Thesis Report

Zachary Heilman
Mechanical Option
The Mirenda Center for Sports Spirituality and Character Development
April 7th 2011
Dr. Jim Freihaut | Dustin Eplee

ARCHITECTURE:
INSIDE THE MIRENDA CENTER FOR SPORT, SPIRITUALITY AND CHARACTER DEVELOPMENT STANDS FIVE ILLUMINATED PILLARS THAT LINE THE ATRIUM — EACH WITH ITS OWN THEME (PLAY, RESPECT, REFLECTION, BALANCE AND BEAUTY) AND WRAPPED IN QUOTATIONS FROM SCRIPTURE, SAINTS AND BOTH MODERN-DAY AND LEGENDARY SPORTS FIGURES.

ZACHARY HEILMAN | MECHANICAL OPTION | WWW.ENGR.PSU.EDU/AE/THESIS/PORTFOLIOS/2011/ZJH106/INDEX.HTML

BUILDING:
THE MIRENDA CENTER FOR SPORTS, SPIRITUALITY, AND CHARACTER DEVELOPMENT

LOCATION:
ONE NEUMANN DRIVE
ASTON, PA 19014-4707

CONSTRUCTION:
2,400 C.Y. OF CONCRETE
80 TONS OF REBAR
9,891 S.F. OF GLASS
14,500 S.F. OF WOOD FLOORING
7,000 S.F. SYNTHETIC TRACK

STRUCTURAL:
THE MIRENDA CENTERS STRUCTURAL SYSTEM IS DIVIDED INTO A CENTRAL ARENA AND A PERIPHERAL SUBSYSTEM. THE CENTRAL ARENA STANDS 43'-10¼" FROM COURT LEVEL. THE ARENA'S SPAN IS SUPPORTED BY 9 (9'-2" DEEP) TRUSSES THAT SPAN 138'8" AND ARE SPACED 20'O.C. THE STRUCTURE IS A STEEL SKELETON WITH SHEAR CONNECTIONS AND A BRACED FRAME. THE PERIPHERAL SYSTEM IS BROKEN INTO A 20' BAY O.C. THAT SPAN 38' (W18X35). THE WHOLE BUILDING IS WRAPPED IN A MASONRY CURTAIN WALL. THE FOUNDATION AROUND THE PERIMETER SUPPORTS BOTH THE STEEL STRUCTURE AND THE 16" CMU WITH STEEL REINFORCING THROUGHOUT.

ELECTRICAL:
THE ELECTRICAL SYSTEM CONSISTS OF A SINGLE OUTDOOR PAD MOUNTED 1500 KVA TRANSFORMER THAT STEPS DOWN MEDIUM VOLTAGE FROM THE UTILITY TO 480/277V. THE CALDWELL GROUND LOOP IS THE GROUNDING METHOD USED UNDER THE TRANSFORMER. INSIDE THE BUILDING IS TWO DISTRIBUTION PANELS. THE MDP FEEDS TWO LIGHTING PANELS DIRECTLY AT 277V, AND 3 TRANSFORMERS STEPPED DOWN FOR RECEPTACLE PANELS AT 208/120V. THE MDP FEEDS THE PPMA WHICH FEEDS THE SIX ROOF TOP UNITS OF THE MECHANICAL SYSTEM AT 480/277V.

MECHANICAL:
THE MECHANICAL SYSTEM CONSISTS OF SIX ROOF TOP AIR HANDLING UNITS WHOSE MAX COOLING LOADS SUM TO 4651.91 MBH AND MAX HEATING LOADS SUM TO 3031.4 MBH. EACH AHU HAS A HEAT RECOVERY WHEEL, ECONOMIZER, FILTERS, DX COIL, GAS FIRED HEATER, AND NECESSARY SENSORY EQUIPMENT FOR OPTIMAL DIRECT DIGITAL CONTROL (DDC). FAN POWERED BOXES PROVIDE INDIVIDUAL ZONE CONTROL AND ELECTRIC BASEBOARD HEAT KEEP CONDENSATION OFF THE STOREFRONT GLAZING. SOLID STATE DDC CONTROLS WITH SCHEDULING FOR EFFICIENCY PERFORMANCE AND SAVINGS.

Contents

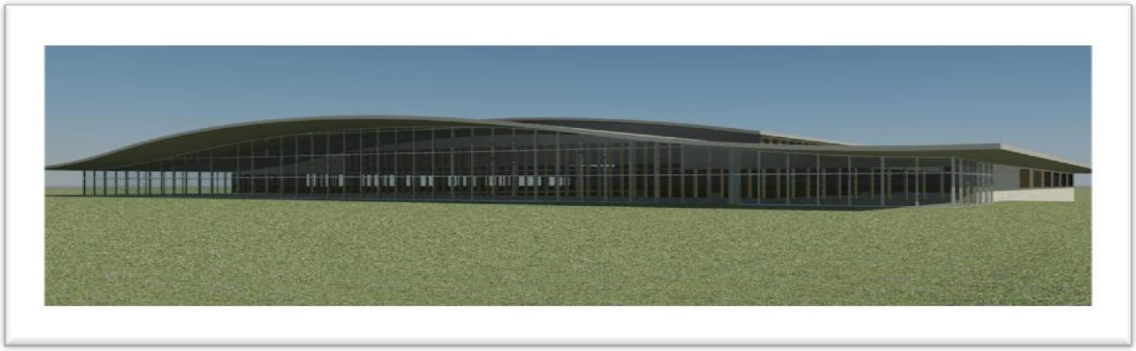


Figure 1 - Front Façade of Energy Model

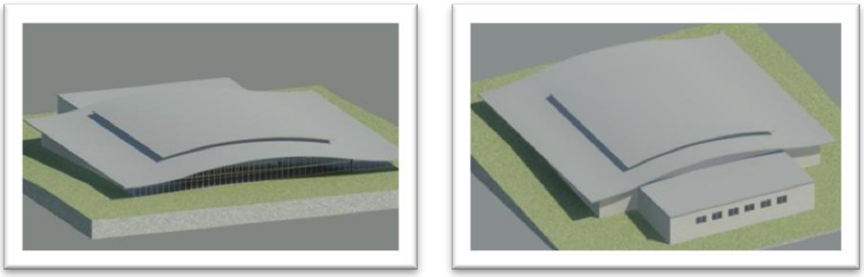
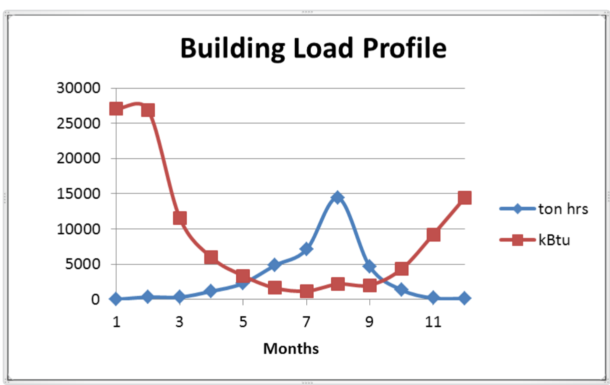


Figure 2 - Aerial Views of Energy Model

Executive Summary

The general purpose of this report is to present the energy savings of a Ground Coupled Heat Pump compared to the Conventional Direct Expansion Cooling System. The objectives of this report are: (1) to assess the GCHP vertical well system that will be capable of rejecting 200 tons of the cooling seasons heating loads. The total load on the system approaches 500 tons, thus the system will be coupled with a cooling tower to reject the remainder of the total system load. The Mirenda Centers located near Philadelphia, Pennsylvania. (2)Also, a structural and lighting design for a mezzanine level in the entry space that will recapture energy that is lost due to **40 foot** high ceilings in the space. The Mirenda Center for Sports Spirituality and Character Development has been constructed since 2010. The redesign includes the combination of **10 zones** of **7 wells in a reverse return configuration** for addition and extraction of heat.

Integrated Master's Criteria: A Life Cycle Cost Analysis was performed for this project, comparing the two different systems. This location of this material can be reference from the table of contents of this document. The cost difference between a conventional RTU Air Source Cooling System and a Ground Coupled Heat Pump is **$635,788**. The annual cost savings associated with operating the GCHP vs. Air to Air system is **$40,013**. Over a life time of with escalating costs of electricity and interest discount rate of 2.7% the 50 year life time discounted savings is **$1,197,413** and will pay the cost difference back in less than **20 years**.



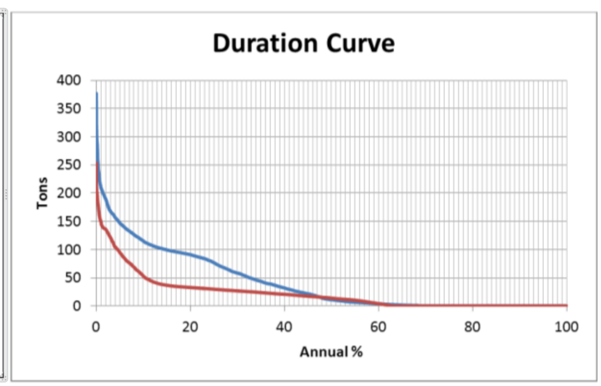


Figure 3 - Existing Energy Consumption (Left) Duration of Building Load (Right)

	Tons	Mbh
RTU 1	70	648
RTU 2	68	650
RTU 3	28	218.7
RTU 4	28	218.7
RTU 5	92	648
RTU 6	92	648
Total	379	3031.4

Table 1 - Existing Packaged Roof Top Capacity

Credits Acknowledgements

Jim Freihaut

Dustin Eplee

Steven Treado

Robert Holland

Kevin Parfitt

Jelena Srebric

Lynda Hannagan

William Bahnfleth

Moses Ling

Thank you for all of your support, and encouragement through the last (4) years. I will use the skills you have given me to design, retrofit, and recommend the best possible solutions for all engineering situations that I may be involved.

Thank you again,

Zachary Heilman

Introduction, Background, and/or Project History

Project Location:

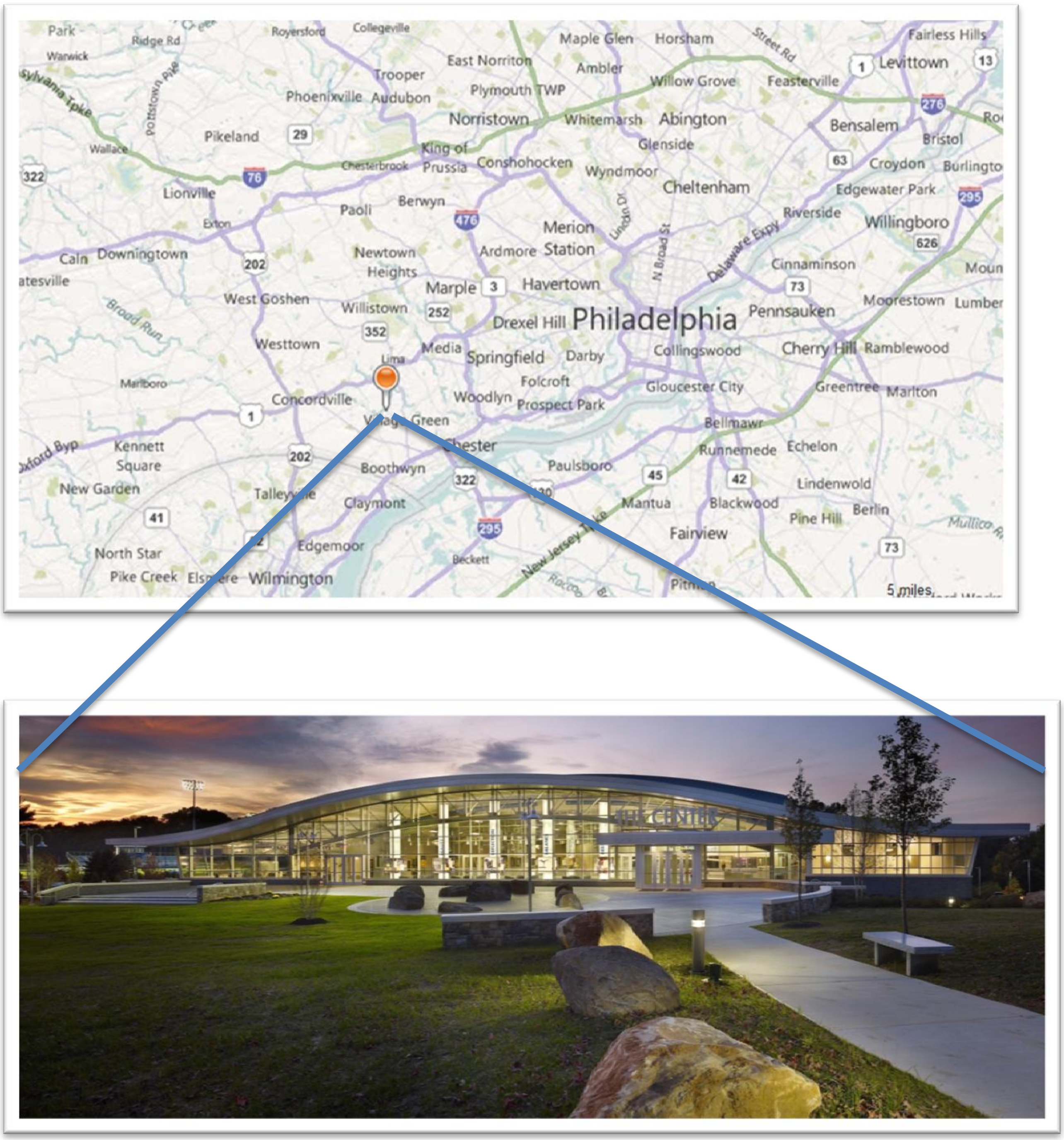
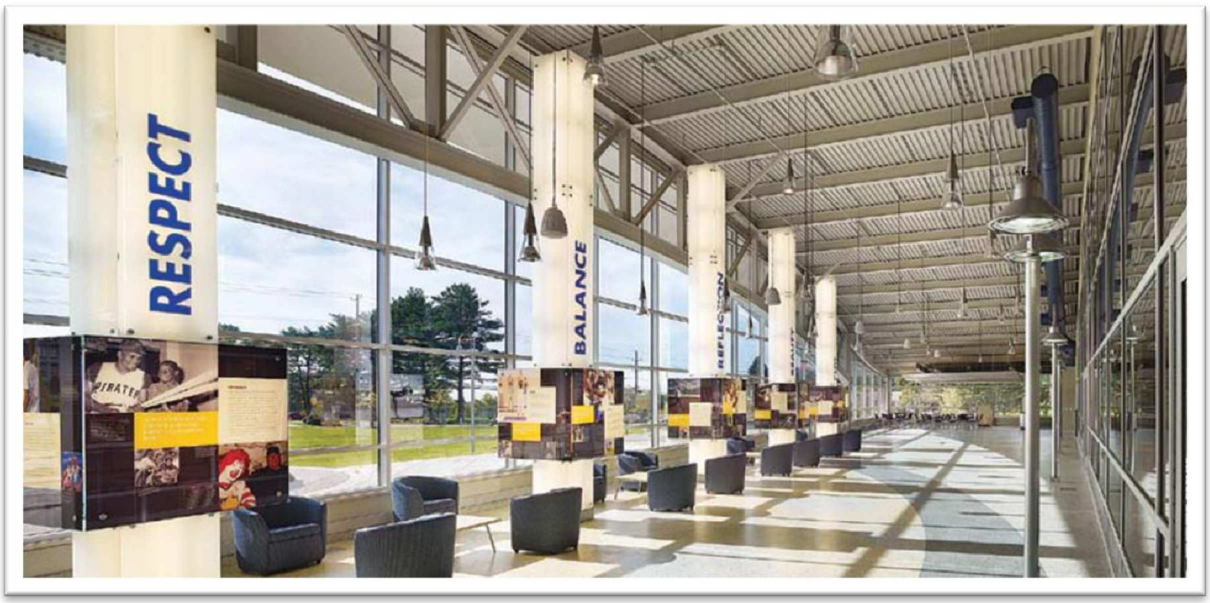


Figure 4 - CSSCD Located in Aston, PA

"The Mirenda Center for Sports Spirituality and Character Development is sports facility on Neumann University Campus. Designed to be more than an athletic center, the building uses exhibits and storytelling to provide a new perspective on sports, one that goes beyond the obvious element of competition to address the myriad ways in which students learn life lessons and develop character through athletics. Inside the main lobby that stretches across the entire façade of the Center, visitors will find five illuminated pillars, each of which is home to an exhibit that focuses on examining sports in conjunction with a specific theme. The topics of play, beauty, respect, reflection and balance guide the content of the exhibits, which explore the connection between sports and spiritual growth. Content ranges from the humorous to the heartwarming.



