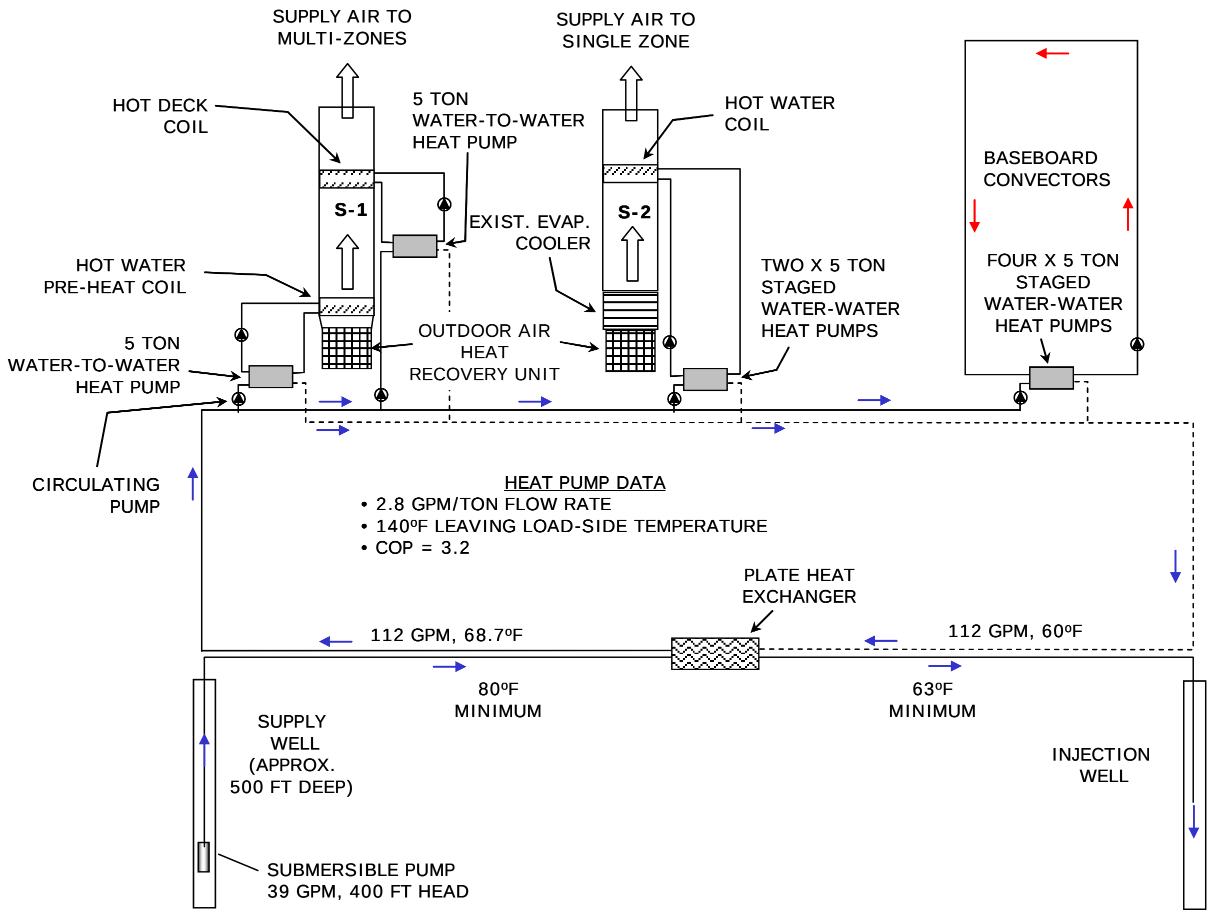

Figure 10. *Schematic of proposed retrofit of the Mount Grant General Hospital boiler system to a geothermal heat pump system.*

