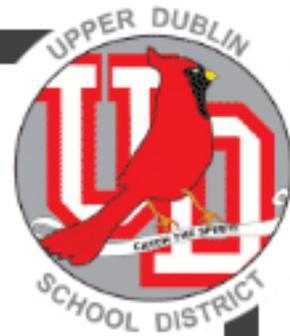

A.E. Senior Thesis - Final Report

April 7, 2010



Upper Dublin High School

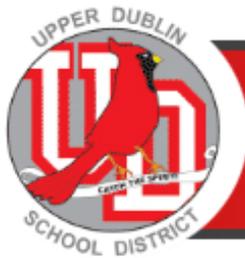
Upper Dublin School District
Fort Washington, PA

Stephen Kelchaw

The Pennsylvania State University
Architectural Engineering
Construction Management Option

Faculty Advisor:
Dr. Chris Magent





Upper Dublin High School

Fort Washington, PA

• Stephen Kelchaw • Construction Management •



Building Statistics

- Size: 368,000 sf
- Height: 2 Stories
- Project Cost: ~\$119.2 M
- Construction Dates: Phase I: Aug '08 - Dec '10
Phase II: Jan '11 - Aug '12
- Delivery Method: Design-Bid-Build

Building Envelope

- White single-ply flat roof
- Standing seam curved metal roofing
- Brick and stone masonry facade with CMU back-up wall
- Cast stone profile separates brick and stone facade

Lighting/Electrical

- Typical lighting consists of surface mounted T8 fluorescent and CFL's
- 480Y/277V and 208Y/120V distributed throughout building
- More than 90 panel boards
- Lighting controlled with occupancy sensors and photosensors

Project Team

- Owner: Upper Dublin School District
- Architect: Gilbert Architects
- CM: D'Huy Engineering
- Site/Civil: CMX Engineering
- Structural: Baker, Ingram, & Associates
- MEP: Snyder Hoffman Associates
- LEED: 7 Group

Mechanical

- 304 Geothermal Wells with a water/glycol mix
- Eleven (11) Energy Recovery Units (ERU)
- Twelve (12) Heat Recovery Units (HRU)
- Temperature controlled through ATC system
- Ductless Split-System Air Conditioning Units
- VAV and Fan-Powered VAV boxes

Structure

- Classroom live load: 40psf
- Spread footing support columns
- 1st Floor: 4" SOG with 6x6-W2.9 x W2.9 WWF on drainage fill and vapor retarder
- 2nd Floor: Structural steel framing with slab on metal deck
- Load-bearing CMU walls and steel joists

<http://www.engr.psu.edu/ae/thesis/portfolios/2010/slk5030>



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Acknowledgements



- **Owner** **The Upper Dublin School District**
Michael Pladus – Superintendent of Schools
Brenda Jones Bray – Business Administrator

- **A.E. Faculty** *Advisor: Dr. Chris Magent*

- **Industry** **D’Huy Engineering, Inc.**
Warren M. Gericke – Senior Project Manager

Gilbert Architects, Inc.
Brian Good

7 Group
Marcus Sheffer – LEED Consultant

- **Family & Friends**

Thank you to everyone that helped make this senior thesis possible!



The research topics included in this analysis deals with the construction of the new Upper Dublin High School. This construction of this project was approved through public referendum. For this reason, the school district needed to support of the public and thus held a variety of town meetings to view their opinions. Two of the main requests were that this building was energy efficient and can be used as a teaching tool for the students. For this reason, the Upper Dublin School District decided to pursue LEED certification. Their initial goal was a LEED Silver rating, but they are currently on track to achieve LEED Gold.

This thesis starts with a fairly thorough description of the project. This takes a look at the owner, the project schedule and site layouts. It also includes information on the phasing sequence of this project and a description of the main building systems.

This leads into my main thesis analysis. For my first analysis I have studied the impact implementing LEED on a project actually has. This takes a look at this topic through independent research and through conversation with members of the project team. This includes conversation with the owner, construction manager, and the LEED consultant.

This moves into my second analysis, an evaluation of the geothermal well system. This takes a look at this system through the expected energy reduction in comparison to traditional heating and cooling systems, as well as the costs and constructability. From here, I move into my first breadth topic. For this breadth I try to supplement the energy used by the geothermal well system with solar electric panels.

For my third analysis I take a look at implementing a small rain water collection system. Although the original intention was to supplement the water use in the building, it was found through my research that there is not the space or available money to complete this successfully. Instead, this system will be implemented with the sole purpose of educating the students. This rainwater collection system must also be relatable and cost friendly for the students to implement a similar system in their own home.

My final analysis topic deals with the evaluation of the lighting system. This analysis takes a look at the components that make up the lighting system and how they compare to other traditional lighting systems. This leads into my second breadth topic. This breadth topic deals with the replacement of the current high-output T5 fluorescent lighting with T5 fluorescent tubes.

Following all of my analysis topics are my conclusions. This includes conclusions on each of my analysis topics and the thesis in general. Following this is the summary of the main thesis investigation areas. This includes the requirement for the MAE program of the graduate classes that were used to help throughout this thesis.



Client Information

The owner of the new Upper Dublin High School is the Upper Dublin School District. The school is located in Fort Washington, PA on the site of the old, and still in use, high school. Upper Dublin is the home of the Cardinals and enrolls approximately 1,500 students with a 99% graduation rate. The mission statement can be seen written below:

"The mission of the School District of Upper Dublin is to provide a safe, supportive environment for all students to become lifelong learners and contributing members of a changing society. Additionally, UDHS works very hard to ensure that its points of pride are maintained and/or exceeded during the course of the year, including:

- *Blue Ribbon School of Excellence*
- *Graduation rate of 99.9%*
- *College Placement of 96% enrolled in post-high school education*
- *Graduates admitted to high-level and elite universities, service academics and university honors programs*
- *18 AP and 29 Honors courses*
- *10% of class achieves National Merit recognition*
- *Ranked 8th in Philadelphia Magazine's 100 Best Public and Private Schools*
- *Named best High School in Montgomery County by Philadelphia Inquirer*
- *2012 completion of state-of-the-art high school with cutting-edge instructional space"*

The purpose for the construction of a new high school is ultimately to update the old and outdated high school that was built in 1948. This new high school will add much needed space and better facilities to help reach the goals mentioned in the mission statement.

During construction, UDSD would, above all, like an on-time, on-budget project that takes special care not to disrupt students in adjacent spaces throughout the entire process. Work on a construction site can be very loud. This is something that must be taken into account as school will be in session during a large part of construction. Another goal for the owner would be to have certain spaces in the new high school available before the entire process is complete. By the end of 2009, construction of the gymnasium and natatorium was complete and ready for use by the owner.

The schedule for this project is extremely important due to the phased occupancy requirements. As part of the new building is completed and ready for use, another section of the old building will be torn down. Coordination of these activities is extremely important to ensure that the students and faculty have all the resources they need throughout the entire process.

This project was approved through public referendum. The total budget for this project is \$119 million with a four-year long construction schedule. Since this was approved through public referendum, the Upper Dublin School district wanted to give the local people exactly what they wanted. Throughout many town meetings on the subject, a majority of the requests from the public was to create an energy efficient school. This led the school district to pursue LEED Certification for the new high school building. They set their sights to obtain a minimum of LEED Silver, but are on the right track currently to obtain LEED Gold.



Main Project Team

The main project team consists of the following members:

Table 1: Main Project Team

Project Area of Expertise	Company
Owner	The Upper Dublin School District
Architect	Gilbert Architects, Inc.
Construction Manager	D'Huy Engineering, Inc.
LEED Consultant	7 Group
Site/Civil	CMX Engineering
Food Service	RMC&A
Structural	Baker, Ingram & Associates
Mechanical/Plumbing/Sprinkler/Electrical	Snyder Hoffman Associates
Acoustical Consultant	Metropolitan Acoustics
Pool Consultant	Wallover Architects, Inc.

Site Plan of Existing Conditions

The Upper Dublin High School is located on approximately 50 acres of land, north of Loch Alsh Avenue and west of Fort Washington Avenue. Bordering the site is Loch Alsh Avenue to the south, residential properties to the north, Fort Washington Expressway (SR 309) to the west, and Fort Washington Avenue to the east. The construction of the new high school requires the demolition of the existing bus garage and the old high school. This will be done in phases in order to keep the high school open during the entire length of the construction project. The site plan of the existing structures before construction can be seen in **Figure 1**, below. The overall demolition and phasing sequence can be seen in **Figure 2**. Refer to **Appendix A** for a complete, full-scale site layout drawing for each phase of construction. All existing lines for electric, sewage, etc. will be utilized for the construction of the new high school. This will limit the cost of adding new utility lines, where instead the old ones will just have to be reconnected. These utilities can easily be seen in the Utility Plans for Phase 1 and 2, located in **Appendix B**.

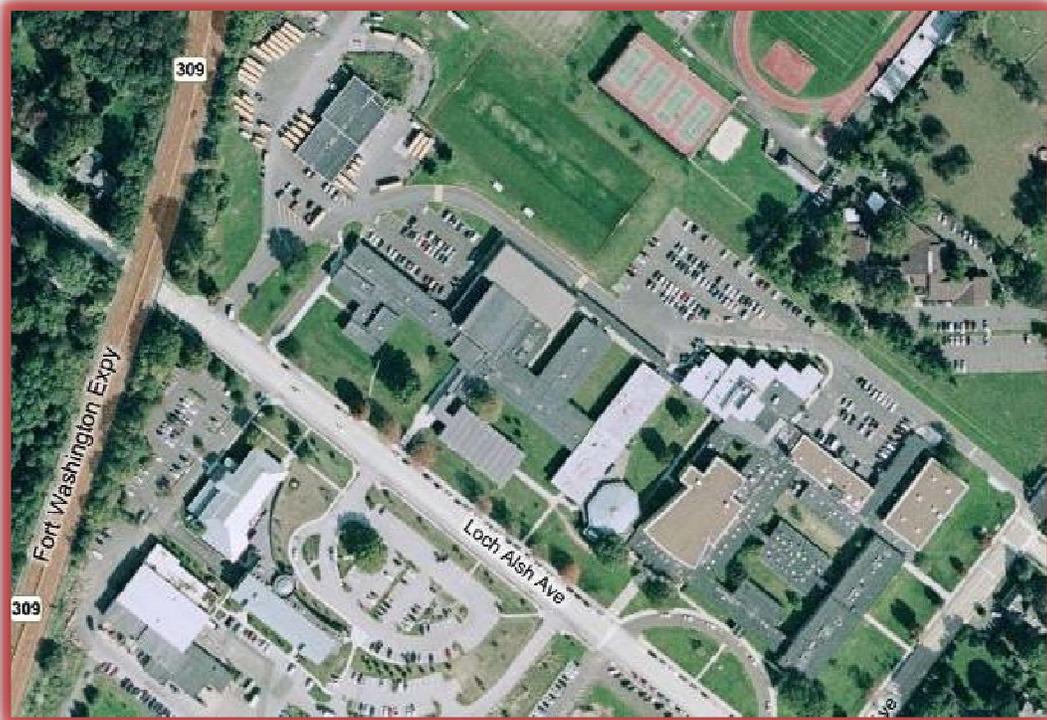


Figure 1: Existing Site Plan View

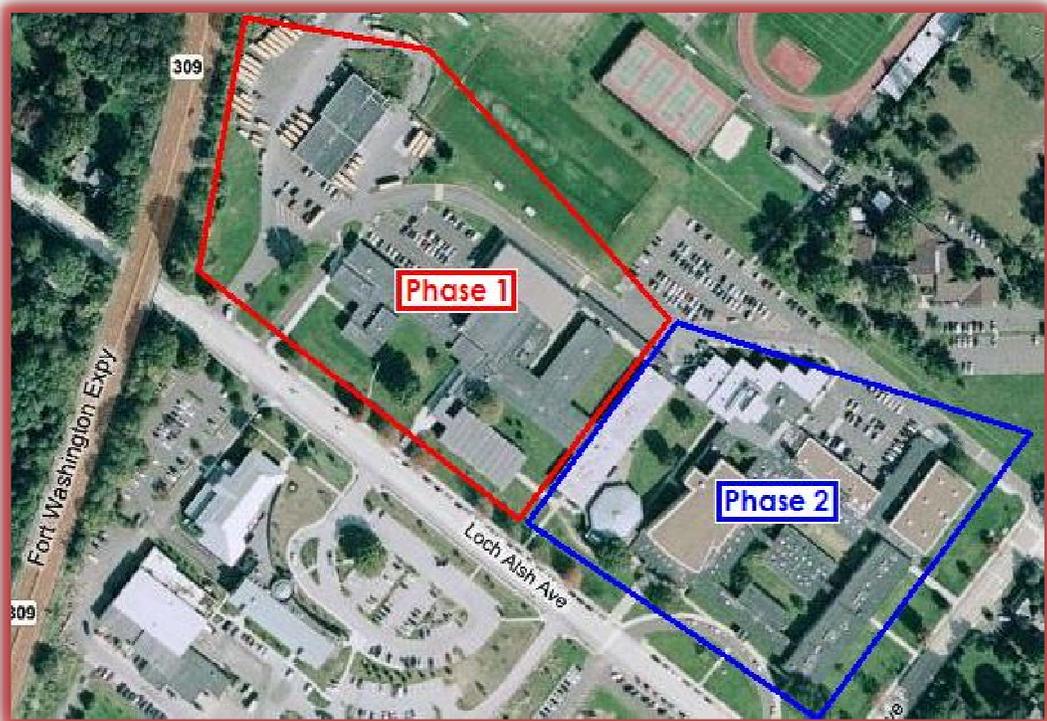


Figure 2: Existing Site Phasing Activities



Project Overview

Construction fences will border the entire site up to the old high school. Entrances for construction vehicles will change based on the phase. During Phase 1, the entrance for construction vehicles will be on the north side of the site off of Loch Alsh Avenue. Once Phase 1 is complete, this entrance will be closed and all future entrance to the site will be to the rear of the building off of Fort Washington Avenue. Since this is being built on the site of the existing high school, fire hydrants and lights are already in place. These will be moved accordingly during different phases of construction, but will stay in place as long as possible. Most of the parking for the existing high school is located in the Phase 2 area or directly across the street. This will not disrupt traffic flow during construction of Phase 1. During the second phase, more parking will have been created behind the building in the Phase 1 location. This is also where classes and sporting activities will commence, so pedestrian and traffic flow will once again not be disrupted.

Project Summary Schedule

Due to the complexity and long time frame of this project, it has been split into two major phases. These two phases are then split up into many smaller sub-phases. For this reason, creating a summary schedule makes it very difficult to really encompass the thoughtfulness and careful planning that went into this project. The project summary schedule, shown in **Figure 1**, highlights the major activities and milestones throughout the course of this four-year long project.

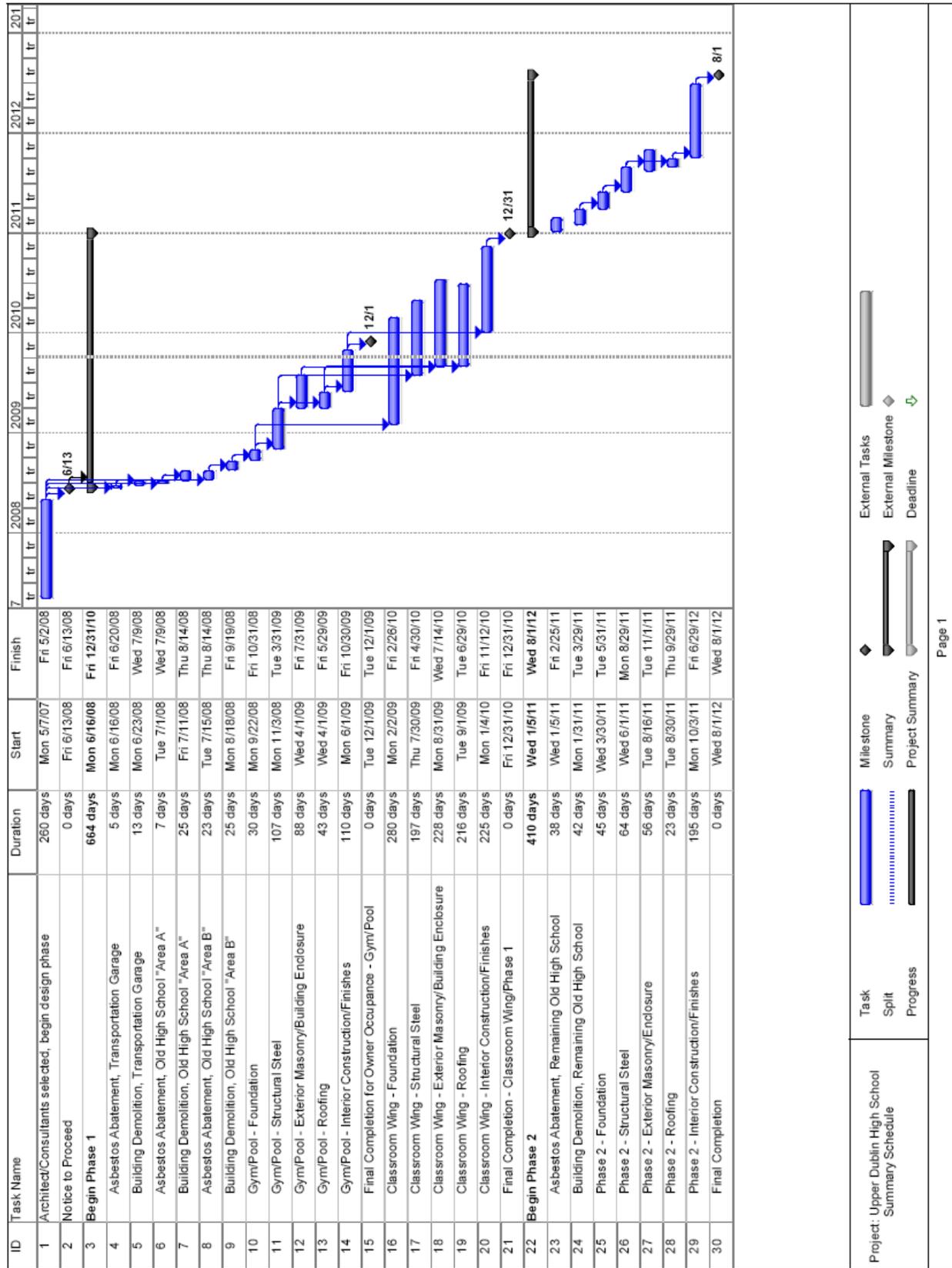


Figure 3: Project Milestone Schedule



Project Sequencing

The Upper Dublin High School Project presents many different challenges with creating an effective schedule. It requires very careful and creative planning to produce a construction sequence that satisfies the expectations of the owner, and met the needs of the students and faculty at the Upper Dublin High School. The timeline for the construction of this project will take four years to complete. Also, the location is on the site of the existing Upper Dublin High School. For these reasons, multiple phases will be needed to successfully build the new high school, while ensuring that the students have a place to attend classes.

There are two major phases for this construction project, with each containing several sub-phases. The direction of each phase will flow from the north-west to the south-east of the project site. This direction has been chosen because the existing high school is situated more towards the east side of the project site. This will leave more of the existing high school standing until sections of the new high school can be completed. As sections of the existing high school are demolished and sections of the new high school are finished, students will be able to utilize that new space to make up for what they lost. Construction has already started in June, 2008, and is scheduled for final completion in August, 2012. A graphical representation of the phasing sequence can be found in **Figure 4**, on the following page. The detailed project schedule for this project can be found in **Appendix C**.

During each stage of the process, some amount of demolition will first occur. Once that specific section of the existing high school has been demolished and removed, excavation and foundation work will begin. As the substructure is completed, the superstructure will follow. In the meantime, more demolition will take place for upcoming phases of the project. This will ensure that construction flow is continuous and smooth throughout the entire length of time. Subsequent to the superstructure is the building enclosure. This is a key step in the process, because once it has been completed and that section of the building is watertight, all interior work can commence. Interior work will start with the plumbing rough-in. This will be followed by the mechanical rough-in, and the general carpentry work. Once all the interior walls have been constructed, the electrical rough-in can begin. Finally, all interior finishes can be installed to complete that phase of the project. This process will continue in a similar manner for each phase and sub-phase of the project. The entire building has been broken up into multiple sections. This will make determining a location in the building much easier, especially when reading the schedule. A diagram of the building divisions can be found following the phasing sequence, in **Figure 5**.

Commissioning and testing will take place periodically throughout most of the construction process, with a majority of the testing happening during the second phase of the project. This can significantly save time and money on the project if any major errors do occur. Due to the sustainability goals for this project, enhanced commissioning will take place. This practice will take a much deeper look into the design and functionality of the building systems, creating a much more efficient building.

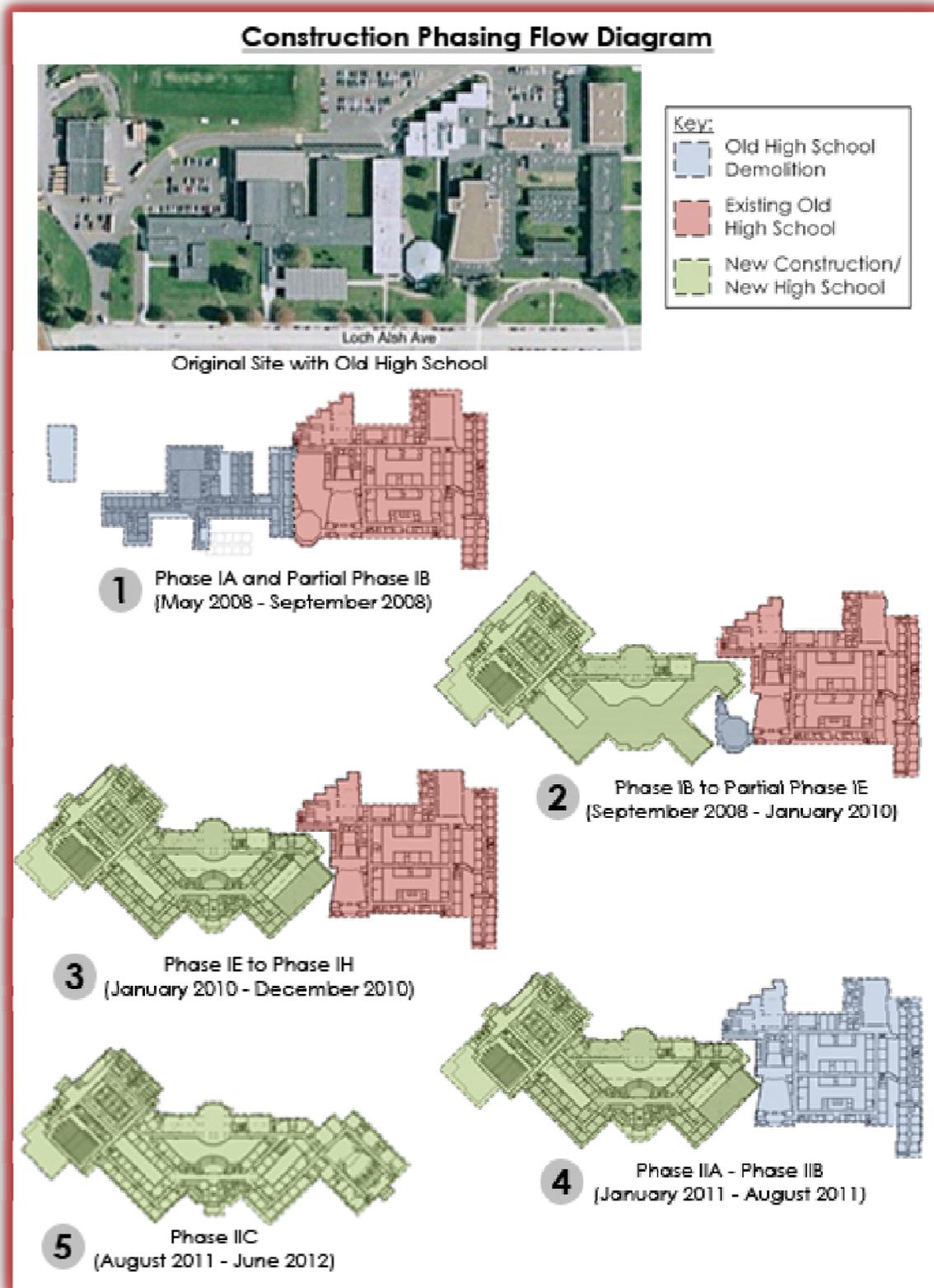


Figure 4: Phasing Sequence

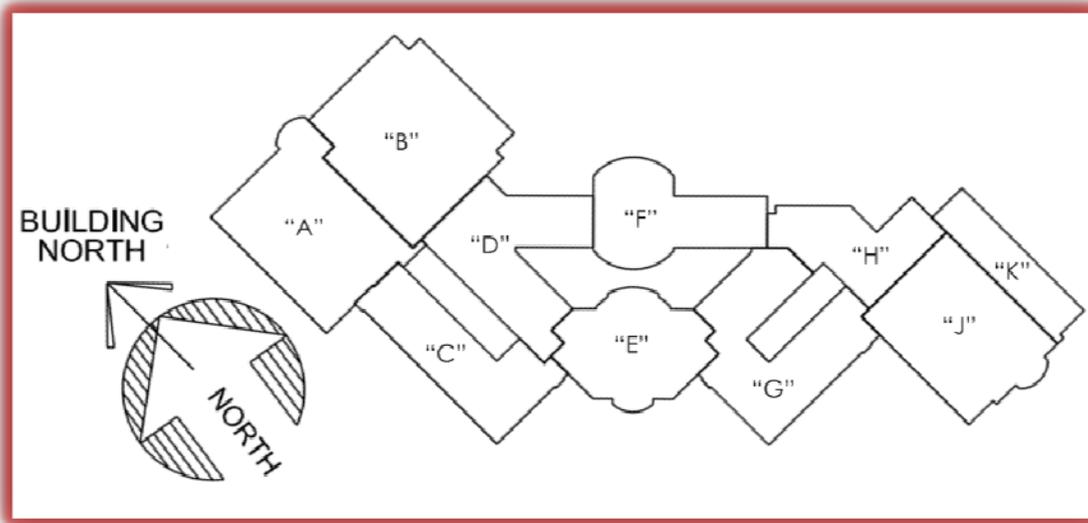


Figure 5: Building Divisions

Building Systems Summary

Table 2: Building Systems Summary

Yes	No	Work Scope
X		Demolition Required?
X		Structural Steel Frame
X		Cast in Place Concrete
X		Precast Concrete
X		Mechanical System
X		Electrical System
X		Masonry
	X	Curtain Wall
	X	Support of Excavation

The purpose of this section is to provide a description of the key aspects of the design and construction for this project. The following paragraphs will summarize each of the items used on this project contained in the above table, **Table 2**.

Demolition Required:

The construction of the new Upper Dublin High School is located on the site of the existing high school. Therefore, the demolition of the old structure is needed to make way for the new one. Since this job will take approximately four years to complete, the construction of the new school will be done in multiple phases. The first phase (Phase IA) will begin with the demolition and asbestos abatement of the bus garage and a partial section of the old high school located in approximately the north corner of the site. This



will make way for the construction of the new gymnasium and natatorium. In a similar manner, all new phases of demolition and construction will work continuously from the northern to the southern corner of the site.