One exhibit tells the touching tale of Sara Tucholsky of Western Oregon University. After she hit her first career home run in a game against Central Washington, she collapsed with a knee injury at first base. In a generous act of sportsmanship, two players from Central Washington's team carried the injured Tucholsky around the bases so she could complete her home run. Images of, quotes by or stories about Kareem Abdul-Jabbar, John Cappelletti, Roberto Clemente, Babe Didrikson, Lou Gehrig, Mike Krzyzewski, Willie Mays, Wilma Rudolph, Jim Valvano and other well-known sports figures are included in the exhibits. Deeper inside the Center, around the running track that circles the main gymnasium, interactive audio exhibits will be installed this year.

The recordings will offer inspirational sports stories and even allow visitors to record their own sports-related experiences that led to a spiritual insight or epiphany. The 72,000-square-foot facility seats 1,400 in the gymnasium and includes team training areas, a fitness center, a dance studio, locker rooms, student lounges, and a media production room. Some offices are also located in the Center, which is fully equipped with wireless computer access. A community hall – suitable for lectures, concerts, dinners and liturgies – is located at the rear of the building. It can accommodate crowds as large as 500. A hospitality suite, a classroom and a café complete the public areas in the Center.

In addition, the University is pursuing Silver LEED accreditation (Leadership in Energy and Environmental Design) for the building, which has many environmentally friendly features: rooftop-mounted HVAC units, air ventilation based on CO2 sensors, large building overhangs, low-flow plumbing fixtures, high-efficiency lighting systems, and many more. The Center is also home to the Institute for Sport, Spirituality and Character Development. Founded in 1999, the four-member Institute promotes the inherent value of sport as a means of moral and spiritual growth through research, presentations, workshops and teaching. The director of the Institute and one of the principal sources of the exhibit content is Ed Hastings, Ph.D. Hastings played basketball at Villanova University and was a starter on the 1971 team that lost the NCAA national championship game to UCLA."

(www.neumann.edu/alumni/acc_winter2010/coverstory.pdf)

Site and General

Architecture:

The Mirenda Center for Sports, Spirituality, and Character Development (CSSCD) is a two story building. The ground floor entrance is at the second level in the front of the building, while the lower level is underground at the front of the building while the sloping topography brings the lower level to exit at ground level in the rear of the building The core of the building is the main gymnasium that seats up to 700 spectators at the lower level. Wrapped around the main gym at the second level is an indoor running track. The outer most perimeter as follows: Offices on the east side, Auxiliary gym on the north side, multipurpose and fitness center on the west side, and open glazed atrium on the south side.

Figure 5 - CSSCD on Neumann University Campus

The Building Façades:

The front façade consists of a 1'- 4" brick veneer block wall (knee wall) with two inch air space on a six inch metal studded drywall system with necessary vapor barriers in place. Above the knee wall is a glazed aluminum curtain wall system. The exterior walls are typical *metal panel wall construction* consists of the following from the inside out: 5/8" G.W.B., 6" MTL Stud Framing, 5/8" Dens Glas Sheathing, Vapor barrier (non-breathable) z-girt/z-clip, 2"rigid insulation, & MTL Panel. The typical exterior *veneer wall construction* consists of the following from the inside out: Solid surface interior sill, 8" CMU, Damp roofing over exterior face of CMU prior to installation of rigid insulation, 2" rigid insulation, 2" cavity, cast stone window sill, 3" split face CMU. The Roofing material is a Carlisle SynTec THERMOPLASTIC POLYOLEFIN ROOFING MEMBRANE. (a.k.a. TPO). This roof falls in the "Built-Up-Roof" category. A roof section consists of the following: steel roof framing, 3" mtl decking, pressure treaded wood blocking, 6" rigid insulation tapered 1" to drain, & tpo adhered membrane roofing.

Structural:

The Mirenda Centers structural system is divided into a central arena and a peripheral subsystem. The central arena stands 43’-10¼” from court level. The arena’s span is supported by 9 (9’-2” deep) trusses that span 138’8” and are spaced 20’o.c. The structure is a steel skeleton with shear connections and a braced frame. The peripheral system is broken into a 20’ bay o.c. that span 38’ (W18X35). The whole building is wrapped in a masonry curtain wall. The foundation around the perimeter supports both the steel structure and the 16” CMU with steel reinforcing throughout.

Electrical:

The electrical system consists of a single outdoor pad mounted 1500 KVA transformer that steps down medium voltage from the utility to 480/277V. The Caldwell ground loop is the grounding method used under the transformer. Inside the building is two distribution panels. The MDP feeds two lighting panels directly at 277V, and 3 transformers stepped down for receptacle panels at 208/120V. The MDP feeds the PPMA which feeds the six roof top units of the mechanical system at 480/277V.

Mechanical:

The mechanical system consists of six roof top air handling units whose max cooling capacity sum to 4651.91 mbh and max heating capacity sum to 3031.4 mbh. Each air handling unit has a heat recovery wheel, economizer, filters, dx coil, gas fired heater, and necessary sensory equipment for optimal direct digital control (DDC). Fan powered boxes provide individual zone control and electric baseboard heat keep condensation off the storefront glazing. Solid state DDC controls with scheduling for efficiency performance and savings.

Figure 6 - Exterior Wall Construction Types

Existing Mechanical System

The existing mechanical System is a Direct Expansion system. The Cooling mode for direct expansion system operates off the principles of refrigeration. The Evaporator, Compressor, Condenser, and Expansion valve cycle. This cycle at best is rate for a Coefficient of Performance of 2.8. Coefficient of Performance is essential the efficiency scale of how well a piece of refrigeration equipment can perform. There are (6) roof top units located on the Auxiliary Gymnasium of The Mirenda Center. The Heating Mode is via Natural Gas piped to each unit. At best heating with natural gas is 85% efficient.

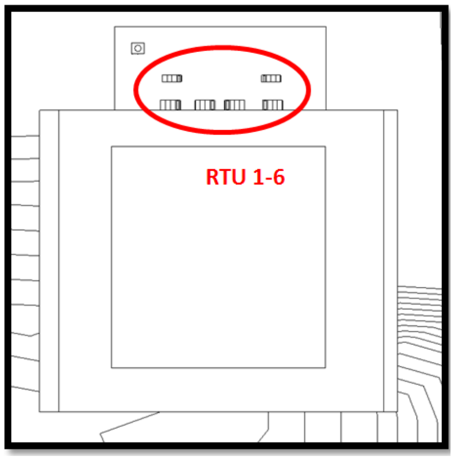
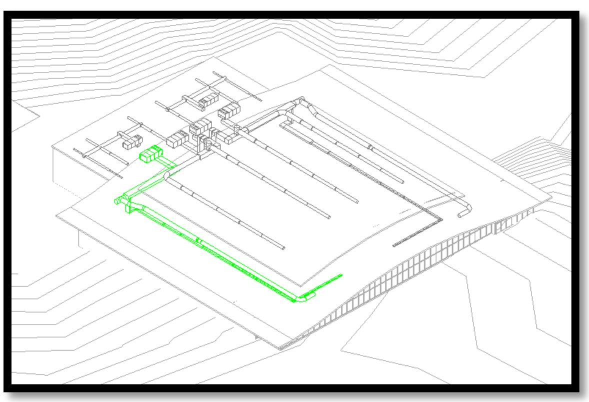


Figure 7 - Existing Packaged Roof Units located on Auxiliary Gym



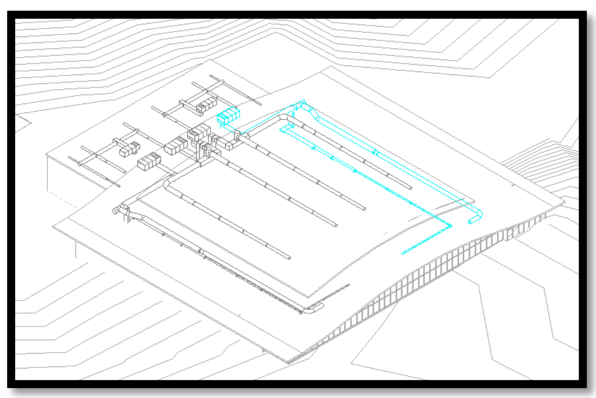


Figure 8 - RTU 1 serves West Perimeter (Left) RTU 2 serves East Perimeter (Right)

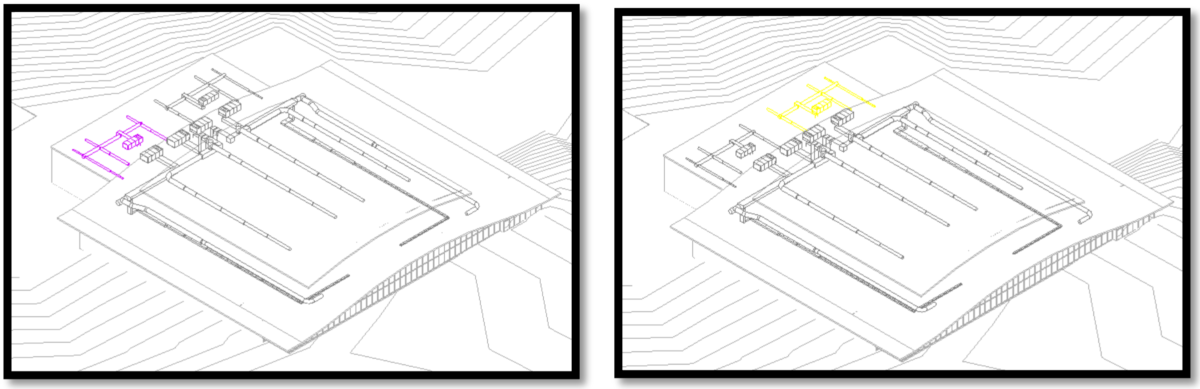


Figure 9 - RTU 3 (Left) and RTU (4) Serve the Auxiliary Gym

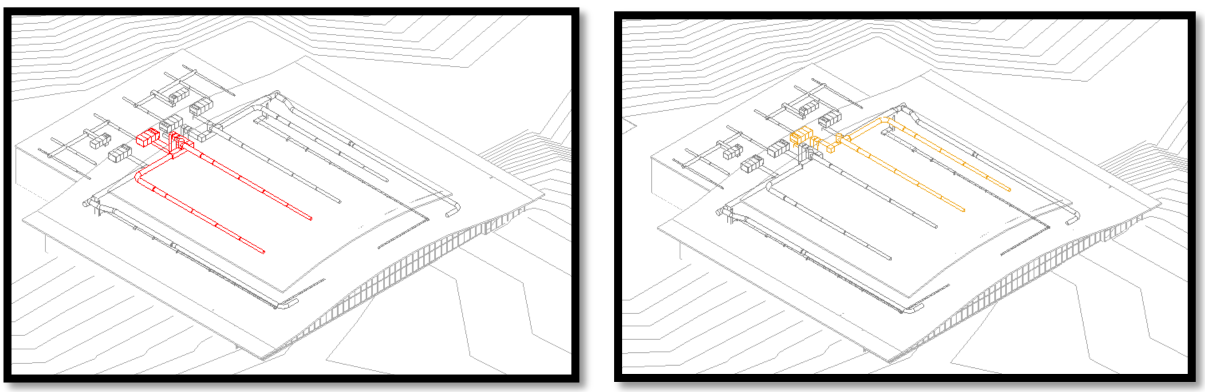


Figure 10 - RTU 5 (Left) and RTU 6 (Right) serve the Main Gymnasium and Running Track

The Existing Roof Top Units are shown above. The green system is RTU 1 which supplies the fitness center, auditorium, and supports spaces. The blue system is RTU 2 which supplies the office spaces and locker rooms. The purple and yellow systems are RTUs 3 & 4, which supplies the auxiliary gymnasium. The red and orange system is RTUs 5 & 6 which supplies the main gymnasium and running track.

Occupancy Data

The occupants of The Mirenda Center are comprised of the following. The office has 178 occupants, the fitness center and auditorium has 100 occupants combined, the welcoming center/atrium/entry has 205 occupants, the remainder of the perimeter spaces has 230 occupants, the auxiliary gym has 98 occupants, and the main gymnasium has 97 for the non-basketball seasons schedule, and 700 occupants for the basketball seasons schedule. The occupancy is at its maximum for all rooms, thus this is most likely an overestimate of the people load for the building. Rarely will all rooms be filled with people at once. This is key in determining the GCHP capacity size.

Occupancy
Building substantial completion September 2009
Building Occupied October 2009

Figure 11 - Building Occupied October 2009

Indoor and Outdoor Air Conditions

Indoor conditions were determined by the designer with the acceptable range of the ASHRAE 55 Thermal Comfort. The values set for winter heating 72 °F and the summer cooling are 74 °F.

Outdoor conditions as referenced in the Design Load Estimation of this section are from the ASHRAE Handbook of Fundamentals for 2008. The locality is Philadelphia, Pennsylvania. The outdoor drybulb temperatures minimum and maximum temperatures are 12 °F dB for the heating season and 93 °F dB/76 °F wB for the cooling season.

Conductance		
Roof	0.047	Btu/ (hr ft^2 °F)
Wall	0.121	Btu/ (hr ft^2 °F)
Overall	0.078	Btu/ (hr ft^2 °F)

Figure 12 - Building Overall Heat Transfer Coefficient Table

Load Sources and Schedules

The exterior loads are the façade exposure to the variation of temperature for the year and variation of solar exposure. The interior loads are people, equipment, lights, and miscellaneous plugs loads. Each of these loads has a schedule associated with them, and the most difficult to quantity with a consistent schedule is not doubt people. There are 4 systems air systems RTUs – 1&2 essentially are for the perimeter loads, RTU-3&4 are paralleled and work together to meet the auxiliary gym's load, while RTU 5&6 are paralleled to meet the main gym's load.