The use of water-source heat pumps requires some other design modifications to the heating system, since the maximum output water temperature for the design proposed here is 140°F. These lower design temperatures entering the hot water coils necessitate the use of outdoor air heat recovery units to reduce required heat pump capacity, thereby considerably reducing first cost and operating costs. The same design for the heat recovery units is used here as for Scenarios 1(b) and 1(c). This allows the outdoor air coil on fan system S-1 to be used as a pre-heat coil, downstream of the heat recovery unit and upstream of the hot deck coil. Fan system S-2 would not require two coils with 30% return air to the fan and the addition of the heat recovery unit. The baseboard convectors in the patient rooms will continue to operate as is (i.e. with supplemental electric resistance heating elements in the unitary air conditioners).

Note that the retrofit design schematic (Figure 10) shows staged 5-ton heat pumps. This is for three main reasons. First, economies of scale of larger capacity water-to-water heat pumps do not exist beyond 5-ton units because larger units are not common in today's applications. Thus, water-to-water heat pumps above 5-ton capacities are built to order and are usually more expensive per ton. Second, smaller heat pumps allow staging, where some units can be turned off when not needed during part load conditions. Third, there would be difficulties and restrictions in installing larger capacity heat pumps due to size and weight limitations. Five-ton units are about 2 ft high x 2 ft wide x 3 ft high and weigh about 360 lbs, which we estimate would be about the maximum size and weight manageable. Hot water generator options are also available on these units, so hot water currently generated by the boiler could be shifted to the heat pumps.

A cost breakdown of Scenario 2(a) is shown in Table 3. The total estimated cost of the supply and injection wells, equipment, mechanical retrofit work, and associated design fees is $213,550. The majority of the project costs (approximately 72%) are attributed to mechanical retrofit. The capital costs of this scenario are one-fifth that of Scenario 1(a).

Table 3. Cost Breakdown for Scenario 2(a).
Geothermal Heat Pump System for Mount Grant Hospital (Original Building)

	Unit	Quantity	Unit Cost	Amount	TOTALS	% of Total Project Cost	Comments
Supply and Injection Wells and Related Costs							
Drilling and well installation	ft	1000	$35	$35,000			
Water sampling, flow testing	lump	1	$5,000	$5,000			
Submersible pump w. VFD	kW	7	$2,000	$14,000			
Underground horizontal transfer piping	ft	200	$25	$5,000			Un-insulated PVC; incl. minor asphalt repairs
TOTAL WELL-RELATED COSTS					$59,000	**27.6%**	
Hospital Mechanical Retrofit							
Heat pumps	ton	40	$1,500	$60,000			Eight 5-ton water-to-water heat pumps
Circulating pumps (heat pump load side)	kW	0.5	$2,500	$1,250			Heat pump load side, 8 circulators
Main circulating pump + VFD	kW	2.0	$1,500	$3,000			Main building circulating pump
Controls (heat pumps & circ. pumps)	lump	1	$40,000	$15,000			
Plate heat exchanger	kW	140	$20	$2,800			
Piping, plumbing, insulation, fittings	lump	1	$5,000	$5,000			
Heat recovery units on S-1 & S-2 fans	lump	1	$17,500	$17,500			
Labor & installation	lump	1	$50,000	$50,000			
TOTAL HOSPITAL MECHANICAL					$154,550	**72.4%**	
Design & Engineering							
Professional engineering fees	%	5%	$213,550	$10,678			Assume 5% of total project cost
TOTAL GEOTHERMAL RETROFIT COST					$213,550		

<u>Economics of Scenario 2(a):</u> The economics of Scenario 2(a) are the most attractive yet, with the lowest capital cost and lowest simple payback period of 8.8 years for the case of 100% energy savings realized by the project owner. The fact that this scenario has a lower net present value that Scenario 1(c) suggests that it would not be the most attractive to an ESCO, but the relatively low capital cost is encouraging since the hospital may be able to own the project outright. This estimated capital cost to retrofit the hospital to geothermal heat pumps is about half the cost quoted to the hospital for boiler upgrade.