Although this may seem odd to do the demolition and construction in multiple phases, this is completely necessary as to not disrupt classes for the high school students present during the length of the project. The goal with this method is to keep students in the old building as long as possible until a section of the new high school is completed. Once this is done, students will be able to utilize parts of the new building, while more demolition and construction take place. Refer to the previous section, "Project Sequencing", and the construction drawings in **Appendix A** for a better description of how this procedure will take place.

As a part of the LEED requirement, all stone and masonry from the demolition of the old building will be crushed and used as a fill material for the new high school. Materials such as metals, glass, wood, etc. will be recycled as well.

Structural Steel Frame:

The structural system of this building consists of a steel frame with load-bearing CMU block walls. Most of the structural steel contained in this building is dedicated to the floor and roof frame construction, but there are also many W-series structural steel columns located throughout the building. The structural steel members that support most of the second floor (40 pounds per square foot classroom live load) are W18x35 I beams spanning approximately 30 feet with 6 foot spacing. Typical floor assemblies are made up of one of two different assemblies. Floor construction type F-1 is 1.5 inch, 20 gage composite decking and 4.5 inches NW concrete topping with 6x6 W2.1xW2.1 WWF. This provides a total floor thickness of 6 inches. Floor construction type F-2 is 2 inch, 18 gage composite decking and 3.25 inches LW concrete topping with 6x6 W1.4xW1.4 WWF. This provides a total floor thickness of 5.25 inches. These floor types are based on the loading in that particular area of the building.

The roof construction takes on many different shapes due to its varying architectural design. There are multiple flat and curved roofs situated around the building. All roof construction consists of a structural steel frame with one of the several assemblies listed below:

- Roof Type R-1: 1.5 inch, 20 gage, Type B roof deck
- Roof Type R-2: 2 inch, 16 gage, ER2RA
- Roof Type R-3: 2 inch, 20 gage, ER2RA
- Roof Type R-4: 3.5 inch, 18 gage, EPIC ER3.5A
- Roof Type R-5: 2 inch, 18 gage, ER2R
- Roof Type R-6: 2 inch, 18 gage, ER2RA
- Roof Type R-7: 3 inch, 20 gage, Type N roof deck

As was just mentioned, the structural steel frame for the roof varies throughout the building due to its loading and architectural design. Some of the typical variations seen throughout the building are 68DLH19 bar joists above the gymnasium and natatorium spaces, and 22K5 bar joists. Depending on the structural needs, there are also a variety



of W-series I beams in certain locations. Finally, curved steel trusses were used to support and create the arched roofs found on the building.

Since this is such a large building and there are many heavy structural steel members, such as the roof trusses above the gymnasium and natatorium, a crawler crane will be used throughout construction. The western side of the building is adjacent to a main street, so the only position for the crane is on the rear side (eastern) of the building. This area will be the future site of a parking lot and a bus drop-off point, so there is more than sufficient space for the crane to move around. Also, by placing the crane here, there is no worry about the swing radius being over any area other than the construction site.

Cast in Place Concrete:

Most of the cast in place concrete on this project can be found in the foundation and first floor. The foundation is made up of spread footings that range in size from 4'x4' all the way up to 20'x20' to support either a structural steel column or a load-bearing CMU wall. These footings also range from 1' to 5' in depth. Most of the first floor is made up of a 4 in slab on grade with 6x6 - W2.9xW2.9 WWF on 4 inches drainage fill and vapor retarder. As was mentioned earlier in the Structural Steel Frame section, the second floor also has cast in place concrete on metal deck. This varies between two different floor assemblies. Type F-1 has 1.5 inch, 20 gage composite decking and 4.5 inches NW concrete topping with 6x6 W2.1xW2.1 WWF, for a total floor thickness of 6 inches. Floor construction type F-2 has 2 inch, 18 gage composite decking and 3.25 inches LW concrete topping with 6x6 W1.4xW1.4 WWF, for a total floor thickness of 5.25 inches. Depending on the location of the pour, the concrete is placed either directly from the truck or with the use of a pump.

Precast Concrete:

Precast concrete can be found on the exterior surface as a profile piece that separates the lower split face CMU façade from the upper brick veneer façade. Other than precast concrete, there is also a large amount of cast stone masonry façade populated around the many main exterior entrances to the building. It is also the material that makes up the lintels and sills above and below the windows, respectively. All of the precast concrete and cast stone masonry will be incorporated with the brick and stone façade. All surrounding joints are filled with mortar and secured to the CMU back-up wall with masonry ties. The cast stone lintels are supported with steel angles, also tied into the CMU back-up wall.

Mechanical System:

One of the more interesting features of the new high school is the geothermal heat pump system. Since the Earth holds a fairly constant temperature of around 55 degree Fahrenheit all year round, this geothermal system will provide very high energy efficient heating and cooling throughout the year. This system contains a total of 320 wells at a depth of 400 feet. The wells are separated into 20 different circuits for a total of 16 wells per circuit. Each well is made from 1.5 inch SDR 11 Polyethylene pipe and connected to a 4 inch supply and return main branch of the same material. The fluid mixture is made up of a Glycol/Water mixture of 20 percent Propylene Glycol mixture with a flow rate of 3800 GPM. **Figure 6**, below, shows a typical well assembly.

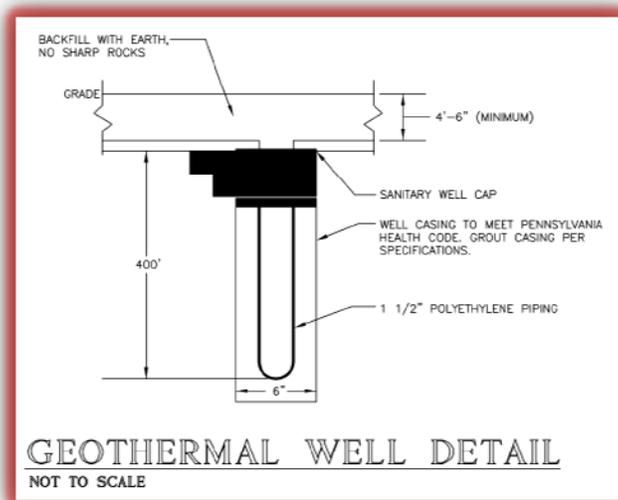


Figure 6: Geothermal Well Detail

The mechanical system also contains 11 Innovent brand Energy Recovery Units (ERU). These units help add to the efficiency of the building with the use of the enthalpy wheel. As the conditioned air leaves the building, it passes through the enthalpy wheel and, in turn, heats or cools the wheel membrane depending on the season. This wheel is constantly spinning. As it reaches the top of the unit, where the supply air flows through, the temperature of the membrane is then passed on to the incoming air. This natural process reduces the load on the building, by allowing the outside air to enter the system at a temperature closer to the indoor conditions than it would have been otherwise. There are a total of 12 Innovent brand Heating Recovery Units (HRU) throughout the building as well. These range in size from 2500-20000 CFM supply air and 2800-17000 CFM return air capacity. Most of these systems are strategically placed on the building rooftop near the location it will be serving. The remainder of the ERU's and HRU's are located in a penthouse near the gymnasium. There are several mechanical rooms located throughout the building containing heat pumps, boilers, etc. The indoor air is closely controlled through a full building Automatic Temperature Control (ATC) system along with VAV and fan powered VAV boxes.

The Upper Dublin High School has a fully automated, fire suppression system. Smoke detectors and audio/visual fire alarms are located throughout the entire building. A majority of the building, especially in all the classrooms and corridors, are equipped with quick-response concealed sprinkler heads colored to match the ceiling. This will provide a more appealing aesthetic feature instead of the sprinkler heads hanging in the open space. Due to the large size of the two floor levels, each floor is divided into multiple zones for fire protection. Each zone is fitted with a hydraulically calculated zone control valve and riser. Black steel schedule 40 piping is typical for all fire suppression lines.

Electrical:

Electrical lines are run into the building through underground power lines. Incoming power first enters a 2500 KVA 13.2KV-480/277V, 3 Φ , 4W pad mounted transformer to be



stepped down for distribution throughout the building. Once inside, power is run through multiple distribution centers around the building and distributed as 480/277V. This is then stepped down to 120/208V through multiple transformers. There are more than 90 panel boards to power lighting, receptacles, equipment, etc. around the building. Most of the building's lighting consists of surface mounted T8 and T5 fluorescent bulbs.

In case of emergency, there are two emergency back-up generators to power emergency lighting and equipment. There is one 250KW emergency generator in a mechanical room on the first floor, and one 450KW portable emergency generator located outside the building.

In order to create more efficient usage of lighting, occupancy sensors and photosensors are equipped throughout the entire building. This reduces the cost of wasted energy due to lights being left on in empty classrooms and bathrooms. This strategy is one of many used at the new Upper Dublin High School to meet the desired goal of LEED Silver Certification.

Masonry:

The new Upper Dublin High School contains a large amount of load bearing and non-load bearing CMU block as well as brick and cast stone veneer. Although many of the interior walls are made of drywall over steel studs, there are also many interior wall assemblies made up of concrete block. This can be found inside many of the large rooms such as the gymnasium and natatorium among others. Many of these walls act as bearing support for the steel structure. A typical load bearing CMU wall detail can be seen in **Figure 7**, below. The concrete block is properly secured to the steel structure with masonry ties. The masonry ties are fastened to the steel frame and inserted in the mortar joint between rows of CMU block. Masonry ties are also needed to connect the brick and cast stone veneer to the CMU backup wall. A typical corner detail can be found in **Figure 8**, below. Since the building is at a reasonable height, single-pole or swing stage scaffolding will likely be used.

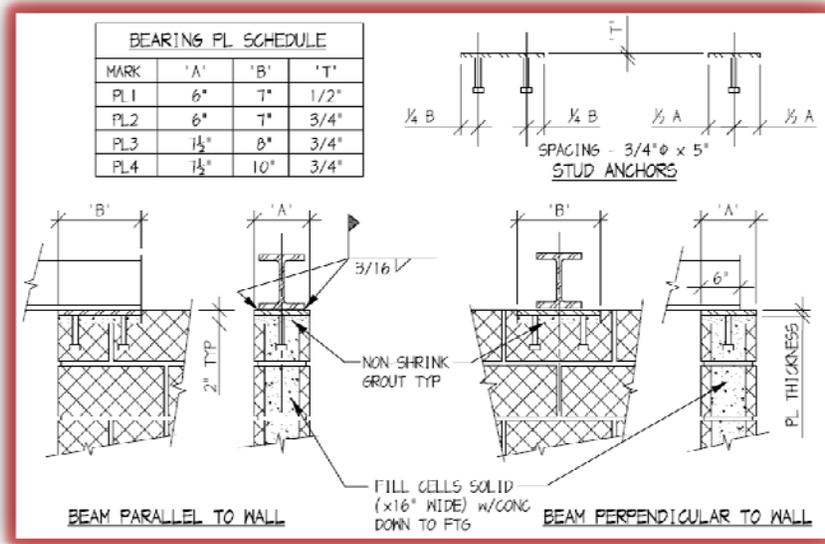


Figure 7: Steel Beam CMU Wall Bearing Details

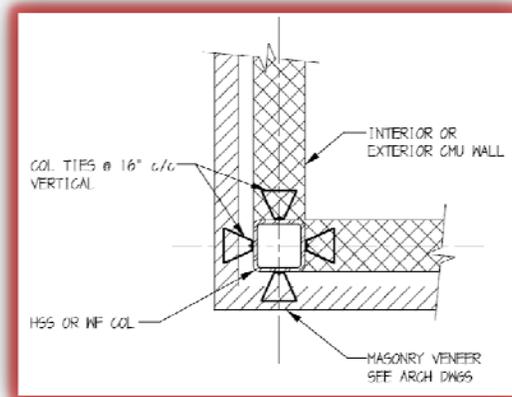


Figure 8: Col/CMU Wall Tie Detail



As what comes with the initial idea to start any construction project, the source of money to pay for the project is always a major concern. When the Upper Dublin School District decided to build a new high school, they made sure to keep the local public and their opinions in mind. This particular high school construction project was approved by public referendum and has a total project budget of approximately \$119 million. Since this was such a large amount of money, the school district held multiple town meetings to ensure that the public would get exactly what they wanted in a new high school. This would also ensure that the school district would have the support of the local community in their endeavors.



Although all the typical topics associated with the construction of a new high school, such as better and more high tech facilities, were brought up there was also a different trend. Many of the people wanted to see a much more sustainable and energy efficient building than is usually typical for high school construction. This idea comes at a very good time, as the deregulation of Pennsylvania energy rates threaten to create much higher than normal electricity bills. This frequent request from the public pushed the Upper Dublin School District to pursue an energy efficient building certified by LEED.

The idea of creating a “green” building certified by LEED adds an extra level to a project. This means more of an understanding of how all the building components work together to create one energy efficient and environmentally friendly structure. Implementing LEED into a construction project, and what comes with it, will be the main theme of this thesis. This can be found in each analysis topic and breadth study. The first analysis topic, “Analysis One – Impact of LEED on a project”, will directly address this theme.



Introduction

High-performance green buildings are becoming increasingly more popular throughout the United States. Throughout the past five years I have spent in college, the idea of integrating LEED into projects has become much more of a prominent topic each year. It can be confusing to really understand what it means to take on a LEED project. People often have much differing views on this topic and whether or not it adds value to the overall finished project. For example, I have seen that there are many people that only view LEED as a point system. When deciding to pursue LEED on a project, their initial tactic is to run through the point system and check off random points without any actual reasoning to support it. This is due to the mindset that they should assume the most amount of points possible to obtain a high rank in the LEED Certification system. There must be another, more organized and proper manner to go about this. Many other people have the impression that taking on a LEED project will, without doubt, create much more up front costs than with a non-LEED project. This view may lead an owner to steer away from this type of project and employ much less efficient, cheaper building systems. Throughout this analysis, a better solution to these topics, along with many others, will be derived.

The first question that someone may ask is why would someone want to create a high-performance green building? In the case of the Upper Dublin School District it was largely due to the opinions and requests of the public. Since this project was approved through public referendum, the school district held many town meetings to gain the local support and to make sure they got exactly what they wanted. According to "Sustainable Construction: Green Building Design and Delivery" by Charles J. Kibert, there are three primary reasons as to why this trend is becoming much more popular in the United States. The first reason is that this type of construction addresses the increasing negative issues associated with the impact our society has on the environment. It also helps to reduce the consumption of natural resources, leaving less of a strain on future generations. Another reason is that on a life-cycle costs basis, green buildings make much more sense economically. With very energy efficient systems, better windows and infiltration protection, and less thermal transmittance through the building enclosure, a green building will cost much less to operate over time than will a building that does not take these components into consideration. Also, rising energy and water costs will not affect a green building as much because it requires much less of these resources. Finally, green buildings take into account the health and well-being of its occupants. By creating an indoor environment with better air quality, people are less likely to become ill due to contamination. This also leads to less time employees will take off due to illness and a much more productive work environment. [1]

Although the reasons mentioned in the previous paragraph help promote LEED as the optimal addition to any construction project, there are still barriers holding back green building construction in the United States. Financial concerns are often at the top of this list. There is a perceived higher cost for this type of construction assumed by many people. Although some building components will cost more up front, there are also many options that will cost little or no additional costs to the project. There is limited research supporting green building projects, as well as how they benefit the end user of the building through a better indoor environment. Finally, there is a lack of awareness



Analysis One – Impact of LEED on a Project

through a continued superiority of conventional thinking and worry that there is too much risk involved. These barriers present concerns for owners with a lack of experience with this type of project. These problems are a usual occurrence until further research can be performed to verify the benefits of a high-performance green building. The following sections will look further into these benefits and associated concerns in order to get a true idea of what it means to implement LEED on a project. [2]

Analysis One Problem Statement

The following paragraph provides a reiteration of the problem statement from my thesis proposal report. These questions will be used as the guidelines throughout this analysis.

When an owner says that they want their project to be “sustainable” and obtain LEED certification, it can be unsure what this will actually entail. The question at hand is how does implementing LEED affect the overall project? Also, how does this change the project structure and timeline?

LEED School Construction Project Case Study

The U.S Green Building Council (USGBC) website offers a variety of different case studies for successfully completed LEED certified projects. During my initial research I happened to stumble upon a high school construction project of similar size to the Upper Dublin High School. The following paragraphs provide my analysis of this project as it pertains to sustainability. For a copy of the actual case study found on the USGBC website, refer to **Appendix D** [3].

The high school featured in this case study is Fossil Ridge High School located in Fort Collins, Colorado and is one of 45 schools contained in the Poudre School District. This project attained a LEED Silver rating through a variety of interesting “green” ideas and technologies. Although this is was not the first high performance building that was constructed by the Poudre School District, it was the first building to pursue LEED Certification. Among the many reasons for the school district to go after LEED certification, one of the main reasons was to provide third-party validation. This is very important, not only to the school district, but to the community as well because it helps verify that the building will perform as it was expected. Just as the Upper Dublin School District did at the start of their project, the Poudre School District sought out the opinions of not only the architects and engineers, but from teachers, maintenance, and the community to make sure they would be able to provide exactly what the people wanted.

From the case study, it appears s if there were three major concerns. These were to construct a building that was healthy, energy efficient, and can be used as a teaching tool. A healthy building was created through operable windows, carbon dioxide sensors, and low VOC paints and furnishings. Each of these add together to create excellent indoor air quality. This building is extremely energy efficient, 60% more efficient than high schools of similar size as noted in the case study. This was reached through a variety of technologies such as occupancy sensors for the lights and on the HVAC coils, heat wheels, and the creation of ice during off-peak hours to keep the building cool throughout the day. Also, some of the energy used in this building is purchased from a



wind farm to make use of reusable energy resources. Finally, all of the different technologies used throughout this building aide as a teaching tool for students. These students will be the next generation of scientists, politicians, etc. So, exposing them to these different types of technologies will influence their choices in the future to make a much more positive impact on the environment.

One other thing that was stressed throughout this case study was that there was no extra cost associated with this project going for LEED Certification. This building is very efficient on both water consumption and energy, creating extra savings for the school district. This saved money can be used more beneficially by being put back into the classroom. All of these savings can be used to buy students better equipment, books, etc.

After reviewing this case study, it appears that this project was extremely successful in meeting the requests and goals of the school district and the community. Even on such a large-scale project there were no additional costs to pursue LEED certification. By using the LEED process they obtained third-party verification and creating a large amount of savings through reduced water usage and energy consumption. These savings can be used for future expenses in the classrooms. Overall, it appears that the choice to pursue LEED had a very positive impact on both the school district and the community.

The LEED Certification Process

One of the many reasons to pursue LEED Certification for a building is that they provide third-party validation that the building performs as it was intended to. With that comes a lot of extra paperwork to document everything LEED needs to know before a building can receive its rating by the USGBC. The following steps summarize the LEED certification process. "These steps include:

1. Ensuring that the building is eligible for certification.
 2. Registering the project with the USGBC.
 3. Ensuring and documenting that the project meets the prerequisites of the applicable LEED rating system.
 4. Documenting that the project attains at least the minimum number of points to achieve at least the minimum rating, the Certified level.
 5. Submitting online to the USGBC the required documentation demonstrating that both the prerequisites and points have been achieved.
 6. If necessary, appealing points denied by the USGBC.
 7. Receiving final notification from the USGBC that the project has been certified."
- [4]

As you can see, there is a large amount of documentation that must be done. This is completely necessary, because without it the USGBC could not actually verify if this project is of LEED standard or not. This paperwork is not the burden of one individual, but is split up among the entire project team. One person, usually the LEED Consultant, is then in charge to collect all of this documentation, make sure that it is properly formatted and consistent, and submit the documentation to LEED-Online. An example of how this work is divided can be found in the next section.



The LEED Checklist and Project Team Responsibilities

One of the main components of the LEED certification process is the LEED checklist. This is, often times, used incorrectly in that it is not supposed to be thought of as a way to get as many points as possible. The LEED checklist has been carefully designed by the USGBC and should be used as a guideline to create the high performance building envisioned at the start of a project. The main thing is to first make sure that all the prerequisites are made for each category. This is mandatory for a building to become certified. After that, all the other points are completely optional. This creates the opportunity to look at the building as a whole. By doing this, you can design all the building systems to work together, rather than just going after random points for the benefit of obtaining a higher rating.

This type of design is called the Integrative Design Process. This process is a way of designing the building as to maximize the potential of all the building components by understanding how each component affects the other. For example, energy savings tactics such as lighting occupancy sensors and larger amounts of natural light were used on this project. For the purpose of this example, say that these tactics reduce energy consumption by 15%. Now, the geothermal well system can be designed 15% smaller to reflect the reduced energy consumption. This is how the Integrative Design Process works. By understanding how one component of the building affects the other, you can create a much more efficient and effective design.

As was mentioned in the previous section, the documentation needed to prove that a certain point was obtained is not the responsibility of one particular individual. Instead, depending on what building component the point relates to, that determines who has the responsibility to complete all the documentation. This doesn't make the paperwork process seem as much of a hassle as one might first believe. Usually, the LEED Consultant has the responsibility, among other things, to gather all the documentation and verify that it is complete and consistent throughout.

The checklist being used for the Upper Dublin High School project is the original LEED for Schools, which was released in 2007. The original goal of the Upper Dublin School District was to reach a LEED Silver rating for this project, but it is currently on its way to reach a Gold rating. A copy of the LEED checklist used for this project can be found in **Appendix E**. A copy of the LEED responsibility matrix for this project can be found in **Appendix F**.

Summary of Interviews

The best way to gain an understanding of the impact implementing LEED on a project is to discuss this topic with members of the actual project team. The sections below provide a summary of the comments made on this subject from three different perspectives. These are the owner, the construction manager, and the LEED consultant.

Owner

The owner of this project is the Upper Dublin School District. Speaking to me on their behalf was the Superintendent of Schools, Michael Pladus. The following paragraphs reflect the information gathered during our conversation.



At first, going for LEED Certification was not even on their list of ideas, but can be credited to the efforts and opinions of the public. This project is different from ever other project in Pennsylvania because it was passed through a public referendum. For this reason, the school district needed to gain a lot of public support. They held a lot of town meetings to try and understand what the community wanted in a new high school. Many of the local people wanted energy conservation. As a result of these meetings, the school board made the commitment to seek a minimum LEED Silver. Going for LEED Silver would also help them receive money from the state. In order for the school board to prove that it actually built this type of building, LEED Certification would be sought after. This is because LEED provides a basis of actually proving you created an environmentally friendly, energy efficient building, rather than just saying you did it.

As far as any experience goes, this is the first green building that both the superintendent and the school district undertook. This meant that some things would have to be done differently. Mainly, there are more things that have to be considered. You need to bring together all the consultants with all the engineers. You also need to provide more specialized services. It adds some things that wouldn't normally be associated with a building construction project. As far as his role on this project and what he had to do differently, the superintended represents the school district. They try to be very inclusionary with the public, since it was approved through referendum. They wanted a unique building that also met their unique educational program. They wanted to make sure their educational model drove the design of the building, but they also wanted a very green and cost effective building. His job is/was to make sure the design addresses all those needs.

There is also often a concern with additional costs associated with this type of construction. In Michael's opinion, the intention is that, hopefully, some of the extra costs can be offset with energy savings. For example, the geothermal well system, with a 12-15 year payback, can help reduce the total energy costs saving money in the long run. This is also beneficial due to the state deregulations on energy costs. Finally, when asked if he would pursue another LEED project in the future, his response was simply, "Absolutely."

Construction Manager

The construction manager on this project is D'Huy Engineering. Speaking to me on their behalf was Warren Gericke. The following paragraphs reflect the information gathered during our conversation.

One major concern for the CM on a project is how implementing something like this will affect scheduling and the overall project timeline. As far as Warren is concerned, implementing LEED doesn't change the structure or timeline of the project, but it does change the cost. By going for LEED on this project creates an extra \$1 - \$2 million dollars extra cost. This is mostly due to the paperwork. They also need a LEED consultant and need to be independently commissioned besides their own start-up and testing of equipment.

The project still has the same day-to-day activities and staffing. The crews still install roofing, masonry, etc. except that some of the materials may be more efficient and



more environmentally friendly than others. There is an increased amount of paperwork. Every submittal also has a LEED verification attached. Contractors have to add a summary to any products they use. Any data associated with a LEED product has to be submitted. This project uses LEED online. This is where all the material sheets and LEED verification papers can be uploaded. LEED looks at end of project at all the materials. LEED looks and verifies all the information before certifying a building. Also, a different skill set is not necessarily required for a LEED project. This project uses almost the same crew as a previous project with D'Huy Engineering. That project was not a LEED project, and actually had more sophisticated lighting that utilized daylight harvesting.

Finally, he had this opinion as far as the benefit of going after LEED certification for a project. All the stuff done on this project can be done without going for LEED certification. The only real difference is that you won't get the plaque to prove that you have a LEED building. One of the main benefits of having a LEED building is for marketing purposes. Having that plaque is proof that you are doing your part for the environment and that you care about it. It also gives you the ability to say you have a LEED building.

LEED Consultant

The LEED consultant for this project is 7 Group. Speaking to me on their behalf was Marcus Sheffer. The following paragraphs reflect the information gathered during our conversation.

This paragraph deals with the topic of the affect on the project timeline. This question depends on project team, mainly have they done a project like this before? This is due to a learning curve associated with LEED. If this is new to a project team, they can spend more time figuring out what is supposed to be done, rather than actually doing it. That is why there is a current market for LEED consultants. Some project teams are experienced with LEED projects and know what exactly has to be done, so it's not a big deal. By far, the biggest variable is experience, which could affect the project tremendously. There's no reason you shouldn't meet a conventional timeline.

As far as project structure, the variable is what you normally do for project structure. One example is building commissioning. If you have an owner that usually does that it doesn't change the structure. At a minimum there are three things that must be done for a LEED project: building commissioning, most of the time an energy model, and time in doing all the paperwork. Everything else is completely optional. Except for the prerequisites, the LEED checklist is a guideline for what can be done. None of this should affect the timeline, especially with an experienced team.

As far as the responsibilities of the LEED consultant, they vary considerably, and depend on what specific services are needed. On this specific project, 7 Group does energy modeling and consults for LEED. Typically, by way of a LEED consultant, they basically fill the vacuum of the knowledge of LEED and sustainability. LEED is trying to change the market. The LEED Consultant basically teaches how to apply LEED. They keep the scorecard, facilitate, schedule meetings, and advise how to implement LEED and score points. Another role is someone to review and/or coordinate the LEED documentation/paperwork. This usually kicks in at the end of the design phase or in the early construction phase. There doesn't have to be a LEED consultant. If the project



team is experienced enough and has all the capabilities, they have no need to hire a LEED Consultant. It is very rare that a LEED consultant puts together all the documentation. You need the different levels of expertise from all the different entities. One entity can't do the storm water analysis, energy model, and day lighting analysis. The LEED consultant coordinates that effort. They also make sure all the paperwork is consistent. USGBC looks for consistency, it is very important for the certification process. 7 Group also did the energy model and day lighting analysis for this project. He also said that the LEED consultant is not completely necessary for this type of project, as mentioned previously. There are, however, other necessary entities for a LEED project. These entities are a third party commissioning agent, and usually an energy modeler as the only added services.