The schedule for RTU – 1&2 is a more common School schedule 7am to 5pm with a dip in the middle for lunch during weekdays. RTU-3&4 is the auxiliary gym where is must be utilized during school hours for recreational class but then also for after school activities such as practices. The most difficult schedule is the main gymnasium with RTUs 5&6.

Overall Building Operation Schedule:

The overall building schedule presents the time the building will be in operation. The overall building schedule does not define when the maximum building heat loads are active.

Building Schedule		
Weekdays	7:00 AM	12:00 AM
Weekends	10:00 AM	11:00 AM
Summer	8:30 AM	10:00 AM

Figure 13 - Building Schedule of Use Table

Design Objectives and Requirements

The program of The Mirenda Center is quite voluminous. The key features of the building that stands out in the foreground of the architecture are the 700 seat main gymnasium and the Indoor running track. The Mirenda Center is for Sports Spirituality and Character Development. The Sports consist of the main gymnasium, the auxiliary gymnasium, the running track, and the fitness center with weight and cardio equipment. These features are the attractive features of the building that attract student activity. The Spirituality consists of Offices for the Institute for Sport, Spirituality and Character Development. The Character Development is integrated with Spirituality and built upon by providing a multipurpose room, a student lounge, dance studio, and a general classroom. All of this must be administrated, thus there is a President's hospitality suite, a catering kitchen, and so much more that brings The Mirenda Center together.

Energy Sources and Rates

The energy sources for The Mirenda Center are electricity and natural gas. Natural Gas is consumed primarily for heating in the Roof Top Air Conditioning Units. The rate structure is fixed $25.00 per month, and varies from $3.78 per Mcf for the first 200 Mcf to $2.64 per Mcf for all additional consumption. All but the heating load for the air system is fueled by electricity. These loads are primarily cooling, including the fans and compressors, and lighting both interior and exterior. The electric rate structure consists as follows: for peak demand $6.65 per kW, for off-peak demand $3.25 per kW, for peak consumption $0.07 per kWh, and $0.06 per kWh. The ratchet clause does apply. There for monthly maximum consumption of energy will have a huge effect on the yearly dollar amount. This point goes to show that even though in the winter less electric energy is used, The Mirenda Center will be charged for 10 months of it maximum consumption during the Month of July and/or August. The ratchet clause is detrimental to The Mirenda Center and could be offset by onsite electric generation.

Comparison of Energy Model to Design Data

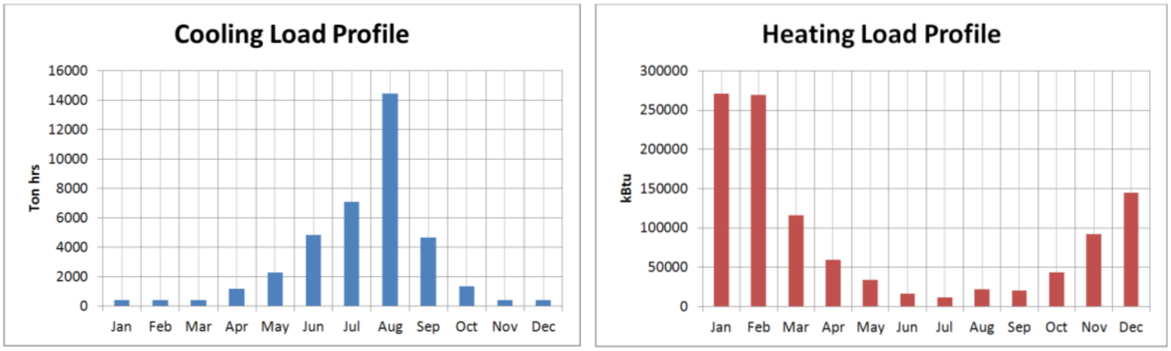


Figure 14 - Cooling (Left) & Heating (Right) Energy Consumption

Students Energy Model				Cooling	Heating
	sqft/ton	*cfm/ton*	*cfm/sqft*	*cfm*	*cfm*
Main Gym	105	182	1.74	27848	27848
Aux Gym	213	175	0.82	7204	7204
Perimeter	327	262	0.8	26980	26980
Designed Documents					
	sqft/ton	*cfm/ton*	*cfm/sqft*	*cfm*	*cfm*
Main Gym	110	275	2.51	17300	12700
Aux Gym	154	282	1.83	7300	7200
Perimeter	221	211	0.95	24200	20100

Figure 2 - Ventilation Compared to Existing Table

The Student Energy Model has redundant cfm values for the cooling and heating. This could partially be because of the outdoor air requirement of 100% in both seasons. The reason they are both so high is because of the maximum occupancy.

Design Ventilation Requirements

ASHRAE Standard 62.1 was used to determine whether the design met the required amount of outdoor air. This procedure is known as the "Ventilation Rate Procedure". Outdoor Ventilation rates were taken from the mechanical drawings of the construction documents. RTU 1 is 8800 cfm, RTU 2 is 8500 cfm, RTU 3&4 combined are 7200 cfm, and RTU 5&6 are 242000 cfm.

The existing mechanical system is Air to refrigerant to Air Heat Rejection system for Cooling with a Natural Gas Furnace for Heating. This is more commonly referred to as Directed Expansion cooling and or Air Source Heat Pump. There is (6) roof top DX air handling units that maintain (5) areas/ zones of The Mirenda Center. The total capacity of the existing cooling piece of the mechanical system is 388 tons. The break-down is 78, 68, 28, 28, 92, and 92 tons for RTU's (1-6) respectively. The cost for the existing DX Air to Air RTU's is $1233.00 per ton which results in $503,956.92 for the whole existing roof top units. Each unit costs approximately $4000 to install, totaling to $24,000. Cost of existing units plus labor costs are $502,113. The annual electric cost to run the Air Source system is $82,735. This includes all the charges from the Peco electric: consumption, demand, and ratchet clause.

Ventilation Performance Requirements					
	Actual	Minimum Req.	Percent	Design Supply	ASHRAE 62.1
	OA (CFM)	OA (CFM)	Exceeded	SA (CFM)	Compliance
RTU_1	8800	3812	43%	22000	yes
RTU_2	8500	5054	59%	17000	yes
RTU_3	3600	1123	31%	8000	yes
RTU_4	3600	1249	35%	8000	yes
RTU_5	12100	4750	39%	20100	yes
RTU_6	12100	4193	35%	20100	yes

Figure 15 – Ventilation Compliance with ASHRAE Standard 62.1

Existing Energy Mechanical Costs

The annual cooling operation costs for the existing Roof Top Units are $82,735. The annual heating costs are $13,731. The total combined cost of operating the cooling and heating plant is $96,466. The combined cost is what will be improved upon in the Depth of study. There are three factors that the electric company uses when charging a commercial building; this does not include onetime fees such as transition charges or taxes. The three factors are consumption, demand, and ratchet. See Energy Sources and Rates section of this report for a better understand of how the electric manufacture defines the previously mentioned terms. These values were calculated based on part load analysis for given that the equipment cop is rated at 2.8. A sample calculation can be found in the appendix.

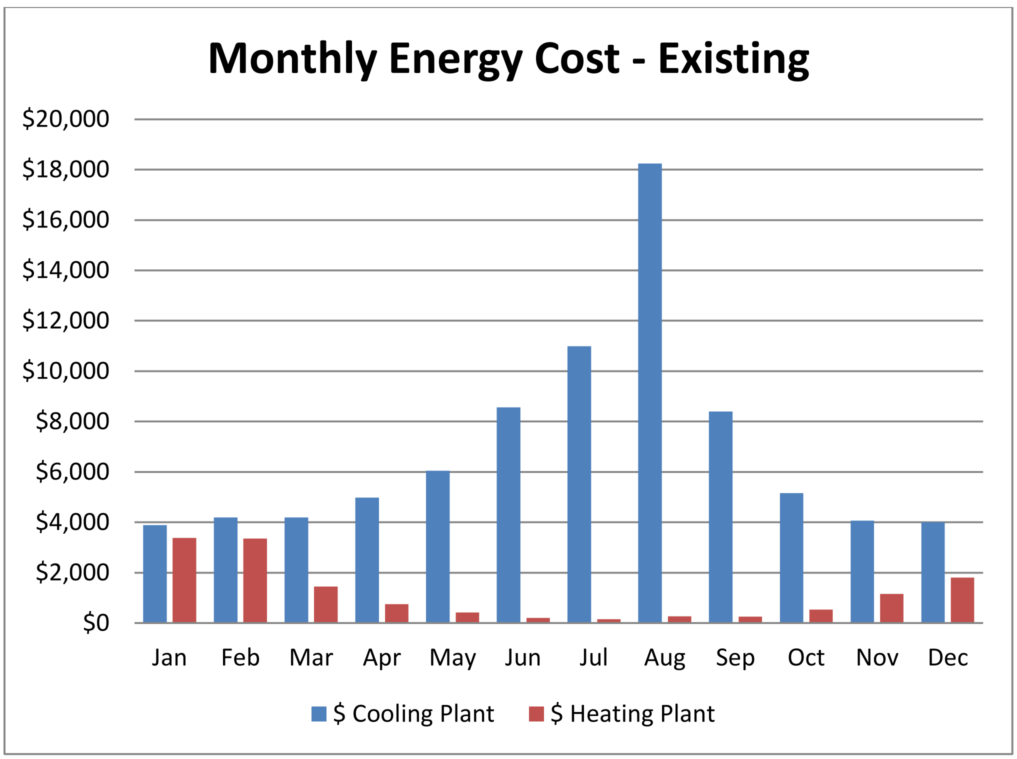


Figure 16 - Monthly Energy Costs

Building Statistics	
Building Gross SF	72648
Total Combined	$96,466
Cooling $/ SF YR	$1.33
Heating $/ SF YR	$0.19

Figure 17 - Building Statistics

Proposal information

The **scope of work** of this proposal is to compare the existing mechanical HVAC system to an alternative Geothermal HVAC system. – The new sports facility has room for improvement due to electric costs being $150,000 per year. The existing mechanical system has been evaluated and an alternative will be explored.

The Mirenda Center is a 72,000 gross square foot building, and is cooled by the six roof top air handling units. The roof units have a total of (28) ¾ hp fans, which consume annual electric energy per year. The proposed thesis will investigate a geothermal heat rejection system in place of the air cooled condensing system. This could potentially reduce the yearly electric consumption.

Ground study of the existing soccer field will be calculated to determine the adequacy of the geothermal system. The ground study will determine the length of piping needed to achieve the heating load of 1291 MBh and cooling load of 379 tons which equates to 4548 MBh.

	Tons	Mbh
RTU 1	70	648
RTU 2	68	650
RTU 3	28	218.7
RTU 4	28	218.7
RTU 5	92	648
RTU 6	92	648
Total	379	3031.4

Figure 18 - Existing RTU Sizes

Aside from the Depth of this paper there will be (2) Breadth Studies performed. They will be a combined effort to reclaim the lost space due to the large ceiling heights. A mezzanine level will be designed in the main entryway behind the architectural columns. This space will require a structural analysis, lighting analysis. The overall goal will be to increase the square footage of the building to utilize the already conditioned air, which will increase efficiency of the building as a whole.

The actual occupancy use of the building as a whole may be sporadic, however once the building is in occupied mode the mechanical equipment must be in operation at all times. Thus the economics of installing a geothermal system are justified.

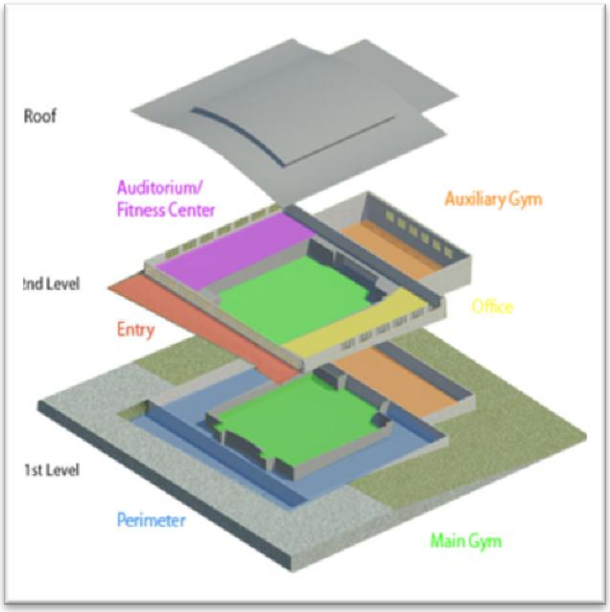


Figure 19 - Building Break Down of Spaces

Depth Study

Study of Efficiency

The main focus of the depth of this mechanical focus is comparing a not so efficiency cooling system to a more efficient cooling system. Specifically a Roof to Air Handling with a rated COP of 2.8 will be compared to Ground Coupled Heat Pump with a rated COP of 4.54.

The focus of this depth of study is to compare the efficiency difference of a Ground Coupled Heat Pump to the existing Roof Top Direct Expansion Air Source Heat Pump. The largest savings that can be achieved with purely because of the geothermal units have a Coefficient of Performance (COP) of 4.54 nominally and the Air Source units have a nominal COP of 2.8. Actual cop values were estimated based off of part loading and curve that was model for air handling equipment. COP and the amount of work need to be put in to a system are inversely proportional.

The GCHP system chosen is the vertical borehole loop system. This type of system allows for a much smaller land area usage compared to the horizontal configuration. This area is preferred to be near the build because this will save money for distribution piping. The nearest location of the well field is the (4) Tennis Courts directly north of the building.