Summary of Economic Alternatives

This section summarizes the results of the economic analysis. Although described briefly above, a more detailed discussion is given below regarding simple payback, net present value, and return on investment.

The simple payback period (in years) represents the length of time that it takes for a proposed project to recoup its own initial cost out of the income or savings it generates. The basic premise of the simple payback method is that the more quickly the cost of an investment can be recovered, the more desirable is the investment. From the point of view of an ESCO, the simple payback method is not a good measure of how profitable one project is compared to another. Rather, it is a measure of time in the sense that it indicates how many years are required to recover the investment for one project compared to another. The simple payback should not be used as the primary indicator to evaluate a project. It is useful, however, as a secondary indicator to indicate the level of risk of an investment. A further shortcoming of the simple payback method is that it does not consider the time value of money, nor the impact of inflation on the costs. On the other hand, the payback period is often of great importance to organizations that are "cash poor". When a firm is cash poor, a project with a short payback period, but a low rate of return, might be preferred over another project with a high rate of return, but a long payback period in order to improve cash flows.

The Net Present Value (NPV) of a project is the value of all future cash flows, discounted at the discount rate, in today's currency. NPV is thus calculated at a time 0 corresponding to the junction of the end of year 0 and the beginning of year 1. Under the NPV method, the present value of all cash inflows is compared against the present value of all cash outflows associated with an investment project. The difference between the present value of these cash flows, called the NPV, determines whether or not the project is generally a financially acceptable investment. Positive NPV values are an indicator of a potentially feasible project. In using the net present value method, it is necessary to choose a rate for discounting cash flows to present value, typically 6% to 11%. A discount rate of 8% was chosen for this study. The rate generally viewed as being most appropriate is an organization's weighted average cost of capital. An organization's cost of capital is not simply the interest rate that it must pay for long-term debt. Rather, cost of capital is a broad concept involving a blending of the costs of all sources of investment funds, both debt and equity.

The return on investment (ROI) represents the true interest yield provided by the project equity over its life before income tax. It is calculated using the pre-tax yearly cash flows and the project life. It is also referred to as the return on equity (ROE) or internal rate of return (IRR). It is calculated by finding the discount rate that causes the net present value of the equity to be equal to zero. Hence, it is not necessary to establish the discount rate of an organization to use this indicator. An organization interested in a project can compare the internal rate of return to its required rate of return (often, the cost of capital). The most obvious advantage of using the internal rate of return indicator to evaluate a project is that the outcome does not depend on a discount rate that is specific to a given organization. Instead, the ROI obtained is specific to the project and applies to all investors in the project.

A summary of the economic analysis is given in Table 4, and return on investment for all cases is plotted on a bar graph in Figure 11. A review of the data presented in Table 4 and Figure 11 shows that some scenarios are economically viable, depending on the ownership structure.

From an ESCO's perspective, cases of "100% of energy savings realized by the project owner" are obviously not possible, since the ESCO is not the building owner. However, for cases of "75% of energy savings realized by the project owner" (i.e. 25% energy savings to the building owner), two Scenarios appear to be marginally attractive and may warrant further investigation: Scenario 1(c) (a district heating system with all county buildings plus the Mineral County Schools) and Scenario 2(a) (geothermal heat pumps serving as a boiler replacement in the original hospital building). Under these scenarios, all economic indicators are marginally attractive. Simple payback periods are just under 15 years, NPVs are positive, and returns on investment are around 10%.