As far as additional costs associated with this type of project, most of the extra costs associated with this type of project come from paperwork and design services. On the materials side, mostly conventional materials were used on this project. This meaning that there wasn't any certified wood, etc. used on the project that would add cost. Some other extra components used in this project are CO² sensors to evaluate indoor air quality. Also, an effort was made to optimize day lighting performance. In the end, the project was within budget, so there were no extra costs for the project as a whole.

This usually brings up the topic of payback. According to Marcus, payback is irrelevant on projects that don't have the extra money to spend. For projects that don't have a certain budget, which usually doesn't happen, payback can be compared between different types of the same building element. You can look at one component instead of the whole. This can be done with any building, not just a LEED building. It all depends on what is being used as the baseline.

When asked about pursuing LEED and what has to be done to reach a certain rating he said, that's something that you want to discover early in a project. Some people look at it for the extra money they can receive from the state. This depends first on aspirations. You should also take an early walk through the LEED checklist. This gives you conversation about different subjects that are raised. Or you can use that for deeper more meaningful conversations. This is why the LEED checklist has question marks. If you don't know that you will get that point, you can use the question mark and come back to it later. This still isn't about points, but rather the checklist helps you understand how the design will affect the overall project design. For example, rainwater harvesting effects like 7 different credits. This may narrow down what you go after. He also added, LEED is not meant to be looked at by way of how many points can be obtained. It's not supposed to be about the points, but there's a big part of market that only looks at LEED as a point hunting exercise. That is not the correct way to go about it. 7 Group uses an integrative design, which also looks a cost effective strategies. With the integrative design approach, the building is looked at as a group of individual pieces.

An example to make a building more energy efficient is to add insulation, add better day lighting, better windows, etc. They cost more up front, but save on other systems in the building. In this example, reducing the energy need by 30-40% reduces the size of the geothermal well system by 30-40%. This leaves extra money to pay for the other upgrades. People often look at this in terms of payback from energy. Since the school



district only has a certain amount of money, payback is completely unnecessary. The best way to get cost effective strategies is to figure out how one system impacts another.

Marcus seemed to have similar opinions to the owner and CM as for the benefit of LEED. He says the benefit of LEED is the difference between saying you did something and proving you did something. They provide third party certification. LEED requires you to prove that you created a sustainable building. If an owner is not interested in that then they don't have to spend the extra money and time to obtain the certification. There are many shades of green and green building design. LEED gives you a baseline definition of the shade of green.

Finally, we spoke briefly about the length of time after a project is complete until the building receives validation. In Marcus's opinion, it's too long. You have a choice to submit a chunk of credits early in the process, but this doesn't necessarily make the certification process go any faster. If you do it at the end it is a minimum 3 month process. Either way, the timeframe is the same. A lot of projects don't finish up paperwork until the building is actually occupied. There wasn't a timeframe before, but there is one now for submitting all the paperwork. For a long project you must petition the USGBC to have an extension on filing paperwork.

Final Analysis

High-performance green buildings have become increasingly more popular over the past few years. As a result of this new movement, people are becoming more interested in constructing LEED certified projects. The main reason for this analysis was to understand what it meant to pursue LEED on a project and its affects on the overall project timeline and structure.

One of the main concerns with a LEED project is that people assume that it will add extra cost. I have found this to not be true, depending on what LEED credits are sought after, and how well of an integrative design approach is taken initially on the project. The first step for an owner after deciding to pursue LEED on a project is to take an initial run through of the LEED checklist with the engineers and architect. This will give the entire project team an idea of which points should further be pursued. From there, each credit can be looked at from the perspective of how each credit will affect each other. This will help in the long run by reducing unnecessary spending on useless credits. Also, saving money through reduced energy costs, for example, on one part of the project may open the doors to better and more efficient materials for another LEED credit. This tactic of saving money in one area and spending the saved money in another area will balance out to create a net zero in extra expenses.

The only major difference as far as the project timeline is the need for a larger volume of paperwork. This is due to the very thorough documentation needed to be certified by LEED. Although this may sound like a daunting task at first glance, it is not much extra work at all. This is due to the paperwork being divided up by the type of work involved with the credit. For example, if the LEED credit involves storm water drainage, the civil engineer would likely be in charge of completing this paperwork.



Analysis One – Impact of LEED on a Project

When talking about the project structure, not much has to change. The only real difference is the addition of a LEED consultant, if needed, and a third-party commissioning agent to the project team. Other than that, all of the same crews that would normally work on a construction project would be involved. Also, a higher level of skills is not required for the laborers performing the work. Although they may be using better materials, they will still be installing roofing, lighting, etc. just as they would on any other project.

The main benefit that seems apparent from all individuals I have spoken with is that LEED is the difference between saying you built a high-performance green building and actually proving it. This shows the public that you care about the environment and are actually doing your part. It also reassures them that their son/daughter will be attending a healthier and more educational facility.

In conclusion, LEED is more than just a point system. It is a guideline to create a high-performance building that provides benefits to the environment and any person that uses it. It is the ability to prove that a building meets the expectations sought after from the start of the project, and with little or no extra costs. It is my opinion that implementing LEED on a project creates a positive impact and should be pursued on any construction project.



Introduction

As was found through town meetings prior to the design of this school and was discussed previously in Analysis One, many of the people wanted an energy efficient building. In order to give the people exactly what they wanted, the Upper Dublin School District attacked the area where a large amount of a building's energy consumption comes from, the heating and cooling system. By equipping the building with a much more efficient way of heating and cooling, especially on such a large scale, large amounts of money can be saved on yearly energy costs. Therefore, the school district decided to go with a geothermal heating/cooling system for the new high school.

Although this type of system may seem to be on the cutting edge of technology, it has actually been around for quite some time. The first instance of this technology was built by Robert C. Webber in the late 1940's, in which he created the first direct exchange ground source heat pump. This technology changed through the years as better materials, such a polybutylene pipe, were incorporated. There is currently more than one million of these type of systems installed around the world.

This type of system, even for how many are installed worldwide, still is rising in popularity. Just like any other heating/cooling system, geothermal has both pros and cons associated with it. These will be looked at in greater detail throughout this analysis, as well as the effects this type of system has on the construction and schedule of a project.

Analysis Two Problem Statement

The following paragraph provides a reiteration of the problem statement from my thesis proposal report. These questions will be used as the guidelines throughout this analysis.

What are the values of installing a geothermal well system compared to a "standard" heating and cooling method? Also, what is the expected lifecycle and payback for this particular system? Finally, how does this system affect the overall construction process, including schedule and cost considerations?

How This System Works Compared to Conventional Systems

There are three major components to a geothermal heating and cooling system. These are the heat pump, the heat source, and the ductwork to the space. The following paragraphs will explain these components.

A geothermal heating and cooling system makes use of a geothermal heat pump, also known as a ground source heat pump. This is similar to the heat pump used in a refrigerator or air conditioner, in which the heat pump moves heat from one place to another. This is often from the outside to the inside of a building. For conventional systems, the source of heat usually comes from the outside air. Based on the time of year, the heat pump will either extract heat from the outside air or put heat into it. For example, during the winter a heat pump will extract heat from the outside air before being conditioned and put into the space. This requires the heat pump to work much

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harder during periods of extremely low temperatures. This will also require the heat pump to consume much more electricity than normal.

This is where the ground source heat pump differs in that its source of heat comes from the steady temperature below the earth's surface. This temperature is fairly constant, approximately 55°F, throughout the year only a few feet from the earth's surface. This is a major advantage, especially on the extremely hot days of the summer, or the very cold days of the winter.

As was stated in the previous paragraph, a geothermal heat pump's source of heat is from the steady temperature of the earth. This requires a loop containing water, or a water/antifreeze mix, to extract the heat from. There are two basic types of loops, open and closed. An open loop system draws water from an aquifer to be passed through the heat pump. This water is then discharged back to the aquifer at some distance from the first. A closed loop consists of a water or water/antifreeze mixture that is continuously circulated through a buried pipe. The particular system used at the Upper Dublin High School is a closed loop system. This is considered to be more environmentally friendly, because the closed loop helps prevent contamination into the soil. During the winter, the cold fluid will circulate down the pipe into the earth. This will then be heated as it comes back up from the bottom of the loop. The warm liquid will then go through the heat pump and its heat will be extracted. Likewise, in the summer the liquid will be warmed from the hot air in the space. This will be sent into the earth where it will cool before coming back up to the surface. This cool liquid can then be used to extract heat from the space.

The Value of a Geothermal Well System

Throughout my research I have found a number of reasons why a geothermal system is a great choice for heating and cooling a building. As was found in the previous section, geothermal heat pumps have much better efficiency than air source heat pumps because the uniform temperature of the earth is much more consistent than air temperatures. This significantly reduces the amount of work the heat pump must do, especially during extreme high or low temperatures, thus reducing the amount of energy consumption.

Another value to this type of system is that it has much less mechanical parts and most of its components are underground. This protects the system from outdoor weather conditions, which may harm mechanical parts on conventional systems. This makes the system much more durable with a life cycle of approximately 25 to 50 years. Since this system uses much less energy than a conventional system and doesn't require the burning of coal or natural gas, it has some of the lowest CO₂ emissions of any available technology. In terms of the energy it does use, studies have shown that around 70 percent of this comes from renewable energy from the earth.

The one major downfall associated with a geothermal system as well. For one thing, it requires much more up-front costs, estimates have shown to be 2-3 times more, than a conventional heating and cooling system. These costs, however, can be recouped fairly quickly with the significant reduction in energy consumption.



Details of the Upper Dublin Geothermal System

Due to the large size of this project, a very large geothermal well field was needed to provide enough capacity to heat and cool the entire building. This was very easy for the Upper Dublin School District, because they had more than enough room on their site for a well field of such size. The location is in the north-west corner of the site under what will be part of a future sports field.

This system contains a total of 320 wells spaced at 15 feet on-center in both directions at a depth of 400 feet. The wells are separated into 20 different circuits for a total of 16 wells per circuit. Each well is made from 1.5 inch SDR 11 Polyethylene pipe and connected to a 4 inch supply and return main branch of the same material. All of these branches run into a 14" main heat pump supply and return pipe into the building. The fluid mixture is made up of a Glycol/Water mixture of 20 percent Propylene Glycol mixture with a flow rate of 3800 GPM. The location and details for this system can be found in **Appendix G**.

Summary of Interview with Construction Manager

The best way to understand the benefit of a geothermal system and its affects on a construction project is to learn from the actual individuals involved with the project. For this reason, I chose to speak with the construction manager, D'Huy Engineering. Speaking on their behalf was Warren Gericke. The following paragraphs summarize our conversation.

We began our conversation with the crew that was in charge of installing the system. According to Warren, there was a specialty contractor that did the well field drilling. They also do the testing and put the piping in he ground. The piping is brought as far as into the mechanical space of the building. From there, the mechanical crew takes over. The well field drillers were actually a subcontractor to the mechanical contractor. This strengthens the fact that you don't need special skills to work on a high performance building. In this case, there was only the need of a specialty contractor to dig the very deep wells. Other than that, the same mechanical crew completed all the work.

Our conversation moved to the advantages and disadvantages of using this type of system. One of the major advantages to a geothermal well system is that it eliminates the need for hot water boilers and chillers. This gets rid of the load on non-renewable resources. One of the major disadvantages is the increased maintenance costs of the heat pumps. There are hundreds of heat pumps in this system, one for each classroom space, etc. There is the risk of compressor failures, and much more equipment to look after. Payback has been calculated to be 15 years. It's cheaper to put in a standard system, but they use more gas/oil etc. and cost more in the long run.

Finally, we spoke about its affect on the schedule and construction process. This particular installation did not cause any delays for other work to be completed on the project. Also, this did not cause any changes to the schedule because the well field was so large and was separate from project, unlike if it was under a parking lot. The well was drilled simultaneously as they ran main underground feeders so parking lot can be



put in. Although this sounds great so far, it does come with a price. For this installation the total cost, including the well field drilling was about \$8.5 million. The well field drilling accounted for nearly one-quarter of the total cost.

Final Analysis

One of the major costs of energy for a building comes from the heating and cooling system. This is something that many of the local people wanted to see taken into consideration during the design. This led the Upper Dublin School District to implement a geothermal well system. This type of system provides many advantages over other conventional systems. For one thing, it makes use of the nearly constant year round temperature of the earth rather than the variable air temperatures as a form of heat source. By doing this, a geothermal system is much more efficient when heating and cooling a space and uses much less energy.

Geothermal systems have much less mechanical parts, and many of its components are underground, preventing and damage from exposure to weather. This makes the system much more durable, with an expected durability of 25 to 50 years. Also, since there aren't any exterior condensing units, this system doesn't create any noise other than from the mechanical space. In terms of environmental impact, studies have shown that 70 percent of its energy use comes from renewable energy from the earth.

There are, however, some downfalls to this system. There is definitely a much higher initial cost than with a conventional system. This system in particular cost about \$8.5 million including all the materials and labor. This extra cost is expected to be made back in approximately 15 years through the major savings in annual energy costs.

As far as scheduling issues, I think this depends on the location of the well field. For example, this project had a large area separate from the actual high school construction site. For this reason, drilling of the well field was able to go on at the same time as construction of the high school. All that was dependent was the supply and return piping from the well field to the building. This was done early in the project, so it had no affect on the schedule. Now, if the well field was located closer to the building under the parking lot, this would have presented a problem with the schedule. This would have delayed construction of other parts of the building until the well field was in place. Also, it would delay the finishing of the parking lot area.

In conclusion, I find that the geothermal heating and cooling system comes with many more pros than cons. It is an extremely efficient, energy saving system. It is also very durable and quiet. Although it costs much more up front, if it is within the budget of the project this money can be made back in a short time period. Finally, depending on the location of the well field on the site, the installation of this system does not create any significant change to the overall project structure and timeline.



Introduction

In the previous analysis, it was found that the geothermal heating and cooling system provides many added benefits to counteract the large initial cost of installation. This is a very efficient system, since it uses the relatively constant temperature of the Earth to transfer heat to and from the building. Depending on the time of year, the Earth can be used as either the heat source, or the heat sink for this system. It was also found that approximately 70% of the energy used by this system comes from the renewable energy of the earth. This leaves 30% of the energy coming from electricity, and opens the doors for the possibility to further reduce the energy consumption of this building. The purpose of this breadth analysis is to find a suitable system that can either replace or supplement the energy consumed by the geothermal well system.

Mechanical Breadth Problem Statement

The following paragraph provides a reiteration of the problem statement from my thesis proposal report. These questions will be used as the guidelines throughout this analysis.

During my review and analysis of the geothermal well system that will be used on the project, an alternate system can also be researched. This system must provide the same benefit expected from the geothermal well system. The main reason for using a geothermal system in this building is for energy savings. To prove that a different system is comparable to the existing one, a performance and energy analysis must be done for both systems and a comparison must be made. Total cost of implementing the system and constructability will also be taken into consideration. At a minimum, if no realistic system can be applied a supplemental system to the geothermal wells can be incorporated.

Replace or Supplement

Due to the extremely positive results found in the analysis of the geothermal well system, I have decided to keep this system as a part of my analysis. Therefore, I will look into a system that can help supplement the energy used by the geothermal well system in order to make it even more efficient than it already is.

Geosolar Systems

A geosolar system is commonly referred to a combination of heating a liquid from the energy of the earth and the sun. Usually, cool water flows through solar arrays, which heat it up and send it to combine with the heated water from the geothermal system. Although this adds more efficiency to the heating system, it does require running a lot of extra piping and can be very costly after the construction of a project is complete. Instead of using solar to make the water heating more efficient, you can also use the solar energy to create electricity. This electricity can be stored and used to run the geothermal heat pumps. In this way, it will make the system more efficient by decreasing energy consumption. With the deregulation of the Pennsylvania energy rates, any reduction in energy costs is a good enough incentive on its own.



Breadth Topic One – Mechanical

Solar electric systems convert sunlight into electricity through the use of semiconductor material. These systems, commonly referred to as photovoltaic (PV) systems, produce minimal power, but through modular expansion can adapt to electrical demands through the use of panels, modules, and arrays. PV arrays can be mounted at a fixed southern angle or on a tracking device to follow the sun throughout the day.

Renewable energy is a pollution-free producer of electricity for use in any facility system. Active solar systems also provide an excellent opportunity for educational outreach. Their non-obtrusive nature is easily adaptable to many existing facilities and the expandable characteristics of PV's allow for continual system upgrades.

This type of system is considered to be an active solar system. An active system utilizes solar gain to heat fluids or produce electricity for facility consumption. Active systems reduce the monthly heating bills and the quantity of air pollution and green house gasses created by traditional heating fuels. System selection is dependent on a number of factors including site, design and heating needs. This site has a lot of opportunity for solar electric systems due to the large amount of flat roof area. Efficiency is also impacted by quality of installation and maintenance. Minimal maintenance, approximately 8-16 hours, per year should be considered for a typical system.

Solar Electric System Selection

In selecting a solar electric system my main goal is to find a product that is very efficient and in a reasonable price range. Also, size and durability play an important role in this selection. The size is important because if a selected solar electric product is too big and heavy, this will affect the loading capacity that was designed for this building.

The particular solar panel that I have chosen to use in this analysis is the ES-A Series Photovoltaic Solar Panel from Evergreen Solar [5]. This has been found to produce the most energy, at 210 W, than many others that I have looked at. It was also one of the cheapest in terms of \$/Watt at \$3.24/Watt [6]. The technical sheet for this particular solar panel can be found in **Appendix H**.

The electricity generated from this panel would be integrated with the grid of the utility company. This is like actually selling electricity to the electric company. Since the electricity is flowing into the grid, it makes the electric meter flow backwards to reflect that energy is being produced rather than used. This is also much more cost effective than buying solar batteries to store the energy. This also is maintenance free unlike solar batteries.

Cost and Performance

When using a solar panel to supplement the energy used by the geothermal heat pumps, I had to first consider how much energy was consumed by the heat pump. There are 180 heat pumps throughout the building consuming an average of 4,000 VA for a total of 720,000 VA. The relationship between VA and Watts lies in the power factor (PF). Since a power factor for these particular heat pumps could be found, for the purpose of this analysis I will use a 0.9 PF. This means that these heat pumps consume an average of $720,000 \text{ VA} \times (0.9)$, which equates to 648,000 Watts.



With one photovoltaic panel creating 210 W of energy, this would require 3,085 solar panels. At \$680.40 each, this would cost approximately \$2.1 Million just for the solar panels. There are also other costs associated with this such as installation fees, mounting hardware, wiring, etc. This turns into a very costly addition to cover the electricity used by the geothermal heat pumps. The other problem is that this many solar panels would require such a large amount of roof space to install.

Now, you could just install enough solar panels to supplement a fraction of the energy used. At approximately 4,000 VA per heat pump and a 0.9 PF, one heat pump would use 3,600 W of energy. This would still take 17 solar panels to create enough electricity. This still does appear to be a feasible addition.

Final Analysis

The overall goal of this breadth analysis was either to replace the geothermal well system with another more feasible heating and cooling system, or, at a minimum, to supplement that system in some way. Due to the large amount of positive results from the analysis of the geothermal well system in the previous analysis, I decided to try and supplement the system in some way. In order to keep the sustainability aspect, I chose to use some form of solar energy. There were two possible ways to supplement this system with solar, either through solar heating of the fluid or through the solar electricity. Because of all the extra piping that would come with solar water heating, I decided to look into solar electricity. This would be much easier from a constructability standpoint, because all the panels would be installed on the roof and wiring could be run and connected to the grid.

In calculating the amount of panels that would be needed to create an equivalent amount of energy in comparison to the geothermal heat pumps, it was found that you would need approximately 3,085 panels. This would cost you approximately \$2.1 Million just for the panels. Also, with that many panels a large amount of the roof surface would be required. This could bring with it negative impacts as far as the structural capacity of the roof. Even considering a fraction of the energy, it would take approximately 17 solar panels to cover the electricity consumed by one heat pump.

In conclusion, supplementing the geothermal well system in terms of energy consumption with solar panels is not a feasible solution. The solar panels don't generate enough electricity per panel and do not justify the associated cost. The only benefit with adding the panels is a reduced amount of energy used by the building. With that being said, the huge initial cost would take long to make up and the roof was not designed to handle the additional loading.



Introduction

The new Upper Dublin High School has thus far taken into consideration the opinions of the public as far as creating an energy efficient building through use of many innovative technologies. Another area of concern is effective water use in a building and water conservation. The water that enters a building has been filtered and cleaned as to make it safe for human consumption. The problem is, that water use in many parts of the building and the surrounding landscape don't require potable water, or water that is safe for human consumption. For example, the water used in toilets, dishwashers, and landscaping don't require the use of potable water, but rather can utilize rainwater. The purpose of this analysis is to take a look into rainwater collection and how it would be beneficial to the overall design of this building.

Analysis Three Problem Statement

The following paragraph provides a reiteration of the problem statement from my thesis proposal report. These questions will be used as the guidelines throughout this analysis.

In order to supplement the water use in the Upper Dublin High School, what would be the most effective and cost friendly rainwater collection system to use on this project? Also, how can this be incorporated into the final design of this building? Finally, what would be the benefit of using this type of system?

Water Use Reduction Tactics

The Upper Dublin School District has taken the idea of water conservation into consideration and it is reflected in the technologies implemented into this building. They have met Credits 1.1 and 1.2 for "Water Efficient Landscaping" under the Water Efficiency category of the LEED checklist. This is a significant reduction because they have such a large amount of landscaped area on their site, especially with all the sports fields. They also created efficient water use inside the building. They implemented technologies such as waterless urinals and automatic sinks in the bathroom. This will further help reduce the amount of water used in this building. In fact, this school has also met Credits 3.1 and 3.2 for "Water Use Reduction: 20% and 30%" under the Water Efficiency category. All of these credits can be found in the LEED checklist found in **Appendix E**.

As you can see, a lot has already been done to decrease the amount of potable water used in this building. This brings with it an added benefit to implementing a rainwater collection system. With significant water reduction throughout the building, a smaller rainwater collection system can be used, thus reducing the overall cost and space that this would take up. This point led me to discussions with the owner and the construction manager on this topic.

Discussions with the Owner and CM

My discussion began with the construction manager of this project, D'Huy Engineering. Speaking to me on their behalf was Warren Gericke. Warren explained to me that rainwater collection was not considered at all during the design of this building. He said



Analysis Three – Rainwater Collection System

they already did a lot in ways to reduce water use throughout and around the building. He was unsure of the exact reason why this was not considered, but felt that it was mainly due to cost considerations and space. There wasn't a lot of room on this site to put large barrels to collect rainwater. This would mean that any system implemented would have to take this into consideration. He also felt that implementing rainwater collection would be a great idea. There is a lot of roof area to collect the water from, and the area receives a good amount of water each year.

My discussion then moved over to the owner. Speaking on behalf of the Upper Dublin School District was Michael Pladus. He also said that rainwater collection was not considered for this project. This was mainly due to added cost and space. He felt the same way as Warren that the design team implemented enough strategies to make this building very water efficient. He also added that much was done in terms of storm water management as far as quality and quantity control. This was accomplished mainly through storm water basins running around the perimeter under the school. In terms of adding a rainwater collection system to the school, he felt that it would be a great idea. His main interest in this idea is that it would be a great teaching tool for the students to learn more about water conservation. This is a very important thing, because the students are our future. The more they can take out of this school as far as what can be done to protect the environment and our natural resources, the better.

From my discussion I found out that rainwater collection wasn't a thought on this project, mainly due to costs and space. Any added rainwater collection system would have to address both of these issues. One of the other added benefits is that this system can be used as a teaching tool for the students. This was the main concern of the Superintendent of Schools, Michael Pladus. This would also have to be taken into consideration when implementing a rainwater collection system.

Rainwater Harvesting Selection

A rainwater collection system implemented into this school would have to consider three main things. These are a low cost to install, a small size, and it must be visible to be used as a teaching tool. These things being considered, I would suggest implementing small rainwater collection barrels at downspout locations in several spots around the building. This suggestion will be further researched throughout the rest of this section.

The new Upper Dublin High School is a 362,000 square foot building with a vast array of roof areas. With an average annual rainfall amount of approximately 48" [7], there are hundreds of thousands of gallons that fall from this roof each year. The problem is that collecting all this water would require a massive amount of space and a lot of added cost, which is unpractical and unfeasible. The main purpose of this system is not to collect every drop of rain that falls from the roof, but rather collect a small fraction of that to supplement water use and mainly be used as a teaching tool.

Analysis Three – Rainwater Collection System



Before a rainwater collection system can be implemented, two things must be considered. These are the type of barrel that will be used and the location. In selecting a rainwater collection barrel my three main criteria were the size, cost, and ease of use and installation. This led me to the Aquascape, Inc. RainXchange website where I found their 75-gallon capacity rain barrel, as seen in **Figure 9** [8]. This rain barrel comes in either terra cotta or sandstone and has a planter built in to the top. This will allow it to blend well into the landscape as to not make it stick out and ruin the overall appearance of the landscape. These rain barrels can be connected in series in case one of the barrels fills up. There is also an internal overflow system in case any or all of the connected rain barrels reach their maximum 75-gallon capacity. These barrels are not overly expensive either, at

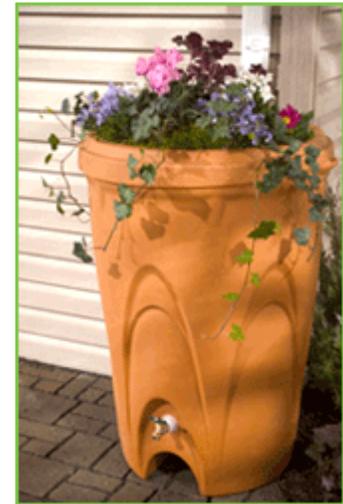


Figure 9: Rain Barrel

\$250 each [9]. Installation is also very easy. The downspout of the gutter system runs right down into a small hole in the top of the barrel. This continues to fill until it either overflows into another barrel or overflows completely, in which it is dispersed out the bottom. When the stored water is ready to be used, it can be removed from a valve at the bottom of the barrel. The Aquascape website also offers an installation guide and owners manual, which can be seen in **Appendix I**. One may ask why such a small barrel would be chosen and what the benefit of this barrel is. The main concern of this analysis was to make sure that it could be used as a teaching tool for the students, is cost effective, and is easy to install. This rain barrel meets all three of those criteria. The best thing about it is that these are reasonable for the average student to implement in their own home. This makes this type of rain barrel much more effective because it is relatable in that it is not some huge system that is completely infeasible for a student to get something out of.

The other important factor with this rain barrel is the location. The best location is somewhere around the school in which students can see these barrels from inside the building and also have access to look up close to them. That is why my suggestion for placement of these rain barrels is in the central courtyard of the school. This is easily accessible by the students, and can be seen from either the library, cafeteria, or surrounding windows. This central location is the best for all students to have access to this barrel both physically and visually. The water collected from these rain barrels can further be used by the students to water the landscape in the courtyard.