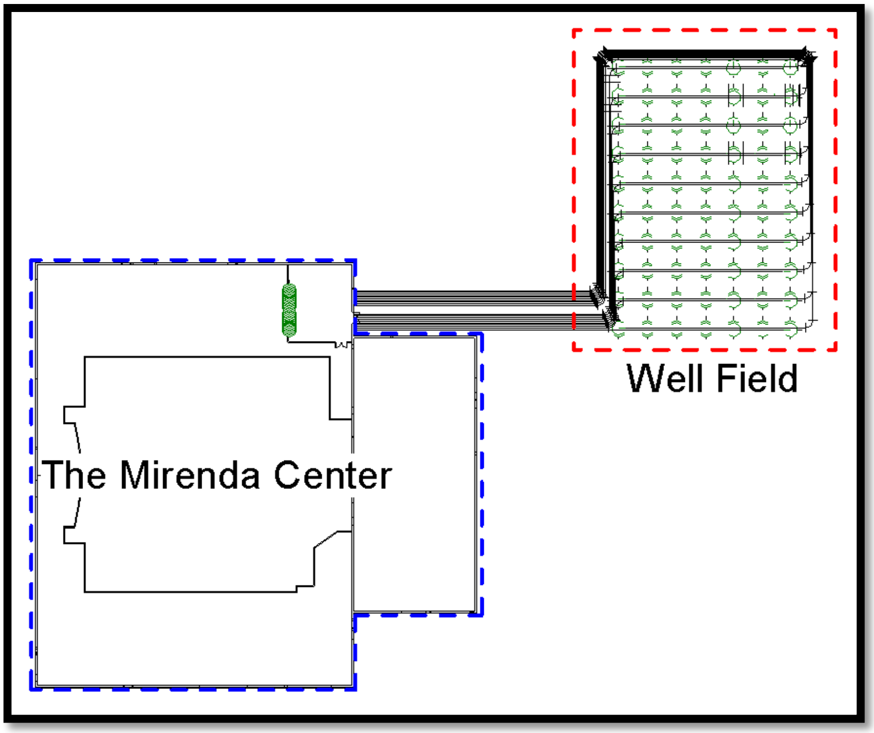


Figure 20 - Conceptual Layout of New System

Rule of Thumb

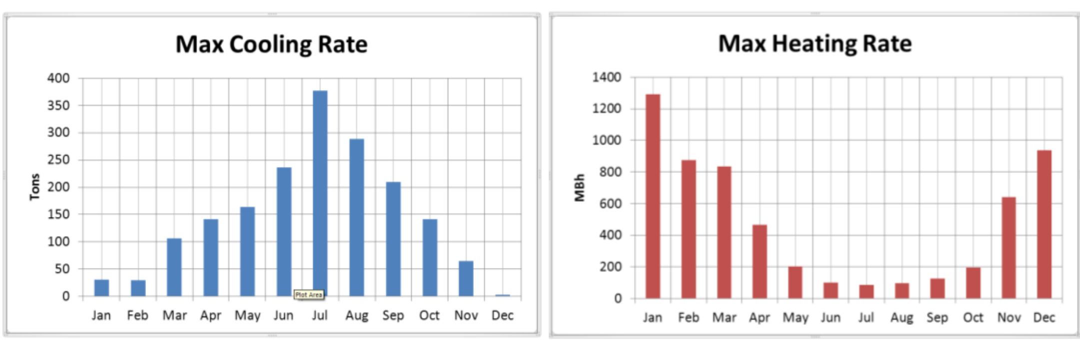


Figure 21 - Peak Building Load Profiles Cooling & Heating

The Rule of Thumb for Sizing a geothermal well field is to make an educated assumption about the amount of heat transfer that can be achieved between the fluid and the earth. The accepted number for the Philadelphia region is 150 ft of pipe per 1 ton of cooling. Using this value a well field can be sized knowing that The Mirenda Center is cooling load dominated. The max load is 379 tons cooling **on** July 27th at the 16 Hour. Meeting this load will require 142 wells at **400 feet** of depth.

GCHP Operation Assumptions

The operation hours for the ground loop system will be the same operation hours as for the building. The cost associated with operating a geothermal packaged roof top unit was calculated given that the COP of the geothermal unit is rated at 4.54. The GCHP operates with the same heat transfer laws as the DX-Expansion Refrigeration Cycle; however the benefit of have a constant ground temperature of 55 F to reject heat to during the cooling season allow for a more efficient system.

Basics of Refrigeration Equations:

Variables:

Q_e= Refrigeration Effect of Evaporative Coil

Q_c= Heat Rejection at Condensing Coil

W_c=Work input by Compressor

COP_c= Coefficient of Performance for Cooling

COP_h= Coefficient of Performance for Heating

$COP_c = \frac{Q_e}{W_c}$ *Equation 1*

$Q_c = Q_e + W_c$ *Equation 2*

$COP_h = \frac{Q_c}{W_c}$ *Equation 3*

$COP_h = \frac{Q_e + W_c}{W_c}$ *Equation 2 into Equation 1*

$COP_h = \frac{Q_e}{W_c} + 1$ *Equation 4*

Equation 1 was manipulated algebraically to determine the amount of work need to be put in to the system in order to meet the desire refrigeration effect at the coil. This coil load came from the Trane Trace Energy Model. Equation 1 was used for both the Existing Mechanical Equipment and then again for the GCHP Equipment. The amount of work that was required for the GCHP was 38.3% less than that of the Existing Mechanical Equipment.

System Comparison	
Building Gross SF	72648
Convention Air HP	$96,466
Geothermal HP	$55,298
Conventional $/SF	$1.33
Geothermal $/SF	$0.76
Annual Savings	$41,168

Figure 22 - Cost Comparison of Energy Savings

Well Field Material and Labor Costs

This well field will required to be price out for a total capital cost to buy materials and install. The total cost per well is **$8,104**. This cost accounts for the grout, 0.75 in high density polyethylene piping, and the drilling cost. Each well has a cost associated with it and there is an additional cost associated with each zone of wells. For every zone there needs to be supply and returning piping elbows, tees, and pumps. The cost per zone (not including the wells) is **$2640**. The zoning of the wells is in a reverse return layout.

GCHP Cost Analysis Option 1		
Cost of (6) RTU	$476,269	
Unit Well Cost (Grout + Pipe + Drilling)	$8,104	$1,077,879
Distribution Piping Zone (2) Pipes per Zone	$1,990	$22,060
Pumps + Elbows + Tees + Valves per zone	$650	$7,204
Number of Wells	133	
Number of Zones	12	
Total Cost		$1,583,413
Cost Difference		$1,107,144
Payback		28

Figure 23 - Payback for ALL GCHP Sizing Method

ASHRAE Length of Piping Calculation:

The calculation technique comes from ASHRAE Application 2003 Handbook. This detailed calculation takes into account multiple environmental considerations. The largest consideration is the amount of heat and cooling that is needed, next is the amount of heating that is transferred to the ground on an annual basis. This is the $\mathbf{q_a}$, the net annual energy transferred to the ground. W_a is the size of the motor used to operate the pump (in Watts) is considered because it will add heat to the water as it is being pumped out to the field. This is a good thing in the heating season and a bad thing in the cooling season. The next consideration is the resistance and or conduction of the ground or soil properties. Assumptions were made about the soils such as 15% moisture content and more of a clay like soil and less sandy. The resistance of the soil changes on the top surface for about 5 feet of depth. There are pulses of heat exchange on (3) different levels that will affect the performance of the calculation. These were taken into account when designing the well field. For the remaining considerations see the legend in the appendix.

$$L_c = \frac{q_a R_a + (q_{lc} - 3.41W_c)(R_b + PLF_m R_{gm} + R_{gd} F_{sc})}{t_g - \frac{t_{wi} + t_{wo}}{2} - t_p}$$

$$L_h = \frac{q_a R_a + (q_{lh} - 3.41W_c)(R_b + PLF_m R_{gm} + R_{gd} F_{sc})}{t_g - \frac{t_{wi} + t_{wo}}{2} - t_p}$$

The length of piping calculation as recommended by ASHRAE was used to plot of range of lengths in order to make the well field to be paid back in savings due to efficiency. The length of pipe needed to meet the load for 99.97% of the compared to 100% is the difference of 50697 feet of pipe, when the well size is 400 foot deep results in 63 wells.

GCHP as per ASHRAE Application		
F_{sc}	1.06	short circuit heat factor 1 bore whole per loop at 2 gpm per ton
L_c	106859	Required Bore Length for Cooling, ft
L_h	33728	Required Bore Length for Heating, ft
PLF_m	1	part load factor during design month
q_a	3257000	net annual average heat transfer to the ground, Btu/h
q_{lc}	4548000	building design cooling block load, Btu/h
q_{lh}	1291000	building design heating block load, Btu/h
R_{ga}	0.62	effective thermal resistance of ground (annual pulse) h ft °F/Btu
R_{gd}	0.58	effective thermal resistance of ground (daily pulse) h ft °F/Btu
R_{gm}	0.60	effective thermal resistance of ground (monthly pulse) h ft °F/Btu
R_b	0.06	thermal resistance pipe h ft °F/Btu
t_g	55	undisturbed ground temperature °F
t_p	3.9	temperature penalty for interference of adjacent bores °F
t_{wi}	75	liquid temperature at heat pump inlet, °F Cooling
t_{wi}	45	liquid temperature at heat pump inlet, °F Heating
t_{wo}	69	liquid temperature at heat pump outlet, °F Cooling
t_{wo}	51	liquid temperature at heat pump outlet, °F Heating
W_c	5993	power input at design cooling load, W
W_h	5993	power input at design heating load, W

Figure 24 - Sizing GCHP with ASHRAE Applications Method

Sizing Methodology:

This ASHRAE recommended calculation resulted in 133 wells to meet the cooling load and 42 wells for the heating season. This does not account for any ground water movement it is purely conduction heat transfer into the ground. The ground temperature is a summed to 55 F. and the difference water temperatures for the cooling season and heating season is sized for 6 F difference. Sizing a ground loop purely on the cooling load has negatives that will affect the total life performance. As a system continually adds heat to the ground during the cooling season and does not extract a ***close*** to equal amount out of the ground during the heating season performance problems may/will accrue. The net annual addition of heat will cause the ground temperature to rise. Temperature of the ground will rise over time.

Optimization in sizing the well field is the number 1 key factor in making the ground coupled heat pump cost effective. Looking at the amount of hours in a year when all of the cooling coils are on and running is the most important metric in understanding how large of a well field is needed. There is obvious risks involved with this understand and using aggressive sizing technique.

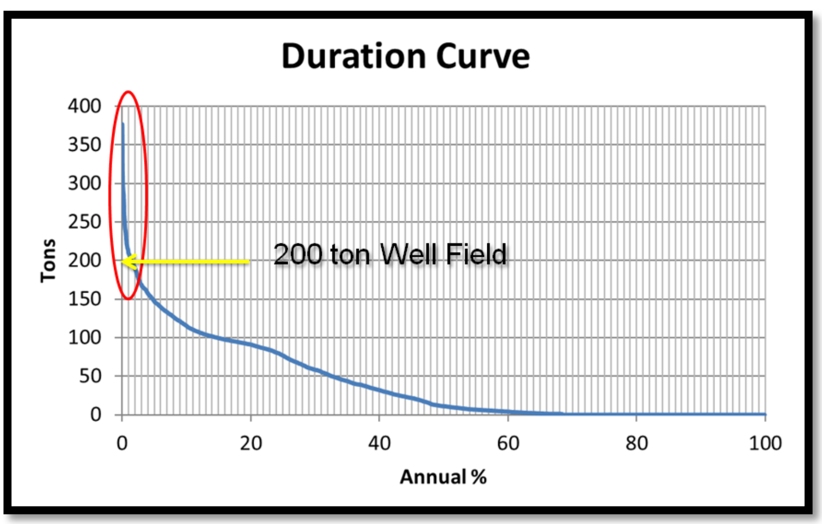


Figure 25 - Meet 99% of Building Load with GCHP

A smaller well field must be used in the design in order to make the well field cost effective. The amount of time in the cooling season that building is actually calling or full capacity is less than 0.007% of the year. This can also be stated that 99.93% of the cooling season the building is calling for 200 tons of cooling or less.

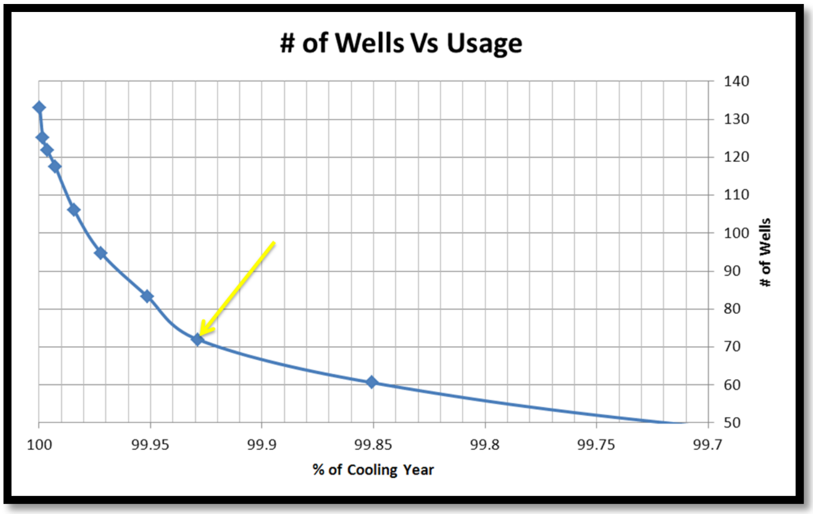


Figure 26 - Number of Wells Need plotted Against Building Load

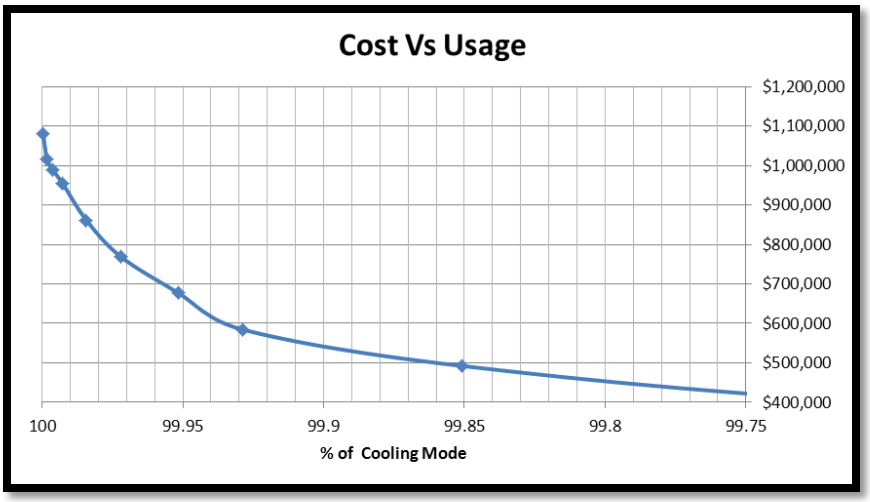


Figure 27 - Cost of Number of Wells needed Plotted against Building Load

The above charts shows number of wells needed with respect to the building load and the associated dollars in order to install that number of wells. Another way to state it would be as the building is calling for cooling it would need the number wells shown on the y-axis. After plugging the new load of 2400000 Btu/h into the calculator keeping all other assumptions the same the Length of piping needed for cooling will still dominate at 56162 feet of HDPE High Density Polyethylene Pipe.