The economic analysis conducted for this study demonstrates the challenge in constructing a district heating system without grants or incentives. Each successive scenario considered above results in additional mechanical retrofit and pipeline construction cost that compete with energy savings. Should more customers be considered beyond Scenario 1(c), a larger capacity pump and pipeline would be needed, which would further compete with savings. Therefore, it appears that a new application with a large heating load would need to exist near the hospital or closer to the El Capitan well for a potentially viable project. In other words, the further the customer is from the well, the larger the heating load needs to be to offset pipeline construction costs. To illustrate this point, consider Scenario 1(b) - Case ii. Under ESCO ownership and 25% energy savings to customers, the simple payback period is 21.2 years for the ESCO investment. This case represents a floor space of about 70,000 ft^2. To bring the payback period down to 10 years would require connecting more than double this amount of floor space (i.e. about 150,000 ft^2 or nearly 10 times the floor space of the original hospital) at zero additional mechanical and geothermal pipeline construction costs. When additional construction costs are added in, the required floor space for a 10-year payback on investment would obviously need to increase.

From the perspective of Mount Grant General Hospital or Mineral County as the project owner, none of the El Capitan well uses appear to be viable, simply due to the large capital cost (i.e. at least $1.1 million). However, Scenario 2(a) (geothermal heat pumps for boiler replacement at the original hospital) is encouraging. The case of the hospital owning this project outright has the greatest return on investment (35.7%) of all the cases examined, as well as the lowest payback period (8.8 years). The estimated capital cost for this case of about $225,000 is approximately half of a quote for boiler upgrade already received by the hospital.

Table 4. Economic Analysis Results

	Scenario	Capital Cost (with 5% Contingency)	Annual Energy Savings	Simple Payback Period (years)			Net Present Value			Return on Investment		
				100% of Energy Savings Realized by Project owner	**75%** of Energy Savings Realized by Project owner	**50%** of Energy Savings Realized by Project owner	**100%** of Energy Savings Realized by Project owner	**75%** of Energy Savings Realized by Project owner	**50%** of Energy Savings Realized by Project owner	**100%** of Energy Savings Realized by Project owner	**75%** of Energy Savings Realized by Project owner	**50%** of Energy Savings Realized by Project owner
1(a)-i	Construct pipeline to Mt. Grant Hospital only - boiler retrofit	$1,098,195	$41,026	26.8	>30	>30	($296,906)	($473,277)	($649,648)	4.8%	2.9%	0.6%
1(a)-ii	Construct pipeline to Mt. Grant Hospital only - boiler + chiller retrofit	$1,164,345	$44,470	26.2	>30	>30	($299,254)	($497,436)	($695,619)	5.0%	3.0%	0.8%
1(b)-i	District heating system for county buildings - Original Hospital, Library, Courthouse, and Public Safety Building	$1,283,746	$60,878	21.1	28.6	>30	($140,030)	($395,930)	($651,831)	6.7%	4.3%	1.8%
1(b)-ii	District heating system for county buildings - Hospital, Library, Courthouse, Public Safety Building, Hospital SNF and CT expansions, Business Office outbuilding, Medical Center, Medical Annex, and Fire Station	$1,438,096	$91,593	15.7	21.2	>30	$218,038	($164,917)	($547,872)	10.0%	6.6%	3.5%
1(c)	District heating system for county buildings - All buildings included in Scenario 1b-ii + Mineral County Schools	$2,068,096	$187,462	11.0	14.8	22.7	$1,206,822	$435,799	($335,223)	17.7%	10.8%	6.1%
2(a)	Geothermal heat pump system for boiler replacement in original hospital only	$224,228	$25,606	8.8	15.4	>30	$215,486	$39,115	($137,256)	35.7%	10.3%	0.3%

NOTE: Values in brackets are negative.