Now that the type of rain barrel and the location has been decided, the next question is how many barrels should be used. There is an average rainfall amount of 4" per month in this area. With four rain barrels connected in series for a 300-gallon capacity, this system has the ability to collect rain off of 120 square feet of roof area per month. In order to make sure that only this amount of roof area contributes to the rainwater runoff in an attempt to direct the other runoff into the storm drainage system, a small portion of the roof can be sectioned off to redirect this water to the rain barrels. The only other extra requirement that would be needed is a small amount of guttering to transport the rain water directly into the rain barrels. The following figure, **Figure 10** shows the proposed layout of this system.

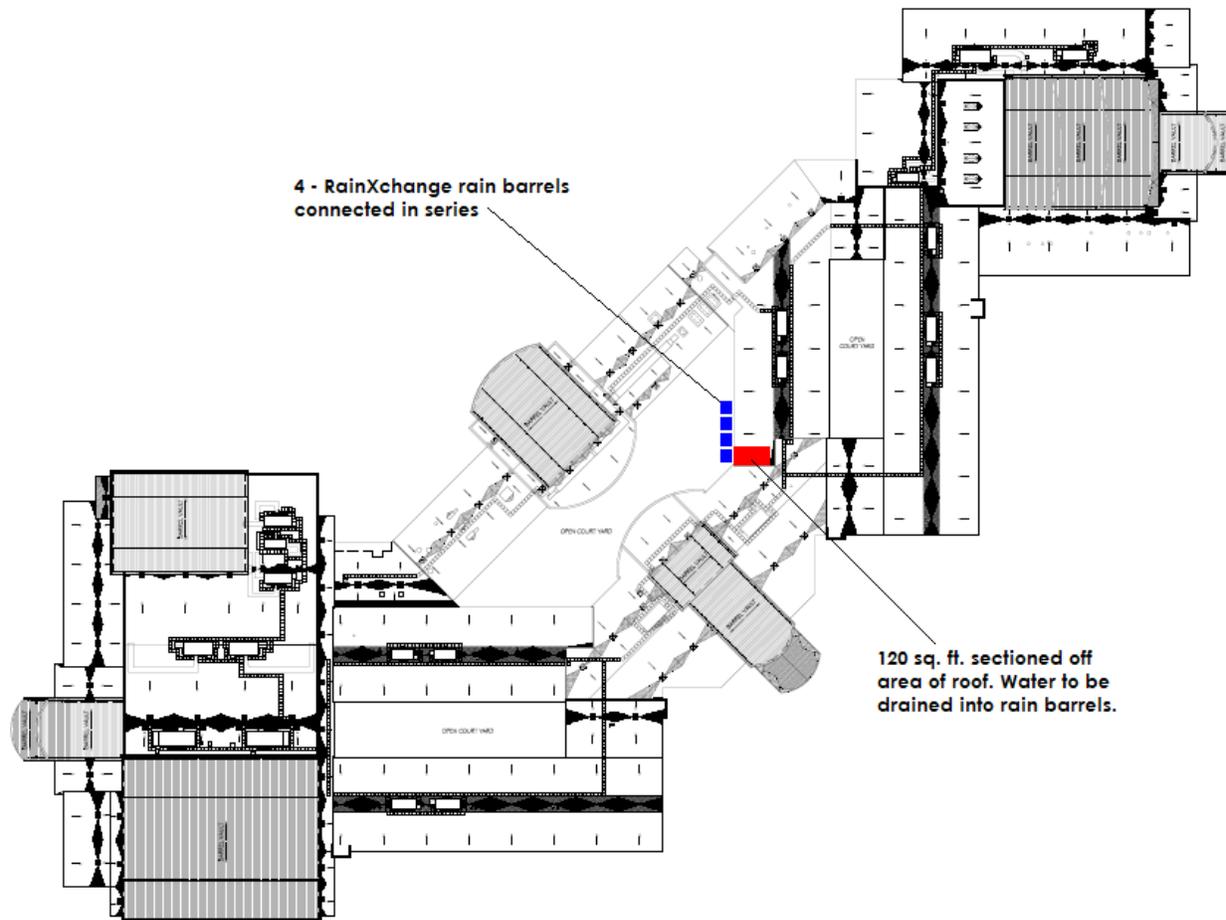


Figure 10: Proposed rain barrel layout

Final Analysis

In conclusion, the large amount of roof area has the potential to collect a vast amount of rainwater that can further be used throughout this building and in the surrounding landscape. The designers for the Upper Dublin High School has already done a great job in reducing the amount of water usage throughout the building by including waterless urinals and automatic faucets in the bathroom. They have also reduced the water needed for the landscape by more than 50 percent. In order to further increase the water efficiency of this building I chose to look into rainwater harvesting.

After discussions with both the owner and the construction manager on the project, I found out that rainwater harvesting was not considered mainly because of the extra cost and the small amount of space to include a large rainwater catchment system. They did, however, think that rainwater collection would have been a great thing to add as far as education for the students. For these reasons I chose to look into a small rainwater catchment system that was affordable and with the main purpose of providing education for the students of this school.



Analysis Three – Rainwater Collection System

This was accomplished with the use of four 75-gallon capacity RainXchange rain barrels. At only \$250 each, these are affordable and feasible for a student to implement in their own home. This was thought to be a great teaching tool for the students because it is relatable and not something that was out of their price range. These rain barrels were positioned in the central courtyard of the building in an area that is accessible and visible for all students. The only added costs other than that of the rain barrels is to install a small amount of guttering and section off a portion of the roof to direct the flow of water into these barrels.

Overall, although it wasn't feasible to implement a large rainwater collection system to supplement and reduce the buildings water use, it did meet the goal of providing an educational tool for students. In the end, this is one of the most important aspects of this building, since this is meant to be a place of learning. This gives the students something sustainable that they can recreate in their own homes.



Introduction

According to the U.S. department of energy, lighting loads currently consume 40% of a building's energy. This is the same amount of energy that is consumed heating and cooling the building. Reducing this load has the potential to have a significant impact on the total energy consumption of the facility. Therefore, this was a critical area to consider during the design of the lighting system for the new Upper Dublin High School. By implementing efficient lighting in this building, the Upper Dublin School District will have the potential to further save money on annual energy costs. With the state deregulations in the energy rate caps, this may have much more of an impact in the future.

Analysis Four Problem Statement

The following paragraph provides a reiteration of the problem statement from my thesis proposal report. These questions will be used as the guidelines throughout this analysis.

How efficient and how much energy savings can be expected from the lighting system used in the Upper Dublin High School? How does this system compare to other lighting systems used in buildings today?

Lighting System Details

The main lighting type used throughout the classrooms of this school is energy efficient, high-output T5 linear-fluorescent lighting. The manufacturer for this lighting fixture is Finelite. More specifically, the catalog number for this light fixture is S12-8'-2T5HO-SC-EP-277-AC18"-CE. This following list breaks down this catalog number to further describe this fixture.

- **S12** – Finelite Series 12 model
- **8'** – 8 feet section length
- **2T5HO** – Total of two high output T5 fluorescent bulbs per fixture
- **SC** – Single circuit
- **EP** - Extended Performance Reflector System
- **277** – 277 voltage
- **AC18"** – Semi-adjustable aircraft cable mounting system spaced at 18"
- **CE** – Curved end cap

This information comes from the technical sheet provided by the Finelite website. To take a look at this Technical Sheet, please see **Appendix J**. The high output T5 lamp is said to have the highest efficiency than any other comparable T8 and T12 lamps. This will be looked at in greater detail in the following sections.

This is not the only component that makes up the lighting system. Each classroom is also equipped with occupancy and daylight sensors. The occupancy sensors do just as their name describes. They sense when a room is occupied. This makes the lighting system much more efficient because it removes the possibility of lights being left on in the room when it is unoccupied. That would be a major waste of energy, so the occupancy sensors help address that.



The daylight sensors are similar to that of the occupancy sensors, except that they sense when there is enough light present in the room from natural day lighting. According to the LEED checklist for this building, this school meets the criteria for Credit 8.1 – “Daylight 75% of classrooms”, and is currently unsure whether they meet the criteria for “Daylight in 90% of classrooms.” Refer to **Appendix E** for the LEED Checklist used on this project. This is a huge energy saver, because most of the classroom space will be used during the daytime hours. By allowing a large amount of natural light to enter these classroom spaces and powering off lights during this time, even less electricity will be used by the lighting system. All of these components working together create the main lighting system for the classroom spaces in this school.

Efficiency, Savings, and Industry Comparison

The T5 lighting used in this building is considered to be some of the most efficient fluorescent tube lighting in the industry today. This is said to replace the most popularly used T8 fluorescent tube lighting. Both of these types replaced the much older T12 fluorescent lighting. One may ask what the difference is between T8 and T5 lighting, as well as how they compare in terms of cost and efficiency. The following paragraphs will address these issues.

The first question may be what “T8” and “T5” actually stand for. The “T” in this abbreviation is for the tubular shape of the bulb. The number refers to the size of its diameter in eighths of an inch. A T8 bulb is 8/8” or 1” in diameter, whereas a T5 bulb is 5/8” in diameter. Other than a difference in diameter, they also have a difference in length. A T5 bulb is slightly shorter than a T8 bulb. For this reason, a T5 cannot directly replace a T8. This means that it requires a slightly different sized fixture. Another major difference is that T5 bulbs require a smaller bi-pin socket and a different ballast to operate. In comparison of a T12 and a T8, the only real size difference is in the diameter. Other than that, the pins and lengths are the same. As you can see, replacing a T8 fixture with a T5 fixture can cost significantly more than going from a T12 to a T8.

In terms of how they compare by performance, a 2-light T5 fixture will typically produce more light than a 3-light T8 fixture. One major advantage that stems from this is that by having more light produced, a lesser amount of fixtures will be needed to provide the same amount of light. This is very beneficial on large projects, because this can save a lot of up-front costs and energy. The other advantage is that you will need less lamps with a T5 fixture.

The question of cost and efficiency is also very important when trying to consider between the T5 and T8 fixtures. The life cycle of both of these bulbs are measured to be about the same, 20,000 hours. This depends on factors such as the amount of times the light is switched on and off throughout it's life cycle. If you leave the light on for longer periods of time, it will last much longer. This presents a problem with the sensors in the room. They will cause the lights to be turned on and off more times than if this has to be done manually.

In terms of cost, T5's are approximately 3-4 times that of a T8. This extra cost should be justified by much better efficiency. The following table, **Table 3** displays several different factors that help determine the efficiency three different fluorescent lighting types.



Analysis Four – Lighting System Evaluation

These factors include (1) The Color Rendering Index (CRI), which represents the quality of light on a scale of 0-100; (2) The Efficacy measured in lumens per watt, which measures the quantity of light; (3) the Co-efficiency of Utilization [10].

Table 3: Lighting Efficiency Comparison

Lamp Type	Color Rendering Index (CRI)	Efficacy (lumens/watt)	Co-efficiency of Utilization (CU)
T12	62	78	0.46
T8	85	92	0.76
T5	85	103	0.90

As you can see from **Table 3** the T5 bulb is the most efficient out of the three. In relation to the T8, the T5 bulb is only 9.0% more efficient. This does not seem to make up the large difference in pricing, but, as was mentioned earlier, the higher light output of the T5 lamps mean less total fixtures than with a T8 lamp. Depending on the size of the project, this can help make back much of the extra money.

In the end, the use of high output T5 lighting, occupancy sensors, and daylight sensors work together to significantly help decrease the amount of energy used from lighting costs. This reduction in lighting load also means the load on the HVAC system will be reduced since the fixtures are not producing as much heat. Obtained from industry averages for this kind of set-up, it is estimated that the combination of technologies used in this lighting system will decrease the overall lighting load by up to 80% compared to standard switching controls.

Final Analysis

One of the major areas of energy usage in a building comes from the lighting system. This can contribute up to 40% of a building's energy use, which is the same amount as the heating/cooling system. This creates the opportunity for savings through a creative lighting system design. The purpose of this analysis was to analyze the main classroom lighting system used in the new Upper Dublin High School in terms of its efficiency and how it compares to other typical industry lighting systems.

The main classroom lighting system used in this high school is made up of high output T5 fluorescent lighting. Typical of each room are a total of six 8' long, two-lamp Finelite fixtures. Complimenting the light fixtures are automatic lighting controls: occupancy and daylight sensors. The daylight sensors are used to measure the amount of daylight present in the room. When it reaches an optimal level, it reduces the artificial lighting in the room, thus saving electricity. The occupancy sensors work in the same manner by shutting off the classroom lighting when the room is not occupied. Together these components are meant to create a highly efficient, energy saving lighting system.

In terms of other typical industry lighting, the T5 lamps used in this school are meant to replace T8 lamps. When comparing these two types of lamps, many pros and cons were found as to justify whether or not T5's are a better, more economical choice. As to the physical differences between these two, T5 lamps are slightly smaller than T8 lamps.



Analysis Four – Lighting System Evaluation

T5 bulbs also require a smaller bi-pin connection and ballast to operate. This means that a T5 bulb cannot directly replace a T8 bulb. In terms of performance, a two-lamp T5 fixture will produce more light than a three-lamp T8 fixture. The initial rated light output of a high-output T5 is 5,000 lumens, whereas for a T8 fluorescent it is only 2,950 lumens [11]. This leads to smaller fixtures and a reduced amount of lamps, saving money on both electricity and material cost. Although this can save a lot on larger projects, this doesn't seem like a reasonable solution for a smaller project. This is because T5 lamps cost 3-4 times as much as a similar sized T8 lamp, and is only 9% more efficient with the same 20,000 hour life cycle.

In conclusion, the entire combination of the high output T5 fluorescents, the occupancy sensors, and the daylight sensors work together to decrease lighting loads by up to 80% compared to standard switching controls. This will further help the Upper Dublin High School save money on annual energy costs. Overall this seems to be an extremely efficient lighting system.



Introduction

The previous analysis of the current lighting system used in this high school was found to be overall very efficient. High output T5 fluorescent lighting offers efficient performance while requiring a lesser number of lighting fixtures than with previous T8 fluorescent technology. The question at hand is, what other lighting technologies are available today on the market? Perhaps there is an even newer technology than T5 fluorescents that will eventually make them obsolete in the lighting industry. The main goal of this breadth analysis is to take a look outside the standard lighting option of linear-fluorescent tubes and find a suitable replacement.

Lighting/Electrical Breadth Problem Statement

The following paragraph provides a reiteration of the problem statement from my thesis proposal report. These questions will be used as the guidelines throughout this analysis.

Analyzing the current lighting system in the Upper Dublin High School brings with it the possibility of a different, more efficient system that could have been used. An alternate lighting system will be considered during the analysis of the current lighting system. This will require calculation of lighting loads throughout the building that will be consumed by this alternate system. This breadth will make use of the topics and ideas learned during the lighting electrical classes.

Alternative Lighting Selection

There are many different ways to light a space. The problem is finding the most suitable replacement for this particular classroom space. As was mentioned in the previous analysis of the lighting system, this school utilizes two-lamp, high-output T5 fluorescent lighting in these spaces. Throughout my research, my two main criteria for selection was a product that (1) made sense price-wise as a suitable replacement, and (2) did not create a large amount of work or time to replace. Both of these criteria were thought to be met when I came across LED fluorescent tubes. This type of lighting mimics that of the current fluorescent tube lighting, except it contains LED's in the tube rather than a gas. Therefore, this technology will be used as the basis for a replacement of the current classroom lighting. The particular lighting selection used for this analysis will come from EarthLED products [12].

About LED Fluorescent Tube Lighting

As was just mentioned in the previous section, LED fluorescent tube lighting mimics regular fluorescent tube lighting, except that it utilizes LED's on the inside of the tube rather than gas. This comes with many added benefits compared to traditional fluorescent tube lighting. For one thing, the lifespan of LED tubes are estimated to be 50,000 hours. This far exceeds the average 20,000 hour lifespan of fluorescent tubes by 2.5 times. Another major advantage of LED tubes is that they do not require a ballast to run. This will further help to decrease energy usage and future maintenance costs. LED tubes start instantly and provide continuous, flicker-free light as is associated with fluorescent tubes. Also, LED tubes are not temperature sensitive and do not contain any



mercury as does traditional fluorescent tubes. Finally, the amount of energy consumed by LED tubes is significantly lower than in the high output T5 fluorescents. A 4-foot EarthLED LED tube will consume 12 watts of power, whereas a high output T5 will consume a nominal 54 watts power. This is a huge advantage for LED tubes because it can help to further decrease the lighting load on the building and save the Upper Dublin School District more money.

With the advantages come some disadvantages. One of the major disadvantages I have seen is that the lumens, or amount of light produced by the light, are significantly lower in LED tubes than in the high output T5 fluorescents. This means that it will take more LED tubes to create the same amount of light as the high-output T5 lighting. Another disadvantage is the initial cost for LED tubes. For the particular product being used for this analysis, one 4-foot T5 LED tube replacement will cost about \$75. This is approximately 8-10 times the cost of regular T5 fluorescent tubes. These get much cheaper as you buy in bulk, where a 4-pack of the same LED tubes will only cost about \$260. Surely this cost must be justified to suggest LED tubes as a suitable replacement.

LED Tube Replacement

One of the main reasons I chose these LED tubes as a replacement for the current high-output T5 fluorescents is that they can be used in the same fixture with a few wiring changes. This is a major money saver in that all the school district would need to buy is the actual lamp, instead of the lamp and a fixture. Since the LED tube does not require a ballast to run, the ballast in the current light fixture would need to be disconnected and bypassed. Then, the LED tube can be inserted into the same mini bi-pin piece and be turned on. This is another huge money saver, because this work will only take a very short amount of time to do and can be done by the maintenance staff at the high school. This gets rid of the extra cost of hiring an outside electrician to do this work. The EarthLED website offers instruction on rerouting the wiring for the fixture in their installation guide. This can be found in **Appendix K**.

Load Reduction and Cost

Replacing the current high-output T5 fluorescent lighting with LED tubes has sounded very convincing up to this point. This section will take a look at some of the more important factors that will determine whether or not this is a suitable replacement.

One advantage that LED tube manufacturers try to push is the amount of energy savings that they create. The following table, **Table 4** compares the amount of energy savings that would be created.



Table 4: T5 Fluorescent vs. LED Tube Energy and Cost Savings Comparison

Energy and Cost Savings Comparison			
	Lamp Type	HO T5 Fluorescent	T5 LED Replacement
1 lamp	Power Consumption (W)	54	12
	KWH/Year ¹	157.86	35.04
	\$/Year ²	23.65	5.26
Classroom (4 lamps per fixture, ≈6 fixtures per room)	KWH/Year	3789	841
	\$/Year	568	126
Building (≈117 classroom spaces)	KWH/Year	443,271	98,392
	\$/Year	66,409	14,770
Total Savings	KWH/Year	-	344,879
	\$/Year	-	51,639

As you can see from the table, replacing the high-output T5 fluorescents with the T5 LED tubes producing significant savings in energy costs per year. The next concern is the payback time for the extra cost of the LED tubes. In calculating simple payback, a price of \$260.00 will be used for a 4-lamp set [13]. With approximately 117 classrooms and 24 lamps per classroom, this results in 2808 total lamps, or 702 sets of 4 for a total of \$182,520. With an average annual savings of \$51,639 per year this leads to approximately 3.5 years payback. According to the **Table 4**, the amounts were calculated using 8 hours run time per day for 365 days per year. With the average 50,000 hour lifespan of the LED tubes, this results to just over 17 years of service. With this length of service and only a 3.5 year payback this definitely seems to be a very positive investment.

The other major concern beside the amount of savings and payback is the quality and amount of light produced by each of these lighting types. As is found in the previous analysis, a high-output T5 fluorescent has an initial light output of 5,000 lumens. In comparison to the T5 LED tubes this is significantly higher, since it only produces 900 lumens of light per lamp. This major difference will create a much dimmer and possibly less than desirable environment in the classroom. Because of this, a greater amount of the LED T5 tubes would be needed to produce the same amount of light as one high-output T5 fluorescent. This results in extra fixtures, bulbs, and wiring by a professional electrician adding significant cost to this replacement.

¹ Calculation is based on 8 hours run time per day for 365 days per year.

² Calculation is based on an average Pennsylvania electric rate of \$0.15 per KWH.



Final Analysis

In an effort to increase the already very efficient lighting system used in the new Upper Dublin High School, I chose to look into a more efficient lighting type. This replacement would have to be a new technology that would make replacement easy and cost effective. For these reasons, I decided to use T5 LED tubes as my replacement option. This lamp was compared to the current high-output T5 fluorescents through a variety of criteria. The following paragraphs summarize my analysis.

LED tube lighting offers a lot of advantages in comparison to fluorescent lighting. It has a much longer life, is mercury free, and uses a significant lower amount of energy. Also, LED lighting is flicker-free and does not require the use of ballasts. This further saves on energy and costs, as ballasts can be expensive to replace. LED tube lighting can be installed in the same fixture as fluorescent lamp. The only change that needs to be made is that the ballast must be bypassed because it is not necessary. This is a very simple procedure that can be done by the schools maintenance crew in a short amount of time. This will remove the extra cost associated with hiring an electrician. Once the wiring changes are complete, the LED tube can be placed in the same fixture as the old fluorescent lamp. This will further save money by reusing the old lighting fixtures.

In comparing energy savings, it was found that by replacing the fluorescent lights in the classrooms with LED lights approximately \$51,000 can be saved annually in electric costs. This large amount of savings will help to cover the very expensive price of the LED lamps in about 3.5 years. With an estimated lifespan of over 17 years, the LED replacement tube looks to be the most reasonable choice.

The problem, though, lies in the amount of light produced by the two different lights. The rated light output for the high-output T5's is 5,000 lumens, whereas for the LED's it is only 900 lumens. This is significantly lower, which will create a noticeable difference in the brightness of the room. In order to combat this difference, more LED tubes would be needed, thus increasing the amount of fixtures, lamps, wiring, and ultimately the cost.

In conclusion, I find that LED fluorescent tubes offer many more advantages than disadvantages. One of the most important things to point out is the incredible amount of money that would be saved if using this technology. That being said, I think that LED technology is on its way to replace fluorescent lighting in the future, but is not quite there yet.



In conclusion, the main theme of this thesis report was the idea of sustainability. Since this building is pursuing LEED certification, specifically a minimum of LEED Silver, they have implemented a lot of new and innovative technologies into the building. Of the many goals of this project, some of the main goals were to create an energy efficient building that would be extremely educational for the students. I feel that with all the different technologies implemented into the design of this building, they have successfully accomplished this goal.

My thesis is made up of a variety of different analyses. My first analysis was of the impact implementing LEED on a project has for the overall project. This was accomplished through independent research and interviews with multiple facets of the project team. From my research, LEED was found to be a very beneficial thing, but I felt I obtained better and more valuable results by speaking with people actually associated with this type of project. Their opinions of LEED were very similar in that they all had a positive experience thus far and would definitely pursue this type of project in the future. As far as how LEED impacted the project, most of the extra work associated was the increased amount of paperwork. There was no major difference in scheduling or the knowledge of the craftsmen working on the project. Finally, since this project had a set budget there was no added expense to implement LEED.

My second analysis dealt with an evaluation of the geothermal well system. It was found that the only real specialty work needed to be done was by the company that drilled the holes for the wells. Other than that it was just the usual running of piping into the building and distributing that to the mechanical equipment. This is also a very efficient system, with approximately 70% of the electricity used coming from the earth. This will significantly reduce the overall energy consumption of the building. This type of system had no effect on scheduling that resulted in delays. This was partially due to the geothermal well system location away from the actual building. This allowed the crew to work on the geothermal well system while other work was being completed on the high school. This may not be the case if the geothermal well system was located closer to the building under a parking lot, for instance.

This brought me to my first breadth topic. In this breadth analysis, I tried to supplement the electric consumption of the geothermal heat pumps by installing solar electric panels. This analysis proved to be unsuccessful in that the cost and amount of solar panels needed to even cover the electric usage of one heat pump was impractical. These types of solar panels are better suited for smaller buildings and to combat items with smaller electric consumption, such as the lighting.

For my third analysis I looked into implementing some sort of rainwater collection system to supplement the water usage in the building. Much has already been done by the design team, such as implementing waterless urinals and automatic faucets in the bathroom, to create an efficient use of water throughout the building. When discussing this idea with the owner, I found out that the main reasons why rainwater collection was not implemented was due to added costs and not enough area to store a collection tank. He did say, however, that rainwater collection would be beneficial to be used as a teaching tool for the students. I feel that I successfully accomplished this by implementing four 75-gallon capacity rain barrels into the central courtyard of the



school. These rain barrels are inexpensive and a relatable for the students in that they can be purchased and implemented into their own homes. This would be a great way to take something they learned from the school and use it in their daily life.

My fourth analysis dealt with an evaluation of the lighting system. The lighting system at the Upper Dublin High School was found to be very efficient. This system utilized high-output T5 fluorescents along with daylight sensors and occupancy sensors. One major component of this analysis was a comparison of the T5 fluorescents to the T8 fluorescents. As a result of my analysis, it was found that the high-output T5's were slightly more efficient than the T8's but this efficiency did not justify the extra cost.

The analysis of the lighting system brought me into my second breadth topic. For this breadth topic I decided to find a suitable replacement for the T5 fluorescents. This was accomplished through a comparison of implementing T5 LED tubes. The LED tubes could be installed in the same fixture as the T5 with a small change in the wiring. This was necessary due to the fact that LED lights do not require a ballast to run. The LED lights are much more expensive than the T5's, but they made that up quickly with the significant reduction in energy costs. The only real problem with this was that the amount of light produced by the LED's was significantly smaller than that of the high-output T5 fluorescents. This would require a larger amount of fixtures to create the same amount of light, thus adding to the costs.

Overall, I feel that my thesis was very successful. The main intention of my thesis was to learn about the idea of sustainability on projects and take a look into some of the technologies implemented. The research performed throughout this thesis allowed me to look at real world applications of these technologies and to compare them to other technologies. This will help me with my future career, as it provides me with some basis of knowledge in multiple aspects of the construction industry.



Summary of Main Thesis Investigation Areas

Weight Matrix

The following weight matrix describes how much of my thesis focuses on the following four areas: Critical Issues Research, Value Engineering, Constructability Review, and Schedule Reduction. The percentages represents how much time was estimated to be spent in each area for each analysis topic.

Description	Research	Value Eng.	Const. Rev.	Sched. Red.	Total
Analysis One	10%	8%	5%	5%	(10 to 40%)
Analysis Two	10%	5%	7%	6%	(10 to 40%)
Analysis Three	5%	5%	7%	5%	(10 to 40%)
Analysis Four	5%	5%	7%	5%	(10 to 40%)
Total	(10 to 30%)	(10 to 30%)	(10 to 30%)	(10 to 30%)	100%

Critical Issues Research

The critical industry issue that has been researched throughout my senior thesis studies is sustainability in the construction industry. This is increasingly becoming a more important topic of discussion for projects and is being incorporated into the design more often than ever before. This topic is particularly close to the project I studied due to the goal of the Upper Dublin School District to obtain LEED Certification, more importantly LEED Silver, for the construction of the new Upper Dublin High School. This is a critical industry issue due to the extra level of discussion and planning it creates for a project. New ideas and technologies will now have to be considered rather than creating cookie cutter type projects with less than efficient systems and designs. All of my analyses are connected through this idea of sustainability. Most importantly, Analysis One looked at this critical industry issue from the standpoint of its effectiveness compared to how it changes the project structure.