GCHP as per ASHRAE Application

F_{sc}	1.06	short circuit heat factor 1 bore whole per loop at 2 gpm per ton
L_c	56162.05361	Required Bore Length for Cooling, ft
L_h	44638.66212	Required Bore Length for Heating, ft
PLF_m	1	part load factor during design month
q_a	698000	net annual average heat transfer to the ground, Btu/h
q_{lc}	2400000	building design cooling block load, Btu/h
q_{lh}	1702000	building design heating block load, Btu/h
R_{ga}	0.619047619	effective thermal resistance of ground (annual pulse) h ft °F/Btu
R_{gd}	0.578947368	effective thermal resistance of ground (daily pulse) h ft °F/Btu
R_{gm}	0.603174603	effective thermal resistance of ground (monthly pulse) h ft °F/Btu
R_b	0.06	thermal resistance pipe h ft °F/Btu
t_g	55	undisturbed ground temperature °F
t_p	3.9	temperature penalty for interference of adjacent bores °F
t_{wi}	75	liquid temperature at heat pump inlet, °F Cooling
t_{wi}	45	liquid temperature at heat pump inlet, °F Heating
t_{wo}	69	liquid temperature at heat pump outlet, °F Cooling
t_{wo}	51	liquid temperature at heat pump outlet, °F Heating
W_c	5993	power input at design cooling load, W
W_h	5993	power input at design heating load, W
	1310	hours that require cooling
	1820	hours that require heating

Figure 28 - Resizing Wells according to ASHRAE Applications

GCHP Cost Analysis Option 2		
Cost of (6) RTU	$476,269	
Well Cost (Grout + Pipe + Drilling)	$8,104	$567,305
Distribution Piping Zone (2) Pipes per Zone	$1,990	$13,933
Pumps + Elbows + Tees + Valves per zone	$650	$4,550
Cooling Tower		$50,000
Number of Wells	70	
Number of Zones	10	
Total Cost		$1,112,057
Cost Difference		$635,788
Payback		16

Figure 29 - Payback associated with the Resizing of Wells

The cost of paying back the capital wih be acheiveable in the life time of the equipment using this method for sizing the geothermal well field. This cost analysis account for the operation less efficient equipment (cooling tower) during the peak hours of the buildings energy consumptions for heating and cooling. The total amount of energy consumed interms of dollars is $5000 extra per year.

Cooling Tower Option

A cooling tower sized pick up the remaining load with no extra “bells and whistles” could be an alternative to achieve the worst case load. A better solution would be to not actually purchase the cooling tower until it can consistently be proven that the geo-well can no longer meet the total building cooing load. The cooling tower cost is $50,000 installed. The cooling tower should be a closed loop, with a force draft. The option to put the cooling tower indoors was considered. This will keep it from freezing in the winter, and no heaters will be needed.

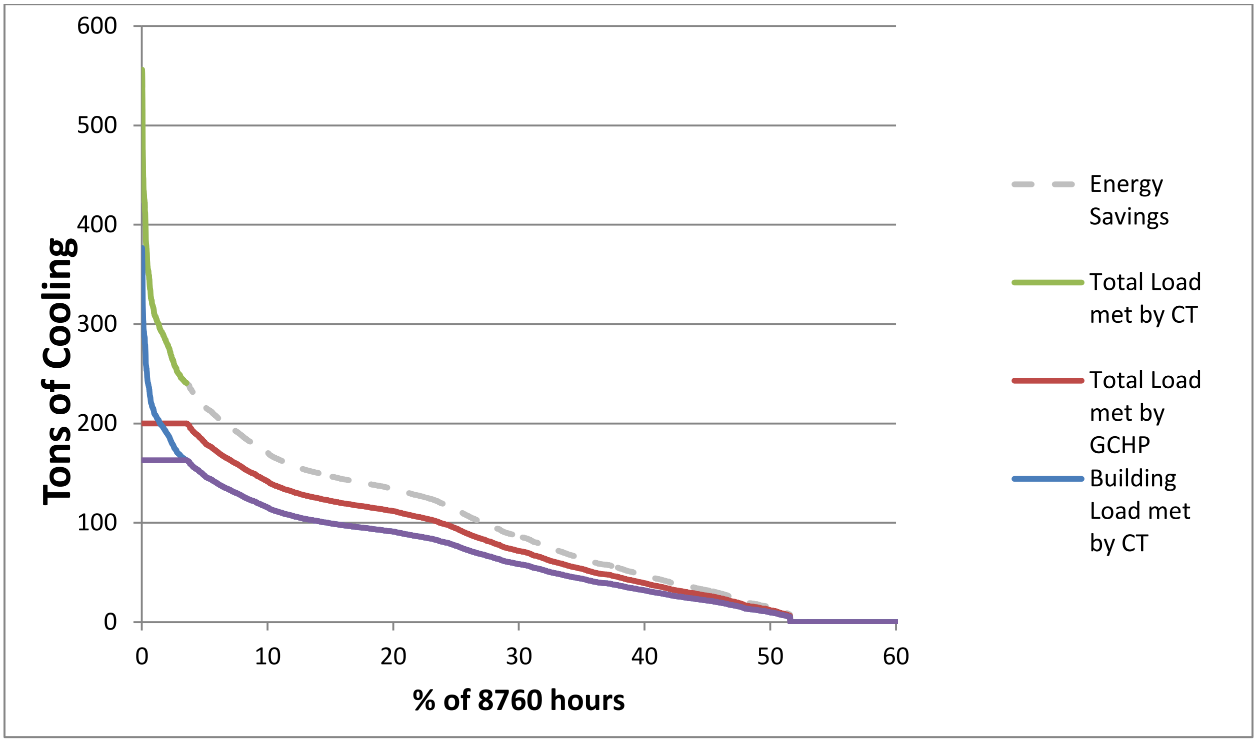


Figure 30 - Duration Curve with CT and GCHP Loads

Annual Fan and Pump Energy Consumption Comparison

Comparing Fan energy consumption to the pump energy consumption can be seen below for the annual operation cycle of The Mirenda Center. The overall results are as hypothesis. The amount of money it takes to pump 1 unit of water is fractional compared to the amount of money it would take to pump (fan) the necessary quantity of air to achieve the same overall heat transfer.

Fans in Existing RTU’s			
	Quantity	Size/fan (HP)	Total/RTU (HP)
RTU 1	6	0.75	4.5

RTU 2	6	0.75	4.5
RTU 3	2	0.75	1.5
RTU 4	2	0.75	1.5
RTU 5	6	0.75	4.5
RTU 6	6	0.75	4.5
Total	28 Fans		21 Horsepower

Figure 31 - Fan Horsepower for Existing System

Pumps for Each Zone	
Size/pump (HP)	
Pump 1	0.75
Pump 2	0.75
Pump 3	0.75
Pump 4	0.75
Pump 5	0.75
Pump 6	0.75
Pump 7	0.75
Pump 8	0.75
Pump 9	0.75
Pump 10	0.75
Total	7.5 horsepower

Figure 32 - Pump horsepower for New System

The size of horsepower fan required to reject the sum total of 4548 Mbh of heat with air is 21 horsepower. The size of horsepower pumps required to reject 4548 Mbh of heat to the well field with water is 7.5 horsepower.

Fan Energy for Each Set of Condenser Fans							
Days	**Months**	**RTU 1**	**RTU 2**	**RTU 3 & 4**	**RTU 5 & 6**	**kwh**	**Dollars**
31	January	1634	1634	136	442	3847	$231
28	February	1490	1490	124	399	3503	$210
31	March	1661	1661	138	442	3903	$234
30	April	1604	1604	134	428	3770	$226
31	May	1634	1634	451	1352	5072	$304
30	June	1309	1309	436	1309	4362	$262
31	July	1352	1352	451	1352	4508	$270
31	August	1352	1352	451	1352	4508	$270
30	September	1604	1604	134	428	3770	$226

31	October	1634	1634	136	442	3847	$231
30	November	1604	1604	134	428	3770	$226
31	December	1634	1634	136	442	3847	$231
							$2,922

Figure 33 - Cost of Annual Fan Energy

(10) Pumps | Energy for Geothermal			
Days	2010	kWh	Dollars
31	January	416.101	$25
28	February	375.833	$23
31	March	416.101	$25
30	April	402.678	$24
31	May	294.738	$18
30	June	285.23	$17
31	July	294.738	$18
31	August	294.738	$18
30	September	402.678	$24
31	October	416.101	$25
30	November	402.678	$24
31	December	416.101	$25
			$265

Figure 34 - Cost of Annual Pump Energy

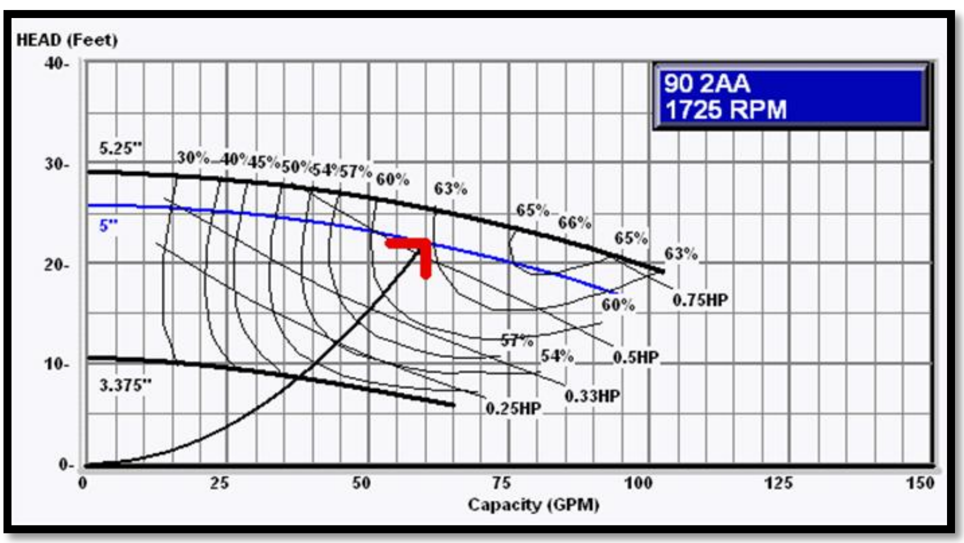


Figure 35 - Sizing of Single Loop Pump

Figure 36 - Inline Pump

A pump was selected from Bell and Gossett's list of pumps. Bell and Gossett's pump selector program was used to select the most efficient pump for the job of overcoming the pressure drop of the longest leg of the well. The farthest zone was used to determine the size of the pump. This pump will be oversized for the closer zones however for the ease of construction and for the sake of not confusion which size pump should go where it may be worth the while to get the same pump for every zone.

Part Load Analysis

It must be understood that a nominal or rated COP is not the actual COP. A prescribed calculation was used to achieve the actual COP. While the Air Handling Units are at Part Load, basically not at the maximum conditions that the best possible COP can be achieved, and then the COP will be less than rated. Part load conditions occur 99.99% of the year typically. The lowest COP that occurred with system (1) is 2.12 and the lowest COP that occurred with system (2) is 4.438. The above savings were calculated form the Part Load Analysis utilizing less than ideal COP values.

The existing mechanical system is Air to refrigerant to Air Heat Rejection system for Cooling with a Natural Gas Furnace for Heating. This is more commonly referred to as Directed Expansion cooling and or Air Source Equipment. There is (6) roof top DX air handling units that maintain (5) areas/ zones of The Mirenda Center. The total capacity of the existing cooling piece of the mechanical system is 388 tons. The break-down is 78, 68, 28, 28, 92, and 92 tons for RTU's (1-6) respectively. The cost for the existing DX Air to Air RTU's is $1233.00 per ton which results in $503,956.92 for the whole existing roof top units. Each unit costs approximately $4000 to install, totaling to $24,000. Cost of existing units plus labor costs are $502,113. The annual electric cost to run the Air Source Cooling system is **$95,312**. This includes all the charges from the Peco electric: consumption, demand, and ratchet clause. The purpose of running the annual energy consumption is to establish a baseline that can be improved upon. The goal for this the DEPTH of Study will be to run an annual analysis on a more efficient piece of equipment that would cost less that Air Source Cooling Equipment.

Max Summer Design Day Cooling Load:

A full year weather profile was used from the published .TMY3 data for the Northeast Philadelphia recorded data. The max design condition occurs on July 27th at 4:00 pm in the Afternoon; this is according the Trane Trace software calculation simulator. The whole building cooling demand at that time is 379 tons of cooling. In order to achieve this load a given amount of work much is put into a compressor or set of compressors. This can be calculated by knowing that COP is proportional to the cooling effect, which in this case is 379 tons, inversely proportional to the amount of work that is need to be put in to achieve that COP. The COP is fixed by the specified piece of equipment, and the cooling load is set by the building materials, occupancy, temperature, building function, etc. Basically the cooling load is determined by an educated guess of interior loads and weather patterns. With a COP of 2.8 and a cooling load of 379 tons the amount of kw need for that hour is 624.956 kwh. With a COP of 4.54 and a cooling load of 379 tons the amount of kw need for that hour is 385.417 kwh. Obviously assumptions need to be made about schedule of use of equipment in order to achieve energy from energy per unit time. The assumptions made about schedule can be found in the earlier section of this report. During the summer 13.5 hours for the work week and 13 hours for the weekend is the schedule of use for the building. The total of 239.539 kwh was saved by using the GCHP over the ASHP. Electricity consumption charges are $0.06 per kwh this results in $14.37 of saving in the (1) hour of the day. This calculation was performed for every hour for a year, which resulted in an annual savings of $13,861. The electric company charges for consumption, peak demand, and also ratchet charges. The peak demand savings for the month of July $1,487. This the maximum peak demand savings charge, which over 12 months results in an annual savings $17,848 per year of savings. The **total savings** combined per year is **$40,014**

Design Layout

The layout of the well field was selected to be nearest to the Mirenda Center as possible. The well field presently is designed to occupy 28,000 SF of the 30,000 SF (Approximately 1/2 football field) the (4) tennis courts that are directly behind The Mirenda Center.