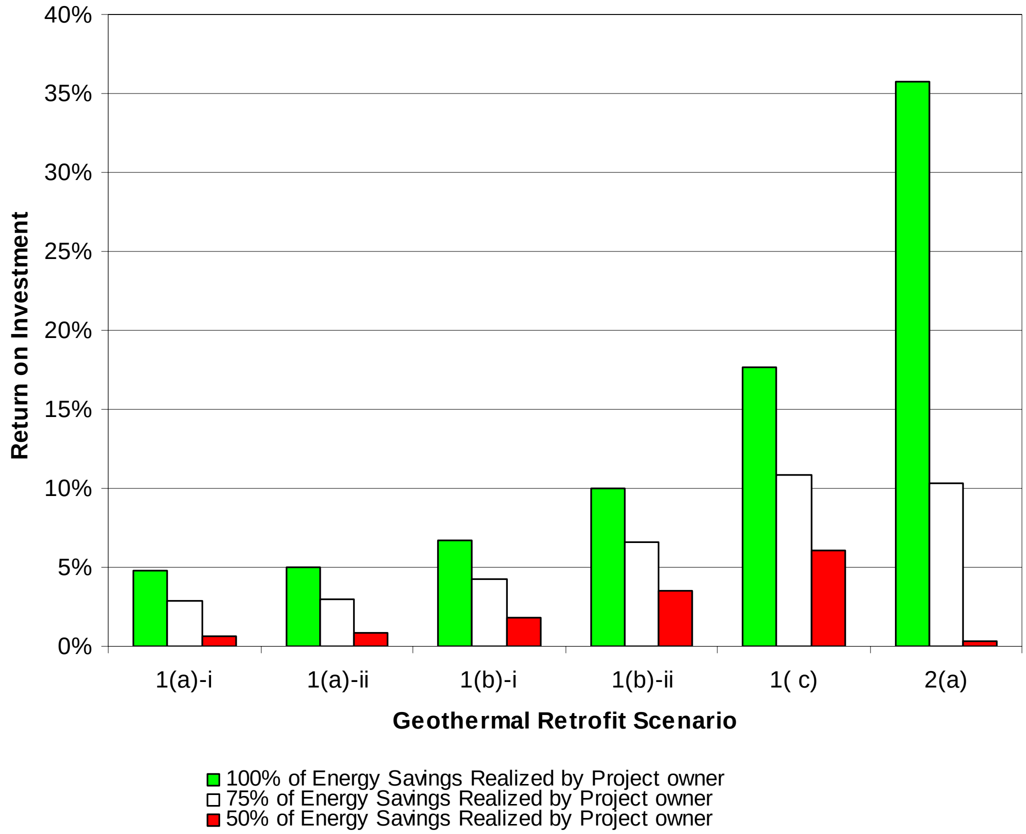

Figure 11. *Return on investment for all geothermal retrofit cases examined.*

CONCLUDING SUMMARY AND RECOMMENDATIONS

The Geo-Heat Center has conducted a feasibility study of replacing the aged heating plant at Mount Grant General Hospital with a geothermal system. The heating, ventilating, and air conditioning (HVAC) system at the Mount Grant General Hospital is a mixture of central and unitary systems and equipment. The original hospital building was constructed in 1963 and is approximately 16,000 ft^2 in plan area. Two additions have been constructed since then: a skilled nursing facility in 1994 at the west end of the original hospital (approximately 4,000 ft^2), and a CT wing in 1997 at the northeast corner (approximately 1,500 ft^2). The original part of the hospital is the only portion heated by hot water. The central (or primary) heating plant consists of two low pressure steam boilers rated at 80 hp input (2.75 million Btu/hr), with one boiler serving as a backup to the other.

Two basic geothermal resource utilization scenarios were identified: (1) use the existing El Capitan well or (2) drill a new well on the hospital property. Within these scenarios, several possibilities emerged to develop the geothermal resource. In Scenario 1, if the El Capitan well were to be used, the economics of a pipeline construction would be more attractive if more customers could share costs and benefits. In Scenario 2, drilling a new well on the hospital property would likely result in encountering lower temperature groundwater at 80-100^{o}F, so retrofit with geothermal heat pumps were considered. Therefore, we examined 6 possible geothermal utilization scenarios as follows:

1. Use El Capitan well
    a. Construct pipeline to Mount Grant General Hospital only
        i. Boiler retrofit
        ii. Boiler + chiller retrofit.
    b. District heating system for county buildings (excluding schools)
        i. Hospital, Library, Courthouse, and Public Safety Buildings.
        ii. Above buildings + hospital expansions and outbuildings + fire station.
    c. District heating system for county buildings (including schools).
2. Drill new well on hospital property
    a. Geothermal heat pump system for the original hospital using lower temperature groundwater (80-100^{o}F).