Value Engineering Analysis

As was mentioned several times before, one of the main goals of the owner is to create a LEED Silver building. Although this may require higher costs up front, designing the building this way can save the district more money down the road and create a much more attractive building in the process. Two of my analyses, Analysis Two and Four, allowed for value engineering strategies to be incorporated. Both of these analyses looked at the value of mechanical and lighting systems that will be used in the building. Additional research was performed to find a realistic replacement/addition to these products with which will provide the same expected results for less of a cost. Also, strategies for reducing the schedule and increasing the constructability of the product were considered.

Constructability Review

Constructability issues were analyzed during my analysis of the geothermal wells, the lighting system, and the research into a supplemental rainwater collection system. All suggestions made during the final analysis of each of these systems were made with the goal in mind of creating a more constructible building. This is extremely important,

Summary of Main Thesis Investigation Areas



because any process during construction that is made easier can save time and money on a project. This also reduces the overall complexity of a building.

Schedule Reduction/Acceleration Proposal

This topic was concentrated most heavily in the same three analyses as was mentioned in the previous section, Constructability Review. As strategies are sought after to increase the constructability of a designed system in the building, chances for schedule reduction were also made possible. Both of these activities go hand in hand and can make a good project even better. The overall success of this project will, in the end, be determined by a project that is completed on time and on budget. That is why it was an important part to consider all of these components throughout my thesis research.

Graduate Class Incorporation

As was required by the Integrated Masters Program, part of the research done in this thesis had to incorporate ideas and skills learned from graduate class work. In particular, the theories and information gathered from AE 597D: "Sustainable Building Methods" helped throughout my senior thesis project. During this class, LEED and its benefits were thoroughly discussed, as well as sustainable technologies and building methods. The topics discussed during AE 572: "Project Development and Delivery Planning" also helped benefit my thesis research. This class taught me different methods to describe and calculate the value of different construction elements. These were used during much of the evaluation needed to complete my thesis studies successfully. It also taught me a variety of research methods that were used throughout my entire thesis project to pull everything together.



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5. Evergreen Solar "ES-A Series (Black Frame)"
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8. Rain Barrel: "RainXchange"
<http://www.rainxchange.com/products/rain_barrel.php>
9. Aquascape, Inc. "Rainwater Harvesting"
<<http://store.aquascapeinc.com/products/category/1784.0.1.1.70984.0.0.0.0>>
10. T8 versus T5 Fluorescent: A Brief Analysis – Lighting Solutions
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11. The T5 Fluorescent Lamp: Coming On Strong
<http://ecmweb.com/ops/electric_fluorescent_lamp_coming/>
12. EarthLED main Website <<http://www.earthled.com/index.html>>
13. The EarthLED Store – DirectLED FLT5 – 4ft.
<<http://store.earthled.com/products/directled-4-foot-led-t5-fluorescent-replacement-tube>>



Appendix



Appendix A
Phasing Site Plans



PHASE I CONSTRUCTION - MILL ESTONES

- 1. OWNER TO RELOCATE EXISTING MIDDLE CLASSROOMS TO SOUTHERN END OF EXISTING SCHOOL UNDER SEPARATE CONTRACT.
- 2. OWNER TO PROVIDE ADDITIONAL NEW MIDDLE CLASSROOMS UNDER SEPARATE CONTRACT AT SOUTHERN END OF EXISTING SCHOOL.
- 3. EXCAVATION AND CONSTRUCTION OF NEW FOOTWAY AND PARKING AREA.
- 4. PROVIDE TEMPORARY BUS BAY OFF PICK-UP ZONE.
- 5. INSTALL CONSTRUCTION AREA FENCING TO SEPARATE PHASE I CONSTRUCTION AREAS OUTSIDE CONSTRUCTION FENCE WILL BE USED FOR PUBLIC AND STUDENT ACCESS. NO BELOW GRADE FENCE POSTS ARE PERMITTED WITHIN TRANSPO BAY OR WAY.
- 6. RELOCATE CONSTRUCTION STAGING AND PARKING AREAS INSTALL ALL OFFICE TRAILERS, PROVIDE POWER, TELEPHONE AND HIGH SPEED INTERNET WIRING FOR USE OF OFFICE TRAILERS BY AUGUST 25, 2009. SITE VISITOR INSTALL OFFICE TRAILERS BY AUGUST 25, 2009. SITE VISITOR INSTALL OFFICE TRAILERS BY AUGUST 25, 2009.
- 7. INSTALL TEMPORARY STAGING, STORAGE SYSTEMS, TEMPORARY STORAGE ACCESS DRIVE AND PARKING LOT EXCLUDING CONSTRUCTION STAGING, STAFF AND FUTURE BUS OFFICE TRAILERS TO BE COMPLETED BY OCTOBER 1, 2009.
- 8. PROVIDE TEMPORARY CONSTRUCTION ENTRANCE (W/ WEST DRIVE) AS STABILIZED DRIVEWAY THROUGH EXISTING PATIENS AND INSTALL TEMPORARY TRAFFIC SIGNALS.
- 9. PERFORM SITE REHABILITATION AT EXISTING TRANSPORTATION BUILDING.
- 10. REMOVE FENCE AND RECONSTRUCTION STAGING TANKS.
- 11. SITE GRADING AND EXCAVATION FOR NEW PARKING AREAS IN PHASE I AREA.
- 12. INSTALL STAGING AREA FOR STAGING AREA USE AND WATER REMOVAL, UTILITIES, CURBS, ETC.
- 13. CORRECTIVE ACTION WORK WITH THE ROAD WORKER. INSTALL UNDERGROUND GEOTECHNICAL PROTECTION WALLS TO NEW BUILDING.
- 14. ASSISTANTS ADJUNCT AT EXISTING TRANSPORTATION BUILDING.
- 15. BUILDING RECONSTRUCTION OF EXISTING TRANSPORTATION BUILDING.
- 16. INSTALL BORE HOLES FOR GROUND SOURCE HEAT PUMPS LOCATED AT WESTERN END OF EXISTING TRANSPORTATION BUILDING.
- 17. PERFORM SITE ENVIRONMENTAL REHABILITATION AT EXISTING SCHOOL WITHIN PHASE I AREA, INCLUDING REMOVAL OF UNDERGROUND STORAGE TANKS.
- 18. CREATE TEMPORARY STAGING AREA AT PROPOSED TENNIS COURTS, STAMP TROUSEL, INSTALL GEOTEXTILE FABRIC AND STONE BASE.
- 19. BEGIN EXCAVATION AND CONSTRUCTION OF NEW FOUNDATIONS AT NEW ATHLETIC WING OUTSIDE OF EXISTING BUILDING FOOTPRINT.
- 20. OTHER DUBS SCHOOL DISTRICT TO RELOCATE EXISTING BUILDING TENNIS/BIKE RACKS AND EQUIPMENT TO EXISTING TENNIS COURTS.
- 21. CONSTRUCT AND INSTALL BASE COURSE OF PAVING AND SIDEWALKS INCLUDING TEMPORARY LANE MARKINGS AND SIGNAGE AT W/ WEST DRIVE AND W/ WEST DRIVE FROM AUGUST 25, 2009.
- 22. PARTIAL BASE COURSE CONSTRUCTION FOR ROADWAY IS BY OWNER UNDER SEPARATE CONTRACT.
- 23. TEMPORARY LANE CHANGING INSTALLED BEFORE AUGUST 25, 2009. RELOCATE LANE CHANGING TO WORK AREA BEING REMOVED.
- 24. ASSISTANTS ADJUNCT AND ADJUNCTS TO OTHER ENVIRONMENTAL MATERIALS AT EXISTING SCHOOL (EAST TO WEST WITHIN PHASE I AREA) COMPLETE ALL WORK BY AUGUST 15, 2009.
- 25. COMPLETE BORE HOLES AND GEOTECHNICAL PILING SYSTEMS AND RESTORE TO ROAD GRADUOS BY NOVEMBER 30, 2009.
- 26. INSTALL WATER CONDUITING OF BORE HOLES AND PILING, TEMPORARY STONE CONTRACTORS PARKING LOT, MOBILITY CONSTRUCTION FENCING AS SHOWN.
- 27. RECONSTRUCTION OF EXISTING BUILDING WITHIN PHASE I AREA AS SHOWN.
- 28. PHASE I RECONSTRUCTION TO BE COMPLETED BY SEPTEMBER 30, 2009.
- 29. INSTALL BINDER COURSE AT NEW PARKING AREAS FOR STAGING USE BY OCTOBER 1, 2009.

PHASE II CONSTRUCTION - MILL ESTONES

- 30. PHASE II (JUNE 1, 2009 to AUGUST 25, 2009)
- 31. INSTALL NEW STAIRWELL WITH APPROPRIATE CONSTRUCTION ENTRANCE AND FENCING BETWEEN JUNE 1, 2009 AND SEPTEMBER 30, 2009.
- 32. CONTINUE WITH CONSTRUCTION OF NEW BUILDING AND STAMPWORK IN PHASE I AREAS.

PHASING TIME LINES

PHASE I	PHASE II
IA: MAY 2008	IA: JUNE 1, 2011
IB: AUGUST 25, 2008	IB: JUNE 1, 2011
IC: AUGUST 25, 2008	IC: AUGUST 25, 2011
II: AUGUST 25, 2009	II: JUNE 1, 2012
III: AUGUST 25, 2009	III: AUGUST 25, 2012
IV: JUNE 1, 2010	IV: JUNE 30, 2012
VE: AUGUST 25, 2010	VE: JUNE 30, 2012
VI: AUGUST 25, 2010	VI: JUNE 30, 2012
VII: AUGUST 25, 2010	VII: JUNE 30, 2012
VIII: AUGUST 25, 2010	VIII: JUNE 30, 2012
IX: AUGUST 25, 2010	IX: JUNE 30, 2012
X: AUGUST 25, 2010	X: JUNE 30, 2012
XI: AUGUST 25, 2010	XI: JUNE 30, 2012
XII: AUGUST 25, 2010	XII: JUNE 30, 2012
XIII: AUGUST 25, 2010	XIII: JUNE 30, 2012
XIV: AUGUST 25, 2010	XIV: JUNE 30, 2012
XV: AUGUST 25, 2010	XV: JUNE 30, 2012
XVI: AUGUST 25, 2010	XVI: JUNE 30, 2012
XVII: AUGUST 25, 2010	XVII: JUNE 30, 2012
XVIII: AUGUST 25, 2010	XVIII: JUNE 30, 2012
XIX: AUGUST 25, 2010	XIX: JUNE 30, 2012
XX: AUGUST 25, 2010	XX: JUNE 30, 2012
XXI: AUGUST 25, 2010	XXI: JUNE 30, 2012
XXII: AUGUST 25, 2010	XXII: JUNE 30, 2012
XXIII: AUGUST 25, 2010	XXIII: JUNE 30, 2012
XXIV: AUGUST 25, 2010	XXIV: JUNE 30, 2012
XXV: AUGUST 25, 2010	XXV: JUNE 30, 2012
XXVI: AUGUST 25, 2010	XXVI: JUNE 30, 2012
XXVII: AUGUST 25, 2010	XXVII: JUNE 30, 2012
XXVIII: AUGUST 25, 2010	XXVIII: JUNE 30, 2012
XXIX: AUGUST 25, 2010	XXIX: JUNE 30, 2012
XXX: AUGUST 25, 2010	XXX: JUNE 30, 2012

GENERAL NOTES:
 1. COORDINATE ALL ACTIVITIES WITH TASK PLANS.
 2. PHASING AREAS HAVE GENERAL INFORMATION ONLY. REFERENCE TASK PLANS AND SPECIFICATIONS FOR ADDITIONAL INFORMATION.
 3. COORDINATE ALL ACTIVITIES WITH ALL PHASING AND PROJECT DRAWINGS AND SPECIFICATIONS.
 4. COORDINATE ALL ACTIVITIES WITH REQUIREMENTS FOR OCCUPANCY OF SCHOOL AND SITE BY STUDENTS, STAFF AND PUBLIC.
 5. ALL PHASING AND MILLSTONE REQUIREMENTS SHALL BE INCORPORATED IN THE PROJECT SCHEDULE AND WILL ONLY BE CHANGED AFTER WRITTEN APPROVAL FROM CONSTRUCTION MANAGER.

PHASES OF CONSTRUCTION FOR NEW HIGH SCHOOL

PHASE I	PHASE II
IA: MAY 2008	IA: JUNE 1, 2011
IB: AUGUST 25, 2008	IB: JUNE 1, 2011
IC: AUGUST 25, 2008	IC: AUGUST 25, 2011
II: AUGUST 25, 2009	II: JUNE 1, 2012
III: AUGUST 25, 2009	III: AUGUST 25, 2012
IV: JUNE 1, 2010	IV: JUNE 30, 2012
VE: AUGUST 25, 2010	VE: JUNE 30, 2012
VI: AUGUST 25, 2010	VI: JUNE 30, 2012
VII: AUGUST 25, 2010	VII: JUNE 30, 2012
VIII: AUGUST 25, 2010	VIII: JUNE 30, 2012
IX: AUGUST 25, 2010	IX: JUNE 30, 2012
X: AUGUST 25, 2010	X: JUNE 30, 2012
XI: AUGUST 25, 2010	XI: JUNE 30, 2012
XII: AUGUST 25, 2010	XII: JUNE 30, 2012
XIII: AUGUST 25, 2010	XIII: JUNE 30, 2012
XIV: AUGUST 25, 2010	XIV: JUNE 30, 2012
XV: AUGUST 25, 2010	XV: JUNE 30, 2012
XVI: AUGUST 25, 2010	XVI: JUNE 30, 2012
XVII: AUGUST 25, 2010	XVII: JUNE 30, 2012
XVIII: AUGUST 25, 2010	XVIII: JUNE 30, 2012
XIX: AUGUST 25, 2010	XIX: JUNE 30, 2012
XX: AUGUST 25, 2010	XX: JUNE 30, 2012
XXI: AUGUST 25, 2010	XXI: JUNE 30, 2012
XXII: AUGUST 25, 2010	XXII: JUNE 30, 2012
XXIII: AUGUST 25, 2010	XXIII: JUNE 30, 2012
XXIV: AUGUST 25, 2010	XXIV: JUNE 30, 2012
XXV: AUGUST 25, 2010	XXV: JUNE 30, 2012
XXVI: AUGUST 25, 2010	XXVI: JUNE 30, 2012
XXVII: AUGUST 25, 2010	XXVII: JUNE 30, 2012
XXVIII: AUGUST 25, 2010	XXVIII: JUNE 30, 2012
XXIX: AUGUST 25, 2010	XXIX: JUNE 30, 2012
XXX: AUGUST 25, 2010	XXX: JUNE 30, 2012

PH1.1

DATE: 04/01/2009

ADDENDA SET

5/13/08

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NEW: UPPER DUBLIN HIGH SCHOOL

SCHOOL DISTRICT OF UPPER DUBLIN

TOWNSHIP OF UPPER DUBLIN, MONTGOMERY COUNTY, PA

D'HUY ENGINEERING, Inc.

CONSULTING ENGINEERS

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- PHASE ID: (AUGUST 25, 2009 to DECEMBER 1, 2009)**
1. MOORE TOWER AND CONSTRUCTION TRAFFIC AND IMPROVE WALKWAYS ROOM SCHOOL (CONSTRUCTION TRAFFIC PERMITTED TO ENTER FROM SR 0909 BY PHASE I).
 2. RECONSTRUCT EXISTING ASSESSMENT PROPERTY PAVING AND LINE ATHLETIC FIELD FOR OWNERS USE.
 3. COMPLETE NEW SWIMMING POOL AND IMPROVE TRAFFIC READY FOR OWNER OCCUPANCY AND WATER FINISHES BY 2010.
 4. FINAL COMPLETION DATE FOR NEW SWIMMING POOL AND GYMNASIUM DECEMBER 1, 2009.
 5. THE PORTION OF NEW BUILDING MUST BE WEATHERIGHT, ENCLOSED, SECURE AND HEATED APPROPRIATELY TO PREVENT ALL UTILITIES THAT SERVICE GYMNASIUM SYSTEMS FROM BEING EXPOSED TO THE ELEMENTS. ACCESS TO GYMNASIUM FROM OWNER, OWNERS PERSONNEL MUST BE PROVIDED ACCESS TO MECHANICAL ROOM FROM REMAINDER OF PROJECT.
 6. COMPLETE WITH CONSTRUCTION OF NEW BUILDING WITHIN PHASE I AREA.
- PHASE II: (DECEMBER 1, 2009 to JUNE 1, 2010)**
1. OWNER TO RELOCATE EXISTING LIBRARY FURNISHINGS TO EXISTING GYMNASIUM.
 2. INITIAL SHORT TERM CONSTRUCTION TRAFFIC AND CONSTRUCTION TRAFFIC BASE PERMITTED FROM SOUTH DUBLIN INSTANT LIBRARY CONSTRUCTION WEATHER PERMIT.
 3. CONTRACTOR TO BEGON ASSESSMENT AND RELOCATION OF EXISTING CONSTRUCTION OF PHASE I AREAS.
- PHASE III: (JUNE 1, 2010 to AUGUST 25, 2010)**
1. COMPLETE WITH CONSTRUCTION OF NEW BUILDING WITHIN PHASE I AREA.
 2. INSTALL NEW SITE IMPROVEMENTS AS FEASIBLE OR REQUIRED TO COMPLETE PHASE I. PARKING AREAS, CURBS, SIDEWALKS, CONC, CONCERNED AREA, EXISTING CURBS, SIDEWALKS AND PARKING TO BE MAINTAINED THROUGH PHASE III.
 3. CLEAN ALL NUMBER COURSE, AREA'S PARKING COURSE AND REPAIRS. REPAIR ANY DAMAGED AREAS, INSTALL LANDING COURSE, AS REQUIRED AND PROVIDE FINAL PAVING AND STRIPING.
- PHASE IV: (AUGUST 25, 2010 to DECEMBER 1, 2010)**
1. PROCEED WITH SEEDING AND LANDSCAPING WITHIN PHASE I AREA.
 2. FINAL CLEAN UP, INSPECTIONS AND SYSTEMS TRAINING FOR PHASE I AREA.
 3. CLEAN ALL NUMBER COURSE AREAS, PARKING COURSE AND REPAIRS. REPAIR ANY DAMAGED AREAS, INSTALL LANDING COURSE, AS REQUIRED AND PROVIDE FINAL PAVING AND STRIPING.
 4. RESTORE CONSTRUCTION STAGING AND PARKING AREAS, AND CONSTRUCT FINAL WORK.
 5. COMPLETE SITE IMPROVEMENTS IN PHASE I AREA.
 6. NOVEMBER 10, 2010 TERM OVER PARTIAL OCCUPANCY OF NEW SECOND FLOOR TO OWNER FOR OWNERS INSTALLED FURNISHINGS.
 7. FINAL CLEAN UP, INSPECTIONS AND SYSTEMS TRAINING FOR PHASE I AREAS.
 8. PHASE I NEW CONSTRUCTION AREAS READY FOR OWNER OCCUPANCY DECEMBER 1, 2010.
- PHASE V: (DECEMBER 1, 2010 TO JANUARY 5, 2011)**
1. OWNER TO COMPLETE MOVING OF FURNISHINGS AND EQUIPMENT TO NEW PHASE I AREAS.
 2. CONSULTANT AND MANAGER CONSTRUCTION STAGING AREA, RELOCATE ALL CONSTRUCTION STAGING TO PHASE I BY FEB. 28, 2011.
 3. CONTRACTOR COORDINATION FOR PHASE II CONSTRUCTION.
- PHASES OF CONSTRUCTION FOR NEW HIGH SCHOOL**
- PHASE I**
- | | | | |
|-----|------------------|----|------------------|
| IA: | MAY 2008 | to | AUGUST 25, 2008 |
| IB: | JUNE 1, 2009 | to | AUGUST 25, 2009 |
| IC: | AUGUST 25, 2009 | to | DECEMBER 1, 2009 |
| ID: | DECEMBER 1, 2009 | to | JUNE 1, 2010 |
| IE: | DECEMBER 1, 2009 | to | DECEMBER 1, 2010 |
| IF: | AUGUST 25, 2010 | to | DECEMBER 1, 2010 |
| IG: | DECEMBER 1, 2010 | to | JANUARY 5, 2011 |
- COMPLETION DATE OF NEW SWIMMING POOL & GYMNASIUM: DECEMBER 1, 2009
 PARTIAL OWNER OCCUPANCY OF NEW SECOND FLOOR: NOVEMBER 10, 2010
 FINAL COMPLETION OF PHASE I CONSTRUCTION: DECEMBER 1, 2010
- PHASE II**
- | | | | |
|------|-----------------|----|-----------------|
| IIA: | JANUARY 5, 2011 | to | JUNE 1, 2011 |
| IIB: | JUNE 1, 2011 | to | AUGUST 25, 2011 |
| IIC: | JUNE 1, 2012 | to | AUGUST 1, 2012 |
- FINAL COMPLETION OF ALL CONSTRUCTION ACTIVITIES: AUGUST 1, 2012
- PHASING TIME LINES**
- | | | | | | | | | | | |
|--|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|
| MAY 2008 | PHASE IA | PHASE IB | PHASE IC | PHASE ID | PHASE IE | PHASE IF | PHASE IG | PHASE IIA | PHASE IIB | PHASE IIC |
| 1 1/2 YRS. POOL & GYM COMPLETE | | | | | | | | | | |
| 2 1/2 YRS. PHASE I CONSTRUCTION COMPLETE | | | | | | | | | | |
| 4 YEARS PROJECT COMPLETION | | | | | | | | | | |

GENERAL NOTES

1. CONSULTANT ALL ACTIVITIES WITH AS PLANS.
2. PHASING PLANS HAVE GENERAL INFORMATION ONLY, REFERENCE PLANS AND SPECIFICATIONS FOR ADDITIONAL INFORMATION.
3. COORDINATE ALL ACTIVITIES WITH ALL PHASING AND PROJECT DRAWINGS AND SPECIFICATIONS.
4. COORDINATE ALL ACTIVITIES WITH REQUIREMENTS FOR OCCUPANCY OF SCHOOL AND SITE BY STUDENTS STAFF AND PUBLIC.
5. ALL PHASING AND MOVING REQUIREMENTS SHALL BE INCORPORATED IN THE PROJECT SCHEDULE AND WILL ONLY BE CHANGED AFTER WRITTEN APPROVAL FROM CONSTRUCTION MANAGER.

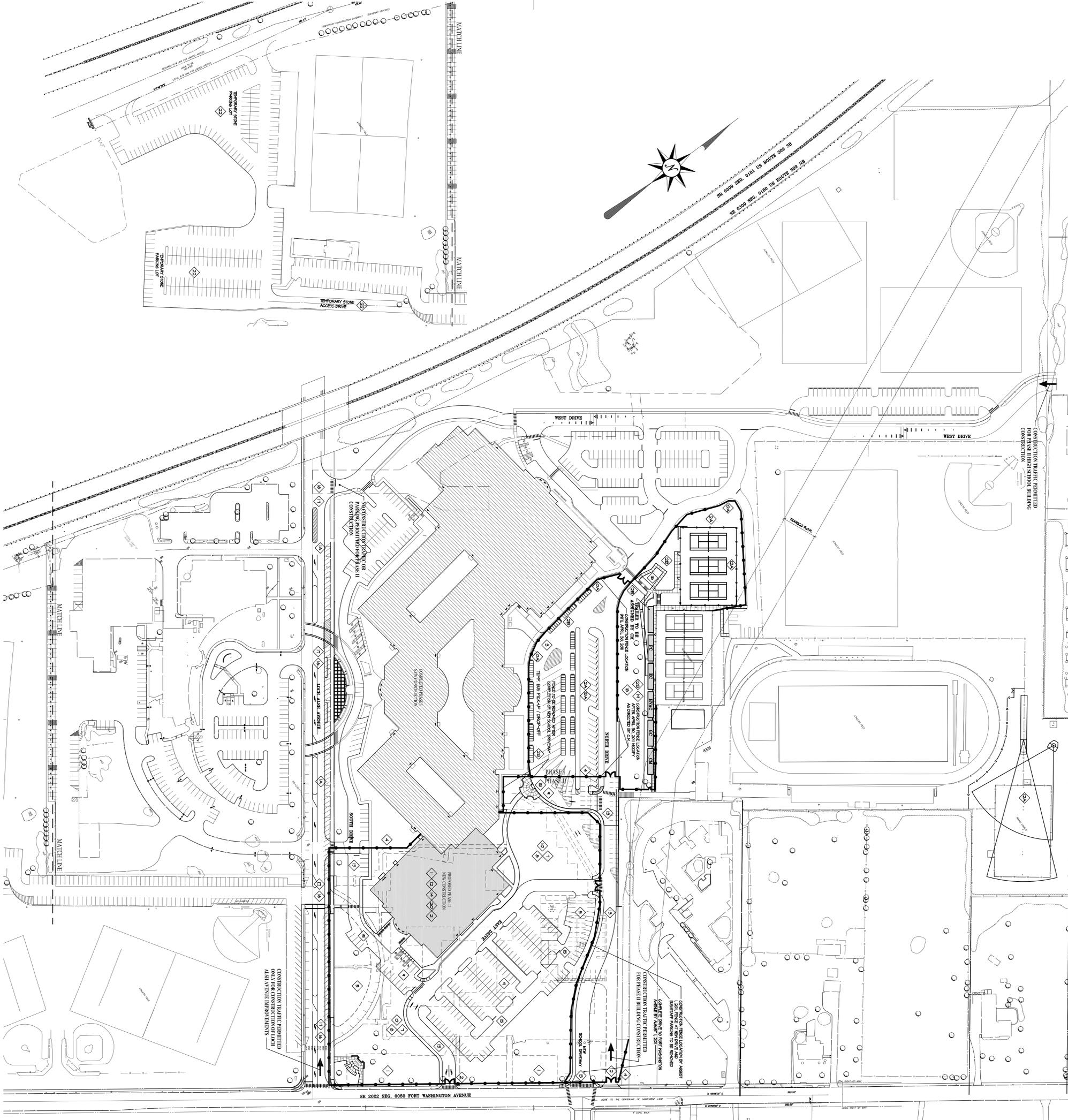
<p>DATE: 04/04/2009</p> <p>PH1.2</p> <p>SHEET NO. 06-46</p> <p>PROJECT NO. 09-018</p> <p>DRAWN BY: GAO/ML</p>	<p>gilbert</p> <p>626 North Charlotte Street Lancaster, PA 17602 P: 717.299.1077 F: 717.292.3923</p> <p>100 South Broad Street, Suite A Middletown, DE 19709 P: 302.449.2400 F: 302.449.2403</p> <p>10451 Mill Run Circle, Suite 400 Owings Mills, MD 21117 P: 410.356.8856 F: 410.654.8802</p>	<p>ADDENDA SET</p> <p>5/13/08</p>	<p>D'HUY ENGINEERING, INC.</p> <p>DEI</p> <p>CONSULTING ENGINEERS</p> <p>Gilbert Architects, Inc. retains all ownership, copyright, and other intellectual property interests in the data and information on these plans. The receiver warrants that it will not reproduce, distribute, or otherwise make use of the data or plans without the permission of Gilbert Architects, Inc.</p>
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SITE PHASING PLAN - PHASE I