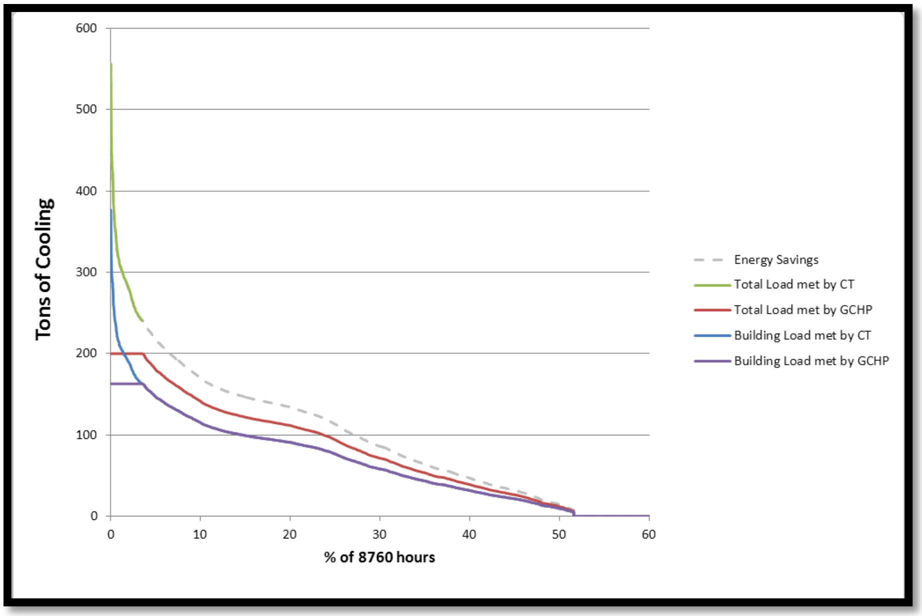


Figure 37 - Total System Load Duration Profile

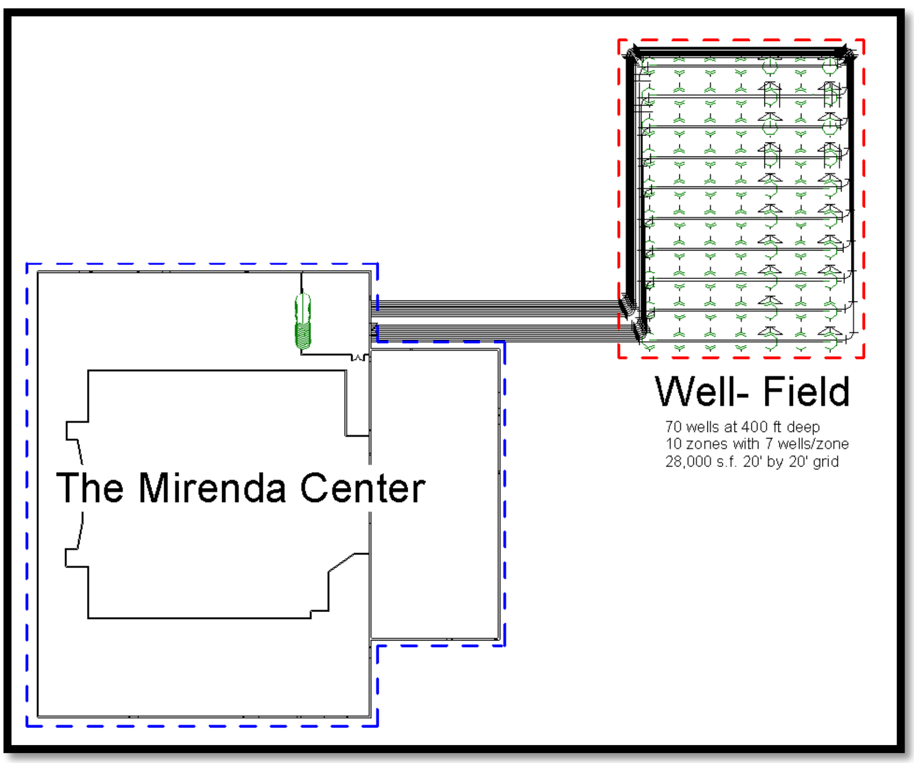


Figure 38 - System Concept

Tools Used to Simulated and Calculate

Trane Trace 500

Trane Trace 500 energy simulator was used to determine the annual heating (Mbh) and cooling (tons) loads in each space of The Mirenda Center for every hour of every day for one year. See the appendix for example calculation. The Trane trace model was built with a lean aspect of load within the space. More detail about the internal loads in the space can be found from previous technical reports.

Microsoft Excel 2010 | Spreadsheet Editor

Excel spreadsheets were used to calculate the energy performance of the air source roof top units based on the model annual energy model from Trane Trace. The excel spreadsheets were also used to analyze the geothermal performance. Excel has been excel in keep data organized and generating graphs.

Autodesk Revit 2011 Architecture | MEP | Structure

Autodesk Revit was used to layout the architectural features of The Mirenda Center. Once the geometry was completed it was then exported in Xgbml format for the Trane Trace software to import. The Revit Mechanical version was used to layout the piping and mechanical equipment. The Revit Structure was utilized to layout the Mezzanine Structural elements, such as the composite deck, columns, the tension

AGI32 LIGHTING

A lighting analysis was done of the mezzanine proposal to determine the spacing of the luminaires. The minimum average foot-candles required for this pace 30 foot-candles. Using AGI32 the 30 foot candles can be set a fixed number for a specific work plane, such as 2.5 feet above the floor. This was the decided acceptable work plane that was used. Once the work plane and foot-candle requirement was input, and specific lighting file is input for the luminaire then the AGI32 will decide the best pattern for that luminaire to be placed in the ceilings grid.

Integrated Master Material

The duration curve was a topic that was presented in Dr. William Bahnfleth's AE 557 Central Cooling Plant graduate course. This was in my design of the geothermal well sizing methodology.

The Lifecycle cost analysis was a topic that was presented in Dr. William Bahnfleth's AE 558 Centralized Heating Plant. The lifecycle cost analysis was done to include the escalating cost of electricity. These values were taken from the Energy Price Indices and Discount Factors for Life Cycle Cost Analysis of 2010. This document can be found on the following website: http://www1.eere.energy.gov/femp/pdfs/ashb10.pdf Also, the cost escalation factors for electric were given only for a 30 year time span, thus any additional years were extrapolated an may be inaccurate.

Integrated Master's Criteria - Zachary Heilman		
Thesis Analysis for IP CREDIT		
Conditioned Area	72,648	sf
Annual Cooling Energy	16	kwh/sf
Total	1,143,345	kwh
Conventional Air Cost (2010)	$96,466	
GCHP Cost (2010)	$55,298	
Savings Associated with Heating	$8,304	

Figure 39 - Integrated Masters Criteria

Savings Breakdown	
1st Year Energy Savings	$49,402
5 year SPB capital $	$247,008
5 year DPB capital $	$266,165
10 year SPB capital $	$642,221
13 year DPB capital $	$762,771

Figure 40 - Saving Breakdown

Break Down of Analysis								
		Cap. Cost	O. Fee	Fee	Esc	Sys (1)	Sys (2)	Savings
2009	1	$635,788	$0	$1,000	1.19	$114,795	$65,805	$55,788.11
2010	2		$0	$1,000	1.20	$115,759	$66,358	$54,711.75
2011	3		$0	$1,000	1.21	$116,724	$66,911	$53,653.43
2012	4		$0	$1,000	1.19	$114,795	$65,805	$51,502.74
2013	5		$0	$1,000	1.20	$115,759	$66,358	$50,509.06
2014	6		$0	$1,000	1.21	$116,724	$66,911	$49,532.03
2015	7		$3,000	$1,000	1.22	$117,689	$67,464	$48,571.46
2016	8		$0	$1,000	1.23	$118,653	$68,017	$47,627.17
2017	9		$0	$1,000	1.24	$119,618	$68,570	$46,698.95
2018	10		$0	$1,000	1.25	$120,583	$69,123	$45,786.63
2019	11		$0	$1,000	1.26	$121,547	$69,675	$44,889.99
2020	12		$0	$1,000	1.28	$123,476	$70,781	$44,307.89
2021	13		$0	$1,000	1.29	$124,441	$71,334	$43,434.19
2022	14		$3,000	$1,000	1.30	$125,406	$71,887	$42,575.81
2023	15		$0	$1,000	1.32	$127,335	$72,993	$42,008.61
2024	16		$0	$1,000	1.33	$128,300	$73,546	$41,173.00
2025	17		$0	$1,000	1.35	$130,229	$74,652	
2026	18		$0	$1,000	1.36	$130,861	$75,014	
2027	19		$0	$1,000	1.37	$132,106	$75,728	
2028	20		$0	$1,000	1.38	$133,351	$76,442	
2029	21		$3,000	$1,000	1.40	$134,596	$77,156	
2030	22		$0	$1,000	1.41	$135,842	$77,870	
2031	23		$0	$1,000	1.42	$137,087	$78,583	
2032	24		$0	$1,000	1.43	$138,332	$79,297	
2033	25		$0	$1,000	1.45	$139,578	$80,011	
2034	26		$0	$1,000	1.46	$140,823	$80,725	
2035	27		$0	$1,000	1.47	$142,068	$81,439	
2036	28		$0	$1,000	1.49	$143,313	$82,153	
2037	29		$0	$1,000	1.50	$144,559	$82,867	
2038	30		$0	$1,000	1.51	$145,804	$83,580	
	Col NPV	$635,788	$6,439	$20,383		$2,570,340	$1,473,417	
						$3,232,950	$2,136,027	
				Energy Pct.		79.5	69.0	
				Maint. Pct.		0.8	1.3	
				Capital Pct.		19.7	29.8	

Figure 41- 30 Year Lifecycle Breakdown Comparison

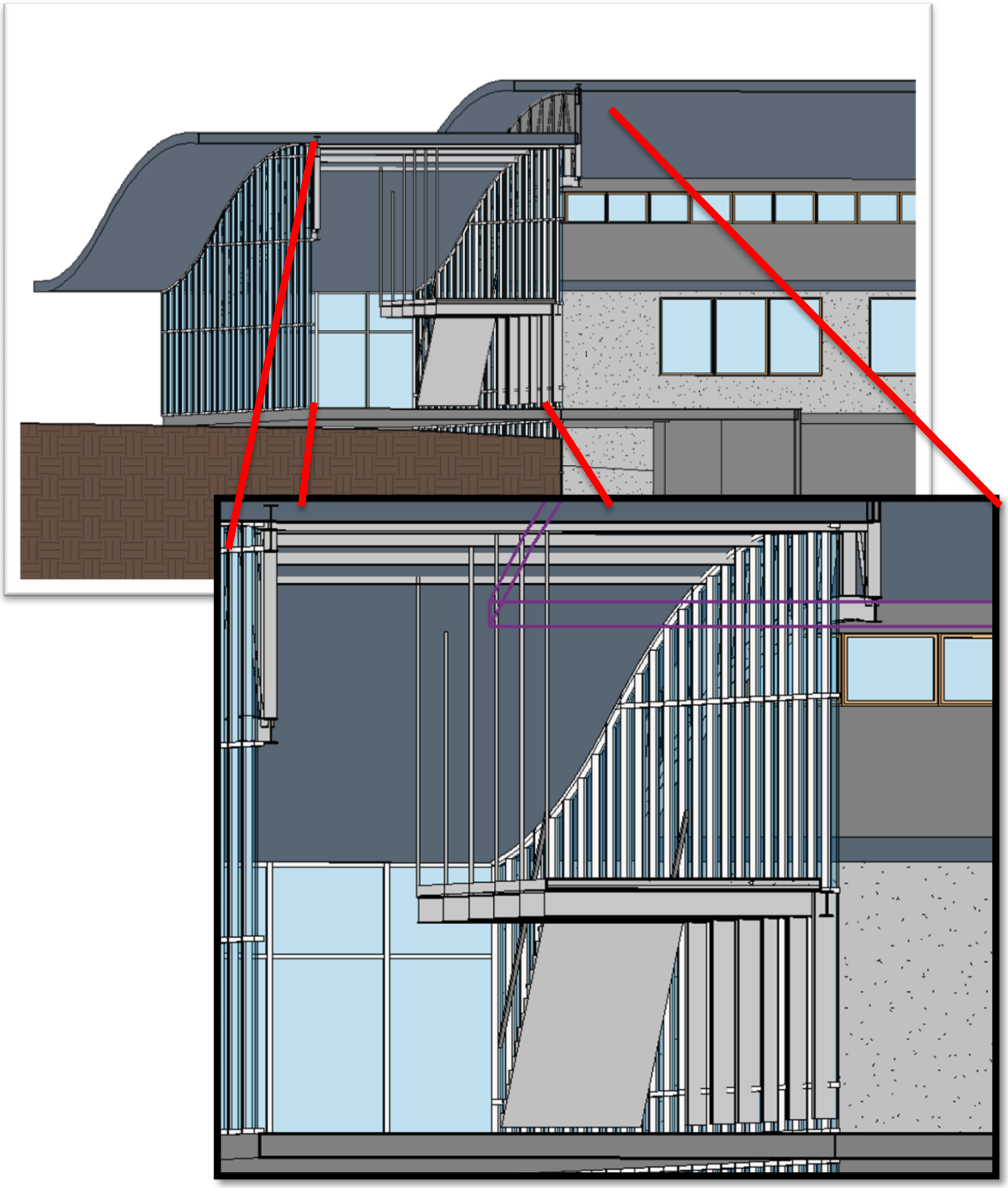


Figure 42 - Structural Mezzanine Design

Load Assumptions & Member Sizing

The Mirenda Center stands 20 feet in height in the welcoming area. There is opportunity to recapture lost conditioned air by way of installing a mezzanine. This mezzanine level will be composite concrete deck. The structural system used will be a simply supported beam with composite deck span over 8 bays. The bays are spaced at 8.5 feet on center. The tributary width of the each bay was determined by the spacing of the panels of the Truss. The reason for this so the suspended members will line up with purlins. The support members are a suspended pipe and a column.

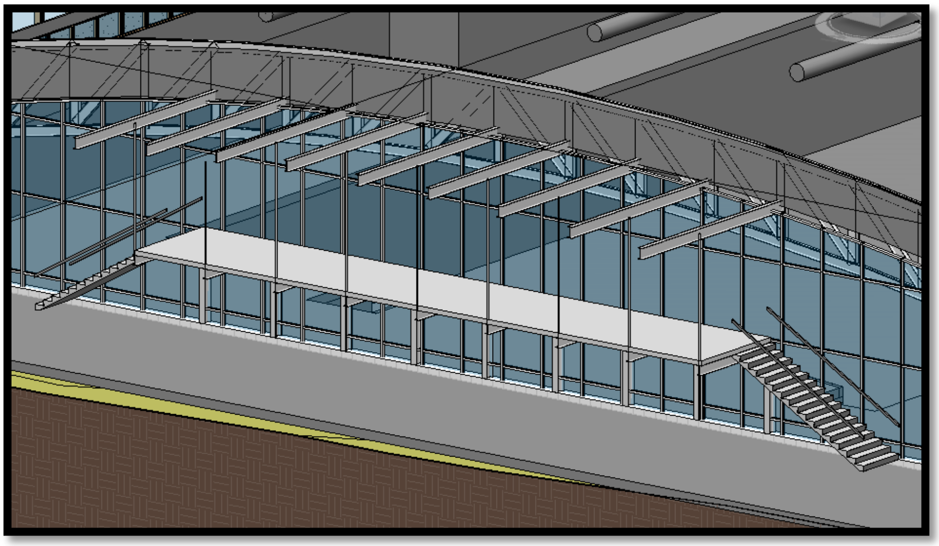


Figure 43- Structural Design Layout

LRFD – Design Conditions		
Dead Load=	40	psf
Self-Weight=	45	psf
Live Load=	80	psf
Total Factored Load=	1.2*(Dead)+1.6*(Live)	
Mezzanine Width=	12	ft
Mezzanine Length=	70	ft
Total Thickness=	5.5	inches
Number of Bays=	8	
Total Unfactored Load (no concrete self-weight)=	120	psf
Total Unfactored Load (with concrete self-weight)=	165	psf
Total Factored Load=	230	psf

Figure 44 - Total Factor Load (LRFD)

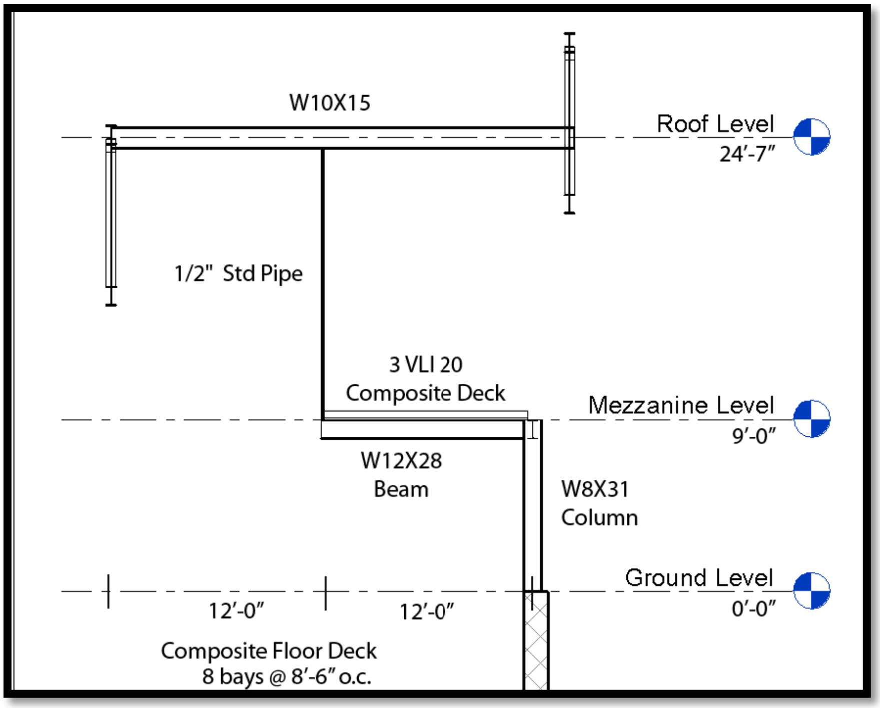


Figure 45 - Structural Section with Member Sizes

The composite deck was sized in accordance with the method prescribed by the Vulcraft Deck Catolog. 3VLI20 Compose Deck was sized based on its capacity to hold the 178 Superimposed Load at 8' – 6" on center. The deck will be oversized for the 8.5 feet on center; however this will also allow the concrete to support itself during construction when the concrete is wet. The 2 span unshored clear spans during construction is 15' - 7".