To compare alternatives, three economic indicators were computed: simple payback period, net present value, and return on investment. Also, for each case we considered ownership by Mount Grant General Hospital (or Mineral County) or by an energy services company (ESCO) offering a 25% and a 50% energy savings to potential customers.

Some specific conclusions of this study are as follows:

- Including absorption cooling in the geothermal retrofit projects does not improve economics significantly.
- From the perspective of an ESCO, Scenario 1(c) and Scenario 2(a) are marginally attractive at 25% (and less) energy savings to customers. Under these scenarios, simple payback periods are about 15 years, NPVs are positive, and returns on investment are about 10%. The economics for an ESCO would improve if less energy savings were

offered to customers, but obviously that would be less attractive to building owners. A more detailed examination of retrofit costs of the Mineral County Schools in Scenario 1(c) would be needed to further investigate Scenario 1(c).

- The economic analysis conducted for this study demonstrates the challenge in making a district heating system viable without grants or incentives, which are currently in limited supply.
- Each successive scenario of using the El Capitan well in a geothermal district heating application that was considered in this study resulted in additional mechanical retrofit and geothermal pipeline construction cost that compete with energy savings. Should more customers be considered beyond Scenario 1(c), a larger capacity pump and pipeline would be needed, which would further compete with savings.
- It would appear from this study that in order for the hospital to connect to an economically viable district geothermal heating system, a new application(s) equivalent to a heating load of about 150,000 ft^2 floor space (or nearly 10 times the floor space of the original hospital), would need to exist near the hospital or closer to the El Capitan well. This is due to the fact that the further the load is from the geothermal source, the more the pipeline construction costs (as well as mechanical retrofit costs) compete with energy savings realized by the project owner.
- From the perspective of Mount Grant General Hospital or Mineral County, none of the El Capitan well uses appear to be viable, simply due the large capital cost (i.e. at least $1.1 million) and relatively long payback periods.
- Scenario 2(a) (geothermal heat pumps for boiler replacement at the original hospital) appears encouraging from an economic standpoint of the hospital as the project owner. The case of the hospital owning this project outright has the greatest return on investment (35.7%) of all the cases examined, as well as the lowest payback period (8.8 years). The estimated capital cost for this case of about $225,000 is approximately half of a quote for boiler upgrade already received by the hospital.
- The Geo-Heat Center recommends the following course of action for the Mount Grant General Hospital:
    - Refurbish or upgrade existing controls, especially on fan dampers
    - It is G. Culver's opinion that the boilers can be successfully de-scaled for future use. This would be required anyway, even with a geothermal retrofit, so that the boilers could be used as a back-up heating system.
    - Consider use of heat recovery units on fan systems S-1 and S-2 to reduce energy consumption in both heating and cooling.
    - Consider pursuing Scenario 2(a) by first drilling a 500-ft deep test well on the hospital property, south of the building, for use in an open-loop geothermal heat pump system. This will give more insight into the geothermal retrofit design, and will help in refining the economics. It is possible that future grants from the U.S. Department of Energy may be available for this type of activity.

REFERENCES

Chilton Engineering, 1981. *Municipality of Hawthorne, Nevada Geothermal District Heating System. Conceptual Design and Economic Feasibility Study Report: Building Site Mechanical Equipment Retrofits*. Prepared for the Geo-Heat Center, Oregon Institute of Technology under United States Department of Energy Contract.

Eco:Logic Engineering, LLC, Inc., 2001. *El Capitan Geothermal Well Evaluation*. Prepared for Mineral County, Nevada, Parks and Recreation Department.