P.L.E. PROJECT NO. 3404

REVISION DATES:

NEW: UPPER DUBLIN HIGH SCHOOL SCHOOL DISTRICT OF UPPER DUBLIN TOWNSHIP OF UPPER DUBLIN, MONTGOMERY COUNTY, PA



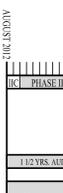
PHASE II CONSTRUCTION - MILESTONES

PHASE II: (JANUARY 5, 2011 TO JUNE 1, 2011)

- 1. OWNER TO REMOVE WORLD WAR CLASSROOMS UPON COMPLETION OF PHASE I BUILDING FROM SITE UNDER SEPARATE CONTRACT.
- 2. RISE PARKING: PICKUP TO BEKAM AT LOCAL ASH AVENUE UNTIL APRIL 30, 2011.
- 3. CREATE NEW CONSTRUCTION ENTRANCE.
- 4. CONSOLIDATE ALL CONSTRUCTION STAGING, RELOCATE TO PHASE IIV APRIL 30, 2011.
- 5. REMOVE 35' WIDE CLASH AREA INSTALLED 1970'S 12" DIAM. CURBS IN ENGINEERING SCHOOL DEYERBENS AND ACCESS UNTIL APRIL 30, 2011. THEREAFTER ENTIRE AREA SHALL BE TURNED OVER TO SCHOOL.
- 6. REMOVE TEMPORARY RISE STORAGE OR PICKUP ZONE STORAGE AND STAGING BY APRIL 30, 2011.
- 7. INSTALL CONSTRUCTION AREA FENCE TO SEPARATE PHASE II CONSTRUCTION FROM PUBLIC AND STUDENT ACCESS. ON-BELOW OR DIFFERENT POSTS ARE PERMITTED WITHIN RANSO DRIEFT OF WAY.
- 8. DESIGNATE CONSTRUCTION STAGING AND PARKING AREAS.
- 9. DETAILING WITH OWNER, TRAFFIC PATTERNS AND INSTALL TEMPORARY TRAFFIC SIGNAGE.
- 10. SITE AND BUILDING ENVIRONMENTAL REMEDIATION WITHIN PHASE II AREA.
- 11. BEGIN BUILDING DEMOLITION OF EXISTING BUILDING IN PHASE II AREA.
- 12. EXCAVATION AND STORM WATER MANAGEMENT AT FUTURE RISE PICKUP STAFF PARKING DRIVEWAYS AND OTHER PARKING AREAS.
- 13. COMPLETE EXISTING BUILDING DEMOLITION AND CREATE STONE STAGING AREA.
- 14. RELOCATE STAGING AREA AND CONSTRUCTION FENCE BY APRIL 30, 2011.
- 15. CONSTRUCTION PICKUP TO BEKAM AT LOCAL ASH AVENUE UNTIL STAGING IS RELOCATED TO PHASE II AREA.
- 16. BEGIN EXCAVATION AND CONSTRUCTION OF NEW BUILDING FOUNDATIONS IN PHASE II AREA.
- 17. PHASE IIB: (JUNE 1, 2011 TO AUGUST 25, 2011)
 - 1. CONTINUE WITH CONSTRUCTION OF NEW BUILDING WITHIN PHASE II AREA.
 - 2. COMPLETE REMAINING SITE IMPROVEMENTS.
 - 3. MAINTAIN TEMPORARY CONSTRUCTION FOR ACCESS AND FUTURE REMOVAL OF OFFICE BUILDINGS.
 - 4. INSTALL CURBS AND PAVING AT FUTURE RISE PICKUP AND STAFF PARKING AREAS INCLUDING DRIVEWAY TO FORT WASHINGTON STREET ROAD FORCE AS NEEDED.
 - 5. CLEAN ALL SURFACE CURBS, ASPHALT PARKING LOTS AND ROADWAYS BEFORE FINAL PAVING AND STAGING COMPLETE BY JULY 30, 2011.
- 18. PHASE IIC: (AUGUST 25, 2011 TO JUNE 1, 2012)
 - 1. CONTINUE WITH CONSTRUCTION OF NEW BUILDING WITHIN PHASE II AREA.
 - 2. INSTALL NEW SITE IMPROVEMENTS IN PHASE IIC AREA: SIDEWALKS, CURBS, PARKING AREAS, LANDSCAPING AND PLANTING.
 - 3. PHASE IID: (JUNE 1, 2012 TO AUGUST 1, 2012)
 - 1. BEGIN ROAD AND SITE IMPROVEMENTS ALONG LOCAL ASH AVENUE: CURBS AND SIDEWALKS BY THE END OF 2012.
 - 2. COMPLETE ROAD AND SITE IMPROVEMENTS INCLUDING COMPLETION OF PEDESTRIAN ADA AT LOCAL ASH AVENUE BY AUGUST 25, 2012.
 - 3. REMOVE OFFICE TRAILERS AND COMPLETE REMAINING SITE IMPROVEMENTS AND UTILITY HELPS FOR ENTIRE PROJECT INCLUDING SIDEWALKS, RAMPS AND STAIRS.
 - 4. RESTORE CONSTRUCTION OFFICE TRAILER CAMPING INCLUDING REMOVAL OF TEMPORARY UTILITIES.
 - 5. FINAL CLEANUP, INSPECTIONS AND SYSTEMS TRAINING FOR PHASE II AREA.
 - 6. PHASE II NEW CONSTRUCTION AREAS READY FOR OWNER OCCUPANCY AUGUST 1, 2012.
 - 7. TEMPORARY OFFICE SITE PARKING LOT TO BE RESTORED BY SEPARATE CONTRACT (NOT IN THIS CONTRACT).

PHASES OF CONSTRUCTION FOR NEW HIGH SCHOOL

PHASE	START DATE	END DATE	COMPLETION DATE
PHASE I	IA: MAY 1, 2008	IB: AUGUST 25, 2008	IC: JUNE 1, 2009
PHASE II	IIA: JANUARY 5, 2011	IIB: JUNE 1, 2011	IIC: JUNE 1, 2012



GENERAL NOTES:

- 1. COORDINATE ALL ACTIVITIES WITH EAS PLANS.
- 2. PHASING PLANS HAVE GENERAL INFORMATION ONLY. REFERENCE PLANS AND SPECIFIC NOTES FOR ADDITIONAL INFORMATION.
- 3. COORDINATE ALL ACTIVITIES WITH ALL PHASING AND PROJECT DRAWINGS AND SPECIFICATIONS.
- 4. COORDINATE ALL ACTIVITIES WITH REQUIREMENTS FOR OCCUPANCY OF SCHOOL AND SITE BY STUDENTS BY AY AND PUBLIC.
- 5. ALL PHASING AND DETAILED REQUIREMENTS SHALL BE INCORPORATED IN THE PROJECT SCHEDULE AND WILL ONLY BE CHANGED AFTER WRITTEN APPROVAL FROM CONSTRUCTION MANAGER.

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P: 410.356.8856 F: 410.654.8802

ADDENDA SET
5/13/08

D'HUY ENGINEERING, Inc.
DEI
CONSULTING ENGINEERS

PH1.3

DATE: 04/01/2009

gilbert

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SITE PHASING PLAN - PHASE II
P.L.E. PROJECT NO. 3404
REVISION DATES:

NEW: UPPER DUBLIN HIGH SCHOOL
SCHOOL DISTRICT OF UPPER DUBLIN
TOWNSHIP OF UPPER DUBLIN, MONTGOMERY COUNTY, PA

DRAWN BY: [blank]
C.D. NO.: [blank]
PROJECT NO.: 08-016
SHEET NO.: [blank]



Appendix B
Site Utility Plans



Appendix C

Detailed Project Schedule



Appendix D
Fossil Ridge High School Case Study



FOSSIL RIDGE HIGH SCHOOL FORT COLLINS, COLORADO

60% more energy efficient

\$11,500 in annual water savings

\$0 additional cost for LEED

LEED® Facts

Fossil Ridge High School
Fort Collins, CO

LEED for New Construction
Certification awarded July 12, 2005

Silver 36*

Sustainable Sites 7/14

Water Efficiency 1/5

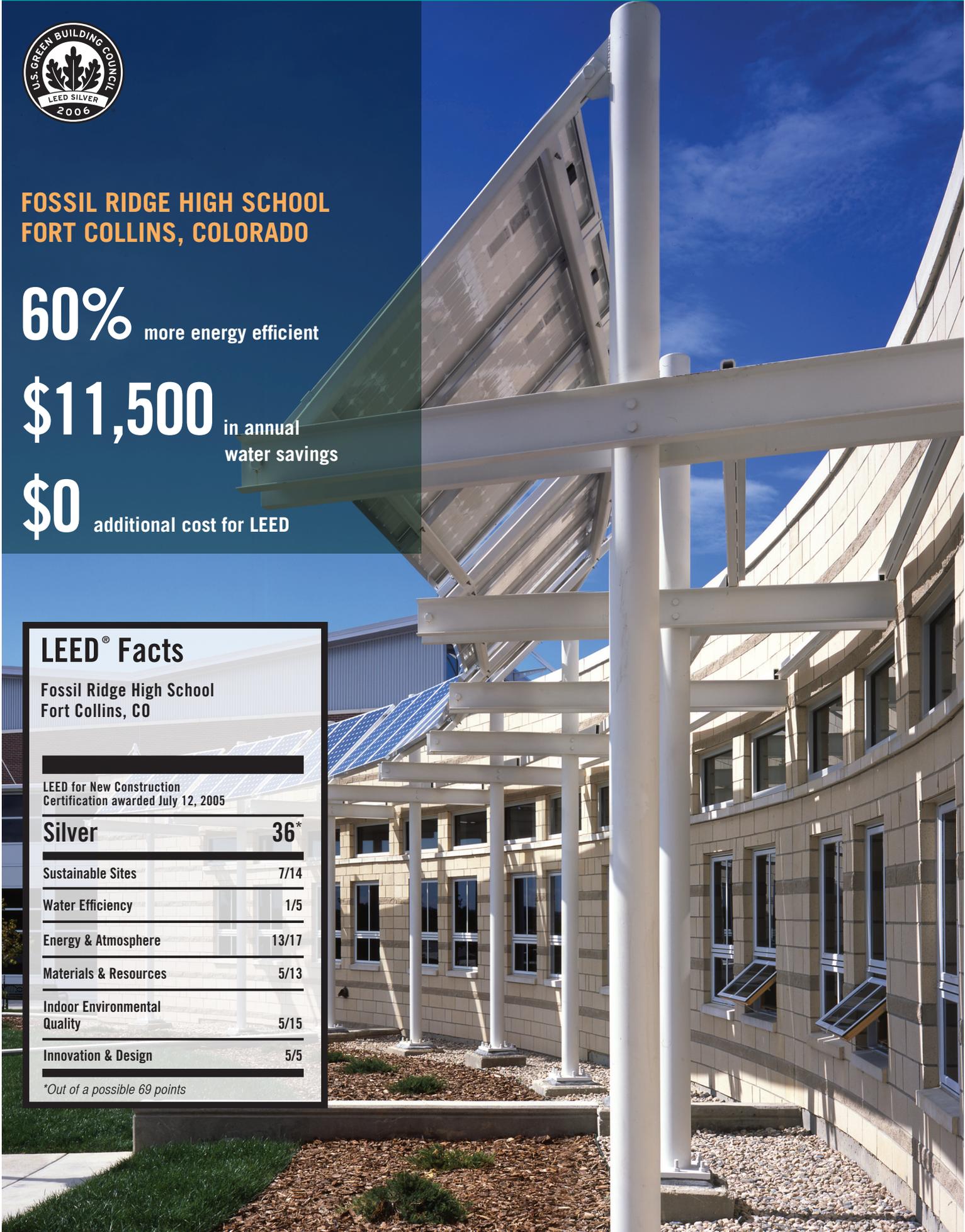
Energy & Atmosphere 13/17

Materials & Resources 5/13

Indoor Environmental Quality 5/15

Innovation & Design 5/5

**Out of a possible 69 points*



FOSSIL RIDGE HIGH SCHOOL

Energy Savings = Classroom Spending

PROJECT BACKGROUND

When building a new high school in Fort Collins, Colorado, Poudre School District's primary goal was to provide students with the healthiest, most comfortable learning environment possible. Poudre also wanted the school to be flexible and adaptable; to make it a teaching tool for environmental stewardship; and to build it for no added cost. To achieve these goals, the district chose to pursue LEED® certification for the new Fossil Ridge High School. The result is a state-of-the-art, 290,000-square-foot building with capacity for 1,800 students—all of whom will learn in an environmentally responsible, healthy building that's saving the school district money.

ENERGY SAVINGS EQUAL CLASSROOM SPENDING

Poudre had built two high performance schools in the past, but wanted LEED certification for Fossil Ridge because of the added benefits of third-party validation. LEED gave the district confidence that its new school would perform as expected, and enabled the district to benchmark the building's performance. LEED also helped justify green practices by demonstrating to building operators how their actions can have a positive impact throughout the building.

Like all school districts, Poudre has to make decisions based on a tight budget. LEED delivered a higher quality building for no added cost: at \$179 per square foot, including design fees, furnishings and equipment, Fossil Ridge's cost compares favorably with other school building projects in the region. And that doesn't include the significant savings from reduced water and energy use. "Fossil Ridge's energy bills will be about one-third less than the newest high school in the district of the same size," said Stu Reeve, energy manager for the district. "And the dollars saved go right back into the classroom."

STRATEGIES AND RESULTS

Poudre's success was a result of involving not just architects and engineers, but also teachers, maintenance staff, and others from the very beginning. Making sure that everyone at the school was committed to achieving LEED goals helped the project team build a school that met the district's goals for student health, operating efficiency, and environmental stewardship, at no additional cost.

Many studies show that natural lighting improves students' reading and math scores, so the team focused on daylighting strategies such as placing windows on multiple sides of classrooms, roof monitors, and Solatubes to bring light into interior spaces. Superior indoor air quality is also a primary concern for schools, so the building features operable windows to let in fresh air; carbon dioxide sensors; and paints and furnishings with low volatile organic compounds (VOCs).

Fossil Ridge is 60% more energy efficient than comparable buildings because of innovative measures including lighting occupancy sensors; connecting HVAC coils to occupancy; and heat wheels for heat recovery. Ice is made and stored during off-peak nighttime hours to cool the building during the day, and energy use is offset by wind power purchases. Water conservation is a key concern across Colorado, so Fossil Ridge uses a raw water pond for campus irrigation; installed low-flow faucets and toilets; and has artificial turf for the athletic field.

The project team saved fuel and transportation costs by using regionally manufactured materials whenever possible, and gave priority to products with high recycled content. Nearly 75% of the construction waste was diverted from landfills through recycling. Fossil Ridge is also a living educational tool, showing the next generation the importance of environmental stewardship and how it can be achieved.

ABOUT POUDBRE SCHOOL DISTRICTS

The Poudre School District comprises 45 schools and nearly 22,500 students around the city of Fort Collins, Colorado. The District has won awards for outstanding student test scores and graduation rates, and strives "to support and inspire every child to think, to learn, to care, and to graduate prepared to be successful in a changing world."

"Building a LEED certified school is the right thing to do, the right thing to teach kids, and the right message to send to the community. And it doesn't cost more."

Michael Spearnak
Poudre School District



Owner: Poudre School District
Architect: RB+B Architects
Contractor: Haselden Construction, Inc.
Project size: 290,000 square feet
Total Project cost: \$179 per square foot; \$28,889 per student

Photography courtesy of RB+B Architects, Inc.

ABOUT LEED

The LEED® Green Building Rating System™ is the national benchmark for the design, construction, and operations of high-performance green buildings. Visit the U.S. Green Building Council's Web site at www.usgbc.org to learn more about how you can make LEED work for you.



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www.usgbc.org
202 828-7422



Appendix E
LEED for Schools Checklist



Upper Dublin High School

LEED for Schools Checklist

Yes ? No

11	1	4	Sustainable Sites	16 Points
-----------	----------	----------	--------------------------	------------------

Y			Prereq 1	Construction Activity Pollution Prevention	Required
Y			Prereq 2	Environmental Site Assessment	Required
Y			Credit 1	Site Selection	1
Y			Credit 2	Development Density & Community Connectivity	1
Y			Credit 3	Brownfield Redevelopment	1
		N	Credit 4.1	Alternative Transportation, Public Transportation Access	1
Y			Credit 4.2	Alternative Transportation, Bicycle Use	1
Y			Credit 4.3	Alternative Transportation, Low-Emitting and Fuel-Efficient Vehicles	1
Y			Credit 4.4	Alternative Transportation, Parking Capacity	1
		N	Credit 5.1	Site Development, Protect or Restore Habitat	1
Y			Credit 5.2	Site Development, Maximize Open Space	1
Y			Credit 6.1	Stormwater Design, Quantity Control	1
Y			Credit 6.2	Stormwater Design, Quality Control	1
		N	Credit 7.1	Heat Island Effect, Non-Roof	1
Y			Credit 7.2	Heat Island Effect, Roof	1
	?		Credit 8	Light Pollution Reduction	1
		N	Credit 9	Site Master Plan	1
Y			Credit 10	Joint Use of Facilities	1

Yes ? No

4		3	Water Efficiency	7 Points
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Y			Credit 1.1	Water Efficient Landscaping, Reduce by 50%	1
Y			Credit 1.2	Water Efficient Landscaping, No Potable Use or No Irrigation	1
		N	Credit 2	Innovative Wastewater Technologies	1
Y			Credit 3.1	Water Use Reduction, 20% Reduction	1
Y			Credit 3.2	Water Use Reduction, 30% Reduction	1
		N	Credit 3.3	Water Use Reduction, 40% Reduction	1
		N	Credit 4	Process Water Use Reduction	1

Yes ? No

12	1	4	Energy & Atmosphere	17 Points
-----------	----------	----------	--------------------------------	------------------

Y			Prereq 1	Fundamental Commissioning of the Building Energy Systems	Required
Y			Prereq 2	Minimum Energy Performance	Required
Y			Prereq 3	Fundamental refrigerant Management	Required
Y			Credit 1.1	Optimize Energy Performance, 10.5% New / 3.5% Existing	1
Y			Credit 1.2	Optimize Energy Performance, 14% New / 7% Existing	1
Y			Credit 1.3	Optimize Energy Performance, 17.5% New / 10.5% Existing	1
Y			Credit 1.4	Optimize Energy Performance, 21% New / 14% Existing	1
Y			Credit 1.5	Optimize Energy Performance, 24.5% New / 17.5% Existing	1
Y			Credit 1.6	Optimize Energy Performance, 28% New / 21% Existing	1
Y			Credit 1.7	Optimize Energy Performance, 31.5% New / 24.5% Existing	1
Y			Credit 1.8	Optimize Energy Performance, 35% New / 28% Existing	1
Y			Credit 1.9	Optimize Energy Performance, 38.5% New / 31.5% Existing	1
Y			Credit 1.10	Optimize Energy Performance, 42% New / 35% Existing	1
		N	Credit 2.1	On-Site Renewable Energy, 2.5%	1
		N	Credit 2.2	On-Site Renewable Energy, 7.5%	1
		N	Credit 2.3	On-Site Renewable Energy, 12.5%	1
Y			Credit 3	Enhanced Commissioning	1

Y			Credit 4	Enhanced Refrigerant Management	1
		N	Credit 5	Measurement & Verification	1
	?		Credit 6	Green Power	1

Yes ? No

6		7	Materials & Resources	13 Points
----------	--	----------	----------------------------------	------------------

Y			Prereq 1	Storage & Collection of Recyclables	Required
		N	Credit 1.1	Building Reuse , Maintain 75% of Existing Walls, Floors & Roof	1
		N	Credit 1.2	Building Reuse , Maintain 100% of Existing Walls, Floors & Roof	1
		N	Credit 1.3	Building Reuse , Maintain 50% of Interior Non-Structural Elements	1
Y			Credit 2.1	Construction Waste Management , Divert 50% from Disposal	1
Y			Credit 2.2	Construction Waste Management , Divert 75% from Disposal	1
		N	Credit 3.1	Materials Reuse , 5%	1
		N	Credit 3.2	Materials Reuse , 10%	1
Y			Credit 4.1	Recycled Content , 10% (post-consumer + 1/2 pre-consumer)	1
Y			Credit 4.2	Recycled Content , 20% (post-consumer + 1/2 pre-consumer)	1
Y			Credit 5.1	Regional Materials , 10% Extracted, Processed & Manufactured Regionally	1
Y			Credit 5.2	Regional Materials , 20% Extracted, Processed & Manufactured Regionally	1
		N	Credit 6	Rapidly Renewable Materials	1
		N	Credit 7	Certified Wood	1

Yes ? No

15	2	2	Indoor Environmental Quality	20 Points
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Y			Prereq 1	Minimum IAQ Performance	Required
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	Required
Y			Prereq 3	Minimum Acoustical Performance	Required
Y			Credit 1	Outdoor Air Delivery Monitoring	1
		N	Credit 2	Increase Ventilation	1
Y			Credit 3.1	Construction IAQ Management Plan , During Construction	1
Y			Credit 3.2	Construction IAQ Management Plan , Before Occupancy	1
Y			Credit 4.1	Low-Emitting Materials , Adhesives & Sealants	1
Y			Credit 4.2	Low-Emitting Materials , Paints	1
Y			Credit 4.3	Low-Emitting Materials , Carpet	1
	?		Credit 4.4	Low-Emitting Materials , Composite Wood	1
		N	Credit 5	Indoor Chemical & Pollutant Source Control	1
Y			Credit 6.1	Controllability of Systems , Lighting	1
Y			Credit 6.2	Controllability of Systems , Thermal Comfort	1
Y			Credit 7.1	Thermal Comfort , Design	1
Y			Credit 7.2	Thermal Comfort , Verification	1
Y			Credit 8.1	Daylight & Views , Daylight 75% of Classrooms	1
	?			Daylight & Views , Daylight 90% of Classrooms	1
Y				Daylight & Views , Daylight 75% of other spaces	1
Y			Credit 8.2	Daylight & Views , Views for 90% of Spaces	1
Y			Credit 9	Enhanced Acoustical Performance	1
Y			Credit 10	Mold Prevention	1

Yes ? No

4	2		Innovation & Design Process	6 Points
----------	----------	--	--	-----------------

	?		Credit 1.1	Innovation in Design:	1
Y			Credit 1.2	Innovation in Design: Exemplary Performance MRc5	1
Y			Credit 1.3	Innovation in Design: Green Building Education	1
Y			Credit 1.4	Innovation in Design: Exemplary Performance MRc4	1
Y			Credit 2	LEED Accredited Professional	1
	?		Credit 3	School As a Teaching Tool	1

Yes ? No

52	6	20	Project Totals	79 Points
-----------	----------	-----------	-----------------------	------------------

Certified 29-36 points Silver 37-43 points Gold 44-57 points Platinum 58-79 points



Appendix F
LEED Responsibility Matrix



**LEED® for Schools Documentation Responsibility Matrix
Upper Dublin High School
Fort Washington, PA**

Yes ?