Composite Deck Sizing		
Bays Span	8'- 6"	o.c.
Dead Load	40	psf
Self-Weight	45	psf
Live Load	80	psf
Load (no S.W.)	120	psf
Load (w/ S.W.)	165	psf
3VLI20 (SuperImposed)	178	psf
1 Span (unSh Constr)	10' – 8"	
2 Span	12' – 11"	
3 Span	13' - 4"	

Figure 46 - Composite Deck Sizing

Beam Sizing		
Span	12	feet
Dead Load	40	psf
Live Load	80	
Trib width	8.5	feet
Uniform Load	1955	plf
Shear (V_u)	11.73	kips
Moment (M_u)	70.38	Kip ft
$Ø_b$	0.9	
$Ø_v$	1.00	
Shear (V_u)	11.73	kip
Moment (M_u)	63.34	kip ft
$Ø_b M_{px}$	65.20	kip ft
$(M_u) \leq (Ø_b M_{px})$		
W12 by 24		

Figure 47 - Beam Sizing

The beam sizing was done with the LRFD method described in THE STEEL MANUAL. This method allows for the structural system to be designed up to 90% of its capacity. The span of each beam is 12 feet, while its tributary area is 8.5 feet. The most important factor in deciding the tributary area is the alignment of the beams to with the panels of the 138’ span trusses.

1” Standard Pipe Sizing		
P_u	11.73	kips
F_y	35	ksi
F_u	60	ksi
A_g	0.460	
A_e	0.345	
0.90 F_y A_g Yielding	14.49	kips
0.75 F_u A_g Rupture	15.525	kips
$P_u < 0.90 F_y A_g$	Yield Controls	
1” Standard Pipe		

Figure 48 - Pipe Sizing

The beam must be supported on both ends. The method of supporting the beam on the southern end of the beam will be achieved by a 1” Standard Pipe that is suspended from the purlins which support the roof. This will inevitable require the purlins to be checked and sized according to the added point load. The 1” Standard pipe was sized in order to overcome an axial load of 11.73 kips. This value is the factored load is the maximum shear value from the beam sizing portion of this text. The 1” Pipe was sized in order to overcome yielding of the steel, yielding will occur before rupture.

Column Sizing		
P_u	11.73	kips
K	1	
L	10	feet
$Ø_c P_n$	313	kips
$Ø_c$	0.9	plf

Pin – Pin		
W8 by 12		

Figure 49 - Column Sizing

The column will support the beam on the northern side of the beams length. This column must be able to support a compression load of 11.73 kips. This axial compression load is minute compared to the readily made available beams that are listed in The Steel Manual. The unbraced length of the beam (L) is assumed to be 10 feet. This is the smallest beam listed in the steel manual that is considered a Wbeam. The W 10 X 30 is able to support a 313 kip axial compression load with the given unbraced length of 10 feet. The W 10 X 30 is more than adequate to serve as a column for this load case.

Purlin Sizing		
Span	24	feet
Dead Load	40	psf
Snow	30	psf
Total Factored Load	1.2*(Dead)+1.6*(Snow)	
Total Factored Load	96	psf
Tributary Width	8.5	feet
Uniform Load (W)	816	plf
P_u	15.607	kips
M_u	128.532	kips ft
$Ø_vM_{nx}$	94.2	kips
$Ø_bM_{px}$	137	kip ft
$(M_u) \leq (Ø_bM_{px})$ thus not Okay		
W10 x 30		

Figure 50 - Purlin Sizing (Uniform Distributed Load with Point Load)

The purlin will have to support more than just the point load of the tension member that supports the Mezzanine. The purlin will have to support the tributary width worth of the roof loads that occur along with the point load at it center. The

Lighting

A lighting analysis was done of the mezzanine proposal to determine the spacing of the luminaires. The minimum average foot-candles required for this pace 30 foot-candles. Using AGI32 the 30 foot candles can be set a fixed number for a specific work plane, such as 2.5 feet above the floor. This was the decided acceptable work plane that was used. Once the work plane and foot-candle requirement was input, and specific lighting file is input for the luminaire then the AGI32 will decide the best pattern for that luminaire to be placed in the ceilings grid.

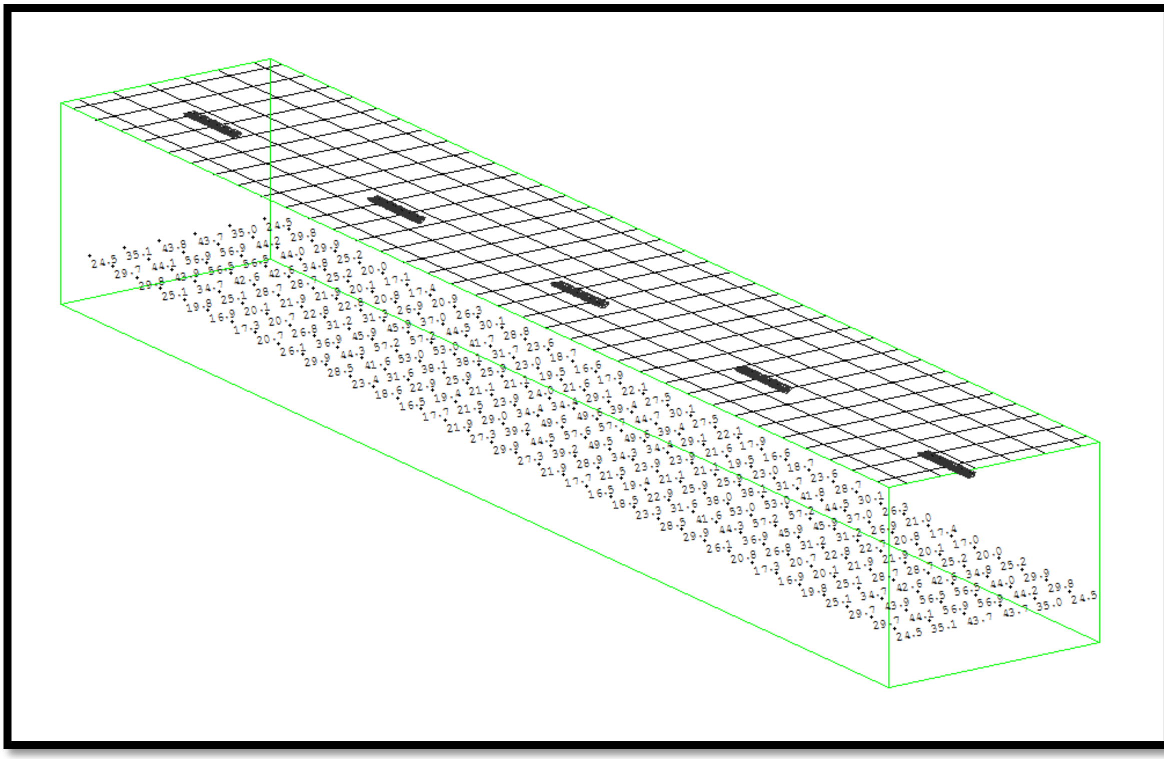


Figure 51 - AGI32 Layout of Mezzanine in Space

Luminaire	
4' Pendant	
Illuminance (Fc)	30
Average	31.47
Minimum	16.5
Maximum	57.7
Ave/Min	1.91
Max/Min	3.5

Figure 52 - Luminaire Layout and Requirements

Summary and Conclusions

The overall recommendation for The Mirenda Center would be to determine the life of The Center for Neumann University. If the life of The Center is more than 50 years, then it may be worthwhile to investigating the possibility of retrofitting The Mirenda Center with the proposed Ground Couple Heat Pump alternative to heat and cool the building.

The GCHP system will lower the monthly energy cost by 40% on average, and will encourage an overall lifetime energy savings of the building. The capacity of the recommended hybrid system will require the least amount of energy input for the a majority of the cooling season. As the load exceeds the GCHP Well Field the Cooling Tower will begin to come on line. This will all be done with Variable Frequency Drive on the pump to match the Flow of the water to the building Load.

It is vital to properly assess all building loads prior to design of any system to accommodate them. Initially the whole Mirenda Center was model for (1) Unit to meet all of its loads, however it is evident now that zoning systems based on their location relative to each other, or matching their loads is an excellent and necessary strategy in organizing zones.

References

Carlson, S 2001. Final Report: Developement of Equivalent faull load heatng and cooling hours for GCHPs applied in various building types and locations. 1120-TRP. ASHRAE.

Bettanini, Gastaldello, Schibuola:Dipartimento di Fisica Tecnica, Universita di Padova, Italy, Dipartmento di Costruzione dell' Architettura, IUAV Universita dedgli Studi, Venezia Italia: SIMPLIFIED MODELS TO SIMULATE PART LOAD PERFORMANCES OF AIRCONDITION EQIUPMNENTS

2003 ASHRAE Applications Handbook

2009 ASHRAE Fundamentals Handbook

2008 ASHRAE Systems and Equipment

Spittler, Jeffery D. Load Applications Manual

Appendix

GCHP as per ASHRAE Application		
F_{sc}	1.06	short circuit heat factor 1 bore whole per loop at 2 gpm per ton
L_c	106575.555	Required Bore Length for Cooling, ft
L_h	44638.66212	Required Bore Length for Heating, ft
PLF_m	1	part load factor during design month
q_a	2834000	net annual average heat transfer to the ground, Btu/h
q_{lc}	4536000	building design cooling block load, Btu/h
q_{lh}	1702000	building design heating block load, Btu/h
R_{ga}	0.619047619	effective thermal resistance of ground (annual pulse) h ft °F/Btu
R_{gd}	0.578947368	effective thermal resistance of ground (daily pulse) h ft °F/Btu
R_{gm}	0.603174603	effective thermal resistance of ground (monthly pulse) h ft °F/Btu
R_b	0.06	thermal resistance pipe h ft °F/Btu
t_g	55	undisturbed ground temperature °F
t_p	3.9	temperature penalty for interference of adjacent bores °F
t_{wi}	75	liquid temperature at heat pump inlet, °F Cooling
t_{wi}	45	liquid temperature at heat pump inlet, °F Heating
t_{wo}	69	liquid temperature at heat pump outlet, °F Cooling
t_{wo}	51	liquid temperature at heat pump outlet, °F Heating
W_c	5993	power input at design cooling load, W
W_h	5993	power input at design heating load, W
	1310	hours that require cooling
	1820	hours that require heating

Figure 53 - Example of GCHP Calc

Soil Pulse Factors				
F_o	Fourier Number			
F_{of}	537022.08			G
F_{o1}	4414.08			0.128
F_{o2}	36.48			0.263
G_f	1.1			0.433
G_1	0.71			0.614
G_2	0.38			0.797
R_{gA}	0.619047619	h ft °F/Btu		0.978
R_{gB}	0.578947368	h ft °F/Btu		1.1595
R_{gC}	0.603174603	h ft °F/Btu		