GeothermEx, Inc., 2004. *New Geothermal Site Identification and Qualification Report and PIER Geothermal Database*. Prepared for California Energy Commission, Public Interest Energy Research (PIER) Program.

Kazemann, R.G. and Whitehead, W.R., 1980. The Spacing of Heat Pump Supply and Discharge Wells, *Groundwater Heat Pump Journal*, Vol. 1, No. 2, Water Well Journal Publishing Co., Columbus, OH.

NAWS, 2002. An Evaluation of the Geothermal Resource Potential at HAWD, Hawthorne, NV. Geothermal Program Office, Naval Air Weapons Station (NAWS) China Lake, California, Power Point Presentation, March 6, 2002.

NRC, 2005. *RETScreen International, Clean Energy Project Analysis Software, Combined Heat and Power Project Model*. Natural Resources Canada (NRC), 2005.

R.S. Means, 2006. *Square-Foot Construction Cost Data*.

Spink Corporation, 1981. *Geothermal Feasibility Study for Mineral County School System, Hawthorne, Nevada*. Prepared for the Geo-Heat Center, Oregon Institute of Technology under United States Department of Energy Contract.

APPENDIX A

EXCERPTS FROM CHILTON ENGINEERING REPORT (1981)

CEC CHILTON ENGINEERING

MARK CHILTON, P.E., R.L.S.
MICHAEL W. LATTIN, P.E., R.L.S.
WILLIAM F. MUELLER, R.L.S.
WILLIAM A. NISBET, R.L.S.
IRA S. RACKLEY, P.E.

December 19, 1980

Gene Culver,
Associate Director,
Geo-Heat Utilization Center
Oregon Institute of Technology
Klamath Falls, Oregon 97601

Re: Adjusted Heat Extration Rates and Fluid Flow Rates for Hawthorne, Nevada Geothermal District Heating System

Dear Gene,

During the course of the meeting (dated 12-17-80) attended by representatives of your organization, the Nevada Department of Energy, Chilton Engineering, and others regarding the Hawthorne, Nevada Geothermal District Heating System, you discussed with Shelly Gordon various aspects of our conceptual geothermal retrofit design. You had a specific concern regarding our use of existing equipment performance specifications to size building and geothermal retrofit equipment. You feel, and we agree, that existing equipment typically is oversized, sometimes significantly, and use of these equipment as a design criteria will therefore lead to oversized geothermal retrofit systems. In reponse to this concern I have generated more accurate building peak thermal loads utilizing actual building fuel oil consumption.

The procedure I used to generate the new figures is the modified degree day energy estimating calculation (reference ASHRAE 1980 Systems Handbook, Chapter 43). The basic equation is:

$$E \doteq \frac{(H_L)(D.D.)(24)}{(\Delta T)(\eta)(V_H)}$$

where:

E	=	fuel consumption per year (Gal/Yr)
H_L	=	design peak thermal load (BTUH)
D.D.	=	number of base 65°F degree days per year. Hawthorne 6000 DD/Yr.
24	=	unit is Hr/Day, converts out degree days
ΔT	=	design temperature difference = 70°F
η	=	heating system efficiency. For oil fired equipment at 5000 ft. elevation this approximates 0.60.
V_H	=	heating value of fuel. For fuel oil this averages 144,000 BTU/Gal.
C_D	=	correction factor for heating effect v.s. degree days. For 6000 DD/Yr the mean C_D = 0.62.

1570 LINDA WAY SPARKS, NEVADA 89431 AREA 702-331-2777

Gene Culver
Page 2
December 19, 1980

This formula is typically used as a simple means of estimating annual energy consumption when the design peak thermal load is known. It is most accurate for residential buildings with the margin of error increasing with the complexity of building type. Since the Hawthorne Buildings (with the exception of the hospital) are relatively simple municipal/commercial type buildings, this method was deemed acceptably accurate. Because annual fuel consumption is already know and the design peak thermal load is the objective. this equation was reconfigured to:

$$H_L = \frac{(E)(\Delta T)(n)(V_H)}{(24)(D.D.)(C_D)}$$

The results of this effort are summarized in Table 1 along with the original figures for comparison. Heat extraction rates are the estimated peak thermal loads and include hot water generation where applicable. The new peak thermal loads have been reduced from 30 to 74 percent with a system average of 57 percent. The 74 percent reduction occurs in the Public Safety Building and is the result mainly of an inadvertent error in the original hot water requirement sizing which caused an excessive hot water thermal load. The new geothermal and building side flow rates which meet the adjusted thermal loads are also included. Again, the flow rates have been reduced on the average by over 50 percent. The worksheets detailing the calculation procedure for each building have been included for your review as Attachments 1 - 3.

It should be emphasized at this point that these figures were generated using a simplified degree day calculation. Any simplified equation, especially involving degree days can introduce wide margins of error, as many factors affecting total building energy consumption do not enter into the calculation process. Further, even some components of the calculation are subject to margins of error. For example, the correction factor C_D varys widely depending on degree day amounts and location. For 6000 degree days per year, plus or minus one standard deviation for C_D ranges from 0.40 to 0.84. Determining very accurate building peak thermal load reflecting the many important factors which influence building energy consumption (such as electrical internal gains, buildin operation and maintenance, and equipment conditions and efficiencies) can only be achieved through detail building energy use analysis which is beyond the present scope of work. It is recommended that this detailed analysis be performed during the initial stages of detailed design process. It is, however, Chilton Engineering's opinion the new figures which follow are adequately representative of the buildings peak thermal loading and thus will serve well as design criteria.

If you have any questions concerning these new figures or the calculation procedure utilized, please do not hesitate to contact me.

Sincerely,

William B. Klingsporn

William Klingsporn

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Oregon Institute of Technology

Attachment 2

Mt. Grant Hospital:

Design Load Capacity:

Heating = 1.673×10^6 BTUH
Hot Water = 1.180×10^6 BTUH

Total = 2.853×10^6 BTUH

Square Footage = 16,000 S.F.

Building Thermal Charac. (HTG. ONLY) = 104.6 BTUH/S.F. = 35.9 BTU/D.D.S.F.

Hot Water Capacity = 708 Gal/Hr @ 150°F
545 Gal/Hr @ 180°F
1,253 Gal/Hr.

Maximum possible demand = 1200 GPH = 1.15×10^6 BTUH
Probable maximum demand = 300 GPH = 0.29×10^6 BTUH

Heating (Proportioned to max capacity)

$$\frac{(12040\ \frac{GAL}{YR})(70°F)(.60\ )(144{,}000\ \frac{BTU}{GAL})}{(24\ \frac{HR}{DAY}\ )(6000\ \frac{D.D.}{YR})(0.62\ C_D)} = 0.82 \times 10^6 \text{ BTUH}$$

Actual Adj. Thermal Char. = 51.3 BTUH/S.F. = 17.6 BTU/D.D.S.F.

The adjusted building heating thermal characteristic and probable hot water demand are most likely correct. However, because heating and hot water requirements for hospitals are critical, a 25% safety correction factor should be used to cover heavy loading situations.

Building thermal characteristic adjustment

17.6 BTU/D.D.S.F. + 25% = 22 BTU/D.D.S.F.

Adj. Peak Heating Load = 1.03×10^6 BTUH

Hot Water Demand Adjustment

0.29×10^6 BTUH + 25% = 0.36×10^6 BTUH

Mt. Grant Hospital (cont'd)

Adj. Building Peak Load = 1.39×10^6 BTUH

Adj. Building/Geo Flow Rate @ 1.39×10^6 BTUH

Note: Calculated flow rates increased 10% to handle decrease equipment performance due to lower supply temperatures (190°F EWT v.s. 210°F EWT)

Geo Side	=	100 GPM
Building Side	=	102 GPM
Heating	=	76 GPM
Hot Water	=	26 GPM