				LEED Consultant	Owner	Cx Authority	Architect	Civil Engineer	Landscape Architect	Mechanical Engineer	Plumbing Engineer	Construction Manager	General Contractor	Mechanical Contractor	Electrical Contractor	Plumbing Contractor	Acoustical Consultant	Documentation Complete	
			Submit a copy of the project's construction waste management plan										X						
			Provide a summary log of all construction waste generated by type, the quantities of each type that were diverted and landfilled, and the total percentage of waste diverted from landfill disposal.										X						
			Provide sample waste hauling trip tickets, certificates, receipts										X						
			If an existing building is being reused and contributes to this calculation, provide a narrative explaining the assumptions for those calculations.										X						
			Optional: Prepare a narrative describing any special circumstances or considerations regarding the approach to the credit										X						
Y	MRc4.1	C	Recycled Content , Specify 10% (post-consumer + 1/2 pre-consumer)	1															
Y	MRc4.2	C	Recycled Content , Specify 20% (post-consumer + 1/2 pre-consumer)	1															
			Complete the LEED Submittal Template															X	
			Calculate Combined Recycled Content Value by providing Total Materials Value and listing the cost, manufacturer, recycled content, and recycled content information source for each material in the Submittal Template calculator.					X										X	
			Provide a product cut sheet, product literature, or letter from the manufacturer/supplier that clearly indicates whether each material contains post-consumer and/or pre-consumer recycled material or both, and the percentages by weight.										X	X	X	X			
			Optional: Prepare a narrative describing any special circumstances or considerations regarding the approach to the credit										X						
Y	MRc5.1	C	Regional Materials , 10% Extracted, Processed & Manufactured Regionally	1															
Y	MRc5.2	C	Regional Materials , 20% Extracted, Processed & Manufactured Regionally	1															
			Complete the LEED Submittal Template															X	
			Calculate the percentage of regional materials by providing Total Materials Value and listing the cost, harvest distance, manufacture distance, and harvest/manufacture information source for each material in the Submittal Template calculator.					X										X	
			Provide a product cut sheet, product literature, or letter from the manufacturer/supplier verifying the location of manufacture and extraction, harvesting, or recovery for each material.										X	X	X	X			
			Optional: Prepare a narrative describing any special circumstances or considerations regarding the approach to the credit										X						
15	2	Indoor Environmental Quality			20 Points														
Y	EQp1	D	Minimum IAQ Performance	Required															
			Complete the LEED Submittal Template, selecting the appropriate compliance path								X								
			Prepare a narrative describing the ventilation design including information regarding fresh air intake volumes and any special conditions affecting the ventilation design.								X								
			Mechanically Ventilated Spaces																
			Meet the minimum requirements of ASHRAE Standard 62.1-2004								X								
			Provide supporting documentation describing the procedure employed in the IAQ analysis (Ventilation Rate Procedure)								X								
			Provide documentation of design criteria and assumptions.								X								
			Provide a design summary table including space names, area (sq ft), # of people per space, cfm per person, and total cfm.								X								
			If there are any extenuating circumstances like reduced occupancy times, allowing for reduced ventilation, provide a schedule, narrative and any other relevant documentation to express so.								X								
Y	EQp2	D	Environmental Tobacco Smoke (ETS) Control	Required															
			Complete the LEED Submittal Template								X								
			Optional: Prepare a narrative describing any special circumstances or considerations regarding the approach to the credit								X								
Y	EQp3	D	Minimum Acoustical Performance	1															
			Complete the LEED Submittal Template															X	
			Provide a narrative describing the procedure for taking the RT measurements															X	
			Provide a narrative describing the procedure for taking the STC measurements															X	
Y	EQc1	D	Outdoor Air Delivery Monitoring	1															
			Complete the LEED Submittal Template, selecting the appropriate compliance path										X						
			Prepare a narrative describing the project's ventilation design and CO2 monitoring system, including specific information regarding location and quantity of installed monitors, operational parameters, sequence of operation, alarm configuration, CO2 concentration differentials, and setpoints.										X						
			Provide drawings highlighting the location and type of installed CO2 sensors (and, if applicable, natural ventilation components such as operable windows, air intakes, etc.).										X						
			Provide summary of target CO2 differentials per end use, including how target CO2 differentials are measured and maintained										X						



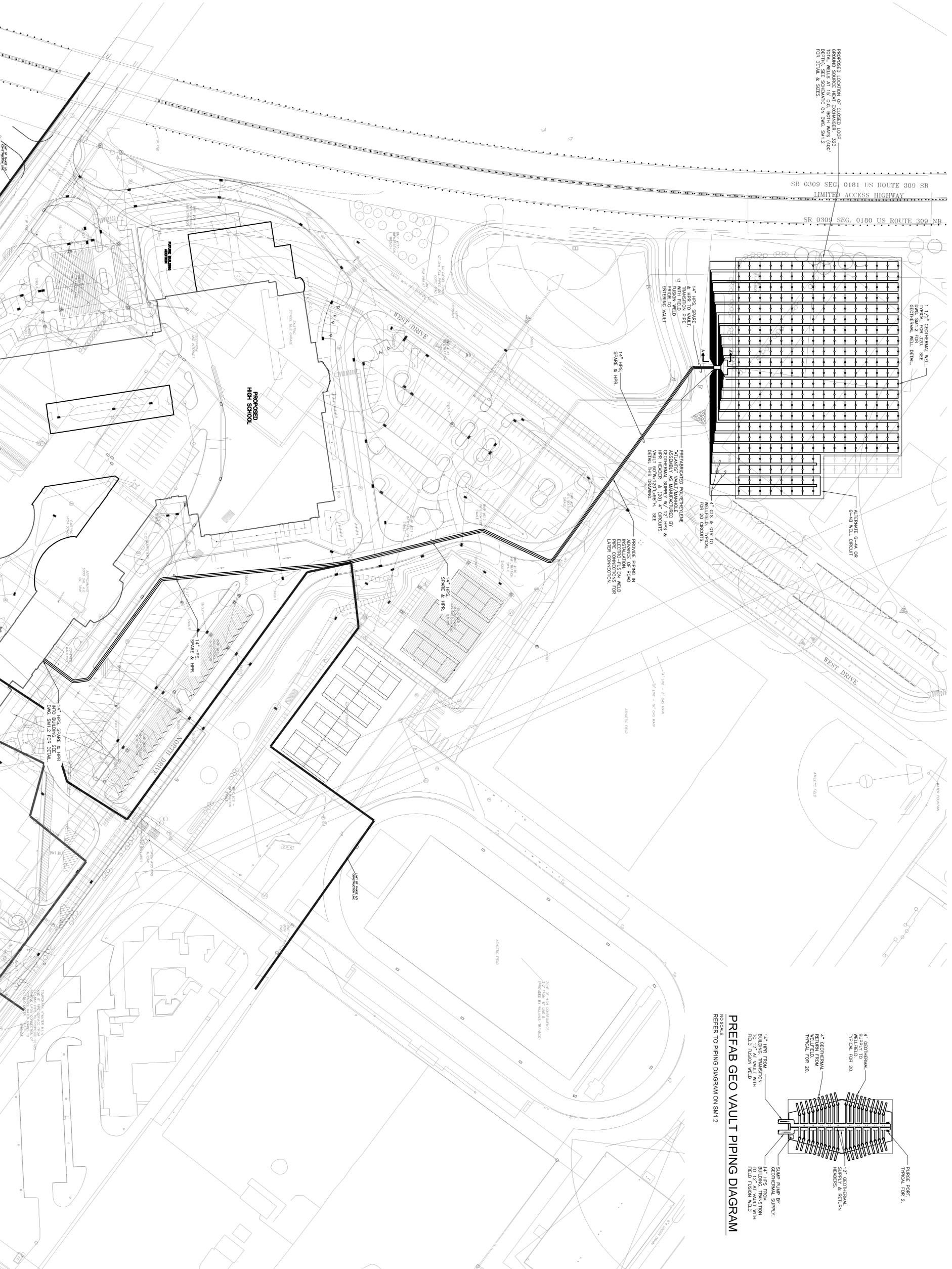
Appendix G

Geothermal Well Field Location and Details

PROPOSED LOCATION OF CLOSED LOOP
 GEOTHERMAL WELLS
 TOTAL WELLS AT 15' O.C. BOTH WAYS (300'
 DEPTH) SEE SIGNIFICANT ON DWG. SM 1.2
 FOR DETAIL & SIZES.

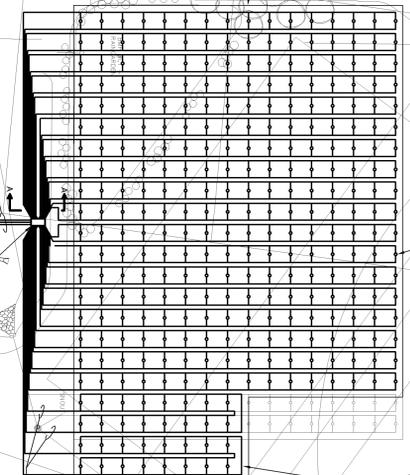
SR 0309 SEG. 0181 US ROUTE 309 SB
 LIMITED ACCESS HIGHWAY

SR 0309 SEG. 0180 US ROUTE 309 NB

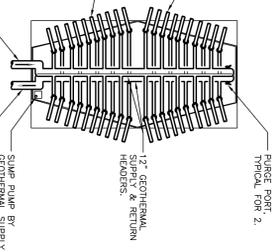


1.1/2\"/>

ALTERNATE C-441 OR
 C-448 WELL CIRCUIT



PREFAB GEO VAULT PIPING DIAGRAM
 NO SCALE
 REFER TO PIPING DIAGRAM ON SM 1.2



SITE UTILITY PLAN - MECHANICAL
 0' 25' 50' 100'
 SCALE: 1" = 50'-0"

MECHANICAL SITE UTILITY PLAN & GEOTHERMAL DETAIL
P.O.E. PROJECT NO. 3404
NEW: UPPER DUBLIN HIGH SCHOOL
SCHOOL DISTRICT OF UPPER DUBLIN
TOWNSHIP OF UPPER DUBLIN, MONTGOMERY COUNTY, PA

gilbert
 626 North Charlotta Street
 Lancaster, PA 17603
 P: 717.291.1077 F: 717.392.3823
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 Middletown, DE 19709
 P: 302.449.2492 F: 302.449.2493
 15451 Mill Run Circle, Suite 400
 Owings Mills, MD 21117
 P: 410.356.8856 F: 410.654.8802

ADDENDA
SET
5/13/08

Snyder Hoffman Associates, Inc.
 Mechanical / Electrical Consulting Engineers
 1005 West Lehigh Street, Bethlehem, Pa. 18018
 Phone: 610-694-8020
 Fax: 610-694-0838
 www.snyderhoffman.com

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Appendix H

Solar Panel Technical Sheet

NEW

ES-A SERIES photovoltaic panels



200, 205 & 210 W Best power tolerance available

A range of high quality String Ribbon™ solar panels offering exceptional performance, cost effective installation and industry-leading environmental credentials made with our revolutionary wafer technology.

- **No power below nameplate**
Never pay for power you're not getting
- **Get up to 5W more than nameplate***
For enhanced field performance
- **Industry's lowest voltage per watt rating**
Delivers the most cost-effective installs
- **UL4703 certified cables**
For use with the highest efficiency transformer-less inverters
- **New extended length cables**
Eliminates home-run wiring
- **New MC® Type 4 lockable connectors****
Complies with the latest codes for accessible arrays
- **Most extensive range of mounting options**
Allows installs virtually anywhere and anyhow
- **Smallest carbon footprint of any manufacturer**
For the greenest of the green
- **100% cardboard-free packaging**
Minimizes job site waste and disposal costs
- **5 year workmanship and 25 year power warranty*****



Born in the USA

*Maximum power up to 4.99 W above nameplate rating; **Locking sleeve not supplied with the panel.

***For full details see the **Evergreen Solar Limited Warranty** available on request or online.

This product is designed to meet UL 1703, UL 4703, UL Fire Safety Class C, IEC 61215 Ed.2 and IEC 61730 Class A standards.

String Ribbon is a trademark of Evergreen Solar, Inc. Evergreen Solar's wafer manufacturing technology is patented in the United States and other countries.

Electrical Characteristics

Standard Test Conditions (STC)¹

	ES-A-200 -fa2*	ES-A-205 -fa2*	ES-A-210 -fa2*	
P_{mp}^2	200	205	210	W
$P_{tolerance}$	-0/+4.99	-0/+4.99	-0/+4.99	W
$P_{mp, max}$	204.99	209.99	214.99	W
$P_{mp, min}$	200.00	205.00	210.00	W
η_{min}	12.7	13.1	13.4	%
P_{ptc}^3	180.6	185.2	189.8	W
V_{mp}	18.1	18.4	18.7	V
I_{mp}	11.05	11.15	11.23	A
V_{oc}	22.5	22.8	23.1	V
I_{sc}	12.00	12.10	12.20	A

Nominal Operating Cell Temperature Conditions (NOCT)⁴

	ES-A-200	ES-A-205	ES-A-210	
T_{NOCT}	44.8	44.8	44.8	°C
P_{max}	146.4	150.1	153.7	W
V_{mp}	16.7	16.8	17.0	V
I_{mp}	8.76	8.93	9.04	A
V_{oc}	20.5	20.7	21.0	V
I_{sc}	9.60	9.68	9.76	A

¹ 1000 W/m², 25°C cell temperature, AM 1.5 spectrum;

² Maximum power point or rated power

³ At PV-USA Test Conditions: 1000 W/m², 20°C ambient temperature, 1 m/s wind speed

⁴ 800 W/m², 20°C ambient temperature, 1 m/s wind speed, AM 1.5 spectrum

* f-framed, a-low voltage, 2-matt blue (textured) cells

Low Irradiance

The typical relative reduction of module efficiency at an irradiance of 200W/m² both at 25°C cell temperature and spectrum AM 1.5 is 0%.

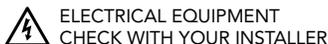
Temperature Coefficients

αP_{mp}	-0.45	%/°C
αV_{mp}	-0.43	%/°C
αI_{mp}	-0.02	%/°C
αV_{oc}	-0.32	%/°C
αI_{sc}	-0.003	%/°C

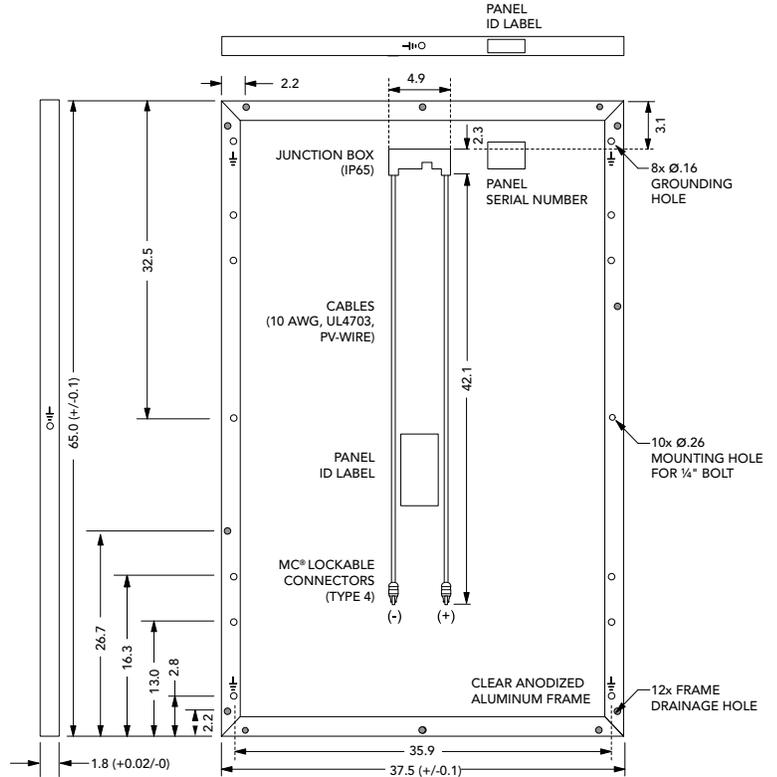
System Design

Series Fuse Rating ⁵	20 A
Maximum System Voltage (UL)	600 V

⁵ Also known as Maximum Reverse Current.



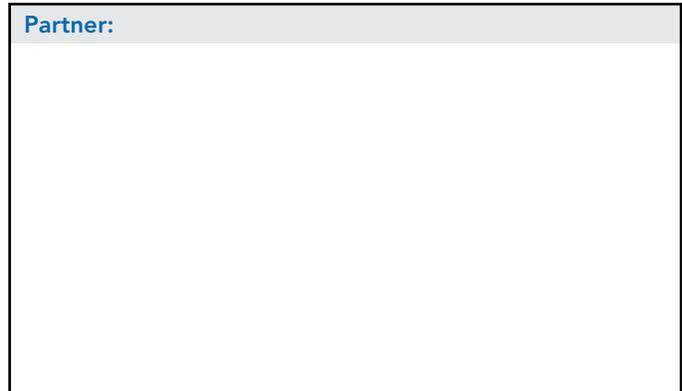
Mechanical Specifications



All dimensions in inches; panel weight 41 lbs

Product constructed with 114 poly-crystalline silicon solar cells, anti-reflective tempered solar glass, EVA encapsulant, polymer back-skin and a double-walled anodized aluminum frame. Product packaging tested to International Safe Transit Association (ISTA) Standard 2B. All specifications in this product information sheet conform to EN50380. See the **Evergreen Solar Safety, Installation and Operation Manual and Mounting Design Guide** for further information on approved installation and use of this product.

Due to continuous innovation, research and product improvement, the specifications in this product information sheet are subject to change without notice. No rights can be derived from this product information sheet and Evergreen Solar assumes no liability whatsoever connected to or resulting from the use of any information contained herein.



ES-A_200_205_210_US_010908; effective September 1st 2008



Appendix I

Rain Barrel Installation Guide



Rain Barrel

Installation Instructions & Maintenance Owner's Manual

• Step-by-Step Installation Instructions for the RainXchange™ Rain Barrel

(Item #98766 - Terra Cotta)
(Item #98767 - Sandstone)

Thank you for choosing Aquascape's RainXchange™ Rain Barrel, the visually appealing option to capturing rainwater from your roof.

How it works:

Rainwater travels through your downspout and enters the RainXchange™ Rain Barrel filter screen, removing large debris such as leaves, sticks, and also prevents mosquitoes from entering the RainXchange™ Rain Barrel. When your RainXchange™ Rain Barrel is full, the barrel will divert the excess water through a large internal 1½" overflow pipe, and out the bottom where it can be directed away from your foundation. The RainXchange™ Rain Barrel can hold up to 75 gallons of rainwater for future use. Multiple RainXchange™ Rain Barrels can be connected together to increase water storage using the optional connection kit (Item #98811).

Your RainXchange™ Rain Barrel includes the following:

- Brass spigot
- 1½" overflow pipe
- Overflow elbow
- Zip ties (2)
- Teflon tape

Installation Tools Needed (not included):

- Hacksaw
- Level
- Tape measure
- Pencil or marker
- Pliers
- Screw driver
- Gloves
- Safety glasses



Aquascape, Inc.
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Rain Barrel

Installation Instructions & Maintenance Owner's Manual

Installing the Spigot

1) Wrap the threads of the brass spigot

Wrap the threads of the brass spigot with Teflon tape and install it into the 1/2" bulkhead fitting, tighten enough to seat the threads firmly, but do not overtighten.

CAUTION: Be careful to not cross-thread when threading the brass spigot into the 1/2" bulkhead fitting.

Installing the Overflow Plumbing

2) Wrap the threads of the overflow elbow

Wrap the threads of the overflow elbow with Teflon tape and nest it into the underside of the 2" bulkhead fitting, with



Step 1

the outlet facing towards the opening at the front of the RainXchange™ Rain Barrel.

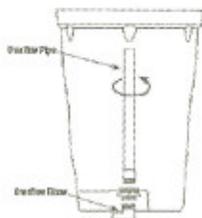
3) Overflow pipe assembly

Take the overflow pipe assembly, wrap the threads with Teflon tape and thread into the 2" bulkhead fitting inside the bottom of the RainXchange™ Rain Barrel.

Prepare Base

4) Prepare the RainXchange™ Rain Barrel location

Make sure that the location the RainXchange™ Rain Barrel is going to be placed is firmly packed and level. While the RainXchange™ Rain Barrel is relatively light when empty, it will weigh approximately 600 pounds when full, so a firm base is essential for support. If desired, concrete patio blocks can be used to build a base.



Steps 2-3

Installing the RainXchange™ Rain Barrel Beneath the Downspout

5) Place RainXchange™ Rain Barrel in front of downspout

Place the RainXchange™ Rain Barrel (with the lid attached) in front of the downspout that you intend to use. This is where you will need to determine the section of downspout that will need to be cut off. The downspout should be trimmed so the downspout elbow clears the top edge of the RainXchange™ Rain Barrel. Mark the location to be removed.



• If you live in regions with heavy rainfall patterns, or have a large area of roof feeding one downspout an additional 45° is recommended to create a "sweep" going directly into the opening.

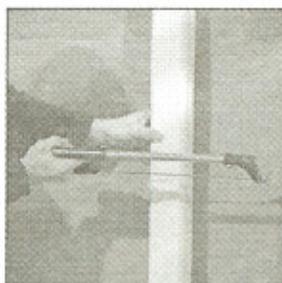


Create a "sweep" going directly into opening.

6) Cut off section of downspout

Loosen the straps that hold the downspout to the side of the house and using a hacksaw, carefully cut off the section of downspout you marked. If needed, a piece of cardboard box can be placed behind the area you are cutting so that the saw blade does not come into contact with the side of your house.

CAUTION: Edges of the downspout may be sharp. The use of work gloves is recommended. Always wear safety glasses when cutting. If the downspout contains heating cables, there is a potential electrocution or fire hazard when cutting through the downspout.



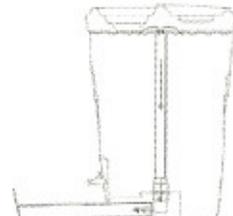
Step 6

7) Install downspout elbow

Install the downspout elbows to the freshly cut section of downspout. You will need to crimp the bottom of the downspout pipe inward so that the downspout elbow will fit onto it. Securely attach the downspout back to the side of the house using the straps.

8) Place overflow drain pipe

Direct excess water away from the foundation using the piece of downspout pipe that you cut off in step #6 over the end of the overflow elbow or if desired, you may use a 3" diameter, non-perforated corrugated pipe. With the corrugated pipe, you have the option to bury it. Make sure that you slope away from the RainXchange™ Rain Barrel to keep water from pooling back at your foundation. It is recommended that the end of the pipe is open, or not buried, to allow water to drain.



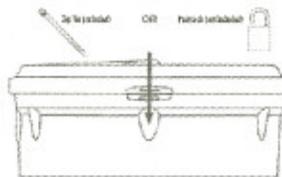
Step 8



Final Assembly

9) Secure the cover

The RainXchange™ Rain Barrel comes with two tie ties, use these to secure the cover on the RainXchange™ Rain Barrel. Or use an optional pad lock to secure. (lock not included)



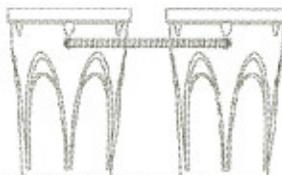
Step 9

10) Start capturing rainwater

Make sure that the brass spigot is fully closed by turning the handle clockwise until it stops.

Connecting Rain Barrels in Series

When using more than one RainXchange™ Rain Barrel to capture rainwater, you will need to purchase item #98811 to attach the barrels to each other. This allows water to flow from the first barrel into the next when the water capacity reaches its maximum amount.



Connecting RainXchange™ Rain Barrels in Series

Maintenance

Your RainXchange™ Rain Barrel should require very little maintenance. You will need to periodically check that the filter screen is clear. To clean, just brush off any leaves or twigs that may have collected on top of the screen.

Winterization

- If you live in an area that experiences temperatures below 32° or 0°C, you will need to prepare your RainXchange™ Rain Barrel for the winter.

Option #1 – Leave the Rain Barrel Outside

- Open the brass spigot and let the water drain out. Remove the lid and unscrew the overflow pipe from the bulkhead fitting located in the bottom of the barrel. The overflow pipe will not be installed during the winter allowing the water entering the barrel to drain out. Replace the lid. Leave the spigot open during the winter.

Option #2 – Remove the Rain Barrel for Winter Storage

- You can also completely remove the barrel from the outside of the house during the winter. Follow the steps above and tip the barrel to remove any remaining water. You'll also need to add a temporary downspout extension onto the existing downspout to ensure proper drainage away from the foundation.

WARNING: Do not use harvested rainwater for drinking, cooking or bathing. If moss killer has been used on the roof, let a few rain events bypass the barrel before collecting water.

Always securely attach the RainXchange™ Rain Barrel lid to avoid a child drowning. Never use the RainXchange™ Rain Barrel without the lid securely attached. Do not allow children to play on, in or around the RainXchange™ Rain Barrel.

Helpful Tips:

Planting Area

- Your RainXchange™ Rain Barrel lid includes an integrated planter that helps naturalize the Rain Barrel into the existing landscape. If drainage is necessary, there are three dimples located on the bottom of the planter area. You can drill holes in place of the dimples to ensure water will properly drain from your plants. Using the dimples as a starting point, we suggest drilling holes using a 1/4" - 1/2" drill bit (not included). If more drainage is needed, use a larger drill bit until you get the desired size.



When using the planting area, place a layer of planting material, such as coconut fiber, to help prevent soil from passing through the drainage holes.

- It is recommended that when using the planting area a layer of fabric or container lining, such as coconut fiber, moss, or planting media be used to prevent any soil from passing through the drainage holes.

Accessing Your Rain Water

- When accessing your rain water, simply place your watering can under the spigot, open, and fill! If your watering can is too large to fit under the spigot, you can easily attach a short 3/4" garden hose (not included) to the spigot and fill your watering can using the hose.



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00-00130-4-0011



Récupérateur d'eau de pluie

Guide d'installation et manuel d'utilisation

• Guide étape par étape pour l'installation du récupérateur d'eau de pluie RainXchange™

(Article 98705 – Terre caillots)
(Article 98707 – Grès)

Merci d'avoir choisi le récupérateur d'eau de pluie RainXchange™ d'Aquascape, la solution esthétique pour récupérer l'eau de ruissellement de la toiture de votre maison.

Méthode d'installation

L'eau de pluie qui s'écoule par la descente de la gouttière traverse le filtre du récupérateur RainXchange™, qui capture les débris comme les feuilles, les brindilles et les branches et empêche les insectes de pénétrer dans le bac. Lorsque le récupérateur RainXchange™ est plein, un gros tuyau de trop-plein de 1 1/2 po de diamètre situé à l'intérieur du récupérateur évacue le surplus d'eau par le bas du bac, en débordant des fondations de la maison. Le récupérateur RainXchange™ peut contenir jusqu'à 75 gallons d'eau de pluie. Il est possible de raccorder en batterie plusieurs récupérateurs RainXchange™ pour accroître la capacité de stockage de l'eau pluviale à l'aide du kit de raccordement vendu en option (article #0011).

Le récupérateur RainXchange™ comprend :

- Robinet en laiton
- Tuyau de trop-plein de 1 1/2"
- Coudé de trop-plein
- Attaches autobloquantes (2)
- Ruban de téflon



Outils nécessaires pour l'installation du récupérateur d'eau de pluie (non compris)

- Scie à métaux
- Niveau
- Ruban à mesurer
- Crayon ou marqueur
- Pince
- Tournevis
- Gants
- Lunettes de protection

Aquascape™
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Récupérateur d'eau de pluie

Guide d'installation et manuel d'utilisation

Pose du robinet

1) Entourer le filetage du robinet de ruban de téflon

Entourer du ruban de téflon autour du filetage du robinet de laiton et insérer le robinet dans le raccord de traversée de cloison de 2 po. Sans serrer pour bien faire tenir le filetage, mais sans serrer.

MISE EN GARDE : Prenez garde de ne pas tasser le filetage en fixant le robinet à la traversée de cloison.

Installation du coude de trop-plein

2) Entourer le filetage du coude de trop-plein de ruban de téflon et visser-le à l'intérieur du raccord de traversée de cloison de 2 po, en

orientant l'embout de sortie vers l'ouverture prévue à l'avant du bac de récupération RainXchange™.



Étape 1

orientant l'embout de sortie vers l'ouverture prévue à l'avant du bac de récupération RainXchange™.

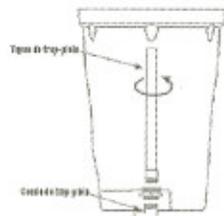
3) Installation du tuyau de trop-plein

Entourez le filetage du tuyau de trop-plein de ruban de téflon et vissez-le de l'intérieur dans la traversée de cloison de 2 po qui se trouve dans le bas du récupérateur RainXchange™.

Préparation de la base

4) Préparation de la base sur laquelle reposera le bac de récupération RainXchange™

Assurez-vous que la surface sur laquelle le récupérateur RainXchange™ sera placé est solide et de niveau. Le récupérateur n'est pas très lourd à vide, mais son poids peut atteindre environ 600 lb lorsqu'il est rempli d'eau. Il est donc très important qu'il repose sur une



Étapes 2 et 3

base bien solide. Vous pouvez, par exemple, l'installer sur une base de pavés de ciment.

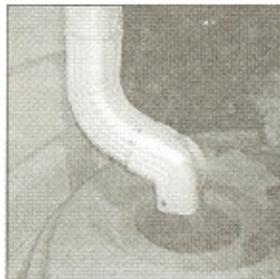
Mise en place du récupérateur RainXchange™ sous la descente de la gouttière

5) Mise en place du récupérateur RainXchange™ devant la descente de la gouttière

Placez le récupérateur d'eau de pluie RainXchange™ (avec son couvercle) devant le tuyau de descente dont vous voulez recueillir l'écoulement. Vous devez maintenant déterminer quelle section du tuyau de descente il faudra couper. Le tuyau de descente doit être coupé de sorte que le coude dégage le dessus du récupérateur RainXchange™. Marquez l'endroit où couper.



• Si vous habitez dans une région à forte pluviosité ou si la superficie de toitures qui ruisselle par la descente est très grande, il est conseillé d'ajouter un coude à 45° pour diriger le débit directement dans l'ouverture du récupérateur.

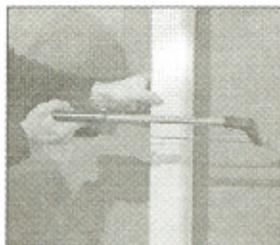


Diriger le débit de ruissellement dans l'ouverture du récupérateur.

6) Coupe du tuyau de descente

Désenrmez les sangles qui retiennent le tuyau de descente au mur de la maison et, à l'aide d'une scie à métaux, coupez soigneusement la section du tuyau de descente à l'endroit marqué. Par mesure de précaution, vous pouvez glisser un morceau de carton derrière le tuyau, à l'endroit où vous allez le couper, de manière à ne pas endommager le mur de la maison avec la scie.

MISE EN GARDE : Le rebord du tuyau de descente peut être coupant. Il est conseillé de porter des gants. Portez toujours de lunettes de protection lorsque vous sciez quelque chose. Si le tuyau de descente comporte un fil chauffant, prenez garde au risque d'électrocution ou de feu en sciant le tuyau.



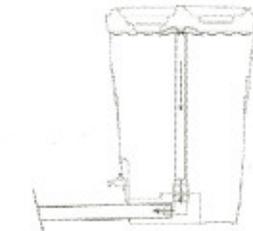
Étape 6

7) Installation du coude de descente

Installez le coude de descente à l'extrémité du tuyau que vous venez de couper. Vous devez pincer l'extrémité du tuyau de descente vers l'intérieur pour que le coude s'y ajuste. Rattachez solidement le tuyau de descente au mur de la maison à l'aide des sangles.

8) Mise en place du tuyau de trop-plein

La section du tuyau de descente que vous avez coupée à l'étape 6 servira à dévier le surplus d'eau loin des fondations de la maison; vous pouvez aussi utiliser à cette fin un tuyau ondulé non perforé de 3/4 po de diamètre. Si vous optez pour un tuyau ondulé, vous pouvez l'enfoncer dans le sol. Assurez-vous que la pente s'élève du récupérateur RainXchange™ pour éviter que l'eau ne s'accumule près des fondations. Il est préférable de laisser l'extrémité du tuyau à la surface du sol, c'est-à-dire de ne pas l'enfouir sous terre, pour favoriser le drainage.



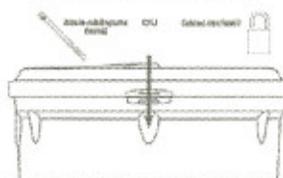
Étape 8



Dernières étapes d'installation

9) Mise en place du couvercle

Deux attaches autobloquantes sont fournies avec le récupérateur RainXchange™; elles servent à attacher le couvercle au récupérateur. Vous pouvez aussi fixer le couvercle à l'aide d'un cadenas (non fourni).



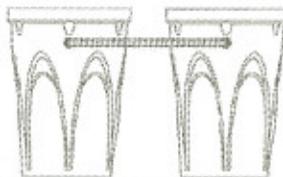
Étape 9

10) Récupération des eaux de pluie !

Assurez-vous que le robinet est bien fermé et le tournant dans le sens des aiguilles d'une montre jusqu'à ce qu'il se bloque.

Raccordement de plusieurs récupérateurs d'eau de pluie

Pour utiliser ensemble plusieurs récupérateurs d'eau de pluie RainXchange™, vous devez vous procurer l'artère portant le numéro 98811, un fil de raccordement les récupérateurs entre eux. Cet accessoire permet à l'eau de passer du premier récupérateur au suivant lorsque le premier est plein.



Raccordement de plusieurs récupérateurs RainXchange™ en batterie

Entretien

Les récupérateurs RainXchange™ nécessitent très peu d'entretien. Vous devez surveiller périodiquement que rien n'obstrue le filtre. Pour nettoyer le filtre, brossez tout simplement les feuilles et enlevez les branches et brindilles accumulées.

Hivérisation

- Si vous habitez dans une région où le mercure peut descendre sous les 32 °F ou 0 °C, vous devrez protéger votre récupérateur RainXchange™ pour l'hiver.

Option 1 – Laisser le récupérateur en place

- Ouvrez le robinet de laiton et laissez l'eau se vidanger. Retirez le couvercle et dévissez le tuyau de trop-plein de la traversée de cloison située dans le bas du récupérateur. Il faut enlever le tuyau de trop-plein pour l'hiver afin que l'eau qui pénètre dans le récupérateur puisse s'écouler. Remplacez le couvercle. Laissez le robinet ouvert.

Option 2 – Ranger le récupérateur jusqu'au printemps

Vous pouvez aussi enlever le récupérateur de son emplacement près de la maison pour l'hiver. Suivez les étapes décrites précédemment et inclinez le récupérateur pour bien évacuer toute l'eau. Vous devez ajouter au tuyau de descente de la gouttière une rallonge temporaire pour dévier l'eau afin qu'elle ne s'accumule pas près des fondations de la maison.



MISE EN GARDE : Ne consommez pas l'eau de pluie pour boire, pour faire la cuisine ni pour vous laver. Si un herbicide de contrôle des mousses a été répandu sur la toiture, attendez après quelques averses pour commencer à recueillir l'eau de pluie. Attachez toujours solidement le couvercle du récupérateur RainXchange™ pour prévenir qu'un enfant puisse s'y noyer. N'utilisez jamais le récupérateur RainXchange™ si le couvercle n'est pas solidement fixé. Ne laissez pas les enfants jouer à l'intérieur ni autour du récupérateur.

Conseils utiles

Plantes ornementales

- Votre récupérateur RainXchange™ comporte une jardinière qui favorise son intégration au paysage. Les trois rainures pratiquées dans le fond de la jardinière servent au drainage. Vous pouvez y percer des trous si vous jugez que les rainures ne sont pas suffisantes pour bien drainer la terre de vos plantes. En vous guidant sur les rainures, nous vous suggérons de percer des trous à l'aide d'un foret de ¼ ou de ½ pouce (non fourni). Au besoin, utilisez un foret d'un diamètre supérieur.
- Si vous utilisez la jardinière intégrée, il est conseillé d'en recouvrir le fond avec une toile ou un revêtement de fibre de coco, de mousse ou de substrat pour empêcher la terre de fuir par les trous de drainage.

Utilisation de l'eau de pluie

- Pour utiliser l'eau de pluie recueillie dans le bac, placez simplement votre arrosoir sous le robinet et remplissez-le. Si l'arrosoir est trop haut pour passer sous le robinet, vous pouvez facilement fixer au robinet un bout de tuyau d'arrosage de ¼ de po (non fourni).



Lorsque vous utilisez la jardinière, recouvrez-en le fond avec une toile ou un revêtement de fibre de coco, de mousse ou de substrat pour empêcher la terre de fuir par les trous de drainage.



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Appendix J

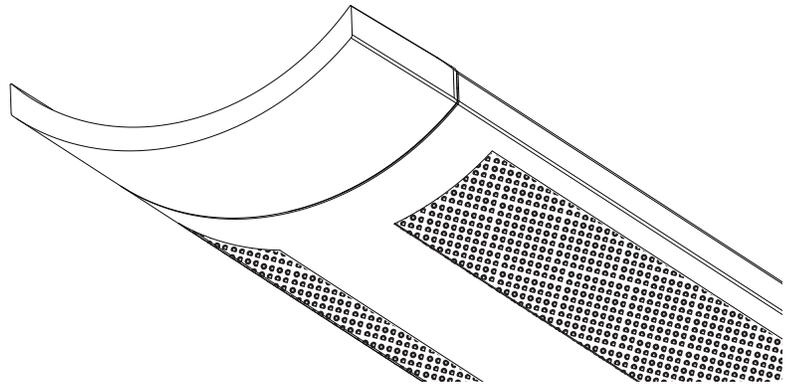
HO T5 Fluorescent Technical Sheet

Project _____

Firm Name _____

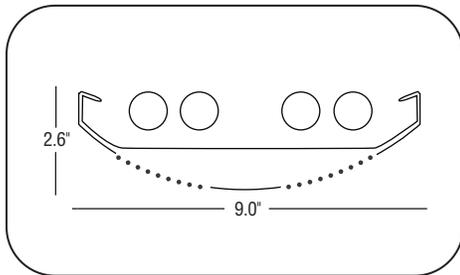
Date _____ Type _____

Series 12-P and S12-I have a modern style with pleasing curves and a low profile that add richness to a wide variety of architectural settings. This luminaire uses sophisticated designs and manufacturing techniques to produce a product that is as affordable as it is beautiful. Series 12-P has two rows of perforations while S12-I is 100% indirect. Both are available in 2, 3, and 4 T8 lamps and 1, 2 or 3 T5 or T5HO lamps in 4', 8', and 12' lengths. Available with standard flat endcaps or optional curved die-cast endcaps.



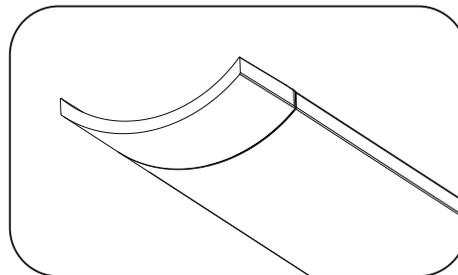
Series 12-P with optional curved die-cast endcap.

FEATURES



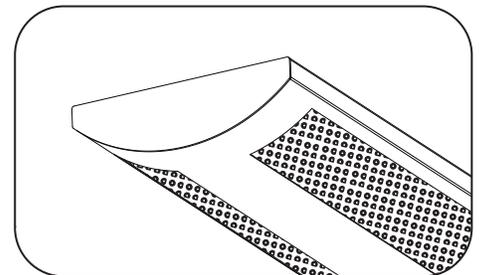
LAMPING

Available in 2, 3, or 4 T8, and 1, 2, or 3 T5 or T5HO lamp cross sections.

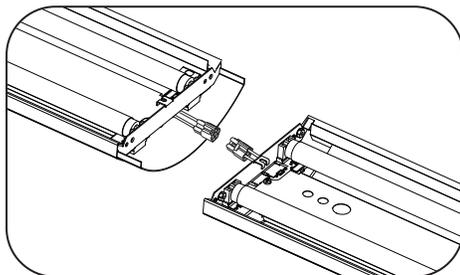


S12-I

S12-I is 100% indirect.

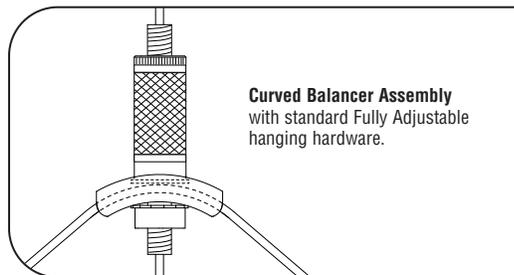


STANDARD FLAT ENDCAP

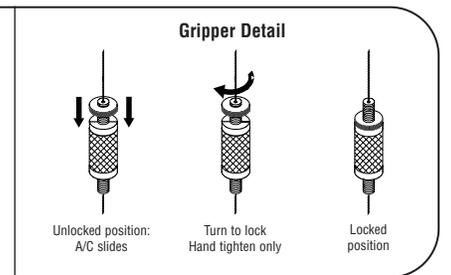


STANDARD PLUG-TOGETHER WIRING

Plug-together wiring is standard on all fixtures. Die-formed aligner plate comes factory installed for smooth joints.

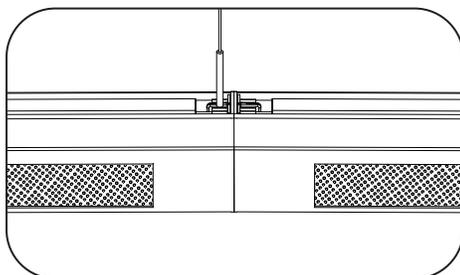


Curved Balancer Assembly with standard Fully Adjustable hanging hardware.



Gripper Detail

Unlocked position: A/C slides
Turn to lock: Hand tighten only
Locked position

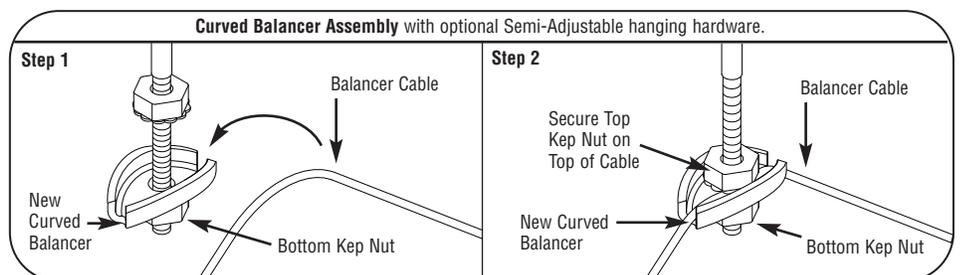


TIGHT JOINS

Fixtures connect together tightly and die-formed internal aligner plate ensures that there are no light leaks.

STANDARD FIXTURE SUPPORT

The Curved Balancer improves the strength of the hardware connection and improves installation. The balancer arrives attached to the fully adjustable hanging hardware. Simply adjust the bottom nut to the desired height, secure it to the balancer cable, adjust the side-to-side level, and secure the top nut. Install safety stop into fixture body.

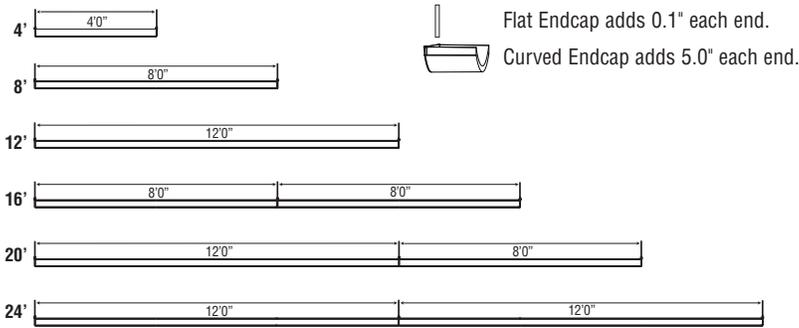


Curved Balancer Assembly with optional Semi-Adjustable hanging hardware.

OPTIONAL SEMI-ADJUSTABLE CABLE SUPPORT

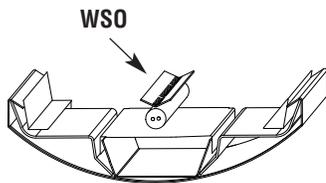
Optional Semi-Adjustable aircraft cable, (AC) $\pm 0.5"$ in lengths of 12", 15", 18", 21", 24", 27", 30", 36". Aircraft cable assembly screws into the balancer. Attach Curved Balancer in the same way as Fully Adjustable assembly.

Series 12-P and S12-I are available in the lengths shown below.



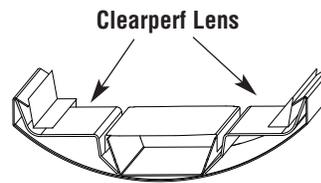
Modular section lengths offer standard 4'0", 8'0" and 12'0" support spacing that aligns with grid ceiling systems.

Additional 4', 8' or 12' segments can be added to create runs as long as required.



WIDE SPREAD OPTICS (WSO)

Special wide spread reflector gives extended distribution and is especially effective in low ceiling areas.



CLEARPERF LENS™

Optional Clearperf Lens assures perforations stay clear and clean, comes standard with T5HO configurations. Made of semi-translucent opal acrylic.

SPECIFICATIONS

CONSTRUCTION: Body is 20-gauge die-formed steel with 18-gauge die-formed internal joiner system, plug-together wiring standard. All components are hard-tooled to tolerances of 0.010". Precision-punched 0.093" diameter perforations cover the bottom side of the fixture in two parallel columns.

ENDCAPS: (FE) Flat endcap standard, 20 gauge die-formed steel, adds 0.1" at each end.

Optional: (CE) Curved endcap, aluminum die-cast endcap with 0.100" reveal, adds 5.0" at each end.

REFLECTORS: Two reflector systems are available. Die-formed pre-painted aluminum, (91W). Optional: Extended Performance Reflector System (EP). T5 or T5HO lamps die-formed pre-painted aluminum, (96W). (WSO) Wide Spread Optic system for 1 T5HO.

ACCESSORY: Optional Dust Cover, clear acrylic, T8 lamps only. NOTE: Will significantly impact light level performance. Consult Factory.

ACCESSORY: Optional Clearperf Lens™, factory installed, semi-translucent opal acrylic, UV stable, covers perforations inside fixture. Standard with T5HO lamps. NOTE: Impacts light level performance. Contact Factory.

ELECTRICAL: 120 or 277V prewired. Fixture and electrical components are UL/C-UL listed and fixture will bear UL/C-UL labels. Optional Adders 347V ballast, prewired dual circuit, emergency circuits, emergency battery packs.

LAMPING: Available in 2, 3, or 4 T8 lamp cross sections or 1, 2, or 3 T5 or T5HO. Contact factory for 1 T8 lamp cross section.

BALLAST: Electronic instant-start ballast <10% THD, .88 BF standard for T8 lamps. Electronic rapid-start ballasts <10% THD, 1.0 BF standard for T5/T5HO lamps. Optional adders: rapid-start ballasts (standard for T5/T5HO), 347V, emergency battery packs, dimming ballasts (controls by others). Requires low-profile ballasts and battery packs.

MOUNTING OPTIONS: Semi-adjustable aircraft cable, (AC) ± 0.5" in lengths of 12", 15", 18", 21", 24", 27", 30", and 36". Order length, e.g., AC 18". Optional Adders: fully adjustable aircraft cable (FA) in lengths up to 150". Rigid stems (Stem).

SUPPORT CABLES: Plated steel cable and hardware.

FEED: 18 gauge straight cord. 14 gauge feed cord used when fixture current exceeds 6 amps. Optional Adders: Coil Cord Feed, Rigid Stem Feed.

FINISHES: Finelite Signal White standard. Optional Adders: 185 colors available from Tiger Drylac's RAL color chart.

LENGTHS: 4', 8', and 12' section lengths can be combined to make longer runs. Contact factory for additional lengths.

WEIGHT: Fixture weight = 2.6 to 3.6 lb/ft. with curved endcaps. Fixture weight 2.0 lb/ft. with flat endcaps.

WALL MOUNT: Complementary wall mount available.

ORDERING GUIDE

Finelite **Series 12 (P-Perforated, I-Indirect)** _____

Run length (4', 8', 12' multiples standard) _____

Number of lamps in cross section (2, 3, 4, T8 or 1, 2, 3 lamp T5 or T5HO) _____

Circuiting (SC-single circuit, DC-dual circuit) _____

Reflector system (91W, EP, WSO) _____

Voltage (120, 277, 347 Volt) _____

Mounting (AC/FA/Stem) _____

Endcap FE (flat), CE (curved) _____

Ceiling type (C1-1" T-bar, C2-9/16" T-bar, C3-Slot Grid, C4-Hard Ceiling) _____

Ballast factor (Standard .88 for T8 lamps, 1.0 for T5 or T5HO) _____

S12-P - 32' - 2T8 - SC - 91W - 277 - AC 18" - FE - C1 - .88



Appendix K

T5 LED Installation Guide

DIRECTLED^{FL}

EarthLED DirectLED FL USER GUIDE

EarthLED
DIRECTLED^{FL}
Fluorescent Tube Replacement Solution



**EarthLED DirectLED FL
Requires No Ballast**

EarthLED
DIRECTLED^{FL}PRO
High Power Fluorescent Tube Replacement Solution



**EarthLED DirectLED FL PRO
Requires No Ballast**

NOTE: This user guide will explain the steps necessary to use and insure peak performance from your new EarthLED DirectLED FL. It is intended to be used as a reference only, by a fully-qualified electrician or technician. This document should never be considered a substitute for any provision of a regulation or state and/or local code. Please read this entire user guide to fully understand and safely use this product. Specifications are subject to change without notice.

GETTING STARTED

EarthLED DirectLED FL LED Fluorescent Lights are the next generation solution to replace conventional fluorescent tubes. LED tubes are more efficient and more reliable and are well-suited for use anywhere conventional fluorescent tubes are used such as homes, offices, museums, galleries, shop windows, hotels, restaurants, meeting rooms, etc. EarthLED DirectLED FL are CE approved and RoHS compliant.

This guide contains important information about installing and operating your new EarthLED DirectLED FL safely and accurately.

Unpacking

1) Unpack and carefully examine the product. 2) Report any damage and save all packing materials if any part is damaged during transport. 3) Do not attempt to use this apparatus if it is damaged.

Warnings

1) Risk of electric shock. Ensure that the power supply is off when wiring sections of the device.
2) The device should be installed by a qualified electrician or technician in accordance with all relevant local codes.

User Responsibilities

It is the responsibility of the contractor, installer, purchaser, owner, and user to install, maintain, and operate the device in such a manner as to comply with all state and local laws, ordinances, and regulations. Note: The instructions and precautions set forth in this user guide are not necessarily all-inclusive, all conceivable, or relevant to all applications as Advanced Lumonics, LLC cannot anticipate all conceivable or unique situations.

PLANNING THE INSTALLATION This device installation requires planning to ensure successful installation with minimal complications and down time.

Installation Steps

Retrofit – existing fixture with ballast

- 1) Take out ballast and starter if so equipped (disconnect the wires and either leave the ballast in place or remove it).
- 2) After disconnecting the ballast, reconnect the circuit. There are two sets of wires that connect to each bulb – only one set is needed to be connected to the respective hot and cold wires. Refer to the wiring diagram.
- 3) If you have a fixture with more than one tube holder (double or quads), make sure only one wire set from each additional fixture is going to the hot and cold supply wires. Disconnect any jumper wires connecting the additional fixtures to each other. In effect, on a single tube there were four wires (two at each end) going to the hot and cold supply wires. Now you only need one going to the hot and cold supply wires from each fixture. Refer to the wiring diagram.
- 4) Install the EarthLED DirectLED FL into the fluorescent light fixture.
- 5) Inspect all wiring connections prior to turning on the power.
- 6) Switch on the power to light EarthLED DirectLED FL .

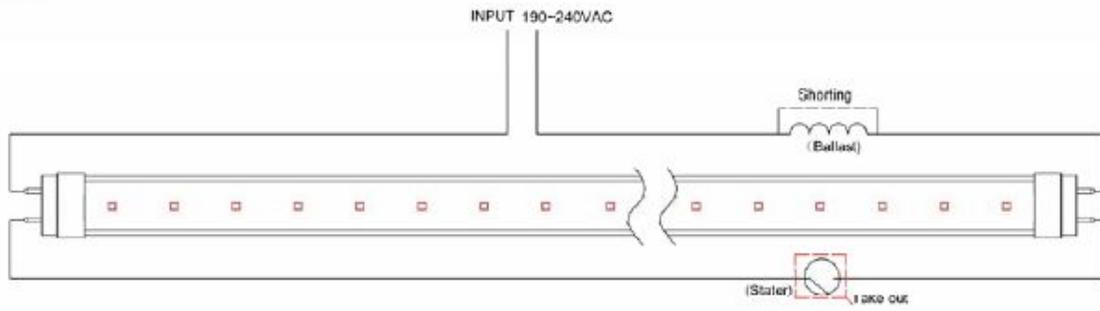
New Installation – fixture without a ballast.

- 1) There are two sets of wires that connect to each bulb – only one set is needed to be connected to the respective hot and cold wires. Refer to the wiring diagram.
- 2) If you have a fixture with more than one tube holder (double or quads), make sure that only one wire set from each additional fixture is going to the hot and cold supply wires. Disconnect any jumper wire connecting the additional fixtures to each other. In effect, on a single tube there were four wires (two at each end) going to the hot and cold supply wires. Now you only need one going to the hot and cold from each fixture. Refer to the wiring diagram.
- 3) Install EarthLED DirectLED FL into the fluorescent light fixture.
- 4) Inspect all wiring connections prior to turning on the power.
- 5) Switch on the power to light EarthLED DirectLED FL .

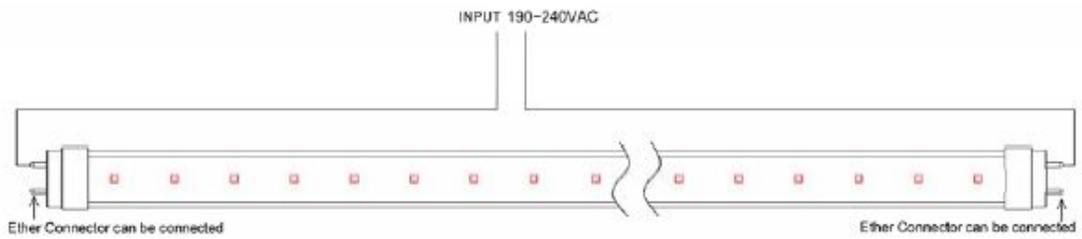
Wiring Diagram

1. Retrofit

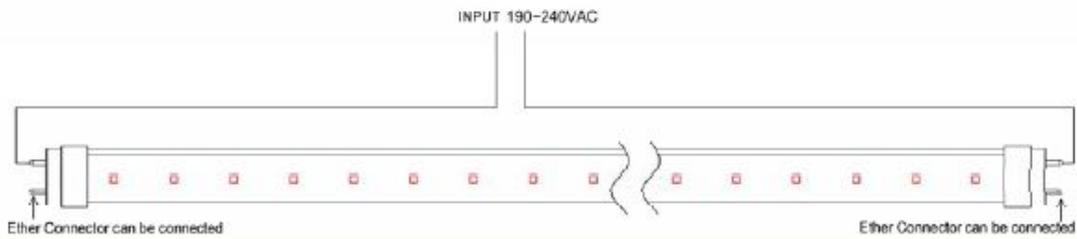
Before:



After:



2. New Installation



Academic Vita of:

Stephen L. Kelchaw

2351 W. Venisa Drive, Hazle Township, PA 18202
E-mail: slk5030@psu.edu

Education

The Pennsylvania State University University Park, PA
Architectural Engineering
Construction Management Option
Integrated B.A.E/M.A.E. Degree

Senior Thesis

Title: The Upper Dublin High School Construction Project Analysis
Thesis Supervisor: Robert J. Holland
Associate Professor of Architecture/Architectural Engineering

Work Experience

Summer 2009 **ARAMARK Technical Services** Philadelphia, PA
Junior Project Engineer

- Performed building commissioning tests and composed reports
- Assisted in performing energy audits/assessments
- Reviewed submittals, created punchlists, etc.

Supervisor: Matt Judge, Director of Technical Services

Summer 2008 **Masonry Preservation Services, Inc.** Berwick, PA
Junior Project Manager

- Assisted with building forensics, solutions, and reports
- Conducted various quality and performance tests
- Ordered materials and created reconstruction plans

Supervisor: Erik Valentino, Vice President – Masonry Preservation Services, Inc.

Summer 2005/07 **American Homes Enterprises, Inc.** Hazleton, PA
Craftsman

- Performed basic carpentry work such as framing, roofing, and installation of windows and doors
- Ran electrical wiring and plumbing
- Read construction documents

Supervisor: Jim Fisher, Owner – American Homes Enterprises, Inc.

Honors and Organizations

- The Schreyer Honors College
- The National Society of Leadership and Success
- Tau Beta Pi, The Engineering Honor Society
- Phi Alpha Epsilon, The Architectural Engineering Honor Society

Grants and Scholarships

- The Mervin G. and Patricia C. Schaeffer Scholarship in Engineering

Engineering Certification

- Passed the Fundamentals of Engineering (FE) Exam. Will obtain Engineer-in-Training (EIT) status upon graduation.

Tutoring Experience

Fall/Spring 2006-2008
Technology Tutor

University Learning Centers

Penn State University

- Assisted students in understanding difficult technology related concepts and skills.
- Taught students new skills mainly in the following areas: C++ programming, website development, Adobe Photoshop, and recording and video editing.
- Aided with basic computer-related troubleshooting solutions.