Figure 54 - Example of Soil Pulse Factors

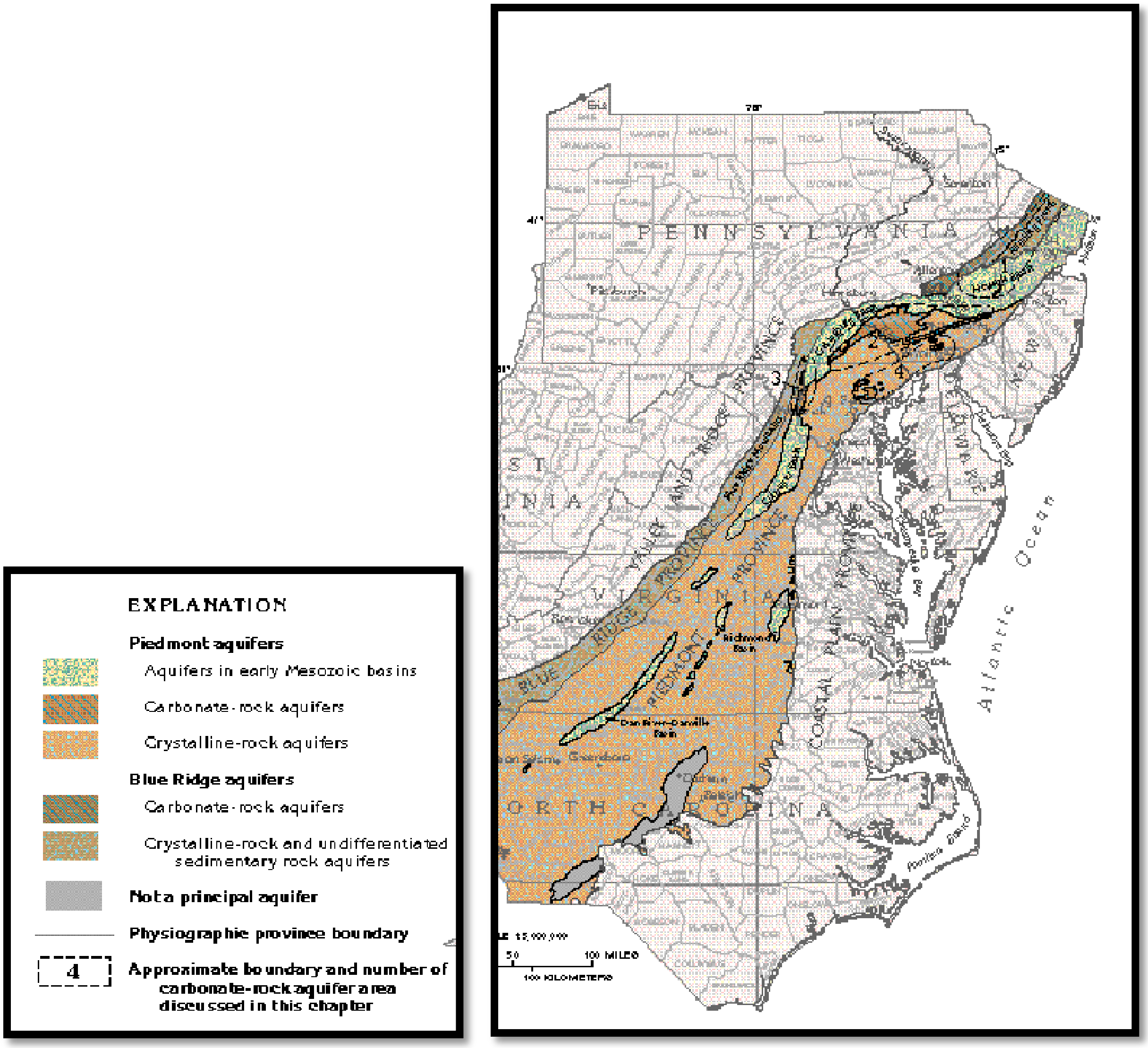


Figure 55- Piedmont Aquifers

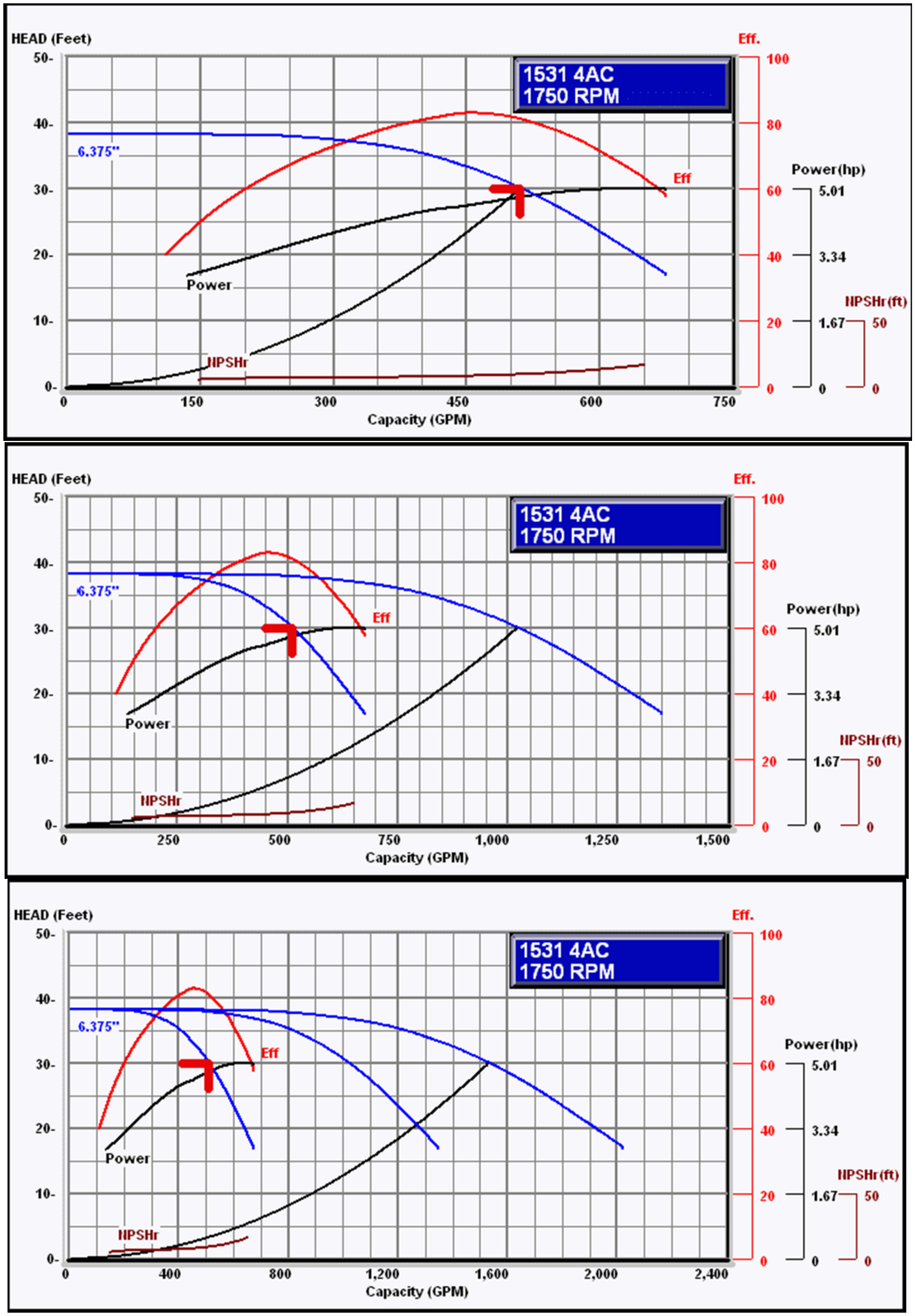


Figure 56 - Pumps in Parallel

General Assumptions for Calculations			
Air to Air	COP =	2.8	3.077374
Geothermal	COP =	4.54	4.54279
	1 ton=	12000	btu/h
	1 watt=	3.412	btu/h
	1 kwh=	1000	wh
	1MBH=	1000	btu/h
	ON Pk CERate=	0.06	$/kwh
	OFF Pk CERate=	0.05	$/kwh
	Demand Rates=	6.21	$/kw
		0.011	$/CF
		1013	BTU/FT^3
Schedule	SWkdy	1	hours
	Wwkwdy	1	hours
	Wkend	1	hours
Rated (Tons)	388		
Rated (MBh)	4652		

Figure 57 - General Input Assumptions for Calculations

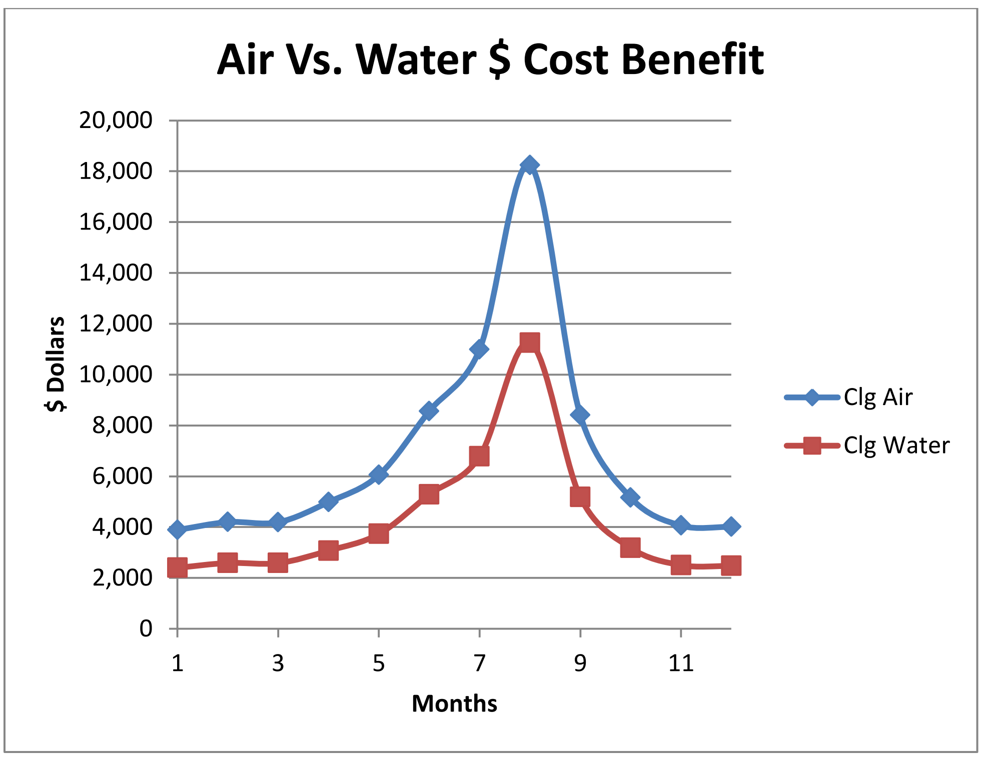
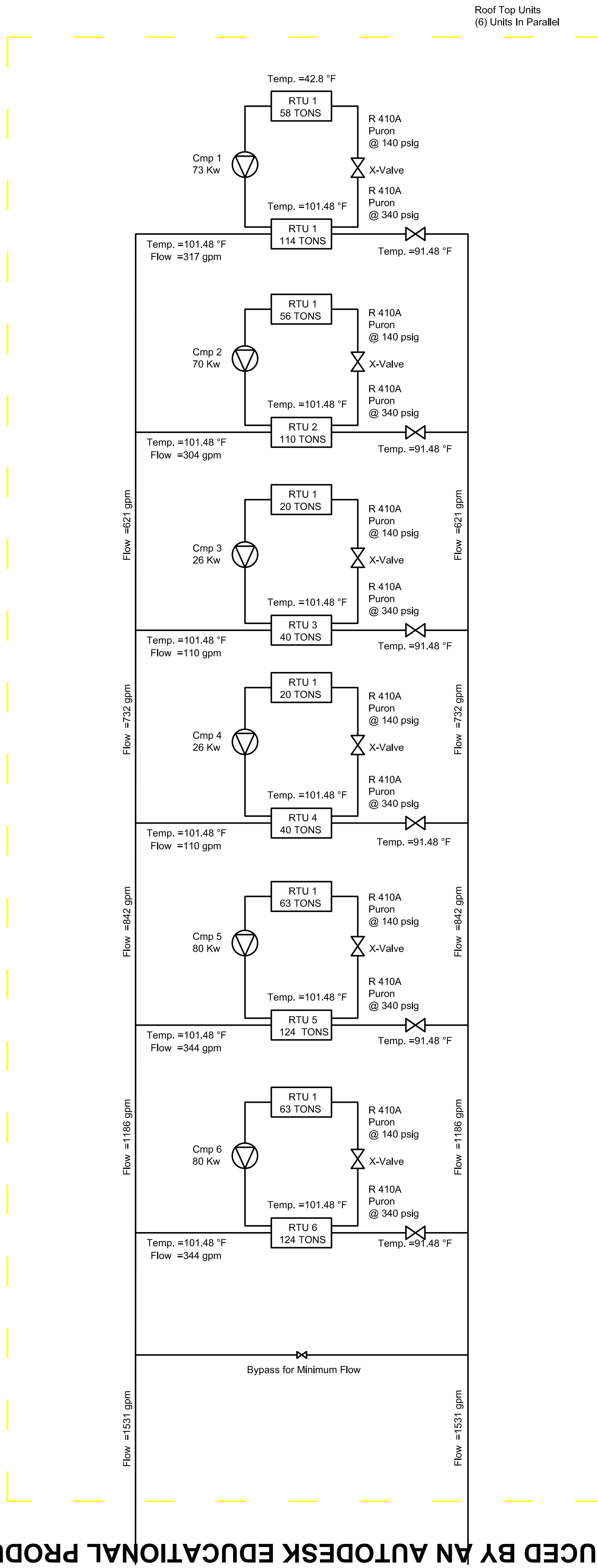
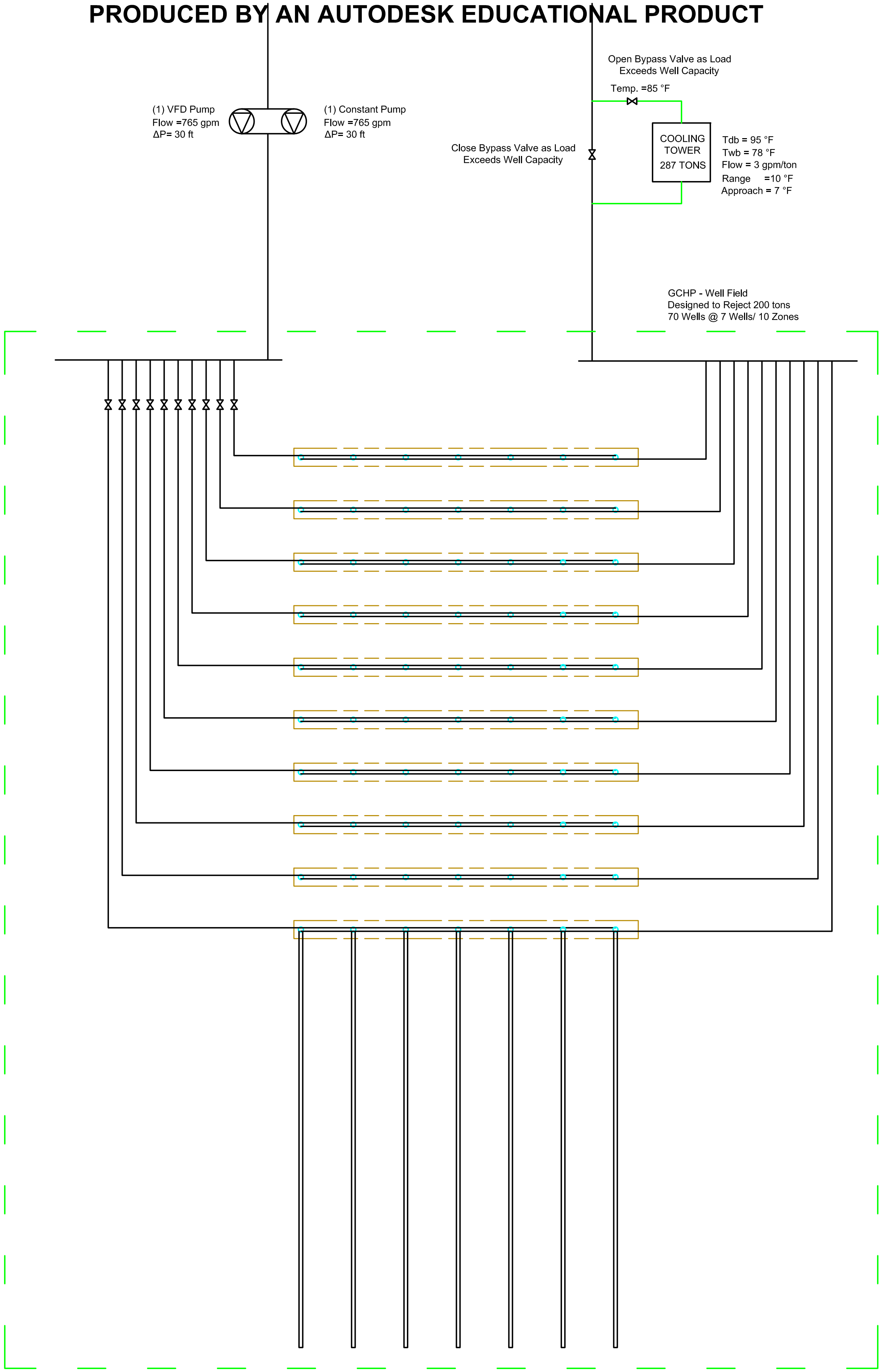


Figure 58 - Cost Benefit b/n Systems



PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT



PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT